

Participant Handbook

Customised Crash Course Programme for COVID Warriors

Sector
Healthcare

Sub-Sector
Allied Health & Paramedics

Occupation
Non-Direct Care

Reference ID: **HSS/Q5604, Version 1.0**
NSQF Level 4



COVID Frontline Worker
Medical Equipment Support

All Rights Reserved,
First Edition, May 2021
Printed in India at

Healthcare Sector Skill Council

Email: info@healthcare-ssc.in

Disclaimer

The information contained herein has been obtained from sources reliable to Healthcare Sector Skill Council. Healthcare Sector Skill Council disclaims all warranties to the accuracy, completeness or adequacy of such information. Healthcare Sector Skill Council shall have no liability for errors, omissions, or inadequacies, in the information contained herein, or for interpretations thereof. Every effort has been made to trace the owners of the copyright material included in the book. The publishers would be grateful for any omissions brought to their notice for acknowledgements in future editions of the book. No entity in Healthcare Sector Skill Council shall be responsible for any loss whatsoever, sustained by any person who relies on this material. The material in this publication is copyrighted. No parts of this publication may be reproduced, stored or distributed in any form or by any means either on paper or electronic media, unless authorized by the Healthcare Sector Skill Council.

The information contained herein has been appropriately obtained from sources reliable to Healthcare Sector Skill Council. This Participant Handbook is designed to skill individuals for medical equipment repair and maintenance during COVID pandemic mapped to required competencies of COVID Frontline Worker (Medical Equipment Support) HSS/Q5604, version 1.0.





Shri Narendra Modi
Prime Minister, Government of India

“ Skilling is building a better India.
If we have to move India towards
development then Skill Development
should be our mission. ”



Certificate

COMPLIANCE TO QUALIFICATION PACK - NATIONAL OCCUPATIONAL STANDARDS

is hereby issued by the

HEALTHCARE SKILL SECTOR COUNCIL

for

SKILLING CONTENT : PARTICIPANT HANDBOOK

Complying to National Occupational Standards of

Job Role/Qualification Pack: **COVID Frontline Worker (Medical Equipment Support)**

QP No. HSS/Q5604, NSQF Level 4"

Date of Issuance Aug 18th, 2021

Valid up to* July 17th, 2022

*Valid up to the next review date of the Qualification Pack

Authorised Signatory
(Healthcare Skill Council)

Acknowledgment

Healthcare Sector Skill Council (HSSC) acknowledges the contribution of all the individuals and organizations who have contributed to the preparation of this book.

We would like to thank Dr Naresh Trehan, Chairman, HSSC for his constant guidance and support.

We would also like to acknowledge the efforts of the HSSC Academic Committee chaired by Dr. Devi Shetty and its eminent members who guided development of the COVID crash courses.

We would also like to acknowledge Dr. S.B.Sinha's efforts - President Biomedical Engineering Society of India. He has been instrumental in writing the course content within time.

Sincere appreciation is extended to our industry partners and all the experts for providing technical inputs and reviewing the individual modules. The development of this book would not have been possible without their strong support and valuable feedback.

The efforts of Team HSSC is especially appreciated for supporting the development of this book.

HSSC dedicates this book to youth of the country who desire to come forward in fight from COVID 19 and learn specialized skills, an invaluable asset for providing the care while making a career in the Healthcare Sector and wish to be part of the most Noble profession of saving lives.

About this book

This Participant Handbook is designed to enable training for the specific qualification Pack(QP). Each National Occupational (NOS) is covered across Unit/s.

Key Learning Objectives for the specific NOS mark the beginning of the Unit/s for that NOS.

- **Introduction Medical Equipment Support (Bridge Module)** -The scope covers the following :

1. Overview Of Program
2. Introduction to the Healthcare Industry
3. Different Departments in a Hospital

- **Follow sanitization and infection control guidelines (HSS/N9622)** - The scope covers the following :

1. Social distancing practices
2. Personal and workplace hygiene
3. Waste disposal methods
4. Reporting and information gathering
5. Mental and emotional wellbeing

- **Understanding the working of basic equipment (HSS/N5607)** - This unit provides knowledge & understanding about functioning of basic medical equipment. The scope covers the following :

1. Electronic circuit
2. Electronic component and application
3. Biomedical instrumentation and measurement
4. Familiarization and working with Ultrasound machine, ECG and x-ray equipments

- **Calibration and maintenance of basic equipment (HSS/N5608)** - This unit provides knowledge & understanding about calibration and maintenance of basic medical equipment. The scope covers the following :

1. Electronic circuit
2. Safety procedural guidelines
3. Installation, Maintenance and Servicing of Medical Equipment

Symbols used in the book have been listed below.

Symbols Used



Key Learning Outcomes



Steps



Time



Tips



Notes



Unit Objectives



Exercise



Skills Practical



OJT

Table of Contents

S. No	Modules and Units	Page No.
1.	Introduction Medical Equipment Support (Bridge Module)	1
	Unit 1.1 Objectives of the Program	3
2.	Health & Hygiene (HSS/N9622)	35
	Unit 2.1- General Practices for an Outbreak/Pandemic	37
	Unit 2.2- Safety and Sanitisation Guidelines	53
	Unit 2.3- Other Common Practices & Guidelines	64
	Unit 2.4- COVID 19 Vaccination	72
3.	Understanding The Working of Basic Equipment (HSS/N5607)	79
	Unit 3.1 - Electronic Circuit	81
	Unit 3.2 - Electronic component and application	95
	Unit 3.3 - Biomedical instrumentation and measurement	123
4.	Calibration And Maintenance of Basic Equipment(HSS/N5608)	134
	Unit 4.1 - Identification of basic equipment	136
	Unit 4.2 - Safety procedural guidelines	149
	Unit 4.3 - Installation, maintenance and servicing of medical equipment	155







1. Introduction Medical Equipment Support

Unit 1.1 - Objectives of the Program



Key Learning Outcomes



After completion of this module, the participants will be able to:

1. Identify the program topics
2. List expectations from the training
3. Understand basic tasks and theories within the healthcare industry
4. Understand the job description and attributes of a COVID frontline worker (medical equipment support)
5. Identify various skills required to perform the role of a COVID frontline worker (medical equipment support)

UNIT 1.1 Objectives of the Program

Unit Objectives



After completion of this unit , the participants will be able to:

1. Learn about the program and the course
2. Understand the healthcare industry and its growth drivers
3. Understand the functioning of the different departments in a hospital
4. Understand the basics of healthcare and medical devices
5. Recognize healthcare delivery systems and role of medical devices
6. Know mechanical knowledge and use of tools
7. Perform the proper lifting techniques
8. Understand the medical terminology

1.1.1 Overview Of Program

1. **Understanding the working of basic equipment (HSS/N5607)** - This unit provides knowledge understanding about functioning of basic medical equipment. This NOS has been derived from the module, Understanding the working of basic equipment of the short term training curriculum: medical equipment technology assistant prepared by MOHFW.
2. **Calibration and maintenance of basic equipment(HSS/N5608)** - This unit provides knowledge & understanding about calibration and maintenance of basic medical equipment. This nos has been derived from the module, calibration and maintenance of basic equipment of the short term training curriculum: medical equipment technology assistant prepared by MOHFW.
3. **Follow sanitization and infection control guidelines (HSS/N9622)** - This OS unit is about following ways for sanitization to prevent the spread of infection as per sectoral working requirements.

1.1.2 Introduction to the Healthcare Industry

The Healthcare industry in India comprises hospitals, medical devices, clinical trials, outsourcing, telemedicine, medical tourism, health insurance and medical equipment. The sector is proliferating due to its strengthening coverage, services, and increasing expenditure by public and private players.

- In India, the hospital industry, accounting for 80% of the total healthcare market, is witnessing a considerable investor demand from both global and domestic investors. As a result, the hospital industry is expected to reach \$132 bn by 2023 from \$ 61.8 bn in 2017, growing at a CAGR of 16-17%.
- The Indian medical tourism market is expected to grow from its current size of \$3 bn to \$7-8 bn by 2020
- The diagnostics industry in India is currently valued at \$4 bn. The share of the organized sector is almost 25% in this segment (15% in labs and 10% in radiology).
- The primary care industry is currently valued at \$13 bn. The share of the organized sector is practically negligible in this case.
- 70,000 Ayushman Bharat centres, which aim at providing primary health care services to communities closer to their homes, are operational in India
- Health insurance contributes 20% to the non-life insurance business, making it the 2nd most extensive portfolio. The gross direct premium income underwritten by health insurance grew 17.16% year-on-year to reach \$6.87 Billion in FY20.

Growth Drivers

1. **Robotic Process Automation (RPA)** – RPA to improve the efficiency of the healthcare workforce; reducing costs and creating the value proposition.
2. **Shifting Disease Burden** - Non-Communicable Diseases (NCDs) account for 50% of the disease burden and 60% of all deaths in India
3. **Rise in Medical Tourism** - Due to the relatively low cost of medical care in India, medical tourism is experiencing a 22-25% growth. It contributes over \$2Bn to the healthcare market in India. Increased demand for healthcare and medical devices from the rise in medical tourism
4. **Policy Support & Incentives** - 100% FDI allowed in Greenfield & Brownfield projects,, measures to correct unfavourable duty structure are being undertaken, single-window clearance e-portal to improve EoD
5. **Atmanirbhar Bharat Abhiyaan - Self Reliant India** - A unique economic and comprehensive package of INR 20 lakh crores towards promoting manufacturing in India
6. **Life Expectancy** - Life expectancy is going to exceed 70 years by 2022; hence more healthcare services require
7. **Insurance Coverage** - 20% Indians covered; expected to rise with rising incomes, urbanization
8. **The emergence of telemedicine** - Along with these, telemedicine and government initiatives like e-health married with tax benefits and incentives drive the healthcare market in India.
9. **Medical Infrastructure** - Over \$200 bn to be spent on medical infrastructure by 2024

1.1.3 Different Departments in a Hospital

According to WHO, hospital is an essential part of the socio-medical institution, the roles of which is to offer comprehensive health care for the population both, curative and preventive and who stretch out to the personal and its home environment. In addition, a hospital is a centre for training of healthcare workers and bio-social research."

Another definition was specified by WHO in 1963 by the expert committee stating that: "Hospital is a residential formation which delivers short tenure and long tenure medical attention containing observational, diagnostic, therapeutic and rehabilitative services for persons suffering or suspected to be suffering from a disease or injury and for the parturient. It may or may not also offer services for in patient or an outpatient basis."

Casualty

It is known as the "accident and the emergency department", which deals in emergency patient cases. Sometimes patients find their way to this department if they meet with an accident or seek immediate medical help. The casualty department works 24/7, and it is equipped to deal with all sorts of emergencies. The patients are examined according to the degree of wound or crisis and then provided immediate medical help before being sent to a specialised department for further treatment.

Anaesthetics

Doctors in this department manage anaesthesia for patients for different procedures and surgeries. In addition, they provide the following services:

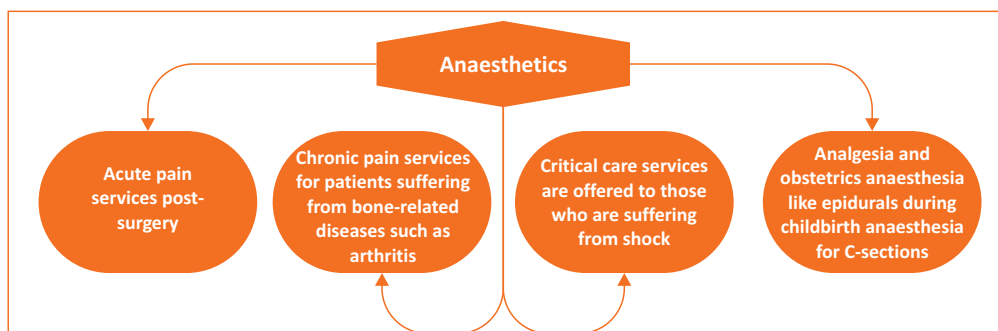


Fig. 1.1.1. Anaesthetics Department

Cardiology

The department deals with the issues of the heart or circulation. In addition, it provides medical treatments to people on in and out patient basis. A few of their procedures contain:

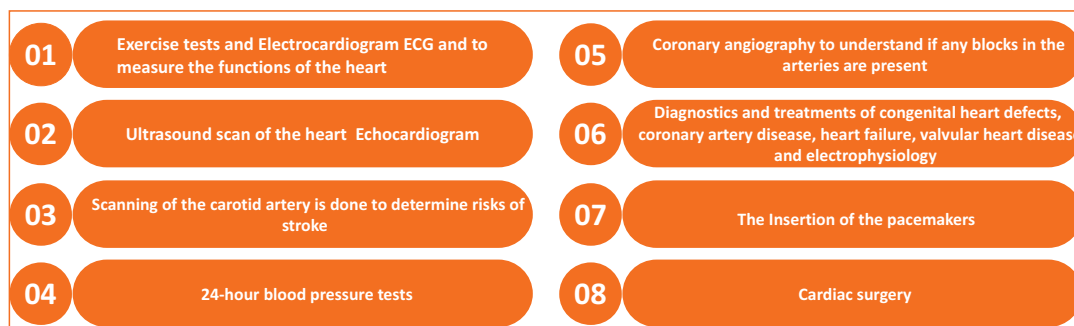


Fig. 1.1.2. Cardiology Department

Critical Care

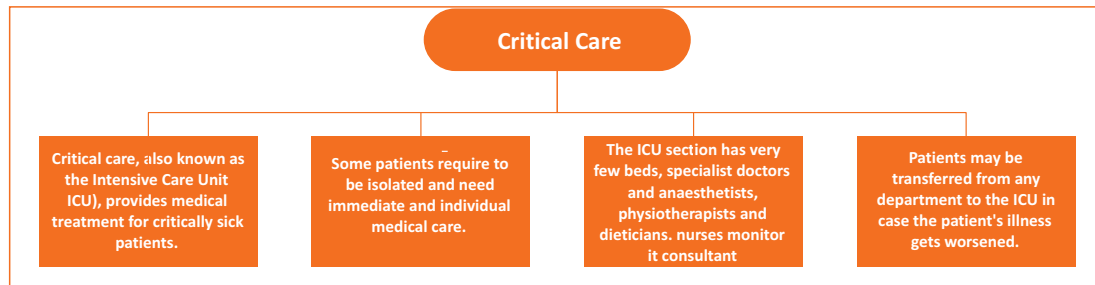


Fig. 1.1.3. Critical Care Department

Ears, Nose & Throat (ENT)

ENT department deals with ailments concerned with the Ear, nose and throat; it includes treatment of a variety of conditions like

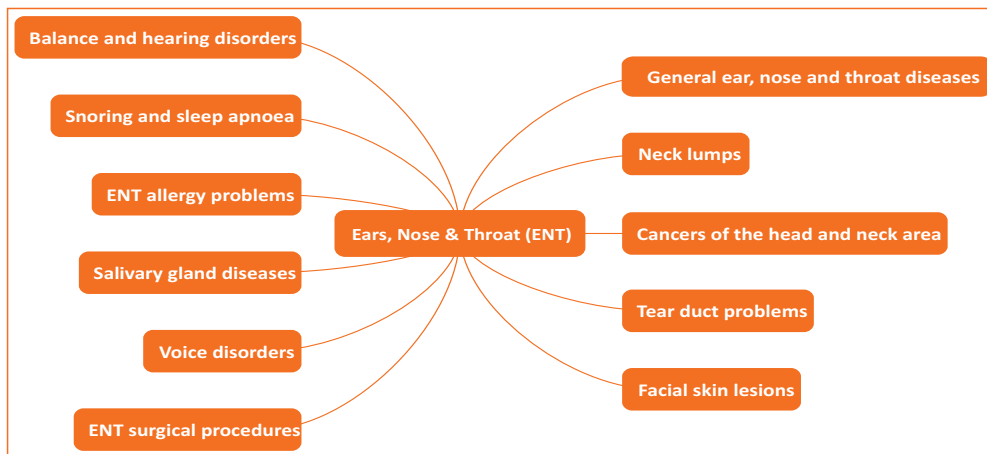


Fig. 1.1.4. ENT Department

Geriatrics

Doctors who specialise in geriatric medicine monitor this department. As the ageing suffer from a range of illnesses and seek medical attention for:

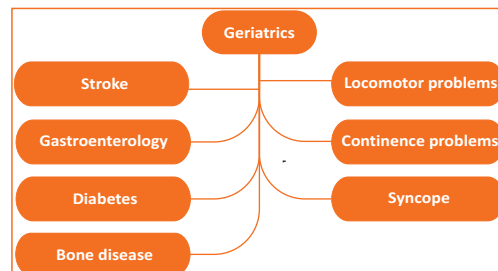


Fig. 1.1.5. Geriatrics Department

This department also provides various community services like home visits, mobile therapy units, palliative care.

Gastroenterology

This department deals with bowel related-medicine. Specialist consultants usually run it and investigate and treat upper and lower gastrointestinal diseases and the pancreas and bile duct system diseases. It also involves endoscopy and nutritional services. Some sub-specialities include:

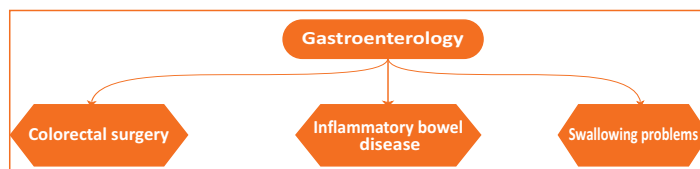


Fig. 1.1.6. Gastroenterology Department

the pancreas and bile duct system diseases. It also involves endoscopy and nutritional services. Some sub-specialities include:

This department deploys proficient nurses; they can perform a wide range of bowel investigations.

General Surgery

The general surgery department includes a wide variety of surgical measures that have: Day surgeries see many patients coming in for minor surgeries such as hernia repairs, piles, etc. These procedures are generally performed by general surgeons and do not typically require exceptional surgeons.

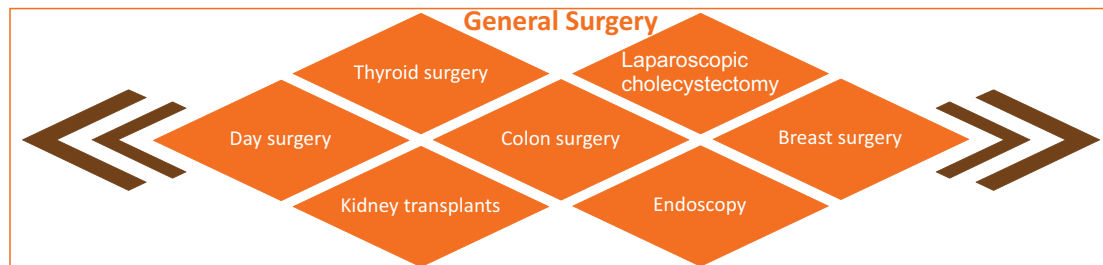


Fig. 1.1.7. General Surgery Department

Gynaecology

Gynaecology deals with investigating and treating difficulties of the female urinary tract and reproductive system. Infertility, dissoluteness and endometritis are some of the issues examined in gynaecology. Additional services include cervical smear screen and post-menopausal bleeding checks. This department usually has a particular ward, day surgery unit, an emergency gynaecology assessment unit and outpatient clinics.

Haematology

Haematology maybe part and parcel of the hospital laboratory or work closely with the hospital laboratory.

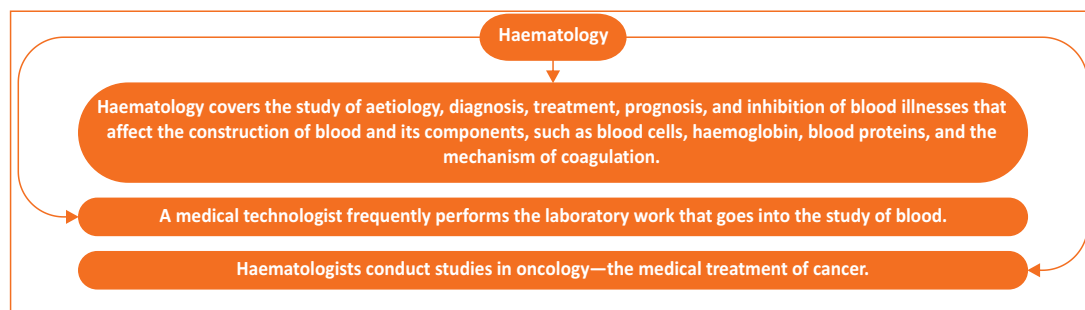


Fig. 1.1.8. Haematology Department

Maternity/Neonatal/Paediatics

All facilities regarding giving birth and child care are provided in this department. These can be separated into three different departments in some hospitals, but most general hospitals provide this care under one department itself. Some of the facilities or treatments include:

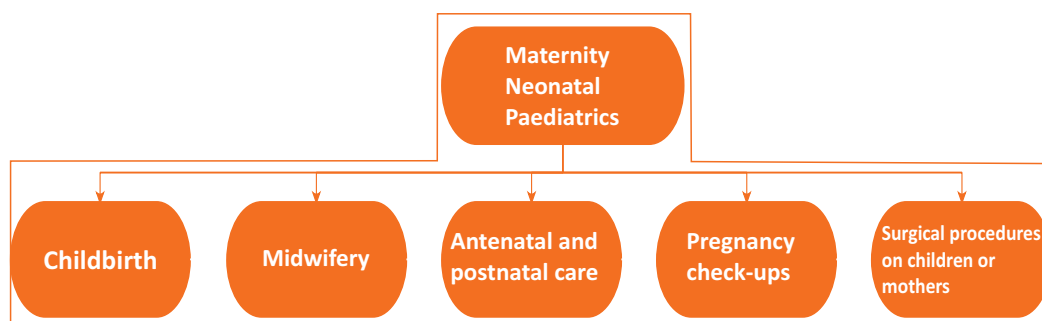


Fig. 1.1.9. Maternity/Neonatal/Paediatics Department

Neurology

Neurology deals with the human nervous system and investigates and treats patients for difficulties that affect their brain and spinal cord. Surgical measures on the brain and spinal cord are hazardous and require highly qualified and experienced doctors and nurses to provide exceptional care. Neurologists examine patients referred to them by other physicians in both the in and out patient surroundings. A neurologist will begin his interactions with a patient by taking a comprehensive medical history and performing a physical examination to evaluate the nervous system. Components of the neurological examination include assessing the patient's cognitive function, cranial nerves, motor strength, sensation, reflexes, coordination, and gait.

Oncology

This subdivision examines and treats all kinds of cancers and offers a wide range of chemotherapy treatments and radiotherapy for cancerous tumours and blood illnesses. This division is typically linked to all the other divisions as referrals can be made when one division cannot detect the patient's problem. Therefore, this subdivision also needs highly competent and skilled doctors and nurses. Doctors also carry out tumour exclusion procedures which are then sent for biopsy to approve whether the tumour is malicious or not.

Ophthalmology

This department deals with investigating and treating the eye problems of adults and children. Their services include:

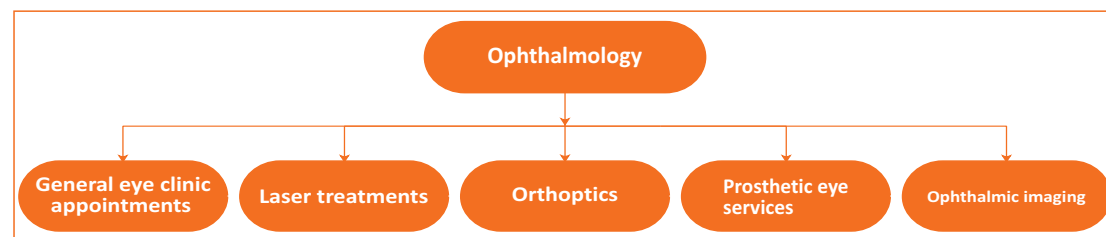


Fig. 1.1.10. Ophthalmology Department

Orthopaedics

This section deals with difficulties that affect the musculoskeletal system. That contains treating bones, muscles, tendons, ligaments, and nerves. Services consist of bone setting and surgeries to repair damaged bones or ligaments or tendons, replacing bones like hip replacement and knee cap replacement. Additional outpatient services also comprise treating fractures and dislocated joints, musculoskeletal injuries and soft tissue injuries.

Urology

This section is usually a surgical department led by surgeons who perform specific services like

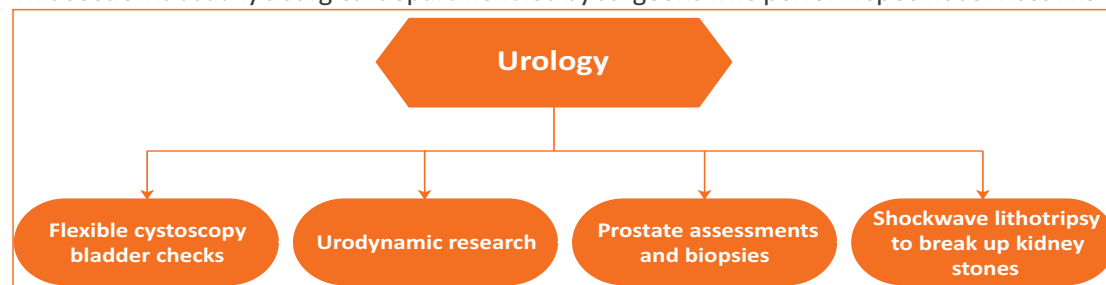


Fig. 1.1.11. Urology Department

Psychiatry

This section deals with examining and treating patients with a wide range of mental ailments and conditions. Some services include:

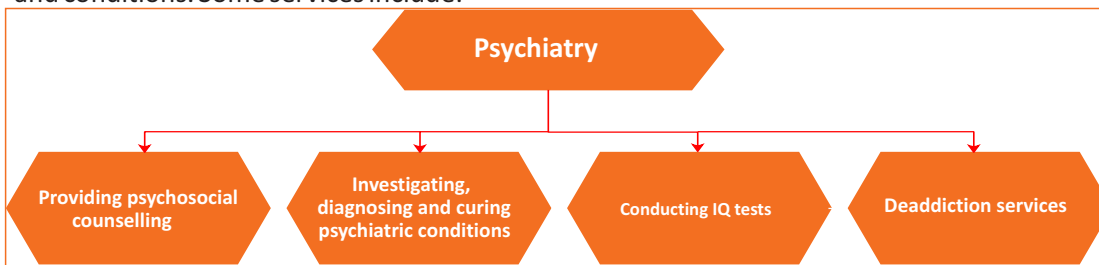


Fig. 1.1.12. Psychiatry Department

Outpatient

In this department, people only come to the hospital for a piece of advice and not for admission. The patients seek medical advice from a specific section depending on their issue, and medics prescribe a cure for them to take for a specified period. Then, patients are asked to come back for a follow-up. The patient's cure within the boundaries of the hospital lasts only a day. The outpatient department runs for a specific time during the day. Consultant doctors are regularly brought in to handle OPD.

Inpatient

This subdivision admits patients at least overnight for treatment. Here, a case history of the patient is taken, and the patient gets a case sheet in which his improvement is recorded. Patients are monitored through the day by nurses, and doctors come on rounds to check on the patients' conditions. The length of stay will depend on the severity of the patient's illness.

Central sterilisation unit

This division is incharge of keeping all the devices used in the hospital clean and sterilised to avoid spreading infections throughout the hospital. They follow a strict procedure for sterilising medical and surgical instruments.

Housekeeping

This division is incharge of custody of the hospital hygiene and neatness. It includes doing the laundry, cleaning all the hospital rooms, and effectively disposing of medical waste according to strict hospital disposal procedures.

Catering & food services

This section offers food services to inpatients, their families, and the hospital's hospital based on a healthy menu provided by the Nutrition Department.

Medical social work

This department, operated by medical social workers, supports patients and their relatives in dealing with a broad range of psychosocial matters and stresses related to coping with the disease and maintaining health. In addition, this subdivision addresses the challenges relatives face, increase accessibility to healthcare and aids as a bridge amid the doctors and the individual, family, and community.

Physiotherapy

This department aims at rehabilitating patients. This department mainly links to the orthopaedics department offers a wide range of body healing therapies to help a patient resume normal functioning. This department provides outpatient as well as inpatient services.

Pharmacy

Every hospital must have to be equipped with a pharmacy that provides drugs for the entire hospital. It includes medication for patients and offers other drugs and devices used by all other departments in the hospital for patient care and surgeries.

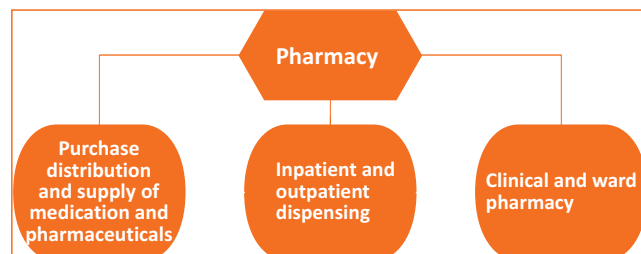


Fig. 1.1.13. Pharmacy Department

Medics are generally given a formulary of drugs by the pharmacy to use as a guide.

Nutrition and dietetics

Specialist in nutrition and dietetics staffs in this department. They are allocated to provide professional advice on diet for hospital inpatient wards as well as outpatient departments. Specific departments require that the patient be put on a diet, and therefore the team works with many other departments that treat:

These specialists and experts can also suggest a dietary chart followed by the hospital

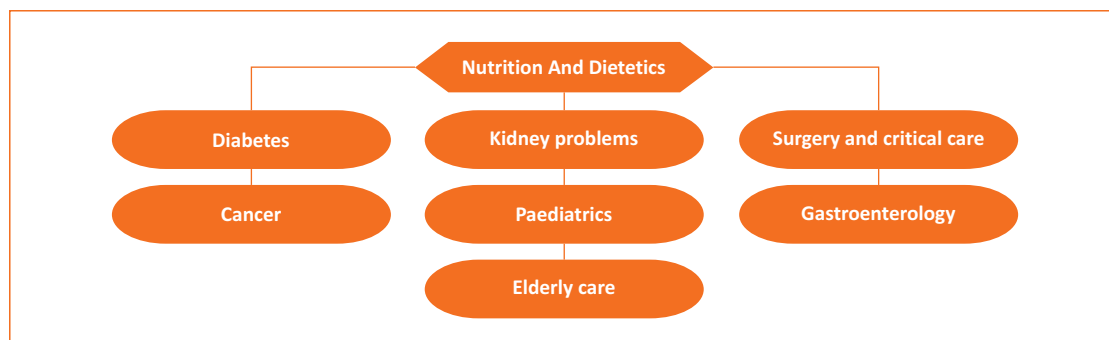


Fig. 1.1.14. Nutrition and Dietetics Department

canteen to ensure that each patient gets nutritious food during their stay.

Microbiology

This department works with the microbial and viral aspects of medicines. Microbiology is critical as the number of hospital-acquired infections is on the rise. These doctors usually carry out examinations on samples from surgeries sent from different other departments and submit reports following biopsies.

Diagnostic imaging

This department is also known as the department of radiology; it provides the following services:

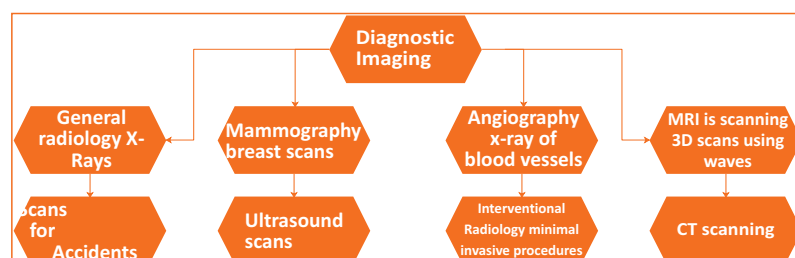


Fig. 1.1.15. Diagnostic Imaging Department

Patients are directed to this department for the services mentioned above as any other departments do not have the required devices to perform diagnostic tests and imaging. Subsequently, the service is provided, reports will be generated about the imaging, and those reports will be given to the department from which the imaging was required.

Medical records

The responsibility of this department is to deal with the records and maintain all the documents, data files of in and outpatients. These are the records from which medical statistics can be formulated, and it serves as a reference for future purposes.

Medical maintenance & engineering

This department makes sure that the equipment of the hospital is always in operable condition. This department plans and executes various projects in the hospital and makes sure that all electrical facilities are in perfect working condition, perform repair and replacement work for air-conditioning units, plumbing, steelworks, and takes care of the complete maintenance of the hospital.

Information technology & communication

Each hospital today uses computers to keep track of patients' records and other medically related matters. Therefore, this department is in charge of keeping the systems updated and providing support to the hospital when systems crash. They provide effective online services for patients and help keep the entire hospital informed of any events within the hospital.

Human Resources

This department does the recruitment of competent human resources for the hospital. It creates policies and procedures for the staff of the hospital. It aims to ensure employee satisfaction, good working conditions and monetary and non-monetary paybacks for the employees. Its responsibility is to provide compensation for the services rendered by the employees.

Finance

This department takes care of the financial aspects of a hospital. It makes budgets, financial plans for the future and allocates financial resources to the hospital's various departments for their upgrade. It also offers wage statements to the staff and oversees medical supplies and pharmaceuticals for the hospital.

Administration

The administration is in charge of looking after the hospital's day-to-day operations. They look after all the hospital paperwork and ensure that every department follows the administrative procedures of the hospital.

Tips



1. Shifting Disease Burden - Non-Communicable Diseases (NCDs) account for 50% of the disease burden and 60% of all deaths in India.
2. The diagnostic imaging is also known as the department of radiology.
3. Haematology carries out the study of aetiology, diagnosis, treatment, prognosis, and inhibition of blood illnesses that affect the construction of blood and its components, such as blood cells, haemoglobin, blood proteins, and the mechanism of coagulation.

Practical



1. List the functions of COVID frontline worker (Medical Equipment Support)
2. Prepare the list of the equipments used in radiology department.
3. Prepare the list of the equipments used in ophthalmology department.

Role Play



1. Do a role play with your classmates where your supervisor asks to do the visual inspection of the equipments .

UNIT 1.2 Basics Of Healthcare And Medical Devices

Unit Objectives

After having studied this module, the learner will be able to:

1. Understand the healthcare delivery systems and role of medical devices
2. Learn mechanical knowledge and use of tools
3. Learn and follow proper lifting techniques
4. Have familiarity with medical terminology.

1.2.1 Healthcare Delivery Systems and Role of Medical Devices

Medical Devices- As per WHO (World Health Organisation), 'medical device' means any instrument, apparatus, implement, machine, appliance, implant, reagent for in vitro use, software, material or another similar or related article, intended by the manufacturer to be used, alone or in combination, for human beings, for one or more of the specific medical purpose(s) of:

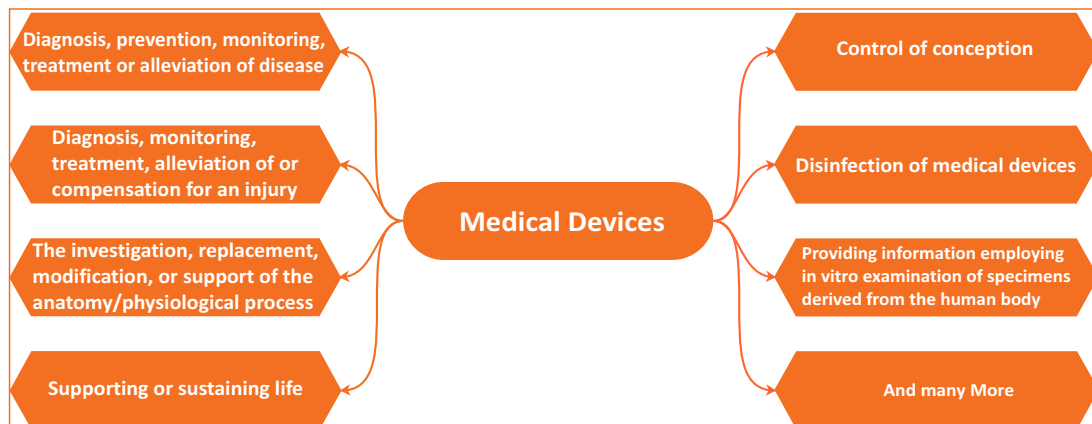


Fig. 1.2.1. Healthcare Delivery System

Medical Equipment - Medical devices requiring calibration, maintenance, repair, user training and decommissioning – activities usually managed by clinical engineers. Medical equipment is used for the specific purposes of diagnosis and treatment of disease or rehabilitation following illness or injury; it can be used either alone or in combination with any accessory, consumable or another piece of medical equipment. Medical equipment excludes implantable, disposable or single-use medical devices.

Healthcare Delivery Systems - Are facilities where Preventive, Diagnostic, Curative and Rehabilitative services are provided.

Healthcare Delivery Systems comprised of the following components, and accordingly, the Medical Devices will vary based on the type of the facility:

- a. **Preventive Care** - This type of care is used to prevent and manage lifestyle diseases. For example, bp machines are used to measure a person's blood pressure and change his dietary habits to prevent hypertension. Similarly, a glucometer is used to measure the blood sugar level in a person to manage his lifestyle to avoid diabetes. These types of care can be provided at home by self-monitoring or at health and wellness centers.
- b. **Diagnostics** - when a patient comes to a healthcare facility, his vital parameters are measured and based on his symptoms, he is advised to get various blood tests done. Based on his tests, his disease is diagnosed, and he is then provided with medications for treatment. His tests are done with a microscope or hematology analysers or biochemistry analysers etc. These tests are done in laboratories, which are available either privately or in the healthcare facility itself.
- c. **Treatment** - based on the test results, the patient is provided with his therapy by giving medications or being admitted to the healthcare facility. Depending upon his conditions, he can be accepted either in a primary healthcare centers or a referral healthcare facility. For specialized treatment, he can be referred to a tertiary care facility having multi disciplinary facilities. Depending upon his condition, he can be admitted to an emergency ward, and after stabilization, he will be shifted to an intensive care unit. He can also be provided surgical interventions to remove the diseases like tumours, kidney stones, appendix removal, kidney and liver transplant in tertiary care. The various equipment used in the healthcare facilities is vital signs monitor, defibrillators, ECG machines, EEG machines, electrosurgical units etc.
- d. **Physiotherapy and other rehabilitation** - After the patient's treatment, depending upon his condition, he is discharged with instructions for medications at home or provided physiotherapy and other facilities for his rehabilitation. In addition, he is provided rehabilitation support by various exercises on machines like treadmills, water bath, wax bath, SW diathermy etc.
- e. **Oral Care** - This is provided in the dentistry department, where the problems related to oral health are taken care of, and maxi facial treatments are provided. Also offered are tooth-related problems solutions like removal of the tooth, provision of artificial tooth sets, Root canal treatments etc.

It needs to be stressed here that a continuum of care must be maintained from prevention to diagnosing diseases to treatment and follow-up of the disease as required.

The various types of facilities are thus sub centers, primary healthcare centers, secondary healthcare canters and tertiary healthcare centers. The tertiary healthcare centers are also available at the medical college levels.

The various facilities have OPD or out patient department where the patient's primary diagnosis is made. If his conditions warrant that he be kept under observation or provided surgical interventions, he is admitted and becomes an inpatient and is admitted in ward or ICU.

He can also be taken straight to the emergency department if the patient is severe. It is a daycare facility where the patient is kept under observation for the day, and he is discharged the same day.

The various departments available in healthcare facilities are as below:

1. **Anesthesia department** - the patient is provided doses of anaesthetic agents to support painless surgeries and after surgery to provide recovery support. Anaesthetic doctors manage critical care patients for recovery. Major equipment used is vital sign monitors, anesthesia machines or Boyle apparatus etc.
2. **Cardiology department** - Treats all cardiac related problems. major equipment used are ECG machines, Holter analysers, bp apparatus, cardiac monitors, stress test machines with treadmill, echocardiography and colour Doppler machines etc.
3. **Cardiothoracic and vascular surgery** - Doctors in this department provide surgical interventions to treat a cardiac abnormality like open heart surgery to replace or repair a heart valve or repair a hole in the heart or CABG (coronary Artery Bypass Graft) etc. Major equipment used is open heart surgery machines, octopus, vital sign monitors etc.
4. **Interventional cardiology department** - Provides identifying for a blocked heart vessel by angiography and treats the same with angioplasty or grafting stents in the blocked heart vessels. Major equipment used is cath lab etc.
5. **Internal medicine department** - An internist can treat you for something as routine as the flu or fatigue or provide inside and out care for diabetes, lung or heart disease. Internists often coordinate many sub-specialists, the patient might be able to see in the process of treating illness. Gastroenterology department- treats all kinds of problems related to digestive systems. Major equipment is various types of endoscopes.
6. **Paediatrics and neonatology department** - Treats all paediatrics and newborn patients. Major equipment is pediatrics/infant ventilators, phototherapy units, radiant warmers, oxygen hoods etc.
7. **Emergency and trauma department**- The emergency department deals with severe patients, and the trauma department deals with accidental cases.

Healthcare set up in public healthcare (government healthcare) : the following types of facilities exist in government setup in India:

- a. **Sub Centre-(SC)** - A sub centre is designed to serve highly rural areas with the expenses fully covered by the national government. Mandates require health staff to be at least two workers (male and female) to serve a population of 5000 people (or 3000 in a remote, dangerous location). Sub centres also work to educate rural peoples about healthy habits for a more long-term impact.
- b. **Primary Health Centres (PHC)** - Primary health centres exist in more developed rural areas of 30,000 or more (20,000 in remote areas) and serve as larger health clinics staffed with doctors and paramedics. Patients can be referred from local sub-centres to PHCs for more complex cases. PHCs also function to improve health education with a more significant emphasis on preventative measures.

PHC and SC are now being renamed as Health and wellness centres, and government plans have 1,50,000 HWC within the next five years.

- c. **Community Health Centres (CHC)** - A community health centre accepts patients referred from primary health centres. It serves 120,000 people in urban areas or 80,000 people in remote areas. Patients from these agencies can be transferred to general hospitals for further treatments. Thus, CHC's are also first referral units, or frus, required to have obstetric care, newborn/childcare, and blood storage capacities at all hours everyday of the week.
- d. **District hospitals** - District hospitals are the final referral centres for the primary and secondary levels of the public health system. It is expected that at least one hospital is in each district of India, although in 2010, it was recorded that only 605 hospitals exist when there are 640 districts. There usually are anywhere between 75 to 500 beds, depending on population demand. These district hospitals often have modern equipment and relations with local blood banks.

1.2.2 Mechanical Knowledge and use of tools

The standard tools for the repair of biomedical equipment are listed below:

1. 30W soldering iron with stand

A soldering iron is a hand tool used in soldering. It supplies heat to melt solder to flow into the joint between two wires or metallic contacts of components like diodes and transistors. A soldering iron is composed of a heated metal tip and an insulated handle. Heating is often achieved electrically by passing an electric current (supplied through an electrical cord or battery cables) through a heating element. Soldering irons are most often used for installation, repairs, and limited production work in electronics assembly.

The soldering is done by melting soldering wire. The Soldering Wire melts with the heat of the tip of soldering iron, and when it cools, it joins the two wires. It is also used to pull out the components like resistances, diodes etc. The desoldering iron tip is kept at the contact, which melts the solder, and a device sucks the melted solder. Next, the desoldering pump sucks the melted solder, and the device is then pulled up with a plier or a tweezer. There are soldering stations available on which the soldering iron can be kept on a stand, and the temperature of the tip can be varied with a rotating knob. The following figures show the Soldering Iron, Soldering Wire and the Soldering Station.



Fig. 1.2.2. Soldering Iron



Fig. 1.2.3. Soldering Wire

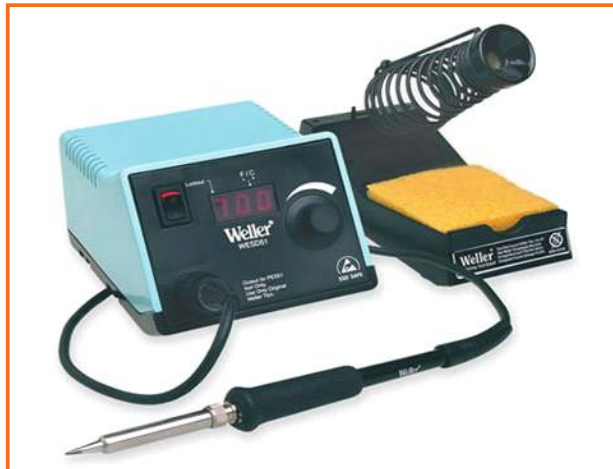


Fig. 1.2.4. Soldering Station with Stand and Temperature Control Knob

2. Desoldering pump

A desoldering pump is a manually operated device used to remove molten solder from a printed circuit board. The pump is applied to a heated solder connection, then managed to suck the solder away. The pump has a cylinder with a spring-loaded piston which is pushed down and locks into place. When triggered by pressing a button, the piston springs up, creating suction that sucks the solder off the soldered connection.



Fig. 1.2.5. Desoldering Pump with the parts opened



Fig. 1.2.6. Working with a soldering iron

3. Screwdriver set (slotted, Phillips and torque type)

A screwdriver is a tool, manual or powered, for turning (driving or removing) screws. A typical simple screwdriver has a handle and a shaft, and a tip that the user inserts into the screw head to turn it. Commonly used tips are flat plain and star or Philips type. Another type is the torque type which will be required for particular purposes.



Fig. 1.2.7. Screwdriver with Flat Tip



Fig. 1.2.8. Torx type screwdriver set.



Fig. 1.2.9. Screwdriver- Star or Philips Type

4. Two precision screwdrivers (slotted/Phillips)

These screwdrivers are smaller than the regular screwdrivers but have smaller and hardened tips and are used for precision fittings. Tips will be either Flat or Phillips type



Fig. 1.2.10. Precision screwdrivers

5. Long nose pliers

Long nose pliers are both cutting and holding pliers used by electricians, network engineers and other tradesmen to bend, re-position and snip wire. Their long nose gives excellent control, while the cutting edge near the pliers' joint provides "one-tool" convenience. In addition, because of their long shape, they help reach small areas where cables or other materials have become tucked or unreachable with fingers or other means. 5" means the long nose length is 5" and is most commonly used.



Fig. 1.2.11. Long Nose Plier

6. Diagonal cutting pliers

Diagonal pliers (or **wire cutters** or **diagonal cutting pliers** or **diagonal cutters**) are pliers intended for cutting wire (they are generally not used to grab or turn anything).



Fig. 1.2.12. Diagonal Cutting Plier

7. IC puller

An **IC extractor** is a tool for safely and quickly removing integrated circuits (ICs) from their sockets. The primary purpose of using this tool is to avoid bending the socket pins.



Fig. 1.2.13. IC Puller (image courtesy Amazon)

8. Wire stripper strips up to 10AWG wire

A simple manual wire stripper is a pair of opposing blades much like scissors or wire cutters. However, the addition of a centre notch makes it easier to cut the insulation without cutting the wire. This type of wire stripper is used by rotating it around the insulation while applying pressure to cut around the insulation. Since the insulation is not bonded to the wire, it then pulls quickly off the end.



Fig. 1.2.12. Diagonal Cutting Plier

7. IC puller

An **IC extractor** is a tool for safely and quickly removing integrated circuits (ICs) from their sockets. The primary purpose of using this tool is to avoid bending the socket pins.



Fig. 1.2.13. IC Puller (image courtesy Amazon)

8. Wire stripper strips up to 10AWG wire

A simple manual wire stripper is a pair of opposing blades much like scissors or wire cutters. However, the addition of a centre notch makes it easier to cut the insulation without cutting the wire. This type of wire stripper is used by rotating it around the insulation while applying pressure to cut around the insulation. Since the insulation is not bonded to the wire, it then pulls quickly off the end.



Fig. 1.2.14. Wire Stripper and Cutter

9. Allen keys

A **hex key**, **Allen key**, or **Allen wrench** is a tool used to drive bolts and screws with **hexagonal** sockets in their heads. -Set of six is common

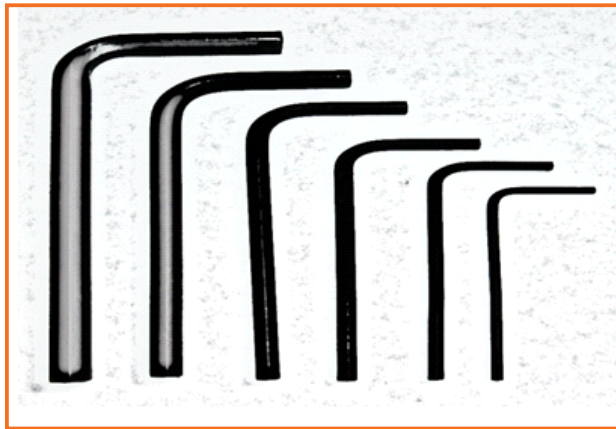


Fig. 1.2.15. Allen Keys Set

10. Long nose tweezers

This is used to hold small components or the tip of a wire.



Fig. 1.2.16. Long nose tweezers.

11. Digital multimeter

Digital multimeter (DMM) is a test tool used to measure two or more electrical values—principally voltage (volts), current (amps) and resistance (ohms). It is a standard diagnostic tool for technicians in the electrical/electronic industries. The values are displayed on display, the display mode is selected with a dial or rotary switch, and the leads are inserted in the input jacks, and the other ends of the leads are connected to the device.



Fig. 1.2.17. A Digital Multimeter (Image Courtesy Fluke)

1.2.3 Proper lifting techniques.

Proper lifting of medical equipment is significant. Improper lifting may cause injury to your backbone.

Follow these instructions to avoid compressing the spinal discs or straining your lower back when you are lifting (courtesy My Health Alberta-Govt. of Alberta)

- **Keep a broad base of support.** Your feet should be shoulder-width apart, with one foot slightly ahead of the other (karate stance).
- **Squat** down, bending at the hips and knees only. If needed, put one knee to the floor, and your other knee in front of you bent at a right angle (half kneeling).
- **Keep good posture.** Look straight ahead, and keep your back straight, your chest out, and your shoulders back. This posture helps keep your upper back straight while having a slight arch in your lower back.
- **Slowly lift** by flattening your hips and knees (not your back). Keep your back straight, and don't bend as you lift.
- **Hold** the weight as adjacent to the body as possible at the level of your gut button.
- **Use your feet** to change direction, taking small steps.
- **Lead with your hips** as you change direction. Keep your shoulders in line with your hips as you move.
- **Set down** your load carefully, squatting with the knees and hips only.

Keep in mind:

- Do not attempt to lift by bending forward. Bend your hips and knees to squat down to your load, keep it close to your body, and straighten your legs to lift.
- Never lift a heavy object above shoulder level.
- Avoid turning or twisting your body while lifting or holding a heavy object.

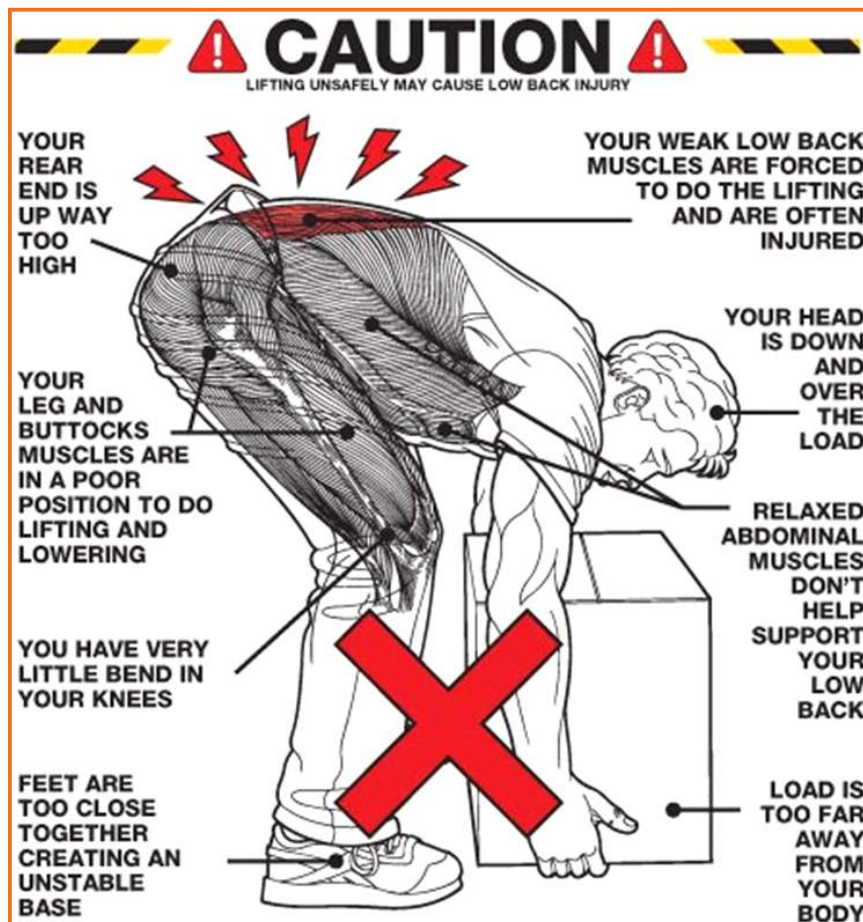


Fig. 1.2.18. Improper Lifting of Equipment may cause Low Back Injury
(Image courtesy The Jamar Company)

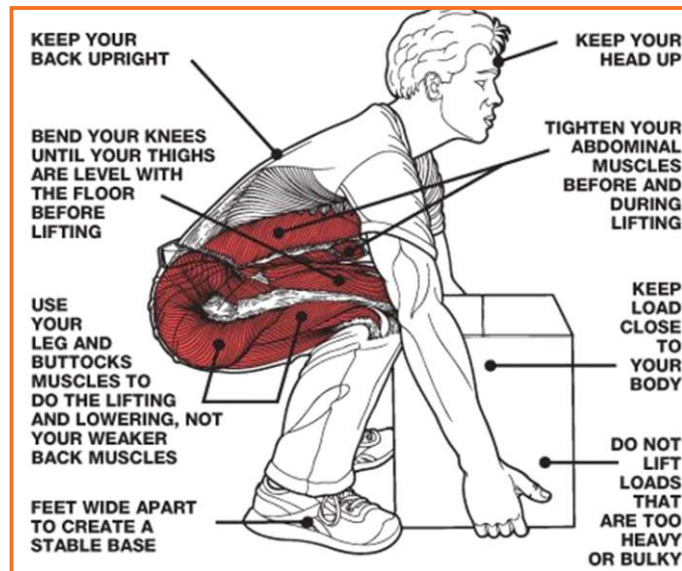


Fig. 1.2.19. Proper Lifting technique (Image Courtesy-the Jamar Company)

1.2.4 Familiarity to Medical Terminology.

Any biomedical engineer should be familiar with the standard medical terminology to use the machines for various applications comfortably. For example, when the complaint is “ the Electrocardiogram is not displaying”, the technician should be immediately linked to the ECG machine's display unit. The following are the essential medical terminology every biomedical engineer should be familiar with.

Anatomy - Is the branch of biology concerned with studying the structure of organisms and their parts.

Anaesthesia - Is the branch of medical science that deals with the temporary induced loss of sensation or awareness for carrying out surgical procedures. The machine used to induce loss of sense is called Anaesthesia Machine. Dr Henry E. G. Boyle introduced the first anaesthesia machine, and thus, the anaesthesia machine is also known as **Boyle's Apparatus**.

Angiography - A diagnostic X-Ray procedure is done to display blood flow in the blood vessels and organs of the body. This Angiography is done by injecting a dye or a contrast medium and utilising X-Ray fluoroscopy techniques. Examples are coronary angiography used for the heart, cerebral angiography for the brain and peripheral angiography used for hands, arms, feet and legs. Angiography is performed in a specialised setup known as cath lab.

The biomaterial - Any substance that is interacts with the body systems. Biomaterials are constructed artificially by synthetic material or metallic or polymers etc. Biomaterials are used to replace or augment various systems inside the body. Examples are heart valves, hip replacement, knee replacements and different dental implants.

Biocompatibility - This is the measure of acceptance of biomaterials by the body.

Bioengineering - This applies concepts and engineering methods by utilising medical sciences, mathematics, physics, etc., to develop systems that can solve health problems.

Bioinformatics - The branch of biology that deals with acquisition, processing, storage analysis and display of biological information. The research includes the mathematical and computational methods to model the biological processes.

Biomedical engineering- or Bioengineering is the application of engineering and design to help solve health problems.

Biomedical Imaging - The science and branch of medicine involve acquiring, displaying, and analysing anatomical images to study tissues and organs' biochemical and physiological analysis.

The bioreactor - The bioreactor is a medical device used to create an environment to study cells and tissues' growth — for example, the Incubator system.

Biological Sensors - A Medical device uses biological materials such as DNA, enzymes and antibodies to detect and analyse the biological chemical and physical process and report and transmit the data.

Brachytherapy - Is a radiation therapy in which the radioactive source is placed in or around the treatment area. The common application is for the treatment of prostate cancers, cervical cancers and breast cancers. The original can be kept for a small duration or a longer duration.

Cardiology - Branch of medicine that deals with diseases and abnormalities of the heart.

CDSS (Clinical Decision Support System) - This is a software-related computerised decision-making tool that helps physicians analyse the disease, apply treatment based on data fed into the database, and use artificial intelligence techniques.

Computational modelling - The use of mathematics, physics, statistics and computer to study the behaviour of a complex system

CT Scans (Computed Tomography) - This is a medical device that uses a focussed beam of X-Ray and rotates the same over the body to provide slices of images of the body's anatomy. The device may use single or multiple slices of the body. CT Scanners are available in Dual Slice, 32, 64, 128, 256 and 512 Slices technology.

Contrast Agent - A chemical used to be injected into the body to provide contrast in the images. For example, blood flow can be visualised in the image of CT Scan or Angiography.

Colour Doppler - An ultrasound machine in which the blood flow can be visualised using Doppler principles. The blood flow is given a colour based on the velocity and direction of flow.

Drug Delivery System - Management of delivery of drug dosages into the body.

DVT (Deep Vein Thrombosis) Pump - DVT pumps are compression pumps designed to prevent people from getting deep vein thrombosis (DVT), which can be a dangerous event. DVT Pumps work in such a way as to deliver the proper compression so that blood within the arteries does no clot.

Elastography - A medical imaging technique that measures the stiffness of tissue. The method utilises sound waves to capture the stiffness in a tissue. For example, a disease in a liver will have more stiffness than a normal liver.

ECG (Electrocardiogram) machine - A medical equipment that captures the electrical activity of the heart.

EEG (Electro Encephalogram) machine - A medical equipment displays the electrical activity on the scalp of the brain's neurons. This EEG detects the abnormality in the brain, for example, epilepsy.

Electromagnetic Radiation - A radiation of electrical and magnetic waves vary simultaneously.

Endoscope - Endoscope a thin illuminated tube-like system with a lens attached to visualise a body's internal hollow structure by direct insertion. These instruments can also be linked for biopsy and surgery. A laparoscope is a typically rigid endoscope injected through an incision in the abdominal wall and is used to visually inspect the interior of the peritoneal cavity — called peritoneoscope.

Fluorescence - Fluorescence is the emission of light by substances that absorb light or other electromagnetic radiation. The absorbed and emitted light have different wavelengths and thus have different colours.

Foetal Doppler - A Foetal Doppler shows the heart rate of a foetus inside the mother's womb.

Foetus and embryo - A baby till 11 weeks after pregnancy is an embryo, and after the 11th week, it is termed the fetus.

Gamma Rays - The electromagnetic radiation that has the shortest wavelength and highest energy.

Glucometers - Devices are used to test for the blood glucose levels inside a patient.

Hepatic - Related to the liver.

Hydrogel - Biomaterials are highly absorbent and flexible as natural tissues.

Hyper and Hypo - Hyper means more than normal value, and hypo means less than normal value. For example, hypertension is high blood pressure, and Hypotension is low blood pressure.

Image-guided robotic interventions - A minimally invasive procedure guided by automatic cameras remotely.

Immunofluorescence - A biological staining technique in which the fluorescent molecule is bound to an antibody bound to a protein.

Implantable medical device - An artificial medical device placed inside the body of a human body to replace the body functions. For example, a hip replacement is done to provide structural support, and a pacemaker is implanted in the body to regulate the heart pumping.

Ionising and non-ionising radiations - Ionising electromagnetic radiation separates the electrons from the atom or molecules (the process is called ionisation) and has shorter wavelengths. examples are Gamma Rays and X-Rays. The other radiations like UV Rays, visible lights, microwaves, infra red and radio waves are non-ionising.

Laparoscope - A rigid telescope-like viewing instrument used to visualise abdominal and pelvic structure by a small incision inside the abdomen. It also assists in minimally invasive surgical interventions in the abdomen.

MRI (Magnetic Resonance Imaging) - This imaging technique uses the resonance of the protons of water molecules inside the body. It does not utilise harmful X-Ray radiations. This MRI is used to study anatomy inside the body and the malfunctions based on the anatomy images.

Mammography - This is an imaging technique based on X-Rays to study the disease of the breast like breast cancers. It is utilised as a screening as well as a diagnostic tool for the detection of breast cancers.

mHealth - It is an abbreviation for mobile health. It is used to define public health delivery with mobile devices such as mobile phone and tablet computer technology.

Microfluidics - It is a multi disciplinary field including engineering, physics, chemistry, and biotechnology to design systems for precise control of fluid flow at micro meter level. Typically the fluids are precisely controlled for the flow, mixing, separation and processing.

Micro particles - A particle of the size of a micrometer. (10^{-6} m)

Microscope - A medical device to magnify and see the particles which can't be seen with naked eyes.

Microscopy - Technique employed to study with a microscope a particle that the naked eye can't see.

Minimally invasive surgery - A surgical procedure that employs one or more incisions to do the surgery using tools like a laparoscope. This procedure reduces the requirements of pain killers, damage to surrounding cells and hospital recovery time.

Nanoparticles - Particles of the size 1-100 nm (1/10,000 that of a human hair) are similar to the size of biological molecules. These can be engineered for various uses like diagnostics devices, drug delivery systems, contrast agents etc.

Nanotechnology - Nanotechnology is manipulating nano-particles for applications related to surface sciences, molecular biology, semiconductor physics and microfabrication.

Neonatology - Branch of medicine dealing with neonates and especially the premature newborn. Neonates are newborn babies till four weeks.

NIRS - Near-Infrared Spectroscopy - Spectroscopy that uses near the infrared frequency of the electromagnetic spectrum. This spectroscopy is typically used for medical diagnostics of blood sugar and saturated oxygen levels.

Neuroimaging - Neuroimaging is an imaging technique to image the functions and anatomy of the brain and spinal cord and associated structures.

Nuclear Medicines - **Nuclear** medical speciality deals in radioactive materials (radio pharmaceuticals) to assess health conditions, diagnose and treat disease.

OCT (Optical Coherence Tomography) - Medical equipment used to obtain sub-surface images, i.e. images just below the skin. For example, ophthalmologists use the OCT for imaging within the retina, and cardiologists use it to image the coronary arteries and diagnose coronary diseases.

Optical imaging - A technique for non-invasively looking inside the body as is done with X-Rays. However, as opposed to X-Rays the optical imaging uses non-ionising radiations like light and distinct properties of photons to obtain detailed images of organs and minor issues and cells inside the body.

Photons - Photons are particles of light or electromagnetic radiation. The energies of photons range from high energy X-Rays and Gamma rays to low energy radio waves.

Piezoelectric crystals - Crystals in the ultrasound transducers that vibrate with electrical energy and generate sound waves. These are known as ultrasound waves which are of a frequency of more than 10 kHz. These penetrate the body, get reflected, hit the piezo electric crystals in the transducer, and convert them into electrical images.

Point of care devices - These are devices used to diagnose the patient and treat them at the site of the patient. Examples are Rapid Diagnostic Kits(RDK) and Glucometers, and BP Machines.

Polymers - Large molecules with repeating sub molecules. Examples are synthetic polymers like polystyrene and natural biopolymers such as DNA.

PET (Positron Emission Tomography) - An imaging technique that uses radio pharmaceuticals to create three-dimensional images. The PET Scanner emits positrons with the decay of the radioactive materials, which react with the electrons and get destroyed, emitting two photons in the opposite directions. The detectors in the PET Scanners use this property to create images of internal organs.

Prosthetics -The design, fabrication and fitting of artificial body parts.

Paediatrics - Paediatrics is the branch of medicine that involves the medical care of infants, children, and adolescents.

Radiation - Emission of electromagnetic waves or as moving sub atomic particles, exceptionally high energy particles that cause ionization.

Radiology - Radiology is the science of diagnosing and treating a patient by applying medical imaging techniques like ultrasound, CT scan, MRI Scan etc.

Radioactive tracers/Radio pharmaceuticals - Radioactive tracers/Radio pharmaceuticals are made up of carrier molecules bonded to the radioactive atom. The transporter molecule is designed to bind to the tissue being inspected so that radioactive particles can be scanned to produce an image of the tissue from the body.

Photons - Photons are particles of light or electromagnetic radiation. The energies of photons

A regenerative medicines - A broad field that includes tissue engineering and self-healing properties of the body every so often with the help of foreign biological materials to rebuild tissues and organs.

Rehabilitation engineering - Rehabilitation engineering application of engineering principles and design to assist individuals with disabilities and recover the functions lost because of any disease. The devices are known as assistive devices.

Robotic surgery - Surgery by minimal incisions or through an orifice by fingers like robotic tools performed by surgeons remotely controlled by telemanipulator or computer interface.

Scaffold - A structure of artificial or natural materials build to mimic a biological process outside the body or replace damaged tissue inside the body.

SPECT (Single Photon Emission Computed Tomography) - SPECT a nuclear imaging technique using gamma rays. SPECT provides three-dimensional images of the distribution of the images formed by the distribution of radio tracer molecules injected inside the body. The rotation of the scanned images generates the 3D images.

Spectroscopy - Spectroscopy is the study of the interaction between matter and electromagnetic radiation and is used to determine the composition, density, temperature and motion of an object.

Stem cell - A unique cell that can replicate into many different cells rapidly. These are used to repair any kind of damaged tissue or blood.

SIM (Structured Illumination Microscopy) - A form of super-high-resolution microscopy that captures extremely clear images of molecules and cells even though they are in quick motion.

Telehealth - Telehealth is a communication method to provide healthcare remotely.

Tesla - A unit of measurement of magnetic field

Tissue engineering - an interdisciplinary and multi disciplinary field that aims at the development of biological substitutes that helps to restore, maintain or improve tissue functions.

Ultrasound - Ultrasound a piece of medical equipment that uses ultrasound frequency in MHZ, i.e. more than audible sound. An ultrasound frequency is transmitted into the body; it gets reflected by the organs and produces images of the anatomy of the organs inside the body.

X-Ray - An X-ray is a form of radiation that can penetrate inside the objects in a body except for the bones and form an image of the bones contrasted with the organs tissues. The X-Ray travels through the body and strikes the X-Ray detectors, including an image of the contrast agent or the bone.

Additional Reference/Resources

- **Fischer Connectors - Connectivity solutions for medical & healthcare**
<https://www.youtube.com/watch?v=kWzazxzFx8c&t=124s>
- **Fischer Connectors - Connectivity solutions for medical applications (Intervention & Surgical)**
<https://www.youtube.com/watch?v=iY1TevSsKAc>
- **Fischer Connectors - Connectivity solutions for medical applications (Diagnostic & Imaging)**
<https://www.youtube.com/watch?v=rAs3Nd37PMU>
- **Fischer Core Series in a nutshell**
<https://www.youtube.com/watch?v=BT-BsgcS6js&list=PLyTH9yU1u8LaxcaCxgo6fTJ32Uz2pUvDO>
- **Fischer UltiMate™ Series in a nutshell**
<https://www.youtube.com/watch?v=YOQg-O1ti4k&list=PLyTH9yU1u8LaxcaCxgo6fTJ32Uz2pUvDO&index=2>
- **Fischer FiberOptic Series in a nutshell**
<https://www.youtube.com/watch?v=2uBetGHWHTw&list=PLyTH9yU1u8LaxcaCxgo6fTJ32Uz2pUvDO&index=3>
- **Fischer MiniMax™ Series in a nutshell**
<https://www.youtube.com/watch?v=vZ22u0LKFDI&list=PLyTH9yU1u8LaxcaCxgo6fTJ32Uz2pUvDO&index=4>
- **Fischer Freedom™ Series in a nutshell**
<https://www.youtube.com/watch?v=KKDhGd8RdyM&list=PLyTH9yU1u8LaxcaCxgo6fTJ32Uz2pUvDO&index=5>
- **PCB Fabrication- Step by step guide**
<https://www.pcbcart.com/article/content/PCB-manufacturing-process.html>
<https://www.vse.com/what-is-the-pcb-fabrication-process/>
- **Design and fabricate a PCB for the same using the links below. DIY PCBs at Home (Single-Sided Presensitized)**
<https://www.youtube.com/watch?v=7wAer7a3tU4>.
- **Making a Circuit Board from scratch. -**
<https://www.youtube.com/watch?v=p9Umk5aG8Y4>
- **Data sheets are the critical parameter specifications for a diode or a transistor.**
https://www.electronicsnotes.com/articles/electronic_components/diode/specifications-parameters-ratings.php
- **Datasheets for any diodes or transistors can be downloaded free from.**
<https://datasheetspdf.com/>

Tips

1. The diagnostics industry in India is currently valued at \$4 bn. The share of the organized sector is almost 25% in this segment (15% in labs and 10% in radiology).
2. Life expectancy is going to exceed 70 years by 2022; hence more healthcare services required

Exercise

1. List down the growth drivers of health care industry in India.
2. Identify which one of the following statements are true or false with respect to medical devices?
 - Diagnosis, prevention, monitoring, treatment or alleviation of disease
 - Diagnosis, monitoring, treatment, alleviation of or compensation for an injury
 - The investigation, replacement, modification, or support of the anatomy or a physiological process
 - Supporting or sustaining life
 - Control of conception
 - Disinfection of medical devices
 - Providing information employing in vitro examination of specimens derived from the human body
3. List the components of healthcare industry in India.
4. What is RPA in healthcare industry?
 - (a) Robotic process automation
 - (b) Robotic progress automation
 - (c) Robotic procedure automation
 - (d) Robotic plan automation

Practical

1. Visit one District Hospital(or scan the HMIS), one PHC, one SC and one CHC and list the Equipment available and Manpower available in these centres. Go through IPHS (Indian Public Health Standards) and find out whether all the equipment/devices are present in the facilities.
2. Identify the various tools used in the repair and maintenance of Medical Equipment.
3. What is the function of a Digital Multimeter?
4. Study the Anatomical Chart and identify the various organs of a body.
5. Study the chart and identify the circulatory system.
6. Practical- Perform proper lifting as per the procedure illustrated in the Figure 2.2.3.2

Role Play

1. Demonstrate the use of the Digital multimeter?

Notes



Lined area for taking notes, consisting of 25 horizontal lines.

