RWANDA TVET BOARD

RQF LEVEL 4

TRADE:

MODULE CODE: GENMW402

TEACHER'S GUIDE

Module name: MECHANICS AND WAVES

MODULE NAME:GENMW402MECHANICS AND WAVES

2022

Table of Contents

Introduction

The current module describes skills, knowledge and attitudes required to apply concepts of mechanics and waves. At the end of the module the trainee should be able to apply static equilibrium, elasticity and thermodynamics, apply optical instrument and examine effects of electric current flow in dc electric circuit. It will help trainee to carry out his/her specialized tasks that are useful in analysing data, solving real life problems encountered in related fields. In a nutshell, the features depicted on above helps trainees identify the essential steps in solving problems and increases their skills as problem solvers.

Module Code and Title: GENMW401, Mechanics and Waves

Learning Units:

1. Apply static equilibrium and elasticity
2. Apply thermodynamics
3. Examine effects of electric current flow in DC electric circuit
4. Apply geometric instruments

Learning Unit 1: Apply static equilibrium and elasticity

Picture/s reflecting the Learning unit 1

STRUCTURE OF LEARNING UNIT

Learning outcomes:

- **1.1.** Explanation of equilibrium conditions
- **1.2.** Application of static equilibrium
- **1.3.** Application of elastic properties

Learning outcome 1.1. Explanation of equilibrium conditions

Duration: 3 hrs

Learning outcome 1.1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. state clearly the equilibrium conditions of static equilibrium for rigid bodies
2. apply properly the free body diagram for static equilibrium
3. apply properly the elastic properties for solids

Resources

Equipment	Tools	Materials
PPE, Whiteboard and chalkboard	Compute, projector, textbooks, scientific calculator, meter ruler, compass	Chalks, Markers

Advance preparation:

. suspend the meter ruler on the stone in order to show the equilibrium

. Use the beam balance to show the equilibrium

The equilibrium conditions for rigid bodies

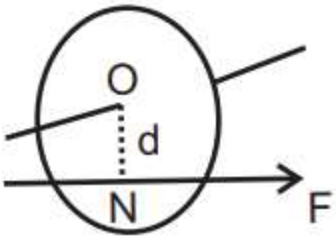
Statics is the part of mechanics which deals with forces acting on bodies at rest. The weight of the body, the tension of a string, the load and the reaction are the different names of forces that are used in statics. Any force can be represented in magnitude and direction by a straight line with an arrow head. The beginning of the line represents the point of application of the force. The arrow head represents the direction of the force.

1.1.1 Moment of a force

Torque associated with the force

Consider a body which is fixed at a point, about which it can rotate freely. Let a force F is acting on the body. The effect of the force is to rotate the body about the fixed point, unless the line of action of the force passes through that fixed point O. This rotating tendency or the turning effect of the force about that point is called moment of force i.e. the turning effect of the force acting on a body about an axis or point is called moment of force.

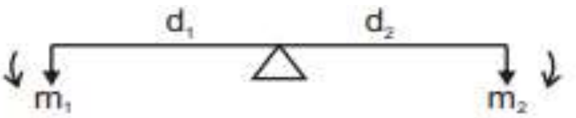
We apply rotates the door about its hinges. This rotating effect is known as the moment of force. Moment of force is also equal to the product of the magnitude of the force and the perpendicular distance of the line of action of the force from the axis of rotation.



Moment of force about the point O = Force´ perpendicular distance of the force from the point O = $F \times ON$. The unit of moment of force is N m and the dimensional formula is $ML^{-2}T^{-2}$.

Rotational equilibrium and static equilibrium

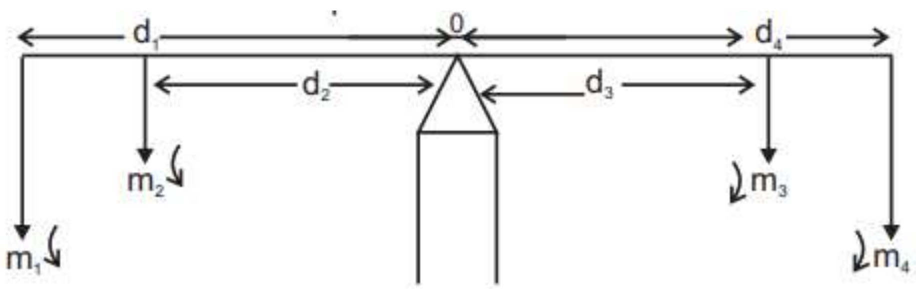
Clockwise and anti-clockwise moments If the moment of a force turns or rotates the body in clockwise direction, then it is called as clockwise moment. If the moment of a force turns or rotates the body in anti-clockwise direction, then it is called anti-clockwise moment.



Clockwise moment= $m_2 \times d_2$

Anti-clockwise moment = $m_1 \times d_1$

The principle of moment states that if a body is in equilibrium under the action of a number of parallel forces, the sum of the clockwise moments about any point must be equal to the sum of anti-clockwise moments about the same point.



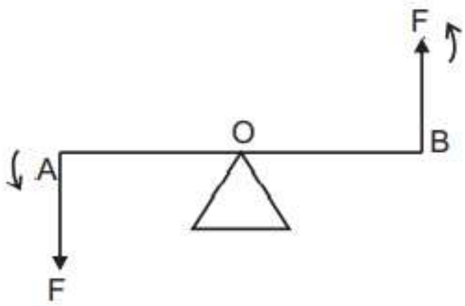
According to the principle of moments, Sum of anti-clockwise moments = sum of clockwise moments

$$m_1d_1 + m_2d_2 = m_3d_3 + m_4d_4$$

Couple: Two equal and opposite parallel forces acting at different points in a body constitute a couple. A body acted upon by the couple will rotate the body in clockwise direction or anti-clockwise direction. Steering wheel and pedals of bicycles are the examples for couple, where the two forces are equal but acting in opposite direction.

Torque acting due to couple (or) Moment of couple Torque is calculated by the product of either of forces forming the couple and the arm of the couple. i.e.)

Torque = one of the force x perpendicular distance between the forces.

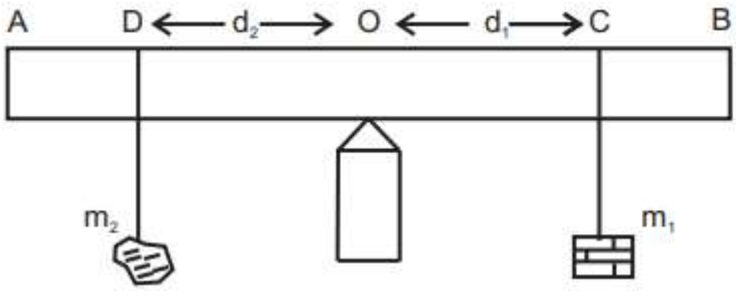


Consider two equal forces F and F acting on the arm AB. Let O be the mid-point of the arm .The forces F and Fare acting in opposite direction as shown in the figure, they constitute a couple. Then

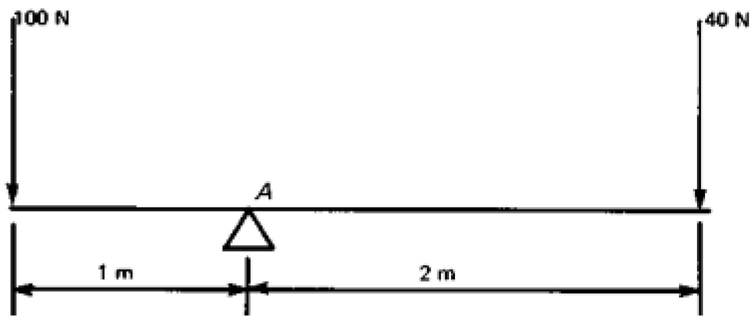
Moment of couple or torque = F $\times$ AB.

If the forces acting on the body have the same line of action then the moment becomes zero. The torque is maximum when the forces are at right angles to the arm i.e.) θ=90º.

Determination of mass of the given body using principle of moments.



Example: A bar of negligible mass is supported at A and loaded as shown in the sketch below. What would be the clockwise and counter-clockwise moments of force at the pivot point, and in which direction would the bar rotate?



Solution:

Taking moments about A: Clockwise moment = 40 N x 2 m = 80 Nm (Ans.)

Counter-clockwise moment = 100 N x 1 m = 100 Nm (Ans.)

Since the counter-clockwise moment is greater than the clockwise moment, the bar would rotate in a counter-clockwise direction.

1.1.2. Necessary Conditions of equilibrium of a body

Equilibrium

The term **equilibrium** implies that either **the body is at rest or it moves with a constant velocity**. We shall deal with bodies at rest, or bodies in static equilibrium. A body is in static equilibrium when the force system acting on it tends to produce no net translation or rotation of the body.

A body is said to be in **static equilibrium** when the resultant force on it must be zero and the body must have no tendency to rotate. This second condition of equilibrium requires that the net moment about any point be zero.

Law of forces

A body is in equilibrium, that is, the body does not accelerate, if the vector sum of all the forces acting on it is zero.

$$\sum \mathbf{F} = 0$$

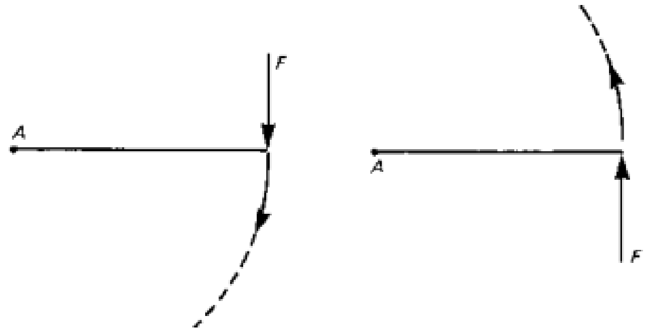
When this condition is satisfied we say that the object is in **translational equilibrium**.

Law of moments

A body in equilibrium cannot have the tendency to start rotating about any point; so the sum of external moments must be zero about any point.

Direction of a Moment of Force A force acting at a distance from a point will produce (or tend to produce) rotation about a point, with the point as center. The rotation will either be in a clockwise or counter-clockwise direction. This direction can be determined by imagining what would happen if the force were free to rotate about the point.

$$\sum \mathbf{M} = 0$$



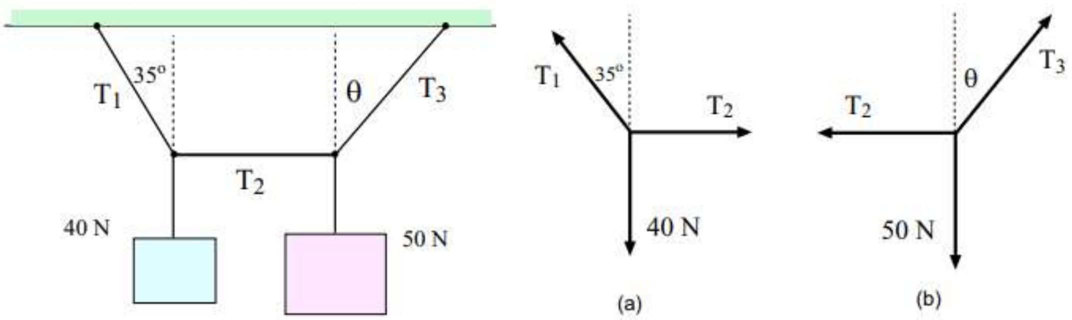
Moment Directions

When this condition is satisfied we say that the object is in **rotational equilibrium.**

Resolving each force and each moment into its rectangular components, we may express the necessary and sufficient conditions for the equilibrium of a body by the following six scalar equations:

$$\sum F_x = 0 \qquad \sum M_x = 0$$
$$\sum F_y = 0 \qquad \sum M_y = 0$$
$$\sum F_z = 0 \qquad \sum M_z = 0$$

The system down is in equilibrium with the string in the center exactly horizontal. Find (a) tension T_1, (b) tension T_2, (c) tension T_3 and (d) angle θ.



Since this junction in the strings is in static equilibrium, the (vector) sum of the forces acting on it must give zero. Thus the sum of the x components of the forces is zero:

$$-T_1 \sin 35^\circ + T_2 = 0$$

and the sum of the y components of the forces is zero:

$$+T_1 \cos 35^\circ - 40\,\mathrm{N} = 0$$

Again, the sum of the x components of the forces is zero:

$$-T_2 + T_3 \sin\theta = 0$$

and the sum of the y components of the forces is zero:

$$+T_3 \cos\theta - 50\,\mathrm{N} = 0$$

from the sum of forces on y components, we get

$$T_1 = \frac{(40\,\mathrm{N})}{(\cos 35^\circ)} = 48.8\,\mathrm{N}$$

from the sum of all forces on x and y components, we get

$$T_3 \sin\theta = T_2 = 28.0\,\mathrm{N}$$

$$T_3 \cos\theta = 50.0\,\mathrm{N}$$

$$\tan\theta = \frac{(28.0\,\mathrm{N})}{(50.0\,\mathrm{N})} = 0.560$$

$$\theta = \tan^{-1}(0.560) = 29.3^\circ$$

Finally, we get T_3 as

$$T_3 = \frac{(50.0\,\mathrm{N})}{(\cos 29.3^\circ)} = 57.3\,\mathrm{N}$$

Summarizing, we have found:

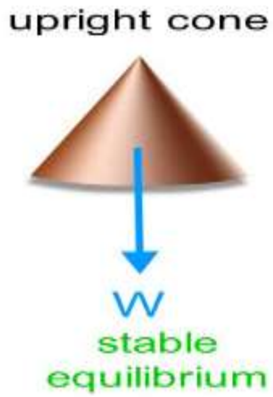
$$T_1 = 48.8\,\mathrm{N} \qquad T_2 = 28.0\,\mathrm{N} \qquad T_3 = 57.3\,\mathrm{N} \qquad \theta = 29.3^\circ$$

1.1.3. States of equilibrium

A body is said to be in equilibrium when it comes back to its original position, after it is slightly displaced from its position of rest. In general, following are the three types of equilibrium :

Stable equilibrium

A body is said to be in stable equilibrium, if it returns back to its original position, after it is slightly displaced from its position of rest. This happens when some additional force sets up due to displacement and brings the body back to its original position. A smooth cylinder, lying in a curved surface, is in stable equilibrium. If we slightly displace the cylinder from its position of rest (as shown by dotted lines), it will tend to return back to its original position in order to bring its weight normal to horizontal axis .

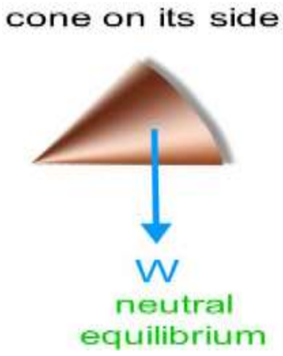


Unstable equilibrium

A body is said to be in an unstable equilibrium, if it does not return back to its original position, and heels farther away, after slightly displaced from its position of rest. This happens when the additional force moves the body away from its position of rest. This happens when the additional force moves the body away from its position of rest. A smooth cylinder lying on a convex surface is in unstable equilibrium. If we slightly displace the cylinder from its position of rest (as shown by dotted lines) the body will tend to move away from its original position.

Neutral equilibrium

A body is said to be in a neutral equilibrium, if it occupies a new position (and remains at rest in this position) after slightly displaced from its position of rest. This happens when no additional force sets up due to the displacement. A smooth cylinder lying on a horizontal plane is in neutral equilibrium .



Stability of structure

Structure is in stable equilibrium when small perturbations do not cause large movements like a mechanism. Structure vibrates about its equilibrium position. Structure is in unstable equilibrium when small perturbations produce large movements – and the structure never returns to its original equilibrium position.

Center of gravity

The center of gravity of an object is where we can consider all of the weight of the object to be concentrated. This is a useful concept in physics and engineering. It is used to determine the stability of objects when they are tilted.

Base of support

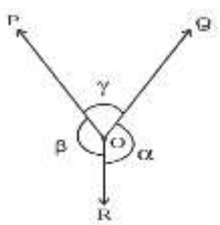
The base of support (BOS) refers to **the area beneath an object or person that includes every point of contact that the object or person makes with the supporting surface**.

Lami's Theorem

It gives the conditions of equilibrium for three forces acting at a point. Lami's theorem states that if three forces acting at a point are in equilibrium, then each of the force is directly proportional to the sine of the angle between the remaining two forces.

Let us consider three forces $\vec{P}$, $\vec{Q}$ and $\vec{R}$ acting at a point O. Under the action of three forces, the point O is at rest, then

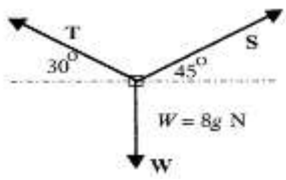
$$\frac{P}{\sin\ \alpha} = \frac{Q}{\sin\ \beta} = \frac{R}{\sin\ \gamma} = \text{constant}$$



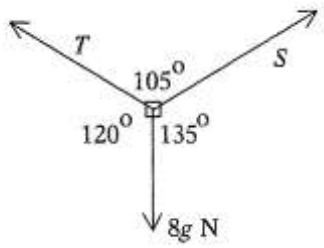
Lami's theorem

Example

A mass of 8kg hangs in equilibrium, suspended by two light, inelastic strings making angles 30° and 45° with the horizontal, as shown in the diagram bellow. Calculate the tensions in the strings.



Solution



Lami's Theorem gives

$$\frac{T}{\sin 135^\circ} = \frac{S}{\sin 120^\circ} = \frac{8g}{\sin 105^\circ}$$

Hence $T = \frac{8g \sin 135^\circ}{\sin 105^\circ} = 57 \cdot 4\text{N}$

and $S = \frac{8g \sin 120^\circ}{\sin 105^\circ} = 70 \cdot 3\text{N}$

Summary for the trainer related to the content.

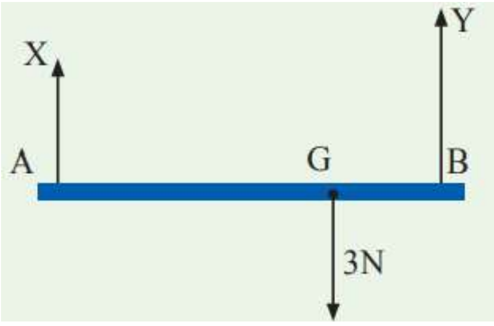
- ✓ A body is said to be in equilibrium when it comes back to its original position, after it is slightly displaced from its position of rest. There is three types of static equilibrium such as stable, unstable and neutral equilibrium.
- ✓ Laws of static equilibrium are **Law of moments which is stating that summation of moments must be equal to zero while law of forces states that the summation of forces must be equal to zero.**
- ✓ The center of gravity of an object is where we can consider all of the weight of the object to be concentrated.

Theoretical learning Activity

1. In groups, the trainees discuss on equilibrium condition.

2. Individually, trainee determine centre of gravity.

3. A horizontal rod AB is suspended at its ends by two strings. (See the figure below). The rod is 0.6m long and its weight of 3N acts at G where AG is 0.4m and BG is 0.2m. Find the tensions X and Y.



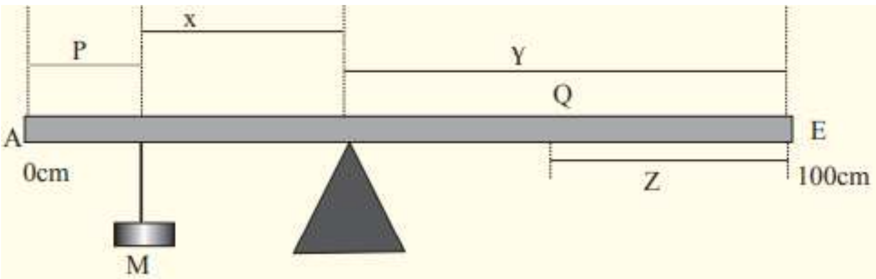
4. A horizontal rod AB of negligible weight, 51cm long is submitted in A and in B to two forces F_1 and F_2 of magnitudes respectively 14N and 7N. The force F_1 makes an angle of 45° with the vertical and the force F_2 is perpendicular to the rod. Their direction is oriented downward. Determine the characteristics of the force which will make the rod in equilibrium.

Practical learning Activity

In groups determine the mass of the object using the principle of moments.

Apparatus required

* 1 uniform meter rule
* A knife edge
* Unknown mass



Instructions In this experiment, the learner determines the mass M of the provided body (meter ruler).

a) Weigh the meter ruler provided to obtain its mass, M. Balance the meter ruler on a knife edge. Read Q the balance point. Find Z.

b) Balance the meter ruler with its graduated face upwards on a knife edge. With the mass M provided at P = 10 cm from A as shown,

c) Measure and record distance X and Y.

d) Repeat procedure (b) and (c) for values of P = 15, 20, 25, 30 and 35cm.

e) Tabulate your results including values of (Y-Z) and (X-P).

f) Plot a graph of (Y-Z) against (X-P).

g) Find the slope “S’’ of your graph.

h) Calculate the mass M of the body from S m = M

Checklist	**Score**		**Observation**
	Yes	**No**	
2 Meter ruler is selected?			
A knife edge is selected?			

Points to Remember (Take home message)

- ✓ Laws of static equilibrium
- ✓ Using Lami’s theorem
- ✓ Rotational equilibrium and static equilibrium

Learning out come 1.1 : formative assessment

Written Assessment

Multiple choice questions

1. What condition or conditions are necessary for rotational equilibrium?

A) $\sum F_x = 0$ B) $\sum F_x = 0, \sum T = 0$ C) $\sum T = 0$ D) $\sum F_x = 0, \quad \sum F_y = 0$

2. What condition or conditions are necessary for static equilibrium?

A) $F_x = 0$ B) $\sum F_x = 0, \ \sum F_y = 0, \ \sum T = 0$ C) $\sum T = 0$ D) $\sum F_x = 0, \ \sum F_y = 0$

3. A sphere hanging freely from a cord is in

A) stable equilibrium. B) unstable equilibrium. C) neutral equilibrium. D) positive equilibrium.

4. A cone balanced on its small end is in

A) stable equilibrium. B) unstable equilibrium. C) neutral equilibrium. D) positive equilibrium.

5. A cube resting on a horizontal tabletop is in

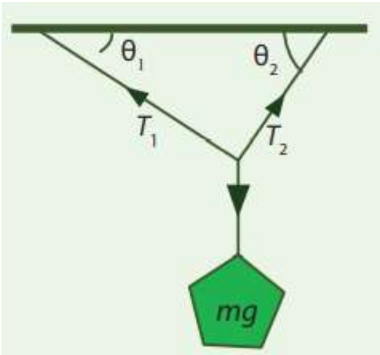
A) stable equilibrium. B) unstable equilibrium. C) neutral equilibrium. D) positive equilibrium

Long questions

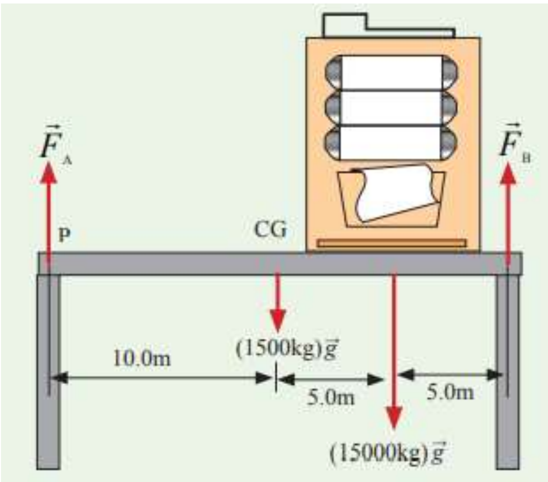
6. A block of mass 330kg is suspended by three unstretchable ropes as shown on the figure below. If the system is in equilibrium,

a) determine T_1 and T_2 in the ropes,

b) If O_1 = 15°, θ_2 = 30°,



7. A uniform 1500kg beam, 20m long, supports a 15,000kg printing press 5 from the right support column, see the figure. Calculate the force on each of the vertical support columns.