Summary

The Healthcare industry in India comprises hospitals, medical devices, clinical trials, outsourcing, telemedicine, medical tourism, health insurance and medical equipment. The sector is proliferating due to its strengthening coverage, services, and increasing expenditure by public and private players.

According to WHO, "Hospital is an essential part of the socio-medical institution, the roles of which is to offer comprehensive health care for the population both, curative and preventive and who stretch out to the personal and its home environment. In addition, a hospital is a centre for training of healthcare workers and bio-social research."

As per WHO (World Health Organisation), 'Medical device' means any instrument, apparatus, implement, machine, appliance, implant, reagent for in vitro use, software, material or another similar or related article, intended by the manufacturer to be used, alone or in combination, for human beings, for one or more of the specific medical purpose(s).

Healthcare Delivery Systems-Are facilities where Preventive, Diagnostic, Curative and Rehabilitative services are provided.

Proper lifting of Medical Equipment is significant. Improper lifting may cause injury to your backbone.

Follow these instructions to avoid compressing the spinal discs or straining your lower back when you are lifting (courtesy My Health Alberta-Govt. of Alberta)

References

BBA in Healthcare and Hospital Management- A Promising
<https://adamasuniversity.ac.in/bba-in-healthcare-and-hospital-management-a-promising-career-choice/>

Healthcare Industry in India, Indian Healthcare Sector
<https://www.investindia.gov.in/sector/healthcare>

Healthcare Industry in India, Indian Healthcare Sector
<https://www.investindia.gov.in/sector/healthcare>

WHO | Medical Device – Full Definition.
https://www.who.int/medical_devices/full_deffinition/en/

WHO | DEFINITIONS. https://www.who.int/medical_devices/definitions/en/

Corporate Accountability: Is Self Regulation The Answer? By
<https://www.countercurrents.org/singh240407.htm>

Public health system in India - Wikipedia.
https://en.wikipedia.org/wiki/Public_health_system_in_India

COMMUNITY MEDICINE DEPARTMENT, B. J. MEDICAL COLLEGE
<http://www.bjmcabd.edu.in/Images/MEDICAL%20STUDENTS%20EXCHANGE%20PROGRAM.pdf>

Health care System in India | Governance | UPSCKeeda. <http://upsckeeda.in/health-care-system-in-india/>

Soldering iron - 2D Symbols - 3D Models.
<https://b2b.partcommunity.com/community/knowledge/en/detail/803/Soldering+iron>

Processes for Fabricating a Prototype - Bourne to Invent.
https://www.bournetoinvent.com/projects/gcse_de_theory/5.7.html

Screwdriver - Essays - Demeter. <https://www.brainia.com/essays/Screwdriver/441328.html>

Workshop Practice (WPC) (Computer Group) (22005).
http://iotmumbai.bharativedyapeeth.edu/media/pdf/lab_manuals/WPC_22005_CM_IF_Manual_101020.pdf

Wire stripper - Wikipedia. https://en.wikipedia.org/wiki/Wire_stripper

What is a hex screw? - True DIY. <https://truediy.net/learn/what-is-a-hex-screw/>

Equipment | EMT Laboratories – Open Education Resources.
<https://openlab.citytech.cuny.edu/emtlabs/equipment/>

Proper Lifting Technique - Junior DeFreitas, M.D.. <https://www.jdefreitas.com/patient-education/health-library/?DOCHWID=hw206944>

Municipal Pipe Inspections | Environmental Pipe Cleaning.
<https://environmentalpipe.com/municipal/importance-of-municipal-pipe-inspection/>

Glossary of Terms | National Institute of Biomedical <https://www.nibib.nih.gov/science-education/glossary>





2. Health & Hygiene

Unit 2.1 - General Practices for an Outbreak/Pandemic

Unit 2.2 - Safety and Sanitisation Guidelines

Unit 2.3 - Other Common Practices & Guidelines

Unit 2.4 - COVID 19 Vaccination



Key Learning Outcomes

After completion of this module, the participants will be able to:

1. Discuss the difference between disease outbreak, epidemic and pandemic
2. Identify correct behavioural practices to be followed to prevent self-infection and spread of the disease to a certain extent
3. Explain social distancing, self-quarantine and self-isolation
4. Identify potential fomites and personal protective equipment (PPE) to be used at workplace
5. Describe common practices and guidelines pertaining to management of waste, measures for dealing with stress and anxiety, and procedure of reporting symptoms

UNIT 2.1: General Practices for an Outbreak/Pandemic

Unit Objectives

After completion of this unit, the participants will be able to:

1. Differentiate between disease outbreak, epidemic and pandemic
2. Explain the rules and guidelines for epidemic/pandemic
3. Distinguish between self-quarantine and self-isolation
4. Discuss norms for maintaining social distance during a pandemic

2.1.1 Disease Outbreaks, Epidemics and Pandemics

What is a Disease Outbreak?

The term 'outbreak' means 'sudden breaking out' or 'occurrence' of a disease, or anything unpleasant. Disease outbreak specifically refers to a sudden occurrence and exponential rise of a disease beyond anyone's expectation and across any community, geographical area, or a country.

Disease outbreak is often caused by an infection which is transmitted to a person from another person, animal, environment or any other source. It may also be caused due to exposure to chemicals or radioactive materials. However, there are times when the cause of outbreak remains unknown. In fact, there is no certainty about the duration of a disease outbreak, for it may last a few days, weeks, months, or even years.

As per the World Health Organisation (WHO) data, disease outbreak happens every year in the form of influenza or the like in different parts of the world. At times, even a single case of an infectious disease is enough for it to be categorized as an outbreak. This is more so in case of a rare disease or that which has serious public health implications, for example, foodborne botulism.

DDT or mercury related diseases are examples of chemical related outbreaks, for example, Zika outbreak in 2015. Aedes mosquito spread the Zika virus in Brazil, America and South East Asia. It caused brain anomalies in the new borns when pregnant women were infected. Most of these infections were asymptomatic.

What is an Epidemic?

Epidemic refers to an infectious disease that spreads actively and substantially across a specific location affecting large number of people within a short span. In fact, epidemics of 21st century are observed to be spreading more rapidly to far off regions than others.

For example, no one had heard of Severe Acute Respiratory Syndrome (SARS) before 2003, but it affected over 8,000 people and killed one out of ten of them. Similarly, epidemic of Middle East Respiratory Syndrome (MERS) across Middle East in 2012 -2013, and the Ebola epidemic in West Africa in 2014 caused fear and panic as well as inflicted massive damage to the economy. Ebola epidemic of 2014 was a viral haemorrhagic fever caused by the Ebola virus. It spreads from infected bats and fluids of infected humans. It was located in the Sub-Saharan Africa mainly.

What is a Pandemic?

When an epidemic spreads across various countries, it becomes pandemic. It affects larger number of people across the globe, causing greater number of deaths as compared to an epidemic. In addition to adversely affecting people, it has a drastic impact on the economy at large. Since pandemics pose far greater challenge than disease outbreaks and epidemics, the measures undertaken to deal with them are quite stringent, such as partial or complete lockdown imposed during covid 19 in 2020.

Influenza pandemic have been the most widely reported. There have been five of them in the past 140 years-the most severe was in 1918 (Spanish flu) and the most recent being the swine flu (2009). It happens when a new strain of the influenza virus is transmitted from any animal species to humans.

The following figure shows some key highlights of a pandemic:

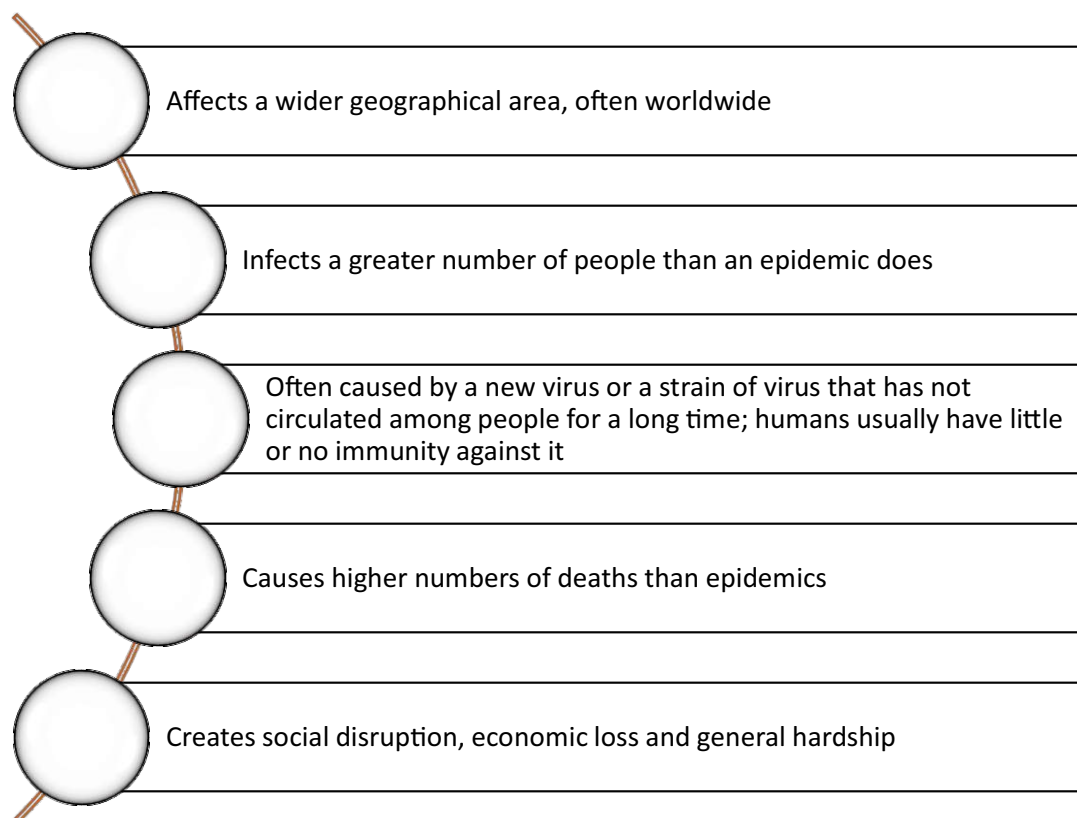


Fig. 2.1.1: Key highlights of a pandemic

2.1.2 Rules and Guidelines during Epidemic/Pandemic

As explained earlier, epidemics and pandemics have a tremendous impact on a large population—across a specific location or various countries respectively. The most significant defence against the outspread of disease is rules and guidelines. It is imperative to adhere to these guidelines for prevention and control of disease. However, first one needs to understand how the viruses/pathogens spread in humans through different means.

The spread of viruses/pathogens in humans is shown in the following figure:

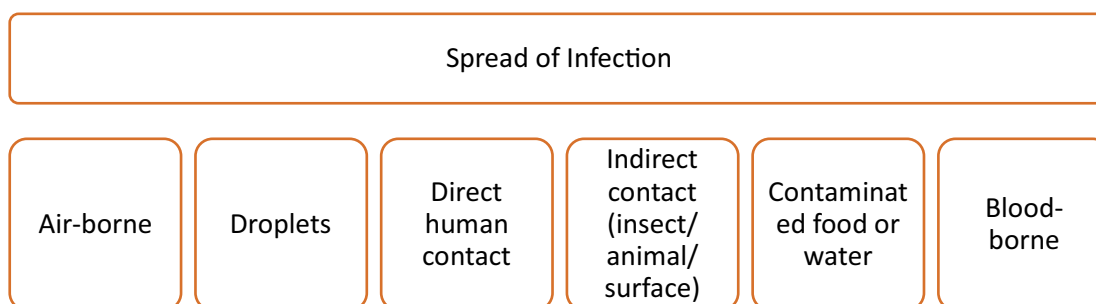


Fig. 2.1.2: Spread of infection

There are four main guidelines to be followed during an epidemic/a pandemic, as shown in the following figure:



Fig. 2.1.3: Guidelines to be followed during epidemic/pandemic

Personal Hygiene

Personal hygiene is significant for prevention of infectious diseases and promotion of overall well-being. It refers to self-care practices for maintaining cleanliness at personal level and preserving health. These practices include bathing every day, washing hands with soap, wearing clean clothes, brushing teeth, grooming and so on. Personal hygiene entails maintaining not only cleanliness but also healthy habits as preventive measures for safeguarding oneself from catching any infection. It becomes all the more important to follow these practices during epidemics and pandemics as the nature of the disease is infectious, i.e., it spreads by coming in contact with infected people or things. Therefore, maintaining personal hygiene is not an option but a compulsion to secure oneself from becoming vulnerable to any infection.

Some points for maintaining personal hygiene are shown in the following image:

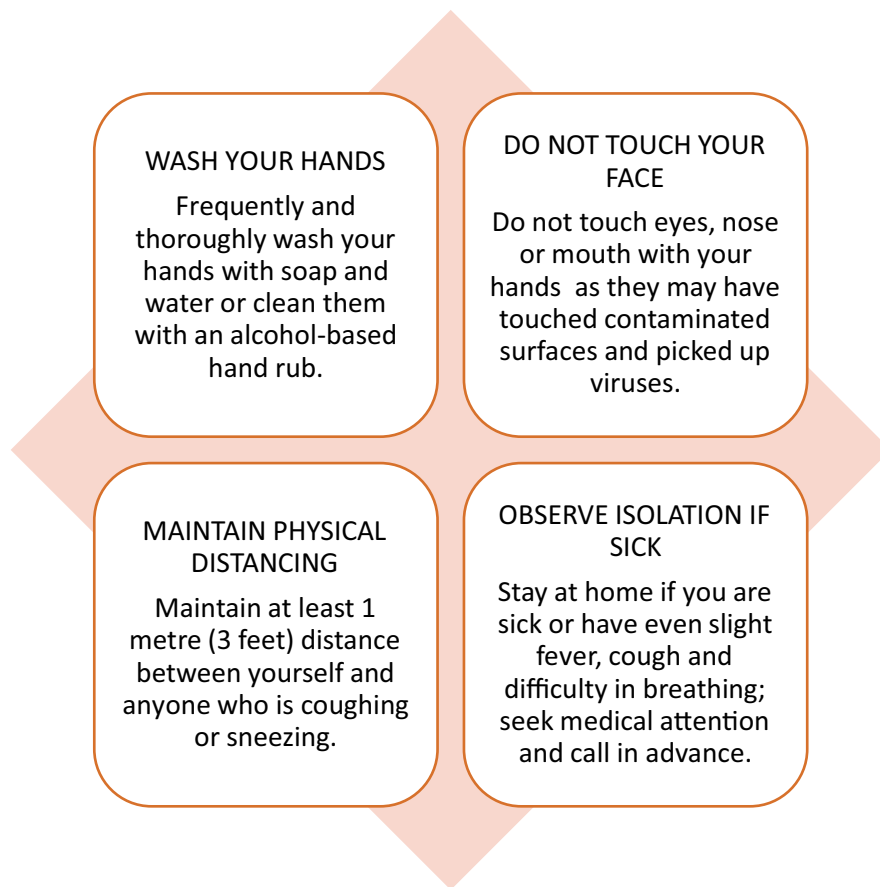


Fig. 2.1.4: Maintaining personal hygiene

Hand Hygiene at Workplace

At work, our hands are exposed to all types of surfaces during the day, as everything we do involves hands in one way or the other—be it when shaking hands with people, eating meals, working on laptop, using mobile phone or common landline phone and so on. This makes them prone to various germs and viruses that can lead to sickness. It is for this reason that proper hand washing is on the top of personal hygiene routine. In fact, it is also one of the simplest and most effective ways to protect oneself and family members from falling prey to illnesses such as cold, cough, flu and gastroenteritis (these can all be contracted or passed on through poor hand hygiene). It is imperative to follow proper hand washing techniques at home and workplace to prevent the spread of diseases.

Some key highlights of maintaining hand hygiene at workplace are shown in the following figure:

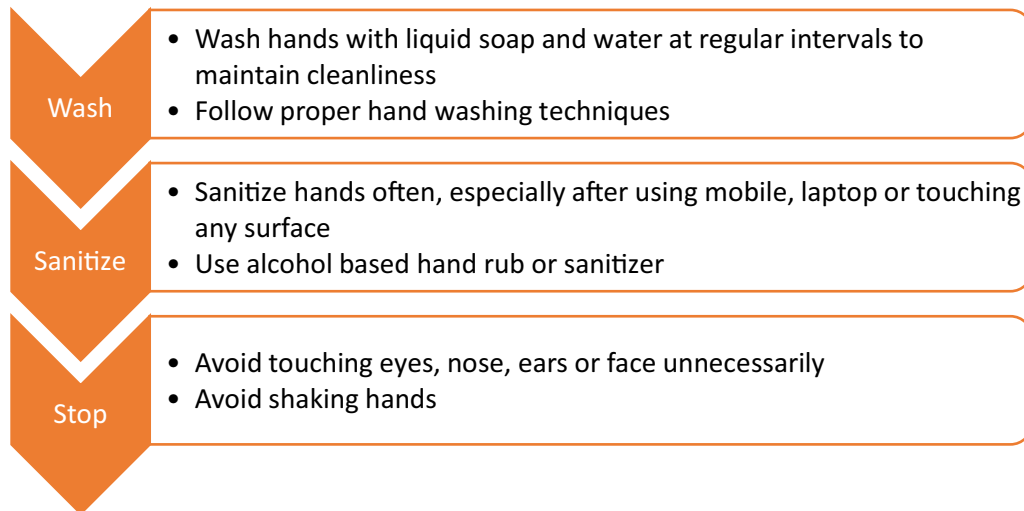


Fig. 2.1.5: Maintaining hand hygiene at workplace

Steps

The detailed process for maintaining hand hygiene is shown in the following set of images:



Fig. 2.1.6(a): Maintaining hand hygiene with soap and water



Fig. 2.1.6(b): Maintaining hand hygiene with alcohol-based sanitizers

Respiratory Hygiene

As the name suggests, respiratory hygiene is all about undertaking preventive measures to prevent the transmission of infection via the respiratory tract. It helps reduce the spread of viruses and pathogens, especially during epidemic or pandemic of an infectious disease.

The effective practices to maintain respiratory hygiene at workplace are shown in the following figure:

Cough/Sneeze Etiquette	Face Masks
<ul style="list-style-type: none"> • Cough or sneeze in the elbow • Use tissues to clean after coughing/sneezing 	<ul style="list-style-type: none"> • Wear appropriate face mask at work place • Avoid touching face and mask unnecessarily • Dispose it off properly in closed bins after use

Fig. 2.1.7: Maintaining respiratory hygiene at workplace

The cough/sneeze etiquette is shown in the following image:



Fig. 2.1.8: Cough and sneeze etiquette

Guidelines for using face masks are given in the following figure:

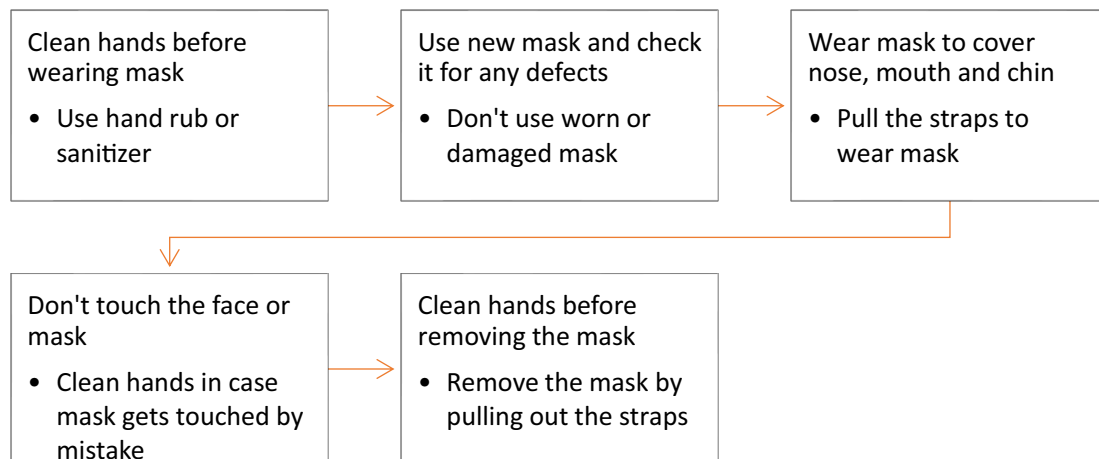


Fig. 2.1.9: Guidelines for using face masks

Steps

The following image shows steps to wear and dispose a surgical mask:

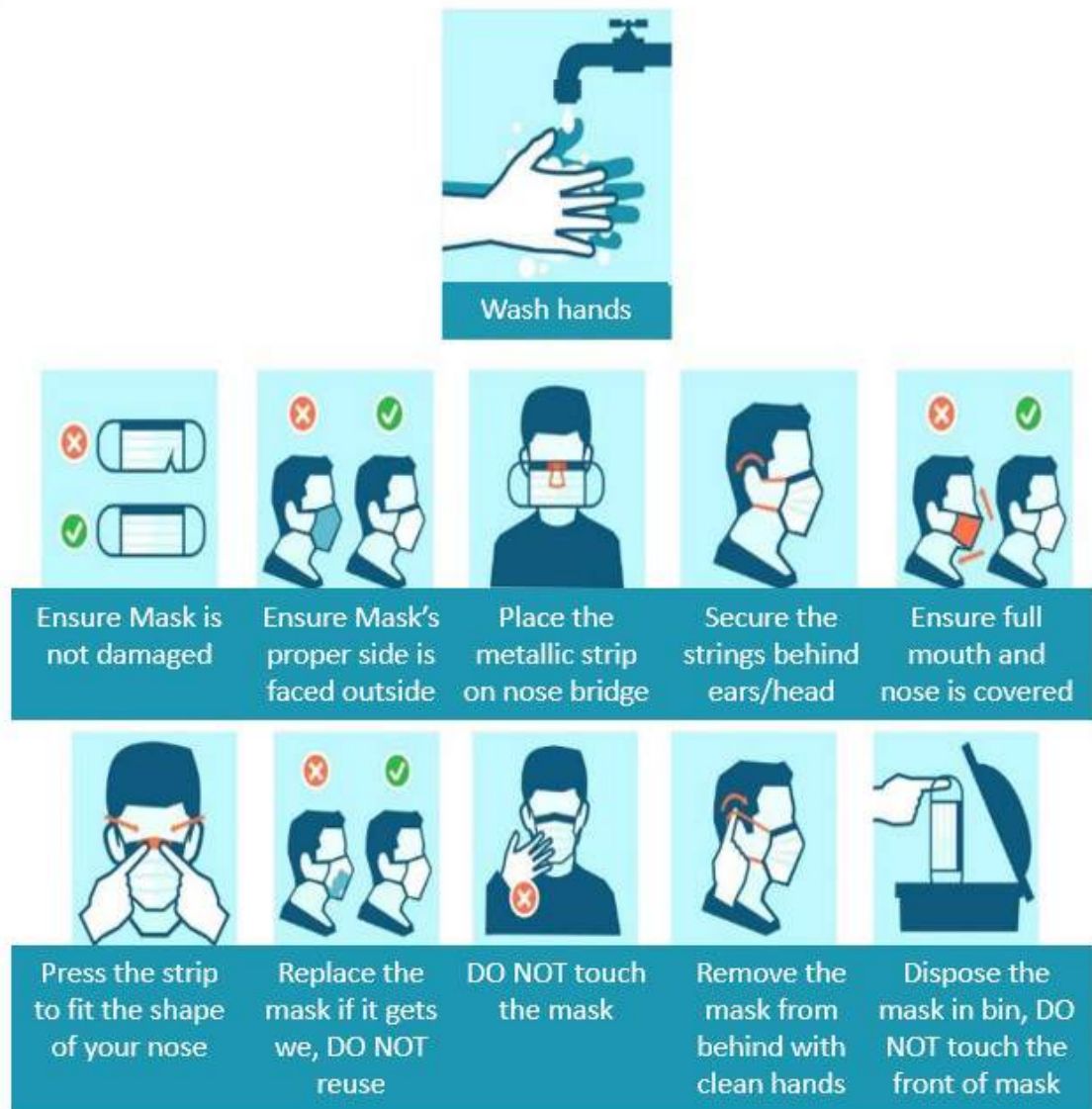


Fig. 2.1.10 (a): Wearing a surgical mask

Steps

The following image shows steps to wear a non-surgical mask:



Fig. 2.1.10 (b): Wearing a non-surgical mask

Types of Face Masks

Face masks play a significant role in protecting the wearer from catching any kind of infection. There are mainly two types of masks, namely, medical masks and non-medical masks (fabric masks) but there are different styles as shown in the following image

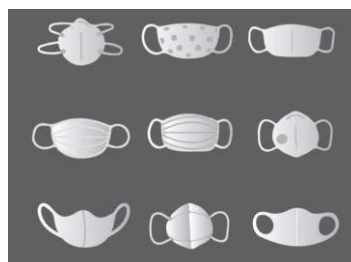


Fig. 2.1.11: Types of face masks

Face masks are worn to protect the wearer and the people surrounding him/her from infection that is carried in the droplets sprayed from coughing, sneezing and talking. They are typically worn to cover the nose and the mouth. There are many types of face masks available and they can be broadly divided into those worn by the healthcare staff and those worn outside a hospital.

Masks worn by non-healthcare givers are largely to protect themselves from dust and microbes. The protection offered depends on the material used and the number of layers. Some common types of masks used by people when they step out of the house are shown in the following images:



Cloth Masks



Surgical Masks



N95 Masks

Fig. 2.1.12: Common type of face masks worn in public place or workplace

Cloth Masks – A simple bandana made of cotton may be fashionably apt but offers virtually no protection from disease bearing droplets. Neck gaiters and balaclavas are effective only if made of cotton. Masks made of synthetic material may lead to more harm than good. There are anecdotal reports of masks made from old T shirts, but these are also equally non effective. For a cloth mask to be effective it should be made of tightly woven 100% cotton and sewn in three layers. Adding a polypropylene filter (which carries an electrostatic charge to trap small particles) can increase the filtration efficiency of a cloth mask to up to 70%. These are reusable masks and should be washed daily after use.

Surgical Masks – These are flat thin paper like masks which filter out 60% of inhaled particles. It provides barrier protection against large droplets but does not have an airtight seal. They are of single use type and should be discarded after each use. When a middle layer of melt blown yarn and a nose clip is added, they are effective in filtration of approximately 95 % of particles.

N95 Masks – These are personal protective devices and are made of melt blown yarn. They are able to filter out 97% of air borne particles. They are tight-fitting masks and have to be worn carefully lest some leakage occurs. People suffering from respiratory distress should not use an N 95 mask. They can be reused a number of times provided proper sanitizing methods are used to disinfect the masks. Masks that have a valve protect the user from the air borne particles that are outside but do not protect the people surrounding the user if he/she is infected.

Social Distancing

We come in contact with people at work place who could be asymptomatic carriers of infection, which makes us all vulnerable unknowingly. An asymptomatic person is someone who shows no symptoms in spite of being infected. In certain cases, even the infected person does not know that he or she is infected without symptoms and is a potential carrier of infection.

Something as simple as talking, coughing or sneezing is enough to spread the infection from an infected person to others. It so happens that tiny droplets that are sprayed while talking, coughing or sneezing may contain virus that is transmitted to the person close by.

That is why social distancing becomes all the more important. Social distancing simply means maintaining physical distance of at least 1 meter (3 feet) from others. It is an effective preventive measure to protect oneself from catching any infectious disease from an infected person. This helps to slow down the spread of disease and safeguard those who are not infected.

The following image shows the sitting arrangement ideal for maintaining social distancing:



Fig. 2.1.13: Social distancing at workplace

Workplace Hygiene

Workplace hygiene is as important as personal hygiene. It has various verticals spanning the work area, meeting etiquette and so on, and has a significant role in prevention of a disease outbreak. It not only helps in keeping oneself safe but also protects others and the environment.

Some key points for maintaining workplace hygiene are given in the following figure:

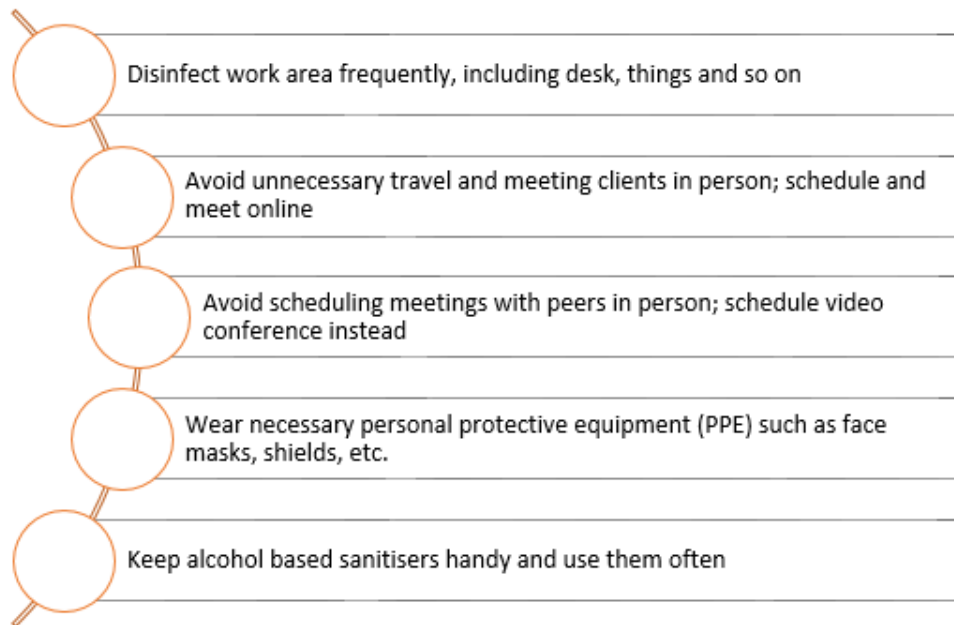


Fig. 2.1.14: Maintaining workplace hygiene

The following figure summarises the do's and don'ts to be practiced at workplace:

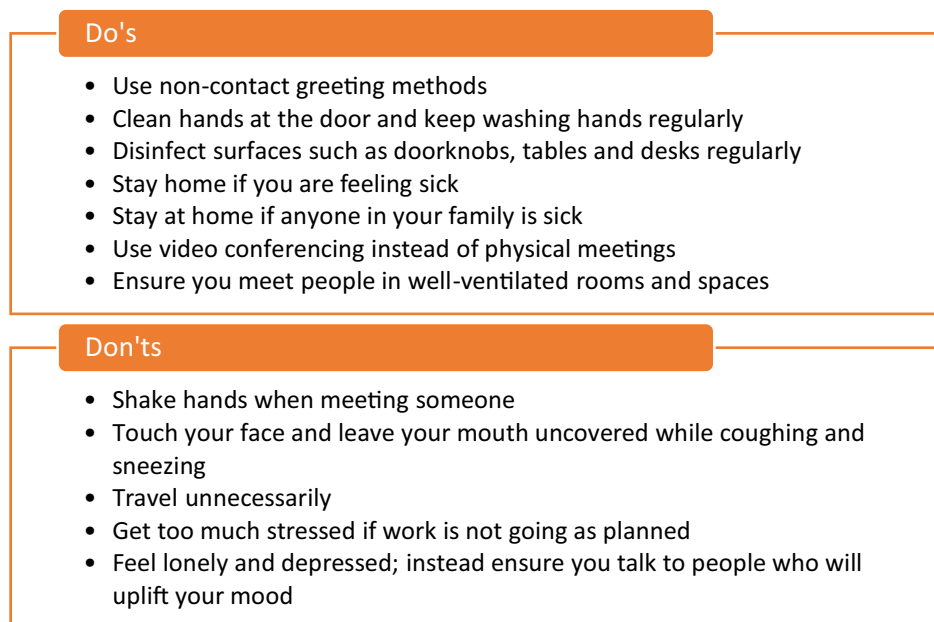


Fig. 2.1.15: Good practices while moving out of home

2.1.3 Self-quarantine vs. Self-isolation

Several preventive measures are undertaken during an epidemic or a pandemic to contain the spread of the disease. Self-quarantine and self-isolation are two such effective ways to prevent the transmission of infection from an infected person to non-infected persons. Both of them are based on social distancing on a broader level, for in both the instances an individual needs to separate oneself from others for a certain period. However, although they are similar, there is a difference between the two.

What is Self-quarantine?

Self-quarantine entails isolating oneself at home or any other place for a period of minimum fourteen days or so. It is meant for people who have been exposed to someone infected with the virus, have travelled during an epidemic/a pandemic, have attended any public gathering, or have been amidst a crowd. If a person has been in any of the above or similar situation then it is not an option but mandatory as per the guidelines that he or she should self-quarantine to prevent any infection or disease from spreading further. If any of the symptoms of infection begin to develop, then the person should contact a medical provider on a priority basis and follow the advice.

What is Self-isolation?

Self-isolation also entails isolating oneself at home or any other place for a period of seventeen days or so. However, it is meant for people who have already tested positive for the virus/infection that has led to the epidemic/pandemic. This is the key difference between self-isolation and self-quarantine. In this case, the person has already caught the infection and needs to isolate to contain the spread of the virus and recover from the disease.

Every disease outbreak, epidemic or pandemic has certain signs and symptoms. For example, in case of Covid 19, symptoms entail fever, cold, cough, shortness of breath and so on. It is recommended to go for the test in case of development of any of these symptoms and follow the advice of the medical provider. As long as the symptoms are manageable, it is often advised to self-isolate at home, but in case of severe complications, the individual is admitted to the hospital.

Both, self-quarantine and self-isolation, involve maintaining personal hygiene and adhering to the guidelines as given in the following figure:

- Stay in a well-ventilated room
- Restrict movement
- No direct contact or face to face interaction with anyone
- Wear face masks to prevent the spread of virus
- Keep your utensils and belongings separate
- Stock up your essentials or go for contactless delivery
- Stay active by doing some exercise or yoga

Fig. 2.1.16 (a): Guidelines for self-quarantine and self-isolation

Guidelines for environmental sanitation during self-quarantine and self-isolation are mentioned in the following figure:

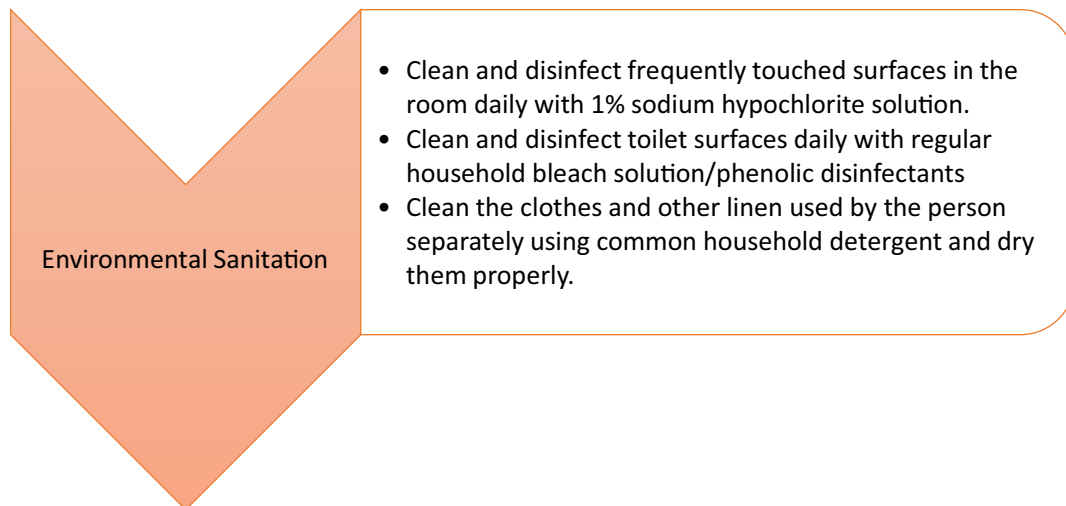


Fig. 2.1.16 (b): Environmental sanitation guidelines for self-quarantine and self-isolation

2.1.4 Social Distancing

As explained earlier, social distancing refers to maintaining physical distance of at least 1 meter (3 ft.) between oneself and others. It also entails not going out in crowded areas or public gatherings during a disease outbreak, an epidemic, or a pandemic. Social distancing combined with strict adherence to personal hygiene routine, respiratory hygiene and workplace hygiene is highly effective in containing the spread of infections/diseases.

Why Practice Social Distancing?

Social distancing protects those who are not infected, as it limits the opportunities of coming in contact with contaminated surfaces or infected people, especially outside home. It is all the more effective in case the epidemic is caused due to a communicable disease, for in such cases the virus can spread from the infected person to other people through droplets of cough or sneeze. The best defence is to wear appropriate face mask and maintain social distance during all interactions, even at home.

Some tips for social distancing are shown in the following figure:

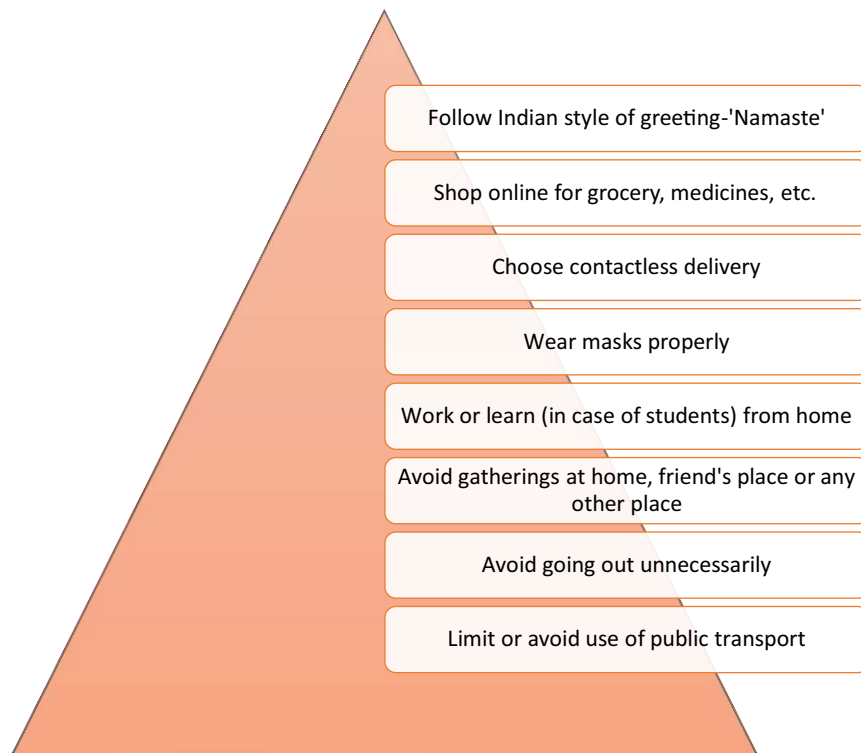
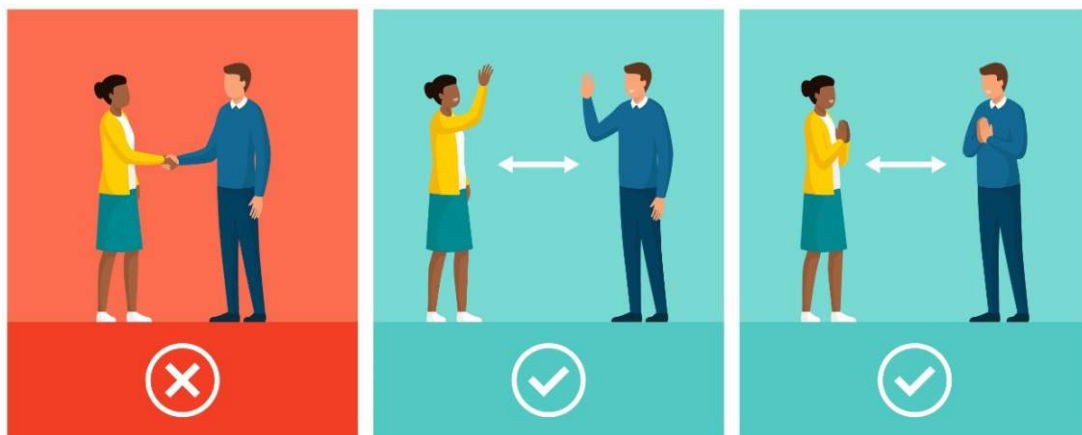


Fig. 2.1.17: Social distancing tips

Some practices while meeting people out of home are shown in the following image:



**DO NOT TRANSFER GERMS WHILE GREETING PEOPLE
AVOID PHYSICAL CONTACT**

Fig. 2.1.18: Greeting while avoiding physical distance

Exercise



1. If soap and water are not available, one can clean hands with which of the following?
 - a. Tissues
 - b. Cloth
 - c. Sanitizer
 - d. Surf
2. Personal hygiene includes which of the following?
 - a. Hand hygiene
 - b. Workplace hygiene
 - c. Social distancing
 - d. Work from home

UNIT 2.2: Safety and Sanitisation Guidelines

Unit Objectives



After completion of this unit, the participants will be able to:

1. Discuss personal and workplace hygiene practices
2. Explain potential fomites at workplace
3. Describe appropriate use and disposal of Personal Protective Equipment (PPE)

2.2.1 Personal & Workplace Hygiene Practices

Good personal hygiene is an effective means to protect oneself and others from illnesses in general and catching infection during a disease outbreak, an epidemic or a pandemic. Personal hygiene entails adopting healthy practices to upkeep personal cleanliness and appearance. It is often mistaken to be akin to cleanliness but it is much broader than that as it includes habits required to maintain health and wellbeing. These practices include washing hands, sanitising hands, bathing, oral care, self-care and so on. In case of people who do not adhere to personal hygiene routine on a regular basis, their body becomes a breeding ground for all types of germs and viruses.

Hand hygiene is an essential part of maintaining personal hygiene. Our hands are the potential carriers of viruses as they are exposed to all types of surfaces and used for carrying out all the tasks during the day. In fact, it is no exaggeration to mention that personal hygiene routine begins with hand hygiene. Keeping them clean and healthy is of prime importance as this would safeguard oneself and others from infections and illnesses.

Washing hands is the quickest and simplest way to get rid of viruses, protect oneself and others, and prevent diseases from spreading. Hand hygiene routine has already been explained in detail in the previous unit. Here we shall learn about when and how to wash hands to stay healthy.

The following images show hand washing techniques:



Fig. 2.2.1: Hand Washing Technique



Fig. 2.2.2: Washing hands with soap and water

Steps

The following figure shows the steps to wash hands properly:

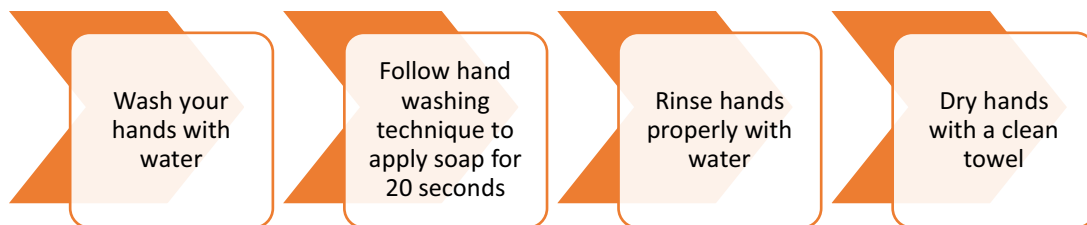


Fig. 2.2.3: Steps to wash hands properly

The Centers for Disease Control and Prevention (CDC) recommend washing hands at certain times, as shown in the following figure:

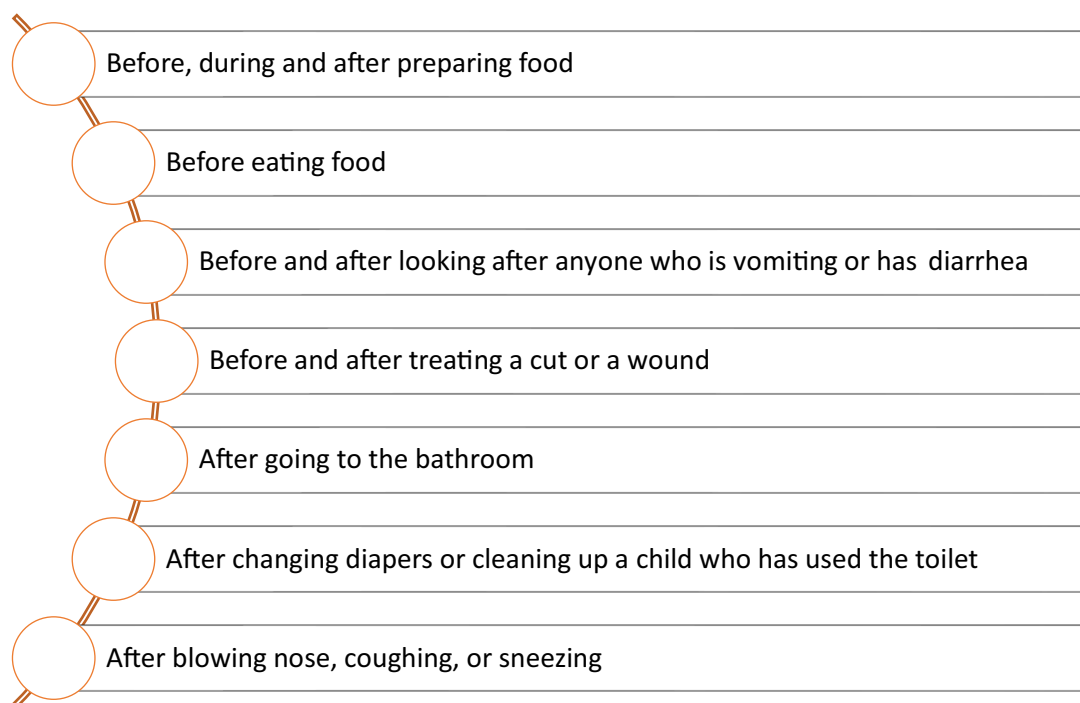


Fig. 2.2.4: Key times to wash hands as recommended by CDC

If soap and water are not available, one must use alcohol-based sanitiser (containing at least 60% alcohol). Although cleaning hands with sanitisers is not a substitute for cleaning them with soap and water, but in case they are not available or one needs to clean hands when not dirty, sanitisers are a good alternative. They help in reducing germs and viruses but don't eliminate them completely, and thus they are less effective in case of dirty or greasy hands.

The following image shows how to use a hand sanitiser:



Fig. 2.2.5: Use of hand sanitiser

Steps

The following figure shows the steps to use sanitiser for cleaning hands:



Fig. 2.2.6: Steps to sanitise hands properly

Personal hygiene should extend to workplace, which is all about keeping the work area clean, tidy and disinfected. This would be required more frequently and regularly during an epidemic or a pandemic. It so happens that often personal hygiene gets priority over workplace place hygiene, whereas both should get equal importance. If required one must modify the setting of the work area to facilitate social distancing and wear necessary PPE as per the profile of the job. In case the work entails meeting the public, then in addition to facemask one must use face shield and sanitiser after any kind of exchange with a person.

In addition to wearing necessary PPE such as masks, gloves and shields, cleaning and disinfecting the work area is also important. It should be carried out with a solution containing 1% sodium hypochlorite disinfectant and a disposable cleaning cloth. Ensure to disinfect the frequently used devices such as laptop, mobile, mouse and so on.

Steps

The following figure shows the steps to perform cleaning and disinfection of work area:

Wear disposable gloves, mask or protective eye wear (if necessary) to carry out cleaning or disinfection of work area.

Clean and disinfect the work area with the help of bleach solution or any disinfectant.

Dispose of cleaning material such as mop or wiping cloth in closed bins.

Fig. 2.2.7: Steps to perform cleaning and disinfection of work area

2.2.2 Potential Fomites at Workplace

Fomites refer to all those objects or surfaces that can become contaminated with viruses when touched by an infected person and can further transmit the infection to those who touch the surfaces next. It is all the more important to clean and disinfect fomites as viruses and germs survive for hours or even months on these surfaces, if not cleaned. Example of fomites include doorknobs, light switches, remote controls, elevator buttons and so on.

Fomites are not just pertinent with respect to disease outbreak, epidemic or pandemic but even in normal circumstances these fomites lead to rapid indirect transmission of viruses, leading to spread of communicable diseases. Thus, cleaning and disinfection of these fomites with a disinfectant solution must be carried out on frequent basis for a healthy workplace environment. Any lapse can be a threat to the health of one and all. Moreover, on a personal level, one can ensure not to touch these surfaces directly but to use any disinfectant tissue or wipe and dispose of it immediately in a closed bin.

A list of potential fomites at workplace is shown in the following figure:

Potential fomites at workplace	Common areas such as pantry, printing stations, etc.
	Vending machines, coffee mug handles, etc.
	Conference or meeting rooms
	Door handles or doorknobs
	Electronic devices such as laptops
	Telephone receivers
	Elevator buttons
	Desks or countertops

Fig. 2.2.8: Potential fomites at workplace

The following image shows cleaning and disinfection of workstation:

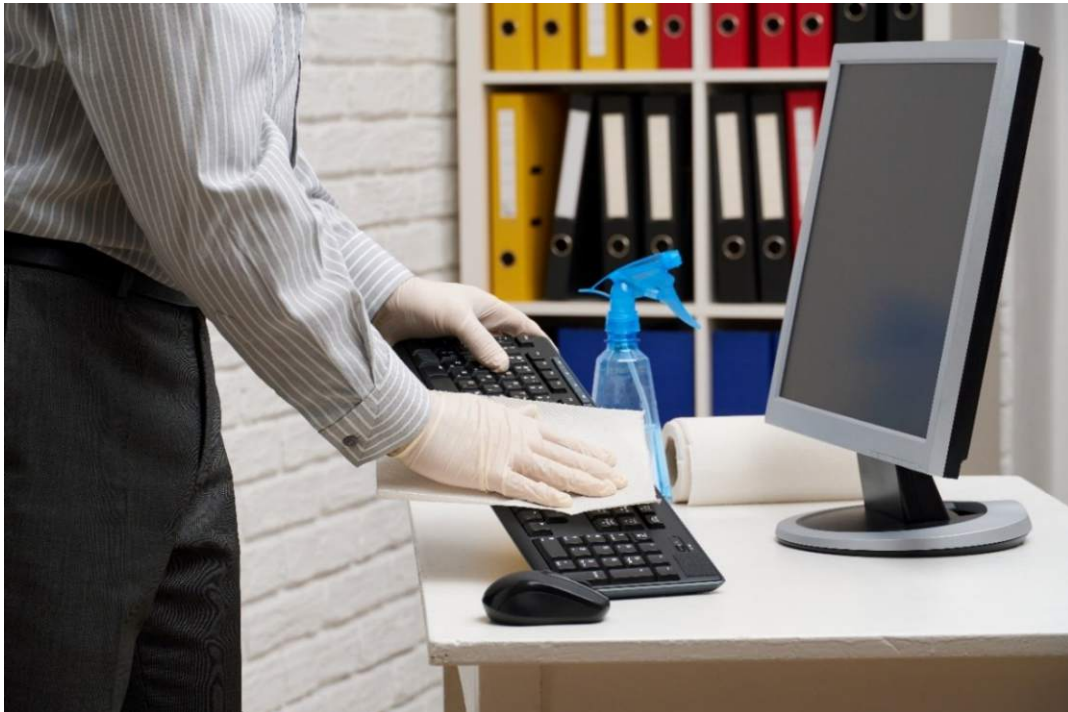


Fig. 2.2.9: Disinfecting workstation

Following image shows cleaning and disinfection of mobile:



Fig. 2.2.10: Disinfecting mobile

2.2.3 PPE to be used at Workplace

PPE refers to protective facemasks, gloves, clothing, helmets, face shields, eye protective wear or other equipment designed to protect the wearer from the spread of infection or illness. PPE should be used in combination with other recommended preventive measures such as maintaining personal hygiene, respiratory hygiene and social distancing, for lack of doing so makes the person vulnerable to viruses and infections.

Let us take an example of Covid 19 pandemic to understand the use of PPE. Covid 19 virus gets transmitted from one person to another through close contact and droplets. Thus, wearing appropriate type of PPE is imperative depending upon the work setting and risk of exposure. The type of PPE used in order to protect oneself is different from the type used when caring for an infected person, as health care workers need extra protection in terms of respirators and fluid resistant gowns. Although PPE is one of the effective means to prevent the spread of virus, it gives benefit only when followed with other preventive measures explained earlier.

Steps

The steps to put on PPE for precaution are given in the following figure:

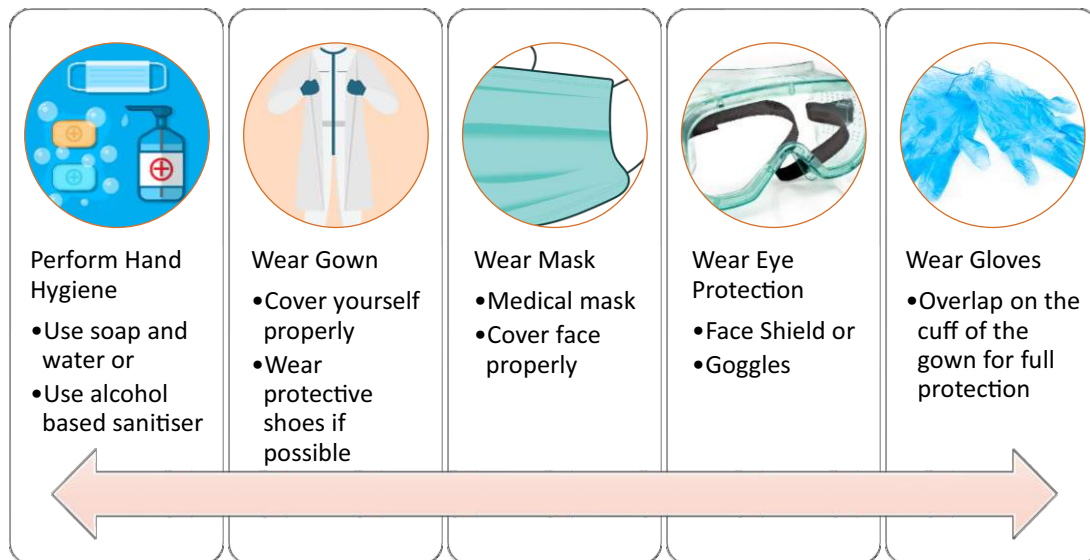


Fig. 2.2.11: Steps to put on PPE

The guidelines for use of PPE are given in the following figure:

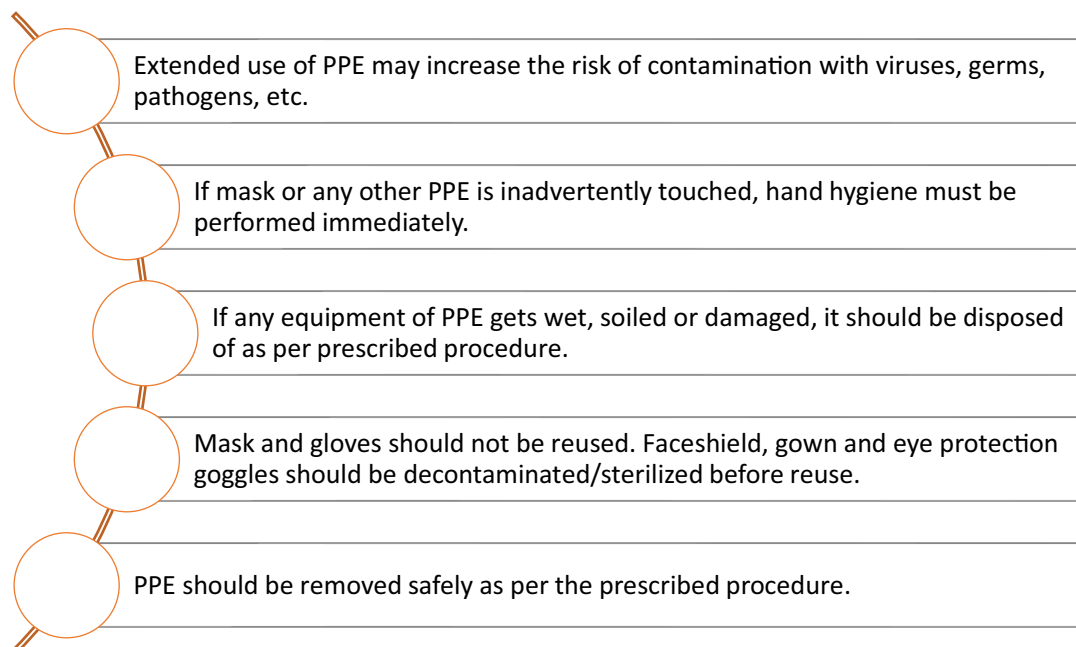


Fig. 2.2.12: Guidelines for use of PPE

Steps

The steps to take off PPE after use are given in the following figure:

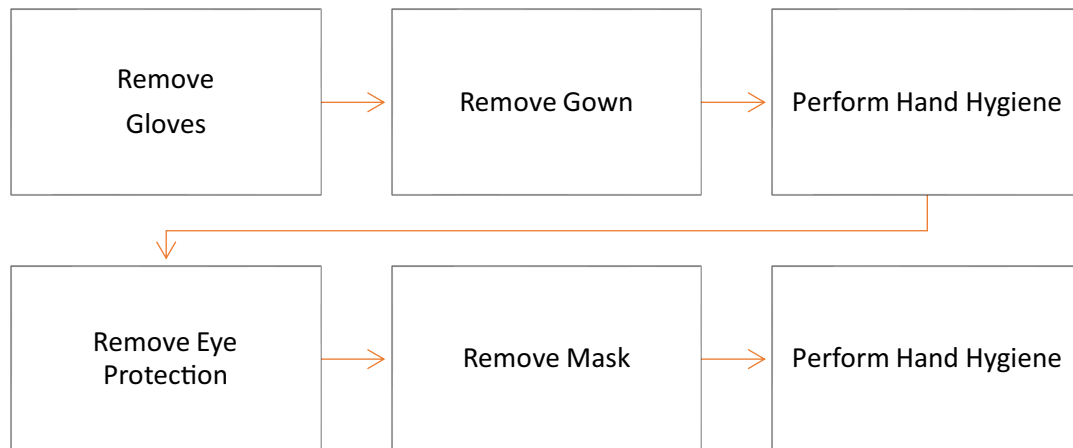


Fig. 2.2.13: Steps to take off PPE

The different PPE required by different professionals is shown in the following set of images:



Fig. 2.2.14 (a): PPE for healthcare professionals



Fig. 2.2.14 (b): PPE for grocery, poultry, or other professionals who work with wet products



Fig. 2.2.14 (c): PPE for other professionals, typically working in offices

Let us now learn about the correct methods of taking off PPE as shown in the following set of images:

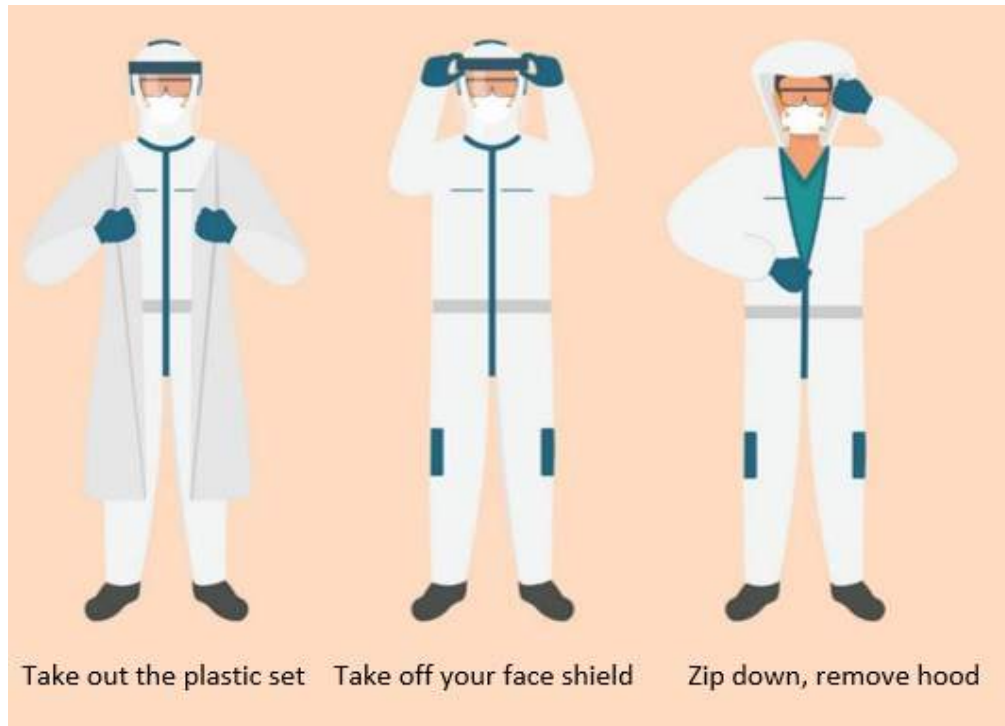


Fig. 2.2.15 (a): Procedure to remove PPE for healthcare professionals



Fig. 2.2.15 (b): Procedure to remove PPE set, boots, leg cover and gloves



Fig. 2.2.15 (c): Procedure to remove goggles and masks

Tips



Washing hands is the quickest and simplest way to get rid of viruses. Workplace hygiene entails wearing necessary PPE as well as disinfecting the work area. Surface touched frequently become potential fomites capable of spreading the infection. PPE should be worn in the following sequence: gown, mask, eye protection and gloves. PPE should be removed in the following sequence: gloves, gown, eye protection and mask.

UNIT 2.3: Other Common Practices & Guidelines

Unit Objectives

After completion of this unit, the participants will be able to:

1. Discuss the importance and process of identifying and reporting symptoms to the concerned authorities
2. Explain the importance and mechanism of proper collection, transportation and safe disposal of waste
3. Select different types of waste and various types of colour coded bins/containers used for disposal of waste
4. Discuss the ways of dealing with stress and anxiety and providing support during an epidemic or a pandemic

2.3.1 Identifying and Reporting Symptoms

Identifying and reporting the symptoms of a disease can help a great deal in seeking timely care and taking immediate actions to prevent further spread of the disease. This is one of the best early control measures in case of a disease outbreak, an epidemic or a pandemic. For example, in case of Covid 19, researches across the world have identified the sequence of symptoms, such as fever, cough, sore throat, shortness of breath, fatigue, aches and pains, headaches, runny nose and so on, which help differentiate Covid 19 from common cold and flu.

It is mandatory for the workplace to have a formal documentation procedure pertaining to identification and reporting of symptoms as per the organisational policy. The employee must immediately inform the concerned officer in-charge and complete the required documentation accordingly in this context.

In addition to this, one needs to inform the local authorities appointed for the purpose and follow the prescribed procedure as given in the following figure:

Be aware of symptoms	Stay informed about the symptoms of the infection
Report to officer in-charge/local authorities	As soon you identify symptoms, inform the person concerned at workplace and local authorities as per your location
Follow reporting procedure	Fulfill documentation with complete details required as per workplace reporting procedure and local reporting procedure
Seek immediate consultation and undergo testing	Consult the appointed medical specialist and undergo the required test to determine the result at the earliest
Decide on self-isolation or hospitalization	Follow the advice of medical specialist, as per the intensity of symptoms, to either go for isolation at home or admission to the recommended hospital
Inform your contacts	Let those who have come in contact with you recently know about your test status and advise them to take necessary measures as per the recommendations of medical specialist

Fig. 2.3.1: Steps to be followed for identification and reporting of symptoms

2.3.2 Handling Waste

Waste management has a significant role to play in controlling the spread of infection. It entails following prescribed procedures for proper collection, segregation, transportation and disposal of waste. During a disease outbreak, an epidemic or a pandemic, waste from households and organisations can transmit infectious germs and viruses and thus pose risk to the health of people. That is why it is imperative to follow health and safety guidelines for waste management at home as well as workplace.

Steps

The guidelines to dispose of waste outside home during a pandemic, for example Covid 19, are given in the following image:



Fig. 2.3.2: Disposing waste during pandemic

Image Credit: Creator— Maria Tsakona and Levi Westerveld, Grida.no. 2020. Quick Tips For Safe Handling Of Waste During The COVID-19 Pandemic | GRID-Arendal. [online] Available at: <<https://www.grida.no/resources/13574>>

Procedure for safe disposal of non-healthcare waste:

1. Waste should be collected in a plastic rubbish bag and tied properly.
2. The plastic bag should then be placed in a second bin bag and tied properly.
3. Waste should be stored safely in a suitable and secure place until the individual's test results are known. This is applicable in case any individual at home or workplace is suspected to have caught the infection.
4. Waste should be kept away from children.
5. Waste should not be thrown in communal waste areas until negative test results are known, or the waste has been stored for at least 72 hours.
6. If storage for at least 72 hours is not appropriate, arrange for collection by the local waste collection authority.

Waste management entails the processes as shown in the following image:

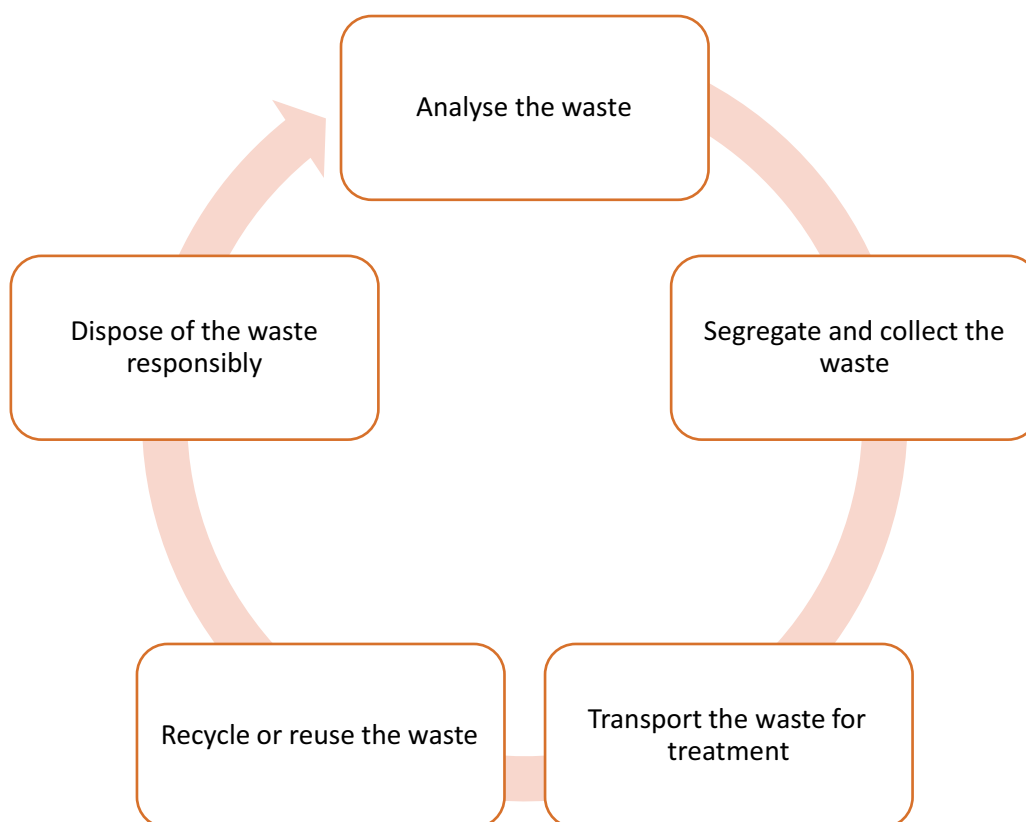


Fig. 2.3.3: Steps of waste management

Procedure for safe disposal of greywater or water from washing PPE, surfaces and floors:

1. WHO recommends that after each time utility gloves or heavy-duty, reusable plastic aprons are used, they should be cleaned with soap and water, and then decontaminated with 0.5% sodium hypochlorite solution.
2. Single-use gloves made of nitrile or latex, and gowns should be discarded after each use and not reused as they could have come in touch with infectious waste.
3. Hand hygiene should be performed after PPE is removed.
4. If greywater includes disinfectant used in prior cleaning, it does not need to be chlorinated or treated again.

Procedure for Safe Disposal of Healthcare Waste

The procedure for disposal of healthcare waste may vary according to the state guidelines on disposal of waste. The following figure shows general information for safe disposal of healthcare waste:

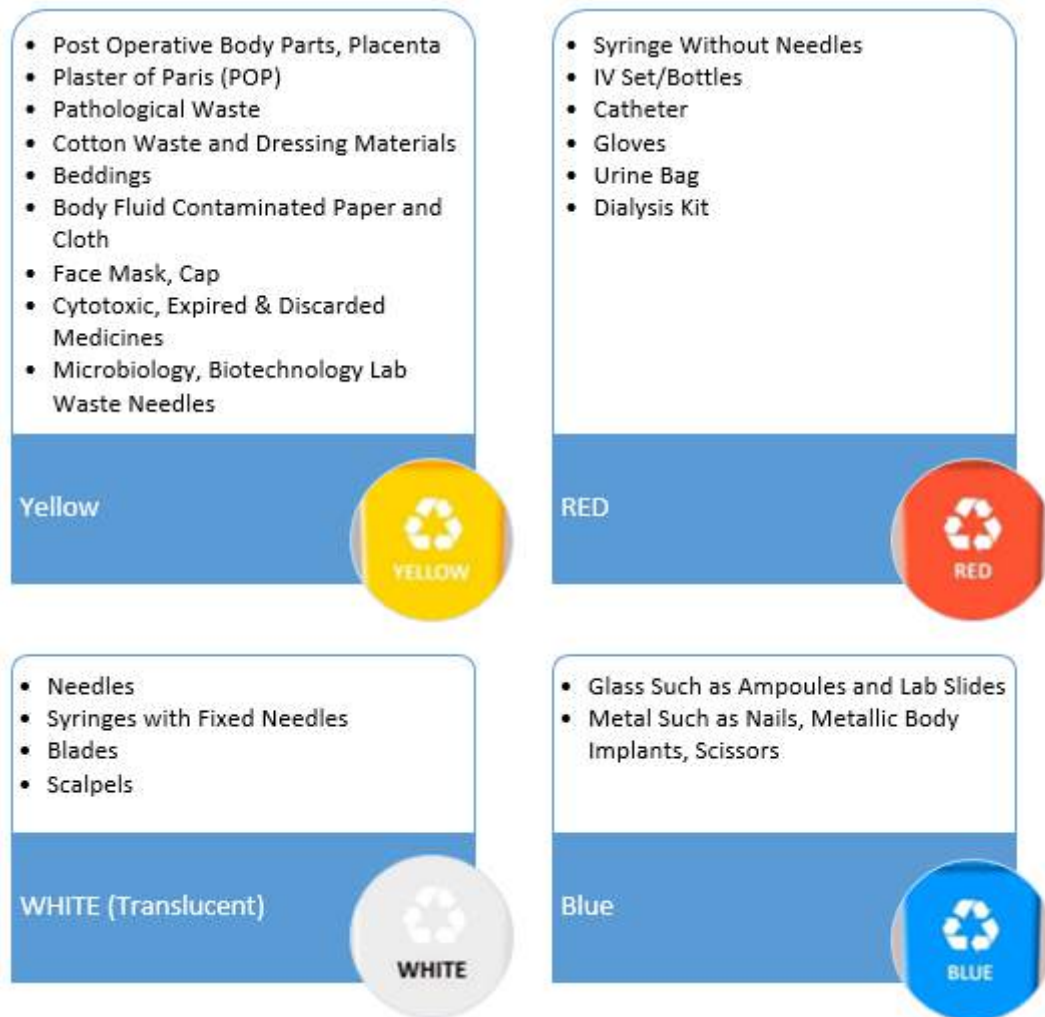


Fig. 2.3.4: Safe disposal of healthcare waste

During a disease outbreak, an epidemic or a pandemic, health of waste- collection workers is very much at risk, given the nature of their job wherein they are exposed to all types of waste. The following image shows how waste-collection workers can minimise risks during a pandemic, for example during Covid-19:



Fig. 2.3.5 (a): Guidelines for waste- collection worker



Fig. 2.3.5 (b): Guidelines for waste- collection worker

The following image shows how waste-collection workers can minimise risks during a pandemic, for example during Covid-19:

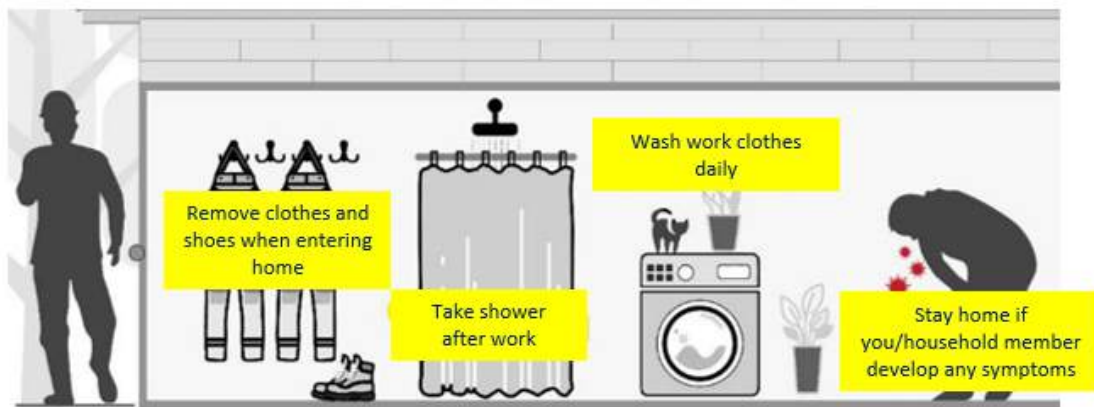


Fig. 2.3.6: Guidelines for waste- collection worker

Image Credit: Creator— Maria Tsakona and Levi Westerveld, Grida.no. 2020. Quick Tips For Safe Handling Of Waste During The COVID-19 Pandemic | GRID-Arendal. [online] Available at: <https://www.grida.no/resources/13574>

2.3.3 Dealing with Stress and Anxiety during a Disease Outbreak

A disease outbreak, an epidemic or a pandemic brings about numerous challenges worldwide. On one hand, we need to deal with the virus and the illness, and on the other hand, we need to deal with the inherent fear, which is the springboard of stress and anxiety. In a way, we need to strengthen both our body and mind to be able to deal with such a challenging situation.

We need to understand the impact of stress and anxiety on our physical and mental health. It poses unnecessary pressure on our body and mind, which lowers our immunity and makes us more vulnerable to viruses and illnesses. To make matters worse, we do not even realise when it begins to build up and overpowers our thinking.

You need to ask yourself certain questions to identify stress and anxiety, such as – Are you fearful and worried about your own health and health of your loved ones? Do you have difficulty sleeping or concentrating? Is your physical and mental health getting worse? Do you constantly fear catching the infection?

If the answer to any of these questions is yes, then you need to change your mindset and take the following practical measures for your safety and security:

People diagnosed with a disease and their family/neighbours often feel sad, stressed, confused, scared or angry. Such people should:

- Talk to people you know will provide help and listen.
- Share your feelings with close friends and family.

People in self-quarantine or self-isolation should:

- Maintain a healthy lifestyle.
- Take proper diet.
- Ensure a healthy routine, proper sleep, exercise and social contact with loved ones at home and by email and phone with other family and friends.
- Do not smoke or consume alcohol/ other drugs to deal with your emotions.
- Ask for professional counselling if extremely stressed.

People living in contamination zones/areas most affected should:

- Gather information to analyse the risk and necessary precautions.
- Find a credible source you can trust such as Arogya Setu app, WHO website or a local health authority.
- Restrict watching too much news or media coverage of the pandemic/epidemic to avoid worry and agitation.
- Focus on personal and inter-personal skills that have helped you to recover from a tragic/difficult experience in the past.

Fig. 2.3.7: Guidelines for dealing with stress and anxiety

UNIT 2.4: COVID 19 Vaccination

Unit Objectives



After completion of this unit, the participants will be able to:

1. Differentiate between different types of vaccine
2. Identify the side-effects of vaccine
3. Explain Cold chain management
4. Explain about vaccine safety and security and avoiding misuse

2.4.1 Coronavirus Disease (COVID-19)

Coronavirus disease (COVID-19), is an infectious disease caused by a newly discovered coronavirus (SARS-CoV-2), which has spread rapidly throughout the world. In March 2020, the World Health Organization (WHO) declared the COVID-19 outbreak a pandemic. The pandemic has severely ravaged health systems, and economic and social progress globally.

While countries, including India, have taken strong measures to contain the spread of COVID-19 through better diagnostics and treatment, vaccines will provide a lasting solution by enhancing immunity and containing the disease spread.

2.4.2 Vaccines for COVID -19

In order to respond quickly and effectively to the COVID-19 pandemic, a broad range of candidate COVID-19 vaccines are being investigated globally using various technologies and platforms. These include viral-vectored, protein subunit, nucleic acid (DNA, RNA), live attenuated and inactivated vaccines.

2.4.3 Types of COVID 19 Vaccines in India

As per the Indian council of Medical Research (ICMR), the following vaccines are in different stages of clinical trials in India:

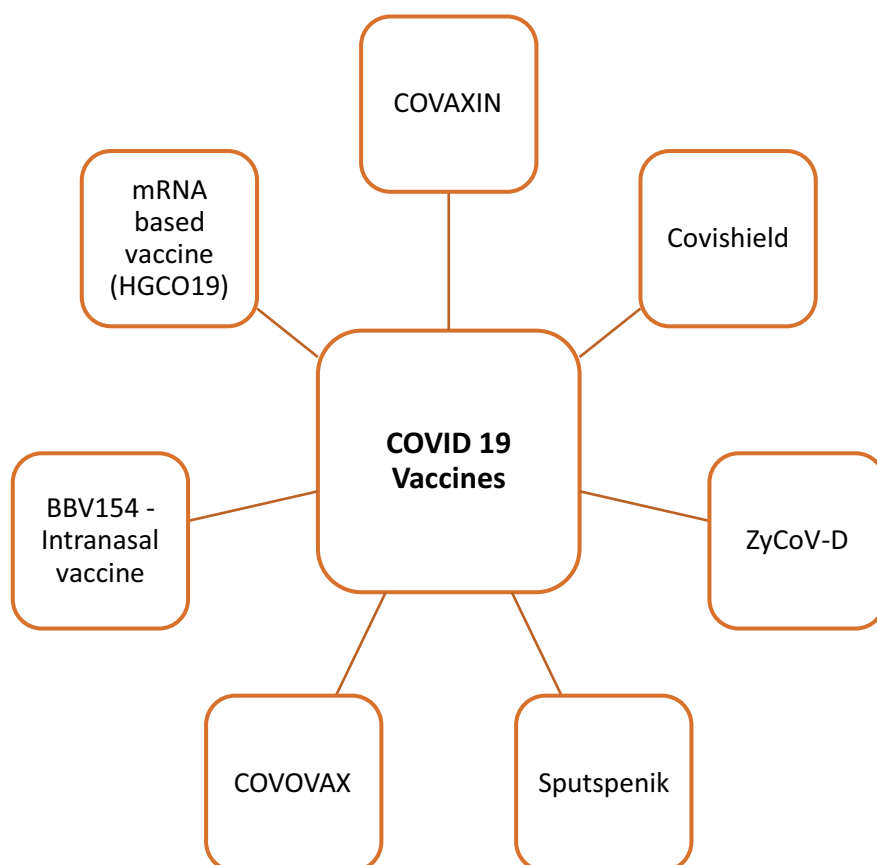


Fig. 2.4.1: Types of COVID 19 vaccines in India

COVAXIN

COVAXIN™, India's indigenous COVID-19 vaccine is developed by Bharat Biotech in collaboration with ICMR.

Covishield

Covishield is developed by Oxford University in partnership with The Serum Institute of India (SII) and Indian Council of Medical Research.

ZyCoV-D

ZyCoV-D is developed by **Zydus Cadila**.

Sputnik

Sputnik is manufactured in Russia but is approved for use in India and is being imported.

COVOVAX

COVOVAX is developed by The Serum Institute of India (SII) and Indian Council of Medical Research.

BBV154 - Intranasal vaccine

Bharat Biotech is conducting multicenter study to evaluate the reactogenicity, safety, and immunogenicity of an intranasal adenoviral vector COVID-19 vaccine (BBV154).

mRNA based vaccine (HGC019)

mRNA based vaccine (HGC019) is developed by Gennova Biopharmaceuticals, in partnership with HDT Biotech Corporation.

Side-Effects of Vaccine

The common side effects of COVID 19 vaccines in some individuals could be mild fever, pain, etc. at the site of injection. Some of the side-effects of Covishield® and Covaxin® are as follows:

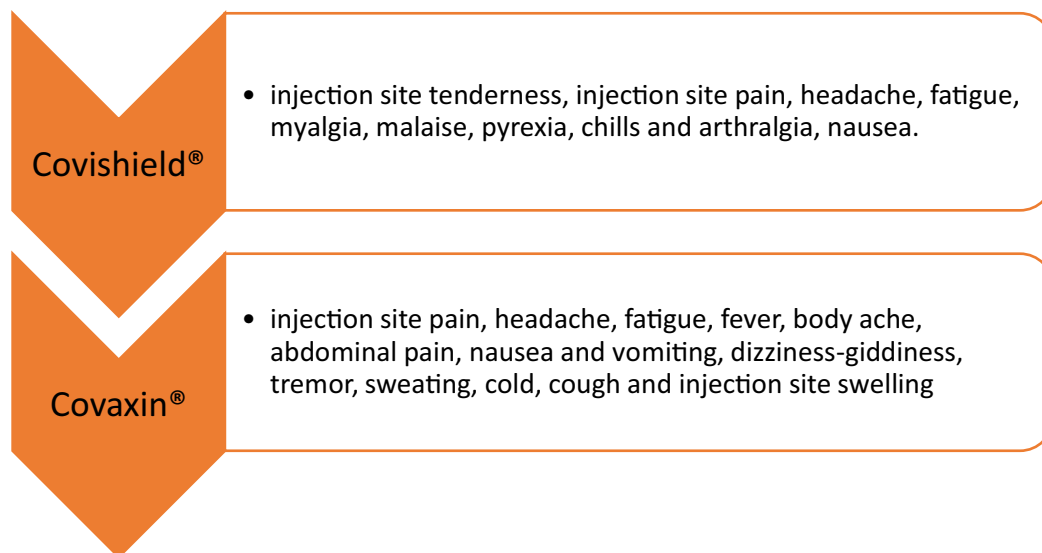


Fig. 2.4.2: Side-Effects of COVID 19 vaccines

2.4.4 Cold Chain Maintenance at Session Site

As there will be no expiry date on the vial of the vaccine, cold chain maintenance is of prime importance. The following points need to be ensured at session site:

Ensure an extra vaccine carrier with conditioned ice packs for immediate replenishment of ice packs in the vaccine carrier

Review and check vaccine carrier temperature and records

Mark date and time of opening vial

Discard all open vaccine vials need after 4 hours of opening or at the end of session

Ensure backup vaccine carrier and icepacks at the session site

Never expose the vaccine carrier, the vaccine vial or icepack to direct sunlight

Keep the vaccines inside the vaccine carrier with the lid closed

At the end of the session, vaccine carrier with all icepacks and unopened vaccine vials should be sent back to the distributing cold chain point

Intact sealed vials returned on the previous session day should be clearly marked and kept separately to be used first on the following session day

Fig. 2.4.3: Cold chain maintenance at session site

2.4.5 Vaccine Safety and Security

Safety and security of each dose of COVID-19 vaccine is of paramount importance and Adequate safety and security measure must be undertaken at location of vaccine storage, during transport and at session site. State/District administration needs to ensure adequate security arrangement for vaccines at:

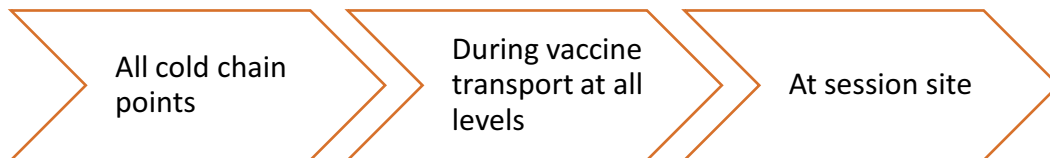


Fig. 2.4.4: Vaccine Safety and Security

Stringent vigilance mechanism must be in place to protect pilferage and theft. Any such activity should be immediately reported, and prompt police action should be initiated with clear accountability.

Exercise

1. Identify which of the following statements are true or false.
 - a. Disease outbreak, epidemic and pandemic are all same types of infection outbreaks.
 - b. Non-surgical mask is a substitute of surgical mask.
 - c. Self-quarantine is done at home and self-isolation is done in a hospital.
 - d. Hands should be washed after every meal.
2. Which of the following is not one of the processes of waste management discussed in this unit?
 - a. Collection
 - b. Transportation
 - c. Treatment
 - d. Disposal
3. List two effective ways of dealing with stress and anxiety.

4. Name the manufacturers of the following vaccines.
 - a. COVAXIN _____
 - b. Covishield _____
 - c. Sputnik _____
 - d. ZyCoV-D _____





3. Understanding The Working of Basic Equipment

Unit 3.1 - Electronic Circuit

Unit 3.2 - Electronic component and application

Unit 3.3 - Biomedical instrumentation and measurement



HSS/N5607

Key Learning Outcomes



After completion of this module, the participants will be able to:

1. Identify circuits and carry out troubleshooting of the circuits
2. Draw and describe the basic circuits
3. Discuss the basic principle of DC power supply
4. Carry out the testing of components using multimeter
5. List the electronic components and their application
6. Discuss the working of spectrum
7. List the types of cables and connectors used in medical equipment
8. Discuss the design rules for fabrication of PCB and types of PCB
9. Prepare the data sheets of diode and transistors and testing
10. Discuss the biomedical instrumentation and its measurements
11. Carry out soldering of surface mounted devices
12. Follow the standard test procedures

UNIT 3.1 Electronic Circuit

Unit Objectives



After completion of this unit , the participants will be able to :

1. Draw the basic circuits and troubleshoot it
2. Understand the basic principle of DC power supply
3. Do the testing using multimeter
4. List the electronic components and their functions
5. Read the various symbols of a circuit diagram and a circuit diagram

3.1.1 Basics Of Electronic Circuits

An electronic *circuit* is a complete path of conductors by which current can flow. Circuits provide a pathway for current to flow. For a circuit, this path must start and finish at the same point. In other words, a circuit must necessarily form a loop. Although an electrical circuit and an electronic circuit have the exact definition, electronic circuits tend to below voltage circuits.

For example, a simple circuit may comprise two apparatuses:

1. A battery
2. A lamp.

The circuit allows current to travel from the battery to the lamp, through the lamp and then back to the battery. Thus, a circuit makes a complete loop.

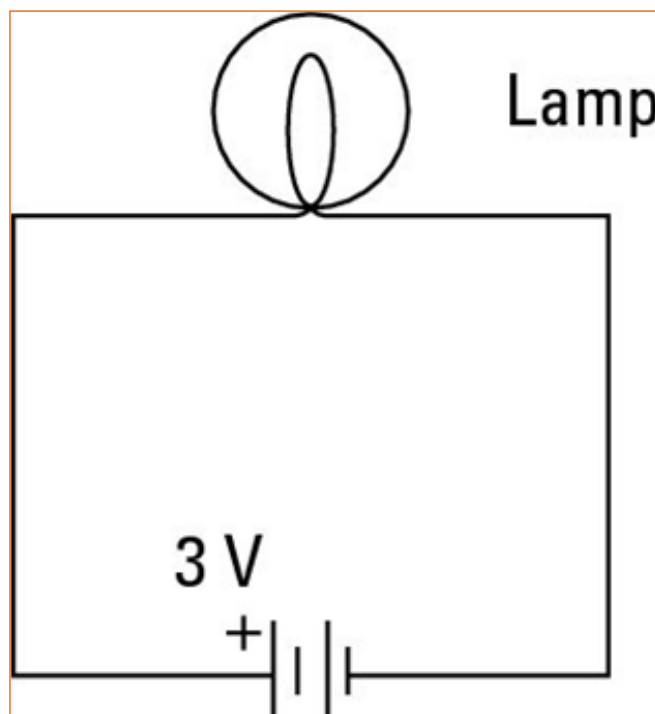


Fig. 3.1.1. Lamp

Indeed, circuits can be more intricate. Nevertheless, all circuits can be put into three essential components:

- **Voltage source:** A voltage source account for current travel, such as a battery, for example.
- **Load:** The load absorbs power; it signifies the actual work done by a circuit. Without the load, there's no point in having a circuit. The load can be as elementary as a single light bulb. However, in complex circuits, the load is a composite of constituents, such as resistors, capacitors, transistors, and many more.
- **Conductive path:** The conductive path offers a route by which current drifts. This route starts at the voltage source, flows through the load, and then returns to the voltage source. This path must construct a loop from the negative side of the voltage source to the positive side of the voltage source.

Let's understand the nature of elementary circuits:

When a circuit is whole and forms a loop that permits current to travel, the circuit is named a *closed circuit*. However, if any fragment of the circuit is disconnected or disordered so that a loop is not constructed, the current cannot drift. In that case, the circuit is termed an *open circuit*.

An *open circuit* is an oxymoron. After all, the components must form a complete path to be considered a circuit. Therefore, if the course is available, it isn't a circuit. Therefore, an *open circuit* is most often used to describe a circuit that has become broken, either on purpose (by the use of a switch) or by some error, such as a loose connection or a damaged component.

A **short circuit** refers to a situation when a circuit does not have a load. For instance, if the lamp is connected to the circuit simultaneously, there is a direct connection between the negative terminal and the battery's positive terminal.

Current in a short circuit can flow at hazardously high levels. As a result, short circuits can damage electronic components, cause a battery to blast, or start a fire.

The short circuit illustrates an essential point about electrical circuits: it is possible — common, even for a circuit to have multiple paths for current to drift. Thus, for example, the current can drift through the lamp as well as through the path that joins the two battery terminals directly.

Current drifts ubiquitously it can. If the circuit has two paths through which the current can drift, the current does not choose one over the other. Nevertheless, all paths are not equal, so current does not drift likewise through all paths.

For instance, the current will drift much more effortlessly over the short circuit than through the lamp. Thus, the lamp will not glow because almost all of the present will evade the lamp favouring the more manageable path through the short circuit. Yet, a small amount of current will drift through the lamp.

3.1.2 Designing of Circuits and Troubleshooting of The Circuits

In an electronic circuit, the matter traveling is the current by electronics, and the source of these electrons is a positive terminal of the voltage source. When this charge drifts from the positive terminal through the path and reaches the negative terminal, the circuit is known to be completed. Yet this circuit contains several apparatuses that affect the drift of the current in numerous ways. For example, some may deter the flow of charge, some simple store or scatter the current.

There are several reasons why a circuit is needed to be constructed a circuit. At times we may need to spark a lamp, run a motor etc. All these devices-a lamp, a motor, an LED, what we call loads. Each load requires a specific charge or power to start its operation. This power can be a constant DC voltage or an AC voltage. Yet, it is not possible to build a circuit just with a source and a load. We need a few more mechanisms that help in the proper drift of current and process the current supplied by the source such that an appropriate amount of currents drifts to the load.

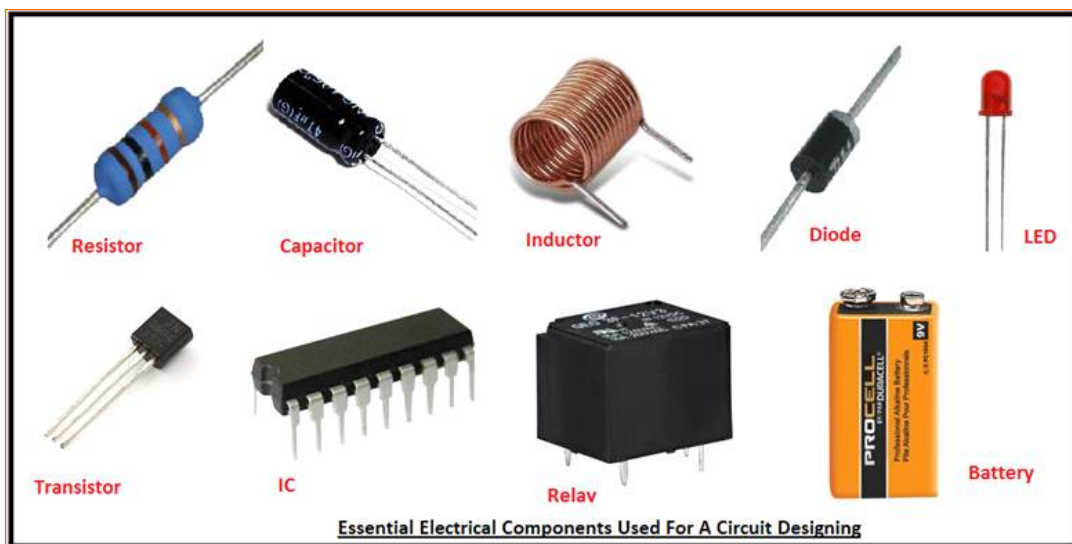


Fig. 3.1.2. Basic Electronic Components used for Circuit Designing

A simple electrical circuit contains a resistor, capacitors, inductors, transistors, diodes and integrated circuits. Conductive wires connect these essential electronic components. Current can easily flow between these wires to put electrical components in working conditions. Therefore, you should also look at these different types of electronics projects, in which these essential electronic components are used a lot.

1. Resistor

- A. A resistor is considered a vital component in the circuit is scheming.
- B. As the name proposes, it is used to create resistance in the flow of charge. As a result, it is extensively used in many electrical and electronics mechanisms.
- C. Some of the components in electronic devices are too delicate and can burn out with a sudden increase in current flow. The resistor works perfectly by preventing the current from getting too high.
- D. We measure the resistance of any resistor in ohms (Ω). The number of resistors we use in an electronic circuit depends on the current measure we wish to restrict flows through the circuit path. Thus, the more the resistance, the more is the capacity of resisting current from the course.

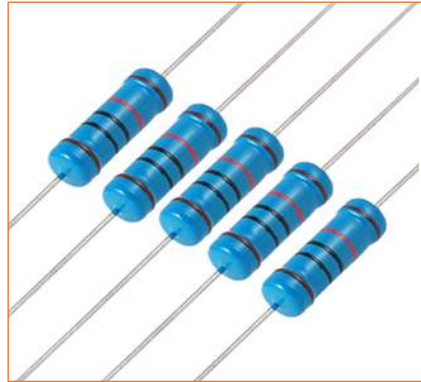


Fig. 3.1.3. Resistor

2. Capacitor

A capacitor is the next most frequently used element in circuit building.

- A. The working principle of a capacitor is the same as a battery. The work of the battery is to store electrical charge. However, some circuits are designed in a way, and they don't get energy directly from the DC source; DC source first charges the capacitor, and the output we get is the energy given by the capacitor.
- B. Capacitors come in several forms, but the most common conditions are "Ceramic Disc and Electrolyte". The capacitance of a capacitor is represented in microfarad and is denoted by μF .

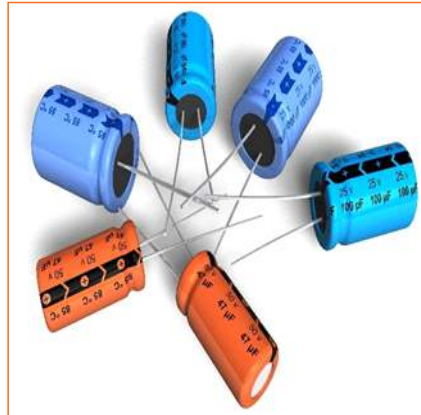


Fig. 3.1.4. Capacitor

3. Inductor

- A. An inductor is a simple coil of wire used in numerous electrical circuits. When a current drifts through the inductor, it stores energy in the magnetic field of the inductor.
- B. The Inductor allows DC to pass through it while it blocks the AC source. The primary application of inductors is in filters for separating the signals of different frequencies.



Fig. 3.1.5. Inductor

4. Diode

- A. A diode is a constituent that allows the current to drift in one direction only. It mainly consists of an anode and cathode.
- B. A charge will only drift when a positive voltage is applied to the anode side, and a negative voltage is applied to the cathode side. Therefore, the charge will not flow in reverse order.

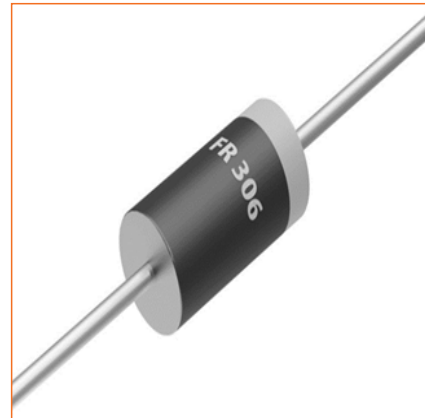


Fig. 3.1.6. Diode

5. LED

- A. An LED is a light-emitting diode that works only when current flows through it. Therefore, it is mainly used for indicating if the circuit is working correctly.
- B. When we connect the LED in series with the circuit and em its light; it works perfectly.



Fig. 3.1.7. LED

6. Transistor

- A. Transistor is more like a switching device chiefly used for switching and amplification objectives. It contains three elements, namely emitter, base, collector. A small voltage of 0.7 V between base and emitter turns it on.
- B. A small amount of current on the base side is used for controlling a large amount of current on the emitter and collector side. This is the property that is used for amplification purposes.

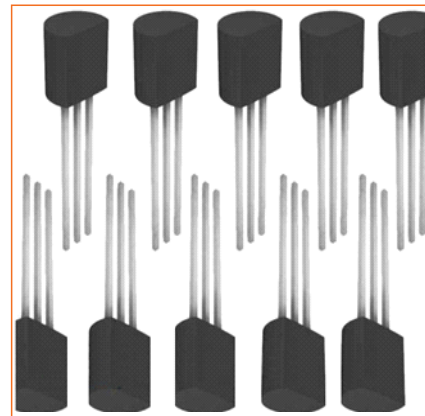


Fig. 3.1.8. Transistor

7. Integrated Circuit

An Integrated Circuit is a whole circuit that contains a transistor, diodes and other essentials. All these elements are placed on a small chip of silicon. Integrated circuits are extensively used in modern electronic devices such as laptops and cell phones.



Fig. 3.1.9. Transistor

8. Relay

- A. A replay is a simple switch that stops more extensive circuits from damaging.
- B. It works as an electromagnetic switch that gets triggered when a small amount of current flows through it.

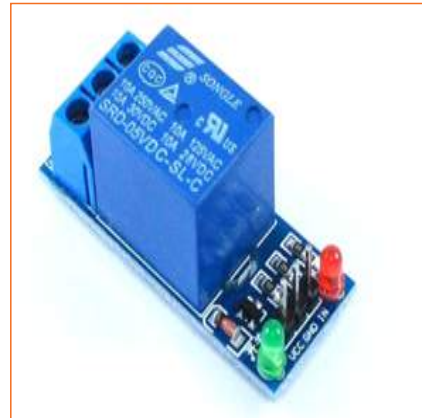


Fig. 3.1.10. Relay

9. Battery

- A. DC battery is a primary source of supply to function the electrical circuits. It translates chemical energy into electrical energy that allows the current to drift.
- B. Different batteries can be connected in series to get more voltage for an electrical circuit.



Fig. 3.1.11. Battery

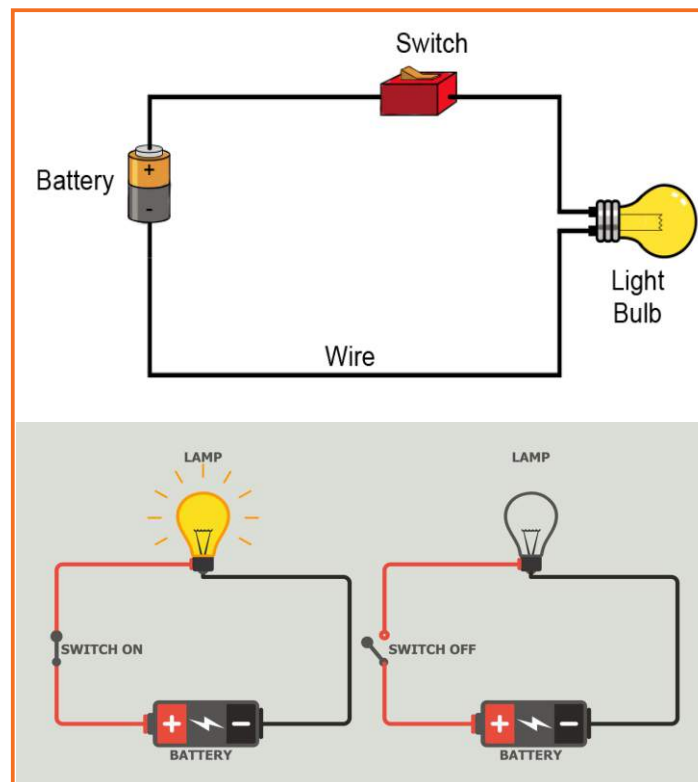


Fig. 3.1.12. Complete Circuit Diagram

3.1.3 Drawing and Describing the Basic Circuits

1. Gaining circuit familiarity

A circuit diagram is a graphical representation of the interconnections of various components constituting the equipment. It is the most crucial document for the maintenance technician. Usually, every assembly in electronic equipment is assigned an assembly number on the circuit board and the diagram. Commonly used symbols in electronic circuits are shown below.

The maintenance technician should be well versed with the circuit of the system before actually starting troubleshooting. A circuit diagram is an essential document for the technician. Unfortunately, Many-a-time the circuit diagram of the system or equipment is not ready or not provided by the manufacturer. In that case, the technician has to prepare the circuit diagram. The circuit diagram makes the fault finding process easy.



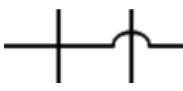
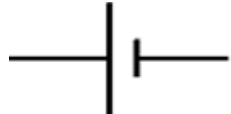
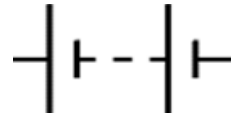

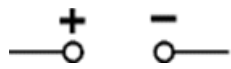


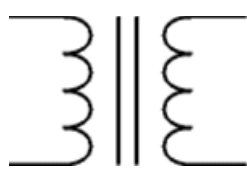
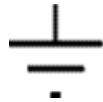
2. Drawing a circuit diagram



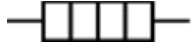

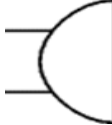

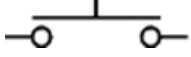


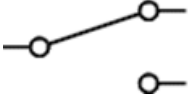
The technician should be experienced enough to draw a circuit diagram. Usually, it is not recommended for larger systems. Instead, a more extensive system is broken into parts (subsystems), and then circuit diagrams for the smaller, suspected systems are drawn to trace the fault. The following points must be noted when preparing a circuit diagram:

- After identifying the type of fault, the first thing to be done is to understand the system functionality. Then, split the plan into a few functional blocks, which will make an available working diagram.
- The components and their types are identified. The specifications of the parts are notes taken from the manual or data book given with the equipment.
- Make a note of the interconnections of various subassemblies like power supply, PCB assembly, front panel, etc.
- The printed circuit board is removed. Usually, individual panels can be removed in industrial systems as they are modular construction for easy maintenance.
- First, locate the components on the paper. Understand the PCB pattern. Place the PCB in front of solid light so that the PCB interconnections are visible. If you look at the back of the PCB, you see the mirror image of the connections as seen from the front. Now, sketch the components and PCB pattern.
- Differentiate between input and output. Start with the supply rail, not the common. Now draw the components connected to the supply lead. The ground or standard lead will be easy to identify.
- Use your knowledge of the functional aspects of the equipment to draw out the stages. Power transistors will be either with the power supply circuit or in the output stage. If one stage gets complicated, try starting from another stage like input or output stages following the signal path.
- Now conventionally redraw the circuit. After the initial attempt, the technician will be able to identify the nature of the circuit.
- Check if all the components on the card are in the sketch and check the polarities of the components.
- Always sketch with a pencil for easy correction.

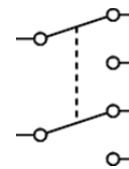
3. Reading a circuit diagram

A circuit diagram is a graphical representation of interconnections of various components constituting the equipment. It is an essential document for the maintenance technician. Usually, every assembly in electronic equipment is assigned an assembly number on the circuit board and the diagram. Commonly used symbols in electronic circuits are shown below:

Wire and connection symbols	
Wires connect the components and pass current quickly from one part of the circuit to another	
Wires joined - A 'blob' should be drawn where wires are connected (joined), but it is sometimes omitted. Wires connected at 'crossroads' should be staggered slightly to form two T-junctions, as shown on the right.	
Wires, not joined -In complex diagrams, are often necessary to draw wires crossing even though they are not connected. The simple crossing on the left is correct but may be misread as a join where the 'blob' has been forgotten. The bridge symbol on the right leaves no doubt!	
Power Supply Symbols	
Cell -Supplies electrical energy. The more significant line is positive (+). A single cell is often called a battery, but strictly speaking, a battery is two or more cells joined together.	
Battery -Supplies electrical energy. A battery is more than one cell. The more significant line is positive (+).	
Solar Cell -Converts light to electrical energy. The more extensive line is positive (+).	
DC supply -Supplies electrical energy. DC = Direct Current, constantly flowing in one direction.	
AC supply -Supplies electrical energy. AC = Alternating Current, continually changing direction.	
Fuse -A safety device will 'blow' (melt) if the current flowing through it exceeds a specified value.	
Transformer - Two coils of wire linked by an iron core. Transformers are used to step up (increase) and step down (decrease) AC voltages. Energy is transferred between the coils by the magnetic field in the core; there is no electrical connection between the coils.	
Earth (Ground) - A connection to the earth. This symbol is used for the 0V (zero volts) of the power supply for some electronic circuits, but it means the earth for mains electricity. Thus, it is also known as ground.	

Output Device Symbols	
Lamp (lighting) - A transducer that converts electrical energy to light. This symbol is used for a lamp providing illumination, such as a lamp to show the lamp in a surgical head lamp.	
Lamp (indicator) -A transducer that converts electrical energy to light. This symbol is used for a lamp, an indicator, for example, a warning light in a pulse oximeter showing a more effective pulse rate.	
Heater -A transducer, which converts electrical energy to heat. Example in a radiant warmer.	
Motor - A transducer mechanical device converts electrical energy to kinetic energy (motion). Example in an electric	
Buzzer - A transducer which converts electrical energy to sound. Example in a ventilator Alarm.	
Inductor, Coil, Solenoid - A coil of wire which creates a magnetic field when current passes through it. There may be an iron core inside the coil. It can be used as a transducer converting electrical energy to mechanical energy by pulling on something magnetically—for example, ultrasonic aspirator transducer.	
Switch Symbols	
Push-to-make switch -A push switch allows current to flow only when the button is pressed. For example, in suction machines when suction takes place at the press of a button.	
Push-to-break switch -This type of push switch is typically closed = on; it is open = off only when the button is pressed.	
SPST, on-off switch - SPST = Single Pole, Single Throw. Current flows only when the switch is in the closed =on position.	
SPDT, 2- way switch -SPDT = Single Pole, Double Throw. A 2-way changeover switch directs the flow of current to one of two routes according to its position. Some SPDT switches have a central off position and are described as 'on-off-on.'	

DPDT switch - DPDT = Double Pole, Double Throw. This switch can be wired up as a reversing switch for a motor. Some DPDT switches have a central off position.

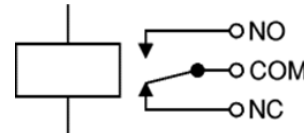


Relay - An electrically operated switch, for example, a 9V battery circuit connected to the coil, can switch off the heater circuit in a radiant warmer. The rectangle represents the coil.

NO = Normally Open

COM = Common

NC = Normally Closed.

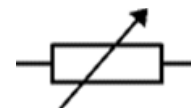


Resistor Circuit

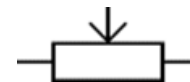
Resistor-A resistor restricts the flow of current. Uses include limiting the current passing through an LED and slowly charging a capacitor in a timing circuit. Some publications use the old resistor symbol: $\sim\sim\sim$



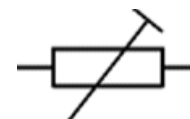
Rheostat variable resistor - A rheostat has two contacts and is usually used to control current. Uses include controlling lamp brightness or motor speed and changing the rate of flow of charge into a capacitor in a timing circuit.



Potentiometer variable resistor-A potentiometer has three contacts and is usually used to control voltage. For example, X-Ray machines are used to control the exposure levels.

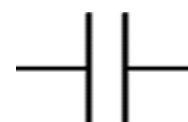


Preset variable resistor-A preset is operated with a small screwdriver or similar tool. It is designed to be set when the circuit is made and then left without further adjustment. It is adjusted only for the calibration of the signals.



Capacitor Symbols

Capacitor, unpolarised-A capacitor stores electric charge. It can be used with a resistor in a timing circuit for smoothing a supply (it provides a reservoir of charge) and can be used as a filter (blocking DC signals but passing AC signals). Unpolarised capacitors usually have small values, less than $1\mu\text{F}$.







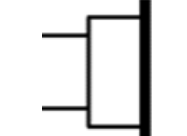
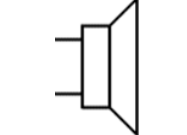






Capacitor, polarised-A capacitor stores electric charge. Polarised capacitors must be connected the correct way round. They usually have larger values, $1\mu\text{F}$ and greater.

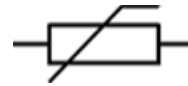


The variable capacitor-A variable capacitor is used with an inductor for providing an appropriate band pass filter by tuning.



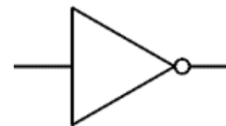
Trimmer variable capacitor: This type of variable capacitor is designed to be set when a circuit is made and then left without further adjustment until an adjustment is required to change the calibration of a function.	
Diode Symbols	
Diode - A device, which allows current to flow in only one direction.	
Light Emitting Diode - LED diode converts electrical energy to light. It is used in pulse oximeters.	
Zener diode - A Zener diode can be used to maintain a fixed voltage and used in voltage regulation.	
Photodiode - A light-sensitive diode operates when it receives light.	
Audio and Signal transmitters	
Microphone - A transducer which converts sound to electrical energy. The example used in sending voice recordings in telemedicine applications.	
Earphone - A transducer which converts electrical energy to sound. The example used in receiving voice messages in telemedicine.	
Loudspeaker - A transducer which converts electrical energy to sound. Example in audio alarms.	
Piezo Transducer - A transducer which converts electrical energy to sound. Example buzzer for Audio Alarms	
Amplifier (general symbol) - An amplifier circuit with one input. Used in block diagrams to denote the Amplifier block.	
Aerial (Antenna) - A device to receive or transmit radio signals. For example, it is used in telemedicine to receive or transmit audio-visual signals.	
Sensor Symbols	
LDR- Light Dependent Resistor - A transducer converts brightness (light) to resistance (an electrical property). For example, it is used to reduce the brightness of a display during the daytime automatically.	

Thermistor - A variable resistor which varies with the temperature. It is used to cut-off temperature in, for example, radiation warmer.



Logic gate symbols.- Logic gates process signals representing true (1, high, +Vs, on) or false (0, low, 0V, off).

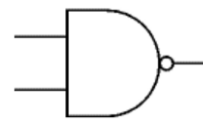
NOT - A NOT gate can only have one input. The 'o' on the output means 'not'. The output of a NOT gate is the inverse (opposite) of its input, so the output is accurate when the input is false. A NOT gate is also called an inverter.



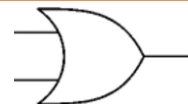
AND - An AND gate can have two or more inputs. The output of an AND gate is accurate when all its inputs are valid.



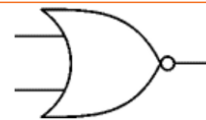
NAND - A NAND gate can have two or more inputs. The 'o' on the output means 'not', showing that it is a Not AND gate. Thus, the output of a NAND gate is accurate unless all its inputs are actual.



OR - An OR gate can have two or more inputs. The output of an OR gate is actual when at least one of its inputs is true.



NOR - A NOR gate can have two or more inputs. The 'o' on the output means 'not', showing that it is a Not OR gate. Thus, the output of a NOR gate is accurate when none of its inputs is true.



EX-OR - An EX-OR gate can only have two inputs. Therefore, the output of an EX-OR gate is valid when its inputs are different (one true, one false).



EX-NOR - An EX-NOR gate can only have two inputs. The 'o' on the output means 'not', showing that it is a Not EX-OR gate. The output of an EX-NOR gate is accurate when its inputs are the same (both true or both false).



Table. 3.1.1. Circuit Diagram Symbols

4. Description of some basic circuits:

Once we have understood the symbols and functions of various components, we can now draw basic circuits with these symbols.

Let's study the description of some of the primary circuits commonly used in medical devices:

I. Single Cell 1.5 V hearing aid

This is a hearing aid circuit with a 1.5v supply. This circuit is used to detect very faint sounds, then deliver the sounds to an 8-ohm earpiece. This circuit requires 1.5v input voltage, need only a single cell battery. Here is the schematic diagram of the circuit:

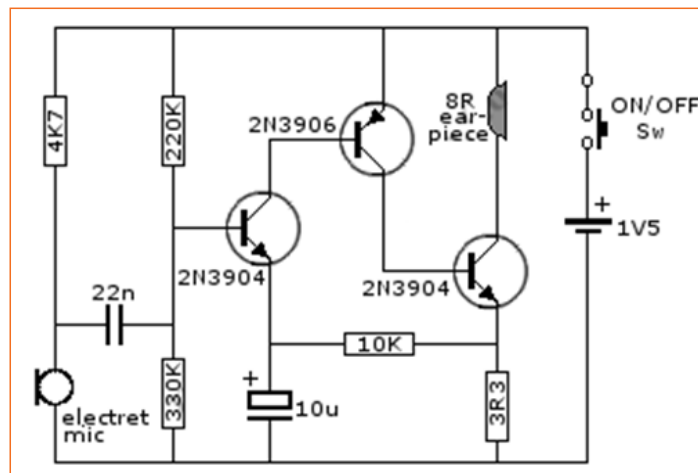


Fig. 3.1.13. Circuit Diagram of single 1.5 V Hearing Aid

This circuit can be assembled on a small board, or you can even do it without a board. To assemble without a board, you can connect every component that leads each other and solder them. Then, align the component bodies and their leads to avoid shorts, secure with insulation tape, glue, or resin.

The voice signals are picked up in the Electric Mike and are amplified by three transistors, 2N 3906 and 2N 3094 and the amplified signals are heard in the Ear piece. The ON/OFF switch provides the electricity through a 1.5 V Cell. The Capacitor filters the noise. The resistances provide the necessary bias voltage for running the transistors.

.II. Heart beat sensor

To build a heart-beat transducer not as difficult as imagined. The circuit below shows a simple heart-beat transducer.

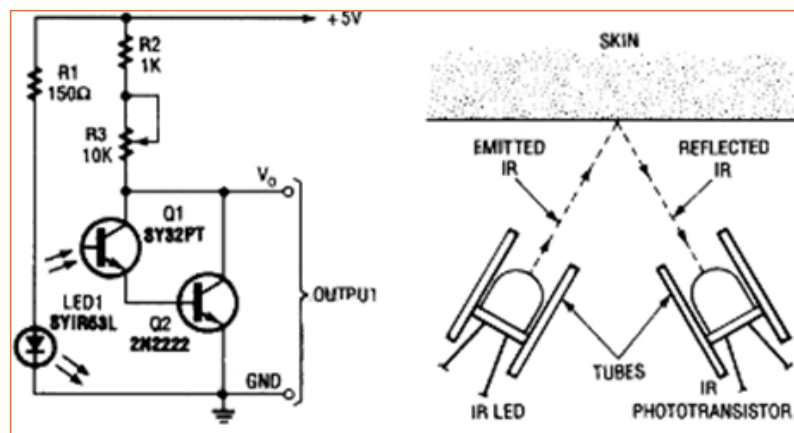


Fig. 3.1.14. A simple heart beat sensor circuit

This circuit made from an infrared photo transistor and infrared LED. This transducer works with the principle of light reflection; in this case, the light is infrared. The skin is used as a reflective surface for infrared light. The density of blood in the skin will affect IR reflectivity. The pumping action of the heart causes the blood density to rise and falls. So that we can calculate the heart rate based on the rise and fall of the intensity of infrared that reflected by the skin, at the output, we can connect a LED to detect the heartbeats. The output can also be connected to a counter and LED Display to count the pulses and display the same.

Tips

1. When a circuit is whole and forms a loop that permits current to travel, the circuit is named a closed circuit.
2. A simple electrical circuit contains a resistor, capacitors, inductors, transistors, diodes and integrated circuits. Conductive wires connect these essential electronic components.
3. A circuit diagram is a graphical representation of interconnections of various components constituting the equipment.

Exercise

1. Prepare the list of the following symbols:
 - Wire and connection symbols
 - Power supply symbols
 - Output device symbols
 - Switch symbols
 - Resistor circuit
 - Capacitor symbols
 - Diode symbols
 - Transistor symbol
 - Audio and signal transmitters
 - Sensor symbols

Practical

1. Draw the following symbols

- | | |
|---------------------|------------------------------|
| • Wires, not joined | • EX-NOR |
| • Wires joined | • Transistor NPN |
| • Cell | • Transistor PNP |
| • Battery | • Light Emitting Diode (LED) |
| • DC supply | • Trimmer variable capacitor |
| • AND | • Capacitor, unpolarised |
| • NAND | |
| • OR | |
| • NOR | |
| • EX-OR | |

Role Play

1. Design and demonstrate a simple circuit?

UNIT 3.2 Electronic component and application

Unit Objectives



After completion of this unit , the participants will be able to :

1. Know the electronic component and application
2. Understand the working of spectrum
3. Understand the applications of EM radiations in medical diagnosis and therapy
4. Identify different types of cables and connectors used in medical equipment
5. Understand the PCB fabrication process
6. Read different data sheets

3.2.1 Working of Spectrum

An electromagnetic spectrum is the entire distribution of electromagnetic radiation according to frequency or wavelength. Although all electromagnetic waves travel at the speed of light in a vacuum, they do so at a wide range of frequencies, wavelengths, and photon energies. The electromagnetic spectrum comprises the span of all electromagnetic radiation and consists of many subranges, commonly referred to as portions, such as visible light or ultraviolet radiation. The various portions bear different names based on differences in behaviour in the emission, transmission, and absorption of the corresponding waves and their other practical applications. There are no precise accepted boundaries between any of these contiguous portions, so the ranges tend to overlap.

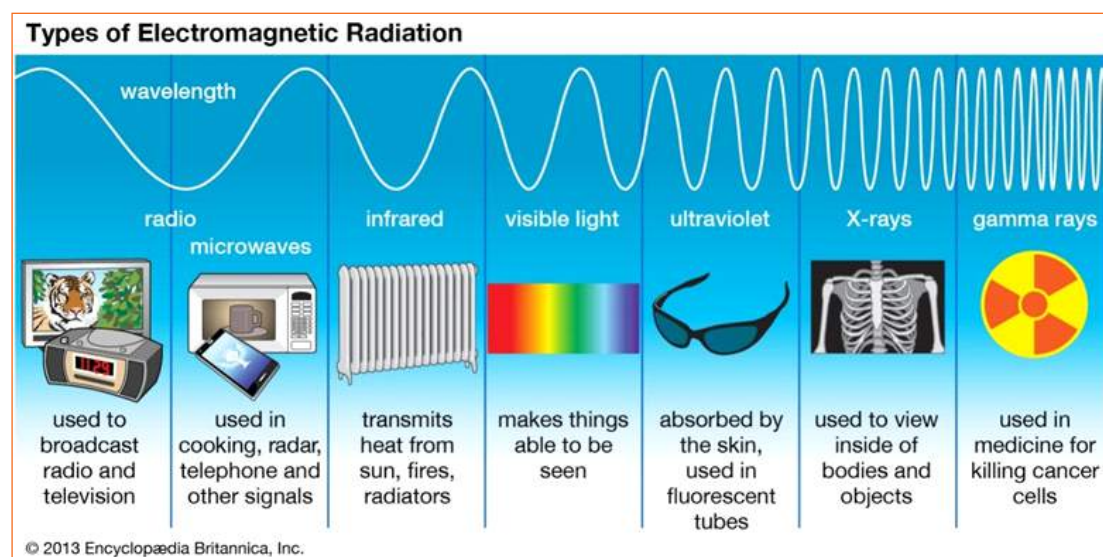


Fig. 3.2.1. Electromagnetic Spectrum and uses.

The frequencies and wavelengths are as given below:

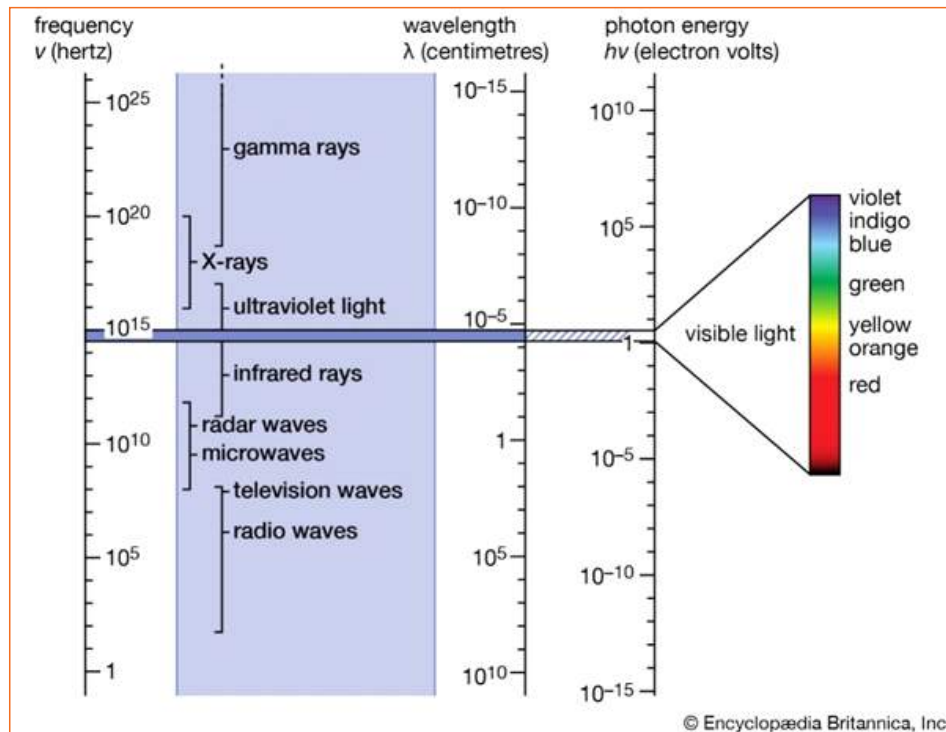


Fig. 3.2.2. Electromagnetic Spectrum wavelengths and classification.

Applications of EM radiations in medical diagnosis and therapy

Various applications of EM Radiations are as given below:

1. **Magnetic resonance imaging MRI-** is a medical imaging technique used in radiology to visualise internal structures. An MRI unit produces three different EMF fields to generate images:
 - A static magnetic field of zero frequency (average magnetic flux density of 1.5–3 Tesla) produced by a giant magnet for the alignment of hydrogen nuclei (protons) inside the body
 - Low power time-varying magnetic field gradients (100 Hz–1 kHz) generated by small magnets in three orthogonal planes (X, Y and Z directions) to provide the spatial position of the protons. Further, these MF gradients allow image slices to be created by focusing on the patient body part under examination
 - RF fields (100–200 MHz) produced in the non-radiative near field of the emitter excite the protons (in the body) and cause the protons to emit radio waves (radiative RF) for the acquisition of anatomical images.

As a source of non-ionising radiation, MRI is considered safer than x-ray imaging and, as such, represents an alternative to some x-ray diagnostic procedures, particularly for imaging children and pregnant patients. In addition, MRI is best suited for imaging soft tissue, making it particularly useful to image some principal anatomical structures (e.g., brain, muscles, heart) and detect cancers. 2,3 Each year, approximately 60 million MRI scans are performed worldwide.

2. **Radio-frequency thermal ablation** Radio - frequency (RF) ablation employs electric current in the **radio-frequency** range (450 – 500 kHz) to heat and destroy cancer tissue. Radio-frequency ablation (RFA) procedures in medicine are mainly used in cardiology to treat cardiac disorders and oncology for tumour treatment. For interventional cardiology, RFA is a minimally invasive medical procedure used to correct irregular heart rhythms (primarily atrial fibrillation). The RF device consists of an ablator (catheter), RF generator, and a control console. The energy-emitting probe (electrode) is at the tip of a catheter inserted through extensive veins into the heart. **Ablation involves destroying small diseased parts of the heart muscle using the resistive heat due to the electric current generated by high-frequency RF waves in the catheter.** RF is also used to treat tumours in the lung, liver, kidney, and bone but with the generator at a higher power than used for cardiology purposes. A needle-like RFA probe is placed inside the tumour. RF waves passing through the probe increase the temperature within tumour tissue resulting in its destruction. RFA may be combined with locally delivered chemotherapy treatment, and it is of particular value in reducing the size of inoperable tumours. RFA is minimally invasive, and repeated procedures can be done with few complications when performed under radiological guidance.
3. **Localised dielectric heating (shortwave diathermy)** - Shortwave diathermy is the therapeutic application of high-frequency alternating current used in physiotherapy treatments. The two **frequencies** designated for microwave **diathermy** are 915 MHz and 2456 MHz. The lower **frequency** is preferred and more commonly **used** because it provides selective heat deep into muscle and because less energy is converted to heat in the subcutaneous fat. RF fields are used to speed up the healing of tissues by providing deep heat to a large area of the body positioned under conductance plates. Continuous shortwave diathermy is the technique of choice when heating of deep tissue is required. Diathermy also allows superficial structures to be heated selectively using various surface heating techniques. Sub-acute or chronic conditions respond best to continuous shortwave diathermy, which can be as effective as high power ultrasound when appropriately used. Diathermy is used to relieve pain and muscle spasms, resolve inflammation, reduce swelling, increase joint range and decrease joint stiffness.
4. **Electrocautery - Electrocautery** also known as thermal cautery, refers to a process in which a direct or alternating current is passed through a resistant metal wire electrode. The heated electrode is then applied to living tissue to achieve hemostasis or varying degrees of tissue destruction. Electrocautery can be used in various minor surgical procedures in dermatology, ophthalmology, otolaryngology, plastic surgery, and urology.

In electrocautery, the current does not pass through the patient; thus, the procedure can be safely used in patients with implanted electrical devices such as cardiac pacemakers, implantable cardioverter-defibrillators, and deep-brain stimulators.

Surgical diathermy involves the passage of high-frequency alternating electric current through body tissues. Heat is produced where the current is locally concentrated, resulting in tissue destruction. Surgical diathermy involves current frequencies in the range of 400 kHz to 10 MHz. Currents up to 500 MA may then be safely passed through the patient.

5. **Phototherapy for newborn babies to treat Jaundice** - Some "normal" jaundice will disappear within a week or two without treatment. Other babies will require treatment because of the severity of jaundice, the cause of jaundice, or how old the baby is when jaundice appears.

Phototherapy (light treatment) is the process of using light to eliminate bilirubin in the blood. Your baby's skin and blood absorb these light waves. These light waves are absorbed by your baby's skin and blood and change bilirubin into products, which can pass through their system.

For over 30 years, phototherapy treatment in the hospital has been provided by a row of lights or a spotlight suspended at a distance from a baby. This would provide light shining directly on an undressed baby (with the diaper on) whose eyes would need protection from the light with soft eye patches applied.

6. **Narrowband UVB phototherapy for the treatment of skin burns** - Narrow band UVB is the most common form of phototherapy used to treat skin diseases. "Narrowband" refers to a specific wavelength of ultraviolet (UV) radiation, 311 to 312 nm. UVB phototherapy was formerly provided as a broadband source (290 to 320 nm).

The narrowband range of UV radiation has proved to be the most beneficial component of natural sunlight for psoriasis. In addition, Narrowband UVB may also be used to treat many other skin conditions, including atopic eczema, vitiligo, pruritus, lichen planus, polymorphous light eruption, early cutaneous T-cell lymphoma and dermatographism.

7. **Sterilisation effects of UV - C Radiations - UVC light** have wavelengths between 100-280 nm, AND it has germicidal properties, i.e. it kills all the harmful microorganisms and sterilises. It is used to sterilise Dental Equipment in UV Cabinet. In hospitals, it is used in sterilising surfaces in OT and in HVAC systems to sterilise the air and in emergency rooms and tb centers, it is utilised to sterilise the room air. **However, it is harmful to the eyes, and hence the radiations are always kept protected to the eyes.**

8. **X-Rays Machines - Uses X-ray**, electromagnetic radiation of the extremely short wavelength and high frequency, with wavelengths ranging from about 10^{-8} to 10^{-12} metre and corresponding frequencies from about 10^{16} to 10^{20} hertz (Hz).

An X-ray imaging system consists of a generator control console where the operator selects desired techniques to obtain a quality readable image (kVp, mA and exposure time). An x-ray generator controls the x-ray tube current, tube kilovoltage and emitting exposure time. An X-ray tube converts the kilovoltage and mA into actual x-rays and into an image detection system that can be either a film (analogue technology) or a digital capture system and a PACS. X-ray machines are used in health care for visualising bone structures during surgeries (primarily orthopaedic) to assist surgeons in reattaching broken bones with screws or structural plates. In addition, it assists cardiologists in locating blocked arteries and guiding stent placements or performing angioplasties and for other dense tissues such as a tumour.

9. **C-Arm image intensifier** - A C-arm is an imaging scanner intensifier. The name derives from the C-shaped arm used to connect the x-ray source and x-ray detector. C-arms have radiographic capabilities. Though they are used primarily for fluoroscopic intraoperative

imaging during surgical, orthopaedic and emergency care procedures, these devices provide high-resolution X-ray images in real-time, thus allowing the physician to monitor progress and immediately make corrections. While X-ray machines are static, the C-Arm is a dynamic machine.

10. CT-Scanner - A computerised tomography scan (CT or CAT scan) uses computers and rotating X-ray machines to create cross-sectional images of the body. These images provide more detailed information than standard X-ray images. For example, they can show the soft tissues, blood vessels, and bones in various parts of the body. This is also a dynamic system as opposed to static images in an X-Ray machine.

11. Gamma rays - **Gamma rays are electromagnetic radiation that cannot be seen or felt with the** smallest wavelengths and most incredible energy on the electromagnetic spectrum (right above x rays on the electromagnetic spectrum) with wavelengths shorter than 0.1 Å. They are usually produced in extremely high temperatures or solar flares. When used in medicine, it can be made in labs either by nuclear collision or artificial radioactivity. The cyclotron and synchrotron are two devices used to produce the high energy nuclei required for the collisions. Unfortunately, gamma rays kill living organisms in a process called irradiation, which can be very harmful when used for any purpose other than medicine.

12. Importance in clinical medicine - The fact that gamma rays kill any living organism is advantageous to the medical field, especially oncology. High doses of gamma rays can kill cancerous cells in radiation therapy (lower doses could lead to cancerous cells). The radiation therapy process kills the DNA of cancerous cells, preventing growth or division using a machine called an accelerator or radioactive sources placed inside the patient. The main focus of the radiation oncologist is to target the dose of radiation to cancer as much as possible to avoid side effects. Side effects depend on the area of treatment. Gamma rays are also used for the sterilisation of medical equipment. Gamma rays quickly pass through medical equipment packaging (can only be stopped by thick lead) and kill living tissue such as viruses and bacteria

13. Microwave technology - **Microwave technology** is now widely used in a variety of medical applications. Most commonly, microwave energy is used to create localised dielectric heating to desiccate human tissue - known as microwave ablation. Common medical areas of application include:

- Oncology
- Cardiology
- Gynaecology
- Rhizotomy
- Otolaryngology (ENT)
- Ophthalmology
- Cosmetic treatments
- Dental treatments

Microwaves have played an essential role in the fight against cancer, providing a new way of treating the disease. Microwave ablation is commonly used to remove unwanted tissue masses, for example, liver tumours, lung tumours and prostate ablation, and the treatment of large tumours. Cancer patients who are poor surgical candidates can also benefit from microwave ablation, as minimally invasive.

Frequency Options

A significant benefit of microwave technology is flexibility - a wide range of medical applications can benefit from the scope of frequencies available. For example, systems operating at 915MHz and 2.45GHz are ideally suited for extensive volume ablation. At the same time, the use of higher frequencies is suitable for treatments such as skin cancer, ablation of the heart to treat arrhythmia, uterine fibroids, multiple small liver metastases, corneal ablation (vision correction), spinal nerve ablation (back pain), varicose vein treatment, verrucae treatment and many other specific treatments. In addition, higher frequency treatments in the range 5.8 GHz - 10 GHz can create shallow penetration of energy and are therefore ideal for surface-based treatments or anything that requires very precise ablations. Microwaves can also be used to coagulate bleeding in highly vascular organs such as the liver and spleen.

14. Microwave Sterilisers - Microwaves produces heat in selected areas, and thus it is used to sterilise medical goods like Tubings, Cloths and other articles for sterilisation.

15. Infra-Red-IR Thermometers - Infrared is an electromagnetic wave with a microwave and visible light wavelength. The wavelength is between 1mm and 760 nanometers (nm), invisible light longer than red light.

Any heated object generates IR. . Infrared can be divided into three parts, namely near infrared, with a wavelength between (0.75-1) to (2.5-3) μm ; mid-infrared, with a wavelength between (2.5-3) to (25-40) μm ; far-infrared, The wavelength is between (25-40) \sim 1500 μm .

Medical infrared can be divided into two categories: near-infrared and far-infrared. Containing thermal energy, the sun's heat is mainly transmitted to the earth through infrared rays.

Within this wave band, only frequencies of 0.7 microns to 20 microns are used for practical, everyday temperature measurement.

Any heated body will generate IR, which is detected by a photodetector that gets heated. The heat is converted to electrical energy and is displayed as temperature readings after calibration. IR thermometer measures the body temperature without touching the body.

3.2.2 Types of cables and connectors

Connections in medical devices encompass a variety of styles, including those that make electrical connections within medical machines and systems, as well as those used to latch and unlatch tubing in medical devices. Connectors are used to transfer power, signal, data or media and can be designed for just one of these operations or as hybrid systems. No matter what type, they must all be safe and hygienic.



Fig. 3.2.3. Medical connector

Electrical connections

Electrical medical connectors and cables are often used in MRI, ultrasound, defibrillators, EKG, heart-lung machines, surgical, diagnostic and therapy systems, to name a few. As a result, reliability is critical. These connectors must be easy for trained professionals to use and connect and disconnect, but also fool-proof to prevent untrained users from damaging or mating cables incorrectly.



Fig. 3.2.4. Medical connector

Tubing connections

The operative demands of your application determine the parameters for tubing and connectors. Fittings, luers and quick disconnect couplings are the most common tubing connectors used in low-pressure environments. They are reliable, cost-efficient, low-weight designs and should be designed to reduce or even eliminate the potential for user fault. Hybrid connector designs help



Fig. 3.2.5. Medical connector

transfer liquid and air media, as well as electrical signals, in one device. While each is appropriate for certain applications, they are not necessarily interchangeable. For example, in applications where spill prevention is desired, a valved connector is a better choice than a luer (see figures 1 and 2). If the application involves frequent connecting and disconnecting, a quick disconnect designed for long-term reliability is a good choice.

These latch and unlatch couplings and fittings used on medical equipment are often of the quick-disconnect design, allowing for quick and secure connections and disconnections. They are used to prevent accidental mis-connections for safe machine and system designs.

As per LEMO®, Founded by engineer Léon Mouttet in Switzerland in the year 1946 Initially a manufacturer of contacts in noble and rare metals, the company took a major step forward in 1957 with the introduction of the push-pull self-latching connector

LEMO and REDEL are the two connector brands of the LEMO group that are used in medical world. REDEL is in general the brand for the medical plastic connectors while LEMO is the brand for the metal connectors (with emc shielding).

EQUIPMENT	BENEFITS	SERIES
Analyzers, monitoring & diagnostics	Reliable connections for gathering data. Sealed for wet applications. Flexibility on glands and seals for demanding environments. Stainless steel for best longevity and hot sterilization.	B Connector E Connector K Connector S Connector T connector
Dental equipment	Mixed configuration inserts, fluidic/pneumatic contact option, fiber optic (can be used for illumination).	B Connector K Connector R Connector REDEL P REDEL SP
Disposable devices (sensors, catheters)	Reliable in a sensitive environment, plastic materials familiar to the medical industry. One time use solutions.	B Connector REDEL P REDEL SP S Connector
Electrosurgical devices	Mixed signal inserts, good RFI/EMI shield performance	B Connector E Connector K Connector S Connector T connector
Pacemakers and hearing devices	Small, lightweight, reliable connectors for external modules or battery packs	B Connector S Connector
Ventilators, anesthesia, intensive care	Connectors with a large choice of colours, immediately identifiable	REDEL P REDEL SP

Table 3.2.1. Medical Equipment & Connector Type

The LEMO B Series offers a modular, ergonomic, rugged and reliable circular multipole connector for applications needing quick and secure Push-Pull latching. Making it an ideal choice for test and measurement, instrumentation, medical devices, research and audio/video applications.

The modular insert configurations include a wide range of high-density multi-pole or hybrid electrical contacts. Contacts can be of solder type, crimp, PCB straight or PCB elbow, fiber, coaxial, thermocouple, pneumatic, fluidic or even high voltage type of contact.