Learning outcome 1.2. Application of static equilibrium

Duration: 3 hrs

Learning outcome 1.2 objectives:

By the end of the learning outcome, the trainees will be able to:

1. present all forces exerting on horizontal beam
2. apply free-body diagram of all forces on horizontal beam.
3. apply free-body diagram Standing on a slope

Resources

Equipment	Tools	Materials
PPE, Whiteboard and chalkboard	Compute, projector, textbooks, scientific calculator, meter ruler, compass	Chalks, Markers

Advance preparation:

. Asking the forces acting on the box which is on the desk.

.

A free-body diagram

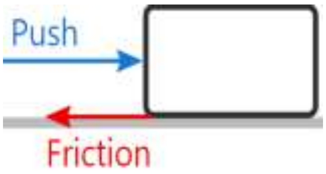
A free-body diagram is a representation of an object with all the forces that act on it. The external environment (other objects, the floor on which the object sits, etc.), as well as the forces that the object exerts on other objects, are omitted in a free-body diagram.

How to draw a free-body diagram?

You can draw a free-body diagram of an object following these 3 steps:

1. **Sketch** what is happening
2. **Determine** the forces that act on the object
3. **Draw** the object in isolation with the forces that act on it

Step 1: Sketch what is happening

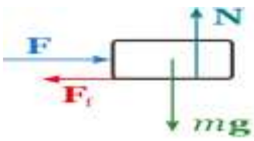


Step 2: Determine the forces that act on the object

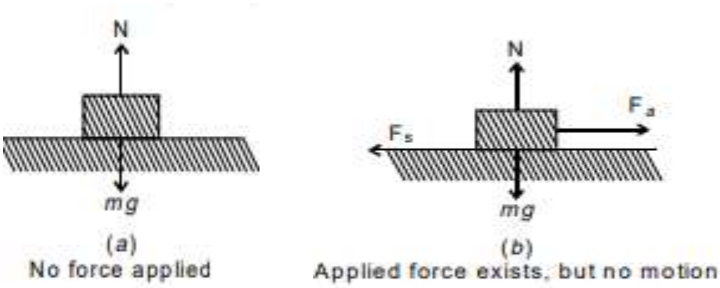
Therefore, we come to the conclusion that 4 forces are acting on our block:

- the push, **F**
- the friction force, $\mathbf{F_f}$
- the normal force, **N**
- and the gravitational force *m***g**

Step 3: Draw the object in isolation with the forces that act on it



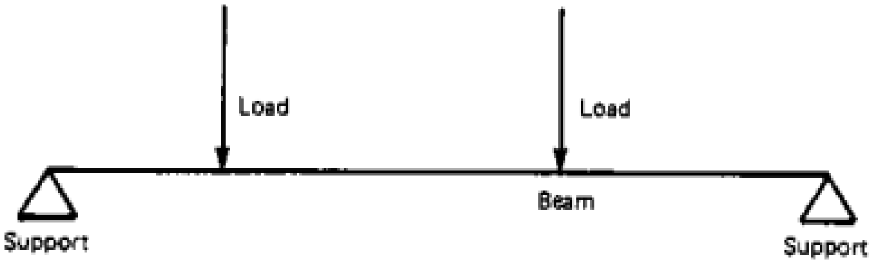
When all the forces that act upon an object are balanced, then the object is said to be in a state of **equilibrium**. The forces are considered to be balanced if the rightward forces are balanced by the leftward forces and the upward forces are balanced by the downward forces.



Upward force is N and downward forces are mg, horizontal forces are F_s and F_a

Horizontal beam

A beam may be defined as a rigid member or bar supported in some way so that it is capable of carrying a load or system of loads.



If the beam rests on supports so that it is free to bend without restriction from the supports, it is called “simply supported”. If the loads on the beam can be considered to be concentrated at various points, they are called point loads. Conditions for Equilibrium of Beams For the beam to be at rest, i.e. in equilibrium:

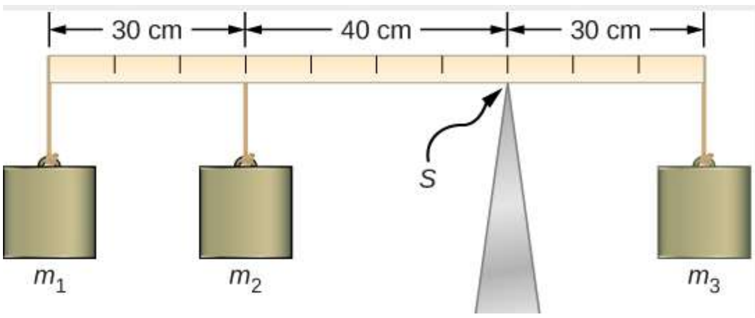
(i) Upward forces = downward forces
(ii) (ii) Forces acting sideways to right = forces acting sideways to left
(iii) (iii) Clockwise moments = anticlockwise moments Reaction at Supports

For equilibrium, the external forces on the beam must be resisted by forces or reactions at the supports.

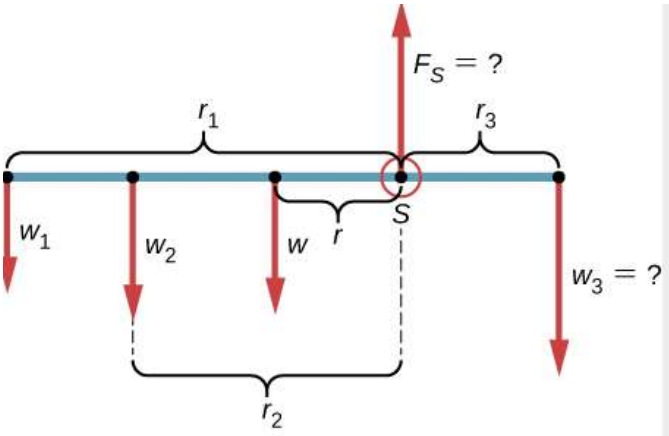
When a beam is simply supported at each end, **all the downward forces are balanced by equal and opposite upward forces** and the beam is said to be held in Equilibrium.

Free body diagrams are the tool that engineers use to identify the forces and moments that influence an object.

Example:



Freebody diagram

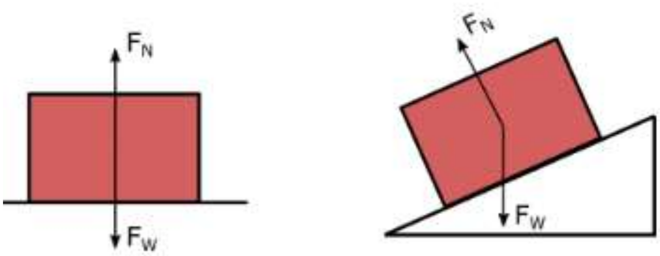


Where W_1, W_2, W_3 and W are the downward forces but F_S is upward force.

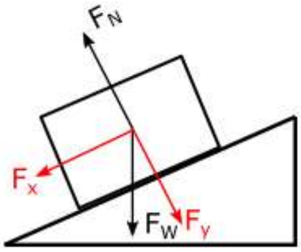
Standing on a slope

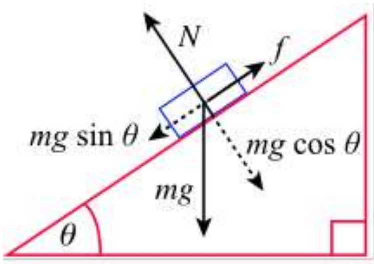
An inclined plane is a flat surface that is tilted or inclined at some particular angle other than the right angle. This means that one end of the surface is lifted higher than the other end. **Inclined plane**, simple machine consisting of a sloping surface, used for raising heavy bodies. The force required to move an object up the incline is less than the weight being raised, discounting friction.

First, consider the **normal force** on an object, which is a force that always acts perpendicular to the surface on which the object is resting.



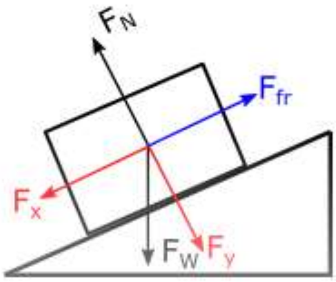
Net Force on Inclined Plane





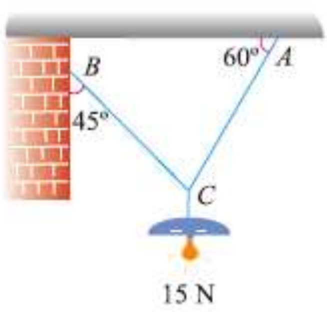
The x and y-components here are defined from the normal axis, as shown in the diagram. These are sometimes called **parallel** and **perpendicular** components. It is then possible to determine these forces if the angle of the inclined is known.

These forces are illustrated in the free-body diagram.



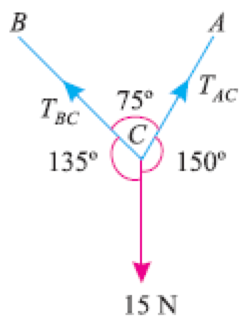
Applications related to equilibrium conditions

An electric light fixture weighting 15 N hangs from a point C, by two strings AC and BC. The string AC is inclined at 60° to the horizontal and BC at 45° to the horizontal as shown in Figure below. Using Lami's theorem, or otherwise, determine the forces in the strings AC and BC .



.

Solution.



Given : Weight at C = 15 N

Let T_{AC} = Force in the string AC, and T_{BC} = Force in the string BC.

The system of forces is shown in Fig. 5.4. From the geometry of the figure, we find that angle between T_{AC} and 15 N is 150° and angle between

T_{BC} and 15 N is 135°.

∴ ∠ ACB = 180° – (45° + 60°) = 75°

Applying Lami's equation at C,

$$\frac{15}{\sin 75^\circ} = \frac{T_{AC}}{\sin 135^\circ} = \frac{T_{BC}}{\sin 150^\circ}$$

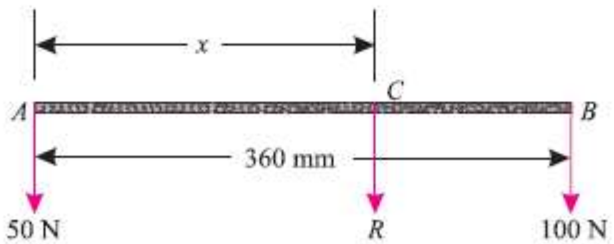
$$\frac{15}{\sin 75^\circ} = \frac{T_{AC}}{\sin 45^\circ} = \frac{T_{BC}}{\sin 30^\circ}$$

$$T_{AC} = \frac{15 \sin 45^\circ}{\sin 75^\circ} = \frac{15 \times 0.707}{0.9659} = 10.98\,\text{N} \qquad T_{BC} = \frac{15 \sin 30^\circ}{\sin 75^\circ} = \frac{15 \times 0.5}{0.9659} = 7.76\,\text{N}$$

2- Two like parallel forces of 50 N and 100 N act at the ends of a rod 360 mm

long. Find the magnitude of the resultant force and the point where it acts.

Solution. Given : The system of given forces is shown in Figure below



Magnitude of the resultant force

Since the given forces are like and parallel, therefore magnitude of the resultant force,

R = 50 + 100 = 150 N **Ans.**

Point where the resultant force acts

Let x = Distance between the line of action of the resultant force (R) and A

(i.e. AC) in mm.

Now taking clockwise and anticlockwise moments of the forces about C and equating the same,

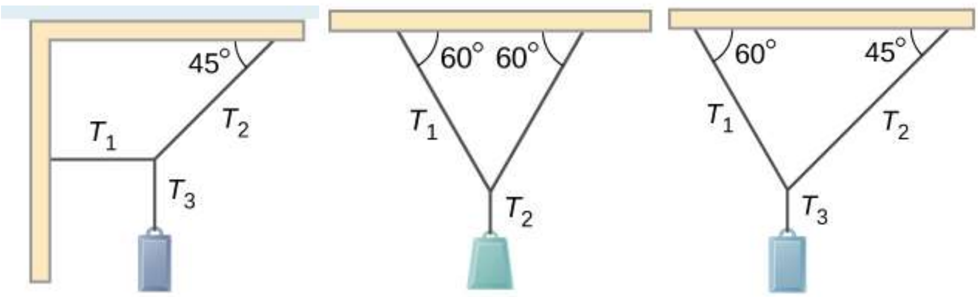
$50 \times x = 100\ (360 - x) = 36\ 000 - 100\ x$

or $150\ x = 36\ 000$

$x = 240$ mm

Exercises

1. Find the magnitude of the tension in each supporting cable shown below. In each case, the weight of the suspended body is 100.0 N and the masses of the cables are negligible.



(a) (b) (c)

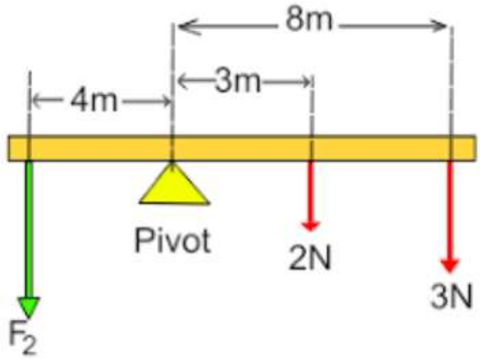
Theoretical learning Activity

- ✓ In group, the learners should sit and discuss on all forces applied on a box resting on the table.
- ✓ In group the learners should sit and discuss on all forces applied on a ladder and present its free body diagram.
- ✓ In group the learners should discuss and present all forces applied on a car resting on an inclined plan in rough road.

Practical learning Activity

1. A SEE-SAW. On one side, there is a person with a weight of 600N. He is sitting 3m away from the pivot. On the other side is a person weighing 450N. How far away must (she)/he sit?

- A. 2m
- B. 4m
- C. 6m
- D. 3.5m
- E. 3m



2. For a see-saw to balance, the anti-clockwise moment must equal the ....

- A. Clockwise Moment
- B. Weight
- C. Mass
- D. None

3. Another name for a pivot is a

- A. Falcon
- B. Tool
- C. Fulcrum
- D. None of these

Checklist	**Score**		**Observation**
	Yes	**No**	
Law of moment is stated?			
Clockwise moment is found?			
Another name of pivot is defined?			

Points to Remember (Take home message)

- ✓ A free-body diagram is a representation of an object with all the forces that act on it.
- ✓ A beam may be defined as a rigid member or bar supported in some way so that it is capable of carrying a load or system of

Learning out come 1.2 : formative assessment

A. Multiple choice questions :

1. Moment is the

- A. Turning effect of a force
- B. Airflow
- C. Mass
- D. Weight

2. What's the unit of the moment?

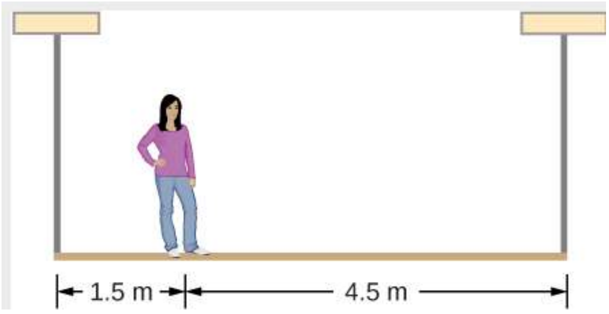
- A. Km
- B. Nk
- C. Kn
- D. Nm

3. The force applied to a lever is called

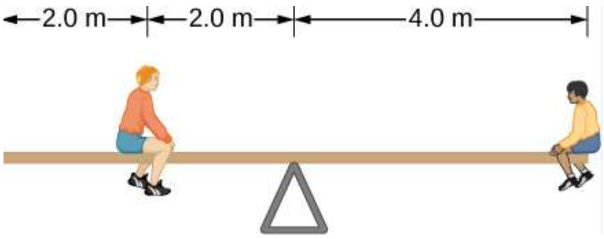
- A. Force
- B. Mass
- C. Effort
- D. None

B. Long questions

4. A 50-kg person stands 1.5 m away from one end of a uniform 6.0-m-long scaffold of mass 70.0 kg. Find the tensions in the two vertical ropes supporting the scaffold.



5. The uniform seesaw is balanced at its center of mass, as seen below. The smaller boy on the right has a mass of 40.0 kg. What is the mass of his friend?



Learning outcome 1.3. Application of elastic properties

Duration: 4 hrs

Learning outcome 1.3 objectives:

By the end of the learning outcome, the trainees will be able to:

1. differentiate clearly the physical properties of solid, liquid and gases

2. explain clearly different terms such as elasticity, plasticity, stress, strain and moduli of elasticity.

3. apply correctly the stress, strain and young modulus formula

Resources

Equipment	Tools	Materials

PPE, Whiteboard and chalkboard	Compute, projector, textbooks, scientific calculator, meter ruler, compass	Chalks, Markers

Advance preparation:

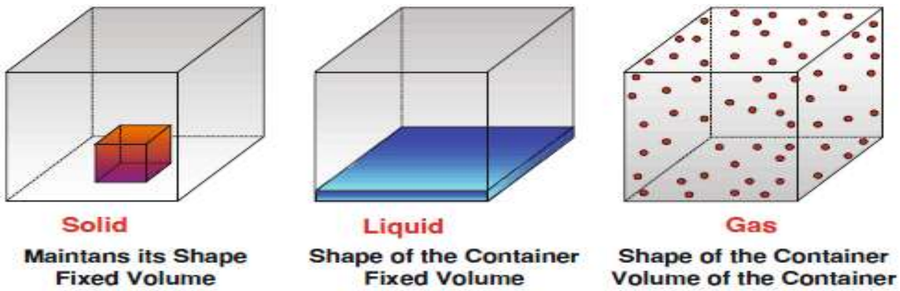
. The trainer uses a meter ruler to show a beam

. The trainer uses a rubber band to show the properties of solid

.

1

The physical states of matter can generally be divided into three broad classes: **solids, liquids,** and **gases,** see Figure. A solid maintains its shape: it resists the action of external forces that tend to change its shape or volume. Liquids and gases are fluids. **Inter molecular Force:** In a solid, atoms and molecules are arranged in such a way that each molecule is acted upon by the forces due to the neighboring molecules. These forces are known as inter molecular forces. A fluid can easily change shape, and flows when subjected to a force. The three states of matter are distinguishable at the microscopic level as follows:



1. A solid is a highly ordered array of atoms or molecules that are bound securely by mutual electrical forces.
2. A liquid is a crowded assembly of mobile atoms or molecules. Each atom or molecule is in contact with several neighbours, but is not bound securely to any of them. As an atom or molecule moves about in a liquid, it collides frequently with its neighbours.
3. A gas consists of atoms or molecules that are far apart and consequently move independently, with no forces keeping them together or pushing them apart. Collisions of atoms or molecules in gases are infrequent in comparison to those in liquids.

When an external force is applied on a body, which is not free to move, the shape and size of the body change. The force applied is called deforming force. When the deforming forces are removed, the body tends to regain its original shape and size due to a force developed within the body.

Bodies, which completely regain their original size and shape after the removal of the deforming force, are called **elastic bodies**.

Bodies which change the shape and size on the application of force and which do not regain their original condition on removal of the deforming forces are said to be **plastic bodies**.

Bodies which do not change their shape and size on application of force are called **rigid bodies.**

Mechanical Properties of solids describe characteristics such as their **strength** and resistance to deformation. It describes about the ability of an object to withstand the stress applied to that object.

Elasticity: It is the property of a material to regain its original shape after the removal of load. When a material is subjected to an external load of such magnitude that deformation continues only with increase in load, and on removing the load it regains its original shape, then the material is said to have elasticity.

Plasticity: The inability of a body to return to its original size and shape even on removal of the deforming force is called plasticity and such a body is called a plastic body.

Hardness: It is the ability of a material to offer resistance to penetration or indentation. It is also the ability to resist wear, abrasion, scratch or cutting.

Ductility: It is a measure of the amount of deformation of a material can withstand before breaking. It is also the ability of a material by which it can be drawn into wires.

Malleability: It is the ability of a material by which it can be rolled into sheets. Malleability is the ability of a material to exhibit large deformation subjected to compressive force whereas ductility is the ability of a material to deform upon the application of tensile force. Aluminium, Copper and gold have good malleability.

All solids are to some extent elastic. This means that we can change their dimensions slightly by pulling, pushing, twisting, and/or compressing them.

Stress

When an external force is acting on an elastic body, it causes deformation (change in shape or in size or both).
Stress is the magnitude of the applied external force that acts perpendicularly on a unit area of the object.

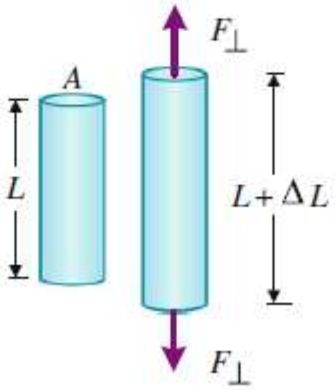
$$\text{Stress} = \frac{\text{Force}}{\text{Area}} = \frac{F}{A}$$

The stress is defined as the restoring force acting on unit area.

The unit for stress is N m^{-2} or 'pascal' with symbol 'Pa'.

Types of strains:

Strain is a measure of the degree of deformation of the object.
Linear Strain: When a wire or bar is subjected to two equal and opposite forces, namely pulls, at its ends, there is an increase in the length.



$$\text{Tensile stress} = \frac{F_\perp}{A} \quad (\text{N/m}^2)$$

$$\text{Tensile strain} = \frac{\Delta L}{L}$$

The relation between the tensile stress and the tensile strain is linear when the rod is in its elastic range. When the stress exceeds what is called the elastic limit, the rod is permanently distorted and will not return to its original shape after the stress is removed. As the stress is increased even further, the rod will ultimately break.

Stress versus strain curve for an elastic solid

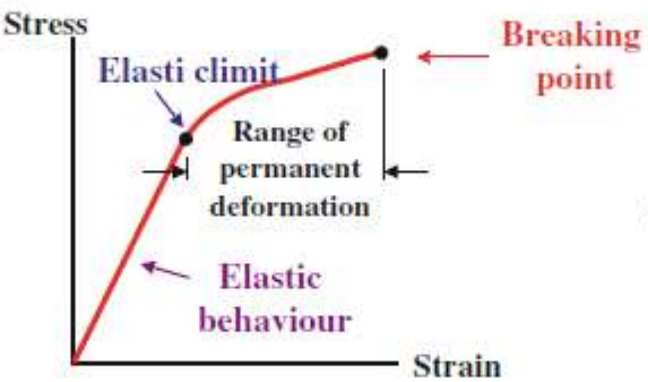


Fig. (a) A rod of height L and cross-sectional area A. The rod stretches by an amount ΔL after application of a tensile stress. (b) The stress versus strain curve for an elastic solid.

Three modulii of elasticity

There are three types of modulii depending upon the three kinds of strain.

a) Young's modulus (E): Measures the resistance of a solid to a change in its length.
It is defined as the ratio of linear stress to linear strain. Let a wire of initial length L and cross-sectional area ' A', undergo an extension l, when a stretching force 'F', is applied in the direction of its length. The modulus of elasticity, in this case, is called Young's modulus and is given by

We define Young's modulus, Y, as:

$$Y = \frac{\text{Tensile stress}}{\text{Tensile strain}} = \frac{F_\perp/A}{\Delta L/L} \quad (\text{N/m}^2)$$

A pendulum consists of a big sphere of mass $m = 30$ kg hung from the end of a steel wire that has a length $L = 15$ m, a cross-sectional area $A = 9 \times 10^{-6}$ m^2, and Young's modulus $Y = 200 \times 10^9$ N/m^2. Find the tensile stress on the wire and the increase in its length.

Solution: The applied force on the wire must equal to the weight of the sphere, i.e. $F_\perp = m\,g$. Thus, the tensile stress will be:

$$\text{Tensile stress} = \frac{F_\perp}{A} = \frac{m\,g}{A} = \frac{(30\text{ kg}) \times (9.8\text{ m/s}^2)}{9 \times 10^{-6}\text{ m}^2} = 3.27 \times 10^7\text{ N/m}^2$$

Using the value of the Young's modulus $Y = 20 \times 10^{10}$ N/m^2 and the length of the steel wire before stretching $L = 15$ m, we get:

$$Y = \frac{F_\perp/A}{\Delta L/L} \quad \Rightarrow \quad \Delta L = \frac{F_\perp/A}{Y} L = \frac{3.27 \times 10^7\text{ N/m}^2}{200 \times 10^9\text{ N/m}^2} \times 15\text{ m} = 2.45 \times 10^{-3}\text{ m}$$

Note that this large stress produces a relatively small change in L.

b) Bulk Modulus or Volume deformation (β): It is the measure of the resistance of a solid (or a liquid) to a change in its volume. When a force is applied parallel to one face of a body, the opposite side being fixed, there is a change in shape but not in size of the body. This strain is called the shearing strain.

It is defined as the ratio of bulk stress to bulk strain. When a body is subjected to a uniform compressive force, its volume decreases and the strain produced is a bulk or volume strain.

Another type of deformation occurs when an object is subject to an equal increase in normal forces acting on all its faces. For such a study, it is appropriate to define the pressure P as the force acting perpendicularly on a unit area of the object. That is

$$P = \frac{F_\perp}{A} \quad (\text{N/m}^2)$$

Hence, we can study the deformation of an object subject to an equal increase in pressure on all its faces. Figure shows a cube of original volume V and face area A under uniform pressure P. When the force $F_\perp$ on each face increases to $F_\perp + \Delta F_\perp$, the pressure will increase to $P + \Delta P$ and consequently the volume V will decrease to $V' = V - |\Delta V|$, where ΔV is negative, see Fig bellow

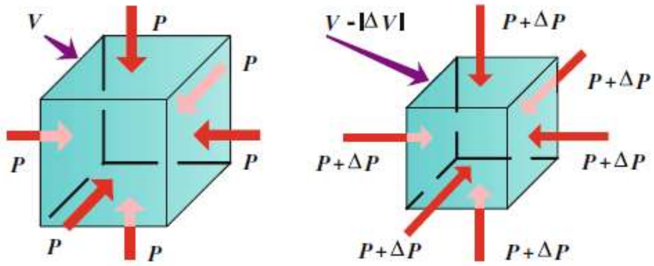


Fig. When the uniform pressure P on each face of a cube of volume V increases to $P + \Delta P$, its volume will decrease to $V - |\Delta V|$.

In light of this, we define the *volume stress* and the *volume strain* as:

$$\text{Volume stress} = \Delta P = \frac{\Delta F_\perp}{A} \quad (\text{N/m}^2)$$

$$\text{Volume strain} = -\frac{\Delta V}{V}$$

We define the *bulk modulus*, B, as:

$$B = \frac{\text{Volume stress}}{\text{Volume strain}} = -\frac{\Delta F_\perp / A}{\Delta V / V} = -\frac{\Delta P}{\Delta V / V} \Rightarrow B = -V\frac{dP}{dV}$$

Example:

A sphere has a volume v = 0.5 m^3 when placed in atmospheric pressure ($P_a \approx 10^5$ N/m^2). The sphere is lowered to a particular depth in the ocean where the water pressure is
P = 10^8 N/m^2 = 1,000 Pa. The bulk modulus β of lead is 8×10^9N/m^2. a) What is the change in volume of the sphere? B) What is the relative density change in lead?

Solution:

(a) From the definition of the bulk modulus, we have:

$$B = -\frac{\Delta P}{\Delta V / V}$$

The change in pressure is:

$$\Delta P = P - P_a = 10^8 \text{ N/m}^2 - 10^5 \text{ N/m}^2 = 9.99 \times 10^7 \text{ N/m}^2$$

$$\Delta V = -\frac{V\Delta P}{B} = -\frac{(0.5\,\text{m}^3)(9.99\times 10^7\ \text{N/m}^2)}{8\times 10^9\ \text{N/m}^2} = -6.2\times 10^{-3}\,\text{m}^3$$

The negative sign indicates a decrease in volume.

(b) We can find the new volume V' of lead as follows:

$$V' = V - |\Delta V| = 0.5\,\text{m}^3 - |-6.2\times 10^{-3}\ \text{m}^3| = 0.4938\,\text{m}^3 \quad \Rightarrow \quad V' = 0.9876\,V$$

If the original density of lead is denoted by $\rho = m/V$, then the new density ρ' will be:

$$\rho' = \frac{m}{V'} = \frac{m}{0.9876\,V} = 1.0126\,\frac{m}{V} = 1.0126\,\rho$$

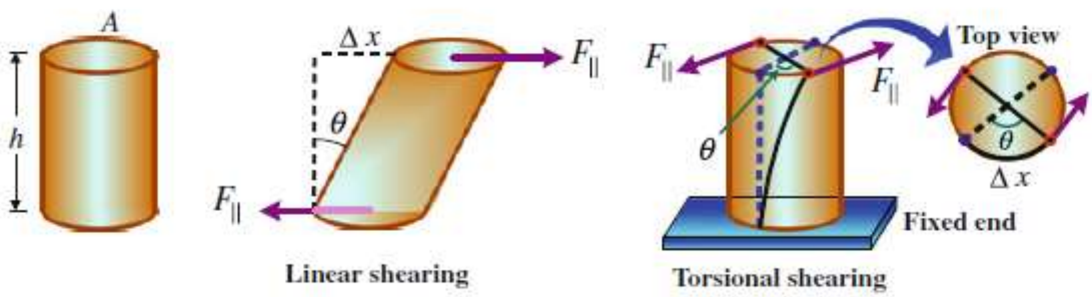
Thus, a thousand times increase in pressure on the surfaces of a sphere of lead causes a *decrease* in its volume by about 1.3% and consequently an *increase* in density by the *same* percentage.

(C) Shearing (or) Rigidity modulus 'S': Measures the resistance to motion of the planes of solids when sliding over each other.

Another type of deformation occurs when a solid is subject to a force applied parallel to one of its surfaces while the opposite surface is kept fixed. Figure shows a cylindrical rod subjected to a linear or torsional shear stress deforming it by an amount Δx due to a force $F_{//}$ parallel to the surface area A. As a final result, the shape of the rod will attain equilibrium when the effect of the shear force $F_{//}$ balances exactly the internal shear forces. For linear shearing, we define **the shearing stress** and the **shearing strain** as follows:

$$\text{Shearing stress} = \frac{\text{Tangential acting force}}{\text{Area of surface being sheared}} = \frac{F_{\|}}{A} \quad (\text{N/m}^2)$$

$$\text{Shearing strain} = \frac{\text{Distance sheared}}{\text{Distance between surfaces}} = \frac{\Delta x}{h} = \tan\theta \simeq \theta$$



The left part shows a cylindrical rod of height h. The middle part shows a linear shear where the rod is subject to a shearing force F// parallel to each of its surface areas. The rod is deformed through an angle θ which is defined as the shearing strain and it is measured in radian. The approximation tan θ = θ is valid for small strains. We define the **shear modulus, S,** as follows:

$$S = \frac{\text{Shearing stress}}{\text{Shearing strain}} = \frac{F_{\parallel}/A}{\Delta x/h} \quad (\text{N/m}^2)$$

The shear modulus, S, is also **called the modulus of rigidity** or **the torsion modulus** and is significant only for solids.

Example: Assume that the rod has a cross – sectional area A = 2×10^{-3} m^2, length h = 1m and is made of brass with a shear modulus S = 36 × 10^9 N/m^2. How large should the shear force $F_{//}$ exerted on each edge of the rod be if the displacement Δx is 0.02 cm?

Solution:

The shearing stress on each edge is:

$$\text{Shearing stress} = \frac{F_{\parallel}}{A} = \frac{F_{\parallel}}{2\times10^{-3}\ \text{m}^2} = 500\ F_{\parallel}\ \text{m}^{-2}$$

The shear strain is

$$\text{Shearing strain} = \frac{\Delta x}{h} = \frac{2\times10^{-4}\ \text{m}}{1\ \text{m}} = 2\times10^{-4}$$

From the definition of the shearing modulus and the last two results, we have

$$S = \frac{\text{Shearing stress}}{\text{Shearing strain}} = \frac{500F_{\parallel}\ \text{m}^{-2}}{2\times10^{-4}}$$

Using the shear modulus value for brass , we get

$$36\times10^9\ \text{N/m}^2 = \frac{500F_{\parallel}\ \text{m}^{-2}}{2\times10^{-4}}$$

Thus: $F_{\parallel} = (36\times10^9\ \text{N/m}^2)(2\times10^{-4})/(500\,\text{m}^{-2}) = 14{,}400\ \text{N} = 1.44\times10^4\ \text{N}$

The lateral strain, and Poisson's ratio: μ

When we carefully study the deformation of the rod, we find that the rod's length L increases by ΔL in the direction of the force while is radius r decreases by |Δr|, where Δr is negative, in a direction perpendicular to the force. The tensile strain ΔL/L of the rod is called the linear strain. The strain -Δr/r is called the lateral strain and Poisson's ratio μ is defined as:

$$\mu = \frac{\text{Lateral strain}}{\text{Linear strain}} = -\frac{\Delta r/r}{\Delta L/L} = -\frac{L}{r}\frac{\Delta r}{\Delta L} \quad \Rightarrow \quad \mu = -\frac{L}{r}\frac{dr}{dL}$$

The minus sign shows that the body has decreased in width.

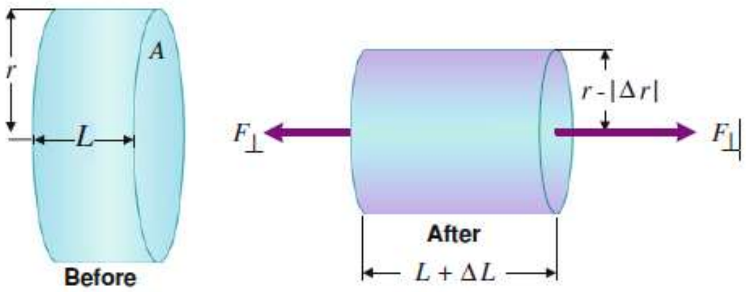


Fig. The length of the rod will increase by ΔL and its radius will decrease by Δr (exaggerated scale) after applying a tensile stress F⊥/A .

Example: A cylindrical steel rod has a length of 2m and a radius of 0.5 cm. A force of magnitude 2×10^4 N is acting normally on each of its ends. Find the change in its length and radius, if the Young's modulus Y is 200×10^9 N/m^2 and the Poisson's ratio μ is 0.25.

Solution:

Using $F_{\perp} = 2 \times 10^4$ N, $A = \pi r^2 = \pi \times (0.5 \times 10^{-2}\text{ m})^2 = 7.9 \times 10^{-5}$ m^2, $L = 2$ m, and $Y = 200 \times 10^9$ N/m^2, we have:

$$\Delta L = \frac{F_{\perp} L}{YA} = \frac{(2 \times 10^4\text{ N})(2\text{ m})}{(200 \times 10^9\text{ N/m}^2)(7.9 \times 10^{-5})} = 2.5 \times 10^{-3}\text{ m} = 0.25\text{ cm}$$

From the definition of the Poisson's ratio μ, we have:

$$\Delta r = -\frac{\mu r \Delta L}{L} = -\frac{0.25 \times (0.5 \times 10^{-2}\text{ m})(2.5 \times 10^{-3}\text{ m})}{(2\text{ m})} = -1.56 \times 10^{-6}\text{ m}$$

Note that $\Delta L \approx 1{,}600\,|\Delta r|$, i.e. $|\Delta r|$ is extremely small compared to ΔL.

Theoretical learning Activity

1. In group , the trainees discuss the similarity between elasticity and plasticity of solid.

2. In group, the trainees stretch the plastic body by applying the external force on the both ends and discuss about the different stages till the breaking point.

**Practical learning Activities:**

Written assessment

Multiple choice questions

1. What condition or conditions are necessary for static equilibrium?

A) $\sum Fx = 0$ B) $\sum Fx = 0$, $\sum Fy = 0$, $\sum T = 0$ C) $\sum T = 0$ D) $\sum Fx = 0$, $\sum Fy = 0$

2. A sphere hanging freely from a cord is in

A) stable equilibrium. B) unstable equilibrium. C) neutral equilibrium. D) positive equilibrium.

3. A cone balanced on its small end is in A) stable equilibrium. B) unstable equilibrium. C) neutral equilibrium. D) positive equilibrium.

4. A cube resting on a horizontal table top is in A) stable equilibrium. B) unstable equilibrium. C) neutral equilibrium. D) positive equilibrium.

5. Stress is A) the strain per unit length. B) the same as force. C) the ratio of the change in length. D) applied force per cross-sectional area.

6. Strain is A) the ratio of the change in length to the original length. B) the stress per unit area. C) the applied force per unit area. D) the ratio of stress to elastic modulus.

7. A lever is 5.0 m long. The distance from the fulcrum to the weight to be lifted is 1.0 m. If a worker pushes on the opposite end with 400 N, what is the maximum weight that can be lifted?

A) 80 N B) 100 N C) 1600 N D) 2000 N

8. A lever is 5.0 m long. The distance from the fulcrum to the weight to be lifted is 1.0 m. If a 3000 N rock is to be lifted, how much force must be exerted on the lever?

A) 600 N B) 750 N C) 3000 N D) 12000 N

9. A 10-m uniform beam of weight 100 N is supported by two ropes at the ends. If a 400-N person sits at 2.0 m from the left end of the beam, what is the tension in the left rope?

A) 130 N B) 250 N C) 370 N D) 500 N

10. A 200-N scaffold is held up by a wire at each end. The scaffold is 18 m long. A 650-N box sits 3.0 m from the left end. What is the tension in each wire?

A) left wire = 520 N; right wire = 130 N , B) left wire = 640 N; right wire = 210 N

C) left wire = 195 N; right wire = 975 N , D) left wire = 295 N; right wire = 1000 N

11. A 5000-N force compresses a steel block by 0.0025 cm. How much force would be needed to compress the block by 0.0125 cm?

A) 1000 N B) 2500 N C) 5000 N D) 25000 N

12. A cable is 100-m long and has a cross-sectional area of 1 mm2. A 1000-N force is applied to stretch the cable. The elastic modulus for the cable is 1.0 × 1011 N/m2. How far does it stretch? A) 0.01 m B) 0.10 m C) 1.0 m D) 10 m

13. A wire of diameter 0.20 mm stretches by 0.20% when a 6.28-N force is applied. What is the elastic modulus of the wire?

A) 2.5×10^{10} N/m^2 B) 1.0×10^{11} N/m^2 C) 2.5×10^{12} N/m^2 D) 1.0×10^{12} N/m^2

14. A bridge piling has an area of 1.250 m^2. It supports 1875 N. Find the stress on the column.
A) 1875 N B) 1875 N/m^2 C) 1500 N/m^2 D) 2344 N/m^2

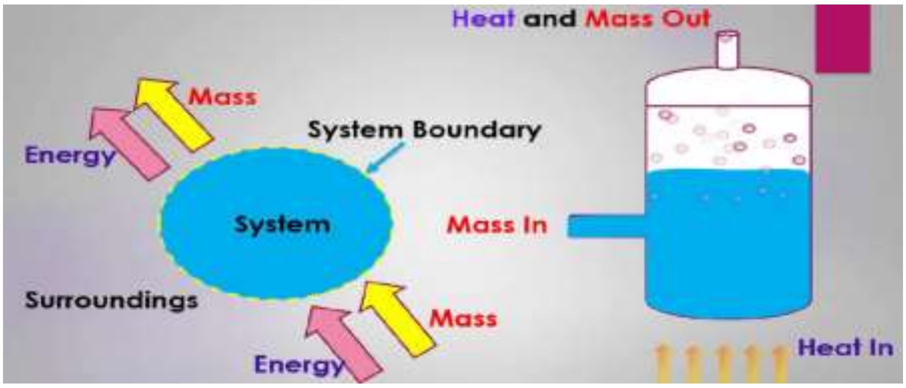
Checklist	**Score**		**Observation**
	Yes	**No**	
Law of force is stated?			
Stress is found?			
Another name of pivot is defined?			
Equilibrium stabilities of solid are defined?			

Points to Remember (Take home message)

- Stress:
  - ✓ A *stress* is a force or combination of forces distributed throughout the whole of an object that acts to deform it.
  - ✓ Stresses take the general form of force divided by area (F/A).
  - ✓ The SI unit of stress is the *pascal* or *newton per meter* [Pa = N/m^2]
- Strain: Strains take the general form of a change in one geometric quantity divided by the original value of that quantity or a similar quantity with the same unit ($\Delta\ell/\ell_0$, $\Delta V/V_0$).
  - ✓ Strains are always dimensionless or unitless.
- modulus (plural, moduli)
  - ✓ Stress is directly proportional to strain.
  - ✓ An *elastic modulus* is the ratio of some stress to the strain caused by that stress.
  - ✓ Elastic moduli are properties of materials, not the objects made from those materials.
- Young Modulus (Y):

Learning Unit 2: Apply thermodynamics

Pictures reflecting to the learning unit



STRUCTURE OF LEARNING UNIT

Learning outcomes:

2.1. Description of fundamental concepts
2.2. Analysing thermodynamic laws
2.3. Application of thermodynamic laws

Learning outcome 2.1. Description of fundamental concepts

Duration: 4 hrs

Learning outcome 2.1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Define clearly the terms: system, boundary, surrounding, extensive & intensive properties, state process
2. explain clearly the heat Transfer and Quantity of heat
3. analyse correctly the thermodynamic laws
4. apply correctly the thermodynamic laws

Resources

Equipment	Tools	Materials
PPE, Whiteboard and chalkboard	Compute, projector, textbooks, scientific calculator, meter ruler, compass	Chalks, Markers

Advance preparation:

. The trainer uses stirrer, calorimeter

The trainer mixes hot and cold water for showing mixtures

2.1.1 Heat Transfer and Quantity of heat

Description of fondamental concepts

System : a set of things working together as parts of a mechanism or an interconnecting network; a complex whole. It is also a regularly interacting or interdependent group of items forming a unified whole.

Boundary : something that indicates bounds or limits; a limiting or bounding line.

Surrounding : The surroundings are everything outside the system and are the place where the observation and measurements of the system are taken. For example, a chemist may be studying the amount of heat evolved (released) during a reaction in a beaker.

Intensive properties do not depend on the quantity of matter. Examples include density, state of matter, and temperature.

Extensive properties do depend on sample size. Examples include volume, mass, and size.

Extensive Property Examples : **Mass and volume are** extensive properties**. As more matter is added to a system, both mass and volume changes.**

Intensive Properties : An **intensive** property is a property of matter that depends only on the type of matter in a sample and not on the amount. Other intensive properties include color, temperature, density, and solubility.

The electrical conductivity of a substance is a property that depends only on the type of substance. Silver, gold, and copper are excellent conductors of electricity, while glass and plastic are poor conductors. A larger or smaller piece of glass will not change this property.

Heat and temperature

The **temperature is** a physical quantity, which indicates the degree **of hotness or coldness of a body**.

Heat is defined as the transfer of energy from one system to another due to a temperature difference between them.

Heat transfer is defined as the process of flow of heat from an object at a higher temperature to an object at a lower temperature.

The formula heat energy describes the amount of heat transferred from one object to another.So, the amount of heat transferred from one object to another is determined by the following heat Transfer formula:

$$\mathbf{Q = m\,C\,\Delta T}$$

Here, Q is the amount of heat added to the system

c = Specific heat capacity of the system

The mass of the system is "m," and ΔT is the temperature difference, measured in K.

Internal energy is all the energy of a system that is associated with its microscopic constituents. Internal energy includes kinetic energy of random translational, rotational, and vibration motion of molecules, potential energy of molecules and between molecules.

Thermometers are devices that are used to measure the temperature of a system. All thermometers are based on the principle that some physical property of a system changes as the system's temperature changes.

2.1. 2 Modes of heat transfer

Mechanisms of Heat Transfer

The conductors and insulators, materials that permit or prevent heat transfer between bodies. Now let's look in more detail at rates of energy transfer. In the kitchen you use a metal or glass pot for good heat transfer from the stove to whatever you're cooking, but your refrigerator is insulated with a material that prevents heat from flowing into the food inside the refrigerator.

How do we describe the difference between these two materials?

The three mechanisms of heat transfer are conduction, convection, and radiation.

Conduction occurs within a body or between two bodies in contact.

Convection depends on motion of mass from one region of space to another.

Radiation is heat transfer by electromagnetic radiation, such as sunshine, with no need for matter to be present in the space between bodies.

Conduction : In Conduction, the molecules of the body are responsible for the heat transfer. Here there is no actual movement of molecules from one place to another place. When a rod is heated at one end, the molecules at the hot end vibrate about their mean position and transfer the heat energy to the neighbouring molecules and thus the heat energy reaches the other end of the rod. Conduction takes place in solids, liquids and gases. Heat transfer occurs only between regions that are at different temperatures, and the direction of heat flow is always from higher to lower temperature.

When a quantity of heat dQ is transferred through the rod in a time dt, the rate of heat flow is $\frac{dQ}{dt}$. We call this rate the heat currents is proportional, denoted by H . Heat current is proportional to the cross section area A of the rod and the tmperature difference (T_H _ T_C) and it is inversely proportional to the rod length L.

$$P = \frac{dQ}{dt} = kA\frac{T_H - T_L}{L}$$ (heat current in conduction)

Hence, Coefficient of thermal conductivity (k) of the material of a conductor is defined as the quantity of heat conducted per second per unit area per unit temperature gradient at the steady state.

The materials with large k are good conductors of heat, materials with small k are poor conductors or insulators.

A glass window pane has an area of 3.00 m2 and a thickness of 0.600 cm. If the temperature difference between its faces is 25.0°C, what is the rate of energy transfer by conduction through the window?