Fig. 3.2.6. LEMO B Series Connectors

E - Connector

- Unipole
- Coaxial 50 and 75 Ω
- Multipole 2 to 106 contacts
- Triaxial 50 and 75 Ω
- High voltage
- Multi or mixed contacts with:
- Coaxial 1 to 8 contacts
- High voltage 1 to 8 contacts
- Thermocouple 2 to 6 contacts



Fig. 3.2.7. LEMO E Series Connectors

K - Connector

- The modular design of the LEMO K series connectors offers a solution for outdoor applications.
- The integral sealing within both plug and socket offers a IP68 watertight connection when mated.
- The push pull latching mechanism provides a secure connection whilst the density of the contacts provide considerable panel space savings.
- Multi key options prevent cross mating of similar connectors within a panel.
- Contact types include LV (low voltage), Fibre Optic and Coax provides for every eventuality. Hybrids including of any combination of contacts types.
- The chrome plated version is resistant to more than 1000hours of salt spray corrosion test.
- The ruggedised design combined with precision manufacturing offers excellent durability, reliability and quality.



Fig. 3.2.8. LEMO E Series Connectors

S - Connector

- Unipole
- Coaxial 50 and 75 Ω
- Multipole 2 to 106 contacts
- Triaxial 50 and 75 Ω
- High voltage
- Multi or mixed contacts with:
- Coaxial 1 to 8 contacts
- High voltage 2 to 8 contacts
- Thermocouple 2 to 6 contacts



Fig. 3.2.9. LEMO S Series Connectors

T- Connector

The LEMO T Series range are small diameter waterproof Push-Pull multipole connectors with an index protection of Ip68.

- T series connectors have been specifically designed for outdoor applications. They include an inner sleeve and seals to prevent penetration of solids or liquids.
- The T Series connectors feature a push-pull self-latching system, mechanical key with multiple keys to avoid cross-mating, and 360° full EMC shielding.
- The T connector outer shell is available in standard LEMO matt chrome or black-chrome finish for use in defence systems such as aircraft communications, land vehicles, night vision equipment, simulation or personal battle equipment. These products can be used for automated test equipment, for electronic test and other applications where the environmental conditions require ruggedised equipment.
- The connector is available with solder, crimp or print contacts.



Fig. 3.2.10. LEMO T Series Connectors

R-Connector

- Multipole 10 to 65 contacts
- Mixed contacts with:
 1. Coaxial 1 to 8 contacts
 2. Fluidic 1 to 8 contacts
 3. High voltage 1 to 8 contacts



Fig. 3.2.11. LEMO R Series Connectors

REDEL - P Connector

- Multipole 2 to 34 contacts
- Voltage mains
- Fluidic
- Mixed contacts in 2P and 3P series with:
 - Coaxial 1 contact
 - High voltage 1 contact
 - Fibre optic 1 contact
 - Fluidic 1 or 3 contacts

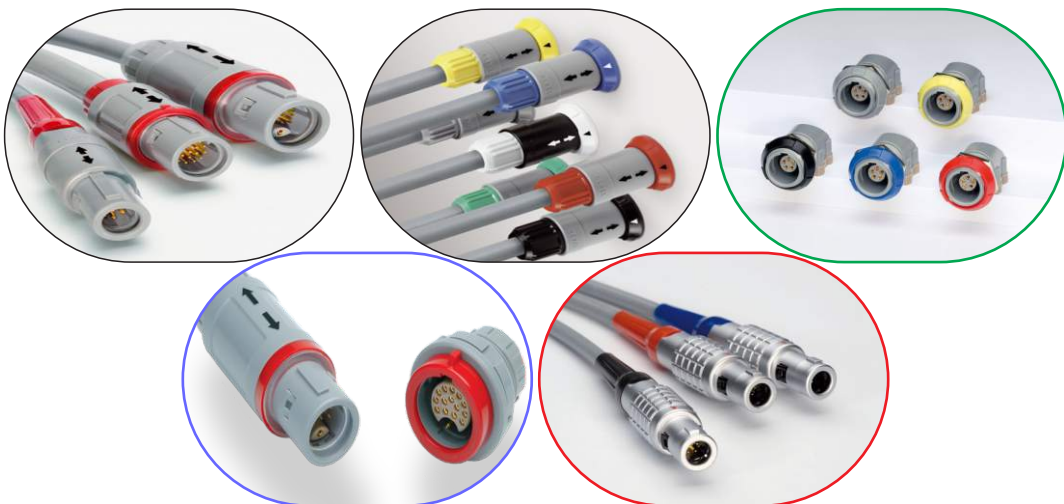


Figure 3.2.12. LEMO REDEL - P Series Connectors

REDEL - SP Connector

- The REDEL SP connectors are plastic Push-Pull connectors offering an ergonomic grip and a variety of colours enhancing usability.
- The latch sleeve is recessed into the connectors body ensuring greater shock resistance. The outer shell in proprietary sulfone PPSU material (FDA approved) enables extensive sterilisation cycles and high chemical resistance.
- The use of a rectangular insert conveniently provides a larger area for higher contact density. Contact configurations are available in solder, crimp and print options.
- The complete connector can be easily assembled from spare parts (even the contact configuration) offering good flexibility in stock keeping.
- These circular plastic connectors are especially adapted for applications such as medical instrument devices, automotive and test & measurement.
- This product is ideally suited to be paired with Northwire's robust USP Class VI silicone cable alternative, BioCompatic cable.



Fig. 3.2.13. LEMO REDEL - SP Series Connectors

3.2.4 Design Rules for Fabrication of PCB and Types of PCB

Printed Circuit Boards (PCBs) form the backbone of all major electronics. These miraculous inventions pop up in nearly all computational electronics, including simpler devices like digital clocks, calculators, medical devices etc. A PCB routes electrical signals through electronics for the uninitiated, which satisfies the device's electrical and mechanical circuit requirements. In short, PCBs tell the electricity where to go, bringing your electronics to life.

PCBs direct current around their surface through a network of copper pathways. The complex system of copper routes determines the unique role of each piece of PCB circuit. Design rules for fabrication of PCB and types of PCB board.

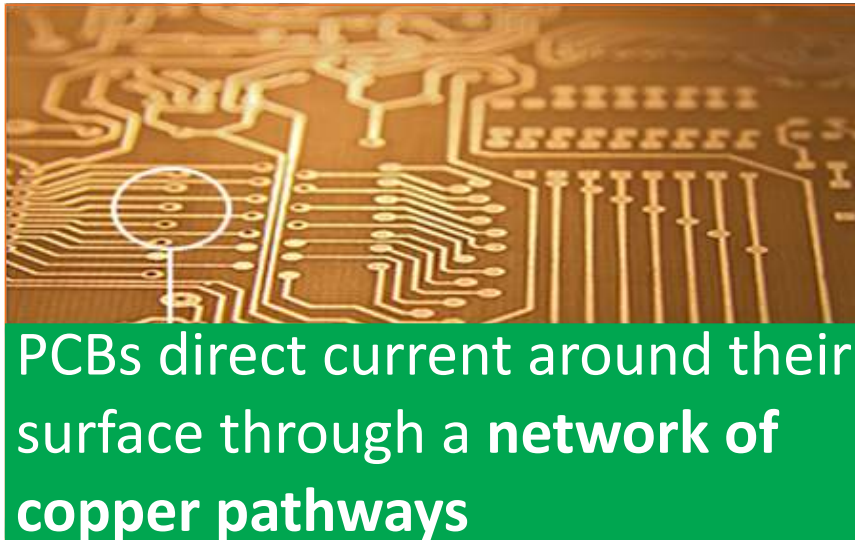


Fig. 3.2.14. PCB direct current around their surface through a network of copper pathways.

Before PCB design, circuit designers are recommended to get a tour of a PC board shop and communicate with fabricators face to face over their PCB manufacturing demands. It helps prevent designers from making any unnecessary errors from getting transmitted during the design stage. However, as more companies outsource their PCB manufacturing inquiries to overseas suppliers, this becomes impractical.

The Following Are The PCB Fabrication Steps:



Step 1. Design and output

Circuit boards should be rigorously compatible with a PCB layout created by the designer using PCB design software. Commonly-used PCB design software includes Altium Designer, OrCAD, Pads, KiCad, Eagle etc. NOTE: Before PCB fabrication, designers should inform their contract manufacturer about the PCB design software version used to design the circuit since it helps avoid issues caused by discrepancies.

Once the PCB design is approved for production, designers export the design into the format their manufacturer's support. The most frequently used program is called extended Gerber.

The PCB industry birthed extended Gerber as the perfect output format. Different PCB design software possibly calls for different Gerber file generation steps; they all encode comprehensive vital information, including copper tracking layers, drill drawing, apertures, component notations and other options. All aspects of the PCB design undergo checks at this point. The software performs oversight algorithms on the design to ensure that no errors go undetected. Designers also examine the plan about elements relating to track width, board edge spacing, trace and hole spacing and hole size.

After a thorough examination, designers forward the PCB file to PC Board Houses for production. To ensure the design fulfils requirements for the minimum tolerances during manufacturing, almost all PCB Fab Houses run Design for Manufacture (DFM) checks before circuit boards fabrication.

Step 2. From file to film

The first step of circuit board fabrication is to transfer the PCB design circuitry image data from the manufacturing files supplied by the CM to the board. Usually, data arrives in a file format known as Gerber, although other formats and databases can be used. The image data will be transferred to the board by one of two different methods:

- **Photo Tooling:** The standard imaging process in PCB fabrication that's been in use for as long as circuit boards have been mass-produced. A precision photoplotter will create the circuitry images on film used in the fabrication process as a template to print the images onto the board.
- **Direct imaging:** A laser prints the circuitry images directly onto the circuit board, bypassing the need for photo tools. This has advantages over using film because it's more precise, there aren't alignment issues, and photo tooling won't require periodic recreation to replace worn-out films. Conversely, each layer will have to be laser printed individually, which is a more expensive process.

The figure below shows the circuit plotted or printed on the film.

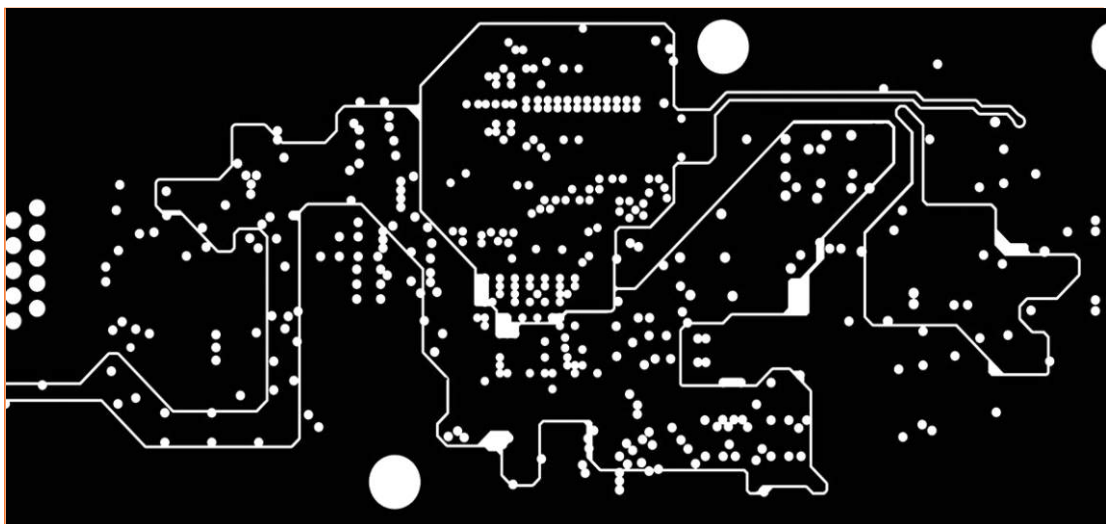


Fig. 3.2.15. The circuit plotted or printed on the film.

Step 3. Printing the inner layers?

The layers of a circuit board

A multilayer circuit board is a composite of different layers of dielectric material and metal conductors. It's composed of layer pairs with a dielectric core material of epoxy resin and glass fibre, more commonly known as FR-4, sandwiched between two layers of copper foil. While other dielectric materials are available, FR-4 is the most common core material used in PCB fabrication.

Multilayer boards will take a thinner version of the same core structure used in creating a double-sided board and laminate it together with other core structures to build the board layer stackup. Each layer must be strictly controlled for its width, copper weight, and layer to layer alignment for a final quality product.

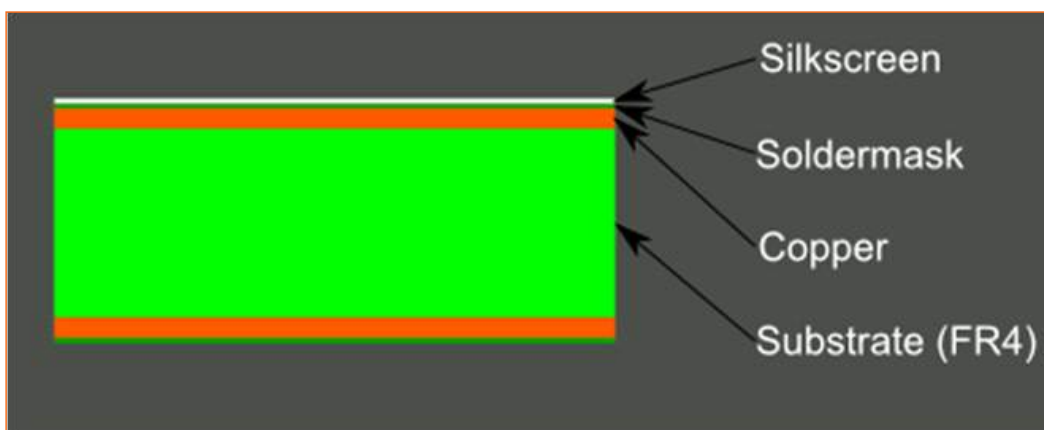


Fig. 3.2.16. Layers in a PCB

The creation of films in the previous step aims to map out a figure of the copper path. Now it's time to print the figure on the film onto a copper image onto the Once each inner layer pair of the board has gone through this same process ready to be laminated into one complete circuit board.

Creating the inner layer circuitry

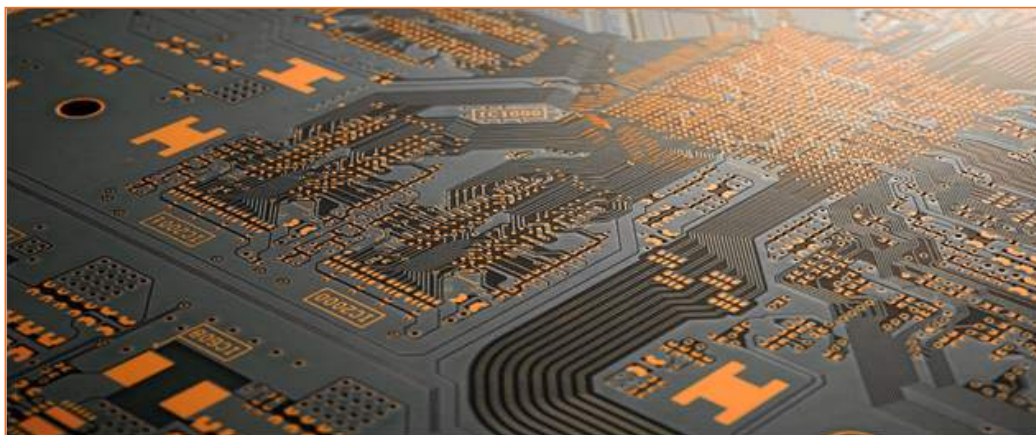


Fig. 3.2.17. Inner Layer Circuitry

The first step in PCB fabrication is to print circuitry images onto the inner layer cores:

- The copper foil of the core is covered with a sheet of photoresist material.
- The photoresist is exposed to either ultraviolet light through photo tooling or by direct imaging with a laser.
- Only the areas of copper circuitry, such as pads and traces, are exposed which polymerizes, or hardens the photoresist over the circuitry patterns.
- The unexposed photoresist, which is still pliable, is chemically removed from the copper.
- The copper layers of the core are etched away, leaving only those areas of circuitry protected by the polymerized photoresist.
- The photoresist is stripped off, leaving only the copper circuitry.

When this process is completed, the core layers will be inspected by an AOI system (automated optical inspection) for defects. Once each inner layer pair of the board has gone through this same process, they'll be ready to be laminated into one complete circuit board.

Step 4. Laminating the layers together

Together with thin layers of copper foil to cover the external surfaces of the top and bottom sides of the board, layer pairs are stacked to create a PCB "sandwich."

To facilitate the bonding of the layers, each layer pair will have a sheet of "prepreg" inserted between them. Prepreg is a fibreglass material impregnated with epoxy resin that will melt during the heat and pressure of the lamination process. As the prepreg cools, it will bond the layer pairs together.

Compositing the board together during this phase requires a lot of attention to detail to maintain the correct alignment of the circuitry on the different layers.

Once the stack is complete, the sandwiched layers are laminated, and the heat and pressure of the lamination process will fuse the layers into one circuit board.

Step 5. Drilling the holes

The next step in PCB fabrication is to drill holes in the board for component mounting, thru-hole vias, and the non-plated holes of mechanical features. The majority of the thru-holes used in a circuit board will be plated and are usually drilled 0.005" more prominent than the specified finished hole size to allow for plating.

If the design contains any blind and buried vias or laser-drilled microvias, those are fabricated before the lamination of the board. The extra process steps for these vias can add additional cost to the board's fabrication but may be required for dense circuitry and/or electrical performance.

Once holes are drilled, they get cleaned using chemical and mechanical processes to remove resin smears and debris caused by drilling. The entire exposed surface of the board, including the holes' interior, is then chemically coated with a thin layer of copper. This creates a metallic base for additional electroplating copper into the holes and onto the surface in the next step.

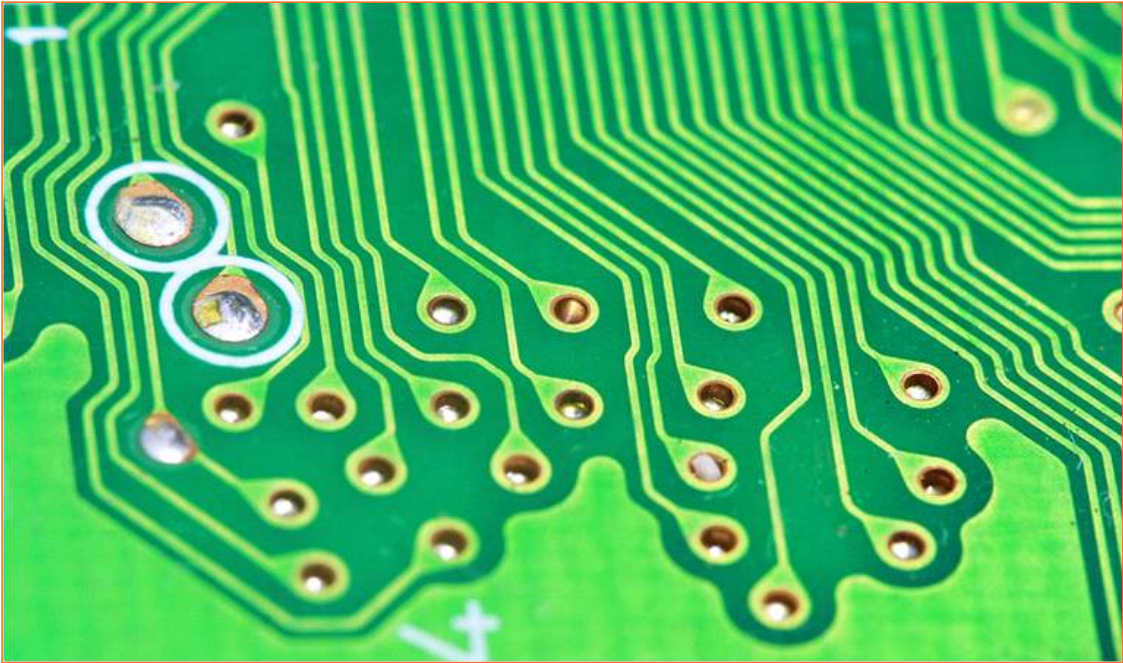


Fig.3.2.18. Metallic base for electroplating

Step 6. Creating the top and bottom layer circuitry

Now the board is ready to have its top and bottom circuitry images printed. To do this, the same photoresist will be used as with the inner layers, but this time the circuitry needs to be unprotected and plated up with additional copper:

- The top and bottom surfaces of the board are entirely covered with a sheet of photoresist material, including the drilled holes to be plated.
- The photoresist is exposed by UV or laser, but contrary to the inner layers, all surface areas of the board are exposed except for the circuitry patterns.
- Once the unexposed photoresist is chemically cleaned off, the circuitry patterns of bare copper are electrically plated with more copper to build up their metal weight.
- Next, tin is plated onto all of the copper circuitry as a protective layer, and the photoresist is stripped off the remainder of the board in preparation for etching.
- The board is etched to remove all copper except for those areas of metal circuitry protected by the tin.
- Finally, the tin is removed, leaving the plated copper pads, traces, and thru-holes. At this point, the board's circuitry is complete, but there are still a couple of more steps to finish the board's fabrication.

Step 7. Solder mask, silkscreen, and surface finishes

To protect the board during assembly, the solder mask material is applied using a UV exposure process similar to what was used with the photoresist. This solder mask will cover the entire surface of the board except for the metal pads and features soldered. In addition to the solder mask, component reference designators and other board markings are silk-screened. Both the solder mask and the silkscreen ink get cured by baking the circuit board in an oven.

The circuit board will also have a surface finish applied to its exposed metal surfaces. This helps to protect the exposed metal and assists in the soldering operation during assembly. One example of a surface finish is hot air solder levelling (HASL). The board is first coated with flux to prepare it for the solder and then dipped into a bath of molten solder. As the board is removed from the solder bath, a high-pressure blast of hot air removes excess solder from the holes and smooths the solder on the surface metal.

In the figure below, the green solder mask is applied to most PCBs, covering up the small traces but leaving the silver rings and SMD pads exposed so they can be soldered to.

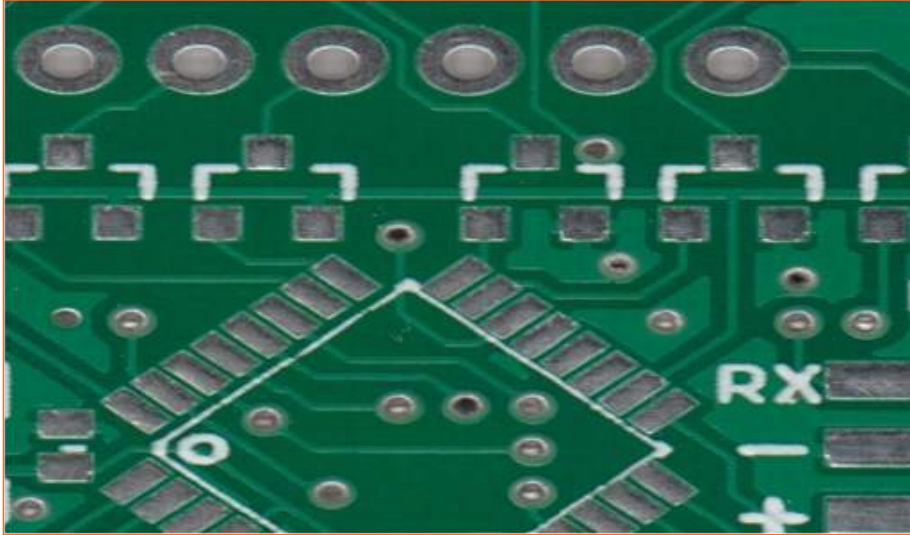


Fig. 3.2.18. Green solder mask

Assembly prep, inspection, and test

The final step of the PCB fabrication process preparing the circuit board for assembly. If necessary, the circuit boards are routed out of their manufacturing panels, or the panels are prepared for a breakout after assembly.

This is done by either scoring a V-cut on the board outline or routing out the board except for small breakout tabs.

The finished board goes through continuity testing with automated test equipment such as a bed of nails test fixture or a flying probe test system.

Tests look for any unintentional shorts between nets, which would invalidate the board.

Once the testing is complete, and the board passes inspections, it's shipped back to the PCB contract manufacturer for component assembly.

The process described above is automated. But it can be done for small prototypes by Screen Printing or by simple Paper print.

3.2.5 Data Sheets Of Diode And Transistors And Testing

Data sheets are the critical parameter specifications for a diode or a transistor.

Understanding diode and Transistor specifications, parameters and ratings can be vital to select the suitable electronic component for a particular electronic circuit design. However, with a massive variety of diodes available on the market, selecting the required one may not always appear easy.

Most of the specifications, ratings and parameters are relatively straightforward to understand, especially with a bit of explanation. Still, a few may require a little more explanation, or they may apply to a limited number of diodes.

Apart from the specifications addressing the electrical performance, the physical packages are also necessary. Diodes and Transistors come in various packages, including wire ended packages and high power diodes and Transistors that bolt onto heatsinks. With the vast amount of highly automated manufacturing and PCB assembly, surface mounts technology components - SMD diodes are used in vast quantities.

The specifications for diodes and Transistors appear in data sheets and describe the performance of the diodes and Transistors. Therefore, inspecting the performance parameters will enable the diode and transistor to be assessed to provide the required performance for its intended function.

Different specification parameters are more applicable for diodes and transistors used in different applications, different electronic circuit designs, etc. For example, for power applications, aspects like the current capability, forward voltage drop, junction temperature and the like will be significant. For RF designs, the capacitance and turn-on voltage will often be of great interest.

The aspects below detail some of the more widely used parameters or specifications used in data sheets for most diode and transistors types.

Some of the critical parameters of diodes are as explained below:

Semiconductor material: The semiconductor material used in the PN junction diode is paramount because the material used affects many of the significant diode characteristics and properties. **Silicon and germanium are two widely used materials:**

- **Silicon:** Silicon is the most widely used material as it offers high levels of performance for most applications and offers low manufacturing costs. The technology for silicon is well established, and silicon diodes can be made cheaply. The forward turn-on voltage is around 0.6V, which is high for some applications, although for Schottky diodes, it is less.
- **Germanium:** Germanium is less widely used and offers a low turn-on voltage of around 0.2 to 0.3 V.

Other materials are generally reserved for more specialist diodes. For example, LEDs use compound materials to provide different colours.

- **Diode type:** Although most diodes have a PN junction as the basis of their construction, different types of diodes are formulated to provide different characteristics. Sometimes, they can operate in different ways. Therefore, selecting the correct type of diode for any given application is critical.
- Zener diodes are used for providing reference voltages, whilst varactor diodes are used to provide a variable level of capacitance in an RF design according to the reverse bias provided. Rectifier diodes may use a straightforward PN junction diode, or in some cases, they may use a Schottky diode for a lower forward voltage. Whatever the application is, it is necessary to use the correct type of diode to obtain the required functionality and performance.
- **Forward voltage drop, V_f :** Any electronics device passing current will develop a resulting voltage across it. This diode characteristic is essential, especially for power rectification, where power losses will be higher for a high forward voltage drop. Also, diodes for RF designs often need a small forward voltage drop as signals may be small but still need to overcome it.

The voltage across a PN junction diode arises for two reasons. The first is the nature of the semiconductor PN junction and results from the turn-on voltage mentioned above. This voltage enables the depletion layer to be overcome and for current to flow. The second arises from the normal resistive losses in the device. As a result, a figure for the forward voltage drop is a specified current level will be given. This figure is crucial for rectifier diodes where significant levels of current may be passed.

Particularly for power rectification diodes, a graph of the forward voltage drop for various current levels is typically provided within the data sheet. This will have a band of typical figures and using this, the range of voltage drop can be determined for the anticipated current levels to be carried. It is possible to determine then the power that will be dissipated into the junction area of the diode.

- **Peak Inverse Voltage, PIV:** This diode characteristic is the maximum voltage a diode can withstand in the reverse direction. This voltage must not be exceeded; otherwise, the device may fail.
- This voltage is not simply the RMS voltage of the incoming waveform. Each circuit needs to be considered on its own merits. Still, for a simple single diode half-wave rectifier with some form of smoothing capacitor afterwards, it should be remembered that the capacitor will hold a voltage equal to the peak of the incoming voltage waveform. The diode will then also see the peak of the incoming waveform in the reverse direction.
- Therefore under these circumstances, it will see a peak inverse voltage equal to the peak value of the waveform.
- **Reverse breakdown voltage, $V_{(BR)}$:** This is a little different to the peak inverse voltage in that this voltage is the point at which the diode will break down.

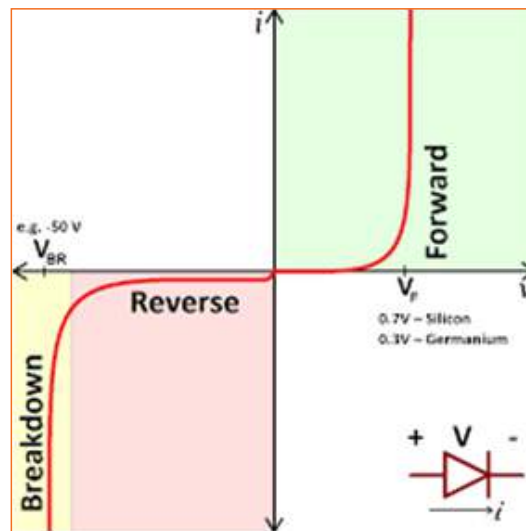


Fig. 3.2.19. PN diode IV characteristic showing the reverse breakdown
(Source -learn.sparkfun.com)

The diode can withstand a reverse voltage up to a certain point, and then it will breakdown. Some diodes and some circuits will cause irreparable damage, although, for Zener / voltage reference diodes, the reverse breakdown scenario is used for the voltage reference. Still, the circuit must be devised to limit the current flowing. Otherwise, the diode can be destroyed.

- **Maximum forward current:** For an electronic circuit design that passes any current levels, it is necessary to ensure that the maximum current levels for the diode are not exceeded. As the current levels rise, so additional heat is dissipated, and this needs to be removed.
- **Junction operating temperature:** Like all electronic components, diodes have a maximum operating temperature. In the data sheet, there will be a section outlining the maximum junction temperature. As the junction temperature rises, so the reliability will fall over the long term. If the maximum junction temperature is exceeded, the diode is likely to fail and even catch fire.

It should be remembered that the junction temperature relates to the diode junction itself inside the package and not the package temperature. A good margin should be allowed between the package temperature and the junction temperature. Often curves will be supplied in the data sheet to enable the junction temperature to be determined. It is also possible to calculate the junction temperature from a knowledge of the current, forward voltage drop and the thermal resistance: specifications mentioned in the data sheets and mentioned here. Because of the long term reliability aspects, it is always best to run the diode well within its ratings. This gives a good margin to ensure reliable long term operation and for the diode to accommodate any short term peaks. This is the same for any electronic component.

Junction to ambient thermal resistance, θ_{JA} : This diode data sheet specification parameter is measured in $^{\circ}\text{C}$ per watt. It means that there will be a given temperature rise above ambient for every watt dissipated in the junction. For example, this means that for a diode with a junction to the ambient thermal resistance of $50^{\circ}\text{C}/\text{W}$, the junction's temperature will rise by 50°C for every watt of power that is dissipated.

The junction to ambient thermal resistance is the sum of a series of individual areas of the diode: junction-to-case thermal resistance, case-to-surface thermal resistance, and surface-to-ambient thermal resistance, as shown by this formula: $\theta_{JA} = \theta_{JC} + \theta_{CS} + \theta_{SA}$.

This overall specification is key to determining the actual junction operating temperature - a key parameter to monitor when designing a circuit in which diodes carry appreciable current such that the current passed will give rise to power dissipation. The junction temperature can be calculated using the formula:

$$T_J = T_{AMB} + I \cdot V_F \cdot \theta_{JA} \quad T_J = T_{AMB} + I \cdot V_F \cdot \theta_{JA}$$

Where:

T_J = junction temperature

T_{AMB} = ambient temperature

θ_{JA} = junction to ambient thermal resistance.

- Leakage current:** If a perfect diode were available, no current would flow when reverse biased. It is found that for a real PN junction diode, a minimal amount of current flow in the reverse direction results from the minority carriers in the semiconductor. The level of leakage current is dependent upon three main factors. The reverse voltage is significant. It is also temperature-dependent, rising appreciably with temperature. It is also found that it depends on the type of semiconductor material used - silicon is very much better than germanium.

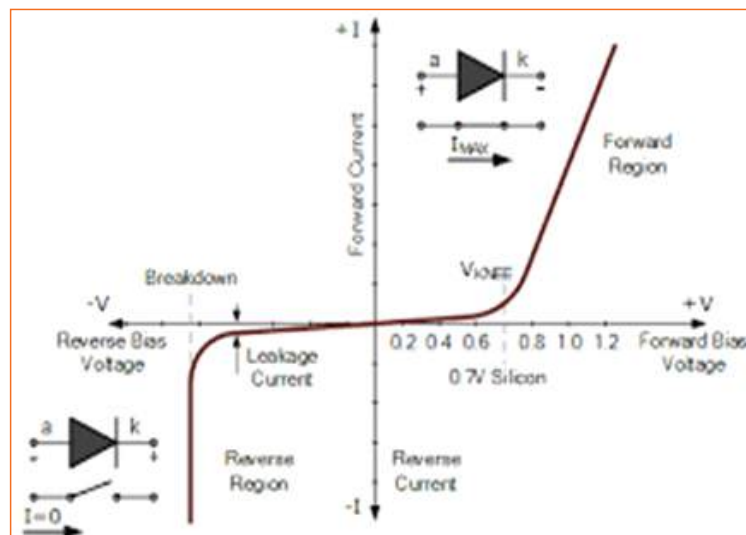


Fig. 3.2.20. PN diode IV characteristic showing the leakage current parameter
(Image Source-electronics-tutorials.ws)

The leakage current characteristic or specification for a PN junction diode is specified at a specific reverse voltage and particular temperature. The specification is typically defined in microamps, μA or picoamps, pA as the levels are usually very low before reverse breakdown occurs.

- **Junction capacitance:** All PN junction diodes exhibit a junction capacitance. The depletion region is the dielectric spacing between the two plates which are effectively formed at the edge of the depletion region and the area with majority carriers. The actual value of capacitance depends on the reverse voltage that causes the depletion region to change (increasing reverse voltage increases the size of the depletion region and hence decreases the capacitance).
- This fact is used in varactor or varicap diodes to good effect and is widely used in variable frequency oscillator and variable frequency filter RF designs. However, for many other applications, especially RF designs where stray capacitance across the diode could affect the performance, this needs to be minimised. As the capacitance is of importance, it is specified. The parameter is typically detailed as a given capacitance (commonly in pF as capacitance levels are relatively low) at a given voltage or voltages. Also, special low capacitance diodes are available for many RF applications.
- For many powers rectifier applications, the capacitance is sufficiently low not to be an issue. For example, the junction capacitance of 1N4001 and 1N4004 is only 15 pF for a reverse voltage of 4 volts and less as the voltage rises. Higher voltage diodes may be less - a 1N4007 has a junction capacitance of 8 pF for a reverse voltage of 4 volts. Accordingly, it is only as the frequencies rise that the effect of the capacitance is noticed. As the capacitance levels are low, frequencies up to around 100 kHz are often not affected by it, and in most cases, it can be ignored up to even higher frequencies.
- **Package type:** Diodes can be mounted in a variety of packages according to their applications, and in some circumstances, especially RF applications, the package is a critical element in defining the overall RF diode characteristics.

Also, for power applications where heat dissipation is necessary, the package can define many of the overall diode parameters. For example, high power diodes may require packages that can be bolted to heatsinks. In contrast, small signal diodes may be available in leaded formats or as surface mount devices. Also, high power diodes may be available as bridge rectifiers containing four diodes in a bridge suitable to full wave rectification applications.

Surface mount diodes, SMD diodes are used in vast quantities because most electronics manufacture and PCB assembly are undertaken using automated techniques and surface mount technology lends itself to this.

- **Bridge rectifier circuit and markings**

In addition to this, diodes are available in both led and those using surface mount technology packages are dependent upon the diode. Most RF and lower power diodes are available in surface mount technology packages making them more appropriate for large scale manufacturing.

- **Diode coding and markings schemes:** Most diodes used have part numbers that conform to the JEDEC or Pro-Electron schemes. Numbers like 1N4001, 1N916, BZY88 and many more are familiar to anyone involved in electronics design and manufacture.

However, when using automated PCB assembly techniques and surface mount technology, it is found that many devices are too small to carry the entire number that might be used in a datasheet. As a result, a somewhat arbitrary coding system has developed, whereby the device package carries a simple two or three-character identification code.

This can generally be accommodated on the small surface-mount diode packages. However, identifying the manufacturers' type number of an SMD diode from the package code may not be easy at first sight. There are some useful SMD codebooks available that provide the data for these devices. For example, the code "13s" indicates a BAS125 surface mount diode in a SOT23 or SOT323 package.

Example of typical diode specifications

Although there are many different diodes with many different specifications, it sometimes helps to see what the various specifications and parameters are and how they are expressed in a similar format to those seen in the data sheets.

TYPICAL 1N5711 CHARACTERISTICS / SPECIFICATIONS			
CHARACTERISTIC	TYPICAL VALUE	UNIT	DETAILS
Max DC Blocking Voltage, V_r	70	V	
Max forward continuous current, I_{fm}	15	mA	
Reverse breakdown voltage, $V(BR)R$	70	V	@ reverse current of $10\mu A$
Reverse leakage current, I_R	200	μA	At $V_R=50V$
Forward voltage drops, V_F	0.41 1.00	V	at $I_F = 1.0\text{ mA}$ $I_F=15\text{mA}$
Junction capacitance, C_j	2.0	pF	$V_R = 0V$, $f=1\text{MHz}$
Reverse recovery time, t_{rr}	1	nS	

Table 3.2.2. Diode specifications

The vast number of diodes have a vast number of different characteristics. Some diodes may be designed purely for rectification, whereas others may be designed to emit light, detect light, act as a voltage reference, provide variable capacitance and the like. Diodes also come in various packages, with the vast majority these days being sold as surface mount diodes for automated PCB assembly.

Whatever the type of diode, many of the basic specifications, parameters and ratings mentioned above will be necessary. Understanding the key parameters and ratings of these electronic components when looking at the specifications in the data sheets is key to selecting a suitable diode. Understanding the specifications enables wise decisions to be made during any project's electronic circuit design process using diodes.

Some of the critical parameters of transistors are as explained below: There are several standard parameters with abbreviations that are used to define the performance of a transistor. The definitions of these parameters are outlined as below:

- **Type number:** The type number of the device is a unique identifier given to each transistor type. This enables the complete data on its specifications to be checked on the manufacturer's transistor datasheet to investigate its performance.

Three international schemes are widely used: the European Pro-Electron scheme, US JEDEC (numbers start with 2N for transistors), and the Japanese system (numbers start with 2S). Apart from just giving a standardised type number to the transistors, these schemes can provide information about the transistor performance. The European Pro-Electron scheme is perfect for this as it distinguishes between different transistors; for example, a BC109 is a silicon audio frequency low power transistor, and a BFR90 is a low power RF transistor.

- **Polarity:** There are two types of transistors: NPN transistors and PNP transistors. It is essential to choose the correct type; otherwise, all the circuit polarities will be wrong. The NPN transistors are more widely used. Like they offer better performance than PNP transistors because electrons are the majority carriers and their mobility is higher than that of holes that are the majority carriers in PNP transistors. The basic circuits for NPN transistors also fit well with the negative earth typically used in DC systems.
- **Material:** One key transistor specification which will be given for any transistor is the material from which it is manufactured. The primary type of material used for semiconductor devices is silicon.

Although other materials like germanium and gallium arsenide are available, silicon is the most popular because it is cheaper to process. In addition to this, the processes are more advanced than for other materials. As it is used for many other semiconductor devices, there are many benefits of scale and technology available.

Silicon offers good overall performance with a base-emitter junction turn-on voltage of around 0.6 volts - it is 0.2 to 0.3 volts for germanium.

- **V_{CBO} :** This parameter is the collector to the base breakdown voltage of a bipolar transistor. It is the maximum collector-base voltage - again, it is generally measured with the emitter left open circuit. This value should not be exceeded in the operation of the circuit.

This parameter is important because some leakage current will flow between collector and base, causing the part to heat up. Alternatively, excessive voltage can damage the collector-base junction. As terminal damage can occur to the bipolar transistor, this rating should not be exceeded, and ideally, the transistor should be run with a good margin in hand.

The collector-base junction is reverse biased in operation, and a slight reverse current will flow (I_{CBO}). As the reverse voltage increases, the electric field in the depletion region of the collector base junction increases, and the reverse current starts to rise as minority carriers gain sufficient energy to generate hole electron pairs, increasing the reverse current. Eventually, avalanche breakdown occurs. This limits the maximum voltage that can be applied to the transistor.

- V_{CBO} is typically higher than V_{CEO} because, with the base terminal of the BJT open, any leakage current will also be the same as externally applied base current. The transistor amplifies this. This will cause even more current to flow through the device, heating it, and for this reason, V_{CEO} is often lower than V_{CBO} .
- **V_{CEO} : Collector to Emitter breakdown voltage.** This transistor specification is the maximum voltage that can be placed from the collector to the emitter. It is typically measured with the base open circuit - hence the letter "O" in the abbreviation. During the electronics circuit design stage, it is essential to ensure that this value is not be exceeded in operation. Otherwise, damage may occur. Ideally, the transistor should be operated with a good margin in hand.
- Often the maximum voltage should only be allowed to rise to 50 or 60% of the maximum value for reliable operation. Note that the collector voltage may rise to twice the rail voltage for circuits using inductors in the collector circuit.
- If the voltage applied between the collector and emitter terminals is high, an increased number of carriers start to diffuse into the collector region from the base. This causes the base-emitter diode in the bipolar transistor to start to become forward biased. This causes current flow between the collector and emitter, even though no external base current has been applied. When a specific voltage, V_{CEO} , is reached, the transistor can entirely turn on, and in some cases, this can result in terminal damage to the device.
- **I_C :** The current collector specification of the transistor is generally defined in milliamps, but high-power transistors may be quoted in amps. The critical parameter is the maximum level of collector current. This figure should not be exceeded; otherwise, the transistor may be subject to damage.
- **V_{CEsat} : The collector-emitter saturation voltage,** i.e. the voltage across the transistor (collector to emitter) when the transistor is turned hard on. It is typically quoted for a particular base and collector current values.
- Under these circumstances, the voltage between the collector and emitter is smaller than that across the base-emitter junction - often, it is around 0.2 volts.
- **h_{FE} & h_{fe} :** This is the current gain for a transistor expressed as an h parameter or hybrid parameter. The letter "f" indicates a forward transfer characteristic, and the letter "e" indicates it is for a standard emitter configuration. Thus, the value for h_{fe} is approximately the same as β .
- Two versions of this parameter are seen: h_{FE} refers to the parameter measured under DC conditions, whereas h_{fe} refers to AC signals.
- **FT:** Frequency Transition - this transistor specification details the frequency where current gain falls to unity. The transistor should usually be operated well below this frequency.
- **P_{tot} : Total power dissipation for the device.** It is generally quoted for an external ambient temperature of 25°C unless otherwise stated. The actual dissipation across the device is the current flowing through the collector multiplied by the voltage across the device itself

- **Package type:** Transistors can be mounted in a variety of packages according to their applications. There are the standard leaded devices that appear in a variety of packages - these packages typically conform to JEDEC standards and start with the letters TO, standing for transistor outline. This is followed by a hyphen and a numeral which is typically up to three digits.

Popular leaded component sizes include TO5 (metal case, cap diameter of 8.1 mm), TO18 (metal case with a cap diameter of the cap is 4.5-4.95mm) and TO92 (also known as SOT54, plastic case off varying sizes but the straight-line lead spacing of 1.27mm).

Surface mount transistors, SMD transistors are used in vast quantities because most electronics manufacture and PCB assembly are undertaken using automated techniques and surface mount technology lends itself to this. Popular sizes include the SOT-23 and SOT-223 outlines.

- **Transistor coding and markings schemes:** Most transistors used have part numbers that conform to the JEDEC or Pro-Electron schemes. Numbers like BC107, BC109, 2N2222A and many more are very familiar to electronics design and manufacture.

However, when using automated PCB assembly techniques and surface mount devices, it is found that many transistors are too small to carry the entire number that might be used in a data sheet. As a result, a somewhat arbitrary coding system has developed, whereby the device package carries a simple two or three-character identification code.

This can typically be accommodated on the small surface-mount diode packages. However, identifying the manufacturers' type number of an SMD diode from the package code may not be easy at first sight. There are some useful SMD codebooks available that provide the data for these devices.

There are many different elements to transistor specifications, both leaded and surface mount transistors. Therefore, to meet the demand for electronics, the manufacture has a considerable variety of transistors from which to choose. However, it is still relatively easy to choose a transistor when using a basic knowledge of the different transistor specifications and parameters.

For general purpose applications, many transistors will suffice, but it is essential to select the correct type of transistor for more specialised applications.

Tips



1. An electromagnetic spectrum is the entire distribution of electromagnetic radiation according to frequency or wavelength.
2. Magnetic resonance imaging MRI- is a medical imaging technique used in radiology to visualise internal structures.
3. Printed Circuit Boards (PCBs) form the backbone of all major electronics.

Practical



1. Perform the following PCB fabrication task
 - Design and Output

Role Play



1. Demonstrate the drilling of the holes in PCB?

UNIT 3.3 Biomedical instrumentation and measurement

Unit Objectives

After having studied this module, the learner will be able to:

1. Do the identification and soldering of surface mounted devices
2. Identify the different tools required to solder and desolder the SMD
3. Identify the typical case sizes
4. Identify the shape and markings of some common SMDs
5. Understand the resistor markings and typical values

3.3.1 Identification and Soldering of Surface Mounted Devices

1. Introduction to surface mount devices

SMD or Surface Mount Devices are ubiquitous these days as the components are miniaturized and occupy less space



Figure 3.3.1. Showing the small size of SMD Devices-From left to right: SOT-23 bipolar transistor, 2.2 mfd tantalum capacitor, ceramic capacitor, and 82-Ohm resistor. Compare the size concerning a Coin.

However, they require special techniques to work on the SMD Devices, and we will learn the same in the following paras.

2. What are the benefits of using SMD?

- The SMD are very small, and they occupy less space and make the devices smaller.
- The SMD can be soldered on the same side of the PCB. It is cumbersome to put the component on one side and solder from the other side of the PCB. Similarly, it helps to desolder the SMD from the main PCB as we don't need to desolder from the other side.
- Its use reduces the number of holes in a PCB, makes the PCB smaller in size, and reduces the PCB layers.

3. Unique safety and precautions requirement for SMD:

- The SMD are very small, and since it is soldered from the same side, it is crucial not to work with SMD with food items in your hand.
- Use of great light and a magnifying glass is also recommended.
- Keep the floors clean so that it is easy to find the small SMD.
- Wear safety goggles while soldering the SMD.
- Work should be away from the edges of the work table to minimize the fall of the SMD.

4. Design a worktable with bright lights:

Because SMDs are very small, it is essential to make them "look" bigger. This can be accomplished by illuminating the work surface with a very bright light. To illustrate this effect, take some difficult-to-read fine print (like on the back of a credit card application) and try reading it in a dimly lit room, then try reading it a few inches from a bright desk lamp. The difference is dramatic.

A swing-arm desk lamp with a 100-watt frosted bulb positioned close to the work surface works very well. The lamp should be adjustable from 6 to 24 inches above the desktop. Regular room lighting or shop lights just are not bright enough. It is also helpful to set up the lamp to be swung over the edge of the desk and illuminate the floor. This helps with finding dropped components.

The second trick is to work on a clean, bright white surface. The SMD work tray shown in Figure 2 works very well. The white paper contrasts the components, and the small sides help prevent the SMDs from getting lost.

Start by removing the cardboard back from a 8 ½" x 11" writing tablet to build the SMD work tray. On one side, glue two sheets of bright white copy paper using rubber cement. Two sheets are necessary because the paper is not entirely opaque. When the glue has dried, flip it over and draw a box ½ inches from all four sides. Bend the cardboard at the lines, forming a 7 ½" x 10" tray. Fold up each corner. Glue the corners together using white glue. Clamp each corner using a clothespin until the glue dries.

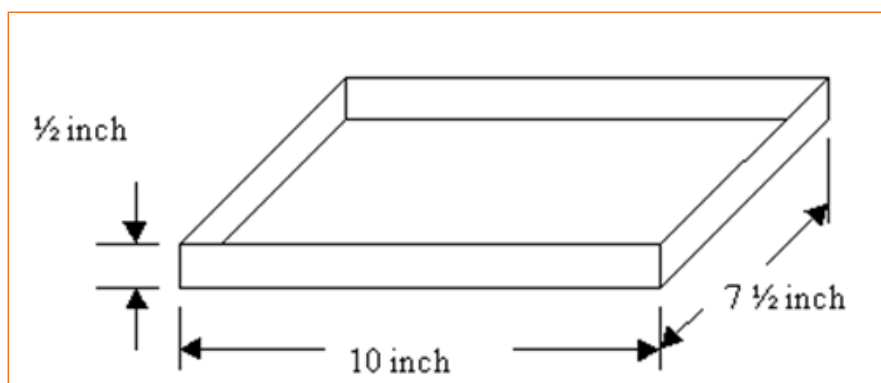


Fig. 3.3.2. A work tray for SMD (Image <http://poeth.com/smtmfq.htm>)

Tools required to solder and desolder the SMD: The following tools will be required to solder SMD

Components:

- Safety Goggles
- Soldering Iron
- Self-locked Tweezers
- Soldering wires
- Desoldering Pump
- Desoldering Wicks.
- A small fan to blow away the fumes from the face.
- Magnet
- Flexible Bright Light
- A magnifying glass with a holder.

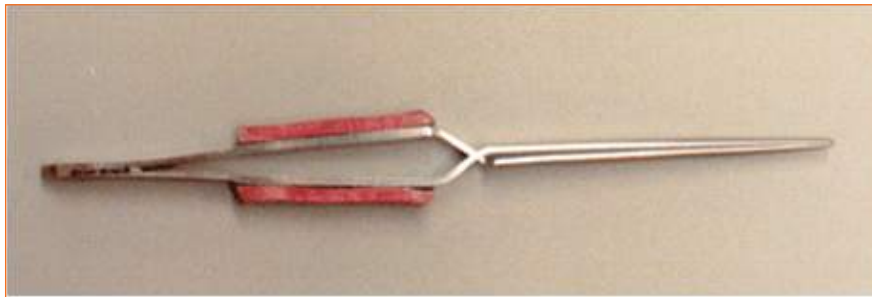


Fig. 3.3.3 - Self-locking tweezer (Image source <http://poeth.com/smtmfg.htm>)

5. Identifying SMDs

The general shape of some common SMDs is shown in Table 1. Note that many components (like chip capacitors) are not routinely labelled. This is why the SMD test tweezers (<http://poeth.com/SMD.htm>) are so helpful. Typical case sizes for chip resistors and capacitors are listed in Table 2. To find the approximate size, multiply the first two digits by 10 to get the length in mils, and multiply the last two digits by 10 to get the width in mils. The most common size for chip resistors and chip capacitors is 1206.

Resistors are frequently marked with a three-digit number, and some typical values are shown in Table 3. The first two numbers are the significant digits of the value, and the last digit is the multiplier (the number of zeros to add to the first two digits). For example, a chip resistor labelled 102 has 1000 Ohms or 1K Ohms.

Case Size	Component Length	Component Width
0603	0.063	0.030
0805	0.080	0.050
1206*	0.126	0.063
2010	0.200	0.100
2512	0.250	0.125

Table-3.3.1. Typical Case Sizes

Resistor Marking	Resistor Value (Ohms)
105	1 meg
820	82
272	2.7K
104	100K

Table-3.3.2. Shape and markings of some common SMDs.





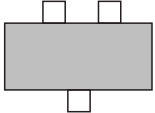

Component	Shape	Markings
Chip resistor		Labeled with value
Chip capacitor		Not marked
Polarized capacitor		Plus end marked with band, Value marked
Diode		Cathode end marked with notch or band
SOT (Small Outline Transistor)		May be marked, un marked, or house numbered
SOIC (Small Outline Integrated Circuit)		May be marked, un marked, or house numbered. Pin one marked with marked with beveled side, dot, band , or notch

Table-3.3.3. Resistor markings and typical values

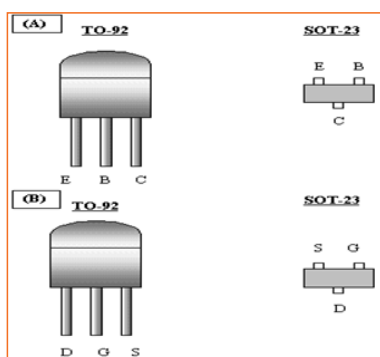


Fig. 3.3.4. (A) Comparison between a TO-92 bipolar transistor and its surface mount counterpart.

(B) Comparison between a TO-92 field-effect transistor and its surface mount counterpart.

SMD transistors are shown in Figure 3.3.1.4 - (A) and 4 (B) compared to the standard TO-92 transistor case style. Notice that the leads for the SOT-23 are different than for the TO-92.

6. Removing individual SMDs

SMDs can be removed using unique soldering stations employing custom desoldering tips or hot air jets. If these are not available, you can (with a bit of practice) remove components using desoldering braid and flux.

To remove an SMD that is already mounted to a circuit board, you will need a roll of fresh desoldering braid and RMA (rosin, mildly activated) flux (liquid or paste). Desoldering braid oxidizes over time, so if it looks dull, replace it.

Infiltrate about one inch of the desoldering braid with flux (if it didn't come that way). Lay the braid over the solder joint and gently press down with the tip of a soldering pencil. The solder will wick into the braid. Each area of braid can only be used once, so trim it after each try. Repeat several times for each solder joint until all solder (except a fragile film) has been removed. Grip the component with tweezers and gently twist to release the component (don't pull, or you may lift the pads). If the component does not release from the pads, go back and try to remove more solder.

This technique takes practice, so try removing several components from a surplus board before attempting it on a substantial project.

7. Soldering SMDs

There are several ways to solder SMD components to a circuit board successfully. Some are easier to learn than others, and some require the use of unique materials (like solder paste, which is a mixture of powdered solder and flux) or special equipment (like SMD solder stations). One of the simplest ways to solder SMDs is to glue the components in position on a PC board and then solder the connections. The procedure is:

- Clean the copper side of the board with a nonconductive abrasive pad until it is shiny.
- Wipe off any residue with a tissue and denatured alcohol.
- Glue the components into position using Duco cement. Apply the cement to the end of a toothpick, then use the toothpick to apply a drop of cement to the circuit board. Do not get any glue on the pads or any place where you want the solder to flow.
- Using self-locking tweezers, position the components on the board. Let the adhesive dry.
- Gently nudge the components sideways with a toothpick. If the component moves, try glueing it again.
- Apply RMA type paste flux to the component terminals and pads using a toothpick. Then, apply the flux where you want to solder to flow. The flux function is to conduct heat from the soldering tip uniformly to the pad and component. The flux also removes surface oxides, which can prevent solder wetting.
- Touch the soldering tip (set to about 600 °F) TO THE PAD. Never apply heat directly to the component (it may crack).
- Apply small diameter 63/37 solder (0.020" works well) to the pad adjacent to the component terminal. The solder will flow to the component and will form a fillet between the component and pad.
- Let the solder cool and remove the flux with denatured alcohol. Inspect with a 4x watchmakers loupe or magnifying glass. The solder joint should be a concave fillet, bright and mirror-smooth with no pits, as shown in Figure 5.

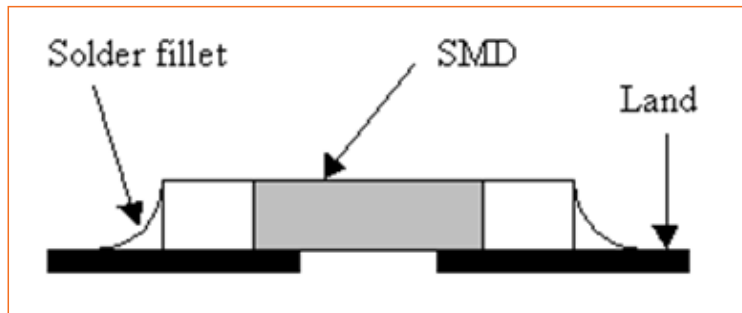


Fig. 3.3.5. A good solder joint will have smooth, concave fillets, as shown in this side view.

How to Solder SMD Parts - Steps



Step 1: Watch the video! - https://www.youtube.com/watch?v=ak1uv_6JEvs

Step 2: Collect the supplies to do SMD soldering:

1. Solder wire (leaded)
2. Solder paste (leaded)
3. Flux pen
4. T12 Soldering Station
5. Reflow Oven
6. IPA (isopropyl alcohol) is suitable for cleaning (get this one locally).

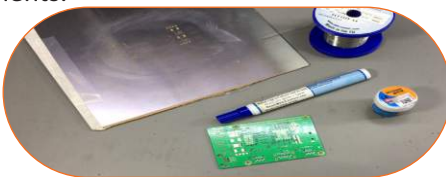
Step 3: Method #1: Soldering directly to the PCB with a soldering iron. This method is used when we assemble one or two pieces.

Step 4 Method #2: using a stencil to apply solder paste and heating with hot air. This method will require ordering a stencil together with the PCBs.

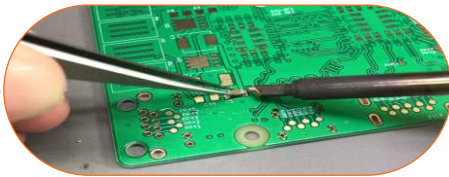
Step 5: Method #3: Using a stencil to apply solder and reflowing with an oven. This method requires a stencil for dispensing the paste on to the PCB and to heating of the PCB board a reflow oven is needed as it renders an enclosed space where temperature can be controlled precisely.

Step 6: Conclusion - There we go, these 3 methods are generally used to assemble SMD components.

Step -2



Step -3



Step -4



Step -4



Step -5



Step -6



Tips

1. The diagnostics industry in India is currently valued at \$4 bn. The share of the organized sector is almost 25% in this segment (15% in labs and 10% in radiology).
2. Life expectancy is going to exceed 70 years by 2022; hence more healthcare services required

Exercise

1. Explain the types of electromagnetic radiation
2. List the areas where microwave technology is used.
3. Identify the different resistor markings and their typical values
4. What is the radiofrequency range _____ to heat and destroy cancer tissue?
 - (a) 400 – 600 kHz
 - (b) 450 – 500 kHz
 - (c) 475 – 550 kHz
 - (d) 500 – 700 kHz
5. List the two frequencies designated for microwave diathermy
 - Explain the following:
 - Diode
 - Zener diodes
 - Forward voltage drop
 - Peak Inverse Voltage
 - Reverse breakdown voltage

Practical

1. Identify various electronic components used in ICU
2. Identify different types of PCBs
3. Identify various types of cables and connectors

Role Play

1. Demonstrate the fabrication of PCB.

Notes



Lined area for taking notes, consisting of 25 horizontal lines.

Summary

An electronic circuit is a structure that directs and controls electric current to perform various functions including signal amplification, computation, and data transfer. It comprises several different components such as resistors, transistors, capacitors, inductors, and diodes. The components must form a complete path to be considered a circuit.

A short circuit refers to a situation when a circuit does not have a load. A simple electrical circuit contains a resistor, capacitors, inductors, transistors, diodes and integrated circuits. A circuit diagram is a graphical representation of the interconnections of various components constituting the equipment. It is the most crucial document for the maintenance technician.

An electromagnetic spectrum is the entire distribution of electromagnetic radiation according to frequency or wavelength. Although all electromagnetic waves travel at the speed of light in a vacuum, they do so at a wide range of frequencies, wavelengths, and photon energies. SMD or Surface Mount Devices are ubiquitous these days as the components are miniaturized and occupy less space.

Because SMDs are very small, it is essential to make them "look" bigger. This can be accomplished by illuminating the work surface with a very bright light. SMDs can be removed using unique soldering stations employing custom desoldering tips or hot air jets.

One of the simplest ways to solder SMDs is to glue the components in position on a PC board and then solder the connections.

References

<https://www.lemo.com/en/products/low-voltage-connector/b-connector>
<https://www.lemo.com/en/products/low-voltage-connector/e-connector>
<https://www.lemo.com/en/products/low-voltage-connector/k-connector>
<https://www.lemo.com/en/products/low-voltage-connector/s-connector>
<https://www.lemo.com/en/products/low-voltage-connector/t-connector>
<https://www.lemo.com/en/products/plastic-connector/r-connector>
<https://www.lemo.com/en/products/plastic-connector/redel-p>
<https://www.lemo.com/en/products/plastic-connector/redel-sp>
<https://www.lemo.com/en/products/low-voltage-connector/e-connector>
<https://www.youtube.com/watch?v=kWzazxZFx8c&t=124s>
<https://www.youtube.com/watch?v=iY1TevSsKAc>
<https://www.youtube.com/watch?v=rAs3Nd37PMU>
<https://www.youtube.com/watch?v=BT-BsgcS6js&list=PLyTH9yU1u8LaxcaCxgo6fTJ32Uz2pUvDO>
<https://www.youtube.com/watch?v=YOQg-O1ti4k&list=PLyTH9yU1u8LaxcaCxgo6fTJ32Uz2pUvDO&index=2>
<https://www.youtube.com/watch?v=2uBetGHWHTw&list=PLyTH9yU1u8LaxcaCxgo6fTJ32Uz2pUvDO&index=3>
<https://www.youtube.com/watch?v=vZ22u0LKFDI&list=PLyTH9yU1u8LaxcaCxgo6fTJ32Uz2pUvDO&index=4>
<https://www.youtube.com/watch?v=KKDhGd8RdyM&list=PLyTH9yU1u8LaxcaCxgo6fTJ32Uz2pUvDO&index=5>





4. Calibration And Maintenance of Basic Equipment

- UNIT 4.1-Identification of basic equipment
- UNIT 4.2-Safety procedural guidelines
- UNIT 4.3-Installation, maintenance and servicing of medical equipment



Key Learning Outcomes



After completion of this module, the participants will be able to:

1. Carryout the identification of essential equipment
2. Follow the procedural safety guidelines
3. Carryout the installation, maintenance and servicing of medical equipment
4. Discuss fundamentals of delivery, installation and setting up of essential medical equipment
5. Carryout the fundamental periodic preventive maintenance of basic medical equipment
6. Carryout the function and operation of all possible essential clinical equipment

UNIT 4.1 Identification of essential equipment

Unit Objectives

After completion of this unit , the participants will be able to :

1. Take the measures in physical quantities
2. Identify the different tools required to solder and desolder the SMD
3. Identify the typical case sizes
4. Identify the shape and markings of some common SMDs
5. Understand the various electrical standards
6. Understand the various temperature standards
7. Understand the various pressure standards

4.1.1 Measuring Physical Quantities

1. What is a physical quantity?

anything that can be measured is a physical quantity. the physical quantity is measured and written as magnitude and the SI unit. SI units are international units of measurements- we have base quantities and derived quantities.

The base quantities are independent physical quantities- These are

1. Mass is measured in Kg(kilogram)-for example weight of the sugar is 1kg.
2. Length is measured in meters-(m)- for example, we say the length of this rope is 1 m.
3. Time is measured in seconds (sec)- for example, there are 60 seconds in one minute.
4. Electric current is measured in amperes(A)- for example, we say the current flowing through the lamp is 1 A.
5. Absolute Temperature is measured in Kelvin(K)- For example, we say the Temperature of this room is 303 deg K. Temperature is also measured in deg F(Fahrenheit) and deg (Centigrade), but the SI unit is Kelvin.
6. The intensity of light is measured in Candella (CD)
7. The amount of substance is measured in Mole

Derived quantities are, as the name implies, derived from the combination of base quantities. For example, speed = distance/time. Here speed is derived quantity and is derived from distance divided by time. The si unit of speed will be thus meter per second or m/s

Calibration refers to checking and adjusting an instrument so that its output faithfully corresponds to its input throughout a specified range. To calibrate an instrument, we must have some means of knowing the input and/or output quantities associated with the instrument under test. A substance or device used as a reference to compare against an instrument's response is called a *calibration standard*. Simply put, a calibration standard is something we may *compare* the calibrated instrument to. Thus, any calibration can only be as good as the standard used.

Calibration standards fall into two broad categories: standards used to produce precise physical quantities (e.g., pressure, temperature, voltage, current, etc.) and standards used to measure physical quantities to a high degree of accuracy. An example of the former would be the use of

boiling water (at sea level) to *produce* a temperature of 100 degrees Celsius (212 degrees Fahrenheit) to calibrate a temperature gauge, whereas an example of the latter would be the use of a laboratory-quality precision thermometer to measure some arbitrary source of temperature in comparison to the temperature gauge being calibrated.

In metrology labs, the ultimate standards are based on fundamental constants of nature and are called *intrinsic standards*. A modern example of an intrinsic standard for time is the so-called *atomic clock*, using isolated Caesium atoms to produce frequencies that are inherently fixed and reproduceable worldwide.

Unfortunately, instrument shops located in industrial facilities cannot afford the capital and consumable costs associated with intrinsic standards and rely on other devices for their calibration purposes. Ideally, there should be a “chain” of calibration from any device used as a shop standard traceable back to some intrinsic standard in a national-level or primary metrology lab.

Calibration standards used in instrument shops for industrial calibration work should therefore be periodically sent to a local metrology lab for re-standardization. Their accuracy may be checked against other (higher-level) standards that are checked against even higher-level calibration standards, ultimately traceable to intrinsic standards.

In each step of the calibration “chain,” there is an advanced degree of measurement uncertainty. Intrinsic standards possess the least amount of uncertainty, while field instruments (e.g., pressure transmitters, temperature gauges, etc.) exhibit tremendous uncertainties.

The degree of uncertainty in the accuracy of a test instrument must be *significantly less* than the degree of uncertainty we hope to achieve in the instruments we calibrate. Otherwise, calibration becomes a pointless exercise. This ratio of uncertainties is called the *Test Uncertainty Ratio*, or *TUR*. A good rule-of-thumb is to maintain a TUR of at least 4:1 (ideally 10:1 or better); the test equipment is many times more accurate (less uncertain) than the field instruments we calibrate with them.

No calibration standard is perfect, but perfection is not what we need. Our goal is to be *accurate enough* that the final calibration will be reliable within specified boundaries.

The following few subsections describe various standards used in instrument shops to calibrate medical instruments.

2. Electrical standards

Electrical calibration equipment – used to calibrate instruments measuring voltage, current, and resistance – must be periodically calibrated against higher-tier standards maintained by outside laboratories. In years past, instrument shops would often maintain *standard cell* batteries (often called *Weston* cells) as a primary voltage reference. These special-purpose batteries produced 1.0183 volts DC at room temperature with low uncertainty and drift but were sensitive to vibration and non-trivial to use. Electronic voltage references have all but displaced normal cells in calibration shops and laboratories, but these references must be checked and adjusted for drift to maintain their NIST traceability.

One enormous benefit of electronic calibration references is that they can generate accurate currents and resistances in addition to voltage (and not just voltage at one fixed value, either!). In addition, modern electronic references are digitally-controlled as well, which lends themselves well to automated testing in assembly-line environments, and/or programmed multi-point calibrations with automatic documentation of as-found and as-left calibration data.

Suppose a hospital cannot afford one of these versatile references for benchtop calibration use. In that case, an acceptable alternative in some cases is to purchase a high-accuracy multimeter and equip the calibration bench with adjustable voltage, current, and resistance sources. These sources will be simultaneously connected to the high-accuracy multimeter and the instrument under test and adjusted until the high-accuracy meter registers the desired value. The measurement shown by the instrument under test is then compared against the reference meter and adjusted until matching (to within the required tolerance).

The following illustration shows how a high-accuracy voltmeter could be used to calibrate a handheld voltmeter in this fashion:

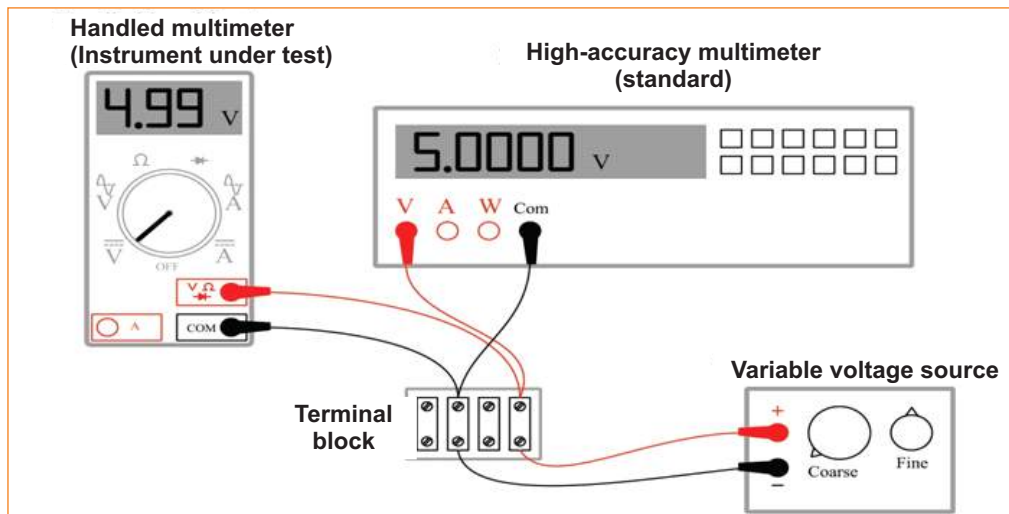


Figure 4.1.1. High-accuracy voltmeter

It should be noted that the variable voltage source shown in this test arrangement need not be sophisticated. It simply needs to be *variable* (to allow precise adjustment until the high-accuracy voltmeter registers the desired voltage value) and *stable* (so the adjustment will not drift appreciably over time). The accuracy of your calibration in the previous circuit originates not from the variable voltage source but rather from the high-accuracy multimeter used as the calibration standard. The high-accuracy multimeter serves as the calibration reference here, not the voltage source – it is the high-accuracy multimeter that functions as the *standard*.

3. Temperature standards

The most common technologies for industrial temperature measurement are electrical: RTDs and thermocouples. The standards used to calibrate such devices are the same standards used to calibrate electrical instruments such as digital multimeters (DMMs). This means a precision resistance standard such as a decade box used to precisely set known quantities of electrical resistance for RTDs. Likewise, this means a precision potentiometer used to generate precise quantities of low DC voltage (in the millivolt range, with microvolt resolution) for thermocouples.

Modern electronic calibrators are also available now for RTD and thermocouple instrument calibration, capable of accurate sourcing quantities of electrical resistance and DC millivolts to simulate RTD and thermocouple elements.

Given an accurate enough voltmeter, it is possible to construct your calibration potentiometer for simulating the millivoltage output of a thermocouple. A simple voltage divider set up to reduce the DC voltage of an ordinary variable-voltage power supply will suffice, so long as it provides fine enough adjustment:

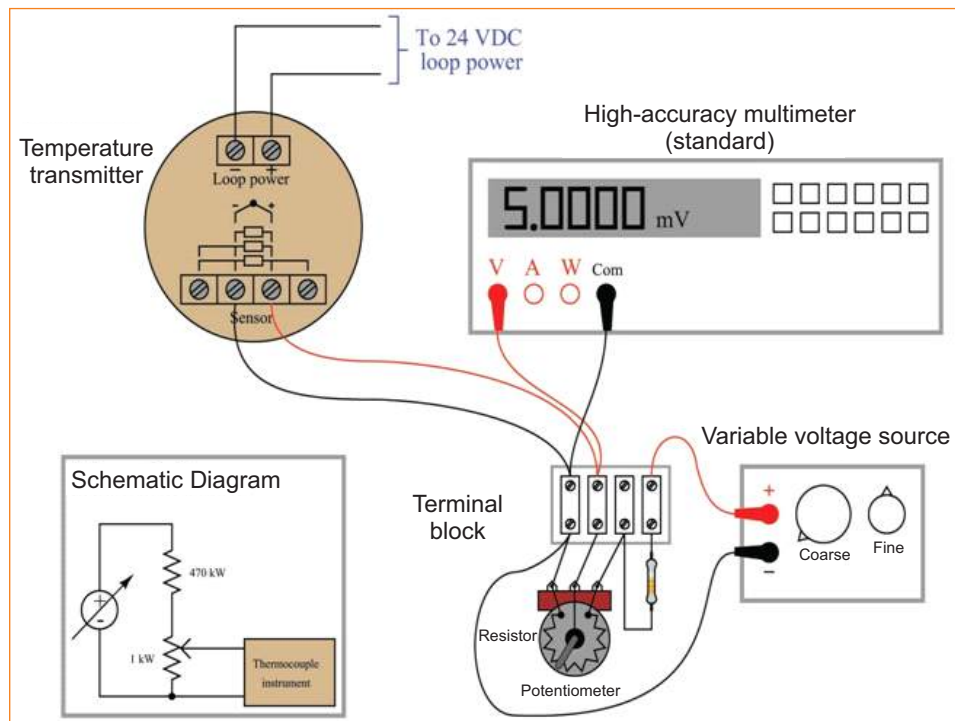


Figure 4.1.2. voltmeter

Unlike the potentiometers of old, providing direct read-out of millivoltage at the potentiometer dial(s), we rely here on the accuracy of the precision multimeter to tell us when we have reached the required millivoltage with our power supply and voltage divider circuit. This means the high-accuracy multimeter functions as the calibration *standard* in this set-up, permitting the use of non-precision components in the rest of the circuit. Since the multimeter's indication is the only variable being trusted as accurate when calibrating the thermocouple-input temperature transmitter, the multimeter is the only component in the circuit affecting the uncertainty of our calibration.

Electrically simulating the output of a thermocouple or RTD may suffice when the instrument we wish to calibrate uses a thermocouple or an RTD as its sensing element. However, some temperature-measuring instruments are not electrical: this category includes bimetallic thermometers, filled-bulb temperature systems, and optical pyrometers. To calibrate these types of instruments, we must accurately create the calibration temperatures in the instrument shop. In other words, the instrument to be calibrated must be subjected to an actual temperature of accurately known value.

Even with RTDs and thermocouples – where the sensor signal may be easily simulated using electronic test equipment – there is merit in using an actual source of precise temperature to calibrate the temperature instrument. Simulating the voltage produced by a thermocouple at a precise temperature, for example, is fine for calibrating the instrument typically receiving the millivoltage signal from the thermocouple. Still, this calibration test does nothing to validate the accuracy of the thermocouple element itself! The *best* type of calibration for any temperature-measuring instrument is to subject the sensing element to a precisely known temperature from the perspective of overall integrity. For this, we need special calibration equipment designed to produce accurate temperature samples on demand.

A time-honoured standard for low-temperature industrial calibrations is pure water, specifically the freezing and boiling points of water. For example, pure water at sea level (full atmospheric pressure) freezes at 32 degrees Fahrenheit (0 degrees Celsius) and boils at 212 degrees Fahrenheit (100 degrees Celsius). Thus, these two points of phase change for water at sea level are defined by the Celsius temperature scale.

To use water as a temperature calibration standard, simply prepare a vessel for one of two conditions: thermal equilibrium at freezing or thermal equilibrium at boiling. “Thermal equilibrium” in this context simply means equal temperature throughout the mixed-phase sample. In the case of freezing, this means a well-mixed sample of solid ice and liquid water. In boiling, this means a pot of water at a steady boil (vaporous steam and liquid water in direct contact). You try to achieve ample contact between the two phases (either solid and liquid; or liquid and vapour) to eliminate hot or cold spots. When the entire water sample is homogeneous in temperature and heterogeneous in phase (i.e., a mix of different phases), the sample will have only one degree of thermodynamic freedom: its temperature is an exclusive function of atmospheric pressure. Since atmospheric pressure is relatively stable and well-known, this fixes the temperature at a constant value. For ultra-precise temperature calibrations in laboratories, the *triple point* of water is used as the reference. When water is brought to its triple point (i.e., all three phases of solid, liquid, and gas co-existing in direct contact with each other), the sample will have *zero degrees* of thermodynamic freedom, which means both its temperature and its pressure will become locked at stable values: pressure at 0.006 atmospheres, and temperature at 0.01 degrees Celsius.

The major limitation of water as a temperature calibration standard is it only provides two points of calibration: 0 C and 100 C, with the latter being strongly pressure-dependent. Therefore, if other reference temperatures are required for calibration, some substance other than water must be used.

4. Pressure standards

To accurately calibrate a pressure instrument in a shop environment, we must create fluid pressures of known magnitude against which we compare the calibrated instrument. Thus, as with other types of physical calibrations, our choice of standards falls into two broad categories: devices that inherently *produce* known pressures versus devices that accurately *measure* pressures created by some (other) adjustable source.

A *deadweight tester* (sometimes referred to as a *dead-test* calibrator) is an example in the former category. These devices *create* accurately known pressures using precise masses and pistons of precise area:

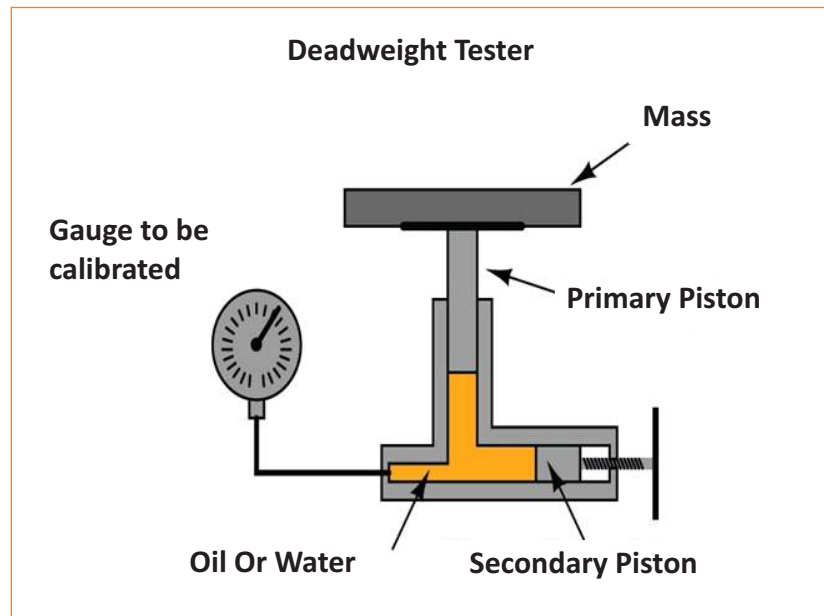


Figure 4.1.3. Pressure Measurement.

5. Simulators

Since medical equipment requires multiple physical quantities to be measured and calibrated, we use medical device simulators for measuring and calibrating the various parameters in medical equipment. Two simulators are very commonly used as below:

- A. Vital Signs Simulator** - once these devices are calibrated from the factory, these provide calibrated outputs which are then provided to the device under test to ascertain the measured data from the vital sign monitors. Riegel Pro Sim 8 is used to ascertain the accuracy of measurements for the following parameters:
 - i. Heart Rate.
 - ii. Blood Pressure.
 - iii. Amplitude
 - iv. Oxygen Level
 - v. ECG
- B. CITREX H5** is intended for testing and calibration purposes on medical devices or systems that generate gas flows or gas pressures. That includes ventilators and anaesthetic equipment with CITREX H5, you have the solution for measurements in the following areas:
Operating manual at <https://www.riegelmedical.com/gb/support/download/115>

Parameters	Measuring	Range Accuracy
1. Flow	± 300 sL/min	$\pm 1.9\%$ of reading or ± 0.1 sL/min
2. Volume	± 10 L	$\pm 2\%$ or ± 0.20 mL (>6 sL/min)
3. Temperature	$0-50^{\circ}\text{C}$	$\pm 1.75\%$ of reading or 0.5°C
4. Oxygen	$0-100\%$	$\pm 1\%$ O ₂
5. Pressure in the flow channel	$-50-150$ mbar	$\pm 0.75\%$ of reading or ± 0.1 mbar

Table 4.1.1. CITREX H5 Measurements

In addition, various ventilation parameters can be measured:

- Ventilation rate
- Time
- Ratio
- Tidal volume and Minute volume
- Peak flow
- Pressure
- Compliance
- Trigger

Thus, we have various ways of measuring physical quantities and simulators aids in measuring and calibration and performance checks.

4.1.2 Reading the Data from Graphs/ Waveforms and Interpreting the Results

1. What is a waveform/graph?

A waveform or a graph represents an electrical signal represented on X and Y-Axis. For example, Voltage Vs Time.

2. How do we read data from graphs/ waveform?

We read data from a waveform with the help of an Oscilloscope. The oscilloscope is an invaluable diagnostic instrument that can be used to read the data from the waveform and use it to calibrate, troubleshoot problem circuits, verify product design before delivery to consumers, and reverse-engineer products for "hacks".

3. Oscilloscope displays

Oscilloscopes allow us to determine relationships between particular variables in electrical circuits. Early oscilloscopes were only able to show the relationship that exists between potential difference and time. Today's oscilloscopes continue the tradition of measuring voltage vs time while also providing an extensive collection of sophisticated data-analysis capabilities, display features, and triggering options. To understand what electrical relationships exist in your circuits, you have to know how to interpret what is presented to you. This is a typical single waveform display in an oscilloscope, showing the horizontal axis and potential difference on the vertical axis.

In the lower-left part of the image, you will see ① 500mV

That indicates two things:

- Channel 1 is displayed on the oscilloscope in yellow.

For channel one, each grid rectangle corresponds to 500 mV in the vertical direction. So we have "500 millivolts per division" with eight vertical rectangles, thus 4V visible in the vertical direction

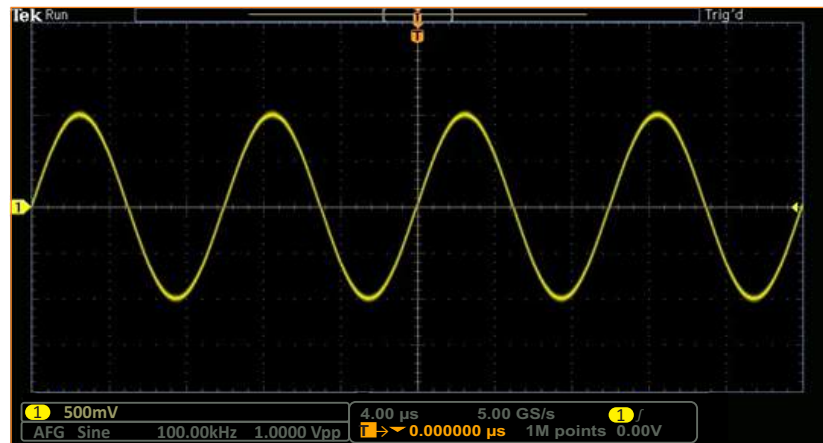


Fig. 4.1.4. A waveform display in an Oscilloscope

- In the bottom left, you will see another box that says AFG Sine 100.00kHz 1.0000 Vpp:
- AFG Indicates the Arbitrary Function Generator is active and used to create this waveform.
- Sine is the shape of the waveform.
- 100.000 kHz is the frequency of the waveform: 100,000 cycles each second. 1.0000 Vpp is the amplitude of the transmitted waveform.

In the bottom-centre there is another box with:

4.00 μ s	5.00 GS/s	①	f
T → 0.000000 μ s	1M points		0.00V

- 4.00 μ s is the value of each rectangle in the horizontal direction: "4 microseconds per division." The display includes 10 rectangles, so $4.00\mu\text{s} \times 10 \text{ divisions} = 40 \mu\text{s}$. $4.00\mu\text{s} \times 10 \text{ divisions} = 40 \mu\text{s}$ of time is visible across the entire screen.
- The oscilloscope is recording 5.00 GS/s, i.e., 5×10^9 samples per second.
- Channel 1 is used to control the triggering of the waveform.
- Triggering occurs on the rising edge of the channel one waveform.
- The image is centred at T → 0.000000 s from the trigger point.
- One million (1 M) data points will be collected.
- 100.000 kHz is the frequency of the waveform: 100,000 cycles each second. 1.0000 Vpp is the amplitude of the transmitted waveform. Triggering occurs when a rising signal passes through 0V.

1. How to make basic measurements with an oscilloscope

There are many different ways the oscilloscope can be used to make fundamental measurements of frequency (or period) and peak-to-peak amplitude. All the images are from Tektronics Oscilloscope

5. Activate the arbitrary function generator

Arbitrary Function Generator is used to learn the basics of the oscilloscope by using the demo frequency generated internally by the oscilloscope. Begin by connecting oscilloscope channel 1 to the Arbitrary Function Generator (AFG) BNC connector on the back of the scope. Activate the arbitrary function generator by pressing the AFG button directly above the Channel 1 probe input. Next, press the first bottom menu button below "Waveform" and use the rotary knob. Multipurpose a to select "Ramp."

6. Turn on channel 1

Press the Channel 1 button to activate it. Rotate the Horizontal **Scale** knob clockwise to adjust the scale to spread out a complete wave over most of the screen. Use the horizontal position knob to adjust its location on the screen if you like.

7. Using the graticule to make measurements

The lines on an oscilloscope display are called a graticule. There are significant and minor gridlines (or dots) that are used to measure waveforms. Major gridlines are displayed as solid or dotted lines that run the width or height of the oscilloscope screen. The voltage and time that correspond to the divisions formed by the significant gridlines are shown at the bottom of the display. Minor gridlines are subdivisions between significant gridlines. There are usually 4 or 5 subdivisions between gridlines. In the following example, the **horizontal position** rotary dial is used to move the waveform so that the positive peaks of the waveform line up with major vertical gridlines.

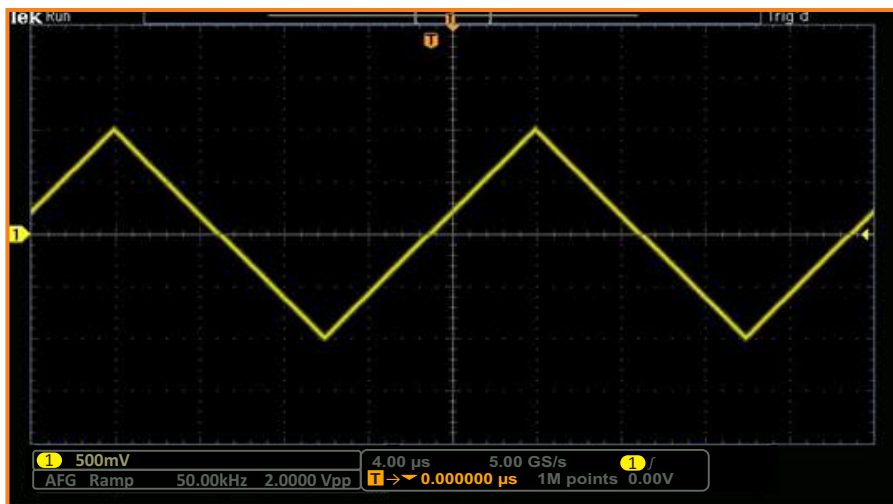


Fig. 4.1.5. Use of cursors to measure the various readings

There is 500 mV per division in the vertical direction, and the distance from the lowest point to the highest point is four rectangles for $500\text{mV}/1\text{division} \times 4\text{divisions}$ from peak to peak = $2000\text{mVpp} = 2\text{Vpp}$.

In the horizontal direction, there are $4.00\text{ }\mu\text{s}$ per division, and there are five divisions before the signal begins to repeat, giving $(4.00\text{ }\mu\text{s}/1\text{division}) \times (5\text{divisions}/1\text{period}) = 20\text{ }\mu\text{s}/1\text{period}$

8. Using the cursors to make measurements

Digital oscilloscopes take all guesswork out of using the graticule. Activate the cursors by pressing the **Cursors** button and use rotary dials **Multipurpose a** and **Multipurpose b** to move them to the parts of the waveform that you would like to inspect. In the following example, the cursors are moved to the positive peaks of the wave.

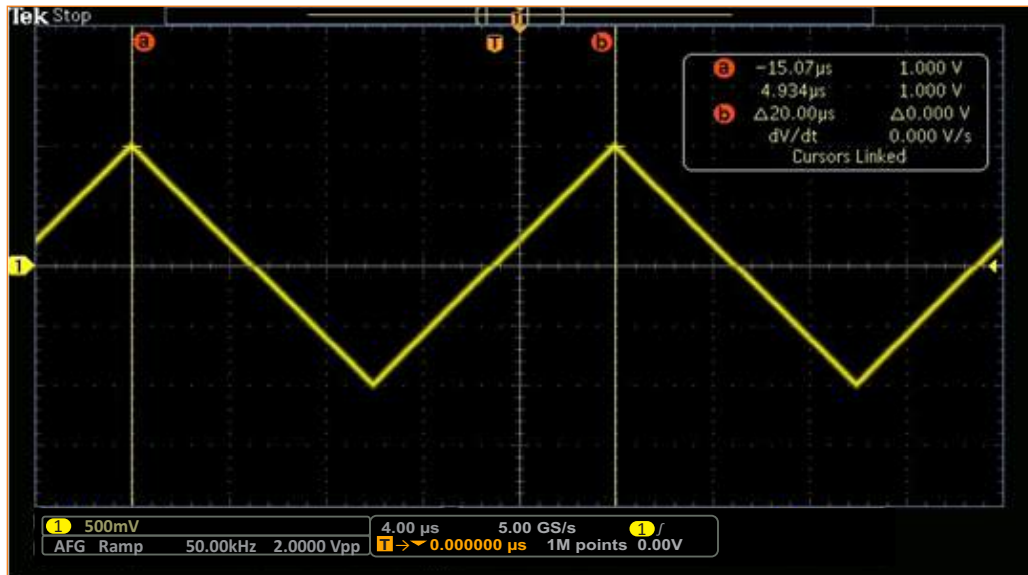


Fig. 4.1.6. Use of cursors to measure the various readings

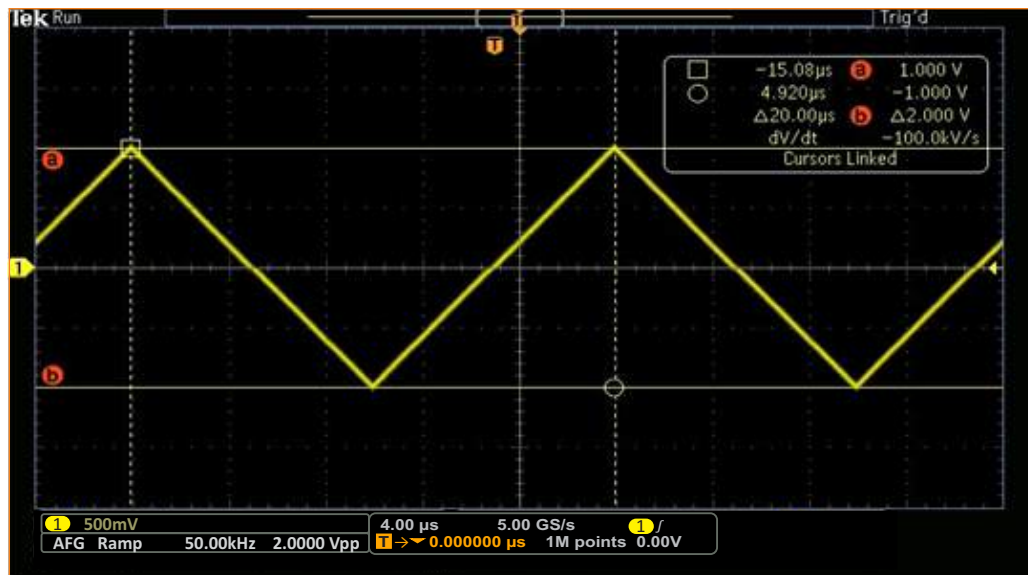


Fig. 4.1.7. Use of cursors to measure the various readings

In the upper right corner, you will see a new box with information about the values of potential difference and time for points a and b. Here we are interested in the interval of time between the two points, i.e., $\Delta 20.00\mu\text{s}$.

To determine the Peak-to-Peak potential difference, switch to horizontal cursors by pressing and holding the **Cursors** button again, selecting "Cursors-Screen" and "Bars-Horizontal." Then use **Multipurpose a** and **Multipurpose b** knobs to adjust the position of the cursors and "Cursors linked" to aid your adjustment. You can move between horizontal and vertical measurements by pressing the **Select** button. Here we are interested in the potential difference between the two points, i.e., $\Delta 2.000\text{V}$.

You can watch the video on tube

<https://www.youtube.com/watch?v=NOFsXoKne98&list=RDCMU CYTq2bhe5pim45pAEU-gDjw>

9. Using the digital volt meter to make measurements

A useful feature found in mid-range oscilloscopes is the DVM (Digital Volt Meter). The DVM tool does everything you might expect a basic multimeter to do. Enable it by pressing the **Measure** button in the Wave Inspector box and then "DVM," and use **Multipurpose** to select (for example) "Frequency." Here we display the frequency (in the centre) and frequency statistics (on the right). We could also display AC+DC RMS voltage, DC voltage, or AC RMS voltage.

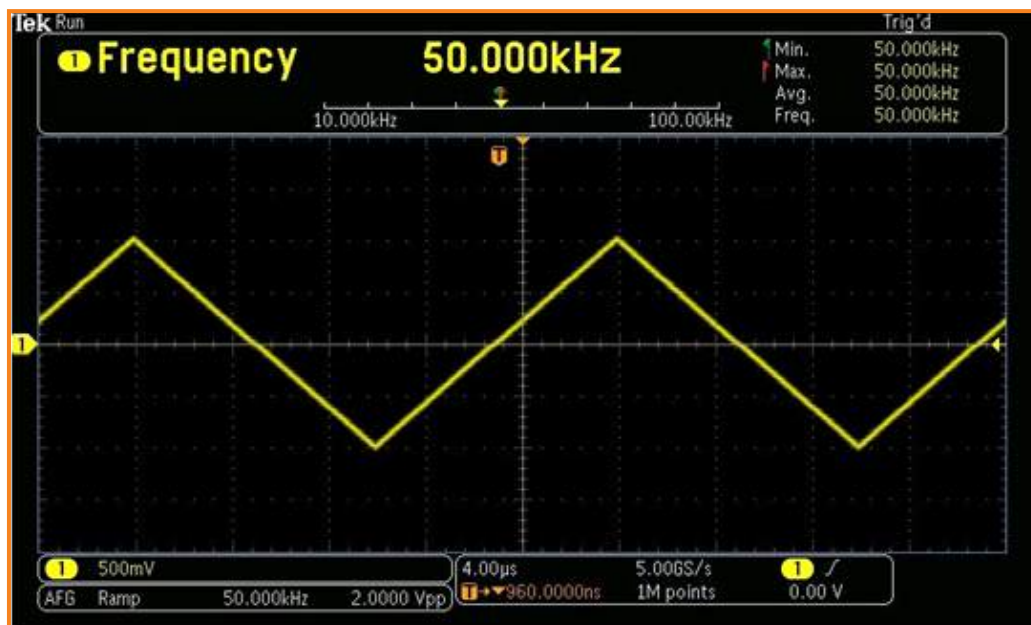


Fig. 4.1.8. Taking Frequency measurements using Digital Multimeter feature

Press the bottom menu button below "Add Measurement" and use Multipurpose b to select "Period", followed by "OK". Then repeat "Add Measurement" and use Multipurpose b to select "Amplitude", followed by "OK". Now Period & Amplitude are shown at the bottom in a less intrusive fashion. You may remove them by selecting the button below "Remove Measurement" followed by "Remove All Measurements". You may simplify the display at anytime by pressing the Menu Off button.

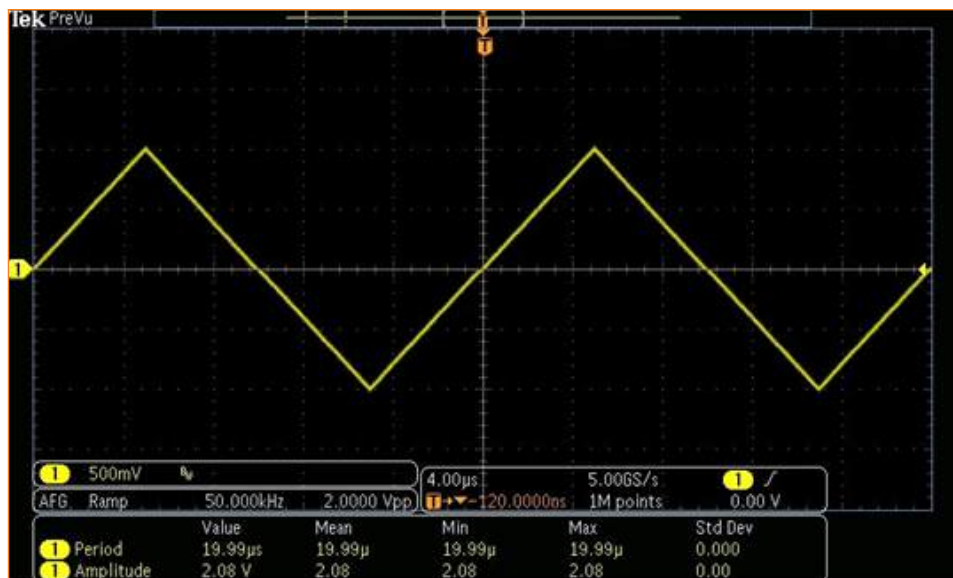


Fig. 4.1.9. Measuring Period and Amplitude.

10. Using advanced math

- The math tool allows all manner of mathematical functions to be performed on waveforms—
- Press the **Math** button to enter the math menu, followed by "Advanced Math", "Edit Expression".
- Use **Multipurpose a** to scroll through the functions and **Select** to choose "Frequency(1)" and finally "OK".

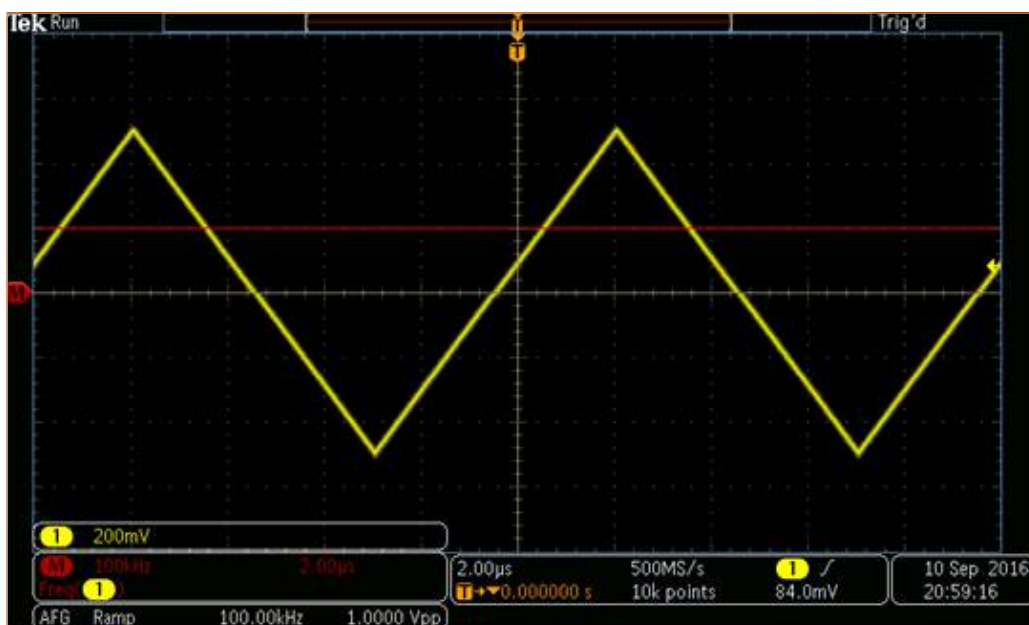


Fig. 4.1.10. Using Maths Tool

The math menu is somewhat challenging to see. It is red in the lower-left corner. Where it displays 100 kHz, it is indicating 100 kHz per division in the vertical direction. The horizontal red line (the result of the math module's computation) is one division above zero, which indicates a constant reading of 100 kHz. The 2.00 µs indicates that there are 2.00 µs per division in the horizontal direction.

Tips

1. In procurement, it should be made mandatory for the vendors to provide the following:
 - a. Training the technicians and operators.
 - b. Providing of user guide / operating manual.
 - c. Providing service/maintenance manual
2. There are two types of maintenance:
 - Corrective or Breakdown Maintenance (or Repair)
 - Planned (or Scheduled) Preventive Maintenance

Practical

1. Demonstrate the use of the digital volt meter to make measurements.

UNIT 4.2 Safety procedural guidelines

Unit Objectives

After completion of this unit , the participants will be able to :

1. Understand the various safety aspects of medical instruments
2. Perform the disinfection of various tools
3. Understand the basics of electrical safety
4. Identify the types of socket outlets, plugs and wiring of sockets and plugs
5. Understand the various plug and socket classifications based on their types

4.2.1 safety aspects of medical instruments

Safety issues, Emergencies and Troubleshooting

While operating Medical Equipment, adequate precautions need to be taken. The following are the various categories of safety:

- a. **Electrical Safety-** The equipment should be appropriately connected with the electrical power.
- b. **Mechanical safety-** The equipment should not have sharp corners to cause injury to the user. The body of the equipment should be appropriately closed with screws, and the screws should not be missing. While opening the equipment, the screws should be kept in a box not to be misplaced. Similarly, good quality mechanical components should be used. For example, trolleys and patient transfer beds should have well-lubricated wheels with appropriate locks.
- c. **Radiological safety-** The equipment like X-Rays that emit radiation should be checked regularly for radiation leakages. The operator should wear appropriate dose badges or dosimeters to see the number of radiations absorbed by the operator. All the radiation-emitting equipment should comply with Atomic Energy Regulation Board (AERB) requirements to avoid radiation hazards. The operator should wear appropriate Aprons to minimise radiation hazards.
- d. **Biological safety-** All medical devices should be used so that biological risks are minimised. For example, UV Lamp radiation can damage the eyes. The heater coil in radiant warmer, if not calibrated well, can burn the child's skin. The TB procedures must disinfect the operators after use.
- e. **Chemical safety-** The equipment using chemicals like Analysers must safely dispose of the chemicals. In addition, the labs must disinfect the chemicals before disposing of them. Thus, electrical safety, personal protective equipment and disinfections are the primary requirements to adhere to safe usage of medical devices.

This chapter will deal in detail with these safety aspects.

1. Disinfection procedures

- A. **Disinfecting hands** - Always wash hands, especially after finishing work on equipment. It is strongly recommended to use gloves while handling equipment. Before leaving the working area, remove gloves and laboratory coat.
- B. **Disinfecting tools** - Used and contaminated tools should be cleaned after use, e.g., by wiping out a moist tissue containing or soaked in a disinfectant such as Cidex solution.

- C. Equipment indirectly connected to the patient** - Equipment removed from the area of use and taken either to the maintenance workshop or elsewhere must undergo an appropriate decontamination process as recommended. The person removing the equipment must ensure that this has been done.
- D. Equipment making contact with body fluids** - The equipment includes suction units, endoscopes, laryngoscopes and some invasive blood pressure monitoring equipment. For site checks or repairs of such equipment, maintenance staff should take similar precautions as staff operating the equipment.
- E. Equipment collecting body fluids** - Suction Pumps and other apparatus used for collecting body fluids must be cleaned out and disinfected before carrying out the maintenance work.
- F. Decontamination of equipment** - Equipment removed from the area of use and taken either to the maintenance workshop or elsewhere must undergo an appropriate decontamination process as recommended. The person removing the equipment must ensure that this has been done.
- G. Maintenance works at laboratory** - Within a Laboratory Environment, maintenance staff should work under the same regulations as the laboratory staff.

2. Some points to be noted:

- Visibly contaminated equipment should not be accepted for repair until adequately cleaned by the appropriate department.
- Appropriate personal protective equipment (like gowns, gloves, masks and goggles) is worn to handle the equipment.
- All clinical engineering technicians will observe isolation guidelines and the dress procedures for their working area.
- Clinical engineering technicians should not enter 'isolation rooms' or 'restricted areas' without obtaining permission from the charge nurse.

3. Basics of electrical safety

If it is misused or poorly maintained, electrical equipment can cause injury, death or fire. On the other hand, if it is well maintained, electrical equipment can save lives, improve lives, and reduce capital expenditure. Electrical equipment and the electrical connections that supply power should always be treated with respect and care.

Careful consideration should always be given to the placing of equipment. Damp conditions should be avoided, and equipment should be positioned in a dry, clean, well-ventilated area on a solid, level base. Equipment should be as near as possible to the electrical supply, and extension leads should be discouraged.

Since most problems in this area occur with the plugs, sockets and cables supplying electrical power, this chapter mainly focuses on the safe use and maintenance of these.

4. Socket outlets and plugs

- A convenient and safe socket-outlet should be available.
- Socket outlets should be at least 2 m from a sink or washbasin.
- The socketoutlet should be adequate for the electrical capacity of the equipment.
- There should be proper grounding in the sockets.
- Plugs should match the socket outlets.



Fig. 4.2.1. Different types of socket outlets and plugs

5. Wiring of sockets and plugs

The wiring of a plug is colour coded to help guard against electrical accidents. The colour codes in India as per Indian Electricity Rules are as follows

- A. Phase (or Live) – red, blue or yellow** - This carries the electrical drive current from the supplier to the equipment. It is the most dangerous line. Only qualified staff should work with this.
- B. Neutral – black** - This returns the current to the supplier. It should not be connected to Earth.
- C. Earth (or ground) – green or green with yellow lines** - This is used for safety and protection. If equipment is housed in a metal case, the earth line will generally be connected to the case. The earth line in a socket is connected to a pipe or plate buried in the ground.

6. Notes on earthing

- A.** The earthing will depend upon the type of equipment being used:
 1. If there are only two wires in the power cable, no earth connection is required
 2. If the cable fitted has three conductors, then equipment needs to be earthed properly
- B.** Always make sure that the earth wire is longer than the other two so that if the cable is accidentally pulled out of the plug, the earth wire is the last wire to become disconnected.

7. Sizes and types of sockets and plugs

The current rating (i.e., the amount and size of equipment they can supply) is measured in Amperes, written 'A'. For example, the rating and length of commonly found plugs and sockets are:

- For low power operations, 5 Amperes – small size
- For large power applications, 15 Amperes – large size

Mains electricity comes at a specified voltage and is measured in Volts, written 'V'. The voltage in India is 220-240 V for single-phase and 440 V for three-phase operations. It also is delivered at a specific frequency, measured in Hertz, written 'Hz'. The mains electricity in India is at 50 Hz.

A variety of electrical plugs are found throughout India, so an adaptor plug set is recommended. Type D is most common, which is also known as the Old British Plug. It has three large round pins in a triangular configuration.



Fig. 4.2.2. Plug and Socket Classifications

The type C European 2-pin plug and electrical outlet is also a very popular connector for standard medical equipment which does not require earthing. Popularly known as the Europlug, it is used throughout continental Europe, parts of the Middle East, Africa, South America, Central Asia, and the former Soviet republics.

8. Mains cables

- Electricity is carried to the equipment through the mains cable. Points to be aware of are:
- No bare metal or internal coloured wire should be visible – the plastic insulation is there for safety
- The cable should not be repaired with insulating tape – water can still get inside
- Long flexible leads are dangerous – leads should be as short as possible
- The cable, plug and socket should never be allowed to get wet – water can conduct electricity

9. Fuses

Fuses are used as protection. If the current through them is more significant than their specified rating, they blow. This breaks the circuit and stops the current, making the equipment safe. Points of safety regarding fuses are:

- Always use the correct rating of fuse – voltage V (volts) and current A (amperes)
- Always use the correct size of fuse – keep the old one to check against
- NEVER replace the fuse with bare wire – it will not be safe
- Circuit breakers are fuses that have buttons or switches for reset – they do generally not need replacing

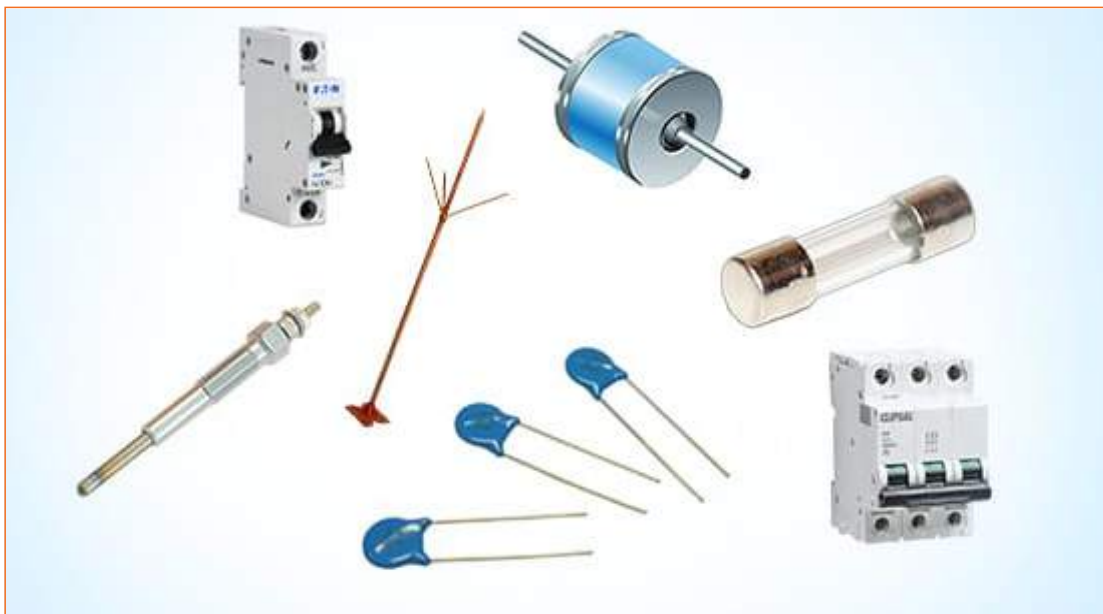


Fig. 4.2.3. Different types of fuse



Figure 4.2.4. Different types of circuit breakers

Tips

The following are the various categories of safety are:

- a. Electrical Safety
- b. Mechanical safety
- c. Radiological safety
- d. Biological safety
- e. Chemical safety

Practical

1. Identify the different types plugs and sockets
2. Perform the decontamination of equipment (any equipment accessible to you)

UNIT 4.3 Installation, Maintenance and Servicing of Medical Equipment

Unit Objectives

After completion of this unit , the participants will be able to :

1. Understand the roles and responsibilities
2. Understand the various checklists
3. Understand the receipt and inspection of incoming equipment
4. Learn the inventory and documentation
5. Follow the guidelines of installation and final acceptance
6. List the equipment history record
7. Understand the basic working, functions and troubleshooting of: Ventilator, BIPAP and CPAP, Oxygen Equipment (Concentrator & Cylinder), Digital Thermometer (IR), Flowmeter, Humidifier, Pulse Oximeter, Multipara Monitor, Nebulizer, BP Instrument, ECG machine, Suction apparatus and its pipelines, Steam inhaler, Spirometer

4.3.1 Fundamental of Delivery, Installation and setting up of basic medical equipment.

Many common problems with medical equipment can be avoided if it is properly delivered, checked for supplies and installed correctly. This chapter aims to assist those responsible for receiving and checking equipment when it arrives. If the right equipment comes in working order with the right parts and manuals, then a long and useful life is more likely.

Receipt and Inspection of incoming equipment - Incoming equipment should be carefully checked and complied with specifications mentioned in the purchase order. Delivery of accessories, spare parts, operating and service manuals should also be checked during equipment supply.

In procurement, it should be made mandatory for the vendors to provide the following:

- 1- Training the technicians and operators.
- 2- Providing of user guide / operating manual.
- 3- Providing service/maintenance manual

Inventory and documentation - Proper entry should be made in the inventory register. The inventory record should contain the Make & Model of the article, serial number of central unit and accessories, date of receipt of the article, and date of completion of installation. The unit price of the central unit and accessories, consumables and spare parts and related details should also be maintained. In addition, details of Warranty, AMC, CMC and contact details of Original Equipment Manufacturer (OEM) and its local authorised service provider should be recorded. If possible, it should also be maintained.

Installation and final acceptance- Installation should be done by the authorised company personnel. In addition, proper demonstration & operational training should be provided during installation by the authorised company personnel to the users and the maintenance personnel.

Equipment history record - There should be an equipment history record sheet to track the performance of the equipment. This sheet should note down the date of installation and commissioning, the events of breakdowns of equipment, cost of repair, and preventive/corrective maintenance steps taken.

4.3.1.1 Roles and responsibilities

Each person in the chain of equipment supply has a particular role and responsibility to fulfil. This applies right from when the need for new equipment is identified to the time when it is used. The following should be used to remind each of their responsibilities and to check their performance.

Specifier	-	Make sure the specification is clear and thorough
Purchaser	-	Select, order and pay correctly, inform the receiver of dates and details
Supplier	-	Check supply against specification, install on time, provide training
Carrier	-	Inform receiver before delivery, deliver safely and completely
Receiver	-	Prepare the site for installation, check delivery against specification
Local technical staff	-	Ensure equipment is correctly installed, learn maintenance checks required
Stores	-	Ensure equipment is complete, report to the purchaser, enter into inventory
User	-	Ensure installed in the right place, check function, get and use user manuals

4.3.1.2 Checklist

When equipment arrives, it will be necessary to record the fact and to check that everything has been supplied that was ordered. It will also be essential to check that the equipment is provided in the right way. The following list will help record all details, and on the next page, a single sheet of checks can be copied or printed for each item of equipment to ensure correct installation is carried out.

INVENTORY NUMBER EQUIPMENT LOCATION

ACCEPTANCE DATE WARRANTY EXPIRY DATE

MAINTENANCE CONTRACT WITH

EQUIPMENT TYPE

NAME OF EQUIPMENT

TYPE/MODEL

ORDER NUMBER SERIAL NUMBER

COST DATE RECEIVED

MANUFACTURER SUPPLIER/AGENT

ADDRESS ADDRESS

PHONE PHONE

Acceptance checks - Delivery

	Yes / Done	No / Not Done	Corrected if Applicable
a) Representative of supplier present?			
b) A Correct number of boxes received?			
c) After unloading, are boxes intact?			
d) If damaged, has this been stated on the delivery note and senior management informed?			

Table 4.3.1. Acceptance Checks

Unpacking (refer to invoices, shipping documents and original specification)

	Yes /	No / Not	Corrected if
a) Is the equipment intact and undamaged?			
b) Equipment complete as ordered?			
c) User/operator manual as ordered?			
d) Service/technical manual as ordered?			
e) Accessories and consumables as ordered?			
f) Spare parts as ordered?			

Table 4.3.2. Unpacking

Installation (refer to manuals)

	Yes / Done	No / Not Done	Corrected if Applicable
a) Was installation carried out satisfactorily?			
b) Were all parts present and correctly fitted?			
c) Were technical staff present as learners?			
d) Was the equipment demonstrated as fully working?			
e) Were staff trained in the operation of the equipment?			

Table 4.3.3. Installation

4.3.2 Fundamental of Periodic Preventive Maintenance of basic medical equipment

Types and approaches to medical equipment maintenance

There are two types of maintenance:

1. Corrective or breakdown maintenance (or repair)

This is done to take corrective action in the event of a breakdown of the equipment. The equipment is returned, repaired and calibrated

2. Planned (or scheduled) preventive maintenance

This work is done in a planned way before the repair is required, and the scheduled time for the work circulated well in advance. It involves cleaning, regular function/safety tests, and ensuring that any problems are picked up while still small.

The choice of approach for “**Preventive and Corrective Maintenance**” depends on the complexity of the equipment and the set present for the maintenance.

A. Maintenance by in-house trained technicians

The majority of the problems are relatively simple and can be corrected by a trained technician. In addition, simple repairs and inspections are less costly when done this way. Workshop requirements for in-house medical equipment maintenance are described in references in the chapter. Vendors should provide training to in-house technicians at the time of installation and commissioning.

B. Maintenance by manufacturer or third party

For specialised and advanced equipment, the vendor should provide maintenance services through a combination of on-call assistance and a maintenance contract negotiated at the time of the purchase. It will rarely be economical to provide this level of service in-house.

4.3.2.1 Levels of Maintenance

There are three levels of maintenance commonly identified:

- **Level 1, the user (or first-line)**

The user or technician will clean the filters, check fuses, check power supplies etc., without opening the unit without moving it away from the point of use.

- **Level 2, Technician**

It is recommended to call the local technician when first-line maintenance cannot rectify a fault or when a six-monthly check is due.

- **Level 3, Specialized**

Equipment such as CT Scanners, MRIs etc., will need specialised engineers and technicians trained in this specific equipment. They are usually employed by third party or vendor companies.

The Specialised equipment will not be covered under this book. The Preventive Maintenance and troubleshooting, along with the working for specific essential equipment, will be covered separately in Modules 3 and 4

4.3.2.2 Planned Preventive Maintenance of Medical Equipment

Planned preventive maintenance is regular, repetitive work done at scheduled intervals to keep equipment in good working condition. The activities under preventative maintenance involve routine cleaning, calibrating and adjusting, checking for wear and tear and lubricating to optimise working efficiency and avoid breakdown. Also, consumables replacement, like fitting new filters, is done as part of this work.

Effective planning for preventive maintenance involves the proper selection of the equipment to be included in the plan. Decisions must be made on what to have to reduce costs. Inexpensive units can be replaced or repaired if they break down, so they need not always be included. The overriding consideration is cost-effectiveness.

Preventive maintenance and calibration interval for medical devices should be as below unless specified otherwise by the manufacturers (NABL 126):

Sl.	Category of Equipment	Interval
01.	Electric-powered equipment	Annual
02.	Battery-powered equipment	Annual
03.	Powered by mechanical systems, electromechanical or fluid	Annual
04.	Resuscitation equipment or life-saving equipment	Quarterly or Biannual
05.	Equipment located in areas of special care	Quarterly or Biannual
06.	Monitoring equipment	Quarterly or Biannual
07.	Equipment that presents high risks to users	Quarterly or Biannual

Table 4.3.4. Preventive Maintenance

Setting up a complete system

When many equipment items are under the care of a single biomedical department, it is better to keep the planned preventive maintenance computerised with a programmed schedule. This will require:

- **An equipment inventory**

All equipment in the hospital should be recorded on cards or in the computerised database. All relevant information about the equipment must be entered, including its location, records of repair and maintenance and manufacturer details. A reference number is written on each item.

- **Definition of maintenance tasks**

These tasks can usually be established by consulting the manufacturer's literature

- **Establishing intervals of maintenance**

The frequency of these tasks must be decided. For example, a heavily used item must be cleaned and checked more frequently than used less often; however, minimum standards must be set. The frequency suggested in the manufacturer's manual can be used as a guide, but the amount of actual usage should determine the maintenance procedure required.

- **Personnel**

The biomedical team will typically monitor the Preventive Maintenance Program.

- **Reminder system**

It will be necessary to develop a reminder system so that staff are prompted to carry out tasks when they are due. A card index/calendar system or a computer program can be used.

- **Special test equipment**

A biomedical team should have a range of test equipment to check the correct equipment functioning and its compliance with electrical and other safety standards.

- **Technical library**

An entire technical library should be available.

- **Surveillance**

After the program has been set up, periodic surveillance must be carried out to ensure that records are legible and that all entries are being made.

Planning User Maintenance Tasks

User Maintenance Tasks should be designed for the equipment used to carry out at the point of equipment use. No special equipment will be needed for these tasks, neither will a computer program be necessary.

The tasks will be separated into 'Daily' and 'Weekly' tables to help users plan a routine of inspections.

4.3.3 Function and Operation of All Possible Essential Clinical Equipment

Medical Devices- As per WHO (World Health Organisation) 'Medical device' means any instrument, apparatus, implement, machine, appliance, implant, reagent for in vitro use, software, material or other similar or related article, intended by the manufacturer to be used, alone or in combination, for human beings, for one or more of the specific medical purposes. Medical Equipment are Medical devices requiring calibration, maintenance, repair, user training and decommissioning – activities usually managed by clinical engineers. Medical equipment is used for the specific purposes of diagnosis and treatment of disease or rehabilitation following disease or injury; it can be used either alone or in combination with any accessory, consumable or other piece of medical equipment. Medical equipment excludes implantable, disposable or single-use medical devices.

4.3.3.1 Ventilator

1. Introduction to medical ventilators

Medical ventilators are also known as mechanical ventilators, artificial ventilators etc. We will henceforth refer to all these as ventilators.

When a patient breathes on its own, it is known as spontaneous breathing, and when the patient is unable to breathe on its own, we use a device called a ventilator which helps the patient breathe artificially. This device is called mechanical ventilation and is a method to mechanically assist the patient to breathe and, in extreme cases, replace the entire breathing process. Spontaneous breathing is done by a process called respiratory system.

Mechanism of Breathing:

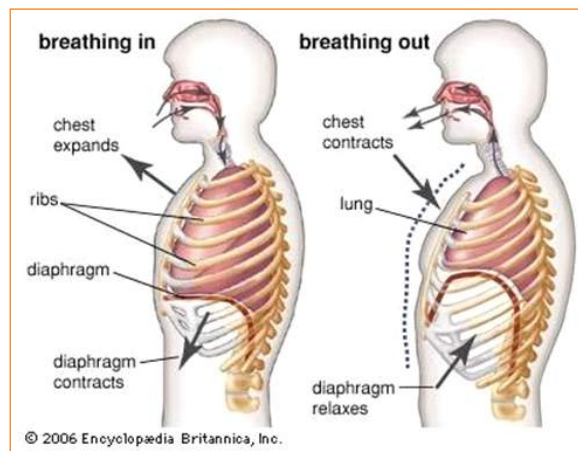


Fig. 4.3.1. Mechanism of Breathing (Image Source-EncyclopediaBritannica)

i. Breathing in is called Inhalation or Inspiration

When the diaphragm contracts, the chest expands, creating a vacuum or negative pressure. The atmospheric air flows from the nose through the wind pipe or trachea to the Lungs. In the lungs, the oxygen of the inhaled air is exchanged with the Carbon Dioxide CO₂ coming from the impure blood.

ii. Breathing out of Exhalation or Expiration

Once the exchange of CO₂ and O₂ has taken place in the lungs, the diaphragm relaxes, and the chest contracts, thus flowing the CO₂ out through the wind pipe and nose. Thus spontaneous breathing has two phases Inspiration and Expiration.

2. What does a ventilator do?

Ventilators provide temporary ventilatory support or respiratory assistance to patients who cannot breathe on their own or who require assistance to maintain adequate ventilation because of illness, trauma, congenital disabilities, or drugs (e.g., anaesthetics)

A medical ventilator is a medical device designed to mechanically force breathable air (mixture of air and oxygen) into and out of the lungs, provide the mechanism of breathing for a physically unable to breathe or breathe in sufficiently.

While modern ventilators are generally thought of as computerised machines, patients can be ventilated indefinitely with a bag valve mask, a simple hand-operated device. Ventilators are chiefly used in intensive care medicine, home care, emergency medicine (as standalone units), and anaesthesia (as a component of an anaesthesia machine). All the ventilators used are known as positive pressure ventilators.

3. What is positive pressure?

When the patient cannot breathe, he cannot generate the vacuum or negative pressure required to flow the air into the lungs. Thus we need to push the air forcefully, or in other words, a positive pressure is forced.

4. How is a positive pressure generated?

If we have to inflate a balloon, we need to force air by mouth or through a pump. This is positive pressure generated by the mouth or by the pump. Similarly, we develop positive pressure for ventilators by a device called air compressor. The air compressor can be at the bedside, or a large air compressor is installed, and the compressed air is supplied through a network of pipelines, and at times this compressed air is mixed with compressed oxygen for patients who have oxygen deficiency. The positive pressure can also be developed by compressed air cylinders and supplied to the patient at the bedside either by the cylinder at the bedside or through a network of pipelines. The group of cylinders are also known as manifold, and the room where these are placed is known as manifold

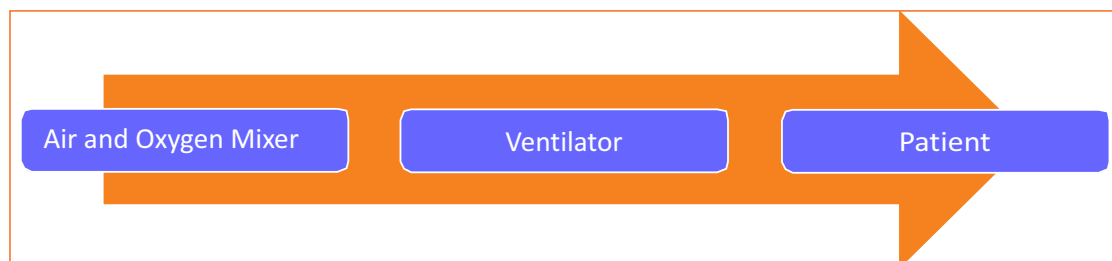


Fig. 4.3.2. Block Diagram of a Ventilator System

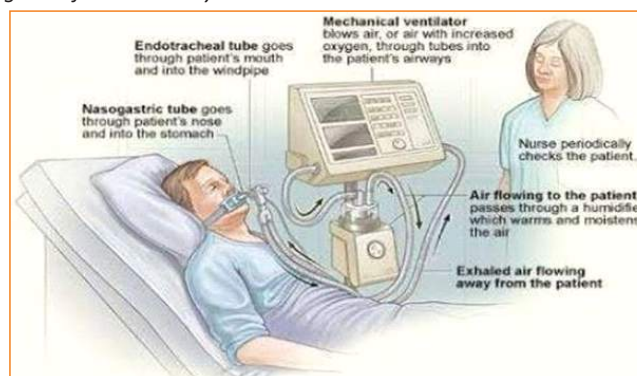


Fig. 4.3.3. Working of a Typical Ventilator (Fig-Source Rajni Mishra-Ventilator-Slideshare)

5. Modes of ventilation

Video link: <https://www.youtube.com/watch?v=3I9thXef8j0>

Modes in a Ventilator- Modes in a Ventilator are how a ventilator will positively pressure the patient.

6. Wherever we write air, it indicates either compressed air or air/ oxygen mixed outlet of a blender.

Before we understand the modes of ventilation, we need to understand the phases of ventilation.

There are two Valves Inspiratory and Expiratory Valves. The Inspiratory Valve is at the outlet of the ventilator. This forces the air out of the ventilator.

The expiratory valve is at the End of the Breathing Circuit. Breathing Circuits are a collection of tubing of which one end is connected to the outlet of the ventilator, and the middle part is connected to the patient. The End part is connected to the Expiratory Valve.

7. Ventilatory phases are as depicted below

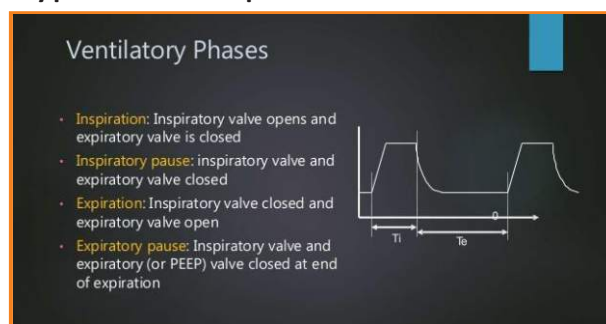


Fig. 4.3.4. Ventilatory phases (Fig: Source Mechanical Ventilation by Dr Farrukh Javed Slide Share)

8. Parameters of a ventilator

Before we understand the ventilation modes, we need to understand the various parameters.

- i. Tidal Volume V_t** - The Tidal Volume is the volume of air delivered in one breath cycle. Settings are 5-15 ml/kg in adults and 6-10 ml/kg in children
- ii. Minute Volume-MV** is the Volume of Air intake per minute.
- iii. Respiration Rate-f**-Also known as frequency is the number of breaths per minute or bpm. In normal adults, it is 10-20 bpm, and in children, it is 30-60 bpm
- iv. Inspiration time- T_i** - Time for which the inspiration takes place in seconds
- v. Expiration time- T_e** - Time for which the exhalation of breath takes place in seconds.
- vi. Peak Inspiratory Pressure or PIP**- is the maximum pressure in the respiration cycle. Unit- mmH₂O
- vii. Positive End Expiratory Pressure or PEEP**- is the pressure in the lungs at the end of the expiration cycle. Positive pressure applied at the end of expiration during mandatory\ventilator breath, and positive end-expiratory pressure is set with positive-pressure (machine) breaths. Unit mmH₂O
- viii. I: E Ratio**- It is the ratio of Inspiration time to Expiration Time. Standard settings are 1 : 2 (T_i/T_e)

9. Types of ventilators are as below

i. Transport ventilator

These are small and portable Ventilators with limited modes and transport patients in Ambulances or Hospitals with ventilation support. This is powered pneumatically or with AC/DC Voltage.



Fig. 4.3.5. Transport Ventilator- (Image Source- surgical. In)

ii. ICU or Intensive Care Ventilator

These are large ventilators and usually runs on AC power with small battery backup for emergency power failures. This is used in ICU and can be operated continuously for a more significant time. ICU ventilators have many advanced modes and have integrated screens to display the pressure, volume and flow graphs.

Intensive Care Ventilator



iii. Neonatal Ventilator

These are specifically designed for neonates, have exact settings for Pressure and Volume and higher sensitivity, and are a subset of ICU Ventilators.



Fig. 4.3.7. Neonatal Ventilator (source-indiamart.com)

10. Two common problems that are frequently used in Ventilation

I. Atelectasis

(at-uh-LEK-tuh-sis) is a complete or partial collapse of the entire lung or area (lobe) of the lung. It occurs when the tiny air sacs (alveoli) within the lung become deflated or possibly filled with alveolar fluid. **Atelectasis** is one of the most common breathing (respiratory) complications after surgery.

ii. Pneumothorax

A pneumothorax (noo-moe-THOR-aks) is a collapsed lung. A pneumothorax occurs when air leaks into the space between your lung and chest wall. This air pushes on the outside of your lung and makes it collapse. A pneumothorax can be a complete lung collapse or a collapse of only a portion. of the lung

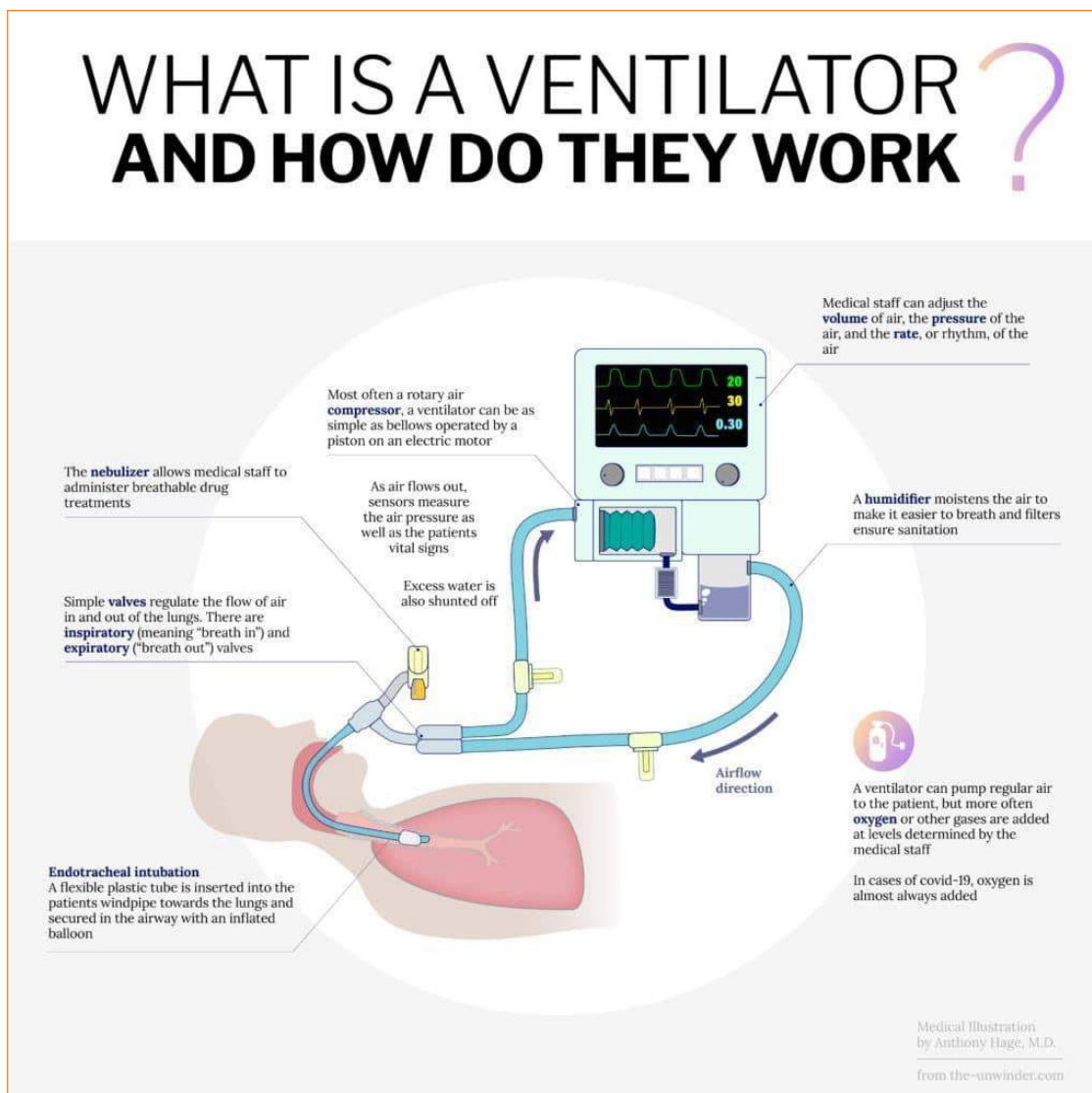


Fig. 4.3.8. Working off a Ventilator- Image source- the unwinder

11. Components of a Ventilator and its connection to the patient:

I. Input Power Source- Electrical or Gas source

- a. Electrically powered ventilators- in this type, the ventilator is powered with electricity with some power backup for power failures or inter-hospital transport.
- B. Pneumatically powered ventilators- these types of ventilators have compressed gases for operation.
- C. Combined power ventilators- having electricity as well as gases for operations.

ii. **Air/oxygen blenders-** oxygen is mixed with air. It is set as fraction of inspired oxygen or FIO_2 - starts with 100 %, and minimum value is 21%.

iii. **Positive pressure generators-** positive pressure is generated by closing the exhalation valve.

iv. Control Systems and Circuits

- a. Open and closed-loop systems to control ventilator function.
- b. Control Panel. (user interface)
- c. Pneumatic Circuit.

v. Power transmission and conversion systems-

- a. Volume displacements, pneumatic designs.
- b. Flow control valves

vi. Outputs- (pressure, volume and flow waveforms)

Vii. Breathing circuits- ventilator circuits-

The breathing circuits are a set of corrugated tubing. One end of the tubing is connected to the inhalation port of the ventilator, and the other end is connected to the Exhalation Valve of the patient. First, the inhalation circuit is connected to a humidifier to add moisture to the air, and also, a water trap is connected, which removes excess water from the course. Then, with a connector, the air is delivered to the patient. The patient inhales the air and then exhales. During exhalation, the input port is closed, and the exhaled air is passed through the other side of the circuit and finally released with exhalation valves opened.

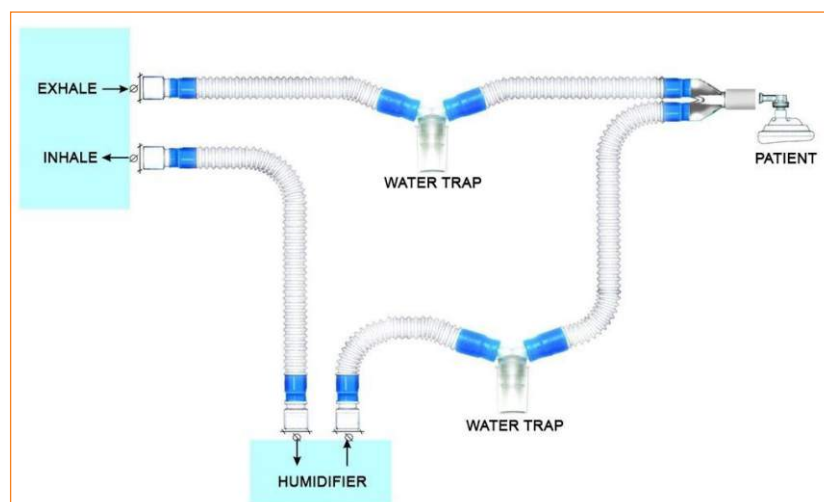


Fig. 4.3.9. Breathing circuit Source StroiReanimatsiya" corporate group

viii. Humidifiers- As shown above, a Humidifier in the Ventilator Circuit moistens the Air/O₂ mixture before delivering the same to the patient. Youtube link

<https://www.youtube.com/watch?v=yGvN7xg3Xlo>

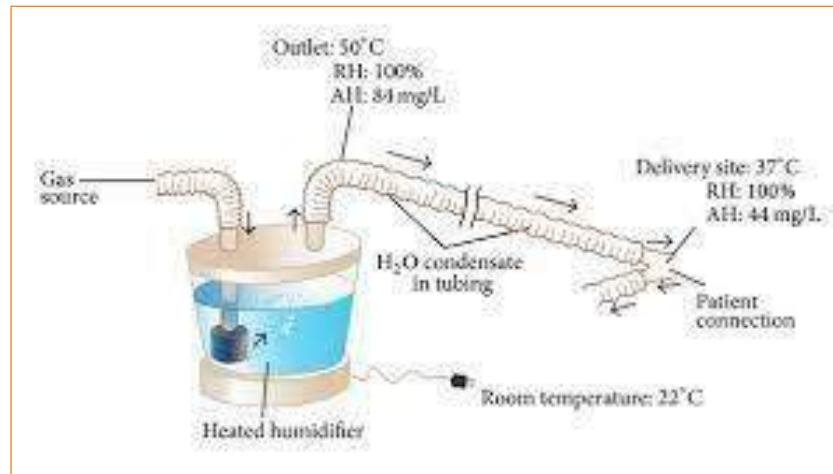


Fig. 4.3.10. Humidifier connections (Source- hindawi.com)

12. Modes of ventilation:

Youtube video link- <https://www.youtube.com/watch?v=3I9thXef8j0>

- I. Volume control modes- In volume control modes, the delivered volume of air is guaranteed.
 - A. **CMV/Assist Control-Continuous Mandatory Ventilation/Assist Control** - These are two modes in some ventilators, but most ventilators are combined. In this mode, the patient not at all able to breathe on their own. The entire breathing function is assisted and controlled by the ventilator. A ventilator with its two valves controls both inspiration and expiration cycles. I: E ratio is kept as 1:2, and bpm is guaranteed at the set rate. Thus the breathing is guaranteed at this set rate. Inspiration is terminated after a pre-set tidal volume has been delivered by the ventilator. The ventilator delivers a pre-set tidal volume (VT), and stimulation stops when the pre-set tidal volume is achieved. In the CMV Mode, the patient is sedated, and absolute control is with the ventilator, and the ventilator delivers all the ventilation. In Asst Control Mode, the patient tries to breathe, but the patient still delivers the breathing. The patient is not allowed to breathe on its own.
 - The ventilator provides the patient with a pre-set tidal volume at a pre-set rate.
 - The patient may initiate a breath independently, but the ventilator assists by delivering a specified tidal volume to the patient. The client can create breaths that are delivered at the pre-set tidal volume.
 - The client can breathe at a higher rate than the pre-set number of breaths/minute
 - The total respiratory rate is determined by the number of spontaneous inspiration initiated by the patient plus the number of breaths set on the ventilator.
 - In A/C mode, a mandatory (or "control") rate is selected.
 - If the patient wishes to breathe faster, they can trigger the ventilator and receive a full-volume breath.