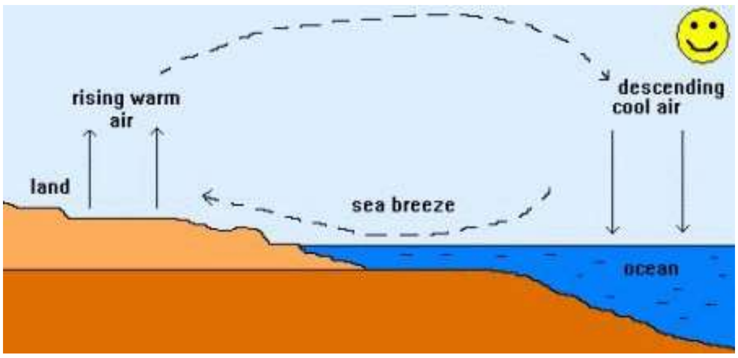
$$\wp = \frac{kA\Delta T}{L} = \frac{(0.800\ \text{W/m}\cdot{}^\circ\text{C})(3.00\ \text{m}^2)(25.0^\circ\text{C})}{6.00\times10^{-3}\ \text{m}} = 1.00\times10^4\ \text{W} = \boxed{10.0\ \text{kW}}$$

Uses of thermal conductors:-

1. Handles made of wood or ebonite are provided for cookers and hot water vessels.
2. Hot water bottles made of rubber are able to keep hot water at high temperature for a considerable period of time.
3. Use of double windows with a thin layer of air enclosed in between them keep the room warm in cold countries.
4. Wool, cork and ebonite are used for the purpose of heat insulation in refrigeration.
5. Wooleen clothes are used in winter to keep the body warm.
6. Sawdust and jute sheet is used to cover ice to prevent it from melting.
7. Vessels made of copper, aluminium, etc., are used for cooking purpose as they easily conduct heat.
8. Copper is used in boilers and radiators, because of its good conductivity.

Convection : Convection **is the transfer of heat by mass motion of a fluid from one region of space to another. The portions of the fluid that get warmed up by contact with the heat source, expand and so move up through the body of the fluid due to the decrease in density. There is an inflow of cooler molecules to take the place of heated mass of the fluid which has moved up. This circulatory motion of the fluid mass by which heat is transferred from place to place is called Convection. Convection is the process in which heat is transmitted from one place to the other by the actual movement of heated particles. Convection takes place only in liquids and gases. It cannot take place in solids.**

Wind formation: Wind is air in motion. It is produced by the uneven heating of the earth's surface by the sun. Since the earth's surface is made of various land and water formations, it absorbs the sun's radiation unevenly. Two factors are necessary to specify **wind**: speed and direction.



Applications of Convection.

1. The wind flow is due to the convection currents in the atmosphere. During day time, parts of earth get heated by the Sun. As the air expands, it rises up and its place is taken by the flow of air from colder areas.

2. The land breeze and sea breeze are due to the convection in the atmosphere. During day time, land mass is heated to a higher level than the sea. So, the warm air over the land rises giving place to the cool air flow from the ocean. This gives the sea breeze. During night time, the land mass cools quickly than the water in the sea. So, cool air flows from land mass towards sea which gives the land breeze.

Radiation: Radiation is the transfer of heat by electromagnetic waves such as visible light, infrared, and ultraviolet radiation. Everyone has felt the warmth of the sun's radiation and the intense heat from a charcoal grill or the glowing coals in a fireplace.

Most of the heat from these very hot bodies reaches you not by conduction or convection in the intervening air but by radiation. This heat transfer would occur even if there were nothing but vacuum between you and the source of heat.

The rate of energy radiation from a surface is proportional to the surface area A and to the fourth power of the absolute (kelvin) temperature T. T_h rate also depends on the nature of the surface. The quantity e is called emissivity. A dimensionless number between 0 and 1, e represents ratio of the rate of radiation from a particular surface to the rate of radiation from an equal area of an ideal radiating surface at the same temperature.

$p = Ae\sigma T^4$, $\sigma = 5.67 \times 10^{-8}\ {}^{w}\!/\!_{m^2k^4}$

Where σ is fundamental physical quantity called Stephan-Boltzmann constant.

Properties of thermal radiation: The nature of thermal radiation is similar to that of light. Some of the properties of thermal radiation.

1. Thermal radiation travels with the velocity of light, which is 3 x 108 ms-1.
2. Thermal radiation obeys the same laws of reflection, refraction etc., as light.
3. Thermal radiation travels through vacuum.
4. It obeys the law of Inverse Square, as light.
5. It travels in straight lines.
6. When thermal radiation falls on anybody, which can absorb it, then converted into ordinary heat, which raises its temperature.
7. It is absorbed by dark rough surfaces and reflected by light smooth surface.

Applications of Radiation.

1. White coloured dresses are used in hot countries to keep the inside cool.
2. In some countries, shining aluminium sheets are used to cover the roof of the house to reflect back the radiant heat and to keep the inside cool.
3. A cooking vessel is painted black at the bottom for greater absorption of heat, but polished at the top to minimize radiation losses.
4. In cold countries, hot air or water runs through the pipes along the walls inside a building and the radiant heat energy keeps the occupants warm by 'Central Heating'.

Example

A thin square steel plate 10 cm on a side, it is heated in a black smith's forge to 800 ^{0}C. If the emissivity is 0.60, what is the total rate of radiation of energy from the plate?

Solution:

The total surface area is $2(0.10\ m)^2 = 0.020\ m^2$ and $T = 800^0\ C = 1073\ K$.
$H = A\sigma eT^4 = (0.020\ m^2 (0.60)(5.67\times10^{-8}\ K^4)(1073\ K) = 900\ w$

Effect of heat energy: When a certain amount of heat energy is given to a substance, it will undergo one or more of the following changes:

- Temperature of the substance rises.
- The substance may change its state from solid to liquid or from liquid to gas
- The substance will expand when heated.

When a liquid is heated, it is done by keeping the liquid in some container and supplying heat energy to the liquid through the container. The thermal energy supplied will be partly used in expanding the container and partly used in expanding the liquid. Thus, what we observe may not be the actual or real expansion of the liquid. Hence, for liquids, we can define real expansion and apparent expansion.

2.1.3 Heat capacity : The quantity of heat energy Q required to raise the temperature of an object by some amount ΔT varies from one substance to another.

The **heat capacity** C of an object is defined as the amount of heat energy needed to raise the object's temperature by one degree Celsius.
Accordingly, if Q units of heat energy are required to change the temperature by
$\Delta T = T_f - T_i$, where Ti and Tf are the initial and final temperatures of the object,
then: $\mathbf{Q = C\ \Delta T}$ **, where** $\mathbf{\Delta T = T_f - T_i}$
Heat capacity C has the unit J/C◦ (J/K) or kcal/C◦ (kcal/K).

2.1.4 Specific heat capacity

The heat capacity for any object is proportional to its mass m. For this reason, we define the "heat capacity per unit mass" or the **specific heat** c which refers to a unit mass of the material of which the object is made.
Specific heat capacity c of an object is defined as the amount of heat energy needed to raise the temperature of a unit mass of the object by one degree Celsius.

Thus, with **C = mc**, becomes: $\mathbf{Q = m\ C\ \Delta T}$ **, where** $\mathbf{\Delta T = T_f - Ti}$
Specific heat c has the unit: **J /kg. C◦ = J/ kg. K** Or **kcal/kg.C◦ = kcal/ kg. K**
The specific heat of water at 15 ◦C and atmospheric pressure is:
C water = 4,186 J/kg. K = 1 kcal/kg. $\mathbf{^0C}$
Note that, when heat energy is added to objects, Q and ΔT are both positive, i.e. the temperature increases. Likewise, when heat is removed from objects, Q and ΔT are both negative, i.e. the temperature decreases.
Table : Specific heat c of some substances at atmospheric pressure and room temperature (20 ◦C) with few exceptions

Examples

The specific heat of zinc is 352 J/kg.^{0}C for temperatures near 25 ◦C. Determine the amount of heat required to raise the temperature of 0.5 kg zinc from 20 to 30 ◦C. Take the specific heat to be constant in that temperature range.

Solution: The given values are c=352 J/kg.^{0}C

,m = 0.5kg, Ti = 20 ^{0}C, and

T_f = 30 ◦C. The temperature change has the following magnitude:

ΔT = Tf − Ti = 30 ^{0}C − 20 ^{0}C = 10 ^{0}C

We find the amount of heat required as follows:

Q = m c ΔT = (0.5kg) (352 J/kg.^{0}C) (10 ^{0}C) = 1,760 J

Example 2

A steel metal object of mass 0.05 kg is heated to 225 ◦C and then dropped into a vessel containing 0.55 kg of water initially at 18 ◦C. When equilibrium is reached, the temperature of the mixture is 20 ◦C. Find the specific heat of the metal.

Solution: For the steel metal object, we are given mx = 0.05 kg and Tx = 225 ^{0}C, but its specific heat cx is unknown. For water, the known values are mw =0.55 kg, Tw = 18 ^{0}C, and cw = 4,186 J/kg.^{0}C . For the mixture, the equilibrium temperature occurs at Tf =20 ^{0}C. Since the heat gained by the water is equal in magnitude to the heat lost by the steel, then we must

have:

mw cw $(T_f - T_w)$ = $-$mx c_x $(T_f - T_x)$, $(T_w < T_f < T_x)$

Solving for cx we get:

$$c_x = c_w \frac{m_w}{m_x} \frac{(T_f - T_w)}{(T_x - T_f)} = (4{,}186\ \text{J/kg.C}^\circ)\frac{(0.55\,\text{kg})}{(0.05\,\text{kg})}\frac{(20\,^\circ\text{C} - 18\,^\circ\text{C})}{(225\,^\circ\text{C} - 20\,^\circ\text{C})} = 449\ \text{J/kg.C}^\circ$$

2.1.5 Latent heat capacity

Phase Changes

Calorimeter means "measuring heat." We have discussed the energy transfer (heat) involved in temperature changes. Heat is also involved in *phase changes,* such as the melting of ice or boiling of water. Once we understand these additional heat relationships, we can analyse a variety of problems involving quantity of heat

Latent heat, energy absorbed or released by a substance during a change in its physical state (phase) that occurs without changing its temperature. The latent heat associated with melting a solid or freezing a liquid is called the heat of fusion; that associated with vaporizing a liquid or a solid or condensing a vapour is called the heat of vaporization. The latent heat is normally

expressed as the amount of heat (in units of joules or calories) per mole or unit mass of the substance undergoing a change of state.
For any given pressure a phase change takes place at a definite temperature, usually accompanied by absorption or emission of heat and a change of volume and density.

A familiar example of a phase change is the melting of ice. When we add heat to ice at **0°C** and normal atmospheric pressure, the temperature of the ice *does not* increase. Instead, some of it melts to form liquid water. If we add the heat slowly, to maintain the system very close to thermal equilibrium, the temperature remains at **0°C** until all the ice is melted. The effect of adding heat to this system is not to raise its temperature but to change its *phase* from solid to liquid.
To change 1 kg of ice at 0°C to 1 kg of liquid water at 0°C and normal atmospheric pressure requires **3.34×10^5 J** of heat. The heat required per unit mass is Called the **heat of fusion** (or sometimes latent heat of fusion), denoted by L_f. For water at normal atmospheric pressure the heat of fusion is
$L_f = 3.34 \times 10^5$ j / kg = 79.6 cal/g.
More generally, to melt a mass m of material that has a heat of fusion Lf requires a quantity of heat Q given by
$Q = m L_f$.
This process is reversible. T freeze liquid water to ice at 0^0 C, we have to remove heat; the magnitude is the same, but in this case, Q is negative because heat is removed rather than added. To cover both possibilities and include other kinds of phase changes, we write
$Q = \pm m L$ (heat transfer in a phase change).

The plus sign (heat entering) is used when the material melts; the minus sign (heat leaving) is used when it freezes. The heat of fusion is different for different materials, and it also varies somewhat with pressure. For any given material at any given pressure, the freezing temperature is the same as the melting temperature. At this unique temperature the liquid and solid phases (liquid water and ice, for example) can coexist in a condition called **phase equilibrium.**

We can go through this whole story again for *boiling* or *evaporation*, a phase transition between liquid and gaseous phases. The corresponding heat (per unit mass) is called the **heat of vaporization** L_V. At normal atmospheric pressure the heat of vaporization L_V for water is

$$L_V = 2.256 \times 10^6 \text{ J/kg} = 539 \text{ cal/g} = 970 \text{ Btu/lb}$$

That is, it takes 2.256×10^6 J to change 1 kg of liquid water at 100°C to 1 kg of water vapor at 100°C. By comparison, to raise the temperature of 1 kg of water from 0°C to 100°C requires $Q = mc\,\Delta T = (1.00 \text{ kg})(4190 \text{ J/kg}\cdot\text{C}°) \times (100 \text{ C}°) = 4.19 \times 10^5$ J, less than one-fifth as much heat as is required for vaporization at 100°C. This agrees with everyday kitchen experience; a pot of water may reach boiling temperature in a few minutes, but it takes a much longer time to completely evaporate all the water away.

Like melting, boiling is a reversible transition. When heat is removed from a gas at the boiling temperature, the gas returns to the liquid phase, or *condenses,* giving up to its surroundings the same quantity of heat (heat of vaporization) that was needed to vaporize it. At a given pressure the boiling and condensation temperatures are always the same; at this temperature the liquid and gaseous phases can coexist in phase equilibrium.

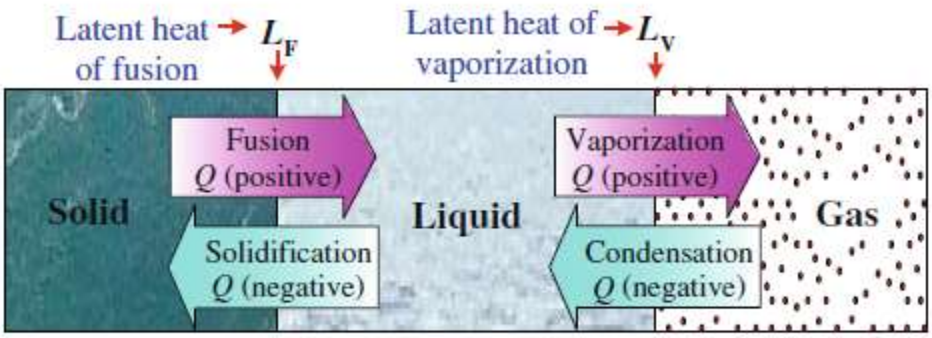


Fig. 12.3 A sketch showing heat of fusion/vaporization (positive Q) as well as heat of condensation/solidification (negative Q)

Example:

Find the quantity of heat required to convert ice of mass 500 g at −10 °C into water at 20 °C. The specific heat of ice is $c_i = 2{,}220$ J/kg.C°, the latent heat of fusion is $L_F = 3.33 \times 10^5$ J/kg, and the specific heat of water is $c_w = 4{,}186$ J/kg.C°.

Solution: The ice gains heat throughout the following three stages.

In stage A we raise the temperature of ice from −10 to 0 °C. Using Eq. 12.4 we get:

$$Q_A = m_i c_i \, \Delta T = (0.5\,\text{kg})(2{,}220\,\text{J/kg.C°})(10\,\text{C°}) = 11{,}100\,\text{J} = 11.1\,\text{kJ}$$

In stage B we melt the 500 g of ice at constant temperature (0 °C) by supplying the latent heat of fusion. Using Eq. 12.7 we get:

$$Q_B = m\,L_F = (0.5\,\text{kg})(3.33 \times 10^5\,\text{J/kg}) = 166{,}500\,\text{J} = 166.5\,\text{kJ}$$

In stage C we raise the temperature of water from 0 to 20 °C. Using Eq. 12.4 we get:

$$Q_C = m_W c_W \, \Delta T = (0.5\,\text{kg})(4{,}186\,\text{J/kg.C°})(20\,\text{C°}) = 41{,}860\,\text{J} = 41.86\,\text{kJ}$$

Note that $Q_B > Q_C > Q_A$ and the total required heat is $Q_{tot} = 219.46\,\text{kJ}$.

Exercises on calorimetry

1. Water at the top of Niagara falls has a temperature of 10^0C, it falls a distance of 50m and all its potential energy goes into heating the water. Calculate the temperature of water at the bottom of the falls.

2. A 400g iron that is initially at 500^0C is dropped into a bucket containing 20kg of water at 20^0C. What is the final equilibrium temperature? Neglect any heat transfer to or from surroundings C_i = 448J/kg^{0}C.

3. An aluminium cup contains 225g of water at 27^0C. A 400 g sample of silver at an initial temperature of 87^0C is placed in the water. A 40 g copper stirrer is used to stir the mixture until it reaches its final equilibrium at 32^0C.
Calculate the mass of Al cup, CA = 900J/kg^{0}C , C_{copper} = 387J/kg^{0}C, C_{silver} = 234J/kg^{0}C.

4. A 50g ice cube at 0^0C is heated until 45g has become water at 100^0C and 5 g has become steam at 100^0C. How much heat was added to accomplish this?

5. A 100g ice cube at 0^0C is placed in 650g of water at 25^0C, what is the final temperature of the mixture

2.1.6 Thermal expansions of substances.

When heat energy is supplied to a body, there can be an increase in the dimension of the object. This change in the dimension due to rise in temperature is called thermal expansion of the object. The expansion of liquids (e.g. mercury) can be seen when a thermometer is placed in warm water. All forms of matter (solid, liquid and gas) undergo expansion on heating.

a) Expansion in solids

When a solid is heated, the atoms gain energy and vibrate more vigorously. This results in the expansion of the solid. For a given change in temperature, the extent of expansion is smaller in solids than in liquids and gases. This is due to the rigid nature of solids.

The different types of expansion of solid are listed and explained below:

1. Linear expansion
2. Superficial (Areal) expansion
3. Cubical expansion

1. Linear expansion:

When a body is heated or cooled, the length of the body changes due to change in its temperature. Then the expansion is said to be **linear or longitudinal expansion**.

The ratio of increase in length of the body per degree rise in temperature to its unit length is called as the **coefficient of linear expansion**. The SI unit of Coefficient of Linear expansion is K^{-1}. The value of coefficient of linear expansion is different for different materials.

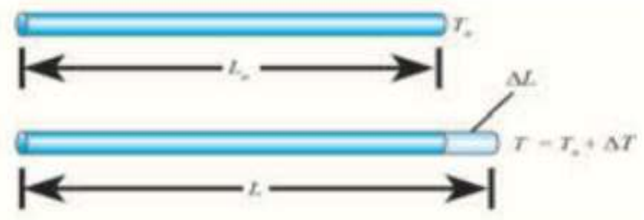


Figure 3.2 Linear expansion

The equation relating the change in length and the change in temperature of a body is given below:

$$\frac{\Delta L}{L_o} = \alpha_L \Delta T$$

ΔL - Change in length (Final length-Original length)

L_o - Original length

ΔT - Change in temperature (Final temperature - Initial temperature)

α_L - Coefficient of linear expansion.

1. Superficial expansion:

If there is an increase in the area of a solid object due to heating, then the expansion is called **superficial or areal expansion.**

Superficial expansion is determined in terms of coefficient of superficial expansion. The ratio of increase in area of the body per degree rise in temperature to its unit area is called as **coefficient of superficial expansion**. Coefficient of superficial expansion is different for different materials. The SI unit of Coefficient of superficial expansion is K^{-1}

The equation relating to the change in area and the change in temperature is given below:

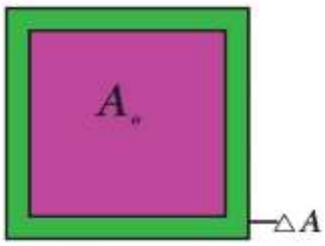


Figure 3.3 Superficial expansion

$$\frac{\Delta A}{A_o} = \alpha_A \Delta T$$

ΔA - Change in area (Final area - Initial area)

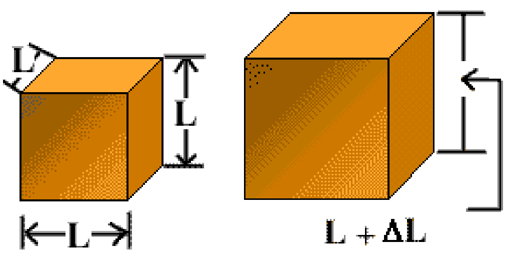
A_o - Original area

ΔT - Change in temperature (Final temperature - Initial temperature)

α_A - Coefficient of superficial expansion.

2. Cubical expansion: If there is an increase in the volume of a solid body due to heating, then the expansion is called cubical or volumetric expansion.

As in the cases of linear and areal expansion, cubical expansion is also expressed in terms of coefficient of cubical expansion. The ratio of increase in volume of the body per degree rise in temperature to its unit volume is called as **coefficient of cubical expansion**. This is also measured in K^{-1}.



The equation relating to the change in volume and the change in temperature is given below:

$$\frac{\Delta V}{V_o} = \alpha_V \Delta T$$

ΔV - Change in volume(Final volume - Initial volume)

V_o - Original volume

ΔT - Change in temperature (Final temperature - Initial temperature)

α_V - Coefficient of cubical expansion.

Different materials possess different coefficient of cubical expansion. Table 3.1 gives the coefficient of cubical expansion for some common materials.

Table 3.1 Coefficient of cubical expansion of some materials

S.No.	Name of the material	Coefficient of cubic expansion (K^{-1})
1	Aluminium	7×10^{-5}
2	Brass	6×10^{-5}
3	Glass	2.5×10^{-5}
4	Water	20.7×10^{-5}
5	Mercury	18.2×10^{-5}

b) Expansion in liquids and gases : The rise in temperature is in proportion to the amount of heat energy supplied. It also depends on the nature and mass of the substance. About the rise in temperature and the change of state, you have studied in previous classes. In the following section, we shall discuss about the expansion of substances due to heat.

When heated, the atoms in a liquid or gas gain energy and are forced further apart. The extent of expansion varies from substance to substance. For a given rise in temperature, a liquid will have more expansion than a solid and a gaseous substance has the highest expansion when compared with the other two. The coefficient of cubical expansion of liquid is independent of temperature whereas its value for gases depends on the temperature of gases.

- ✓ **Intensive properties do not depend on the quantity of matter. Examples include density, state of matter, and temperature.**
- ✓ **Extensive properties do depend on sample size. Examples include volume, mass, and size.**

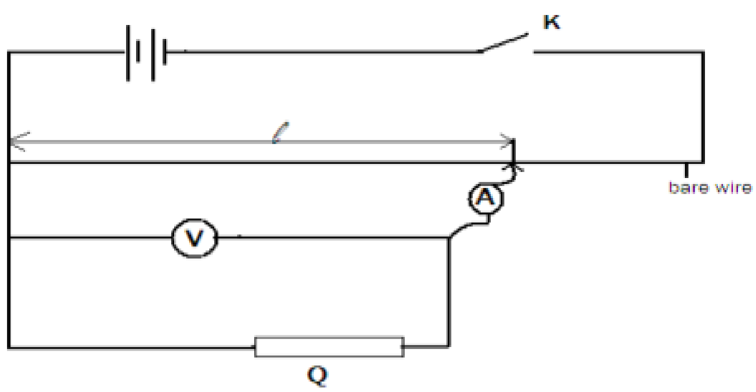
Theoretical learning Activity

- ✓ In group the trainees will discuss about why the metals are heated before being transformed into long wires or plane surfaces.
- ✓ In group, the trainees will discover the method of heat transfer for liquid which is boiling.
- ✓ In groups, the trainees discover the method of heat transfer when the sun is radiating into the earth.