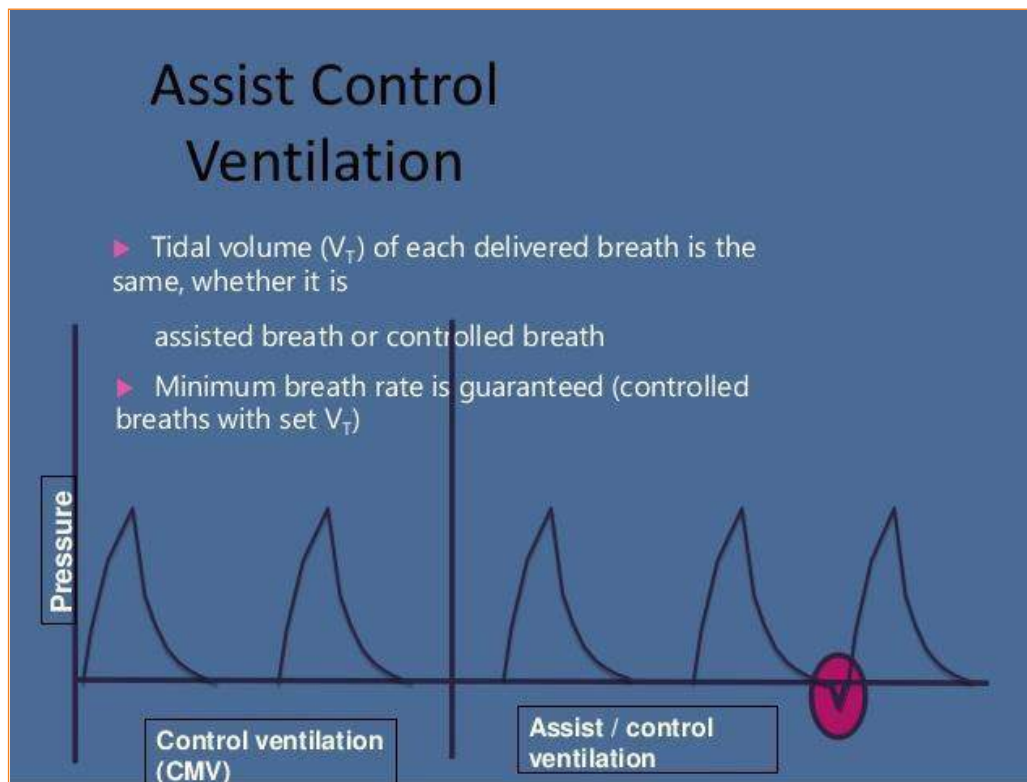


Fig. 4.3.11. Assist Control Mode (Source- Slideshare.net)

The figure above shows CMV and asst control mode ventilation. In the CMV Mode, the patient does not breathe at all, and in the Asst/Control Mode, the patient triggers the ventilator, and the ventilator provides a Breath.

- B. SIMV- synchronised intermittent mandatory ventilation** - This mode is used when the patient has started breathing. Thus patient breathing is synchronised with the ventilation by the ventilator. The patient will be allowed to breathe, and when it is unable to breathe, the ventilator will provide breathing. The patient's bpm is set as per requirement, and this breathing is guaranteed to the patient, but this consists of partially the patient breathing and partially by the ventilator.
- The ventilator provides the patient with a pre-set number of breaths/minute at a specified tidal volume and FiO_2
 - In between the ventilator-delivered breaths, the patient can breathe spontaneously at his tidal volume and rate with no assistance from the ventilator.
 - However, unlike the A/C mode, any breaths taken above the set rate are spontaneous breaths taken through the ventilator circuit.
 - The tidal volume of these breaths can vary drastically from the tidal volume set on the ventilator because the patient's spontaneous effort determines the tidal volume.
 - Adding pressure support during spontaneous breaths can minimise the risk of increased work of breathing.
 - The ventilator's breaths are synchronised with the patient spontaneous breathing. (no fighting)
 - It is used to wean the patient from the mechanical ventilator.

- Weaning is accomplished by gradually lowering the set rate and allowing the patient to assume more work

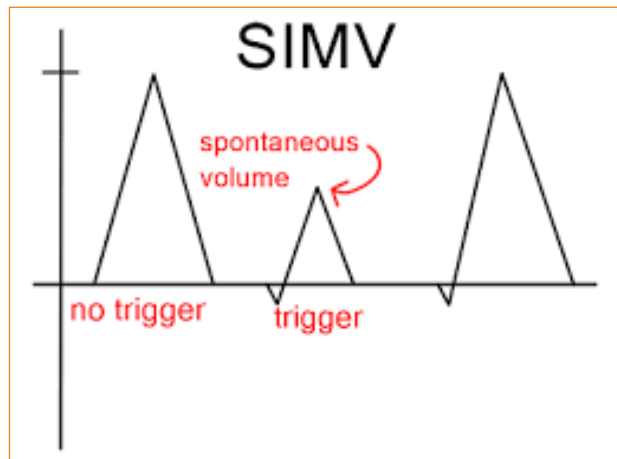


Fig. 4.3.12. SIMV Mode (source-criticalpractitioner.co.uk)

In the figure above, the 1st tidal volume is delivered by the ventilator as per the set Tidal Volume. The second one is the patient's spontaneous breathing. The third one is patient triggered and synchronised by the ventilator.

II. Pressure control modes

In this mode, the inspiration cycle maintains a pressure limit set by the machine. The volume may not be guaranteed, but the pressure will never exceed the ventilator's maximum pressure set. In pressure controlled mode, inspiration is terminated when a specific airway pressure has been reached. The ventilator delivers a pre-set pressure; once this pressure is achieved, end inspiration occurs.

- In pressure-controlled ventilation, the breathing gas flows under constant pressure into the lungs during the selected inspiratory time.
- The flow is highest at the beginning of inspiration (i.e. when the volume is lowest in the lungs).
- As the pressure is constant, the flow is initially high and then decreases with increasing filling of the lungs.

III. Pressure support ventilation

The patient breathes spontaneously while the ventilator applies a pre-determined amount of positive pressure to the airways upon inspiration.

- Pressure support ventilation augments the patient's spontaneous breaths with a positive pressure boost during inspiration, i.e. assisting each spontaneous inspiration.
- It helps to overcome airway resistance and to reduce the work of breathing. Indicated for patients with small spontaneous tidal volume and complex to wean patients.
- The patient must initiate all pressure support breaths.
- Pressure support ventilation may be combined with other modes such as SIMV or used alone for a spontaneously breathing patient.

IV. CPAP- Continuous Positive Airway Pressure

- Constant positive airway pressure is used during spontaneous breathing. Thus, the patient breathes with a continuous supply of air from the ventilator.
- CPAP allows the nurse to observe the ability of the patient to breathe spontaneously while still on the ventilator.
- CPAP can be used for intubated and non intubated patients.
- It may be used as a weaning mode and for nocturnal ventilation (nasal or mask CPAP). There are separate Ventilators with just CPAP Mode and are known as CPAP Machines. It is used to support the patients with positive pressure to keep on breathing spontaneously.
- CPAP as a standalone unit provides a non-invasive form of mechanical ventilation provided by a nasal mask or nasal prongs, or a full-face mask.

V. BiPAP- Bi-level Positive Airway Pressure

BiPAP is a non-invasive form of mechanical ventilation provided using a nasal mask or nasal prongs, or a full-face mask.

- The system allows the clinician to select two levels of positive-pressure support: An inspiratory pressure support level (referred to as IPAP)
- End expiratory pressure called EPAP (PEEP/CPAP level).
- Some Ventilators perform just BIPAP and CPAP functions and are known as

BIPAP Machines.

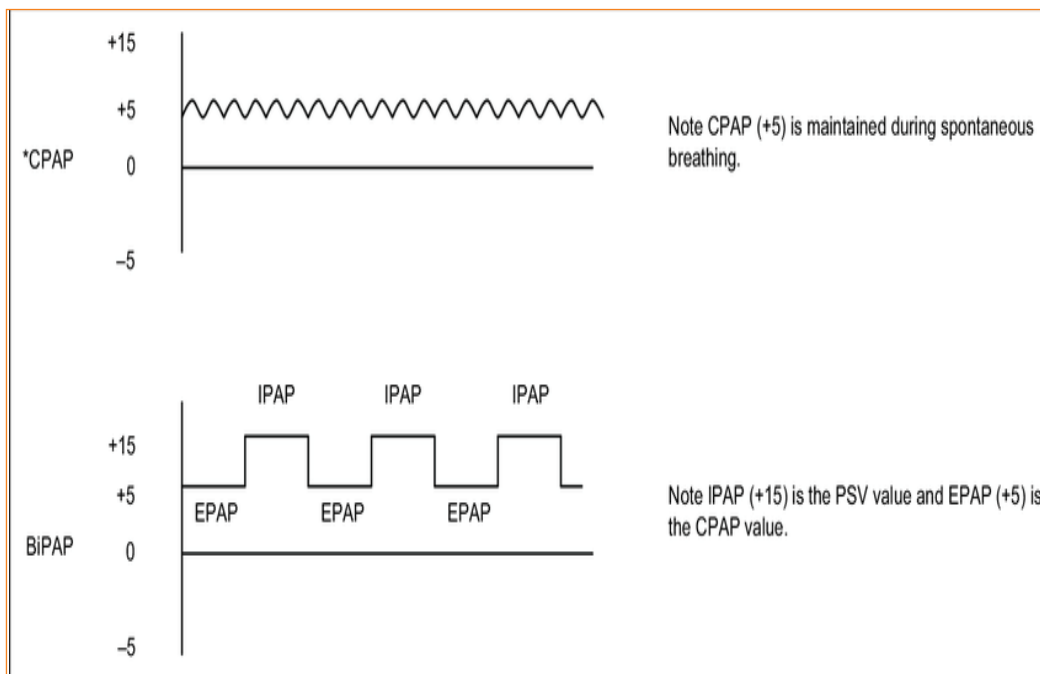


Fig. 4.3.13. BIPAP and CPAP Waveforms (Source uploaded by Michael J Cawley)

Youtube link for CPAP and BIPAP is <https://www.youtube.com/watch?v=WZRuOsJuYTY>

We will have a separate handbook for CPAP AND BIPAP Ventilation.

VI. High-frequency ventilation

In some advanced ventilators, this mode is present. High-frequency ventilators use small tidal volumes (1 to 3 mL/kg) at frequencies greater than 100 breaths/minute. The high-frequency ventilator accomplishes oxygenation by the diffusion of oxygen and carbon dioxide from high to low gradients of concentration

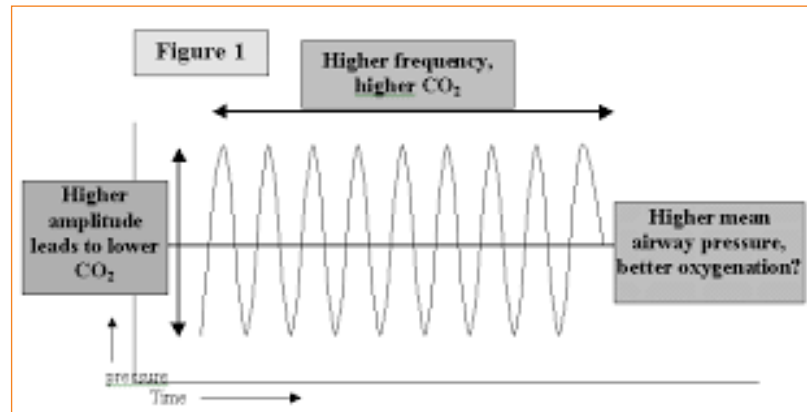


Fig. 4.3.14. High-Frequency Ventilator (Source slhd.nsw.gov.au)

Common Ventilator Settings:- youtube link

<https://www.respiratorytherapyzone.com/ventilator-settings/>

13. Common Ventilator Settings

To give a brief definition, ventilator settings are the controls on a mechanical ventilator that can be set or adjusted to determine the amount of support delivered to the patient.

Support can be provided in the form of ventilation and oxygenation. You must understand how each setting can be adjusted to provide more or less of each type of support for the patient.

- I. **FiO₂- Fraction of Inspired Oxygen-** The per cent of oxygen concentration that the patient receives from the ventilator. (Between 21% & 100%) (room air has 21% oxygen content).

Initially, a patient is placed on a high level of FIO₂ (60% or higher). Subsequent changes in FIO₂ are based on ABGs and the SaO₂.

- II. **Tidal Volume-TV-** The volume of air delivered to a patient during a ventilator breath. This is also the amount of air inspired and expired with each breath. The usual book selected is between 5 to 15 ml/ kg body weight).

- III. **Flow rate-FR-** This is the rate at which the air is delivered to the patient and is expressed in Liters/Minute(lpm). There is a flow sensor at the exhalation valve, which senses the flow. The inspiratory flow rate is a rate that controls how fast the ventilator delivers a tidal volume. The setting can be adjusted depending on the patient's inspiratory demands.

The average inspiratory flow rate should be set at around 60 L/min. With that said, most ventilators can deliver up to 120 L/min if a patient needs a prolonged expiratory time. This is necessary when obstructive diseases are present.

If the flow rate is set too low, it could result in patient-ventilator mismatch and an increased work of breathing. Conversely, if the flow rate is set too high, it could decrease mean airway pressures.

IV. Frequency /Respiration Rate/ Breathing rate-f- The number of breaths The ventilator will deliver in one minute and is represented as bpm. This is generally set at 10-16 bpm for Adults and 30-60 bpm for Pediatric and Neonates. Therefore, the total respiratory rates displayed will be the Ventilator Set rate plus the patient's Spontaneous breathing rate.

V. Minute Volume-MV- This is the amount of air delivered to the patient in one minute.
MV=TV*f

VI. PEEP or Positive End Expiratory Pressure- 5-10 cm H2O- PEEP is a positive pressure that is delivered during the expiratory phase of the breathing cycle to prevent the closure of alveoli and allow increased time for oxygen exchange to occur.

It's typically indicated in patients with refractory hypoxemia and those who have not responded well to a high FiO₂.

VII. I: E Ratio- Ti: Te- Set at 1:2

VIII. Pressure Limit- 10-25 cm H2O

IX. Trigger sensitivity

The sensitivity control determines how much effort (negative pressure) the patient must generate to trigger a breath from the machine. The standard sensitivity setting should be set between -1 and -2 cmH₂O. If the sensitivity is set too high, it will cause the ventilator to initiate auto-triggering and increase the total frequency of breaths. Conversely, if it's set too low, the patient could have difficulty creating a breath.

14. Ventilator Alarms

A ventilator alarm is a safety mechanism on a mechanical ventilator that uses set parameters to provide alerts whenever there is a potential problem related to the patient-ventilator interaction.

I. Common Ventilator Alarms Include:

- The high-Pressure alarm is triggered when ventilation resistance is high. It is caused by inappropriate ventilator settings, excessive tidal volume etc.; circuit problems like fluid accumulation in the circuit/filter, kinking of circuits; ET tube obstruction due to obstruction, kinking, biting; increased airway resistance due to bronchospasm, decreased respiratory system compliance, reduced chest wall compliance.

Air leaks trigger o Low-Pressure alarm. It is caused by patient disconnection, circuit leaks, exhaled valve leaks- leaking valves or improperly connected valves, airway leaks caused by inadequate cuff inflation, leak in a pilot balloon, rupture of cuff/tube.

- Low Expired Volume
- High Frequency

- Apnea alarm is activated when no exhalation is detected for a selected period (e.g. 20 ms). It can be accompanied by low pressure/ low minute volume alarms. It is caused by patient apnea, patient disconnection, system leaks, inadequate machine sensitivity; inappropriate apnea parameters settings,
- High PEEP
- Low PEEP

Sigh- Sigh are the volume of air that is delivered 1.5 to 2 times the tidal volume of 6 to Ten times per hour to prevent atelectasis.

15. Initial ventilator settings

Once it has been determined that mechanical ventilation is indicated for a patient who needs help with oxygenation and/or ventilation, you must know how to input the initial settings correctly.

Each mechanical ventilator machine is different, so be sure to abide by the guidelines provided by the manufacturer. However, here are some general guidelines that you can use when determining the initial ventilator settings.

- **Mode** – Any operational mode will work when setting up the initial ventilator settings! So don't get too caught up in deciding on the right way. Just as a reminder, you can select A/C if they need full support or SIMV if they only need partial help.
- **Tidal Volume** – The initial tidal volume setting should be 5 – 10 mL/kg of the patient's ideal body weight (IBW).
- **Frequency** – The initial frequency setting should be 10 – 20 breaths/min.
- **FiO₂** – The initial FiO₂ setting should be 30 – 60% unless the patient was previously receiving a higher percentage of oxygen before intubation. Then you would use that previous FiO₂. Strive to provide the lowest concentration of oxygen that's possible to maintain a normal PaO₂. An FiO₂ up to 100% as an initial setting is appropriate for patients with severe oxygenation issues.
- **Flow Rate** – The initial flow setting should be 40 – 60 L/min.
- **E Ratio** – The initial I: E ratio setting should be 1:2
- **Sensitivity** – The initial sensitivity setting should be between -1 and -2 cmH₂O.
- **PEEP** – The initial PEEP setting should be 4 – 6 cmH₂O

16. Cycling of a ventilator

In a Ventilator, Cycling means causing the Ventilator cycle or changing from one phase of the respiratory process to another. It can be Volume, Pressure, Time or Flow cycled ventilator.

17. Pressure cycled ventilator

The ventilator pushes the air until a pre-set pressure is reached. It is used for short periods, such as post-anaesthesia care unit and respiration therapy.

18. Volume cycled ventilator

The ventilator pushes the air into the lungs until a pre-set volume is delivered.

19. Time cycled ventilator

The ventilator pushes the air into the lungs till a pre-set time is reached. It is primarily used in paediatrics and neonatal ventilation.

20. Installation and operation of ventilator - read the manual supplied with the machine to install and operate the ventilator properly.**i. Connecting the power supply.**

Use a wall supply with an appropriate power plug. Check the ground. If the ground is not working, connect a separate ground wire for the ventilator. All the ventilators will have a ground connection pin which should be connected to the ground. Check the AC output of the power plug is 220-240 V.

ii. Connecting the Air and Oxygen sources

The manufacturer will supply two high-pressure hoses. If it is not supplied, please ask them to supply one. One end will be connected to the appropriate inlets at the back of the ventilator, and the other end will be to the appropriate source. It will be mostly compressor and at times from wall outlet and for oxygen or compressed air cylinders for air. It will be mainly compressed oxygen is available from a wall outlet, or sometimes it is from cylinders.



Fig. 4.3.15. High-Pressure Hose for Compressed Air outlet. This is usually coloured Yellow. (Image source Smith Medical)



Fig. 4.3.16. High-pressure Hose for Oxygen outlet. This is usually coloured green. (Image source Zoll Webstore)



Fig. 4.3.17. Connect appropriate connectors from one of these connectors.

There will be two inlets at the back of the ventilator, one for compressed air and the other for compressed oxygen if the air oxygen blender is inside the ventilator. If the blender is outside the ventilator, the hoses should be appropriately connected to the inlets in the blender



Fig. 4.3.18. Air/ Oxygen Blender (Image source- IndiaMART)



Fig. 4.3.19. Back View of a Ventilator with Oxygen and Air Hose connection

iii. Assembling the humidifier and patient circuits and connecting them

The patient circuit is assembled and connected to the humidifier. One end of the humidifier goes to the ventilator input port, and the other end goes to the tubing connected to the lungs. The outlet from the lungs is connected to the exhalation port for exhaling the air. Refer to the descriptions above to see the connections.

Youtube links

1. Understanding the patient circuit in a ventilator - <https://www.youtube.com/watch?v=jBuopUg5-88>
2. Assembling a patient circuit for a ventilator - <https://www.youtube.com/watch?v=VW-JyDKnHGk>
3. Understanding the parts in a ventilator humidifier - <https://www.youtube.com/watch?v=yGvN7xg3Xlo>
4. Essential components in a Ventilator - <https://www.youtube.com/watch?v=aBrw1JcN31I>

- iv. Connect a Test Lung of 500 ml



Fig. 4.3.20. Test Lung- source Draeger (Source- ECRI-Guidance [Health Devices Sep-Oct 1998;27(9-10):33-4])

- v. Switch on the ventilator.
- vi. Do the following minimal tests

21. Minimum requirements for ventilator testing

A. Verifying ventilator operation

All ventilators should be tested after each use to verify performance before the unit is used for another patient. Ideally, a complete operational verification procedure, established by the facility and usually based on the manufacturer's recommendations, will be performed each time. These procedures should be described in a facility's policies and procedures.

There is, however, an interim solution for instances when the staff has insufficient time to complete an entire operational verification procedure on an older unit. The team can instead test only those features that will be or are likely to be required for the patient about to be ventilated. This will ensure the patient's safety while reducing testing time to under 20 minutes—or even less for ventilators with a limited number of features. A complete operational verification procedure can then be performed at the next opportunity.

B. Minimum Ventilator Tests

The minimum tests that should be performed and documented to ensure safe use are listed below. It is important to remember that this list is a stopgap measure and should be used only when necessary, not as a routine procedure. Users can substitute equivalent tests where appropriate and delete those tests for which a ventilator does not have corresponding features or accessories.

- **Battery test/power loss alarm.** With the unit turned on, momentarily disconnect and then reconnect the power source while the ventilator is not used on a patient. The machine's battery backup and its disconnection alarms should function appropriately.
- **Lamp test.** Test lamps according to the manufacturer's procedures.
- **Audible and visual alarms.** Disconnect the oxygen supply hose and, separately, the air supply hose (if used). Appropriate alarm(s) should result. Reconnect the hoses. Using a test lung, check for the proper activation of all audible and visual alarms. Specifically, momentarily disconnect the circuit to test the low pressure, low exhaled volume, and apnea alarms. Occlude the circuit to test the high-pressure alarm. Or, as an alternative to these steps, momentarily change the alarm setting parameter to trigger the alarm under test (e.g., FiO₂ alarm). The inverse inspiratory: expiratory (I: E) ratio alarm can be verified by momentarily adjusting peak flow to create an inverse-ratio condition.
- **Proximal airway pressure gauge and positive end-expiratory pressure (PEEP) control.** Set the PEEP level required for the patient. The manometer reading should cycle and return to the appropriate baseline (± 1 cm H₂O) at the end of each breath delivered to the test lung. First, check the manometer zero (± 1 cm H₂O) by momentarily disconnecting the circuit's pressure line or inspiratory limb.
- **Leak tests.** Perform either or both of these tests as the machine allows:

Occlude the patient connection, set the pressure limit and tidal volume to their maximum levels and the peak flow and rate to their minimum levels, and initiate a breath. The manometer should reach the set maximum level, and the high-pressure alarm should activate.

Set the inspiratory pause to 2 sec, if possible, and set the PEEP level to 0. When the ventilator cycles, observe the pressure during the pause (i.e., the plateau pressure); the amount of drift should not exceed $\pm 10\%$ of the plateau pressure.
- **Modes.** Set the mode to be used for the patient. Using a test lung, verify proper operation for that mode as the ventilator cycles.
- **Ventilator rate (and rate display).** Count the number of breaths delivered during a convenient interval, timed using a clock or watch with a second hand. The measured rate should be within ± 1 breath per minute of the rate-setting (and the rate display, if so equipped).
- **Volume (and volume display)—tidal volume, sigh volume,* and minute volume.** Use an external device such as a Wright respirometer or equivalent to measuring exhaled volume independently. Connect a test lung to the circuit, cycle the machine, and compare the measured exhaled tidal volume and minute volume to their respective settings. Manually trigger a sigh of breath, if possible, and compare the measured value to the setting. All measurements should be within $\pm 5\%$ of the settings (and displays, if so equipped).
- **Sensitivity.** Put the ventilator into an assist mode. Squeeze and release the test lung; an inspiration should result when the airway pressure drops to the intended sensitivity level.
- **Oxygen calibration.** Expose the oxygen monitor (or analyser) used with the ventilator to room air, wall oxygen (100%), and calibrate it. Final readings should be within $\pm 2\%$. Set the oxygen concentration to be delivered by the ventilator. Verify this concentration ($\pm 2\%$ FiO₂) using the oxygen monitor (or analyser).

- **Nebuliser (if present).*** Turn the ventilator's nebuliser on, and verify that flow is produced at the nebuliser output port during each inspiratory cycle.
- **Filters.** Ensure that a high-efficiency particulate-air (HEPA) filter is present on the main inspiratory line.
- **Remote alarm operation (if present).*** Set up a convenient alarm condition (e.g., power loss, high pressure), and verify that appropriate alarm notification occurs at the remote location.

* Perform only if this feature or accessory is used to treat the patient about to be ventilated.

C. Quick testing of the ventilator before every use:

1. Attach the Calibrated Test Lung of 1 litre with Max Volume Set at 650 ml
2. Switch ON and Quick Check Test Parameter set as below:
 - a) Mode- Asst Control/CMV
 - b) TV- 500 ml
 - c) RR- 15 bpm
 - d) Ti= 1.3 Sec
 - e) PEEP= 5 cm H₂O
 - f) FiO₂= 60%
 - g) Waveform- Square
3.
 - i. Check the PIP display. It should be 27 cm H₂O+/-2
 - ii. Check the FiO₂ display- It should be 60%+/-3%

D. Common problems

Ventilators are a small group of life support devices that, if it fails, death will occur unless there is intervention by staff and a replacement device available. In addition, the lungs are a very delicate tissue that a poorly calibrated ventilator can quickly destroy. With that knowledge, it is paramount that the ventilators are kept in top working condition. However, the dangers posed by a lack of ventilation combined with the risks posed by a poorly calibrated ventilator places the Biomedical Engineer in a challenging position. On the one hand, without specific training on the ventilator at hand, you may endanger the patient by working on the device. On the other hand, with no substitute ventilator available, you will indeed jeopardise the patient if you do not work on the device.

Fortunately, ventilators are very reliable devices. The most common problems are

1. User error- Ensure that the user manuals are available and used as per the manual's instructions.
2. The power supply and other external problems- If the problem is related to the power supply to the ventilator or a simple mechanical problem (such as the wheels, lid or tubing arm), the repair is straightforward.
3. Filtration -Identify the filters and clean them or replace them as per instructions in the manual.
4. The tubing and associated parts. The most common problem with the tubing is that disposable tubing is being reused. As a result, the nonrebreathing valve may break, or the tubing may leak. Leaks can be fixed with epoxy or a silicone sealant in most cases. The non-rebreathing valve cannot be repaired in general. However, it may be possible to adapt the non-rebreathing valve from one leaking circuit to another circuit that doesn't leak but has a non-rebreathing problem. If the problem is not one of the problems described above, it is probably better not to fix the ventilator without specialised training. However, your decision should be made in careful consultation with the physicians.

Discuss the risks to the patient if you do not work on the machine and what the chances are to the patient if you work on the device and it accidentally over pressurises or under-ventilates the patient. Ultimately the decision is the physicians, and you must follow his instructions.

E. Suggested minimal testing -source WHO

Suppose your repair has been a simple mechanical fix or the power supply. Then you can release the machine to the floor for use with only simple testing. The simple testing should measure the breathing rate (within a few breaths per minute of the setting over the entire range) and calculate the inspiratory/expiratory ratio (within approximately 20% of the set ratio). Test the pressure limit by partially occluding the connection to the patient with your hand. The pressure limit light should flash. If the ventilator is likely to be used in an intensive care unit, it will likely be used to wean patients. In this case, check that the assisted mode is working. After conducting the simple tests, you can connect the ventilator to yourself. Do this by gently placing the patient tube in your mouth (ensuring that you can easily remove it if there is a problem). As long as you breathe in the assisted mode, the device will deliver gas only when you inhale. Then, remove the tube from your mouth. The device should take over in a controlled breathing fashion. Place the tube back in your mouth and breathe normally, and the device should automatically return to assisted mode. If your repair has been on the breathing circuit, you only need to test the tubing and the nonrebreathing valve. The tubing should be leak-free (occlude one end and blow hard into the other end with the tube submerged in water. There should be no bubbles. The non-rebreathing valve is a one-way valve. If it does not connect to the ventilator, you can check it by simply blowing into the patient connection end and ensuring that the air goes down the expiratory tube. Then suck from the patient end and make sure the air is coming in from the inspiratory tubing. If the nonrebreathing valve has a connection to the ventilator, then you will have to operate the ventilator. Check that the gas flows down the correct tubing by occluding the other tubing by squeezing the appropriate tubing and ensuring no change in delivering or collecting air. If your repair has been anything more than the power supply, tubing or mechanical, then you must complete more tests. Be sure to discuss your limited ability to test the machine with the physician and the potential dangers to his patients before conducting any repairs beyond the power supply, tubing or simple mechanical repairs; however, if you and the physician determine that you must attempt a repair; complete at least two more tests before releasing the ventilator: the pressure limit and the delivered volume. Both the volume and pressure are typically tested with dedicated equipment you will likely not have. However, they can be approximated.

The pressure limit is adequately tested by connecting the patient tubing to a u-shaped bend of tubing filled with water. The ventilator should push the far end of the column of water to the height of the pressure setting and then indicate a pressure limit alarm. For example, if the pressure limit is set to 25 cm of water, the top of the water column away from the ventilator should be 25 cm of water higher than the top of the water column near the ventilator. Test several settings of the pressure limit. Discuss the accuracy of the limit test with the physician. The volume can be approximated by connecting a balloon to the patient tubing. It would help if you calibrated the balloon to the volume before you begin. The easiest way to do this is to fill the balloon with a known volume of water. Make two marks on the balloon a fixed distance apart, indicating the volume next to the mark. Repeat this procedure for several volumes. Now, when the balloon expands to the stated volume, the marks should be your set distance apart. To use your calibrated balloon, clamp off the balloon at the end of the inspiratory cycle. Test several settings of the volume and discuss the accuracy of the test with the physician.

22. Ventilator preventive maintenance

DAILY	
Cleaning	Remove any dust, dirt, water, waste matter, tape and paper
Audiovisual Checks	If any leak is audible, check with a soapy solution. Check all moving parts move freely; all holes are unblocked. Check all seals, connectors, adapters, and parts are tight.
Function checks	Check all the functions and set them right if there is a problem. After checks, depressurise the system and replace all caps and covers.

Table 4.3.5. Daily Maintenance Ventilator

Weekly	
Cleaning	Clean inside and outside with damp clothes and dry off. Remove dirt from wheels and other moving parts.
Audiovisual Checks	Check connections for leaks with the soap solution and dry off. Check all fittings and valves for proper assembly. Replace and deteriorated tubing and hoses. If seal, plug, sockets are damaged, replace them.
Function checks	Check all the functions and set them right if there is a problem. After checks, depressurise the system and replace all caps and covers.
Every Six Months	
Full Ventilator Check required by Biomedical Engineer.	

Table 4.3.6. Weekly Maintenance Ventilator

23. Calibration of ventilator - Tools and parts required

1. Large jug
2. Transparent rubber tube, atleast 40cm in length
3. Rubber or latex glove
4. Balloon
5. Syringe, largest available
6. String, atleast 1 m
7. Tape measure or ruler
8. Marker
9. Watch
10. Pen or pencil
11. Graduated cylinder (1L)
12. Large tub

A. Introduction

A ventilator is a machine used to assist patients in breathing. A ventilator can breathe for patients entirely. A ventilator may include a pump or compressed gases to provide gas to the patient.

There are three basic modes of ventilation: volume limited, pressure limited, and timed cycle.

- a. Volume limited ventilation delivers a pre-determined volume of gas to the patient.
- b. Pressure limited ventilation delivers gas until a pre-determined pressure is reached in the lungs.
- c. Timed cycle ventilation delivers gas based on a pre-determined volume, pressure, respiration rate, and inspiratory/expiratory ratio. In timed cycle ventilation, the pre-determined volume is delivered at the respiration rate as long as the pre-determined pressure is not exceeded. A ventilator uses a non-rebreathing valve to prevent the patient from breathing his expired gas. This valve opens when the patient expires gas.

B. Identification and diagnosis

Calibration of ventilators does not require a diagnosis. Calibrate each ventilator every six months as part of your planned preventative maintenance.

I. Procedure

Before a ventilator is placed into service, it should be calibrated to ensure patient safety. Three outputs must be calibrated: pressure, volume, and flow.

Pressure Calibration Steps



1. Construct a manometer to measure pressure in centimetres of H₂O.
 - a. Use a sizeable non-inflatable jug as the reservoir. Most water jugs will work.
 - b. Fill the jug half-full with water.
 - c. Insert the patient output from the ventilator into the plastic jug. Also, insert one end of the clear plastic tubing into the plastic jar. The end of the plastic tube should be near the bottom.
 - d. Seal the tubes with latex gloves and tape. Ensure that no air can escape from the jug opening.
2. Set the pressure limit on the ventilator. Record this pressure in Table 1 below.
3. Hold the clear plastic tubing straight up. Use a tape measure to measure the peak height of the water in cm H₂O. Measure from the water level in the jug to the maximum height reached in the clear plastic tubing. Record this measurement in the table below. The height of the water is the pressure.
4. Repeat Steps 2-3 for four settings of pressure.
5. To determine if the ventilator is accurate enough, show your table to the physician that uses the ventilator. The set and measured reading should match

Set pressure- Step-2	Measured Pressure- Step-3

Table 4.3.7. The set and measured reading format

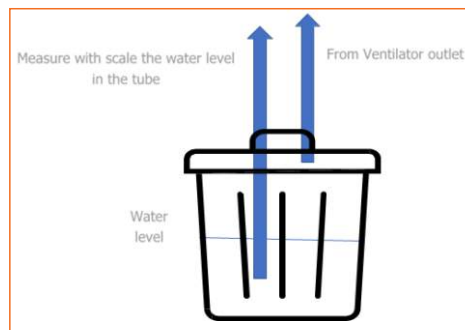


Fig. 4.3.21. Calibrating the pressure level.

Calibrating the volume: source <https://build-a-vent.org/overview/calibration> and WHO

1. Ensure that the patient output tube is at least 80 cm long.
2. Set the tidal volume to 500 ml which is the average tidal volume for adults.
3. Fill a plastic tub with water. The tub should be big enough to accommodate a 1 litre graduated cylinder.

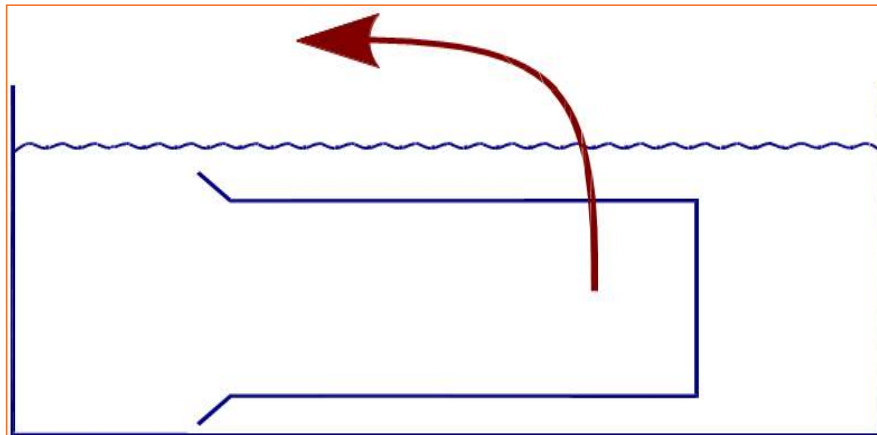


Fig. 4.3.22. 1 liter graduated cylinder.

4. Then, turn the measuring cylinder up by 90 degrees, so it sits up-side-down in the basin as below:
5. Connect a tube to the output of the ventilator (typically, the tube leading to the patient would be connected here). The other end of the tube is placed within the measuring cylinder.

iii. **Lift the measuring cylinder close to the water level, as fig below.**

Note down the exact level of water in the measuring cylinder (if it is not filled with water).

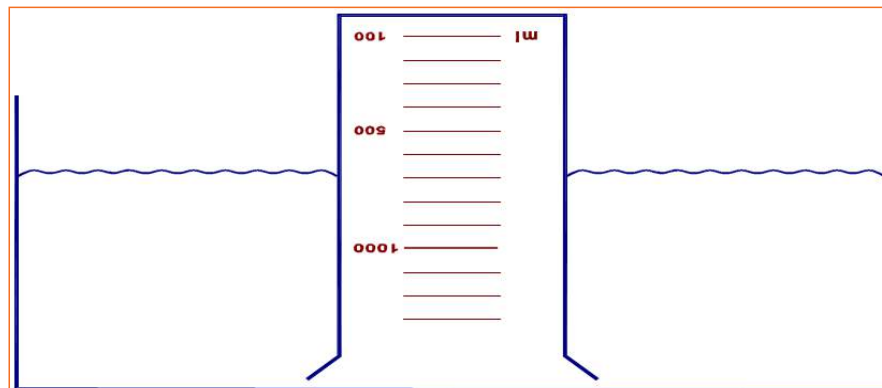


Fig. 4.3.23. Volume Calibration- tub with 1000 ml graduating cylinder

6. Turn ON the Ventilator. Allow the ventilator to deliver 01 breath. The top of the graduated cylinder should fill up with air, as shown in the figure below. Now stop the ventilator. Read the air level that has displaced the water level. This is the tidal volume. Repeat the process and take four readings and tabulate as in table-2 below

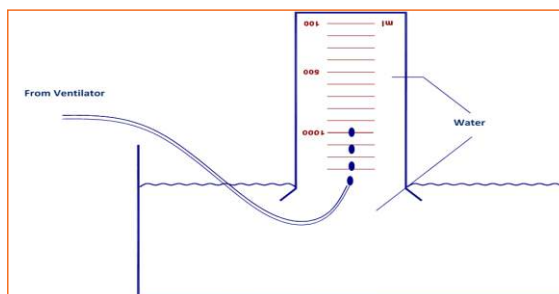


Fig. 4.3.24. Measuring cylinder

Set Tida Volume in the Ventilator	Measured Tidal Volume
400 ml	
400 ml	
400 ml	
500 ml	
500 ml	
500 ml	
600 ml	
600 ml	
600 ml	

Table 4.3.8. Volume Calibration

4.3.3.2 BIPAP and CPA

Introduction CPAP and BIPAP module.

Definitions

CPAP and BIPAP Machines are used to ventilate the patient in a Non Invasive manner. Thus, the ventilation being used is known as Non-Invasive Ventilation. Earlier, we used two separate CPAP and BIPAP but knew a day BIPAP machines provide for CPAP Mode. Thus, we will discuss only BIPAP machines and will cover the CPAP in the mode.

Parts of a BIPAP Ventilator- Philips A40 is a famous BIPAP Machine, and the commonly used parts are as below.

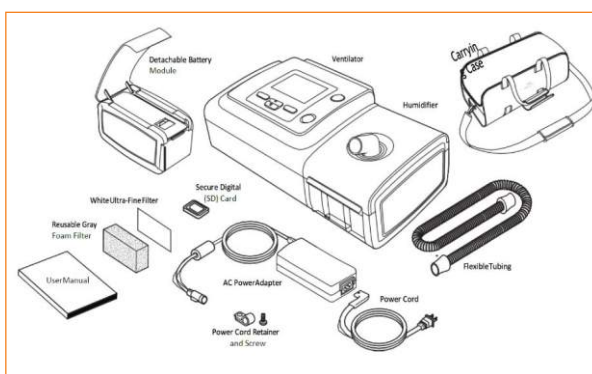


Fig. 4.3.25. Parts of a BIPAP Ventilator- Philips A40

The **BiPAP A40** system may include the following components. In addition, some features are optional accessories that may not be packaged with the device.

YouTube link- <https://www.youtube.com/watch?v=IhKSkfUqqyQ> Source- Philips A40- User Manual

Where and when do we use a BIPAP machine:

The BIPAP machine is intended to provide invasive and non-invasive ventilatory support to treat adult and pediatric patients weighing over 10 kg (22 lbs) with Obstructive Sleep Apnea (OSA), Respiratory Insufficiency, or Respiratory Failure. It is intended to be used in the home, institutional/ hospital, and portable applications such as wheelchairs and gurneys. It is not intended to be used as a transport ventilator and is not designed for life support.

Overview of a BIPAP machine:

The BiPAP ventilator can provide non-invasive or invasive ventilation, but it is frequently used to provide non-invasive ventilation. The device supports patient breathing by supplying pressurized air through a patient circuit. It senses the patient's breathing effort by monitoring airflow in the patient circuit and adjusts its output to assist in inhalation and exhalation. This therapy is known as Bi-level ventilation.

Bi-level ventilation provides a higher pressure, known as IPAP (Inspiratory Positive Airway Pressure) when you inhale, and a lower pressure, known as EPAP (Expiratory Positive Airway Pressure), when you exhale. The higher pressure makes it easier for you to inhale, and the lower pressure makes it easier for you to exhale.

The device can also provide a single pressure level, known as CPAP (Continuous Positive Airway Pressure).

The ventilator can be operated using AC power, a detachable battery, or an external battery. Several accessories are available for use with the device. The following figure illustrates some of the device connectors and features described in the table that follows.

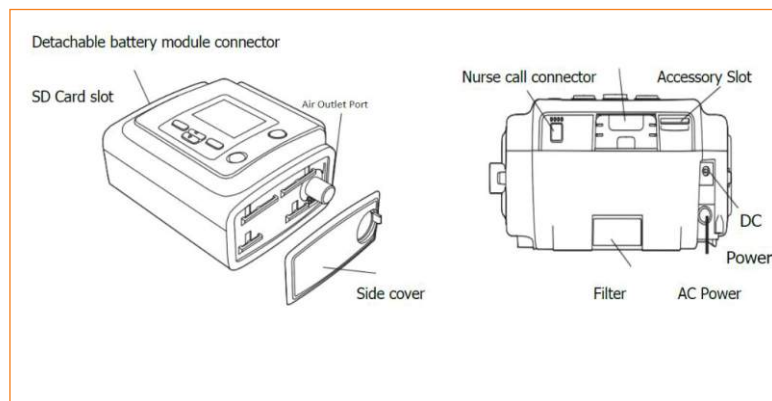


Fig. 4.3.26. BIPAP Machine – Front and Back View

Understanding BIPAP and CPAP- First, we will understand what is positive pressure.

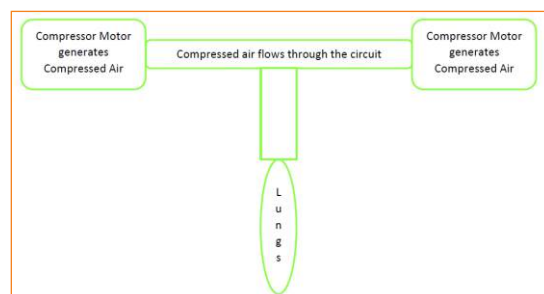


Fig. 4.3.27. Positive Airway Pressure Generation

The compressor motor generates positive airway pressure flow, which is passed through the breathing circuits. The exhalation valve is present at the end is partially opened. As a result, compressed air is forced through the lungs. The lungs inhale this positive air, and when it exhales, the air is forced out from the exhalation valve. The positive air pressure is known as continuous positive airway pressure. This pressure can be increased by closing the exhalation valve more, and similarly, the CPAP is decreased by opening the exhalation valve more.

Since there is a constant positive airway flow, this is known as continuous positive airway pressure.

This is what is done in CPAP machines.

In BIPAP, we continuously keep closing and opening the exhalation valves at the preset level to generate two pressure levels.

- IPAP- Inspiratory Positive Airway Pressure.
- EPAP- Expiratory Positive Airway Pressure.

In CPAP, A CPAP machine's compressor (motor) generates a continuous stream of pressurized air that travels through an air filter into a flexible tube. This tube delivers purified air into a mask that's sealed around your nose or mouth.

In BIPAP -The machine's compressor (motor) generates a continuous stream of pressurized air at two levels that travels through an air filter into a flexible tube. This tube delivers purified air into a mask that's sealed around your nose or mouth at two levels

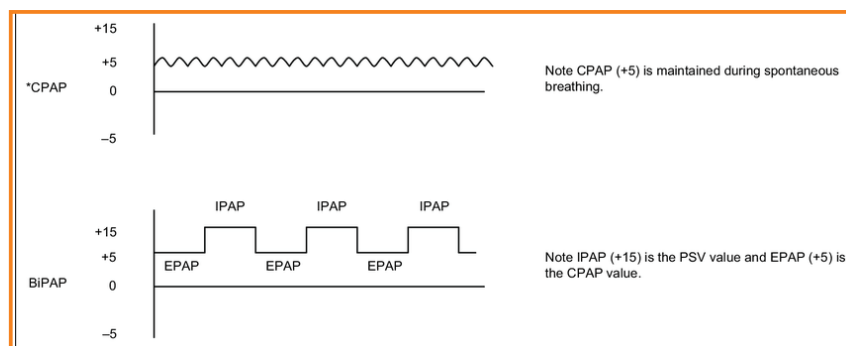


Fig. 4.3.28. CPAP and BIPAP (Source Reasearchgate)

What is the level of IPAP and EPAP?

1. IPAP- is kept at eight cmH₂O- Is increased when the carbon dioxide level in the blood increases (PaCO₂)
2. EPAP- is kept at 4 cm H₂O- Is increased when the O₂ Level in the blood (SPO₂) is decreased.
3. The difference between IPAP and EPAP is at least 4 cm H₂O.

When will you use the BIPAP?

The machine is always used in the Non-Invasive Model for spontaneously breathing patients. The patient is facing difficulty in breathing because of decreased Oxygen level(hypoxic) or increased carbon dioxide (hypercapnic), problem in weaning, Congestive Heart Failure (CHF) or Obesity Hypoventilation syndrome (OHS)

- For OHS and CHF, we will use CPAP Mode.
- In CPAP, there is only one pressure, and thus IPAP=EPAP

The setting of various modes

Spontaneous Mode-S

Whenever the patient is breathing spontaneously, we put the patient in automatic mode. But, first, we set the IPAP and EPAP levels. EPAP is similar to PEEP in ventilator, which is Positive End Expiratory Pressure.

Spontaneous and Time Mode-S/T

When the patient is breathing spontaneously, but sometimes the patient misses the breath, he becomes panic this mode is set. The settings here will be a backup rate so that when the patient is not breathing, the machine will trigger at a fixed timing and give the breathing.

Time Mode-T

This mode is used when the patient is not breathing independently, and the machine will deliver the set rates as per set time cycles.

PAP Mode-

This mode is used when the patient is breathing spontaneously but needs support.

When not to use the BIPAP/CPAP- Don't use the machine in the following cases:

1. If the patient is not cooperating and the patient is drowsy
2. If the patient has a pneumothorax
3. If the patient is having the risk of aspiration
4. If the patient has regurgitation
5. If the patient has facial trauma and burns.

In short, the patient is not cooperating because of any of the above conditions.

An advanced feature in some machines

AVAPS- Average Volume Assured Pressure Support (AVAPS) is a feature available in the S, S/T, and T modes. (In AVAPS-AE mode, the AVAPS feature is always enabled.) AVAPS helps patients maintain a tidal volume (VT) equal to or greater than the target tidal volume (Tidal Volume setting) by automatically controlling the pressure support (PS) provided to the patient. The AVAPS feature adjusts PS by varying the IPAP level between the IPAP Min and IPAP Max settings (or Pressure Support Min and Pressure Support Max in AVAPS-AE mode). In addition, AVAPS will retain the learned PS for the patient so that each time therapy is started; the PS will begin with the learned PS.

Ventilator Alarms - In the event of any malfunction, the ventilator will show audio/visual alarms. The following are the essential alarms:

Alarms (Patient alarms)

1. **Circuit disconnect alarm** - This is a high priority alarm. It occurs when the breathing circuit is disconnected or has a large leak. However, the device continues to operate. The alarm will automatically terminate when the circuit is reconnected, or the leak is fixed.
2. **Apnea alarm** - This is a high priority alarm. It occurs when the patient has not triggered a breath within the time specified in the apnea alarm setting. The device continues to operate. The alarm will automatically terminate when two consecutive patient breaths are detected that meet the apnea alarm time setting.

3. **High respiratory rate alarm** - This is a high priority alarm. It occurs when the respiratory rate is greater than the high respiratory rate alarm setting. The device continues to operate. The alarm will automatically terminate when the measured respiratory rate is less than the high respiratory rate alarm setting.
4. **Low minute ventilation alarm** - This alarm is a high priority alarm. It occurs when the patient's minute ventilation is less than the low minute ventilation alarm setting. The device continues to operate. The alarm will automatically terminate when the calculated minute ventilation is more excellent than the low minute ventilation alarm setting.
5. **Low tidal volume alarm** - This is a high priority alarm. It occurs when AVAPS is enabled (or in AVAPS-AE mode), and the ventilator cannot reach the target tidal volume setting. The device continues to operate. The alarm will automatically terminate when the target tidal volume is reached.

System Alarms

1. **Loss of power** - This occurred when a complete power failure occurred, and power was lost while the device provided therapy.
2. **Ventilator inoperative alarm** - This occurs when the ventilator detects an internal error or a condition that may affect therapy. The device will shut down if the cause of the failure indicates that the device cannot deliver treatment.
3. **Low battery alarm** - This is a high priority alarm that occurs in two stages. The medium priority alarm indicates that approximately 20 minutes of operation remain, and the high priority alarm suggests that less than 10 minutes of operation remain. Actual run time may be more or less than this and varies with battery age, environmental conditions, and therapy.
4. **Pressure regulation alarm** - This is a high priority alarm. It occurs when the ventilator cannot regulate pressure to an acceptable accuracy. The device continues to operate.
5. **Low circuit leak alarm** - This is a high priority alarm. It occurs when the device detects that the exhalation port is partially or fully occluded.
6. **High temperature alarm** - This is a high priority alarm. It occurs when the device is close to reaching a high-temperature limit. However, the device continues to operate.
7. **AC power disconnected alarm** - This is a medium priority alarm. The AC power source was lost, and the device has switched to DC (battery) power. The device continues to operate. The alarm terminates when the ventilator begins working from AC power again.
8. **Keypad stuck alarm** - This is a low priority alarm. It occurs when a key becomes lodged inside the case of the device.
9. **Replace detachable battery alarm** - The replace detachable battery alarm occurs when the detachable battery is nearing the end of its useful life, or a failure in the detachable battery that prevents it from charging or discharging has been detected. The alarm can be an informational message or a medium priority alarm. The device may continue to operate depending on the condition causing the alarm.
10. **Insert SD card alarm** - This is a low priority alarm. It occurs when a pulse oximeter is connected to the ventilator, and no SD card is inserted in the ventilator. As a result, the device continues to operate, but no oximeter data is recorded on an SD card.

11. **Card error info message** - This info message occurs when an unusable SD card is inserted into the ventilator. The device continues to operate, but data cannot be logged onto the SD card.
12. **Start on battery info message** - This info message indicates that the ventilator has started on battery power and no AC power is available. So the device operator should verify that this is what is wanted.
13. **Check AC power supply info message** - This info message occurs when the AC power input to the ventilator is incorrect. As a result, the device continues to operate, but therapy may not start.
14. **Battery disconnected info message** - This info message occurs when the battery is disconnected from the ventilator while, operating. However, the device continues to work on AC power.
15. **Battery discharging stopped due to temperature info message** - This info message occurs when the detachable battery becomes overheated while providing power for the device. The device continues to operate. The battery is not used, and the power source is switched to the next available power source.
16. **Battery not charging due to temperature info message** - This info message occurs when the detachable battery becomes too hot while charging or the device is too cold or hot in an environment before starting. Then, the device continues to operate. Battery charging stops until the battery cools or warms sufficiently.
17. **Battery not charging info message** - This info message occurs when the device has detected a condition that prevents the battery from accepting a charge. The device continues to operate. Battery charging stops.
18. **Battery depleted info message** - This info message occurs when the external battery is fully depleted. After that, the device continues to operate using the detachable battery if it is available.



Fig. 4.3.29. Ventilator Alarms

- 19. Detachable battery disconnected info message** - This info message occurs when the detachable battery power source is lost, and the device has switched to an alternate power source. If detachable battery power returns, the ventilator will beep, but no message will appear on display.

Installation

- 1. Installing the air filter** - The device uses a grey foam filter that is washable and reusable and a white ultra-fine filter that is disposable. The reusable filter screens out everyday household dust and pollen, while the ultra-fine filter provides complete filtration of excellent particles. The grey reusable filter must be in place at all times when the device is operating. The ultra-fine filter is recommended for people who are sensitive to tobacco smoke or other small particles. One reusable grey foam filter is supplied with your device. A disposable ultra-fine filter may also be included.

If your filter is not already installed when you receive the device, you must install the reusable grey foam filter before using the device. To install the filter(s):

- a. If you use the white disposable ultra-fine filter, insert it into the filter area first, with the smooth side facing toward the device.
- b. Insert the required grey foam filter into the filter area after the ultra-fine

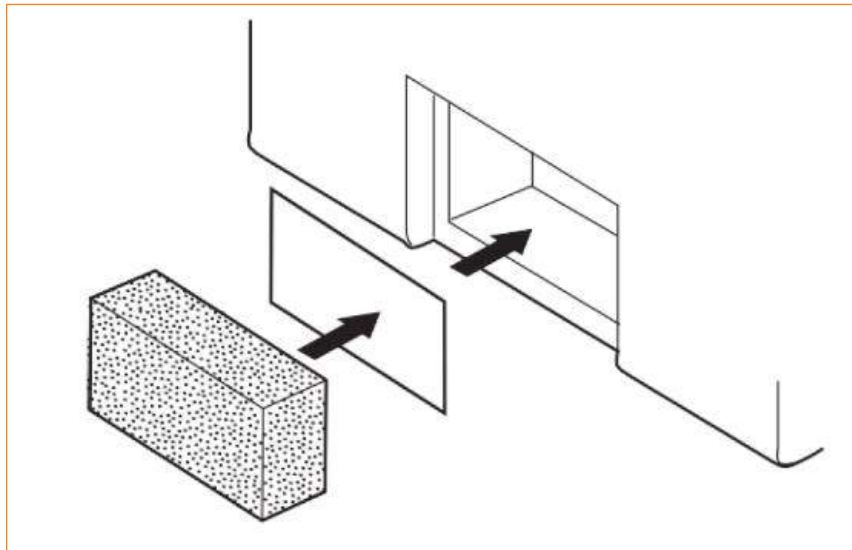


Fig. 4.3.30. Air Filter Working

2. Where to place the device

Place the device upright on a firm, flat surface somewhere within easy reach of where you will use it, at a level lower than your sleeping position. Ensure the filter area on the back of the device is not blocked by bedding, curtains, or other items. Air must flow freely around the device for the system to work correctly. Ensure the device is away from any heating or cooling equipment (e.g., forced air vents, radiators, or air conditioners).

3. Connecting the breathing circuit

You will need the following accessories to assemble the recommended circuit:

- Philips Respironics interface (nasal mask or full-face mask) with integrated exhalation port or Philips Respironics interface with a separate exhalation device (such as the Whisper Swivel II)
- Philips Respironics 22 mm or 15 mm flexible tubing
- Philips Respironics headgear (for the mask)

I. Connecting a non-invasive circuit

Complete the following steps to connect a non-invasive breathing circuit to the device:

1. Connect the flexible tubing to the air outlet on the side of the device.
 - a. If required, connect a bacteria filter to the device air outlet, and then connect the flexible tubing to the outlet of the bacteria filter.
 - b. When using the bacteria filter, the device performance may be affected. However, the device will remain functional and deliver therapy.
2. Connect the tubing to the mask. Refer to the instructions that came with your mask

ii. Connecting an invasive circuit

1. Connect the flexible tubing to the air outlet on the side of the device.
 - a. If required, connect a bacteria filter to the device air outlet, and then connect the flexible tubing to the outlet of the bacteria filter.
 - b. When using the bacteria filter, the device performance may be affected. However, the device will remain functional and deliver therapy.
2. If using, connect an invasive humidifier or Heat Moisture Exchange filter (HME). An invasive humidifier meeting EN ISO8185 is recommended.
3. Connect the flexible tubing to the humidifier or HME, and then place an exhalation device (such as the Whisper Swivel II) in line with the patient end.
4. Connect a trach adapter to the exhalation device if needed, and then attach the patient's tracheostomy tube.

4. Supplying power to the device

The device can operate on AC or DC power. The ventilator accesses power from potential sources in the following order:

- AC power
- External battery
- Detachable battery pack

I. Using AC power

- An AC power cord and power supply are included with the device.
- Plug the socket end of the power cord into the power supply.
- Plug the pronged end of the power cord into an electrical outlet that is not controlled by a wall switch.

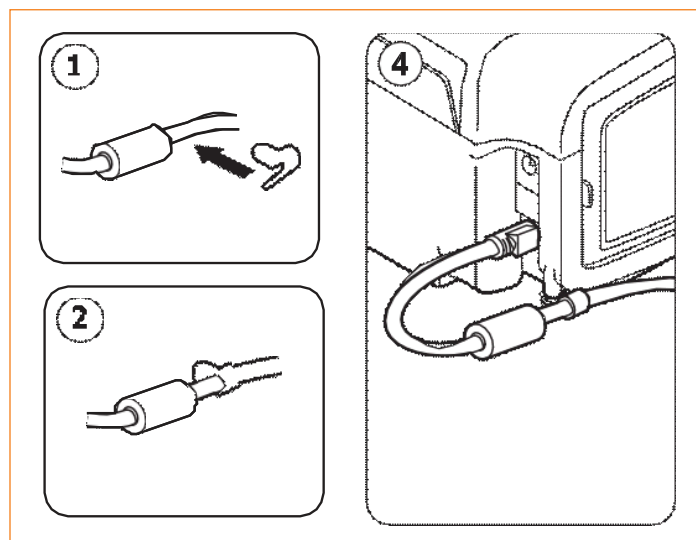


Fig. 4.3.31. AC Power Supply

Note: Some devices have a locking-type power connector. To avoid damage to the connector, when disconnecting the power cord, pull the connector at its base, not the cord, to disengage the lock.

II. Using DC power

You can operate the ventilator using an external battery or detachable battery pack.

a. External battery

The ventilator can operate from a 12 VDC lead-acid battery using the Philips Respironics external battery cable. This cable is pre-wired and properly terminated to ensure the safe connection of an external battery to the ventilator. Battery operating time depends on the characteristics of the battery and usage of the device.

Due to various factors, including battery chemistry, age, and use profile, the external battery capacity as shown on the device display is only an estimate of the actual remaining power.

Refer to the instructions supplied with the External Battery Cable for detailed information on how to operate the device using an external battery.

b. Detachable battery

Philips Respironics offers a detachable Lithium-Ion battery pack. You can connect the detachable battery to the device and recharge the battery using the Philips Respironics Detachable Battery Module. Refer to the instructions included with your Detachable Battery Pack and Detachable Battery Module for more information.

III. Device power source indicators

There are many power source indicators on the device and the display screen. These indicators are described in detail below.

a. AC Power indicators

When AC power is applied to the device and the airflow is off, the green AC LED indicator on the Start/Stop button lights. When AC power is used and the airflow is on, the white AC LED indicator on the Start/Stop button lights.

b. DC Power indicators

When DC power is applied to the device, battery symbols will appear on-screen to indicate the battery status. The detachable and external battery symbols will only appear on-screen if a detachable or external battery is attached to the device. The shading in the battery icon indicates the power remaining in the battery.

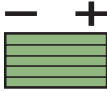

Battery	Symbol
External Battery	
Detachable Battery	

Fig. 4.3.32. Battery Symbols

Several DC power indicators will display on-screen to indicate which battery is in use (if applicable), if the batteries are low, charging, or discharged, etc.

The following table explains all DC Power indicators

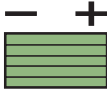


DC Power Indicator	Description
The battery in Use Indicator	A black box will appear around the battery that is in use. For instance, if the external battery is currently in use, the symbol  appears on-screen.
Green Fully Charged Battery Indicator	When a battery is charged to greater than 90% of its capacity, all of the bars in the battery symbol will appear in green.
Partially Charged Battery Indicator	When a battery symbol is partially charged, some of the bars in the battery symbol will appear in green, while others will be clear. For instance, if the external battery is 50% charged, the following character displays on-screen:
Yellow Low Battery Indicator (Medium Priority)	When the device detects that an in-use battery's charge is low (has approximately 20 minutes of charge left), the inside of the box surrounding the battery symbol turns yellow. (In addition, a medium priority alarm message will display indicating "Low Battery. The yellow indicator is for the last available battery source.
Red Low Battery Indicator	When the device detects that an in-use battery's charge is nearly depleted (has approximately 10 minutes of charge left), the inside of the box surrounding the battery symbol turns red. In addition, a high priority alarm message displays indicating "Low Battery." See Chapter 3 for more information. The red indicator is for the last available battery source.
Yellow Battery Recharging Symbol 	Whenever AC power is applied to the device, the detachable battery will recharge as needed. If the detachable battery is being recharged, the symbol  displays.

Table 4.3.9. DC Power indicators

Note: The detachable battery pack will automatically recharge whenever connected to the therapy device, and the device runs on ac power.

Cleaning and maintenance

I. Cleaning the ventilator

The ventilator's exterior surface and the detachable battery pack compartment and battery pack(if used) should be cleaned before and after each patient use and more often if needed.

1. Unplug the device and clean the front panel and exterior of the enclosure as needed using a clean cloth dampened with water and a mild detergent.
2. Inspect the device and tubing for damage after cleaning. Replace any damaged parts.
3. Allow the device to dry completely before plugging in the power cord.

II. Cleaning and disinfection for multiple users

Warning: If you use the device on multiple users, discard and replace the bacteria filter each time the device is used on a different person. When using the device on multiple users, complete the following steps to clean and disinfect the machine before each new user.

1. Unplug the device before disinfecting.
2. Disinfect the outside of the device only. Use a cloth with one of the following cleaning agents to clean the exterior of the device:
 - a. Hydrogen Peroxide, 3%
 - b. 91% Isopropyl Alcohol
 - c. Vinegar, 5% acidity
 - d. Water
 - e. Chlorine bleach, household, 5.25% sodium hypochlorite, 1-to-5-part reduction with water
 - f. DisCide Towelettes
3. Allow the device to dry completely before plugging in the power cord.

III. Cleaning and replacing the air inlet filter

Under normal usage, you should clean the grey foam filter at least once every two weeks and replace it with a new one every six months. The white ultra-fine filter is disposable and should be replaced after 30 nights of use sooner if it appears dirty. DO NOT clean the ultra-fine filter.

1. If the Device is operating, stop the airflow. Then, disconnect the device from the power source.
2. Remove the filter(s) from the enclosure by gently squeezing the filter in the centre and pulling it away from the device.
3. Examine the filter(s) for cleanliness and integrity.
4. Wash the grey foam filter in warm water with a mild detergent. Rinse thoroughly to remove all detergent residue.
5. Allow the filter to air dry completely before reinstalling it. If the foam filter is torn or damaged, replace it. Only Philips Respironics-supplied filters should be used as replacement filters.
6. If the white ultra-fine filter is dirty or torn, replace it.
7. Reinstall the filters, inserting the white ultra-fine filter first if applicable.

IV. Cleaning the reusable tubing

1. Clean the tubing daily.
2. Disconnect the flexible tubing from the device.
3. Gently wash the tubing in a solution of warm water and a mild detergent.
4. Rinse thoroughly and air dry

4.3.3.3 Oxygen Equipment (Concentrator & Cylinder)

Description of the device

An oxygen concentrator draws in room air, separates the oxygen from the other gases in the atmosphere and delivers the concentrated oxygen to the patient. When set at a rate of two to three litres per minute, the gas that is delivered by the concentrator is more than 90% oxygen. It is used for situations where a bottled gas supply is impractical or expensive and can be used by patients in the hospital or the home. Oxygen concentrator intended use is to provide supplemental low flow oxygen therapy for patients suffering from COPD, cardiovascular disease, and lung disorders. The oxygen concentrator is used in home type environments, homes, nursing homes, patient care facilities, etc.

How it works

Atmospheric air consists of approximately 80% nitrogen and 20% oxygen. An oxygen concentrator uses air as a source of oxygen by separating these two components. It utilizes the property of zeolite granules to absorb nitrogen from compressed air selectively. Atmospheric air is gathered, filtered and raised to a pressure of 20 pounds per square inch (psi) by a compressor. The compressed air is then introduced into one of the canisters containing zeolite granules, where nitrogen is selectively absorbed, leaving the residual oxygen available for patient use. After about 20 seconds, the compressed air supply is automatically diverted to the second canister, where the process is repeated, enabling the output of oxygen to continue uninterrupted. While the pressure in the second canister is at 20 psi, the pressure in the first canister is reduced to zero. This allows nitrogen to be released from the zeolite and returned to the atmosphere. The zeolite is then regenerated and ready for the next cycle. By alternating the pressure between the two canisters, a constant supply of oxygen is produced, and the zeolite is continually being regenerated. Individual units have an output of up to five litres per minute with an oxygen concentration of up to 95%.



Fig. 4.3.33. Working of Oxygen Concentrator with parts

Essential parts of the Oxygen Concentrator with their functions are:

1. Green Power light – illuminates when your concentrator is operating.
2. Power Switch – To switch ON and OFF the concentrator.
3. Flowmeter knob -To select the flow of oxygen.
4. Flowmeter.- To show the flow of the oxygen.
5. Circuit breaker – resets the unit after electrical overload shutdown.
6. Oxygen outlet – oxygen is dispersed through this port
7. OSD- Oxygen Sensing Device to monitor Oxygen output with Normal Oxygen (green) light; Low Oxygen (yellow) light; Red Service Required light –(when illuminated contact your technician).
8. Handgrip
9. Exhaust WARNING – When the device is used under extreme operating conditions, the temperature near the exhaust vents on the bottom of the unit may reach 145°F (63°C). Keep body parts a minimum of 32" away from this area.
10. Power cord and/or IEC power connector.
11. Line cord strap
12. Air filter – prevents dirt, dust, and lint from entering your unit.
13. Oxygen Outlet Port: The concentrator is equipped with an auxiliary oxygen port that can fill oxygen cylinders with a cylinder filling device designed to use oxygen from a concentrator to fill a cylinder.
14. Circuit breaker- Is provided for disconnection on any short-circuiting.

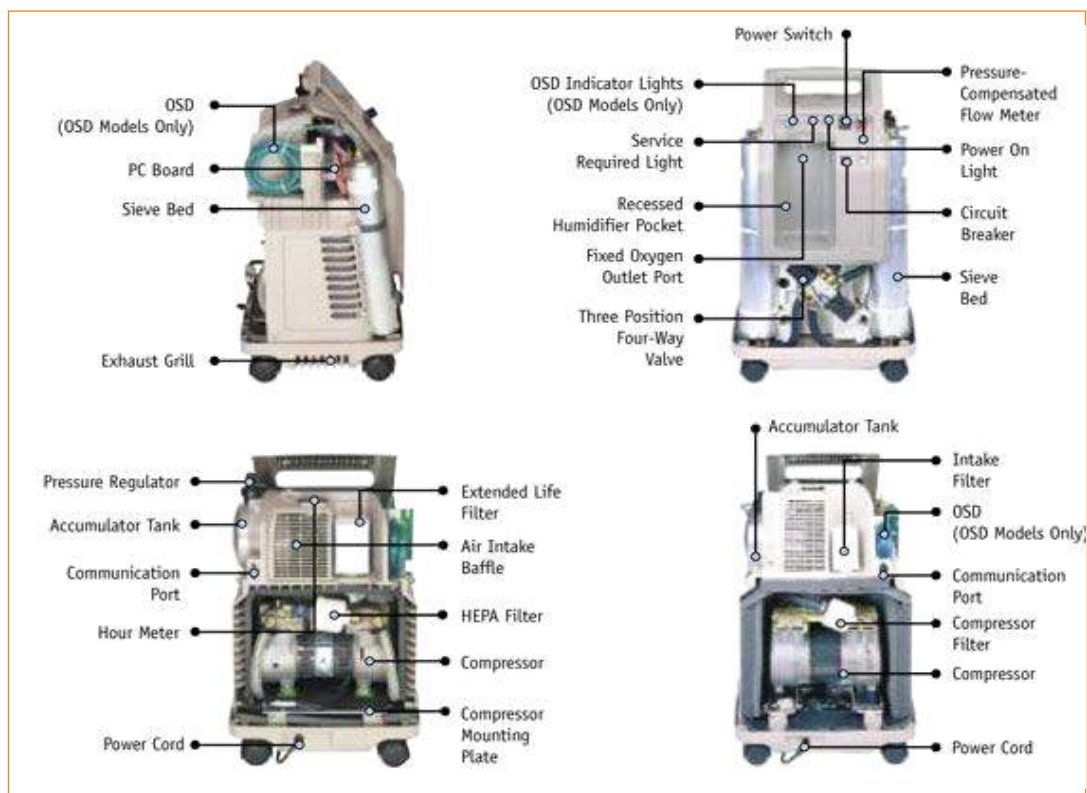


Fig. 4.3.34. Oxygen concentrator opened view

User maintenance of Oxygen Concentrator:

Daily	
Cleaning	Remove any dust/dirt with a damp cloth and dry off Fill humidifier bottle up to marker with clean distilled water
Visual checks	Check all screws, connectors, tubes and parts tightly fitted
Function checks	Check oxygen flow before clinically required

Table 4.3.10. Daily maintenance of Oxygen Concentrator

Weekly	
Cleaning	Wash the filter in warm water and dry. Replace if damaged Clean humidifier bottle thoroughly and dry off
Visual Checks	Replace the humidifier bottle if covered with limescale If mains plug, cable or socket are damaged, replace
Function Checks	Run the machine for two minutes and check no alarms occur Check (see bubbles) that flow rate varies with flow control

Table 4.3.11. Weekly maintenance of Oxygen Concentrator

Every six months, Preventive Maintenance required.