Practical learning Activity

The trainees in pair, perform the following activities: experiment you will determine the resistance of a resistor.

a) Connect the dry cells, resistor Q , the bare wire, a voltmeter and an ammeter as shown down.



b) Adjust the length L of the resistance wire to 20 cm .

c) Close switch K and record the voltmeter reading V and the ammeter reading I.

d) Repeat procedures (b) to (c) for l = 30, 40, 50, 60 and 70 cm.

e) Record your results in a suitable table. f) Plot a graph of V against I .

g) Find the slope, S of the graph.

Cheklist

Checklist	**Score**		**Observation**
	Yes	**No**	
voltmeter is stated?			
ammeter is found?			
Electric cables are selected ?			
Switch is selected?			
Cells are selected?			
Resistance is selected?			

Points to Remember (Take home message)

- Specific heat capacity
- Latent heat
- Expansion of solid

Formative assessment

Written assessment

1) Ice has a latent heat of fusion of 80 kcal/kg. How much heat is required to melt 200 g of ice? A) 400 J B) 160 J C) 67 kJ D) 16 kJ

2) 400 cm^3 of mercury at ^{0}C will expand to what volume at 50 ^{0}C? Mercury has a volume expansion coefficient of 180 ¸ 10^{-6} /^{0}C

3) The length of iron rod at 100^{0}c is 300.36 cm and at 150^{0}c is 300.54cm. Calculate its length at 0^{0}c and coefficient of linear expansion of iron.

4) The radius of a ring at 20^{0}c is 20cm. if the final radius at 100^{0}c is 20.5 cm, determine the coefficient of area expansion and the coefficient of linear expansion.

5) How much heat energy is needed to change 10 kg of ice at -20eC to water at 50 ^{0}C?

A) 4.2×10^5 J B) 3.3×10^6 J C) 4.2 ×106 J D) 5.8×10^6 J

6. A metal scale is graduated at 0^0C. What would be the true length of an object which when measured with the scale at 25^0C, reads 50cm? α of metal is $18x10^{-6}/^0C$.

7. A metal rod is 64.522cm long at 12^0c and 64.576cm at 90^0c. Find the coefficient of linear expansion of its material.

8. At 20^0c, the length of a sheet of steel is 50cm and the width is 30cm. If the coefficient of linear expansion for steel is $10^{-5}\ {}^0c^{-1}$, determine the change in area and the final area at 60^0c.

9. At 30^0c, the area of sheet of aluminium is $40cm^2$ and the coefficient of linear expansion is $24x10^{-6}C^{-1}$. Determine the final temperature if the final area is 40.2 cm^2.

Learning outcome 2.2. Analysing thermodynamic laws

Duration: 3 hrs

Learning outcome 2.2 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Explain correctly Zeroth law and temperature measurement
2. State correctly the first Law of Thermodynamics and Some Simple Processes
3. State correctly the Second law statements

Resources

Equipment	**Tools**	**Materials**
PPE, Whiteboard and chalkboard	Compute, projector, textbooks, scientific calculator, meter ruler, compass	Chalks, Markers

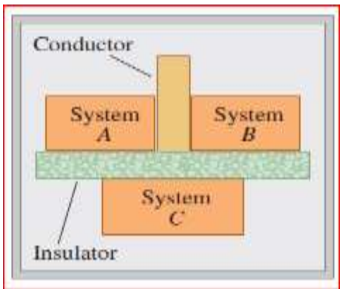
Advance preparation:

. Trainer uses iron metal, solid insulator to show how heat transfer from hot to cold places.

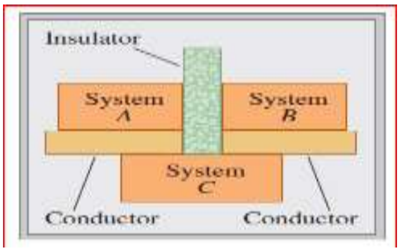
2.2.1 Zeroth law and temperature measurement

The Zeroth Law of Thermodynamics

We can discover an important property of thermal equilibrium by considering three systems, A, B, and C, that initially are not in thermal equilibrium. We surround them with an ideal insulating box so that they cannot interact with anything except each other. We separate systems A and B with an ideal insulating, but we let system C interact with both systems A and B. This interaction is shown in the figure by a yellow slab representing a thermal **conductor,** a material that permits thermal interactions through it. We wait until thermal equilibrium is attained; then A and B are each in thermal equilibrium with C. **Two systems are in thermal equilibrium if and only if they have the same temperature.**



Systems A and B are in thermal equilibrium



Systems A and B are in thermal with system C equilibrium with each

Temperature scales : Number of temperature measuring scales came up from time to time. The text ahead gives a brief idea of the different temperature scales used in thermometry. Different temperature scales have different names based on the names of persons who originated them and have different numerical values assigned to the reference states.

(a) Celsius Scale or Centigrade Scale: Anders Celsius gave this Celsius or Centigrade scale using **ice point of 0°C as the lower fixed point and steam point of 100ºC as upper fixed point** for developing the scale. It is denoted by letter C.

Ice point refers to the temperature at which freezing of water takes place at standard atmospheric pressure.

Steam point refers to the temperature of water at which its vaporization takes place at standard atmospheric pressure.

The interval between the two fixed points was equally divided into 100 equal parts and each part represented 1ºC or 1 degree celsius.

(b) Fahrenheit Scale: Fahrenheit gave another temperature scale known as Fahrenheit scale and has the lower fixed point as **32°F** and the upper fixed point as **212°F**. The interval between these two is equally divided into 180 parts.

It is denoted by letter F. Each part represents **1°F**.

(c) Rankine Scale

Rankine scale was developed by William John MacQuorn Rankine, a Scottish engineer. It is denoted by letter R. It is related to Fahrenheit scale as given below.

$\mathbf{T_R = T_F + 459.67}$

(d) Kelvin Scale: Kelvin scale proposed by Lord Kelvin is very commonly used in thermodynamic analysis. It also defines the absolute zero temperature. Zero Kelvin or **absolute zero temperature** is taken as **–273.15ºC**. It is denoted by letter K.

SCALE	*ICE POINT*	*STEAM POINT*	*TRIPLE POINT*
KELVIN	273.15K	373.15K	273.15K
RANKINE	491.67R	671.67R	491.69R
FAHRENHEIT	32^0F	212^0F	32.02^0F
CENTIGRADE	0^0C	100^0C	0.01^0C

To convert a temperature from one scale to the other, we must also take into account the fact that the zero temperatures of the two scales are not the same. The general relation between a Fahrenheit temperature $\mathbf{T_F}$ and Celsius $\mathbf{T_C}$ temperature is

$$T_F = \frac{9}{5}T_C + 32°F$$

Fahrenheit–centigrade conversion

$$t_C = \frac{5}{9}(t_F - 32°) \qquad (\text{or } t_F = \frac{9}{5}t_C + 32°)$$

Celsius–absolute conversion

$$T = t_C + 273.15\text{ K}$$

To find a relationship between changes in temperature on the Celsius, Kelvin, and Fahrenheit scales:

$$\Delta T_C = \Delta T = \frac{5}{9}\Delta T_F$$

General expression which is combining Celsius, Kelvin and Fahrenheit temperature scales is

$$\frac{T_C}{100} = \frac{T_F - 32}{180} = \frac{T_K - 273.15}{100}$$

Examples

1. Determine the human body temperature in degree celsius (°C) if the temperature in Fahrenheit is 98.6°F.

Solution:

Degree Celsius and Fahrenheit are related as below,

$$T\,(°C) = \frac{T°(F) - 32}{1.8}$$

Substituting values.

$$T\,(°C) = \frac{98.6 - 32}{1.8} = 37°C$$

Temperature in degree celsius shall be **37°C**. **Ans.**

Example 2

The normal boiling point of nitrogen is −195.75 ◦C.

(a)What is this temperature in Kelvin and in Fahrenheit?

(b) If the temperature changes from −195.75 ◦C to −100 ◦C, find the change in the temperature on the Fahrenheit scale.

$$T = T_C + 273.15 = -195.75 + 273.15 = 77.4\ \text{K}$$

$$T_F = \frac{9}{5}T_C + 32 = \frac{9}{5} \times (-195.75) + 32 = -320.35\ ^\circ\text{F}$$

Thus, −195.75 ◦C, 77.4K, and −320.35 ◦F are equivalent temperatures on different scales.

(b) For a change ΔT_C =[−100 ◦C–(−195.75 ◦C)]=95.75C◦

We find the change in temperature on the Fahrenheit scale as:

$$\Delta T_F = \frac{9}{5}\Delta T_C = \frac{9}{5}[-100 - (-195.75)] = 172.35\ \text{F}^\circ$$

Thus, a change **95.75C◦ =172.35 F◦** , where the notations **C◦ and F◦ refer to temperature difference, not to be confused with actual temperatures**, which are written in terms of symbols ◦C and ◦F.

EXERCISES

(1) Convert the temperatures −30 ◦C, 10 ◦C, and 50 ◦C to Kelvin and Fahrenheit.

(2) Express the normal human body temperature, 37 ◦C, and the sun's surface temperature, ∼6000 ◦C, in Fahrenheit and Kelvin.

(3) A Celsius thermometer indicates a temperature of−40 ◦C.

(a)What Fahrenheit and Kelvin temperatures correspond to this Celsius temperature?

(b) If the temperature changes from −40 ◦C to+10 ◦C, find the change in temperature on the Fahrenheit scale.

2.2.2 First Law of Thermodynamics and Some Simple Processes

The thermodynamic process is the method by which a system is changed from one *state* to another. The state of a system is described by a set of **state variables** such as **pressure, temperature, volume, number of moles, and internal energy**. State variables describe the state of a system at some instant of time but not how the system got to that state. Heat and work are *not* state variables, they describe *how* a system gets from one state to another.

Thermodynamic processes can be precisely categorized as cyclic process and non-cyclic process. **The cyclic process is the one in which the initial and final states are identical i.e. system returns to its initial states after occurrence of process. The non cyclic process is the one in which the initial and final states are different i.e**. the occurrence of process is accompanied by the state change.

We can expand the work done by the gas as follows: $dw = pdv$.

If the gas expands then dV is positive and the work done by the gas is positive, whereas if the gas is compressed, dV is negative, indicating that the work done by the gas is negative. When we remove the amount of load from the piston, the volume of the gas changes from V_i to v_f and the total work done by the gas is:

$$W = \int dW = \int_{V_i}^{V_f} P\,dV$$

During the change in volume of the gas, the pressure and temperature of the gas may also change. To evaluate the integral in the last equation, we need to know how the pressure varies with volume. For example, Fig. 12.7 indicates that the work done by the gas is represented by the area under the PV diagram of the figure.

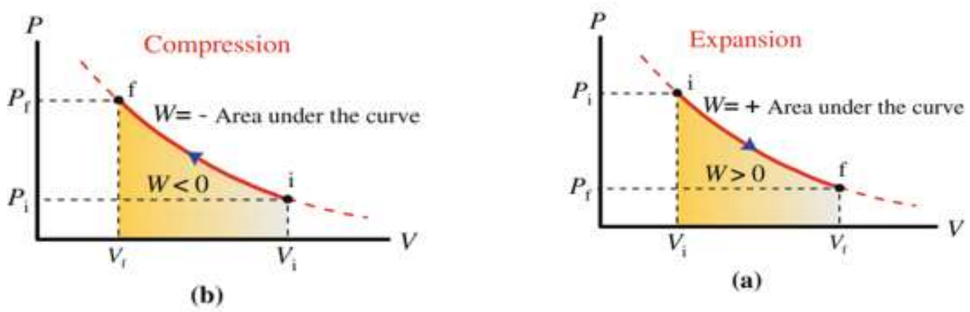


Figure 1

Figure 1. The figure shows a gas that goes from an initial state i to a final state f by means of a thermodynamic process. (a) When the gas expands, the work done by the gas is positive and equals the area under the PV curve. (b) Similar to (a), except that the gas is compressed and the work done by the gas is negative.

(*i*) *Constant pressure process or isobaric process*:

It refers to the thermodynamic process in which there is no change in pressure during the process. Such type of processes are also known as isobaric processes.

Some Special Cases of the First Law of Thermodynamic

Adiabatic processes : An adiabatic process is one that **occurs so rapidly or occurs in a system that is so well insulated that** no transfer of energy as heat occurs between the system and its environment. **Putting Q = 0 in the first law (Eq. 18-26) yields**

$$\Delta E_{int} = -W \qquad \text{(adiabatic process).}$$

This tells us that if work is done by the system (that is, if W is positive), the internal energy of the system decreases by the amount of work. Conversely, if work is done on the system (that is, if W is negative), the internal energy of the system increases by that amount.

Constant-volume processes : If the volume of a system (such as a gas) is held constant, that system can do no work. Putting W = 0 in the first law yields.

$$\Delta E_{int} = Q \quad \text{(constant-volume process).}$$

Thus, if heat is absorbed by a system (that is, **if Q is positive**), the internal **energy of the system increases**. Conversely, if heat is lost during the process (that is, if Q is negative), the internal energy of the system must decrease.

Isobaric Process : An isobaric process is one that takes place at constant pressure. In general, the first law of thermodynamics does not assume any special values for the isobaric process; that is, Q, W, and ΔE int are all non-zero.

$$W_{isobaric} = P(V_f - V_i) \quad \text{(Isobaric process)}$$

Isothermal Process : An isothermal process is one that takes place at constant temperature**.**

$$W = nRT \ln\left(\frac{V_f}{V_i}\right)$$

Process	W (Work)	Q (Heat)	ΔU (internal energy)
Isochoric ΔV = 0	W = 0	W = 0	Q = n Cv ΔT
			ΔU = Q
Isobaric ΔP = 0	W = P ΔV	Q = n Cp ΔT	ΔU = n Cv ΔT
	= n R ΔT		
Isothermal ΔT = 0	W = P ΔV	Q = W	ΔU = 0
	W = nRT ln (P_1/P_2)	Q = nRT ln (P_1/P_2)	$P_1V_1 = P_2V_2$
Adiabatic Q = 0	W = -nc_v ΔT	Q = 0	ΔU = -W

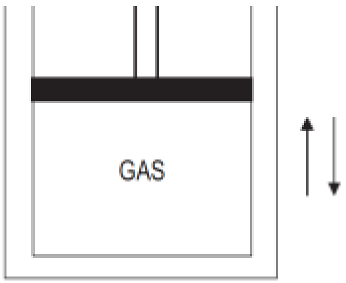
Where Cp is molar heat capacity at constant pressure and Cv is the molar heat capacity at constant volume.

Table 12.3 The first law of thermodynamics in five special cases

Process	Restriction	Consequence
Adiabatic	$Q = 0$	$\Delta E_{\text{int}} = -W$
Free expansion	$Q = W = 0$	$\Delta E_{\text{int}} = 0$
Isobaric	$P = \text{constant}$	$W_{\text{isobaric}} = P(V_f - V_i)$
Isovolumetric	$V = \text{constant}, W = 0$	$\Delta E_{\text{int}} = Q$
Isothermal (ideal gas)	$T = \text{constant}, \Delta E_{\text{int}} = 0$	$Q = W = nRT \ln(V_f / V_i)$

ADIABATIC EQUATIONS

When the pressure and volume of a gas change, but no heat is allowed to enter or leave the gas, the change is called as adiabatic change. During the adiabatic change, no heat leaves or enters the gas. That is dQ = 0. The work is done at the cost of internal energy. The gas energy equation, for the adiabatic change becomes,



dQ = Change in internal energy + External work

$0 = dE + W$ (or) $W = dE$

For a perfect gas, adiabatic change can be represented by the equation,

PV^{γ} = a constant Also $P_1V_1^{\gamma} = P_2V_2^{\gamma}$

The equation relating the temperature and volume of the gas is

$$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$$

The equation relating the temperature and pressure of the gas is

$$T_1^{\gamma}P_1^{1-\gamma} = T_2^{\gamma}P_2^{1-\gamma}$$

Where $\gamma = C_P / C_V$ is the ratio of the two specific heat capacities of the gas.

Table 3.1 *Thermodynamic processes*

Sl. No.	*Process*	*Governing equations*	*Heat interaction*	*Displacement work or non flow work during state change from 1 to 2* $W = \int_1^2 p.dV$
1.	Isobaric process	p = constant $\frac{T_2}{T_1} = \frac{V_2}{V_1}$ index $n = 0$	$q = c_p \times (T_2 - T_1)$	$W = p(V_2 - V_1)$
2.	Isochoric process	V = constant $\frac{T_1}{T_2} = \frac{p_1}{p_2}$ index, $n = \infty$	$q = c_v \times (T_2 - T_1)$	$W = 0$
3.	Isothermal process	T = constant $p_1V_1 = p_2V_2$ index, $n = 1$	$q = p_1V_1 \times \ln\left(\frac{V_2}{V_1}\right)$	$W = P_1V_1 \ln \frac{V_2}{V_1}$
4.	Adiabatic process	$p_1V_1^\gamma = p_2V_2^\gamma$ $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$ $\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}}$ index, $n = \gamma$	$q = 0$	$W = \frac{p_1V_1 - p_2V_2}{\gamma - 1}$

3. Worked Problems:

1. A gas at 2 ATP is compressed to half of its original volume. Calculate the final pressure, if the compression is (i) isothermal and (ii) adiabatic (γ = 1.4)

Let V be the original volume

Given; P_1 = 2 atmosphere, V_1 = V and V_2 = ½ V

1) For Isothermal change, the equation is $P_1V_1 = P_2V_2$

$$\therefore P_2 = \frac{P_1V_1}{V_2} = \frac{2 \times V}{(1/2)V} = 4 \text{ atmospheric pressure}$$

ii)Adiabatic equation is $P_1V_1^\gamma = P_2V_2^\gamma$

$$\therefore P_2 = \frac{P_1V_1^\gamma}{V_2^\gamma} = \frac{2 \times V^\gamma}{\left(\frac{V}{2}\right)^\gamma} = \frac{2 \times V^\gamma \times 2^\gamma}{V^\gamma}$$

$$= 2 \times 2^\gamma = 2 \times 2^{1.4}$$

$= 2 \times 2^{1.4} = 5.278$ Atmospheric Pressure.

2. Air at a pressure of 0.75 m of mercury and of volume 1 litre is compressed to a pressure of 1.5 m of mercury under isothermal process. Calculate the resulting volume.

The equation for Isothermal change is $P_1V_1 = P_2V_2$

Given; $P_1 = 0.75$m of Hg

$P_2 = 1.5$m of Hg

$V_1 = 1$ litre

$\therefore V_2 = (P_1V_1)/P_2 = (0.75 \times 1)/1.5 = 0.5$ litre

3. A certain mass of gas at 3 atmosphere is compressed adiabatically to half of its volume. Calculate the resulting pressure if $\gamma = 1.4$

Given; $V_1 = V$, $V_2 = ½ V$ and $P_1 = 3$ At. pr.

$P_2 = P_1V_1^\gamma / V_2^\gamma$

$P_2 = P_1V^\gamma/(½V)^\gamma$

$P_2 = (3 \times V^{1.4})/(½V)^{1.4} = 3 \times 2^{1.4} = 7.92$ At. pr.

Clausius Statement:

It is impossible for a self-acting mechanism working in a cyclic process unaided by an external agency to transfer heat from a body at a lower temperature to the body at a higher temperature. This part of the law is applicable in the case of ice plants and refrigerators. i.e., Heat itself cannot flow from a body at a lower temperature to a body at a higher temperature, on its own.

EXERCISES ON FIRST LAW OF THERMODYNAMIC

1. Nitrogen amounting to 10.5 grams expands isothermally at a temperature of 23^0C from a pressure of $P_1 = 2.5$ atm. Find the work performed by the gas during expansion.
2. One litter of He in standard conditions expands isothermally to a volume of 2 liters at the expense of heat received from a hot source. Find a) the work performed by the gas during expansion, b) the amount of heat received by the gas
3. Upon isothermally expansion of $2m^3$ of a gas its pressure changes from $P_1 = 5$ atm. to $P_2 = 4$ atm.
4. What temperature of air at 0^0C be cooled to expand adiabatically from a volume of V to $V_2 = 2V$
5. Upon the isothermal expansion of 100grams of nitrogen at a temperature of 17^0c. The work performed equal to 860J. How many times did the pressure of nitrogen change upon expansion.
6. Two moles of air at the normal conditions compressed to pressure of 6 atm. Find the volume and temperature after compression if a) the air is compressed isothermally, b) the air is compressed adiabatically. Find the work in each process.

2.2.3 Second law statements

The second law clearly explains that it is impossible to convert heat energy to mechanical energy with 100 per cent efficiency.

Clausius's Statement : It is impossible to construct a device operating in a cycle that can transfer heat from a colder body to a warmer one without consuming any work. Also, energy will not flow spontaneously from a low-temperature object to a higher temperature object.

2nd Law of Thermodynamics:

1. Heat flows spontaneously from a hot body to a cool one.
2. One can not convert hear completely into useful work.
3. Every isolated system becomes disordered in time.

Theoretical learning Activity

The trainees brainstorm about

1) processes done in the cylinders when the oil is burning.

2) relationship between Clausius statement and second law of thermodynamics.

Practical learning Activity

Trainees in pair perform the following activities:

1) In an isobaric process, there is no change in

A) pressure. B) temperature. C) volume. D) internal energy.

2) An ideal gas is compressed to one-half its original volume during an isothermal process. The final pressure of the gas

A) increases to twice its original value. B) increases to less than twice its original value. C) increases to more than twice its original value. D) does not change

3) When the first law of thermodynamics, Q = DU + W, is applied to an ideal gas that is taken through an isothermal process, A) DU = 0 B) W = 0 C) Q = 0

Points to Remember (Take home message)

- ✓ An adiabatic process is one that occurs so rapidly or occurs in a system that is so well insulated that no transfer of energy as heat occurs between the system and its environment
- ✓ An isobaric process is one that takes place at constant pressure
- ✓ Clausius's Statement: It is impossible to construct a device operating in a cycle that can transfer heat from a colder body to a warmer one without consuming any work. Also, energy will not flow spontaneously from a low-temperature object to a higher temperature object.
- ✓ General expression which is combining Celsius, Kelvin and Fahrenheit temperature scales is

$$\frac{T_C}{100} = \frac{T_F - 32}{180} = \frac{T_K - 273.15}{100}$$

Learning out come 2.2 : formative assessment

Multiple choice questions

1. A gas is allowed to expand at constant pressure as heat is added to it. This process is

A) isothermal. B) isochoric. C) isobaric. D) adiabatic

2. In an isochoric process, there is no change in

A) pressure. B) temperature. C) volume. D) internal energy.

3. A gas is confined to a rigid container that cannot expand as heat energy is added to it. This process is A) isothermal. B) isochoric. C) isobaric. D) adiabatic

4. A gas is confined to a rigid container that cannot expand as heat energy is added to it. This process is A) isothermal. B) isochoric. C) isobaric. D) adiabatic.

5. 200 J of work is done in compressing a gas adiabatically. What is the change in internal energy of the gas?

A) zero B) 100 J C) 200 J D) There is not enough information to determine.

6. A heat engine receives 7000 J of heat and loses 3000 J in each cycle. What is the efficiency?

A) 57% B) 30% C) 70% D) 43%

Learning outcome 2.3. Application of thermodynamic laws

Duration: 7 hrs

Learning outcome 2.3 objectives:

By the end of the learning outcome, the trainees will be able to:

1. apply second law of thermodynamics accurately on Refrigerators
2. apply second law of thermodynamics accurately on Heat engines
3. apply second law of thermodynamics accurately on Ventilators

Resources

Equipment	**Tools**	**Materials**
PPE, Whiteboard and chalkboard	Compute, projector, textbooks, scientific calculator, meter ruler, compass	Chalks, Markers

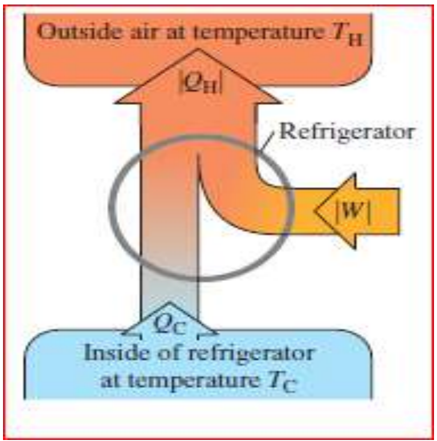
Advance preparation:

. The trainer shows to the trainees refrigerator, water heater and heat pumb where they are available.

2.3.1 Refrigerators

Refrigerators

We can think of a **refrigerator** as a heat engine operating in reverse. A heat engine takes heat from a hot place and gives off heat to a colder place. A refrigerator does the opposite; it takes heat from a cold place (the inside of the refrigerator) and gives it off to a warmer place (usually the air in the room where the refrigerator is located). A heat engine has a net *output* of mechanical work; the refrigerator requires a net *input* of mechanical work.

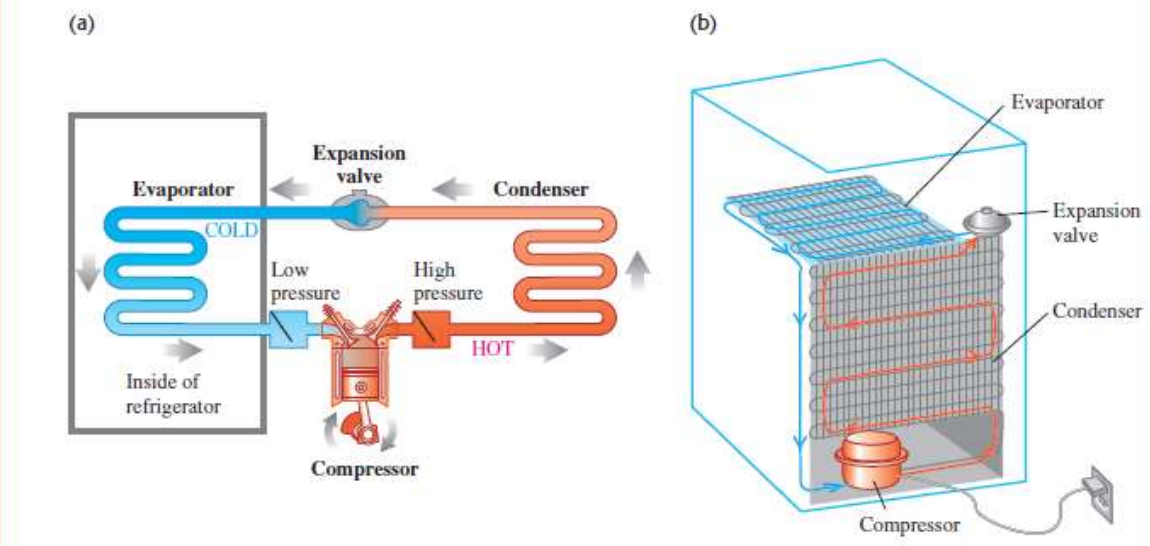


Coefficient of performance of refrigerator is

$$COP = \frac{Q_c}{w} = \frac{|Q_c|}{|Q_H - Q_c|}$$

From an economic point of view, the best refrigeration cycle is one that removes the greatest amount of heat $|Q_c|$ from the inside of the refrigerator for the least expenditure of mechanical work W,

(a) Principle of the mechanical refrigeration cycle. (b) How the key elements are arranged in a practical refrigerator.



The compressor takes in fluid, compresses it adiabatically, and delivers it to the condenser coil at high pressure. The fluid temperature is then higher than that of the air surrounding the condenser, so the refrigerant gives off heat Q_H and partially condenses to liquid. The fluid then expands adiabatically into the evaporator at a rate controlled by the expansion valve. As the fluid expands, it cools considerably, enough that the fluid in the evaporator coil is colder than its surroundings.

2.3.2 Heat engines

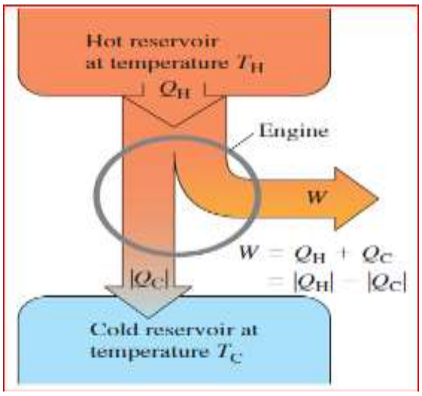
Heat reservoir is the system having very large heat capacity i.e. it is a body capable of absorbing or rejecting finite amount of energy without any appreciable change in its' temperature.

Thus in general it may be considered as a system in which any amount of energy may be dumped or extracted out and there shall be no change in its temperature. Such as *atmosphere* to which large amount of heat can be rejected without measurable change in its temperature. Large river, sea etc. can also be considered as reservoir, as dumping of heat to it shall not cause appreciable change in temperature.

Heat reservoirs can be of two types depending upon nature of heat interaction i.e. heat rejection or heat absorption from it.

Heat reservoir which rejects heat from it is called *source*. While the heat reservoir which absorbs heat is called ***sink.*** Sometimes these heat reservoirs may also be called Thermal Energy Reservoirs (TER).

Heat engine is a device used for converting heat into work. Thus, heat engine may be precisely defined as "a device operating in cycle between high temperature source and low temperature sink and producing work". Heat engine receives heat from source, transforms some portion of heat into work and rejects balance heat to sink. All the processes occurring in heat engine constitute cycle.



Block diagram representation of a heat engine is shown above.

When an engine repeats the same cycle over and over, and represent the quantities of heat absorbed Q_H and Q_c rejected by the engine *during one cycle; Q_H* is positive, and Q_C is negative. The *net* heat *Q* absorbed per cycle is

$$Q = Q_H + Q_c = |Q_H| - |Q_c|$$

The useful output of the engine is the net work *W* done by the working substance.

From the first law,

$$w = Q_H + Q_c = |Q_H| - |Q_c|$$

Efficiency of heat engine

Efficiency of heat engine can be given by the ratio of net work and heat supplied.

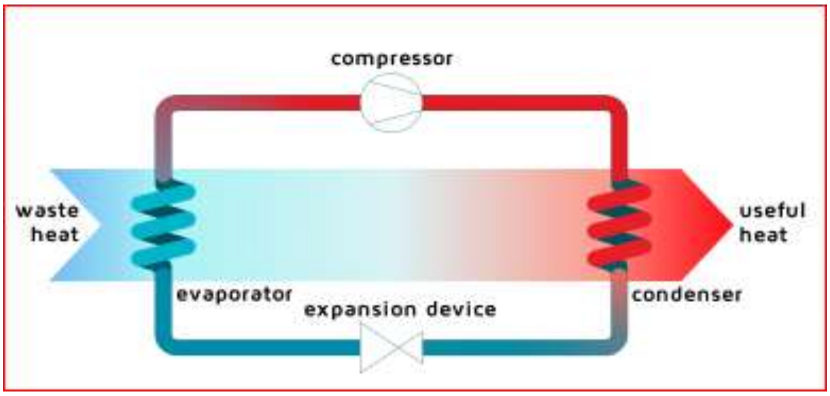
$\eta_{heat-engine} = \frac{W}{Q_1}$, where W is the net work and Q_1 is the heat supplied.

The efficiency can be given as $\eta = \frac{w}{Q_H} = 1 - \frac{Q_c}{Q_H}$, where work is $w = |Q_H| - |Q_c|$

Ideally, we would like to convert *all* the heat Q_H into work; in that case we would have $Q_H = w$ and $Q_c = 0$. Experience shows that this is impossible; there is always some heat wasted, and Q_c *is never zero.*

2.3.3 Heat pumb

A **heat pump** is a device used to warm and sometimes also cool buildings by transferring thermal energy from a cooler space to a warmer space using the refrigeration cycle, being the opposite direction in which **heat transfer** would take place without the application of external power. The heat pump has four main components: evaporator, compressor, condenser and expansion device. In the evaporator heat is extracted from a waste heat source. In the condenser this heat is delivered to the consumer at a higher temperature level. Electric energy is required to drive the compressor and this energy is added to the heat that is available in the condenser. The efficiency of the heat pump is denoted by its COP (coefficient of performance), defined as the ratio of total heat delivered by the heat pump to the amount of electricity needed to drive the heat pump.



Where CP is the coefficient of performance. Q_H is the input heat and W is the work done.

$$CP = \frac{Q_H}{W} = \frac{Q_H}{Q_H - Q_C} \Rightarrow \frac{T_H}{T_H - T_C}$$

Coefficient of Performance for Heat Pumps

$$COP_{hp} = \frac{Heating\ Effect}{Work\ Input}$$

$$COP_{hp} = \frac{Q_H}{W_{net,in}} = \frac{\dot{Q}_H}{\dot{W}_{net,in}}$$

2.3.4 Ventilators Power plant

Wind energy as a clean energy source that has an enormous potential, but in its use is still very small [6]. Small amount of electrical power generation turbo ventilator more efficient as camper to solar panel. There are two different modes of ventilation techniques. Passive Ventilation Technique 2. Active Ventilation Technique Turbo ventilators are Active ventilators .This ventilator works on natural wind energy. A turbo ventilator consists of number of vertical blades in a spherical array mounted on a frame. At the center, a shaft is supported by upper and lower bearings. A rainproof dome is provided on top of the frame of turbo ventilator. When wind blows on the blades the resulting lift and drag forces cause the turbine to rotate Due to this rotation, produces a negative Pressure at the center of the turbine ventilator which extracts hot air.

Theoretical learning Activity

In pair, the trainees perform the following tasks;

- ✓ In group, the trainees discuss about open and closed system and give some examples on each system.
- ✓ In group, the trainees discuss on 4 stages of Carnot cycle by relating each stage with second law of thermodynamics.
- ✓ In group, the trainees discuss about the differences between heat pump and refrigerator.

Practical learning Activity

Trainees in pair perform the following activities:

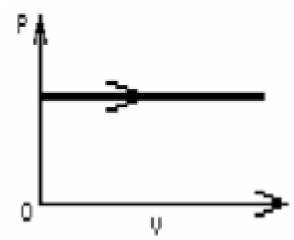
- ✓ Suppose you have an ideal refrigerator that cools an environment at -20^{0}C and has heat transfer to another environment at 50^{0}C. What is its coefficient of performance.
- ✓ In a very wild winter climate, a heat pump has heat transfer from an environment at 5^{0}C to one at 35^{0}C. What is the best possible coefficient of performance for these temperature?
- ✓ Suppose you want to operate an ideal refrigerator with a cold temperature of -10^{0}C and you could like it to have a coefficient of performance of 7. What is the hot reservoir temperature for such a refrigerator?
- ✓ An ideal heat pump is being considered for use in heating an environment with a temperature of 22^{0}C. What is the cold reservoir temperature if the pump is to have a coefficient of performance of 12.

Points to Remember (Take home message)

- **System** : a set of things working together as parts of a mechanism or an interconnecting network; a complex whole..
- Surrounding : The surroundings are everything outside the system and are the place where the observation and measurements of the system are taken.
- **Clausius Statement:** It is impossible for a self-acting mechanism working in a cyclic process unaided by an external agency to transfer heat from a body at a lower temperature to the body at a higher temperature.
- Applications of refrigerator as uses second law of thermodynamics by applying work in order to get coldness as output.
- Applications of heat pump as uses second law of thermodynamics by applying work in order to get hotness as output.

Formative assessment of learning outcome 2.3.

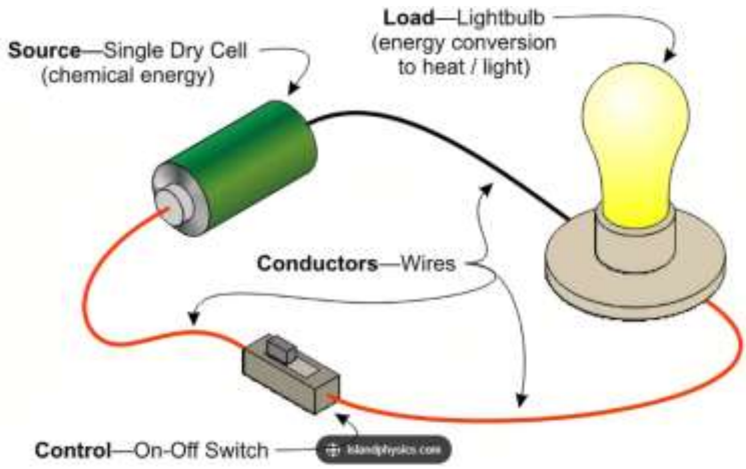
- A gas is expanded to twice its original volume with no change in its temperature. This process is A) isothermal. B) isochoric. C) isobaric. D) adiabatic.
- An ideal gas is compressed isothermally from 30 L to 20 L. During this process, 6.0 J of energy is expended by the external mechanism that compressed the gas. What is the change of internal energy for this gas?
- An ideal gas is compressed to one-half its original volume during an isothermal process. The final pressure of the gas A) increases to twice its original value. B) increases to less than twice its original value. C) increases to more than twice its original value. D) does not change.
- When the first law of thermodynamics, $Q = \Delta U + W$, is applied to an ideal gas that is taken through an adiabatic process, A) $\Delta U = 0$. B) $W = 0$. C) $Q = 0$. D) none of the above
- The process shown on the PV diagram is an



A) adiabatic expansion. B) isothermal expansion. C) isometric expansion.
D) isobaric expansion

Learning Unit 3: Examine effects of electric current flow in DC electric circuit

Picture/s reflecting the Learning unit 3



STRUCTURE OF LEARNING UNIT

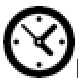
Learning outcomes:

3.1. Simple electric circuit is properly described based on ohm's law

3.2. Electric current, resistances and voltages in DC electric circuits are accurately determined based on Kirchhoff's laws

3.3. Electric energy, work or power in DC electric circuit are correctly determined in accordance with the law of conservation of energy.

Learning outcome 3.1. Simple electric circuit based on ohm's law

**Duration: 7 hrs**

Learning outcome 3.1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. state correctly the elements of simple electric circuit in DC
2. use properly the instrument of measuring voltage
3. use properly the instrument of measuring current

Resources

Equipment	Tools	Materials
PPE, whiteboard, chalkboard, optical benc, optical slides, computer, projector, textbooks	Compute, projector, textbooks, scientific calculator.	Chalks, Markers, cables, switch, bulbs, bulb holders and cells

Advance preparation:

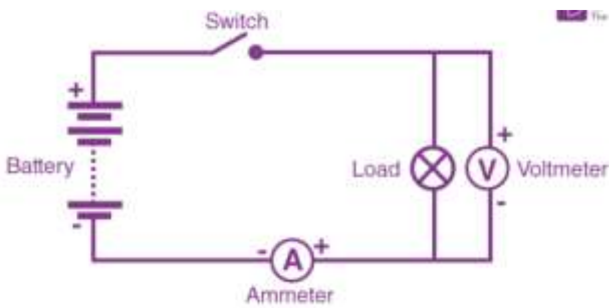
. Trainer shows to the trainees voltmeter, ammeter and power supply

3.1.1 DC electric circuit

Elements of DC electric circuit

Direct current (DC) and alternating current (AC) are the two main types of electricity. DC circuit and AC circuit show the structure of the respective circuit systems.

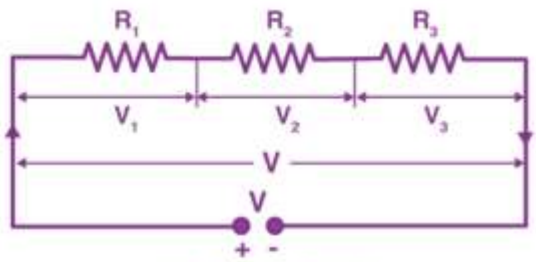
Elements of a DC circuit are mainly resistive, which contains a DC battery, a switch, ammeter, voltmeter, a load lamp and connecting leads.



Every electrical circuit can be classified into three groups – series, series-parallel and parallel. Thus, DC circuits can be divided into three categories: series DC circuit, series and parallel DC circuit, and parallel DC circuit.

Series DC Circuit

When components are connected end to end, they are called a series circuit. In series DC circuits, resistive elements are connected in an end to end way, creating a linear path for flowing current.



DC Series Circuit

The total effective resistance is equal to the sum of all individual resistances.

In these types of circuits, the entire system is controlled by a single switch. We cannot individually control each section of the circuit.

Then

$$V = V_1 + V_2 + V_3$$
$$V = IR_1 + IR_2 + IR_3$$

If R is the total circuit resistance, then

$$IR = IR_1 + IR_2 + IR_3$$
$$R = R_1 + R_2 + R_3$$

When numerous electrical elements are attached in series, current propagates through all the circuit elements. Effective voltage over a series DC circuit is always directly proportional to its effective resistance value.

The applied voltage over a series circuit is equivalent to the aggregate total of voltage drops over each element.

Examples:

Multiple choice questions

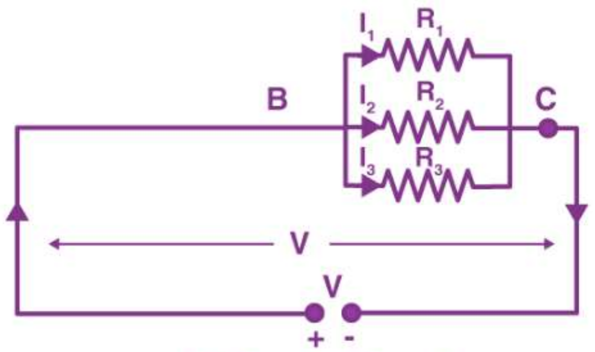
1. The potential difference between the terminals of a battery, when no current flows to an external circuit, is referred to as the **A) emf.** B) terminal voltage.

2. Between the terminals of a battery, when current flows to an external circuit, is referred to as the A) emf. **B) terminal voltage.**
3. Four 20-W resistors are connected in series. What is the equivalent resistance?
4. **A) 80 W** B) 20 W C) 10 W D) 5.0 W

Parallel DC Circuit

When multiple electrical components are attached in parallel, one end of each element is attached to a common point, and the other end is attached to a different common point. Here one end of all resistors are connected to a common point, and the remaining ends are connected to another common point (current flows through them).

All the components will have an equal voltage drop over them, and it will be equivalent to the voltage between the two common joints where the components are joined.



DC Parallel Circuit

In the above circuit diagram, resistors R_1, R_2 and R_3 are joined in parallel over a V voltage supply. I_1, I_2, and I_3 are the currents flowing through them.

The total current flowing through the circuit is

$$I = I_1 + I_2 + I_3$$

$$I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

Then total electrical resistance R,

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{\mathrm{R_{parallel}}} = \frac{1}{\mathrm{R1}} + \frac{1}{\mathrm{R2}} + \frac{1}{\mathrm{R3}}$$

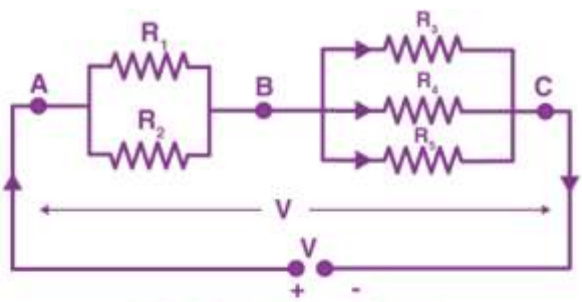
- Voltage drops are equal over all the components attached in parallel.
- Current through separate components attached in parallel is inversely proportional to their resistances.
- The total effective circuit current is the total sum of the currents flowing through individual elements attached in parallel.

Examples:

1. When two or more resistors are connected in parallel to a battery,
 A) the voltage across each resistor is the same. B) the total current flowing from the battery equals the sum of the currents flowing through each resistor. C) the equivalent resistance of the combination is less than the resistance of any one of the resistors. **D) all of the given answers**
2. When resistors are connected in parallel, we can be certain that A) the same current flows in each one. **B) the potential difference across each is the same.**
 C) the power dissipated in each is the same. D) their equivalent resistance is greater than the resistance of any one of the individual resistances.
3. Three identical resistors are connected in parallel to a 12-V battery. What is the voltage of any one of the resistors? A) 36 V **B) 12 V** C) 4 V D) zero
4. Three identical resistors are connected in parallel to a battery. If the current of 12 A flows from the battery, how much current flows through any one of the resistors? A) 12 A **B) 4 A** C) 36 A D) zero
5. As more resistors are added in parallel to a constant voltage source, the power supplied by the source A) increases. **B) decreases** C) does not change.
 D) increases for a time and then starts to decrease.

Series-Parallel DC Circuit

In reality, electrical circuits are usually a combination of both series and parallel DC circuits. These complex circuits are solved using Ohm's Law and rules for parallel and series DC circuits.



DC Series Parallel Circuit

In the above circuit diagram, resistors R_1 and R_2 are joined parallel over the terminal AB. Resistor R_3, R_4, and R_6 are attached in parallel with each other over the terminal BC.

The two batches of resistors RAB and RBC are joined in series with each other over the source voltage V. The effective total resistance of the entire circuit can be calculated as given below,

$$\frac{1}{R_{AB}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{R_1+R_2}{R_1R_2}$$

$$R_{AB} = \frac{R_1R_2}{R_1} + R_2$$

$$\frac{1}{R_{BC}} = \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} = \frac{R_3R_4+R_4R_5+R_5R_3}{R_3R_4R_5}$$

$$R_{BC} = \frac{R_3R4R_5}{R_3R_4+R_4R_5+R_5R_3}$$

The effective total resistance of the circuit

$$R = R_{AB} + R_{BC}$$

Exercises

6. Four resistors of 12, 3.0, 5.0, and 4.0 W are connected in series. A 12-V battery is connected to the combination. What is the current through the battery? A) 0.50 A B) 1.0 A C) 1.5 A D) 2.0 A
7. Three resistors of 12, 12, and 6.0 W are connected in series. A 12-V battery is connected to the combination. What is the current through the battery? A) 0.10 A B) 0.20 A C) 0.30 A D) 0.40 A
8. When resistors are connected in series, A) the same power is dissipated in each one. B) the potential difference across each is the same. C) the current flowing in each is the same. D) More than one of the given answers is true.
9. Three identical resistors are connected in series to a battery. If the current of 12 A flows from the battery, how much current flows through any one of the resistors? A) 12 A B) 4 A C) 36 A D) zero

Electric current

Direct current refers to the unidirectional propagation of electric charge. It is commonly used in batteries and solar cells. Thomas Edison invented DC current, which allowed him to power numerous complex electrical systems.