Oxygen Cylinders and Flowmeters.**Description and Function of the Device:**

Medical gases such as oxygen, nitrous oxide etc., are intended for administration to a patient in anaesthesia, therapy or diagnosis. An oxygen cylinder is a cylindrically shaped metal container used to store oxygen that has been compressed to very high pressure. Oxygen cylinders, which come in different sizes, are usually black coloured with a white top; in some cases, it may be a small cylinder that is entirely black. The black colour helps to differentiate it from other substances that are stored in similar containers. Cylinders are fitted with customized valves (either 'bullnose' or 'pin index' type) with valve guards opened with valve keys.

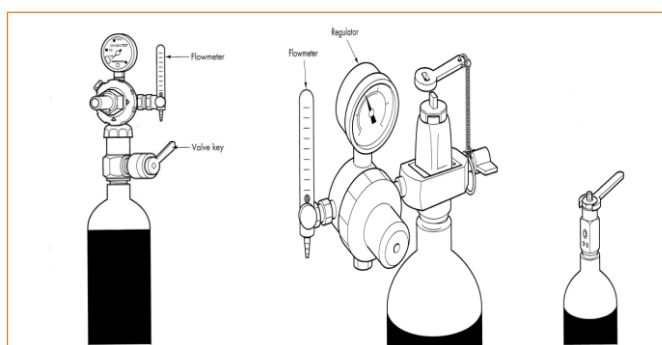


Fig. 4.3.35. Cylinder with Flowmeter and Valve Keys

A flowmeter is an instrument used to measure the flow rate of a liquid or a gas. In healthcare facilities, gas flowmeters are used to deliver oxygen at a controlled rate directly to patients or through medical devices. Oxygen flowmeters are used on oxygen tanks and oxygen concentrators to measure the oxygen reaching the patient or user. Sometimes bottles are fitted to humidify the oxygen by bubbling it through the water.

Daily	
Cleaning	Ensure delivery tubes and masks are sterile If humidifier bottle is used, refill with clean water
Visual checks	Check cylinder is the correct type and marked oxygen Check all parts are fitted tightly and correctly
Function checks	Before use, ensure the cylinder is filled and flow is present Close cylinder valve after each use.

Table 4.3.12. Daily maintenance Flowmeter

Weekly	
Cleaning	Clean cylinder, valve and Flowmeter with a damp cloth
Visual Checks	Check for leakage: hissing sound or reduction in pressure
Function Checks	Remove valve dust with brief, fast oxygen flow Check flow can be varied using flow control

Table 4.3.13. Weekly maintenance Flowmeter

Preventive maintenance check required every six months

4.3.3.4 Flowmeters

Flowmeter

Flowmeters on anaesthesia machines are classified into:

1. Variable orifice (constant or fixed pressure drop) flowmeters (Rotameter): The conventional ones are used.
2. Electronic flowmeters: They are available now in the recent anaesthetic machines. In these new machines, there must be a backup conventional (Thorpe) auxiliary oxygen flowmeter, which is used in case of failure of the electronic type

Other models of anaesthesia machines have the conventional flowmeters, but measurement of the gas flow is done electronically along the Thorpe tube, or there are digital/graphic displays of the flow

Variable orifice (constant or fixed pressure drop) flowmeters (Rotameter)

Flowmeter and delivering a controlled flow of oxygen, nitrous oxide, or air also reduce the pressure of these gases from the 4.1 bar (in the pipelines) to 1 bar, delivered to patients.

Flowmeter Assemblies.- The flowmeter assembly consists of the flow control valves and the flowmeters, and its purposes are precise control and measurement of gas flow travelling to the standard gas outlet.

The valves

The valves represent a crucial anatomic landmark within the anaesthesia workstation because they separate the intermediate-pressure section from the low-pressure area. The operator regulates flow entering the low-pressure circuit by adjusting the flow control valves. After leaving the flowmeters, the mixture of gases travels through a standard manifold and may be directed through an anaesthetic vaporizer if selected. The total fresh gas flow and the anaesthetic vapour then travel toward the standard gas outlet.

Flow control valves.

The flow control valve assembly consists of a flow control knob, a tapered needle valve, a valve seat, and a pair of valve stops. The inlet pressure to the assembly is determined by the pressure characteristics of the intermediate-pressure segment of the respective machine; secondary pressure regulators are often used before the flow control valves to provide stable input pressure despite fluctuations in hospital pipeline supply pressure.

The location of the needle valve in the valve seat changes to establish different orifices when the flow control valve is adjusted.

Gas flow increases when the flow control valve is turned counterclockwise, and it decreases when the valve is turned clockwise.

Safety Feature:

Control knobs have the same colour code as the gas cylinders (Figure 4.3.3.6)



Fig. 4.3.36. Control knobs

The oxygen knob is usually fluted, more oversized and protrudes further than the other knobs.

Flow tubes.

A tapered glass or plastic tube (Thorpe tube), narrow at the bottom and wide at the apex like an inverted cone, is present vertically where a light metal alloy bobbin (its trade name is Rotameter®) or ball present inside the tube.

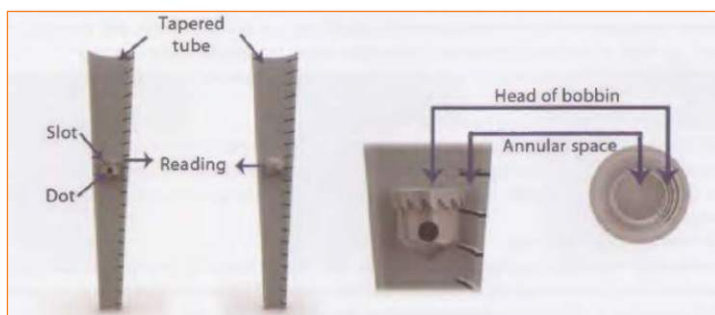


Fig. 4.3.37. Variable Orifice Flowmeter

The quantity of flow is indicated on a scale associated with the flow tube. Referred to as variable orifice area flow tubes or Thorpe tubes, these glass tubes are narrowest at the bottom and widen vertically.

- An indicator float is housed within the tube that is free to move vertically
- Opening the flow control valve allows gas to travel through the space between the float and the flow tube.
- This space is known as the annular space, and it varies in size depending on the position of the indicator in the tube.

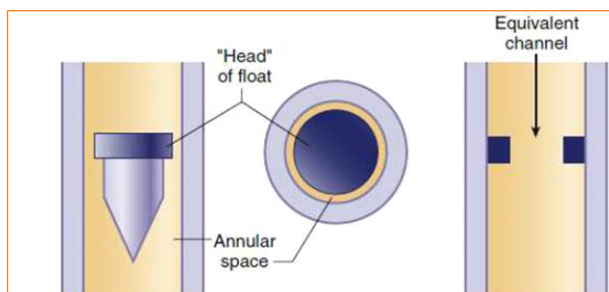


Fig. 4.3.38. The annular space

The indicator float hovers freely in an equilibrium position in the tube where the upward force resulting from gas flow equals the downward pressure on the float resulting from gravity at a given flow rate.

These flowmeters are commonly referred to as constant-pressure flowmeters because the decrease in pressure across the float remains constant for all positions in the tube. The reverse occurs when the flow decreases as the bobbin or the ball fall in the narrower parts of the tube and the annular orifice around it decreases; therefore, the flow resistance increases and the clearance around the bobbin or the ball drops, and so the pressure across the bobbin (or the ball) stays constant despite the flow decreases, i.e., there is a variable orifice and fixed pressure drop around the bobbin (or the ball).

- At low flow rates, the narrow annular space between the bobbin (or the ball) and the wall mimics a tube, and the flow becomes laminar.
- At high flow rates, the width of the annulus is large relative to the height of the bobbin (or the ball), the annular space forms an orifice, and the flow becomes turbulent.
- At low rates, the viscosity of gas determines the position of the bobbin (as it is laminar flow),
- Whereas at higher rates, the effect of density of the gas becomes more important (as it is turbulent flow).

Recently electronic flowmeters have been available on the computer screen



Fig. 4.3.39. Flowmeters available on the computer screen

Electronic Flow Sensors.

Flows can be displayed numerically or sometimes graphically in the form of a virtual, digitalized flowmeter.

Numerous types of flow sensor technologies can be applied, such as hotwire anemometers, a differential pressure transducer method, or mass flow sensors.

An example of an electronic mass flow sensor :

A device relies on the principle of specific heat to measure gas flow. As gas streams through a heated chamber of known volume, particular electricity must maintain the chamber temperature. Thus, the amount of energy required to maintain the temperature is proportional to the flow of the gas and the gas's specific heat.



Fig. 4.3.40. Electronic mass flow sensor

Factors Affecting the Performance of the Rotameter:

1- The viscosity and density :

Because the flow in this flowmeter is a mixture of laminar (at low flow rates) and turbulent (at high flow rates) flow, so both the viscosity (in laminar) and density (in turbulent of the gas is essential.

Therefore, each rotameter must be calibrated for a specific gas, i.e., different gases can not be used in the same flowmeter except after recalibration or change of the scale written on the tapered tube.

- Although temperature and barometric pressure can influence gas density and viscosity, under standard clinical circumstances, flow tube accuracy is not significantly affected by mild changes in temperature or pressure
- 2- Sticking The bobbin may touch the wall of the tapered tube and stick to it. To avoid this:
- The flowmeter tube must be kept vertical to reduce the friction between the bobbin and the tube.

- As electrostatic charges (which increase sticking) may build up on the bobbin and the wall of the tube, it rubs against the wall of the tube; therefore, to conduct away from the electrostatic charges:-
- Some tubes are coated inside by a conductive transparent material (as gold or tin" stannous oxide").
- A conductive strip is present from inside the tube.
- The plastic cover of the rotameter is sprayed with an anti-static spray such as Croxtine.
- Small slots are placed around the top of the bobbin, causing it to rotate centrally in the gas flow and a dot is present in the body of the bobbin indicating its rotation (the dot is not used to indicate the level for which readings are done).

The ball is used as sticking is less.

- Dust is prevented by incorporating a dust filter in the needle valve at the bottom of the tube because dust on the bobbin may cause sticking or even alteration in size of the annulus, which causes inaccuracies

Accuracy

- Avoid sticking, as above
- Readings are made from the upper surface of the bobbin (more accurate as there is a well-defined surface for reading) or the central equator (the middle) of the ball (less accurate).

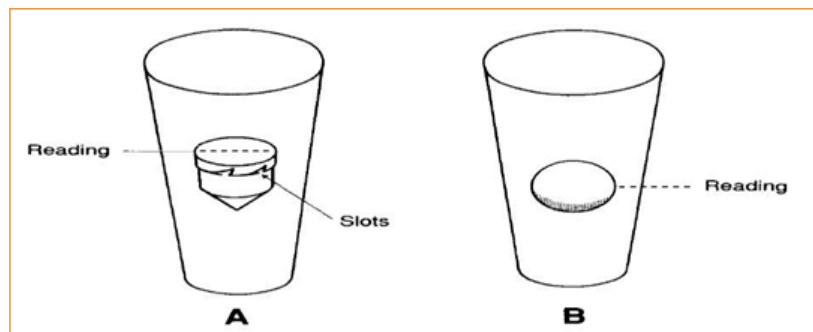


Fig. 4.3.41. Variable Orifice Flowmeter

- In recent anaesthetic machines where shallow flows are needed in closed circuits, two flowmeters, one for the common and one for high flows, are made in series and controlled by one valve.

- Attachment of a vaporizer or a ventilator, e.g., Manley, after the flowmeter, produces back pressure, increasing the resistance in front of the flowmeter.

This, in turn, increases the pressure at the outlet of the flowmeter. This increased pressure affects, in turn, the calibration of the flowmeter due to the affection of the viscosity and density of the gases, which affect the accuracy as there may be as much as 10% more gas flow than that indicated on the flowmeter.

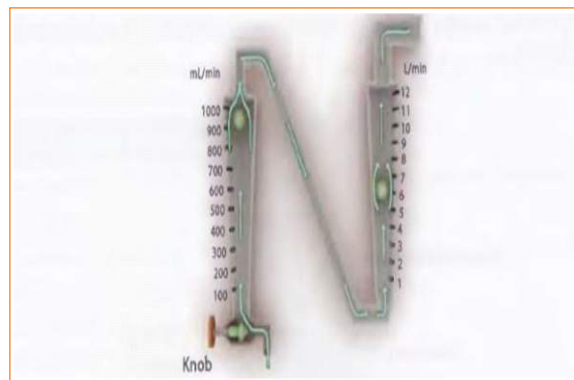


Fig. 4.3.42. Two tube flowmeter

Some flowmeters are now pressurized and calibrated to work at a high pressure of several bars, which minimizes the effect of the relatively more minor pressure change in the outlet.

Safety:

The position of the flowmeters

When there are flowmeters in series, e.g., one for O₂ and the other for N₂O, and a break in the junction between two flowmeters occurs, e.g., in the airflow meter, the concentration of the gas mixture obtained from flowmeters may be changed and become hypoxic as follows:

The O₂ flowmeters are located at first, and the N₂O flowmeter is situated after the airflow meter; the O₂ may w out of the break in the system as in (A), and a hypoxic gas mixture is obtained

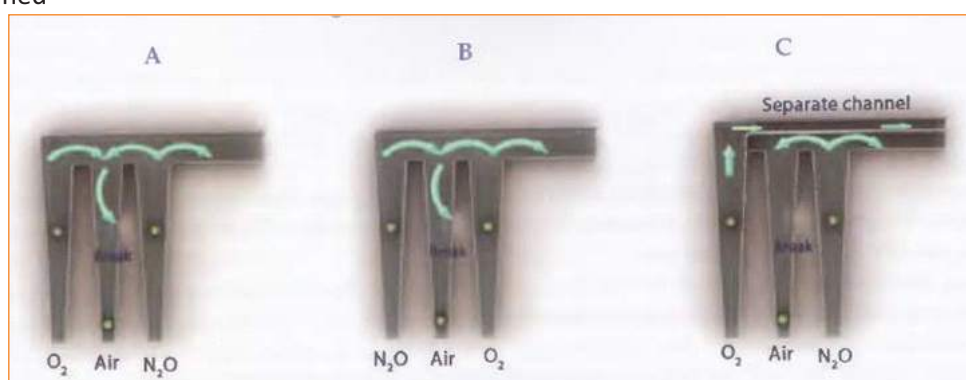


Fig. 4.3.43. Arrangement of the flowmeter

A leak in the oxygen flow tube may result in the creation of a hypoxic mixture even when oxygen is located in the downstream position

Oxygen escapes through the leak, and nitrous oxide continues to flow toward the standard outlet, particularly at high ratios of nitrous oxide to oxygen flow.

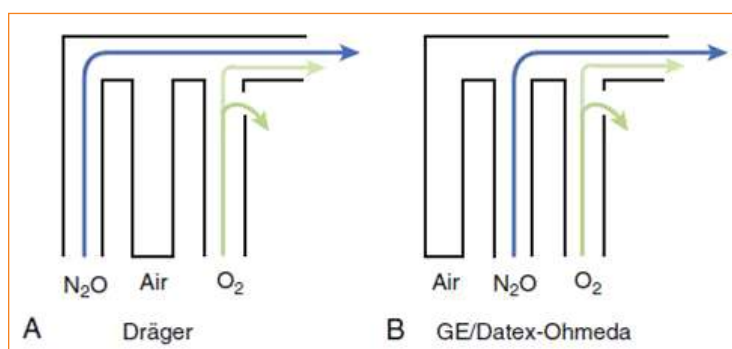


Fig. 4.3.44. An oxygen leak through the flow tube

- Oxygen/nitrous oxide ratio: In modern anaesthetic machines, there is a link between the oxygen flow controller and nitrous oxide controller to ensure administration of at least 25% O₂ when the N₂O flowmeter is turned on alone.

When the N₂O flowmeter is turned on alone, the O₂ flowmeters is turned on _obligatorily to at least 25% of the total gas mixture; therefore, hypoxia is avoided.

A. This is achieved by one - the following methods: A-mechanical method: where a chain - link is present between the O₂ and N₂O flowmeter control knobs



Fig. 4.3.45. A Chain-link is present between the O₂ and N₂O flowmeter control knobs

Datex-Ohmeda Link-25 Proportion-Limiting Control System

The system is based on a mechanical integration of the nitrous oxide and oxygen flow control valves, and a difference in the taper of the needles of the oxygen and nitrous oxide flow control valves.

It allows independent adjustment of either valve, yet it automatically intercedes to maintain a minimum oxygen concentration with a maximum nitrous oxide-oxygen flow ratio of 3:1.

The Link-25 automatically increases oxygen flow when then nitrous oxide flow is increased to more than a certain point relative to oxygen flow to prevent delivery of a hypoxic mixture.

GE, Datex-Ohmeda link-25 nitrous oxide: oxy-gen proportioning system. The system prevents the operator from selecting more than a 75% nitrous oxide-25% oxygen (3:1) mixture by two separate but interdependent means, A, Mechanical linkages of the control valves maintains no more than a 2:1 ratio, B, A faster taper of the nitrous oxide valve needle allows more gas flow through the valve per turn relative to flow through the oxygen valve per turn, thus resulting in the maximal 3:1 ratio. In addition, a stable and equal pressure supply to the valves is provided by the secondary pressure regulator for oxygen and a balance regulator for nitrous oxide; see text for additional details

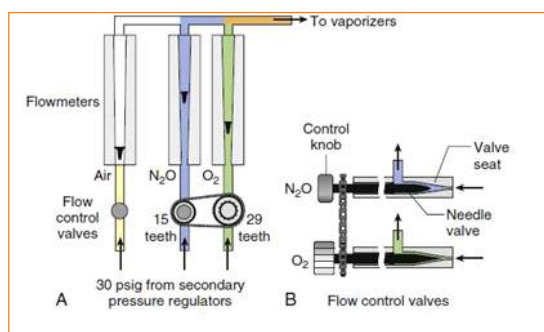


Fig. 4.3.46. GE/Datex-Ohmeda link-25 nitrous oxide

A. A Pneumatic method: where a pneumatic mixing valve is present.

The North American Dräger sensitive oxygen ratio controller system (SORC) is a pneumatic, mechanical, oxygen–nitrous oxide interlock system designed to maintain a ratio of no less than 25% oxygen to 75% nitrous oxide flow into the breathing circuit by limiting the nitrous oxide flow when necessary.

The SORC is located between the flow control valves and the electronic flow sensors.

The SORC consists of an oxygen chamber with a diaphragm, a nitrous oxide chamber with a diaphragm, and a nitrous oxide proportioning valve.

All interconnected by a mobile horizontal shaft. Pneumatic input into the device comes from the oxygen and nitrous oxide flow control valves

North American Drager sensitive oxygen ratio controller system (SORC) (Drager Medical, Telford, Pa.). The SORC is a pneumatic-mechanical inter-lock system designed to maintain a ratio of no less than 25%/750/0 nitrous oxide regardless of operator input. Main components. Differential oxygen and nitrous oxide flows and the resultant chamber backpressures determine the nitrous oxide proportioning valve position. See text for details. B, Complete the proportioning valve when the oxygen flow is decreased to less than 200 mL/minute. (Modified from Yoder M: Gas supply systems. In Understanding modern anaesthesia systems, Telford, Pa., 2009, Drager Medical.)

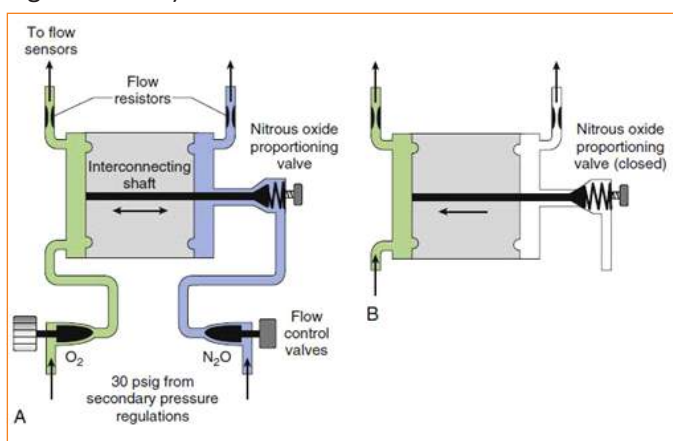


Fig. 4.3.47. North American Drager sensitive oxygen ratio controller (SORC) (Drager Medical, Telford, Pa.).

As oxygen flows out of the SORC, it encounters a resistor that creates backpressure

This backpressure is transmitted to the oxygen chamber diaphragm, which causes the diaphragm to move to the right, thereby opening the nitrous oxide proportioning valve. As the oxygen flow is increased, so too is the backpressure and the rightward motion of the shaft.

If the nitrous oxide flow is now turned on, it will also flow into the SORC, through the proportioning valve, and past its resistor to create backpressure that will press on the diaphragm in its respective chamber.

The counterbalance between the two gas flows (backpressures) determines the positioning of the nitrous oxide proportioning valve

If the oxygen is turned down too low (<25% of the nitrous oxide flow), the shaft will move to the left and thus limit the nitrous oxide flow.

If the operator tries to turn up the nitrous oxide too high relative to the oxygen flow, the SORC will limit the nitrous oxide flow regardless of how far the flow control valve is opened. If the oxygen flow is decreased to less than 200 mL/minute, the proportioning valve will close completely

B. An electronic method.

Minimum oxygen flow: Some recent flowmeters allow minimum oxygen flow of 150 mL/min O_2 when the anaesthesia machine is turned on, even when the oxygen flow valve is turned off.

This safety feature helps ensure that some oxygen enters the breathing circuit even if the operator forgets to turn on the oxygen flow.

The Quantiflex mixer flowmeter eliminates the possibility of reducing the oxygen supply inadvertently

because:

1. One dial is set to the desired % of oxygen, and it is adjusted first
2. Then, the total flow rate is adjusted independently by another dial (the black knob).
3. Therefore, the percentage of O_2 is fixed, and there is no need to readjust the flow of O_2 manually

whenever the flow rate is changed.

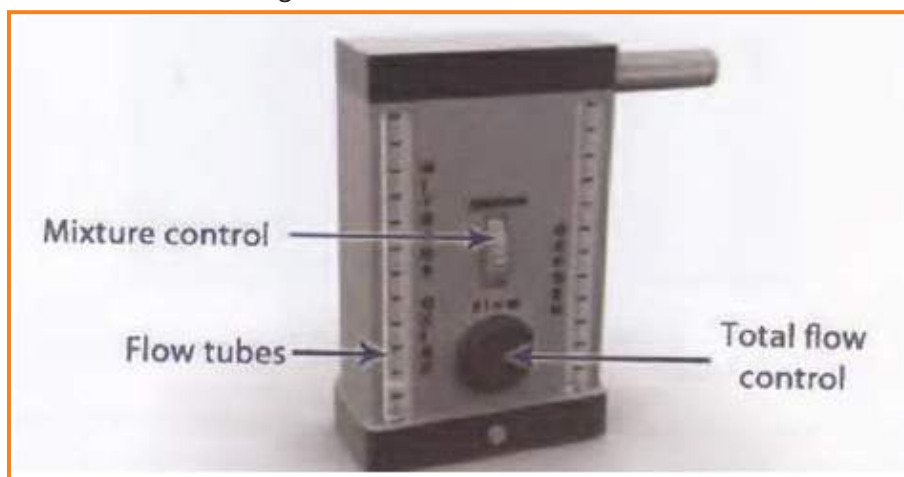


Fig. 4.3.48. - A - The Quantiflex mixer flowmeter

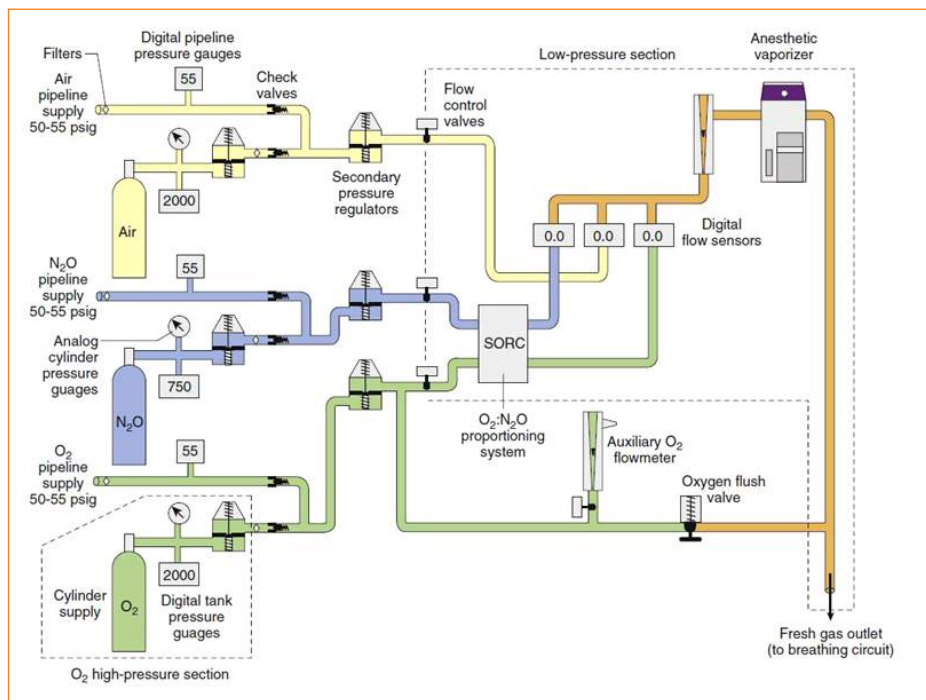


Fig. 4.3.48. - B - The Quantiflex mixer flowmeter

Flow valves

They constitute an essential landmark of the anaesthesia machine because they divide the device into two gas circuits

- The high-pressure circuit: is the part of the machine that is upstream from the flow control valves and consists of the pipeline system, the gas cylinders and the tubes connecting them to the machine.
- The low-pressure circuit: is the part of the machine that is downstream from the flow control valves and consists of the flowmeters, the vaporizers and the standard gas outlet that receives all gases and vapours from the machine

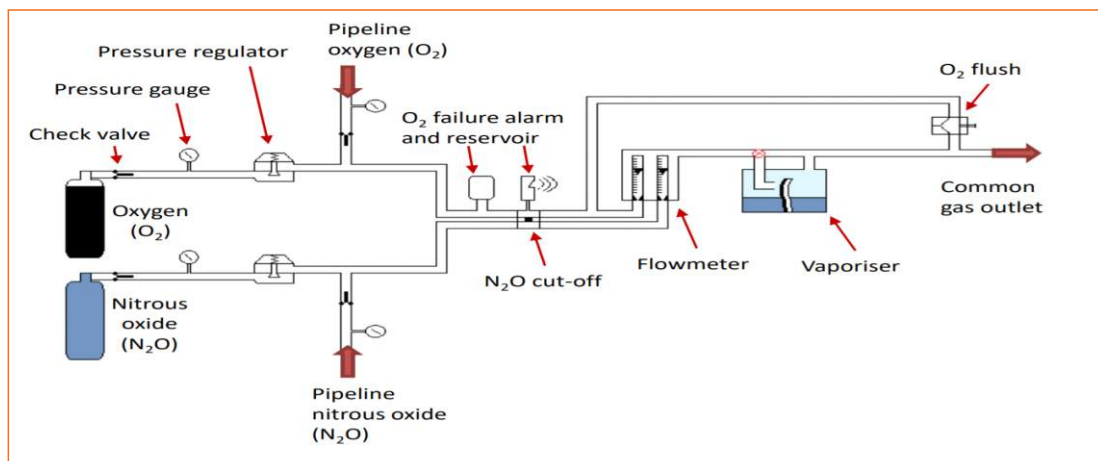


Fig. 4.3.49. Anesthetic machine

4.3.3.5 Digital Thermometer (IR)

What is a digital thermometer?

A **Digital thermometer** has electronic circuits and has a digital display to show the readings either in degree Celsius or degree Fahrenheit.

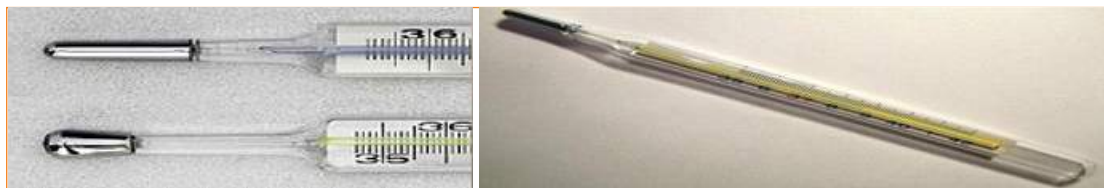


Fig. 4.3.50. Analog thermometer

How does a digital thermometer work?

Digital thermometers are different because they use a computer chip to tell the temperature instead of mercury. You would generally have to wait three whole minutes for the mercury to heat up and give you a reading. Instead, it takes only 30 seconds for a digital thermometer to give you a reading because the heat-sensitive tip can accurately tell the computer chip inside what the temperature is.

The Celsius scale is used in most countries, aside from the USA, because it is a metric system.

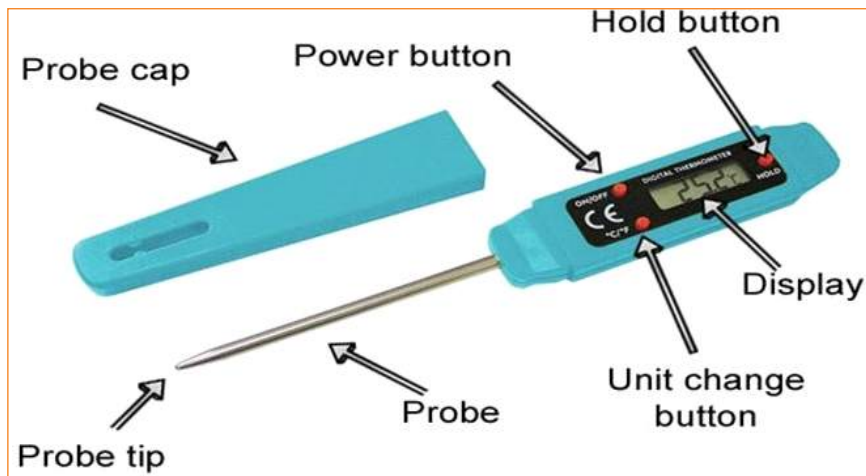


Fig. 4.3.51. A digital thermometer

The thermometer can be used in three ways:

- Oral (in the mouth)
- Rectal (in the bottom)
- Axillary (under the arm)

Do not use the same thermometer for both oral and rectal readings. Be sure to label your thermometer either “oral” or “rectal” to know the difference.

How to Use

1. Wash your hands with soap and warm water.
2. Use a clean thermometer, one that has been washed in cold water, cleaned with rubbing alcohol, and then rinsed to remove the alcohol.
3. Do not eat or drink anything for at least five minutes before taking temperature reading. Mouth should be closed during this time.
4. Place the thermometer tip under the tongue.
5. Hold the thermometer in the same spot for about 40 seconds.
6. Readings will continue to increase, and the F (or C) symbol will flash during measurement. Usually, the thermometer will make a beeping noise when the final reading is done. If you are keeping track, record the temperature and the time.
7. Rinse the thermometer in cold water, clean it with alcohol, and rinse again.

Precautions while using digital thermometer:

- Insert the batteries as indicated into the battery compartment. If not, the device will not work.
- When (Low battery mark) appears on display, it indicates that the battery is low. At this stage, measurement is still possible.
- When (Low battery mark) flashes on display, replace both batteries with new ones. Do not mix old and new batteries. It may shorten the battery life or cause the device to malfunction.
- Battery life varies with the ambient temperature and maybe shorter at low temperatures.
- Use the specified batteries only. The batteries provided with the device are for testing monitor performance and may have a limited life.
- Do not measure the temperature of the metal. It will give a low reading.

- Do not immerse the thermometer into the fluid. It will damage the lens of the probe.
- Do not expose the thermometer to flame or high temperatures. It will damage the lens of the probe.
- Remove the batteries if the device is not to be used for a long time. The batteries may leak and cause a malfunction.

Digital Thermometer (IR)

Introduction

When the outbreak of COVID-19 took place, the IR Thermometers have been of immense use. This device can measure the temperature without touching the patient, and its measurement doesn't require contact with the person. In addition, it provides fast temperature measurement and is highly accurate.

We will study how the infrared thermometer works and explain its accuracy and the factors that affect it.



Fig. 4.3.52. A commonly used IR Thermometer to take a contact-less reading of patients.

For seeing What is there inside the IR Thermometer, watch the YouTube video at

<https://www.youtube.com/watch?v=01n-KEG-zj8>

For Working Principles, watch the video at YouTube-

<https://www.apogeeweb.net/electron/how-do-infrared-thermometer-work-how-accurate-are-they.html>

What is an Infra-Red (IR)

Infrared is an electromagnetic wave with a wavelength between microwave and visible light. The wavelength is between 1mm and 760 nanometers (nm), invisible light longer than red light.

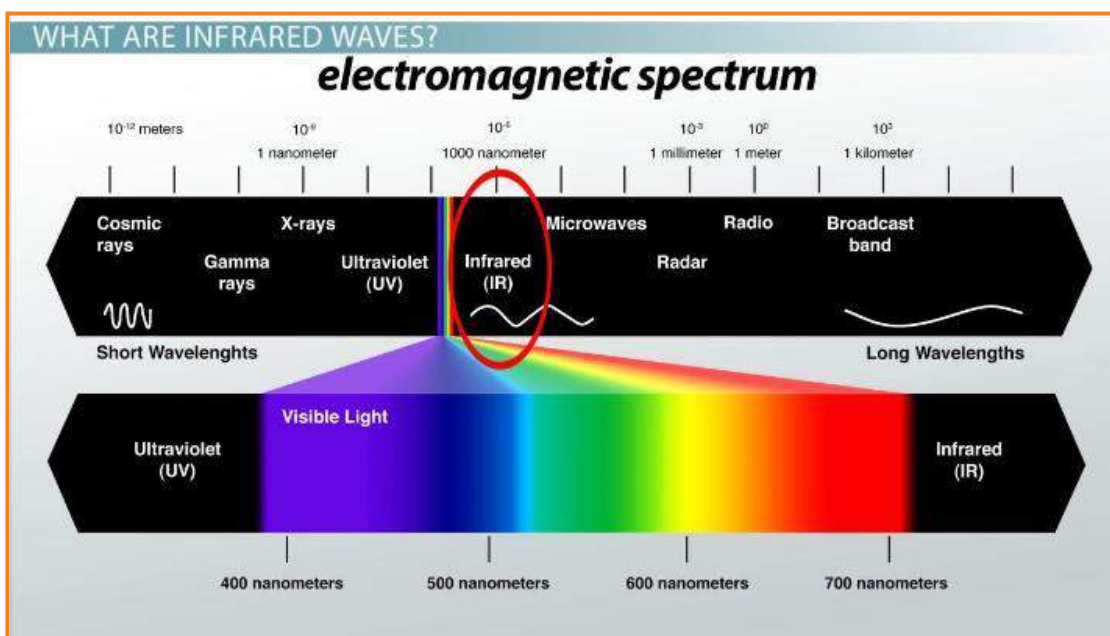


Fig. 4.3.53. Infrared Waveform- Image Source-<https://www.apogeeweb.net/>

Any heated object generates IR. Infrared can be divided into three parts, namely near-infrared, with a wavelength between $(0.75-1)$ to $(2.5-3) \mu\text{m}$; mid-infrared, with a wavelength between $(2.5-3)$ to $(25-40) \mu\text{m}$; far-infrared, The wavelength is between $(25-40) \sim 1500 \mu\text{m}$.

Medical infrared can be divided into two categories: near-infrared and far-infrared, containing thermal energy; the sun's heat is mainly transmitted to the earth through infrared rays. Within this wave band, only frequencies of 0.7 microns to 20 microns are used for practical, everyday temperature measurement.

Working of an IR thermometer:

The IR thermometer consists of the following parts:

- A laser pointer light that points to where the temperature is required to be taken.
- A Thermo detector- The heat from the body emits IR lights detected by the thermal sensor and gets heated by the IR.
- A convertor- The heat energy is converted into electrical energy.
- LCD/LED Display- The converted electrical signals are then displayed after proper calibration as Temperature in Deg C or Deg F.

How to select an IR thermometer for medical use-

The following needs to be considered while choosing a medical IR digital thermometer:

- Temperature range-** The temperature range is the minimum and maximum that it can read within the given accuracy. For Medical use, the temperature is selected to be 32 deg C to 42 deg C.
- Accuracy-** Accuracy is how accurate is the reading to the actual value. The accuracy to be ± 1 deg C.
- Measurement distance-** For what length the measurement is taken from the body. It should be up to 3-5 cm
- Display resolution-** What is the last reading of the thermometer. It should be 0.1 deg C \pm

- e. **Response Time**-How fast it can show the captured reading- It should be within 5-10 Sec.

Cleaning and maintenance of IR thermometers

How do you clean an infrared thermometer gun? General maintenance and cleaning can go a long way towards the longevity of your IR thermometer. However, improper cleaning techniques can damage the thermometer, even beyond repair, and utilizing the wrong utensils can have a similar effect.

It is of the utmost importance to pay close attention to details whenever you clean your infrared thermometer guns. You take every precaution to avoid damaging the sensitive devices that make up the working components of your infrared thermometer guns.

How to clean an infrared thermometer gun?

It would help if you always built a habit of constantly cleaning your infrared thermometer after being exposed to any conditions that may soil it. Use in any dirty, foggy, humid and dusty conditions will require immediate cleaning. No matter what the conditions are, extreme care should always be taken to keep the lens utterly free of debris.

Steps to clean your infrared thermometer:

1. Dampen a soft cloth or cotton swab with water or medical alcohol. Never use soap or any other chemicals.
2. Gently wipe the lens first and then the body of the infrared thermometer. Never submerge any part of your infrared thermometer.
3. Allow the lens and body to dry completely before storing or using the infrared thermometer.

How often should you clean infrared thermometer gun?

It is an excellent idea to clean your infrared thermometer every six months. This is, of course, depending on use, so more or less frequency may be required due to the regularity. No matter what, if you ever have to use your infrared thermometer in contaminated conditions, you should clean it immediately after use.

4.3.3.6 Humidifier

Humidity- The water vapour present in the air makes the air moist, known as humidity. Humidification is done in respiration therapy to add moisture and sometimes heat to the inspiratory air as the air output coming off the ventilator is dry. Humidification is done to maintain the normal physiological conditions in the body. If forced into the lungs, the dry air of more than four lpm causes immediate loss of water and heat. The unit of humidity is mg/litre.

- The humidifier is a device that adds molecular water to the air.
- Principle- The more significant the temperature of the gas, the more water it can hold.

Types of Humidifiers: Humidifiers are classified as below:

Source- Humidification during Mechanical Ventilation in the Adult Patient Haitham S. Al Ashry¹ and Ariel M. Modrykamien

1. Active Humidifiers

Active humidifiers act by allowing air passage inside a heated water reservoir. These devices are placed in the inspiratory limb of the ventilator circuit, proximal to the ventilator. After the air is loaded with water vapour in the reservoir, it travels along the inspiratory limb to the patient's airway. As a condensation of water vapour may accumulate as the surrounding temperature of the inspiratory limb decreases, these systems are used with the addition of water traps, which require frequent evacuation to avoid the risk of contamination of the circuit.

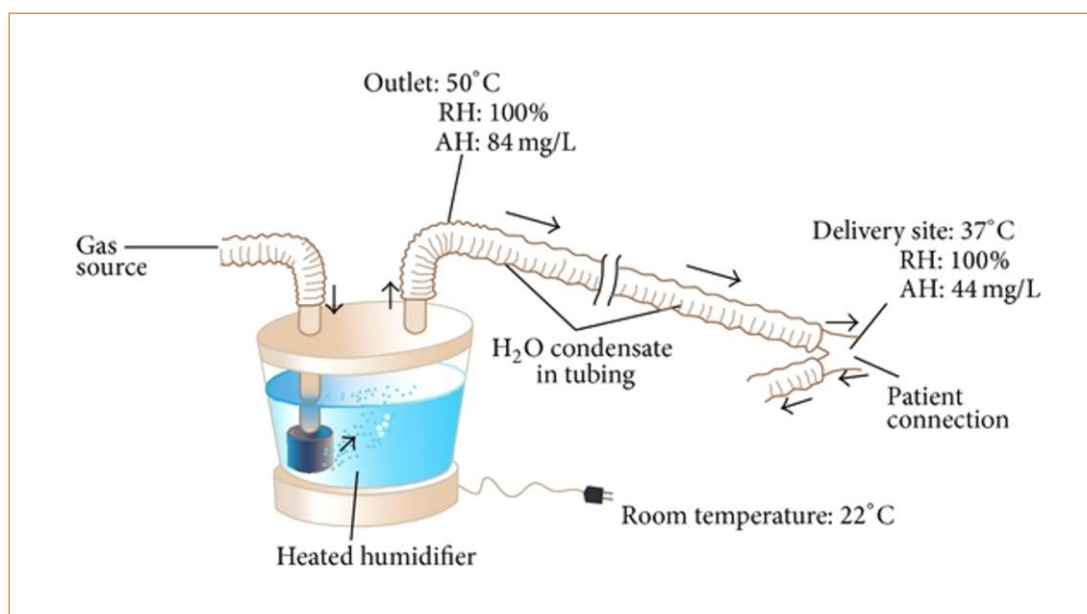


Fig. 4.3.54. Active Humidifier-Heated humidifier and condensation, adapted from Egan's Fundamentals of Respiratory Care, 10th edition, St. Louis: Mosby-Elsevier; 2012: 1424 [R. M. Kacmarek, J. K. Stoller, and A. H. Heuer, Egan's Fundamentals of Respiratory Care, Mosby-Elsevier, St. Louis, Miss, USA, 10th edition, 2012.]

Some active humidifiers have internal heated wires to control the condensation. These are known as servo controlled humidifiers.

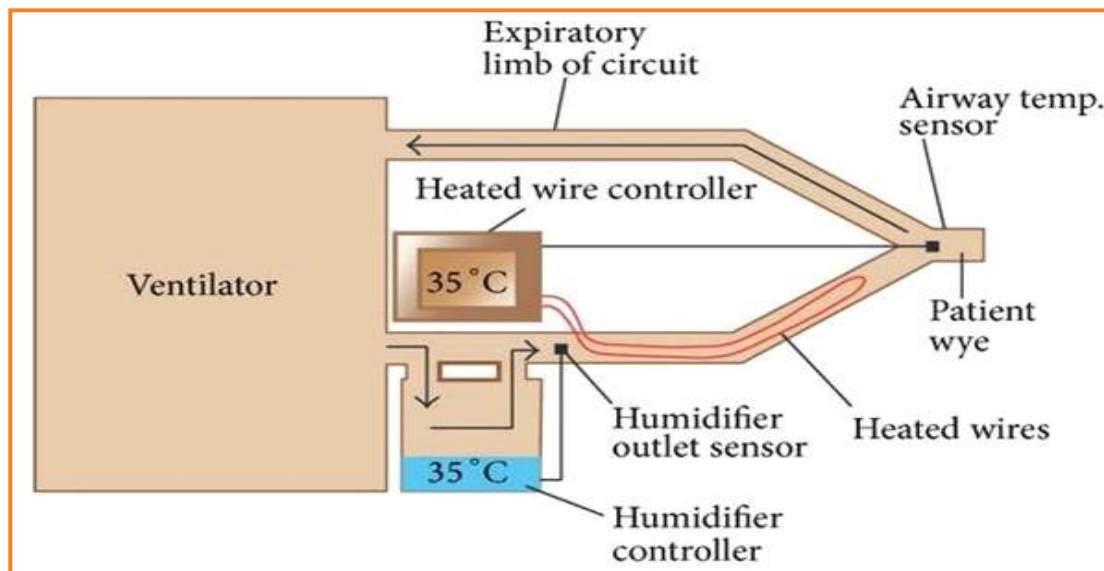


Fig. 4.3.55. Servo Humidifiers with internal heating wires to control the condensation. Humidifier with heated wire in the inspiratory limb, adapted from Egan's Fundamentals of Respiratory Care, 10th edition, St. Louis: Mosby-Elsevier; 2012: 1424 [R. M. Kacmarek, J. K. Stoller, and A. H. Heuer, Egan's Fundamentals of Respiratory Care, Mosby-Elsevier, St. Louis, Miss, USA, 10th edition, 2012.]

These types of Humidifiers are commonly used with ventilators. Types of active humidifiers are as below:

A. Bubble humidifiers

Bubble. In bubble humidifiers, gas is forced down a tube into the bottom of a water container (Figure 4.3.3.6.3)). The gas escapes from the distal end of the tube under the water surface, forming bubbles, which gain humidity as they rise to the water surface. Some of these humidifiers have a diffuser at the distal end of the tube that breaks gas into smaller bubbles. The smaller the bubbles, the larger the gas-water interface allowing for higher water vapour content. These types of humidifiers are more used with CPAP/BIPAP machines.

B. Passover humidifiers

In Passover humidifiers (Figure 4.3.3.6.3), gas passes over a heated water reservoir carrying water vapour to the patient. These are typically used for invasive and noninvasive mechanical ventilation. Another variant of Passover humidifiers is the wick one (Figure 4.3.3.6.3). In this type of device, the gas enters a reservoir and passes over a wick that acts as a sponge with its distal end immersed in heated water. The wick pores provide a more gas-water interface allowing for more humidification than simple Passover humidifiers. The third type of Passover humidifier involves a hydrophobic membrane (Figure 4.3.3.6.3). As with the wick device, dry gas passes through a membrane. Nevertheless, its hydrophobic characteristic only allows passage of water vapour, precluding liquid water from travelling through it. Thus, similarly to the wick humidifier, bubbles and aerosols are not generated.

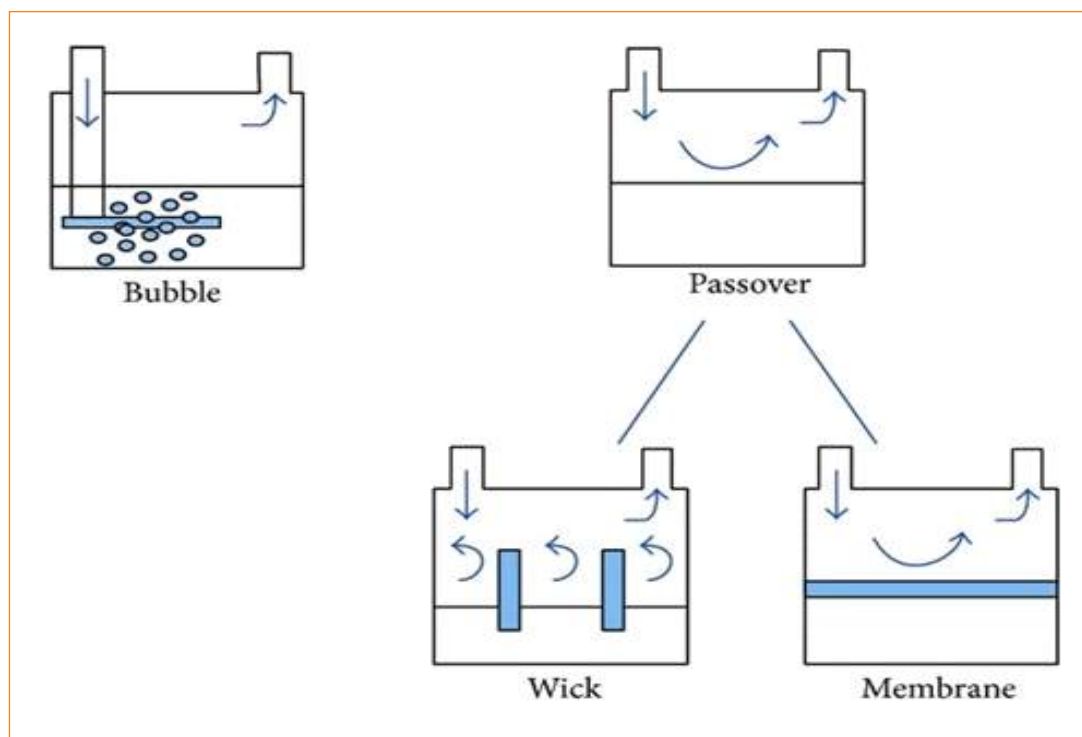


Fig. 4.3.56. Bubble and Passover humidifiers, adapted from Egan's Fundamentals of Respiratory Care, 10th edition, St. Louis: Mosby-Elsevier; 2012: 1424 [R. M. Kacmarek, J. K. Stoller, and A. H. Heuer, Egan's Fundamentals of Respiratory Care, Mosby-Elsevier, St. Louis, Miss, USA, 10th edition, 2012.]

2. Passive humidifiers

Utilises patients' temperature and hydration to achieve humidification in successive breaths.

- A. HME- Heat and moisture exchangers- Captures heat in the Exhaled gas and provides the next inspiration cycle.

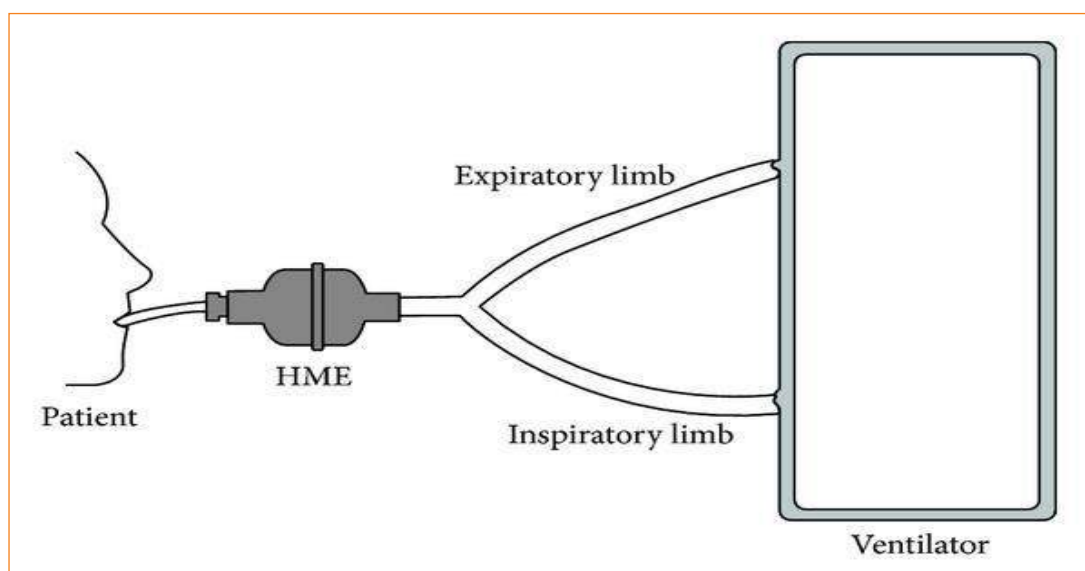


Fig. 4.3.57. HME position in the ventilator circuit.

Newer designs of HMEs include hydrophobic, combined hydrophobic hygroscopic, and pure hygroscopic HMEs. In hydrophobic HMEs, the condenser is made of the water-repelling element with a low thermal conductivity that maintains higher temperature gradients than simple HMEs. In combined hydrophobic hygroscopic HMEs, a hygroscopic salt (calcium or lithium chloride) is added inside the hydrophobic HME. These salts have a chemical affinity to attract water particles and thus increase the humidification capacity of the HME. Pure hygroscopic HMEs have only the hygroscopic compartment. During exhalation, the vapour condenses in the element as well as in the hygroscopic salts. Water vapour is obtained from the salts during inspiration, obtaining an absolute humidity ranging between 22 and 34 mg H₂O/L. Figure: 4.3.3.6.5 illustrates the basic structure and work principle of HMEs. It is best suited for short term mechanical ventilation

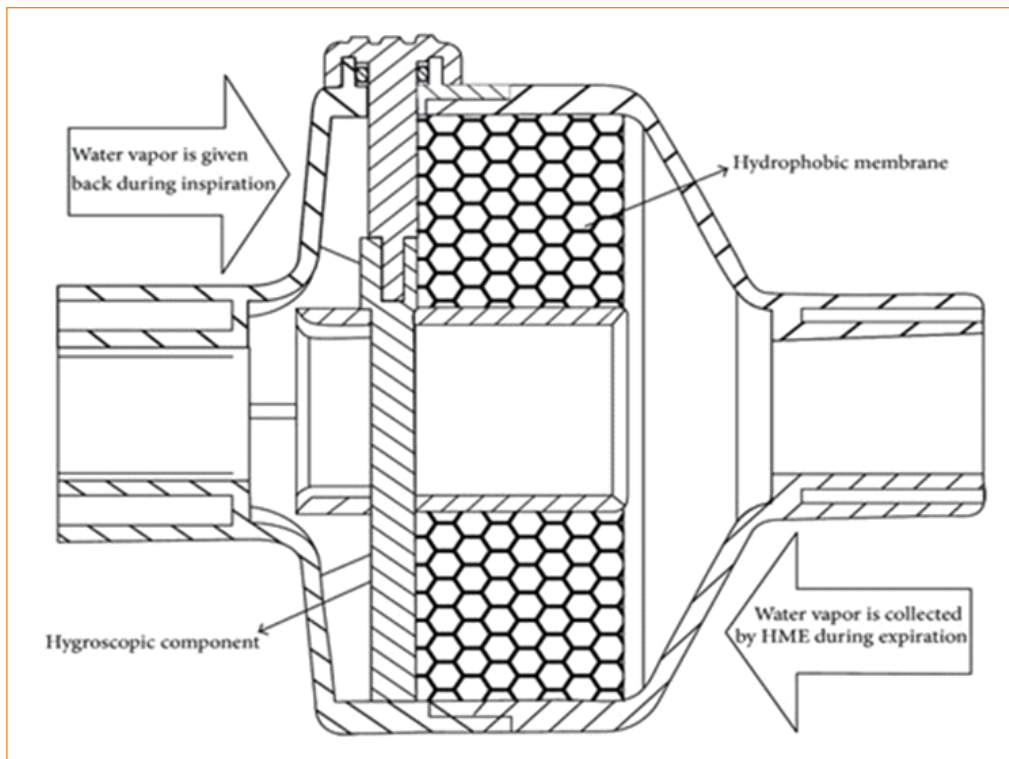


Fig. 4.3.58. HME Working

Preventive maintenance and troubleshooting of humidifiers:

1. Replace the paper filters on each use inside the humidification chamber.
2. Check the increase in temperature on increasing the temperature settings.
3. Check the heated wire for continuity.
4. Check the ON/OFF Switch and fuses and power cables if the mains outlet has power, but the humidifier is not switching ON.
5. Check that the patient circuit is connected appropriately.
6. Check the temperature probes are correctly connected.

Your tube link: understanding the parts in a ventilator humidifier - [\(470\) Mechanical Ventilation: Patient Circuits: Part 2: The Humidifier - YouTube](#)

For Oxygen Concentrators, a simple bubble humidifier without a heater is used.

Water bottle humidifier for oxygen concentrator oxygen bottle includes a pressure relief valve and downspout diffuser, ensuring a high flow delivery of 6 lpm humidifier bottle designed to work with oxygen concentrators to decrease drying out of the upper respiratory tract during long term oxygen use. Adaptable – water bottle humidifier attaches easily to the most oxygen concentrator. Maintains desired oxygen saturation – bubble humidifier is specifically made to deliver high oxygen flow rates via a face mask. Soft-start – water bottle humidifier is easy to use and clean. Adapter for connecting oxygen concentrator to humidifier - one end of the adapter slips over the nipple port on the concentrator. The other end threads into the attachment site on the humidifier bottle.



Fig. 4.3.59. Bubble Humidifier for Oxygen Concentrators.

For Humidifiers used with Oxygen Concentration - [\(470\) Oxygen Concentrator Humidifier Maintenance - YouTube](#)

4.3.3.7 Pulse Oximeter

Description of pulse oximeter:

Body cells need oxygen to perform aerobic respiration. Respiration is one of the key ways a cell gains sound energy. Blood red cells contain a protein called haemoglobin. When oxygen reacts with this protein, it gets attached to it and generates Oxyhemoglobin (HbO_2). Red cells with oxygenated haemoglobin circulate in the blood through the whole body, irrigating tissues. When blood gets in contact with a cell, the red cell's haemoglobin releases oxygen and becomes Deoxyhemoglobin (Hb) (deoxygenated haemoglobin).

Note: It is a primary tool to measure the SpO_2 & pulse rate at any point of time without waiting for an invasive laboratory method, which takes time for measurement. For its portability, noninvasive method and battery operation, it has been widely used in all departments.

Working principle:

A pulse oximeter is a non-invasive device measures and displays the pulse rate and the saturation of haemoglobin in arterial blood. This saturation of haemoglobin is a measure of the average amount of oxygen bound to each haemoglobin molecule. The absorption of visible light (emitted by LEDs and received by Photoresistor) by a haemoglobin solution (blood) varies with oxygenation. The chemical bonding of the different types of haemoglobin species changes the physical properties of the haemoglobin as well. The oxygen chemically combined with haemoglobin inside the red blood cells makes up nearly all of the oxygen present in the blood (there is also a minimal amount dissolved in the plasma). Oxygen saturation, which is often referred to as SaO_2 or SpO_2 , is defined as the ratio of oxyhemoglobin (HbO_2) to the total concentration of haemoglobin present in the blood:

Working of the pulse oximeter

The pulse oximeter probe consists of two diodes that emit equal intensities of red and infrared light sequentially into pulsatile tissue bed with two different wavelengths, i.e. 940 nm (infrared) and 660 nm (red), respectively. A variable amount of these lights are absorbed by oxygenated and reduced haemoglobin. The Reduced haemoglobin absorbs redder than infrared light, and oxygenated haemoglobin absorbs more infrared than red.

A photo-detector placed on the opposite side senses the ratio of red and infrared light based on which the proportion of oxygenated and reduced haemoglobin is estimated and displayed.

Red blood cells contain haemoglobin. One molecule of haemoglobin can carry up to four oxygen molecules, after which it is described as “saturated” with oxygen. If all the binding sites on the haemoglobin molecule carry oxygen, the haemoglobin is said to have a saturation of 100%. Most of the haemoglobin in the blood combines with oxygen as it passes through the lungs. A healthy individual with normal lungs, breathing air at sea level, will have an arterial oxygen saturation of 95%– 100%. Extremes of altitude will affect these numbers. Venous blood collected from the tissues contains less oxygen and has typically a saturation of around 75%. Arterial As a result, arterial looks bright red, whilst The colour difference is due to the difference in haemoglobin saturation.

Pulse oximetry is based on two physical principles: (a) the presence of a pulsatile signal generated by arterial blood, which is relatively independent of non-pulsatile arterial blood, venous and capillary blood, and other tissues and (b) the fact that oxyhemoglobin (O_2Hb) and reduced haemoglobin (Hb) have different absorption spectra. Currently available oximeters use two light-emitting diodes (LEDs) that emit light at the 660 nm (red) and the 940 nm (infrared) wavelengths. These two wavelengths are used because O_2Hb and Hb have different absorption spectra at these particular wavelengths. In the red region, O_2Hb absorbs less light than Hb ,

Age	Normal Heart Rate	Normal oxygen saturation (SpO ₂)
Newborn – 2 years	100 – 180	All patients should have an
2-10 years	60 - 140	SpO ₂ of 95% or above
Ten years -adult	50 - 100	

Table 4.3.14. Pulse Oximeter Ranges

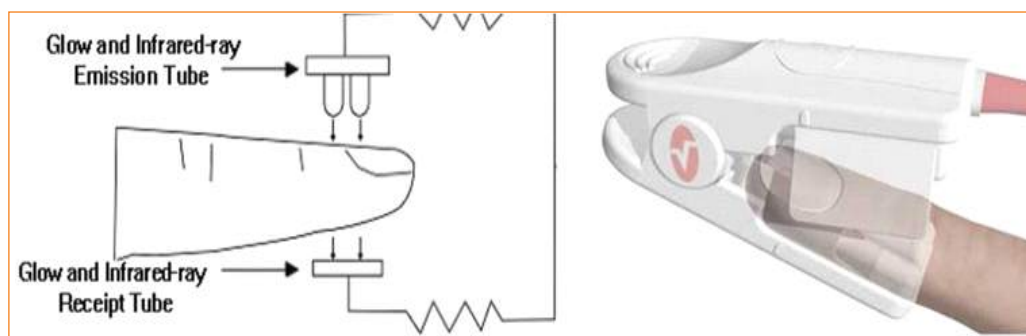


Fig. 4.3.60. Pulse Oximeter Working

Sl. No	Name & Description	Picture
1	DISPLAY: It shows the numerical value measured Spo ₂ saturation in % & Heart rate. Indications for alarm & battery. Graphical display of Plethysmograph(Pulsatile Blood Flow Graph)	
2	Finger Probe/ Sensor: A wired like probe have a specific design type fixed on the patient, either on the finger, earlobe or heel (neonate)	
3	Base Unit: Main unit with integrated display, socket for probe fixation, battery compartment.	

Fig. 4.3.61. Pulse Oximeter unit description with parts:

Practical:

- Identify the various accessories of the pulse oximeter.
- Operate the pulse oximeter and take your SPO₂ three times at an interval of 5 minutes.



Fig. 4.3.62. Pulse Oximeters and accessories

Operation of pulse oximeter:

Squeeze the clamp put a finger into the SPO2 sensor hole.

- Press the Power Button on the front panel until the device turns on.
- Do not shake the finger and keep the patient in a stable state during the process.
- The data can be read directly from the screen on the measuring interface.

Pause alarm

- Alarms include major parameters going beyond the limits, low- voltage and the alarm of finger out of position.
- If the alarm function is on the measuring interface, you can pause it by pressing the button shortly during the alarming period, but the function will be renewed in about 60 seconds.
- If you want to turn off the alarm for good, you should enter the menu for operation

Menu operations

- The user can set up the following parameters in the settings menu – backlight brightness, alarm
- High-low limits, data transmission, data storage (recording), data upload to computer.

Instructions for safe operations

- Check the central unit and all accessories periodically to ensure no visible damage that may affect the patient's safety and monitoring performance about cables and probes.
- It is recommended that the device should be inspected at least once a week. Please stop using the monitor if there is evident damage to the device.

- Necessary maintenance must be performed by qualified service engineers ONLY. There are no user-serviceable parts, and users are not permitted to service the device by themselves.
- The Oximeter cannot be used together with devices not specified in the User's Manual.
- Only the accessory appointed or recommendatory by the manufacture can be used with the device.

Do's and do nots

- Explosive hazard—DO NOT use the Oximeter in the environment with flammable gas such as some ignitable anaesthetic agents.
- Don't use the Oximeter while the tested measured by MRI and CT.
- Please choose the accessories and probe (optional) approved or manufactured by the manufacturer, or else it may damage the device.
- Keep the Oximeter away from dust, vibration, corrosive substances, explosive materials, high temperature and moisture.
- If the Oximeter gets wet, please stop using it immediately.
- When it is carried from a cold environment to a warm or humid climate, please do not use it immediately
- DO NOT operate keys on the front panel with sensitive materials.
- High temperature or high-pressure steam disinfection of the Oximeter is not permitted. Refer to User Manual for instructions on cleaning and disinfection.
- Do not immerse the Oximeter in liquid. When it needs cleaning, please wipe its surface with the disinfectant solution using a soft cloth. Do not spray any liquid directly onto the device.
- When cleaning the device with water, the temperature should be lower than 60degree.
- The fingers that are too thin or too cold would probably affect the standard measure of the patient's SpO2 and pulse rate; please clip the thick finger such as thumb and middle finger deeply enough into the probe.
- Use required probe type as per patient category, i.e. adult, paediatric or infant,
- The update period is less than 5 seconds, which is changeable according to different individual pulse rates.
- Please read the measured value when the waveform on-screen is equably and steady-going; this measured value is the optimal value. And the waveform at the moment is the standard one.
- If some abnormal conditions appear on the screen during the test process, pull out the finger and reinsert to restore regular use. This device has the function of alarming; users can check on this function accordingly
- The device has the function of limits alarming; when the measured data exceeds the highest or lowest limit, the device will start alarming automatically on the premise that the scary part is on.
- The device has the function of alarming; this function can either be paused or closed for good,
- A flexible circuit connects the two parts of the device. Do not twist or pull on the connection.
- The unit shall be fully charged when it's kept in an Idle state.
- The battery compartment should be checked from time to time for any leakage.
- Timely replacement of the battery and sensor in case of expiry of life.

Notes for proper operations:

- Please check the device before using, and confirm that it can work typically.
 - The finger should be in a proper position, or else it may result in inaccurate measurements.
 - The SpO2 sensor and photoelectric receiving tube should be arranged with the subject's arteriole in a position there between.
 - The SpO2 sensor should not be used at a location or limb tied with the arterial canal or blood pressure cuff or receiving an intravenous injection.
 - Do not fix the SpO2 sensor with adhesive, or else it may result in venous pulsation and inaccurate measure of SpO2 and pulse rate.
 - Excessive ambient light may affect the measuring result. It includes a fluorescent lamp, dual ruby light, infrared heater, direct sunlight, etc.
 - Strenuous action of the subject or extreme electrosurgical interference may also affect the accuracy.
 - The nail cannot use enamel or other makeup.
 - Please clean and disinfect the device after operating according to the User Manual
- General cleaning for Pulse Oximeter sensors:
- Turn off the Oximeter before cleaning
 - Wipe exposed surfaces with a soft cloth or a pad moistened with a mild detergent solution or medical alcohol (70% isopropyl alcohol solution)
 - Clean your Oximeter whenever you see any type of soil, dirt or obstruction in it

Clean the inside of the elastic thimble and the two optical elements inside with a cotton swab or equivalent moistened with a mild detergent solution or medical alcohol (70% isopropyl alcohol solution).

Ensure that no dirt or blood is on the optical components inside the elastic thimble

Caution: Do not spray, pour, or spill any liquid on the oximeters, their accessories, switches or openings

User Maintenance Checklist:

Daily	
Cleaning	Remove any dust with a damp cloth and dry off.
Visual	Check the central unit and all accessories periodically to ensure no visible damage that may affect patient safety and monitoring performance of cables and sensors. Check power cable and connector for any damage or loose contact.
Function	After switching on the left, the monitor for its self-test.

Table 4.3.15. Daily Maintenance Checklist pulse oximeter

Weekly	
Cleaning	Clean the front panel, basinet by using damp cloth soaked in mailed detergent/soap water. Disinfection as per the manufacture's recommendation.
Visual	Check all screws and wheels of the bassinets. Check power cable, sensor and connector for any damage or loose contract.
Function	After switching on, leave the monitor for its self-test, see the light of the sensor probe.

Table 4.3.15. Weekly Maintenance Checklist pulse oximeter

Preventive Maintenance Every three months.

4.3.3.8 Multipara Monitor



Fig. 4.3.63. Multipara Monitor

In medicine, monitoring is the observation of a disease, condition or one or several medical parameters over time.

It can be performed by continuously measuring specific parameters by using a medical monitor

What are vital signs?

Vital signs are measurements of the body's most basic functions. The four main vital signs routinely monitored by medical professionals and health care providers include the following:

1. Body temperature
2. Pulse rate
3. Respiration rate (rate of breathing)
4. Blood pressure (Blood pressure is not considered a vital sign but is often measured along with the vital signs.)
5. Vital signs help detect or monitor medical problems.
Vital signs can be measured in a medical setting, at home, at the site of a medical emergency, or elsewhere.

Features Matrix

1. ECG 3 leads
2. ECG 5 leads
3. ECG 10 leads
4. Invasive BP
5. Dual Temp/C.O.
6. NIBP
7. SpO2



Fig. 4.3.64. Multi Para Feature Matrix

Classification by target parameter

- Cardiac monitoring
- Hemodynamic monitoring,
- Respiratory monitoring
- Neurological monitoring
- Blood glucose monitoring
- Childbirth monitoring
- Body temperature

Cardiac Monitor Defibrillators

- The phase cardiac monitoring generally refers to continuous monitoring of the heart activity
- Monitor/Defibrillators
- Some digital patient monitors, especially those used in EMS services, often incorporate a defibrillator into the patient monitor itself.

Hemodynamic monitoring

- Cardiac output and flow rate ;
- The heart is the driver of the circulatory system, pumping blood through rhythmic contraction and relaxation.

- The blood flow rate out of the heart, meaning literally "blood flow, motion and equilibrium under the action of external forces", is the study of blood flow or circulation. It explains the physical laws that govern the flow of blood in the blood vessels.

Respiratory monitoring

- Measurement of airway pressure (Paw), flow (F) and volume (Vol) during mechanical ventilation assists in the differential diagnosis of respiratory failure. The airway occlusion technique makes it possible to carefully characterize the mechanics of the lung, chestwall, and the total respiratory monitoring system
- Pulse oximetry; which involves measurement of the saturated percentage of oxygen in the blood, referred to as SpO₂, and measured by an infrared finger cuff,
- Capnography involves CO₂ measurements, referred to as (EtCO₂) or end-tidal carbon dioxide concentration. The respiratory rate monitored as such is called AWRR or (airway respiratory rate).