Any flow of charge such as this is called an electric current. More precisely, the electric current in a wire is defined as the net amount of charge that passes through the wire's full cross section at any point per unit time. Thus, the current I is defined the amount of charge that passes through the conductor at any location during the time interval Δt.

$$I = \frac{\Delta Q}{\Delta t},$$

Electric current is measured in coulombs per second.

Example: A steady current of 2.5 A exists in a wire for 4.0 min. (a) How much total charge passes by a given point in the circuit during those 4.0 min? (b) How many electrons would this be?

Solution: Since the current was 2.5 A, or then in 4.0 min the total charge that flowed past a given point in the wire.

$$\Delta Q = I\,\Delta t = (2.5\ \text{C/s})(240\ \text{s}) = 600\ \text{C}.$$

(*b*) The charge on one electron is 1.60×10^{-19} C, so 600 C would consist of

$$\frac{600\ \text{C}}{1.6 \times 10^{-19}\ \text{C/electron}} = 3.8 \times 10^{21}\ \text{electrons}.$$

3.1.2 Measuring instruments used in DC electric circuit

Ammeter

Voltmeters

As the name suggests, **voltmeter** is a measuring instrument which measures the voltage across any two points of an electric circuit. The units of voltage are volt and the measuring instrument is meter. Hence, the word "voltmeter" is obtained by combining the two words **"volt"** and **"meter"**

Ohmmeter

Ammeter is a measuring instrument which measures the current flowing through any two points of an electric circuit. The unit of current is ampere and the measuring instrument is meter. The word “ammeter” is obtained by combining **“am”** of ampere with **“meter”**.

Theoretical learning Activity

- ✓ In group, the trainees discuss about how the current changes when resistances are connected in series.
- ✓ In group, the trainees discuss about how the current changes when resistances are connected in parallel.
- ✓ In group, the trainees discuss how the ammeter and voltmeter are connected in circuit.

Practical learning Activity

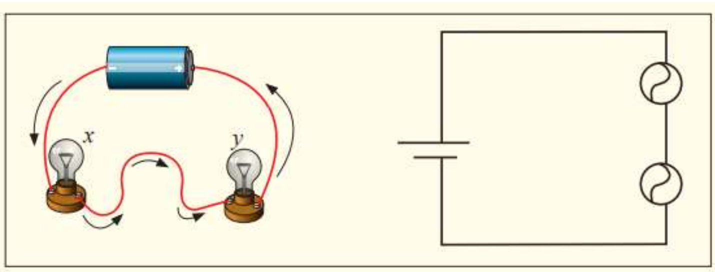
- ✓ Trainees in pair perform

Materials: * 1 Battery . * 3 Bulbs. * 3 bulb holders . * Assembled battery holder.

* 4 Pieces of copper wire (as needed).

1. Construct a complete circuit with a battery and a bulb.

2. Using another wire, add a second bulb as shown on the picture below.



3. What did you notice happened to the first bulb when the second bulb was added?

Look carefully at how the series circuit is set up. Write a prediction of what you think will happen if you unscrew one of the bulbs.

4. Why did you make this prediction?

5. Unscrew bulb “X”. Describe what happens to bulb “Y”.

6. Tighten bulb “X”, and unscrew bulb “Y”. Describe what happens to bulb “X”.

7. Add a third bulb to your series circuit. What happens to the brightness of the bulbs each time another bulb is added to the series?

8. Add a third bulb to your series circuit. What happens to the brightness of the bulbs each time another bulb is added to the series?

9. Draw a schematic diagram of the circuit you constructed with three bulbs.

Points to Remember (Take home message)

- ✓ Elements of a DC circuit are mainly resistive, which contains a DC battery, a switch, ammeter, voltmeter, a load lamp and connecting leads.
- ✓ When components are connected end to end, they are called a series circuit.
- ✓ Voltage drops are equal over all the components attached in parallel.
- ✓ Electric current is measured in coulombs per second.
- ✓ As the name suggests, **voltmeter** is a measuring instrument which measures the voltage across any two points of an electric circuit.
- ✓ **voltmeter** is a measuring instrument which measures the voltage across any two points of an electric circuit.
- ✓

Multiple choice questions :

1) A 14-A current flows into a series combination of a 3.0-W and a 4.0-W resistor. What is the voltage drop across the 4.0-W resistor?

A) 38 V B) 42 V C) 56 V D) 98 V

2) A 14-A current flows into a series combination of a 3.0-W and a 4.0-W resistor. What is the voltage drop across the 3.0-W resistor?

A) 42 V B) 56 V C) 98 V D) 38 V

3) A 22-A current flows into a parallel combination of 4.0 W, 6.0 W, and 12 W resistors. What current flows through the 12-W resistor?

A) 18 A B) 11 A C) 7.3 A D) 3.7 A

4) A 22-A current flows into a parallel combination of a 4.0-W, 6.0-W, and 12-W resistors. What current flows through the 6.0-W resistor?

A) 18 A B) 11 A C) 7.3 A D) 3.7 A

5) A 22-A current flows into a parallel combination of a 4.0-W, 6.0-W, and 12-W resistor. What current flows through the 4.0-W resistor?

A) 18 A B) 11 A C) 7.3 A D) 3.7 A

Learning outcome 3.2. Determination of electric current, resistance and voltage in DC electric circuit

Duration: 7 hrs

Learning outcome 3.2 objectives:

By the end of the learning outcome, the trainees will be able to:

1. state the junction rule and loop rule
2. use appropriately the conventional signs for closed loop
3. apply correctly the junction and loop rules

Resources

Equipment	Tools	Materials

PPE, whiteboard, chalkboard, optical benc, optical slides, computer, projector, textbooks	Compute, projector, textbooks, scientific calculator.	Chalks, Markers, cables, switch, bulbs, bulb holders and cells

Advance preparation:

. Trainer shows to the trainees a junction of wires

3. 2. 1 . Key concepts

An **electrical circuit** consists of batteries, resistors, switches. An electrical network consists of a closed loop. A circuit is a closed path where electrons flow in a wire.

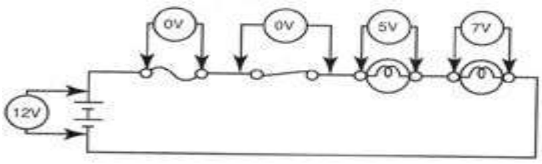
Furthermore, the amount of current (amps) a circuit carries is dependent on the power and number of electrical devices whose connection is to the circuit.

Loops in Electric Circuit

An electric circuit has numbers of nodes. If one starts from one node and after going through a set of nodes returns to same starting node without crossing any of the intermediate node twice, he has travels through one **loop** of the circuit.

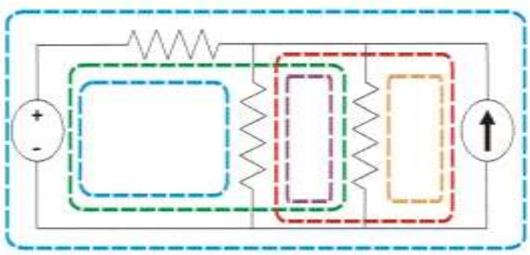
Voltage drop

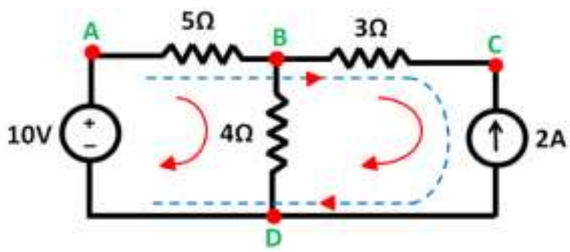
Voltage drop is simply the arithmetical difference between a higher voltage and a lower one.



Voltage gain

Example: In the case of Signal amplifier, operational amplifier, **audio amplifier**, the **'Voltage Gain'** term is used because they work on the principle of voltage amplifying.

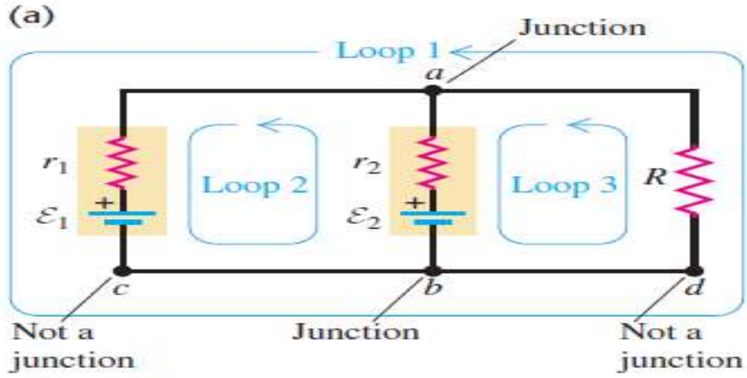




A MESH: A mesh is a closed path in the circuit, which does not contain any other close path inside it.

Note: All Mesh are loops but not all the loops are Mesh.

A **junction** in a circuit is a point where three or more conductors meet. A **loop** is any closed conducting path.



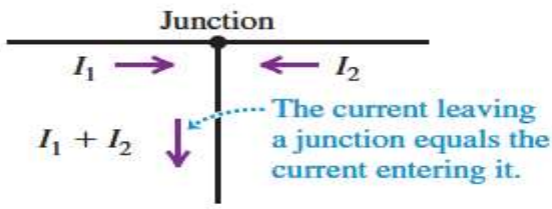
Kirchhoff's rules are the following two statements:
Kirchhoff's junction rule: The algebraic sum of the currents into any junction is zero. That is,

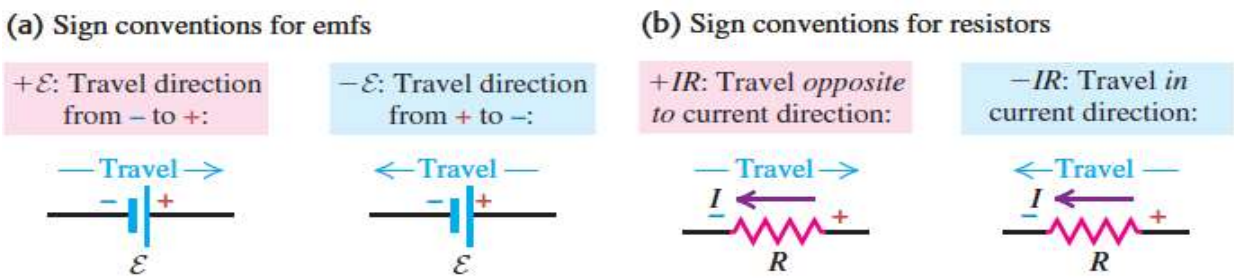
$$\sum I = 0 \qquad \text{(junction rule, valid at any junction)}$$

Kirchhoff's loop rule: The algebraic sum of the potential differences in any loop, including those associated with emfs and those of resistive elements, must equal zero. That is,

$$\sum V = 0 \qquad \text{(loop rule, valid for any closed loop)}$$

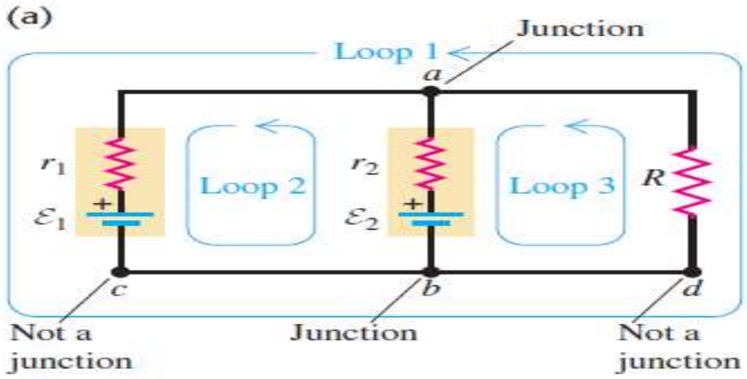
(a) Kirchhoff's junction rule





1.2.1 Kirchoff's laws

A **junction** in a circuit is a point where three or more conductors meet. A **loop** is any closed conducting path.



Kirchhoff's rules are the following two statements:

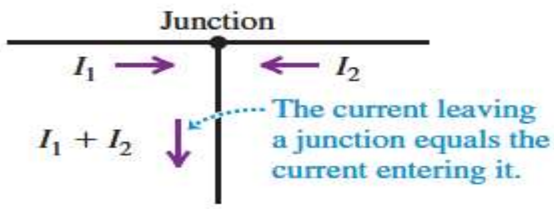
Kirchhoff's junction rule: The algebraic sum of the currents into any junction is zero. That is,

$$\sum I = 0 \qquad \text{(junction rule, valid at any junction)}$$

Kirchhoff's loop rule: The algebraic sum of the potential differences in any loop, including those associated with emfs and those of resistive elements, must equal zero. That is,

$$\sum V = 0 \qquad \text{(loop rule, valid for any closed loop)}$$

(a) Kirchhoff's junction rule



3.2.2 Analyze circuit using Kirchoff's laws

EXAMPLE 1:

The circuit shown in Fig. 10a contains two batteries, each with an emf and an internal resistance, and two resistors. Find (a) the current in the circuit, (b) the potential difference V_{ab} and (c) the power output of the emf of each battery.

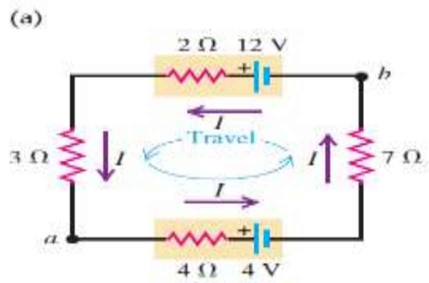


Fig. 3.2.3. 1

SOLUTION:

(a) Starting at a and traveling counterclockwise with the current, we add potential increases and decreases and equate the
sum to zero as in Eq. (6):

$$-I(4\ \Omega) - 4\ \text{V} - I(7\ \Omega) + 12\ \text{V} - I(2\ \Omega) - I(3\ \Omega) = 0$$

Collecting like terms and solving for I, we find

$$8\ \text{V} = I(16\ \Omega) \quad \text{and} \quad I = 0.5\ \text{A}$$

(b) To find the potential V_{ab} at a with respect to b, we start at b and add potential changes as we go toward a. There are two paths from b to a; taking the lower one, we find

$$V_{ab} = (0.5\ \text{A})(7\ \Omega) + 4\ \text{V} + (0.5\ \text{A})(4\ \Omega)$$
$$= 9.5\ \text{V}$$

Point a is at 9.5 V higher potential than b. All the terms in this sum, including the IR terms, are positive because each represents an increase in potential as we go from b to a. Taking the upper path, we find

(c) The power outputs of the emf of the 12-V and 4-V batteries are

$$P_{12V} = \mathcal{E}I = (12\ \text{V})(0.5\ \text{A}) = 6\ \text{W}$$
$$P_{4V} = \mathcal{E}I = (-4\ \text{V})(0.5\ \text{A}) = -2\ \text{W}$$

$$V_{ab} = 12\ \text{V} - (0.5\ \text{A})(2\ \Omega) - (0.5\ \text{A})(3\ \Omega)$$
$$= 9.5\ \text{V}$$

EXAMPLE 2:

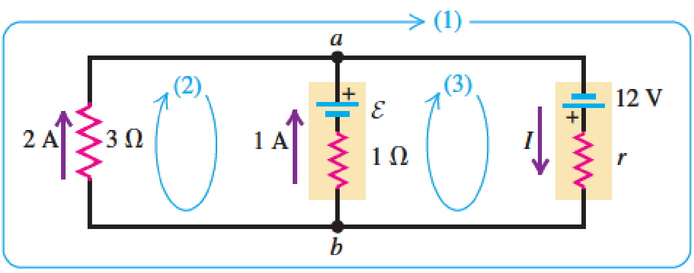


Fig. 3.2.3. 2

We apply the junction rule, to point a:

$$-I + 1\text{ A} + 2\text{ A} = 0 \qquad \text{so} \qquad I = 3\text{ A}$$

To determine r, we apply the loop rule, Eq. (6), to the large, outer loop (1):

$$12\text{ V} - (3\text{ A})r - (2\text{ A})(3\ \Omega) = 0 \qquad \text{so} \qquad r = 2\ \Omega$$

To determine $\mathcal{E}$, we apply the loop rule to the left-hand loop (2):

$$-\mathcal{E} + (1\text{ A})(1\ \Omega) - (2\text{ A})(3\ \Omega) = 0 \qquad \text{so} \qquad \mathcal{E} = -5\text{ V}$$

The negative value for $\mathcal{E}$ shows that the actual polarity of this emf is opposite to that shown in Fig. 11. As in Example 3, the battery is being recharged.

EVALUATE: Try applying the junction rule at point b instead of point a, and try applying the loop rule by traveling counterclockwise rather than clockwise around loop (1). You'll get the same results for I and r. We can check our result for $\mathcal{E}$ by using the right-hand loop (3):

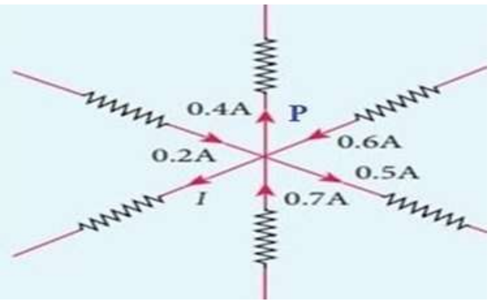
$$12\text{ V} - (3\text{ A})(2\ \Omega) - (1\text{ A})(1\ \Omega) + \mathcal{E} = 0$$

which again gives us $\mathcal{E} = -5$ V.

As an additional check, we note that $V_{ba} = V_b - V_a$ equals the voltage across the 3-Ω resistance, which is $(2\text{ A})(3\ \Omega) = 6$ V. Going from a to b by the top branch, we encounter potential differences $+12\text{ V} - (3\text{ A})(2\ \Omega) = +6$ V, and going by the middle branch, we find $-(-5\text{ V}) + (1\text{ A})(1\ \Omega) = +6$ V. The three ways of getting V_{ba} give the same results.

Theoretical learning Activity

1. From the given circuit in the below image, find the value of *I*?



2. Determine the current in the 7-W resistor.

A) 0.28 A B) 1.3 A C) 1.6 A D) 2.1 A

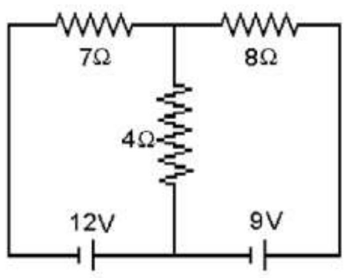


Fig. 3.2.3. 3

3. Determine the current in the 8-W resistor in Fig. 3.2.3. 4

A) 0.28 A **B) 1.3 A** **C) 1.6 A** **D) 2.1 A**

4. Determine the current in the 4-W resistor in Fig. 3.2.3. 5

A) 0.28 A B) 1.3 A C) 1.6 A D) 2.1 A

Points to Remember (Take home message)

- ✓ A mesh is a closed path in the circuit, which does not contain any other close path inside it.
- ✓ A **junction** in a circuit is a point where three or more conductors meet. A **loop** is any closed conducting.
- ✓ **Kirchhoff's junction rule:** The algebraic sum of the currents into any junction is zero.
- ✓ **Kirchhoff's loop rule:** The algebraic sum of the potential differences in any loop, including those associated with emfs and those of resistive elements, must equal zero.

1. Which of the equations here is valid for the circuit shown?

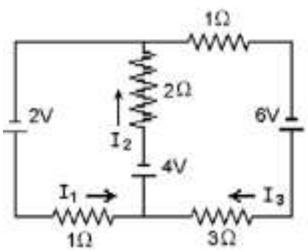
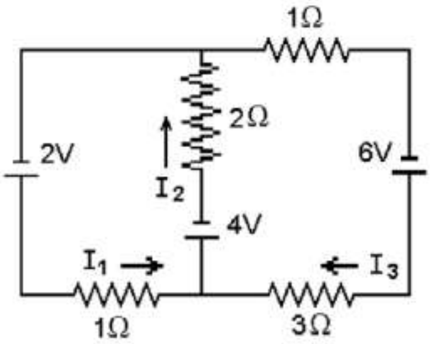


Fig. 3.2.3. 6

A) $2 - I_1 - 2I_2 = 0$ B) $2 - 2I_1 - 2I_2 - 4I_3 = 0$ C) $4 - I_1 + 4I_3 = 0$ D) $-2 - I_1 - 2I_2 = 0$

B) E) $6 - I_1 - 2I_2 = 0$

2. Kirchhoff's junction rule is an example of A) conservation of energy. B) conservation of charge. C) conservation of momentum. D) none of the given answers
3. Kirchhoff's loop rule is an example of A) conservation of energy. B) conservation of charge. C) conservation of momentum. D) none of the given answers
4. . Which of the equations here is valid for the circuit shown?

- 

- **Fig. 3.2.3. 7**

- A) $2 - I_1 - 2I_2 = 0$
- B) $2 - 2I_1 - 2I_2 - 4I_3 = 0$
- C) $4 - I_1 + 4I_3 = 0$
- D) $-2 - I_1 - 2I_2 = 0$
- E) $6 - I_1 - 2I_2 = 0$

Learning outcome 3.3. Determination of electric energy, work and power in DC electric circuit

Duration: 6 hrs

Learning outcome 3.3 objectives:

By the end of the learning outcome, the trainees will be able to:

1. compute correctly the power dissipated in a given load

2. computer correctly the energy dissipated in a given load

Resources

Equipment	Tools	Materials

PPE, whiteboard, chalkboard, optical benc, optical slides, computer, projector, textbooks	Compute, projector, textbooks, scientific calculator.	Chalks, Markers, cables, switch, bulbs, bulb holders and cells
Advance preparation: . Trainer shows to the trainees a load (different types of resistance)		

Force is any interaction that changes the motion of an object. A push or pull.

$$F = m\,a.$$

The general definition of *work* is "force acting through a distance" or

W = F. d, In electric field notation, W = q E.d

Energy is "the ability to do work." When an object has energy, it has the ability to do work.

Electrical Energy is the ability of an electrical circuit to produce work by creating an action. This action can take many forms, such as thermal, electromagnetic, mechanical, electrical, etc. *Electrical energy* can be both created from batteries, generators, dynamos, and photovoltaic, etc. and stored for future use using fuel cells, batteries, capacitors or magnetic fields, etc. Thus electrical energy can be either created or stored.

Electric power is the rate, per unit time, at which **electrical** energy is transferred by an **electric** circuit. The SI unit of **power** is the watt, one joule per second. **Electric power** is usually produced by **electric** generators, but can also be supplied by sources such as **electric** batteries.

Law of conservation of energy

Total energy is constant in any process. It may change in form or be transferred from one system to another, but the total remains the same.

Transformation of energy

The transformation of energy from one form into others is happening all the time. The chemical energy in food is converted into thermal energy through metabolism; light energy is converted into chemical energy through photosynthesis. In a larger example, the chemical energy contained in coal is converted into thermal energy as it burns to turn water into steam in a boiler. This thermal energy in the steam in turn is converted to mechanical energy as it spins a turbine, which is connected to a generator to produce electrical energy. (In all of these examples, not all of the initial energy is converted into the forms mentioned. This important point is discussed later in this section.)

Power calculation

Three expressions for electric power are listed together here for convenience:

$P = IV$

$P = \frac{V^2}{R}$

$P = I^2R$

Example 2 If a current of 30 A flows through a resistor to which a voltage of 100 V is applied, what power is dissipated in the resistor?

From $P = VI$ and the given data

$$P = 100\,\text{V} \times 30\,\text{A} = 3,000\,\text{W} \quad (\text{or } 3\,\text{kW.})$$

There are other ways of writing the power $P = VI$.

Quiz As well as $P = VI$, which of the equations below also describes the power dissipated by an electrical circuit? (*Hint*: use Ohm's law.)

(a) $P = \frac{I^2}{R}$ (b) $P = I^2R$ (c) $P = \frac{R}{V^2}$ (d) $P = V^2R$

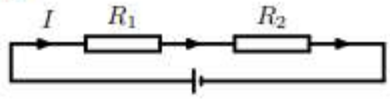
Quiz What is the power consumption of a $100\,\Omega$ resistor if a 50 mA current flows through it?

(a) 0.25W (b) 2.5×10^6W (c) 2.5×10^4W (d) 5×10^5W

From Ohm's law, there are three equivalent expressions for the power dissipation in a circuit:

$$P = VI, \qquad P = \frac{V^2}{R}, \qquad P = I^2R$$

In a **series circuit**:



the same current flows through each resistor. Hence in the diagram the power dissipated in them are

$$P_1 = I^2 R_1 , \quad \text{and } P_2 = I^2 R_2 ,$$

respectively and the total power dissipated is

$$P_T = I^2 (R_1 + R_2) ,$$

By Ohm's law the voltage source is $V = I(R_1 + R_2)$, the power can also be written as $P_T = \dfrac{V^2}{R_1 + R_2}$.

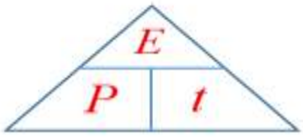
Energy calculation

Electrical Energy

The following formula gives the relationship between Electrical Energy and Power

$$E = Pt$$

$$P = \frac{E}{t}$$



E = Energy in Joules (J)
P = Power in Watts (W)
t = Time in Seconds (s)

E = I × V × t

where:

E is the energy transferred in joules, J

I is the current in amperes, A

V is the potential differences in volts, V

t is the time in seconds, s

Examples:

1. As more resistors are added in parallel to a constant voltage source, the power supplied by the source A) increases. B) decreases. C) does not change. D) increases for a time and then starts to decrease. **Answer: A**

Effects associated with electric current in a circuit

When current flows in a circuit it exhibits various effects. The main effects are heating, chemical and magnetic effects.

Joule effect

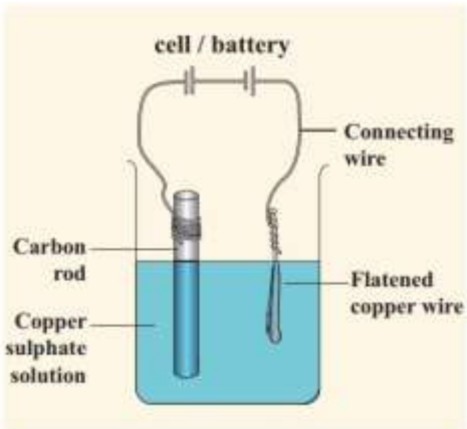
The **electric current circulating in a conductive material causes power loss** (the Joule effect) in the form of heat generation. If electricity circulates in an electrical conductor, a part of the kinetic energy of the electrons is transformed into heat, raising the temperature of the conductor. Part of the electrical power supplied is converted into thermal energy, which is dissipated as heat. Therefore, the heat produced is wasted energy and, consequently, a decrease in its efficiency.

Work done = Heat = $I^2 R t$ … Joules

Heating effect

When the flow of current is 'resisted' generally heat is produced. is is because the electrons while moving in the wire or resistor su er resistance. Work has to be done to overcome the resistance which is converted in to heat energy. **The conversion of electrical energy in to heating energy is called 'Joule heating'** as this effect was extensively studied by the scientist Joule. is forms the principle of all electric heating appliances like iron box, water heater, toaster etc. Even connecting wires o er a small resistance to the flow of current. at is why almost all electrical appliances including the connecting wires feel warm when used in an electric circuit.

Chemical effect



So far we have come across the cases in which only the electrons can conduct electricity. But, here when current passes through electrolyte like copper sulphate solution, both the electron and the positive copper ion conduct electricity. **The process of conduction of electric current through solutions is called 'electrolysis'. The solution through which the electricity passes is called 'electrolyte'.** The positive terminal inserted in to the solution is called 'anode' and the negative terminal 'cathode'. In the above experiment, copper wire is anode and carbon rod is cathode.

Magnetic effect of Electricity

A wire or a conductor carrying current develops a magnetic field perpendicular to the direction of the flow of current. It is called magnetic effect of current. The discovery of the scientist Oersted and the 'right hand thumb rule' are detailed in the chapter on Magnetism and Electromagnetism in this book.

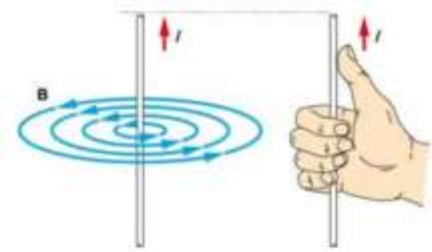


Figure 2.18 Direction of current and magnetic field

Direction of current is shown by the right hand thumb and the direction of magnetic field is shown by other fingers of the same right hand.

Theoretical learning Activity

- ✓ In group, the trainees put the iron filling on the paper and then dispose the wire conducting electric current in order to observe how magnetic effect causes the metal to attract the powder of metals.
- ✓ In group, the trainees connect the solenoid of any number of turns on the 12 V of Dc electric current and then put the iron inside the metal then after observe what is happening.

Practical learning Activity

Trainees in pair perform the following activities

- ✓ The potential difference between the terminals of a battery, when current flows to an external circuit, is referred to as the A) emf. B) terminal voltage.
- ✓ When two or more resistors are connected in series to a battery A) the total voltage across the combination is the algebraic sum of the voltages across the individual resistors. B) the same current flows through each resistor. C) the equivalent resistance of the combination is equal to the sum of the resistances of each resistor. D) all of the given answers
- ✓ When resistors are connected in series, A) the same power is dissipated in each one. B) the potential difference across each is the same. C) the current flowing in each is the same. D) More than one of the given answers is true

- ✓ Three resistors of 12, 12, and 6.0 Ω are connected in series. A 12-V battery is connected to the combination. What is the current through the battery?

  A) 0.10 A B) 0.20 A C) 0.30 A D) 0.40 A

- ✓ If you connect two identical storage batteries together in series ("+" to "-" to "-" to "+"), and place them in a circuit, the combination will provide

  A) zero volts.

  B) twice the voltage, and different currents will flow through each.

  C) twice the voltage, and the same current will flow through each.

  D) the same voltage, and different currents will flow through each.

- ✓ If you connect two identical storage batteries together in series ("+" to "-" to "+" to "-"), and place them in a circuit, the combination will provide

  A) zero volts.

  B) twice the voltage, and different currents will flow through each.

  C) twice the voltage, and the same current will flow through each.

  D) the same voltage, and different currents will flow through each.

Points to Remember (Take home message)

- ✓ **Electrical Energy** is the ability of an electrical circuit to produce work by creating an action.
  - Electric energy is given as $E = P \times t$
- ✓ **Electric power** is the rate, per unit time, at which **electrical** energy is transferred by an **electric** circuit.
  - Electric Power is given as $P = I V$
- ✓ **Law of conservation of energy**
  - Total energy is constant in any process. It may change in form or be transferred from one system to another.

Learning Unit 4: Apply optic instruments

Picture/s reflecting the Learning unit 4


STRUCTURE OF LEARNING UNIT 4

Learning outcomes:

4.1. Optical instruments are effectively described on its corresponding types
4.2. Magnification of optical instruments is correctly determined in accordance to the image location
4.3.Optical aberration are effectively corrected based on the types of aberrations

Learning outcome 4.1. Optical instruments are effectively described on its corresponding types

Duration: 4 hrs

Learning outcome 4.1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Single lens optical instruments

2. Multi-lens optical instruments

Resources

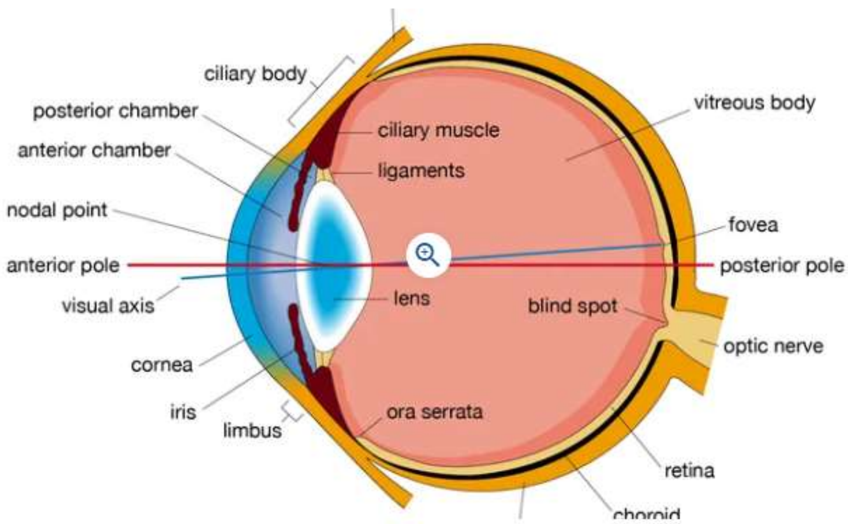
Equipment	Tools	Materials

PPE, whiteboard, chalkboard, optical benc, optical slides, computer, projector, textbooks	Compute, projector, textbooks, scientific calculator	Chalks, Markers, Candles, Water
Advance preparation: . A trainer shows a microscope . A shows the magnifying glasses of different focal lengths		

4.1.1 Single lens optical instrument

The Human Eye and Vision

The eye is a biological instrument used to see objects at different distances. It uses a convex lens system to form a small, inverted, real image of an object infront of it.



The Retina and the Optic Nerve

The coating on the interior back of the eye is called the **retina**. When light strikes the retina, two types of cells are activated. **Rods** detect light and dark and help form images under dim conditions. **Cones** are responsible for color vision. The three types of cones are called red, green, and blue, but each actually detects a range of wavelengths and not these specific colors. When you focus clearly on an object, light strikes a region called the **fovea**. The fovea is packed with cones and allows sharp vision. Rods outside the fovea are largely responsible for peripheral vision.

Rods and cones convert light into an electric signal that is carried from the optic nerve to the brain. The brain translates nerve impulses to form an image. Three-dimensional information comes from comparing the differences between the images formed by each eye.

Accommodation of the eye.

Accommodation of the eye is the ability of the eye to see near and distant objects. The eye is capable of focusing objects at different distances by automatic adjustment of the thickness of the eye lens which is done by the ciliary muscles. To focus a distant object, the eye lens is made thinner, so less powerful, and the rays from the object are brought to focus on the retina by the eye lens. In this case, the ciliary muscles are relaxed and pull the lens. For nearer objects, the eye lens must be made thicker and hence more powerful so that the rays from the near object can be brought to a focus on the retina. In this case, the ciliary muscles tighten and squeeze the lens

Magnifying glass

A magnifying glass is **a convex lens that is used to produce a magnified image of an object.** The lens is usually mounted in a frame with a handle. A magnifying glass can be used to focus light, such as to concentrate the sun's radiation to create a hot spot at the focus for fire starting.

The magnification of a magnifying glass depends upon where it is placed between the user's eye and the object being viewed, and the total distance between them.

A magnifying glass is a convex lens that is used to produce a magnified image of an object. The lens is usually mounted in a frame with a handle. A magnifying glass can be used to focus light, such as to concentrate the sun's radiation to create a hot spot at the focus for fire starting.

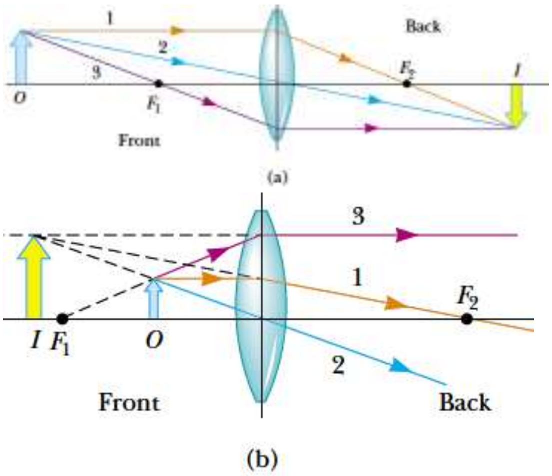
Single lens camera

The lens forms a **real and inverted image** of an object on the sensitive film placed behind it. A system is provided in the camera to move the lens back and forth so that sharp image is obtained on the film. There is shutter behind the lens that remains close normally.

Image formation in thin lenses

Rays for thin lenses

- Ray 1 is drawn parallel to the principal axis. After being refracted by the lens, this ray passes through the focal point on the back side of the lens.
- Ray 2 is drawn through the center of the lens and continues in a straight line.
- Ray 3 is drawn through the focal point on the front side of the lens (or as if coming from the focal point if p * f) and emerges from the lens parallel to the principal axis.



(a) When the object is in front of and outside the focal point of a converging lens, the image is real, inverted, and on the back side of the lens.
(b) When the object is between the focal point and a converging lens, the image is virtual, upright, larger than the object, and on the front side of the lens.

Thin lens Equation

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

f = focal length

u = object distance

v = image distance

(c) When an object is anywhere in front of a diverging lens, the image is virtual, upright, smaller than the object, and on the front side of the lens.

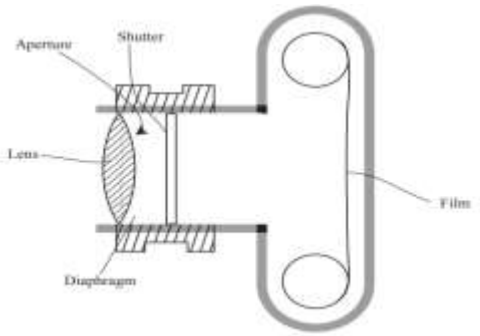
Magnification: The **magnification** is equal to the ratio of the objective and eyepiece focal lengths, and the image is inverted:

$$M = \frac{h'}{h} = -\frac{q}{p}$$

when M is positive, the image is upright and on the same side of the lens as the object. When M is negative, the image is inverted and on the side of the lens opposite the object.

Normal adjustment: Normal adjustment of the simple microscope is when the Image is at the near point.
The near point of the eye is the nearest point that can be focused by the un aided eye. It is a closest distance that the 'normal' human eye can observe clearly; without any strain to the eye. It is called the least distance of distinct vision. The near point of a normal eye is 25 cm.

Single lens Camera

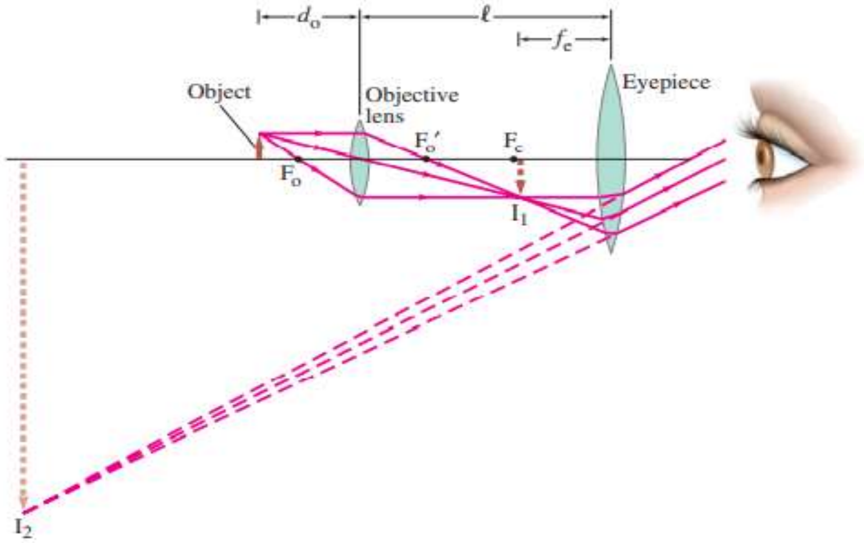


The lens focuses light from the object onto a light sensitive film. It is moved to and fro so that a sharp image is formed on the film. In many cameras, this happens automatically. In cheaper cameras, the lens is fixed and the photographer moves forwards and backwards to focus the object. The diaphragm is a set of sliding plates between the lens and the film. It controls the aperture (diameter) of a hole through which light passes. In bright light, a small aperture is used to cut down the amount of light reaching the film and in dim light, a large hole is needed. Very large apertures give blurred images because of aberrations so the aperture has to be reduced to obtain clear images.

4.1.2 Multi-lens optical instrument

Microscope
Definition: A microscope is an instrument that makes an enlarged image of a small object, thus revealing details too small to be seen by the unaided eye. The most familiar kind of microscope is the optical microscope, which uses visible light focused through lenses.
This instrument allows a scientist or doctor to magnify an object to look at it in detail. Many types of microscopes exist, allowing different levels of magnification and producing different types of images.
A compound microscope consists of two convex lenses of short focal lengths referred to as the objective and the eye piece. The objective is nearest to the object and the eye piece is nearest to the eye of the observer.

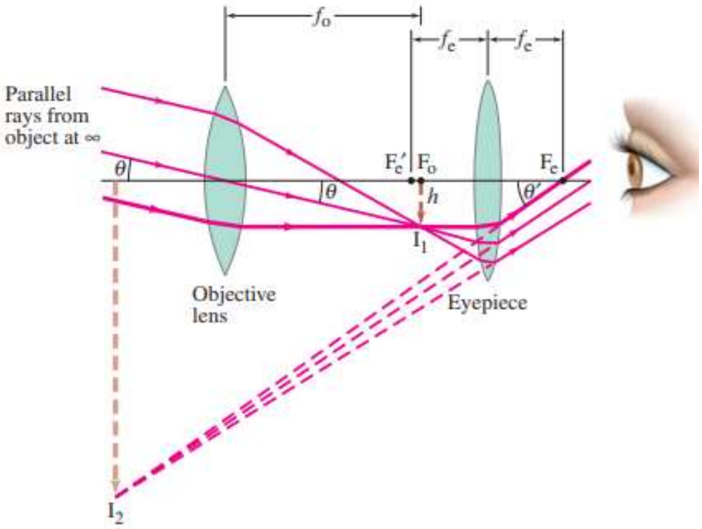
The object to be viewed is placed just outside the focal point (at a distance just greater than the focal length) of the objective lens. This objective lens forms a real, magnified, inverted image at a point inside the principal focus of the eye piece. This image acts as an object for the eye piece and it produces a magnified virtual image. So the viewer, looking through the eye piece sees a magnified virtual image of a picture formed by the objective i.e of the real image.



The distance between the lenses is **$l = d_i + f_e$,** where f_e is the focal length of the eyepiece and d_i is the image formed by objective lens.

Telescope

A telescope is used to magnify objects that are very far away. In most cases, the object can be considered to be at infinity. It is **an instrument used to see objects that are far away.** Telescopes are often used to view the planets and stars.

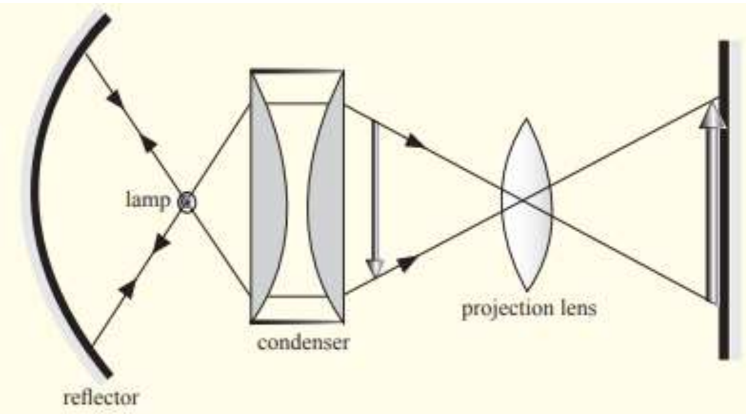


Several types of **astronomical telescope** exist. The common **refracting** type, sometimes called **Keplerian**, contains two converging lenses located at opposite ends of a long tube. The lens closest to the object is called the **objective lens** (focal length) and forms a real image I_1 of the distant object in the plane of its focal point fo (or near it if the object is not at infinity). The second lens, called the **eyepiece** (focal length), acts as a magnifier.

Projector

A slide projector is an opto-mechanical device for showing photograhic slides.

The pictures are thrown on the screen using a slide projector. A projector is a device used to throw on a screen a magnified image of a film or a transparent slide. It produces a magnified real image of an object.



It consists of an illumination system and a projection lens. The illumination system consists of a lamp, concave reflector and the condenser. The illuminant is either a carbon electric arc or a quartz lamp to give a small but very high intensity source of light in order to make the image brighter.

The lamp is situated at the centre of curvature of the mirror so that the rays are reflected back along their original path. The concave mirror reflects back light which would otherwise be wasted at the back of the projector housing. The condenser consisting of two Plano concave lenses collects light which would otherwise spread out and be wasted, and concentrates it on to the film (slide) so that it is very bright and evenly illuminated. The light is then scattered by the film and focused by a convex projection lens on to the film. The projection lens is mounted in the sliding tube so that it is moved to and fro to focus a sharp image on the screen.

Theoretical learning Activity

- ✓ (i) Carefully place a magnifying glass above some prints on a piece of paper and adjust it until they are seen clearly.
  (ii) Make sure that you don’t feel tired in the eye while you are observing.
  (iii) What do you think is the position of the image from the eye?
- ✓ The trainers in group construct the image of an object when an object is placed between Centre of curvature and focal point and explain the properties of the image formed.
- ✓ The trainers in group construct the image of an object when an object is placed at the focal point.

✓ Using the knowledge from thin lenses, draw a ray diagram to show the formation of an image by a magnifying glass. State the characteristics of the image formed.

Practical learning Activity

Trainees in pair perform the following exercises

1. The principal refraction of light by the eye occurs at the

A) cornea. B) lens. C) retina. D) iris.

2. The closest distance at which an eye can see objects clearly is

A) the near point. B) the far point. C) near-sightedness. D) farsightedness

3. The farthest distance at which an eye can see objects clearly is

A) the near point. B) the far point. C) near-sightedness. D) Farsightedness

4. What type of lens is a magnifying glass?

A) Converging B) diverging C) spherical D) cylindrical

Points to Remember (Take home message)

- A telescope is used to magnify objects that are very far away. In most cases, the object can be considered to be at infinity.
- A microscope is an instrument that makes an enlarged image of a small object, thus revealing details too small to be seen by the unaided eye.
- A slide projector is an opto-mechanical device for showing photograhic slides.

Learning out come 4.1 : formative assessment

Written Assessment: Multiple choice questions:

1. Light travels fastest

A) in a vacuum. B) through water. C) through glass. D) through diamond.

2. A convex lens has a focal length f. An object is placed between f and 2f on the axis. The image formed is located

A) at 2f. B) between f and 2f. C) at f. D) at a