Neurological monitoring – EEG

- Intracranial pressure. Also, there are special patient monitors which incorporate the monitoring of brain waves
- A blood glucose meter; is an electronic device for measuring the blood glucose level
- Childbirth; also known as labour, delivery, birth

Body temperature monitoring

- "Body temperature" redirects here. For information regarding average human body temperature

Components of medical monitor

- Sensor
- Translating component
- Display device
- Communication links
- Alarm

Spo2 Sensor



Fig. 4.3.65. Spo2 sensor

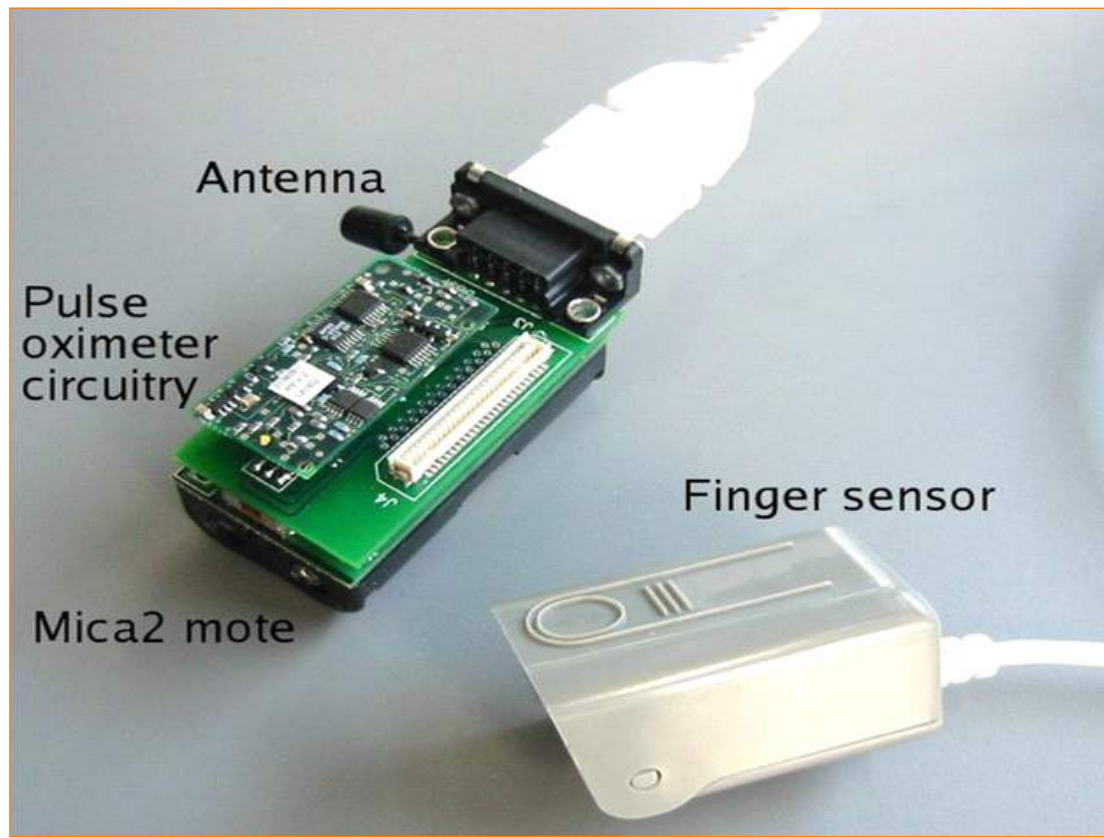
Spo2 sensor board

Fig. 4.3.66. Spo2 sensor board

Invasive BP sensor

Fig. 4.3.67. Invasive BP sensor

NIBP CUFF, connector

Fig. 4.3.68. NIBP CUFF, CONNECTOR

ECG sensor

Fig. 4.3.69. ECG sensor

ECG placement

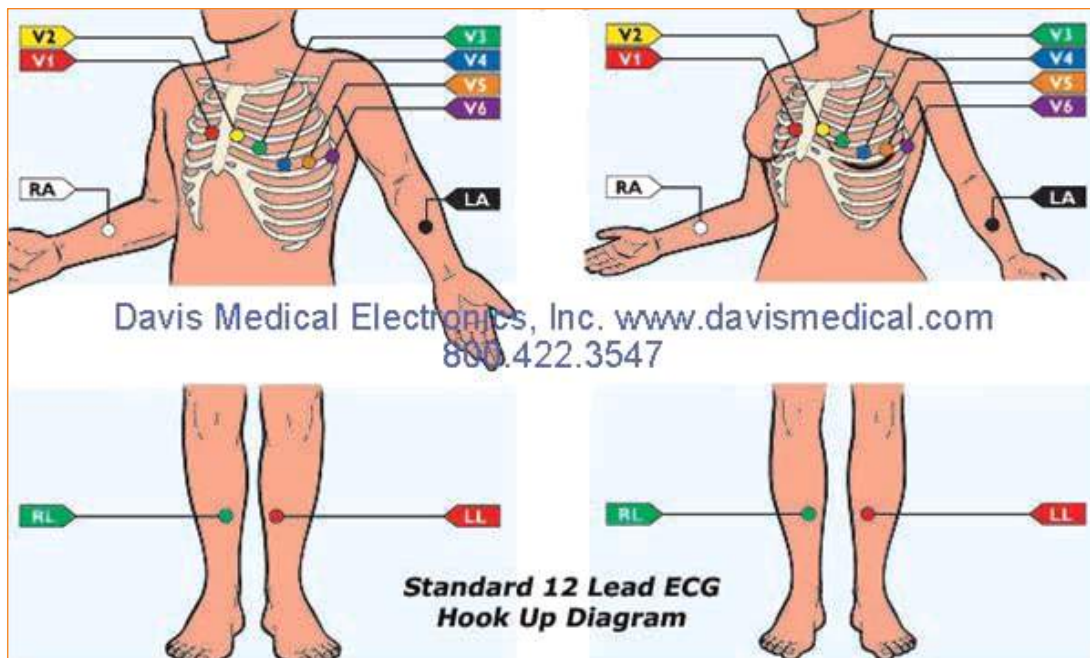


Fig. 4.3.70. ECG placement

ECG sensor board

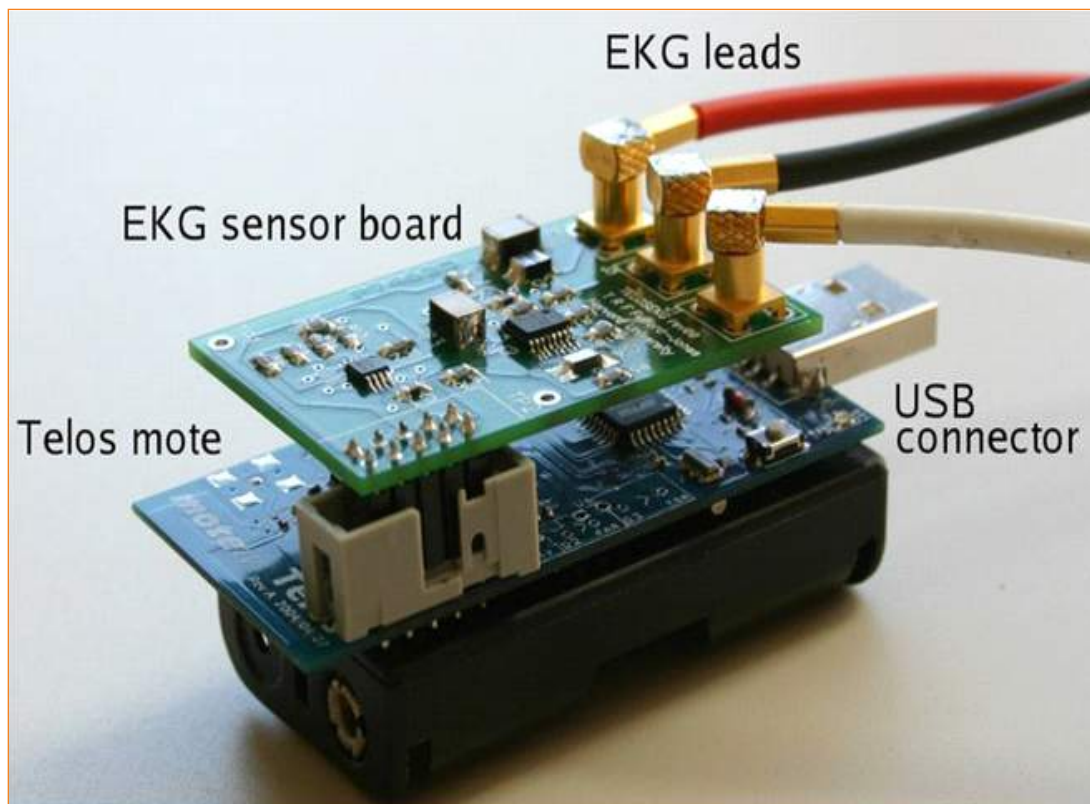


Fig. 4.3.71. ECG sensor board

Temp sensor



Fig. 4.3.72. Temp sensor

Panel dismolding



Fig. 4.3.73. Panel dismolding

Dismolding

- ECG, NIBP, SpO₂, TEMP, RESP, PULSE, Built-in rechargeable battery



Fig. 4.3.74. Dismolding

Potton & Connector Dismolding



Fig. 4.3.75. Potton & Connector Dismolding

Display Dismolding



Fig. 4.3.76. Display Dismolding

Power supply unit & fuse



Fig. 4.3.77. Power supply unit & fuse



Fig. 4.3.78. ECG module & PCB kit

Multi Paramonitor

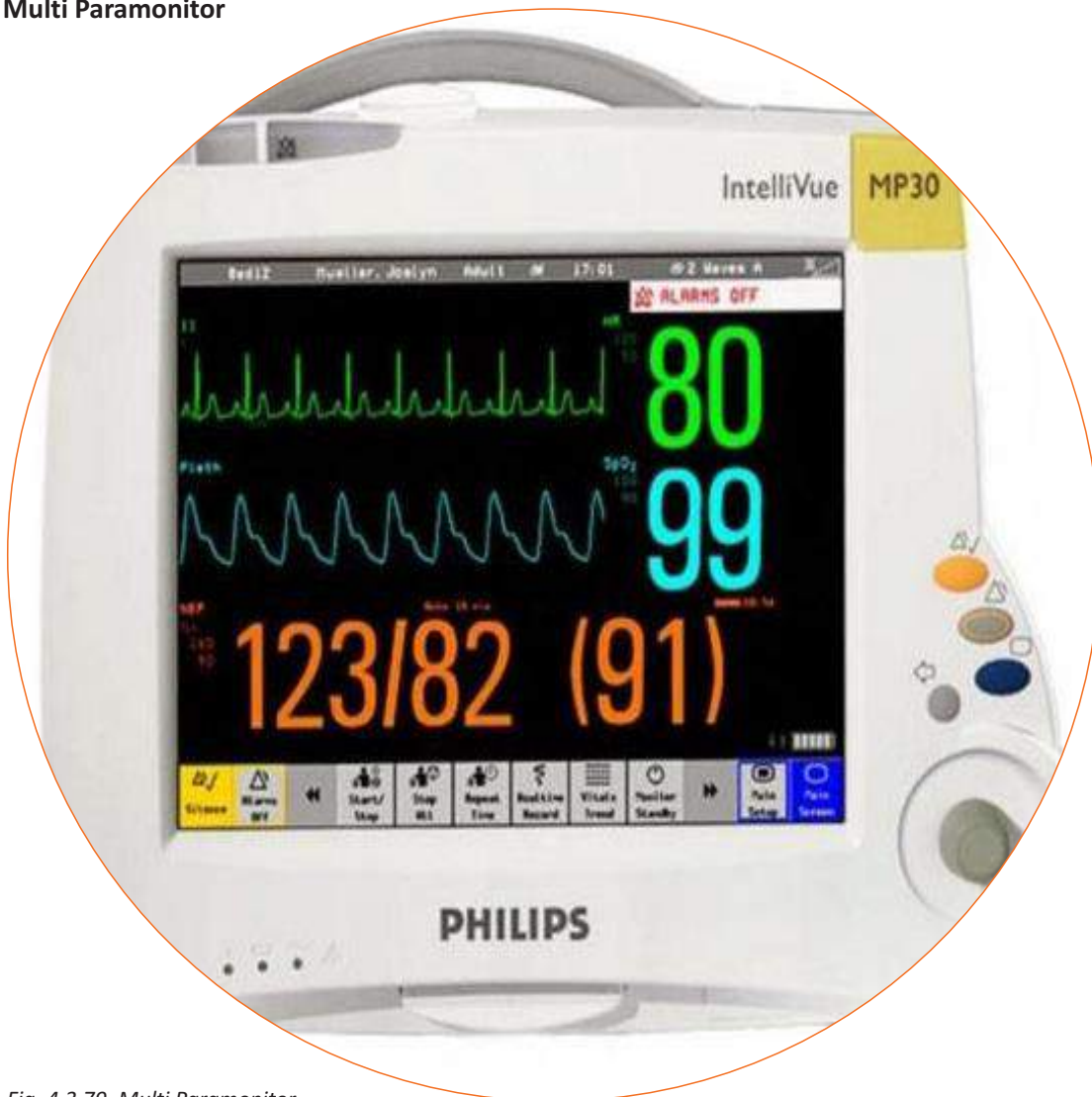


Fig. 4.3.79. Multi Paramonitor

4.3.3.9 Nebulizer

A nebulizer is a device used to administer medication in the form of a mist inhaled into the lungs. Nebulizers are commonly used for the treatment of cystic fibrosis, asthma and other respiratory diseases. The reason for using a nebulizer for medicine to be administered directly to the lungs is that tiny aerosol droplets can penetrate the thin branches of the lower airways. Large droplets would be absorbed by the mouth cavity, where the clinical effect would be expected.

The common technical principle for all nebulizers is to use oxygen, compressed air or ultrasonic power to break up medical solutions or suspensions into tiny aerosol droplets. These are passed for direct inhalation either through the mouthpiece of the device or a hose set. Gas-powered devices use a small pump to force the gas through the solution and filter the gas inlet. Ultrasonic devices use a small crystal to generate vibrations in the solution that cause droplets to break off.

Types of nebulizers

There are two types of nebulizers

- **Atomizer jet or compressor nebulizer:** It uses an aerosol compressor to vaporize droplets of medicine.
- **Ultrasonic or "mesh nebulizers":** Uses high-frequency sound waves to make liquid medicine breathable. While ultrasonic models produce results comparable to jet nebulizers, they offer faster delivery of medication and operate more quietly.

With both types of nebulizers, the patient inhales vapour through a mouthpiece or face mask.

Parts of nebulizer:

Compressor: The compressor creates a pressurized stream of air that passes through the liquid medicine placed in the nebulizer cup.

Air Tubing: A tube is used to connect the compressor to the nebulizer cup.

Nebulizer Cup: A small cylindrical container meant to add nebuliser medication and convert liquid medicine into an aerosol mist.

Mouthpiece or Mask: The nebulizer cup is connected to a mouthpiece/mask that is meant for delivering the mist to the mouth

Use of Nebulizer - Steps

Step 1. Wash your hands: Use soap and water.

Step 2. Connect the compressor to the electric plug.

Step 3. Place the suitable saline and medication / premixed medicine amounts into the container (Nebulizer Cup) using a dropper or syringe.

Step 4: Attach air tubing to nebulizer and machine.

Step 5: Attach a Face mask or mouthpiece to the nebulizer cup. Placement to the patient:

Mouthpiece: Place the voice in your mouth between your teeth and close your lips tightly. It is essential to breathe in from the mouth, out from the nose. Until the technique is mastered, plug the nose during inhalations.

Face mask: Attach to the face with the elastic band if possible (the further it is from the beginning, the more medicine escapes, and the treatment loses effectiveness).

Step6: Hold nebulizer upright and turn the machine on (A mist will come from the nebulizer) Continue until all medication is gone (about 7-10 minutes). When the mist slows, you can shake the medicine cup and flick it with your finger to help the last drops of medication be nebulised.



Fig. 4.3.80. Parts of Nebulizer

How to clean nebulizers:

- Regular cleaning of its parts is essential for preventing infection and other problems.
- Remove the mask or mouthpiece, T-shaped elbow, and the medicine cup, and wash them in warm water after each nebulization.
- Use a clean toothbrush to scrub these parts, then use distilled or sterile water to rinse the nebulizer parts. Keep them on a soft and clean cloth, and allow them to air dry. After completely dry, wipe them with a clean, dry cloth before storing them in a zip lock bag.
- For the drying cup, tube and mask, attach the assembly with the machine and keep the device on for 2-3 minutes for inside dry.
- Clean the outer surfaces of the leading machinery with a damp cloth regularly.
- Check air filter and replace as needed/returned it after its life.
- Replace the nebulization kit every 3-6 months/ based on usages

Block Diagram of nebulizer:*Fig. 4.3.81. Block Diagram of Nebulizer***User maintenance of nebulizers**

Daily	
Cleaning	Remove any dust/dirt with a damp cloth and dry off Clean and sterilize mouthpiece and medicine chamber
Visual checks	Check all parts are present and tightly fitted Check all moving parts move freely; all holes are unblocked
Function checks	Check the whole system function before use

Table 4.3.16. Daily Maintenance Nebulizer

Weekly	
Cleaning	Unplug, clean inside and outside with a damp cloth and dry off Clean filter and air chamber of the compressor
Visual checks	Clean chamber and tube seals, replace if damaged If mains plug, cable or socket are damaged, replace them
Function checks	When next used, check for adequate nebulization Check compressor fan is working without excessive noise

Table 4.3.17. Weekly Maintenance Nebulizer

Preventive maintenance required every six months

4.3.3.10 BP Instrument

Sphygmomanometers (BP Apparatus)

A sphygmomanometer /blood pressure meter/blood pressure monitor/blood pressure gauge is a measuring or monitoring device used to measure a (Systolic and Diastolic).

Description of the device:

Any blood pressure apparatus consists of an inflatable cuff, a measuring unit (the mercury manometer or aneroid gauge), and a mechanism for inflation, a manually operated bulb and a valve or a pump operated electrically.

BP Apparatus parts description:

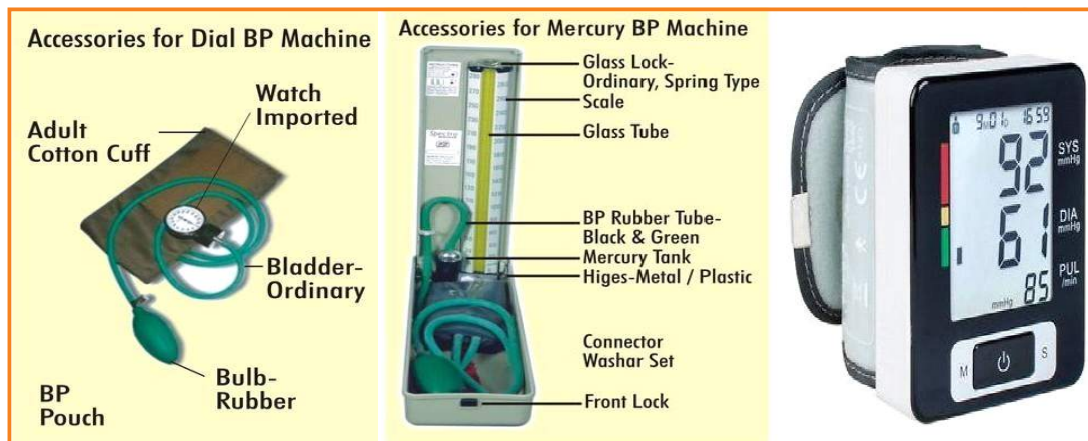


Fig. 4.3.82. Parts of BP Apparatus

The various parts of the BP Apparatus are as below:

1. **Bladder** - A flexible elastic inflatable bag that occludes the artery when compressed.
2. **Cuff with tube** - It is designed to hold the bladder around the limb to prevent bulging and ensure proper placement or positioning.
3. **Manometer** - This is the portion of the sphygmomanometer that includes aneroid style or, mercury style or digital, which show the reading.
4. **Air release valve** - A deflation valve is present (screw type knob) with the sphygmomanometer to allow for controlled deflation for measurement.
5. **Inflation bulb** - A rubberized bulb that pumps the air into the cuff.

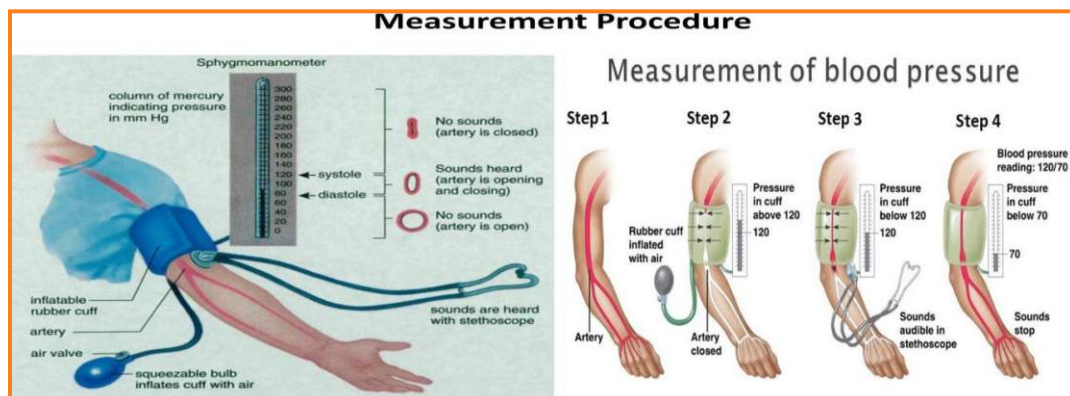


Fig. 4.3.83. Measurement of BP

Steps to Measure Blood Pressure



Step1

Wrap the blood pressure cuff around your patient's arm, right above the elbow, as shown in the above figure. Press the diaphragm of the stethoscope over the brachial artery just below the cuff's edge. Find your pulse in your inner arm to help you determine where your brachial artery is located.

Step 2

Inflate the cuff to 180mmHg or 30mm above your expected systolic blood pressure by looking at the sphygmomanometer gauge.

Step-3

Release air from the cuff by unscrewing the release valve at a moderate rate (3mm/sec). While releasing the air, listen with the stethoscope and keep your eyes on the sphygmomanometer gauge. Listen for Korotkoff sounds. The first knocking sound that you hear in the stethoscope is your patient's systolic blood pressure.

Step-4

Note that number, but keep watching the sphygmomanometer. After the first sound stops, note the number that it stops on. That number is the diastolic pressure.

Note:- In order to ensure that you have the best experience with your sphygmomanometer, we recommend storing them at temperatures ranging from 50°F to 104°F (10°C to 40°C) at a relative humidity level of 15% to 85%.

Manometer

The manometer (gauge) attached to your sphygmomanometer requires minimal care and maintenance. The manometer may be cleaned with a soft cloth but should not be dismantled under any circumstances. Gauge accuracy can be checked visually; simply be sure the needle rests within the printed oval when the unit is fully deflated. It is recommended that you perform a calibration check every 1 years by your own/authorised service agency as per requirement.

Cuff cleaning and disinfection

Use one or more of the following methods and allow to air dry:

- Wipe with mild detergent and water solution (1:9 solution). Rinse.
- Wipe with 70% isopropyl alcohol.

Disinfection

Remove the bladder from the cuff. Spray the detergent solution liberally onto the cuff and use a sterile brush to agitate the detergent solution over the entire cuff surface for five minutes. Rinse continuously with distilled water for five minutes. Leave the cuff to air dry.

Tube: constructed of crack-resistant, non-sticking, high-density hypoallergenic latex-free PVC

CAUTION: Do not iron the cuff.

CAUTION: Do not heat or steam sterilize the cuff.

Table II Acceptable dimension of the rubber bladder for different sizes of arms

Cuff denomination	Arm Circumference (cm)	Cuff width (cm)	Bladder length (cm)
Infant	6-15	5	15
Child	16-21	8	21
Small adult	22-26	10	24
Adult	27-34	13	30
Large adult	35-44	16	38
Thigh	45-52	20	42

Table 4.3.18. Parts of BP Apparatus



Fig. 4.3.84. Parts of BP Apparatus

Practical- Identify the various parts of a BP Apparatus

4.3.11 ECG machine

Description of the device

ECG (or Electrocardiographs) machines are used to monitor the heart's electrical activity and display it on a small screen or record it on a piece of paper. The recordings are used to diagnose the condition of the heart muscle and its nerve system.

How it works

The electrical activity is picked up using electrodes placed on the skin. The signal is amplified, processed if necessary and then ECG tracings displayed and printed. Some ECG machines also provide preliminary interpretation of ECG recordings. There are 12 different types of recording said depending upon the points from where the recordings are taken. Care must be taken to make the electrode sites clean of dirt before applying electrode jelly. Most problems occur with the patient cables or electrodes.

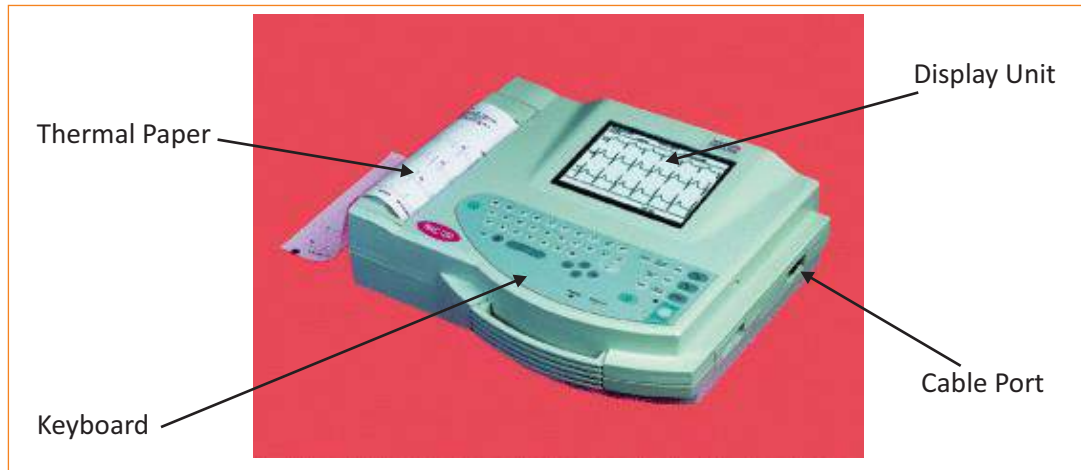


Fig. 4.3.85. ECG Machine



Fig. 4.3.86. Accessories ECG Machine

There are two types of electrodes:

1. Limb Electrodes- can be placed on any part of the patient's respective limbs. Just make sure the leads are symmetrical. For example, don't put one lead on the left shoulder and the other lead on the right forearm. I've heard of one local doctor that preferred all four leads to be placed relatively equal distances distally. For example, if you put leads on the wrists, leads should also go on the ankles. I haven't found anything to back that, but that's at least one professional's theory. Leads are named per their position- LA-Left Arm, RA- Right Arm, LL- Left Leg and RL-Right Leg.

2. Chest Electrodes-The 6 leads are labelled as "V" leads and numbered V1 to V6. They are positioned in specific positions on the rib cage.

Practical-

1. Place the Limb and Chest Electrodes on a dummy patient and identify the positions of the various Chest Electrodes to be placed.
2. Identify the difference between disposable and reusable Electrodes.
3.
 - a. Identify the 12 different types of the waveform that are generated and name them.
 - b. Draw a typical ECG Waveform and mark P, Q, R, S and T points. (The twelve different types of ECG Waveforms are known as Leads. L-1 is the waveform between LA and RA; L-2 is between LL and RA, and L-3 is between LL and L A; Augmented Waveforms- aVf- is between the Centre of the body to LF; aVL is between the centre of the body to LA; aVR is between the centre of the body to RA and V1, V2, V3, V4, V5, V6 are Chest leads available at various locations on the Chest. Reference in all the cases is the Right Leg-RL)

Daily	
Cleaning	Clean off dust with a dry cloth and replace the dust cover
Visual checks	Check that the battery charge indicator, power indicator and patient cable connector indicators are working
Function checks	Check the calibration of the machine before use using a 1mV pulse Check the baseline of the ECG recording is steady Check the printing is clear

Table 4.3.19. Daily maintenance ECG machine

Weekly	
Cleaning	Clean the printing head
Visual checks	Check all cables are not bent, knotted or damaged Replace any damaged electrical plugs, sockets or cables Check all knobs, switches and indicators are tightly fitted
Function checks	Check the calibration of recordings with ECG simulator Check battery power can operate the equipment

Table 4.3.20. Weekly maintenance ECG machine

Preventive maintenance every six months

4.3.3.12 Suction Apparatus And Its Pipelines

Description of the device

Suction machines (also known as aspirators) are used to remove unwanted fluid from body cavities. They are found in operating theatres, delivery suites, ENT and emergency departments. In addition, smaller specialised suctions are used in dental departments.

How it works

A pump generates suction. This device is usually an electrically powered motor, but manually powered versions are also often found. The pump generates a suction that draws air from a bottle. The reduced pressure in this bottle then draws the fluid from the patient via a tube. The liquid remains in the bottle until disposal is possible. A valve prevents fluid from passing into the motor itself.

Suction apparatus / aspirator are of two types

- A. Mechanical driven suction apparatus-foot operated and hand-operated suction device.
- B. Electrical driven suction apparatus



Fig. 4.3.87. Hand-operated suction device



Fig. 4.3.88. Foot-operated suction device

Foot-operated suction devices are more common than hand-operated suction devices:

Parts:

- Suction tubing/ hose
- Suction bottle
- Bellows for placing the foot

Working Principle:

- Connect suction catheter to patient end of suction tubing attached to the suction machine
- Place the foot suction on the floor across and in front of the resuscitation trolley, with bellows on the right side (if you use your right foot) and a fluid collection jar on the left side.
- Ensure that foot suction is close to the resuscitation trolley so that it can be operated on while resuscitating the baby
- Ensure that suction catheter is placed on the baby mattress and tube length is not short
- Place right foot on bellows and press down, ensuring that it slides down in contact with the central vertical metal plate. In addition, this device provides that bellows do not tilt outwards, preventing slipping of the foot.
- Foot pressure can be adjusted to ensure adequate suction pressure.
- Pinching the suction catheter end press bellows and check for suction pressure
- The safety of newborn maximum suction pressure is limited to 100 mm Hg, irrespective of foot pressure.
- It is most effective if regular rhythmic compression of the bellows is performed

Do's:

- Always do gentle suction to prevent tissue trauma
- Maintain asepsis by proper hand washing, face mask
- Use disposable suction catheters and always check the suction pressure

Don'ts:

- One should avoid solid and deep suction.

Cleaning/sterilization:

- The foot suction must be cleaned immediately after use.
- Empty the fluid collection jar.
- The fluid collection jar can be autoclaved at 124 degrees centigrade.
- This can also be washed with soap and water.
- Re-assemble when dry. Replace in the carry case.
- Empty fluid jar immediately when filled more than half
- If the fluid pot cannot be emptied immediately when complete, to prevent fluid overflow into a bellow, open the alternate suction inlet.
- No suction pressure will be created even if below is compressed.

Suction apparatus (electrical)

Suction machines (also known as aspirators) are used to remove unwanted fluid from body cavities. This is a crucial patient care device widely used in OPD/Indoor/OT/LR/Emergency and ambulance.

Working Principle:

A pump generates suction. This is usually an electrically powered motor. The pump generates a suction (negative pressure) that draws air from a bottle. The reduced pressure in this bottle then draws the fluid from the patient via a tube. A valve prevents fluid from passing into the motor itself when the bottle is filled. Thus, motor speed determines the suction strength.

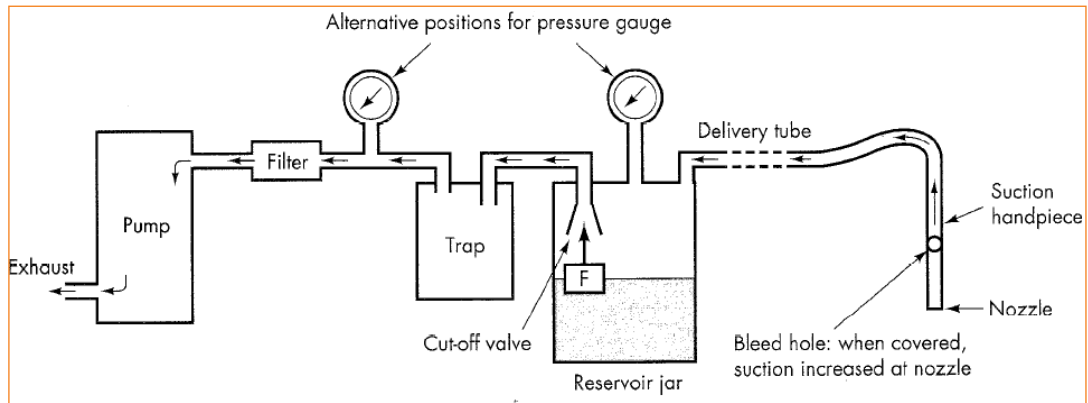


Fig. 4.3.89. Diagram of the electrical suction machine.

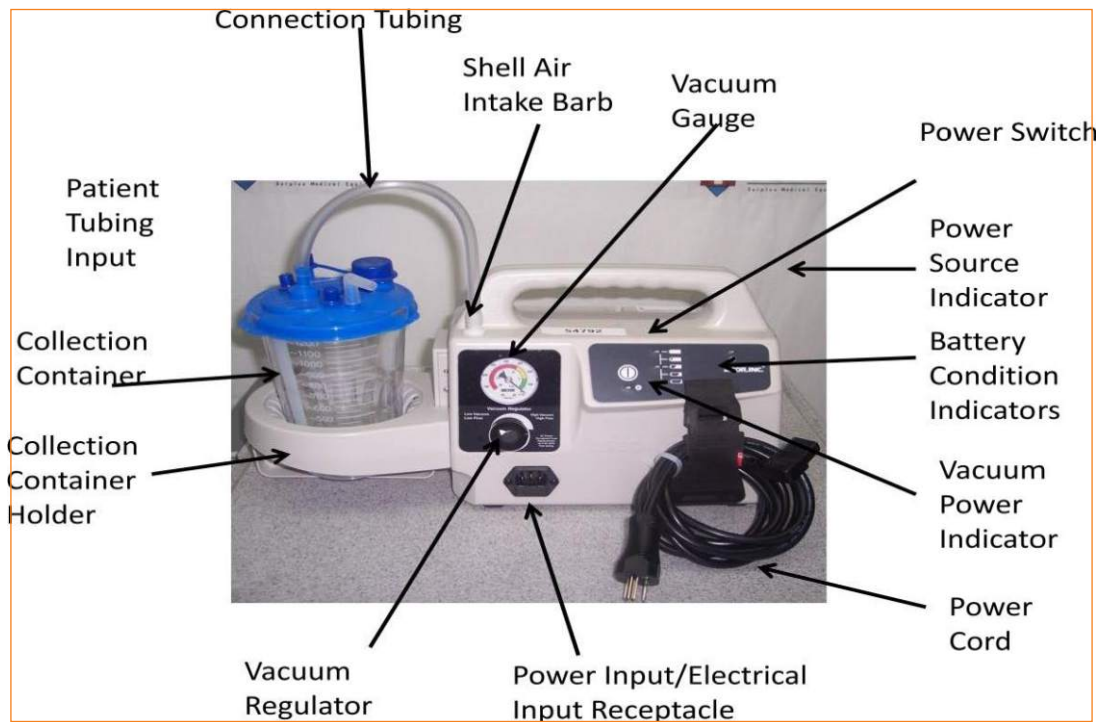


Fig. 4.3.90. External view of Electric Suction Machine

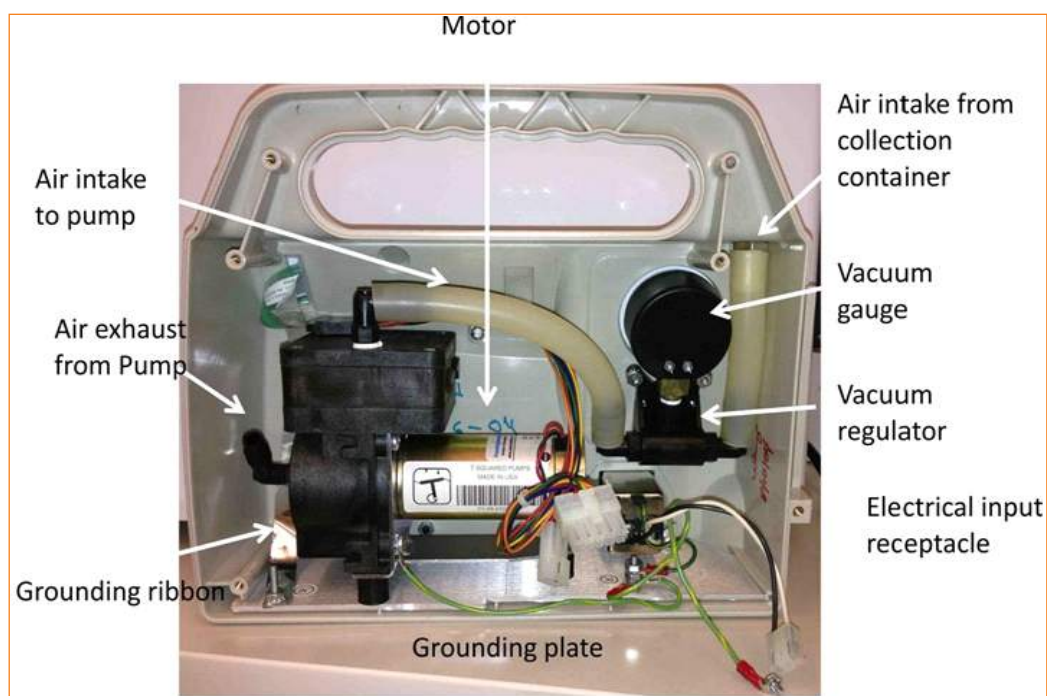


Fig. 4.3.91. Internal View of Electrical Suction Machine

Operation of electrical suction apparatus:

- Position the unit close to the patient
- Plug into AC power (do not use extension cords)
- Attach first suction tubing from pump suction control to collection bottle outlet
- Attach second suction tubing to collection bottle inlet
- Check all components and connections for a tight fit
- Turn suction pump on (on/off electrical switch)
- Crimp tubing coming from the collection bottle inlet
- To test the full range of suction
- Adjust suction to the desired level while observing vacuum gauge
- Initiate suction procedure

Cleaning/Sterilization

- The suction must be cleaned immediately after use.
- Empty the fluid collection jar.
- The fluid collection jar can be autoclaved at 124 degrees centigrade.
- This can also be washed with soap and water.
- Re-assemble when dry. Replace in carrying case.
- Empty fluid jar immediately when filled more than half
- If the fluid pot cannot be emptied immediately when complete, to prevent fluid overflow into a bellow, open the alternate suction inlet.

User Maintenance Checklist:

Daily	
Cleaning	Wipe dust off the exterior and cover equipment after checks Clean filters Clean air vents Disinfect jars, tubing, other components that come into contact with patient fluids between each use in the solution of water, detergent, and disinfectant
Visual checks	Check all fittings and accessories are mounted correctly Check filter is clean
Function checks	Check if not use on that day, run a brief functional check before clinical use. Ensure vacuum works over the full range of suction pressures if there is a control/knob

Table 4.3.21. Daily maintenance suction apparatus

Weekly	
Cleaning	Unplug, clean outside with a damp cloth and dry off Wipe round bottle seal with a damp cloth, replace if cracked. Remove dirt from wheels/moving parts.
Visual checks	Check parts are fitted tightly and replace any cracked tubes. Check mains plug screws are tight. Check mains cable has no bare wire and is not damaged
Function checks	Check all switches and vacuum control operate correctly.

*Table 4.3.22. Weekly maintenance suction apparatus***Preventive maintenance every six months**

Practical-

1. Identify the various parts of Foot Operated, Hand Operated and Electrical Suction machines.
2. Assemble the Electrical suction machine and adjust the vacuum by the knob.
3. Learn sterilisation procedures for the suction jar.
4. Learn to replace the tubing in a suction machine.

4.3.3.13 Steam Inhaler

Steam inhalation module

Steam inhalation is one of the most widely used home remedies to soothe and open the nasal passages and relieve symptoms of a cold or sinus infection.

Also called steam therapy, it involves the inhalation of water vapour. The warm, moist air is thought to work by loosening the mucus in the nasal passages, throat, and lungs. This module may relieve symptoms of inflamed, swollen blood vessels in your nasal passages.

While steam inhalation won't cure an infection, like a cold or the flu, it may help make you feel a lot better while your body fights it off. But as with any home remedy, it's important to learn best practices not to hurt yourself in the process.

What are the benefits of steam inhalation?

A stuffy nose is triggered by inflammation in the blood vessels of the sinuses. The blood vessels can become irritated because of an acute upper respiratory infection, such as a cold or a sinus infection.

The main benefit of breathing in moist, warm steam may help ease irritation and swollen blood vessels in the nasal passages. The moisture may also help thin the mucus in your sinuses, which allows them to empty more quickly. This module can allow your breathing to return to normal, at least for a short period.

Steam inhalation may provide some temporary relief from the symptoms of:

- The common cold
- The flu (influenza)
- Sinus infections (infectious sinusitis)
- Bronchitis
- Nasal allergies

While steam inhalation can provide subjective relief from a cold and other upper respiratory infection symptoms, it won't make your infection go away any faster.

Steam inhalation doesn't kill the virus responsible for the infection. At best, steam inhalation might make you feel a little better as your body fights your cold.

One review of six clinical trials evaluating steam therapy in adults with the common cold had mixed results. Some participants had symptom relief, but others didn't. Additionally, some participants experienced discomfort inside the nose from the steam inhalation.

Another recent clinical trial looked at the use of steam inhalation in treating chronic sinus symptoms. The study, however, didn't find that steam inhalation was beneficial for the majority of sinus symptoms, except for a headache.

Although the results of clinical studies have been mixed, anecdotal evidence claims steam inhalation helps alleviate:

- Headache
- Congested (stuffy) nose
- Throat irritation
- Breathing problems caused by airway congestion
- Dry or irritated nasal passages
- Cough

How to inhale steam?

You'll need the following materials:

- A large bowl
- Water
- A pot or kettle and a stove or microwave for heating water
- Towel

Here's the process:

- Heat the water to boiling.
- Carefully pour the hot water into the bowl.
- Drape the towel over the back of your head.
- Turn on a timer.
- Shut your eyes and slowly lower your head toward the hot water until you're about 8 to 12 inches away from the water. Be extremely careful to avoid making direct contact with the water.
- Inhale slowly and deeply through your nose for at least two to five minutes.

Don't steam longer than 10 to 15 minutes for each session. However, you can repeat steam inhalation two or three times per day if you're still having symptoms.

You can also purchase an electric steam inhaler (also called a vaporizer) online or at a drugstore. For these, you need to add water to the level indicated and plug in the system. The vaporizer uses electricity to make steam that cools before exiting the machine. Some vaporizers come with a built-in mask that fits around your mouth and nose.

Steam vaporizers can get dirty with germs quickly, so you'll need to wash them often to prevent bacterial and fungal growth. Wash the bucket and filter system every few days during use, too.

Side effects of steam inhalation

Steam inhalation is considered a safe home remedy if done right, but it's possible to hurt yourself unintentionally if you're not careful.

There's a risk of scalding yourself if you make contact with the hot water. The most significant risk is accidentally knocking over the bowl of hot water into your lap, which can cause severe burns in sensitive areas.

To avoid burns:

Ensure the bowl of hot water is on a level, sturdy surface and can't be knocked over.

Don't shake or lean on the bowl.

Avoid allowing the steam to make contact with your eyes. Instead, your eyes should be closed and directed away from the moisture.

Keep the bowl of hot water out of reach of children or pets.

Steam inhalation isn't advised for children due to the risk of burns. One study trusted Source found that most people who received burns from steam inhalation therapy were children. However, you can have your child sit in a steamy bathroom while you run hot water in the shower for a similar effect.

Steam inhalation systems that you can purchase online or in stores are generally safer, as the water is enclosed and can't easily spill on your skin.

The takeaway

Steam inhalation may be an effective way to clear up your nasal and respiratory passages when you're sick with a cold or the flu, but it won't cure your infection. Your body's immune system will still do the bulk of the work to get rid of the virus causing your symptoms.

Like many home remedies, always proceed with a grain of salt. What works for one person might not work for you.

If you experience any discomfort, pain, or irritation from using steam therapy, stop using it and look for other ways to alleviate your symptoms.

If you're feeling under the weather for more than a week or have severe symptoms, make an appointment to see your doctor.

Steam Inhalation precautions

Steam Inhalation of warm, moist air into the mucous membranes and respiratory tract.

- The temperature of the water should remain between 120 to 160 F or 54.5 to 76.5 C
- Water in the inhaler should remain just below the spout to avoid the scalding
- Keep the patient warm & prevent drought before, during & when inhalation.
- Observe the patient closely throughout the procedure.

Type of inhalation:**1. Dry inhalation**

- The inhalation of fumes from volatile drugs is known as dry inhalation.
- Example- ether, chloroform, nitrous. oxide, menthol, ammonia

2. Moist inhalation

The inhalation of plain steam or steam impregnated with a drug is known as moist inhalation.

Moist steam inhalation is defined as the utilization of moist heat to loosen lung congestion & helps to liquefy secretions

- Example- Steam, tincture benzoin
- An Electronic Steam Inhaler is shown below

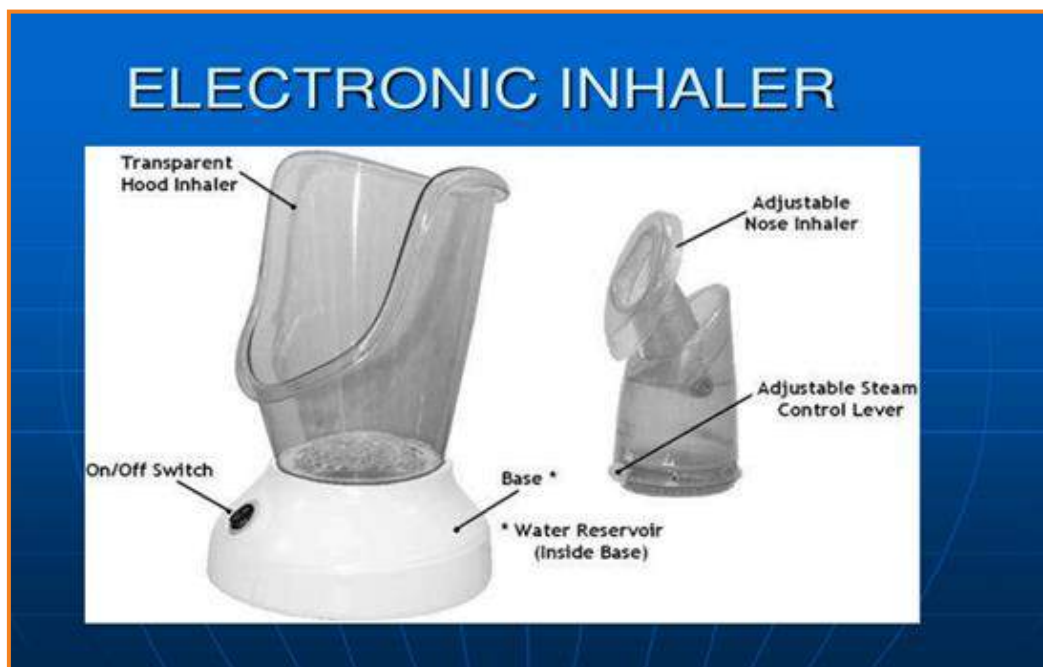


Fig. 4.3.92. Electronic Inhaler

Troubleshooting – Steam inhalation

Symptoms	Possible Cause	Solution
The Steam inhalation machine fails to start up	AC power not connected	Check that AC power is connected correctly.
Coil & atomizer does not work	The coil & atomizer not correctly attached	Make sure the coil & atomizer is properly attached & and the battery is fully charged.
Inhalation not properly	Check nose inhaler	Adjustable nose inhaler.

Table 4.3.23. Troubleshooting steam inhaler

User maintenance check list

Daily	
Cleaning	Clean off dust with water and dry cloth
Visual checks	Check that the power indicator and cable connector are working fine
Function checks	Check the water heater before using

Table 4.3.24. Daily maintenance steam inhaler

Weekly	
Cleaning	Clean off dust with water and dry cloth
Visual checks	Check that power cables are not bent or damaged Replace any damaged electrical plugs, sockets or cables Check all knobs, switches and indicators are tightly fitted
Function checks	Check the water heater before using

Table 4.3.24. Weekly maintenance steam inhaler

4.3.3.14 Spirometer

Spirometer - Module

Basics of Respiration

The respiratory tract consists of the trachea, lungs, bronchi, bronchioles, and The alveoli constitute both the functional unit of the lung and the site of cellular respiration

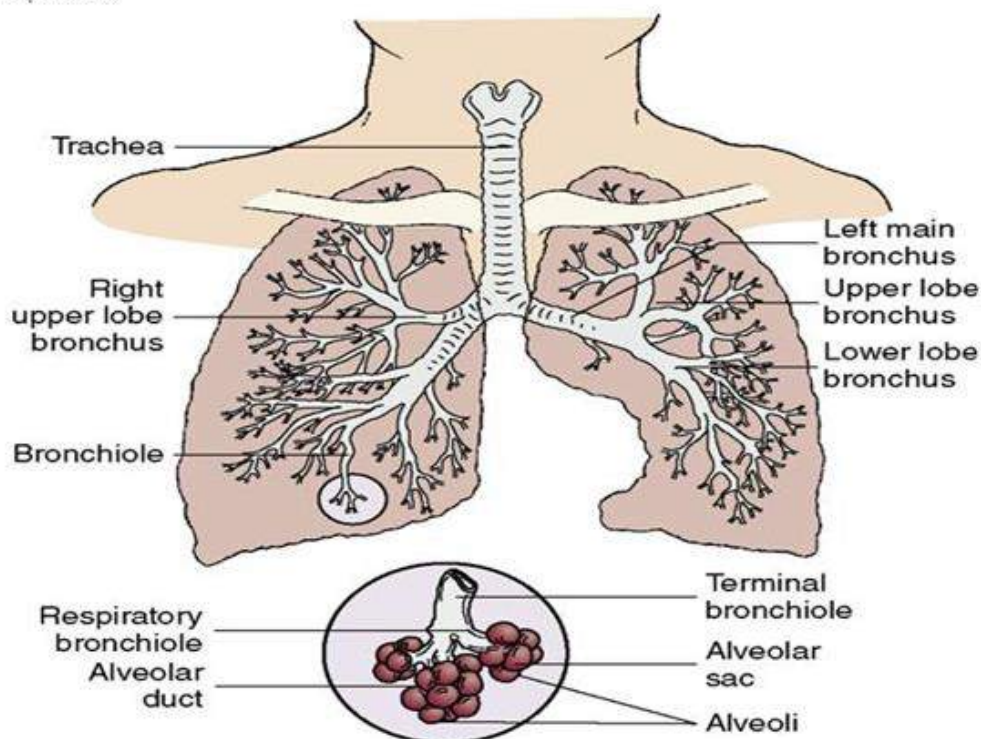


Fig. 4.3.93. Basics of Respiration

Spirometry – It is derived from the Latin word-s SPIRO (to breathe) and METER(to measure)

Spirometry which means "the measuring of breath," is a routinely used pulmonary function test (PFT) that measures the amount and speed of air that a person can inhale and exhale. Results from the trial can be used to estimate lung function and aid in the diagnosis of certain respiratory disorders.

A spirometer is an apparatus for measuring the volume of air inspired and expired by the lungs. In addition, a spirometer calculates ventilation, the movement of air into and out of the lungs. The spirogram will identify two different types of abnormal ventilation patterns, obstructive and restrictive.

Spirometry is a simple test used to understand how well the lungs function by measuring the amount of air inhaled, exhaled and how this happens. More technically speaking, it is one of the simplest Pulmonary Function Tests (PFT). Spirometry is used to diagnose a host of breathing disorders like Asthma, COPD, etc. It is also used to track recovery from a chronic lung condition. A Spirometer is a device used to perform the "Spirometry Test". It is also known as Respirometer or Lung Exerciser and measures the volume of air inhaled and exhaled by the lungs. Different types of Spirometers are - fully electronic, incentive, peak flow meter, etc. Following are the cases when it is used:

1. To diagnose lung diseases
2. To check lung function before planned surgeries
3. To assess the effect of medicines taken to treat pulmonary disease
4. To measure effects of exposure to harmful chemicals or pollutants on the lungs
5. To track the progress of lung disease treatment with a Lung Exerciser

Types of spirometers

- Bellows' spirometers - Measure volume, mainly in the lungs function unit.
- Electronic desktop spirometer – Measure flow and volume with real-time display.
- Small hand-held spirometers – Inexpensive and quick to use but not print



Fig. 4.3.94. Types of spirometers

How the Spirometer test is done:

1. A Weighing Machine measures body weight.
2. The nose is clipped to obstruct breathing through the nose.
3. Blow into a mouthpiece connected to the spirometer.
4. A spirometer creates the waveform of lung functions.

Purpose of the test:

Spirometry measures critical aspects of pulmonary (lung) function. Thus, the test can play an essential role in diagnosing and managing many lung problems. It can help distinguish between diseases with similar symptoms and determine whether the condition is obstructive (exhalation is impaired) and/or restrictive (inhalation is impaired).

Spirometry is rarely used alone to diagnose a lung condition. Instead, it is typically combined with other findings, such as a physical exam, medical history review, and imaging tests, to reach a diagnosis.

As part of a panel of PFTs, spirometry may be used to help diagnose:

- Chronic obstructive pulmonary disease (COPD)
- Emphysema (a type of COPD)
- Bronchiectasis (a type of COPD)
- Chronic bronchitis (a type of COPD)
- Asthma
- Pulmonary fibrosis, including idiopathic pulmonary fibrosis
- Cystic fibrosis

Spirometry is also helpful for evaluating disease progression (namely, whether it is getting better, worse, or staying the same). This process can help determine if a treatment is working or needs to be modified.

Spirometry may also be used before lung cancer surgery to predict how well a patient will tolerate the operation and manage once a portion or lobe of a lung is removed.

Contraindications**People should not undergo a spirometry test if they:**

- Have chest pain or have recently had a heart attack or stroke
- Have a collapsed lung (pneumothorax)
- Had recent eye surgery (deep breathing increases eye pressure)
- Had recent abdominal or chest surgery
- Have an aneurysm in the chest, abdomen, or brain
- Have tuberculosis (TB)
- Have a respiratory infection, such as a cold or the flu

There are certain conditions under which a person may not be able to breathe as fully and deeply, potentially undermining the accuracy of the test. While not necessarily contraindications, an evaluation from a doctor may be required before the test can proceed. The conditions include:

- Pregnancy
- Stomach bloating

- Extreme fatigue
- General muscle weakness

Spirometry –Possible side effects

- Feeling light-headed
- Headache
- Facial redness
- Fainting: Reduced venous return or vasovagal attack (reflex)s

Lung volume and capacities:

- Tidal Volume-TV- The volume of breath inhaled and exhaled during one breath.
- IRV- Inspiratory Reserve Volume- The amount of air that can be forcibly inhaled after an average tidal volume. IRV is usually kept in reserve but is used during deep breathing.
- Inspiratory Capacity- IRV+TV
- Expiratory reserve Volume- ERV- ERV is defined as the effort-driven volume that can be exhaled after a normal expiration, requiring good patient cooperation to yield accurate results. Low ERV can be seen in obstructive and restrictive -extrinsic or intrinsic- lung diseases
- Vital Capacity-VC- It is the total amount of air exhaled after maximal inhalation. The value is about 4800mL, and it varies according to age and body size. It is calculated by summing tidal volume, inspiratory reserve volume, and expiratory reserve volume. $VC = TV + IRV + ERV$.
- Total Lung Capacity-TLC-It is the maximum volume of air the lungs can accommodate or the sum of all volume compartments or volume of air in lungs after ultimate inspiration. The average value is about 6,000mL(4-6 L)
- Residual Volume- RV- It is the volume of air left in the lungs after exhalation.

Two important parameters

Forced expiratory volume (**FEV**) measures how much air a person can exhale during a forced breath. The amount of air exhaled may be measured during the first (**FEV₁**), second (**FEV₂**), and/or third seconds (**FEV₃**) of the forced breath. **Forced vital capacity (FVC)** is the total amount of air exhaled during the **FEV** test. The FEV₁ and FVC of COPD and Normal patients are shown in the graph below:

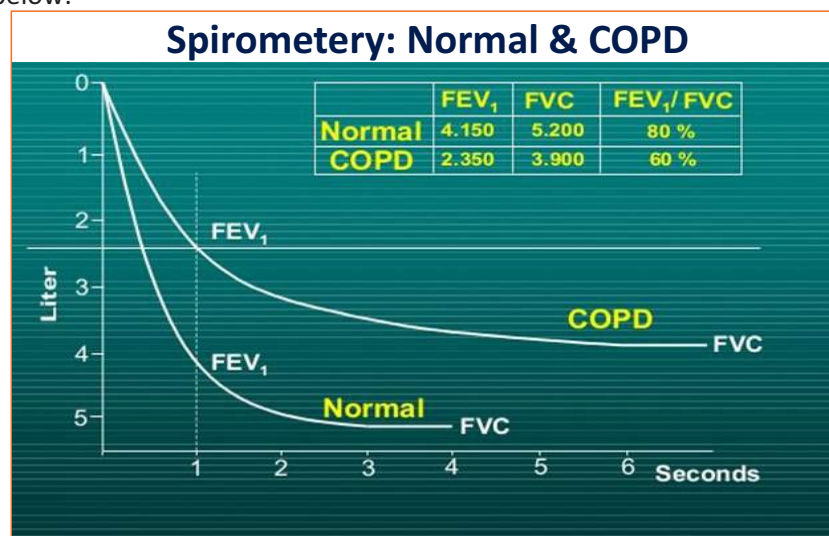


Fig. 4.3.95. Spirometry Normal and COPD

Spirometers for Exercise of lungs - **How to use a Spirometer to do lung exercises to increase lung capacity?**

An Incentive Spirometer used to help patients improve their lung capacity and lung function. It is generally used by patients who have had surgery that impedes lung function. Following are the steps of using a lung exerciser and how to increase lung capacity:

1. Put your mouth tightly around the mouthpiece
2. Inhale gradually and profoundly and try to raise the three balls as high as possible, and keep them there for at least three seconds
3. Now, take the mouthpiece out and exhale normally
4. Repeat this 5-10 times every two hours or as directed by your doctor



Fig. 4.3.96. Spirometer for Lungs Exercise

User maintenance check list

Daily	
Cleaning	The spirometer must be cleaned and disinfected internally at the Start of Stand, Weekly, and End of Stand
Hoses Cleaning	Clean the house; any hoses that leak be thrown away
Hoses and hose adapters	Used during day will be changed daily. Used hoses and adapters will be stored in a plastic bag and placed in the belly compartment

Table 4.3.25. Daily maintenance Spirometer

Tips

1. Anything that can be measured is a physical quantity. The Physical Quantity is calculated and written as magnitude and the SI Unit.

Exercise

1. List down the various disinfection procedures.
2. List the plug and socket classifications
3. Explain the roles and responsibilities chain of equipment supply.
4. Riegel Pro Sim 8 is used to ascertain the accuracy of measurements for which of the parameters list them.
5. CITREX H5 is intended for testing and calibration purposes on medical devices.
 - (a) True
 - (b) False
6. What is a waveform/graph explain?
7. How do we read data from Graphs/ Waveform?
8. As per NABL 126, how should the preventive maintenance and calibration interval for medical devices be?
9. List the details of setting up a complete system for preventive maintenance.
10. Prepare a 'Daily' and 'Weekly' maintenance task list for ventilators.
11. Effective planning for preventive maintenance involves selecting the equipment to be included in the plan explain.
12. List the system alarms for BIPAP and CPA.

Practical

1. Identify the Oxygen Cylinder, Valve keys and Flowmeter.
2. Connect the Oxygen Cylinder with a Flowmeter.
3. Open the Oxygen Flow with the keys and adjust the Flowmeter for various flows at 2 LPM and 5 LPM
4. Identify the various accessories of the pulse oximeter.
5. Operate the pulse oximeter and take your SPO2 three times at an interval of 5 minutes.
6. Identify the various parts of a BP Apparatus
7. Place the Limb and Chest Electrodes on a dummy patient and identify the positions of the various Chest Electrodes to be placed.
8. Identify the difference between disposable and reusable Electrodes.
9.
 - a. Identify the 12 different types of the waveform that are generated and name them.
 - b. Draw a typical ECG Waveform and mark P, Q, R, S and T points. (The twelve different types of ECG Waveforms are known as Leads. L-1 is the waveform between LA and RA; L-2 is between LL and RA, and L-3 is between LL and LA; Augmented Waveforms- aVf- is between the Centre of the body to LF; aVL is between the centre of the body to LA; aVR is between the centre of the body to RA and V1, V2, V3, V4, V5, V6 are Chest leads available at various locations on the Chest. Reference in all the cases is the Right Leg-RL)
10. Identify the various parts of Foot Operated, Hand Operated and Electrical Suction machines.
12. Assemble the Electrical suction machine and adjust the vacuum by the knob.
13. Learn sterilisation procedures for the suction jar.
14. Learn to replace the tubing in a suction machine.

Notes



Lined area for taking notes, consisting of 25 horizontal lines.

Summary

Many common problems with medical equipment can be avoided if it is properly delivered, checked for supplies and installed correctly. This chapter aims to assist those responsible for receiving and checking equipment when it arrives. If the right equipment comes in working order with the right parts and manuals, then a long and useful life is more likely.

Calibration refers to checking and adjusting an instrument so that its output faithfully corresponds to its input throughout a specified range.

The most common technologies for industrial temperature measurement are electrical: RTDs and thermocouples.

To accurately calibrate a pressure instrument in a shop environment, we must create fluid pressures of known magnitude against which we compare the calibrated instrument.

Oscilloscopes allow us to determine relationships between particular variables in electrical circuits.

While operating Medical Equipment, adequate precautions need to be taken. The following are the various categories of safety:

Many common problems with medical equipment can be avoided if it is properly delivered, checked for supplies and installed correctly.

Each person in the chain of equipment supply has a particular role and responsibility to fulfil. This applies right from when the need for new equipment is identified to the time when it is used.

When equipment arrives, it will be necessary to record the fact and to check that everything has been supplied that was ordered.

Medical Ventilators are also known as Mechanical Ventilators, Artificial Ventilators etc. We will henceforth refer to all these as Ventilators.

CPAP and BIPAP Machines are used to ventilate the patient in a Non Invasive manner.

An oxygen concentrator draws in room air, separates the oxygen from the other gases.

These flowmeters are commonly referred to as constant-pressure flowmeters because the decrease in pressure across the float remains constant for all positions in the tube.

A Digital thermometer has electronic circuits and has a digital display to show the readings either in degree Celcius or degree Fahrenheit.

Steam inhalation is one of the most widely used home remedies to soothe and open the nasal passages and relieve symptoms of a cold or sinus infection.

Spirometry is a simple test used to understand how well the lungs function by measuring the amount of air inhaled, exhaled and how this happens.

References

<https://www.youtube.com/watch?v=NOFsXoKne98&list=RDCMUcYTq2bhe5pim45pAEU-gDjw>
<https://www.youtube.com/watch?v=NOFsXoKne98&list=RDCMUcYTq2bhe5pim45pAEU-gDjw>
 Video link: <https://www.youtube.com/watch?v=3I9thXef8j0>
<https://www.youtube.com/watch?v=yGvN7xg3Xlo>
 Youtube video link- <https://www.youtube.com/watch?v=3I9thXef8j0>
<https://www.youtube.com/watch?v=WZRuOsJuYTY>
<https://www.respiratorytherapyzone.com/ventilator-settings/>
<https://www.youtube.com/watch?v=jBuopUg5-88>
<https://www.youtube.com/watch?v=VW-JyDKnHGk>
<https://www.youtube.com/watch?v=yGvN7xg3Xlo>
<https://www.youtube.com/watch?v=aBrw1JcN31l>
<https://www.youtube.com/watch?v=IhKSkfUqqyQ>
<https://www.youtube.com/watch?v=01n-KEG-zj8>
<https://www.apogeeweb.net/electron/how-do-infrared-thermometer-work-how-accurate-are-they.html>
<https://www.youtube.com/watch?v=yGvN7xg3Xlo>
<https://www.youtube.com/watch?v=YDIObOpzHyo>
 Smith Medical
 Zoll Webstore
 IndiaMART
 ECRI-Guidance [Health Devices Sep-Oct 1998;27(9-10):33-4
<https://build-a-vent.org/overview/calibration>
 Reasearchgate
<https://www.smartmedicalbuyer.com/collections/spirometer-lung-exerciser>
<https://www.smartmedicalbuyer.com/collections/spirometer-lung-exerciser>
<https://www.uofmhealth.org/health-library/aa73564>
https://www.physio-pedia.com/Lung_Volumes
https://www.physio-pedia.com/Lung_Volumes
<https://www.verywellhealth.com/asthma-and-spirometry-200531>
<https://en.wikipedia.org/wiki/Spirometer>
<https://manualzz.com/doc/6320361/ministry-of-health-health-infrastructure-division>
https://phd.spc.int/sites/default/files/p-related-files/2018-12/2015%20User%20Care%20of%20Medical%20Equipment_2015_Final_SSCSiP.pdf
https://www.slideshare.net/Rv_252/steam-inhalation-73041444
<https://www.healthline.com/health/steam-inhalation>
<https://www.citypeopleonline.com/why-many-families-are-going-for-steam-inhalation/>
<https://manualzz.com/doc/6320361/ministry-of-health-health-infrastructure-division>
<https://www.ontop-in.org/ontop-pen/Week-7/FOOT%20SUCTION%20MACHINE.pdf>
<https://www.primemedicaltraining.com/12-lead-ecg-placement/>
<https://www.adctoday.com/learning-center/about-sphygmomanometers/care-and-maintenance>
<https://healthhearty.com/nebulizer-machine-parts>
<https://www.slideshare.net/thangadurai13/patient-monitor-ppt-siva-hospital-nagarcoil>
https://en.wikipedia.org/wiki/Medical_monitoring
[https://en.wikipedia.org/wiki/Monitoring_\(medicine\)](https://en.wikipedia.org/wiki/Monitoring_(medicine))
<http://manual.pulseoximeter.org/CMS-50F.pdf>
https://www.med-linket.com/uploads/AM-601_user-manual_English.pdf
<https://www.gruasyaparejos.com/en/pulse-oximeter/pulse-oximeter-readings-normal-range/>
<https://www.hindawi.com/journals/bmri/2014/715434/>

References

<https://www.s-laser.com/info/what-is-the-range-of-the-infrared-spectrum-54445143.html>
<https://www.apogeeweb.net/electron/how-do-infrared-thermometer-work-how-accurate-are-they.html>
<https://medical.andonline.com/sites/default/files/documents/I-MAN-UA-651BLE-V-Rev3.pdf>
<https://www.wanlongstone.com/How-many-kinds-of-stone-infrared-cutting-machine.html>
<https://www.aandd.jp/products/manual/medical/ut601.pdf>
<https://www.zoeruth.com/blog/how-to-take-your-temperature>
<http://www.noranaes.org/logbook/resources/Ebooks/Miller1/Miller%20-%20Anesthesia%206th%20Ed/das/book/body/0/1255/232.html>
<http://error.nflint.com/403.html>
<https://wavehealthcare.com/docs/manuals/Philips-HCP-Cleaning-Disinfection-Guidance.pdf>
<https://www.manualslib.com/manual/1766499/Respironics-Bipap-Plus.html>
<https://manualzz.com/doc/6956616/bipap-a40-user-manual>
<https://www.slideshare.net/melendezcuauro/ventilador-pulmonar>
http://www.frankshospitalworkshop.com/teaching_learning/chris/CM%20Ventilator%20pp.pdf
http://mdsr.ecri.org/summary/detail.aspx?doc_id=8305
<https://www.chegg.com/homework-help/questions-and-answers/exploration-expectations-health-related-scientific-question-ideal-gas-human-arm-model-expl-q30890056>
<https://www.mayoclinic.org/diseases-conditions/pneumothorax/symptoms-causes/syc-20350367>
<https://www.mayoclinic.org/diseases-conditions/atelectasis/symptoms-causes/syc-20369684>
<https://www.slideshare.net/jayavardhanreddygur/mechanical-ventilation-1>
<https://www.primedeq.com/blog/how-to-compare-and-choose-the-best-ventilator-for-you/>
<http://purewondermed.com/endotracheal.html>
<http://www.yspuniversity.ac.in/cic/inst-manual-web.pdf>
<https://doku.pub/documents/hospital-operations-management-mba-hospital-management-o0m9xdr4kwqd>
<http://www.yspuniversity.ac.in/cic/inst-manual-web.pdf>
<https://www.allaboutcircuits.com/technical-articles/basic-waveform-analysis-with-an-oscilloscope/>
https://sosteneslekule.blogspot.com/2016/09/basic-waveform-analysis-with_23.html



Customised Crash Course Programme for COVID Warriors



Skill India
कौशल भारत - कुशल भारत



सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP



N.S.D.C.
National
Skill Development
Corporation
Transforming the skill landscape



Corporate Office:
Healthcare Sector Skill Council
520-521, 5th Floor, DLF Tower A Jasola District Center
New Delhi - 110025, India
Tel : 011-41017346, 40505850
Email : info@healthcare-ssc.in
Website: www.healthcare-ssc.in

Registered Office:
Healthcare Sector Skill Council
23, Institutional Area, Lodi Road
The Mantosh Sondhi Centre
New Delhi – 110 003 (India)

Price: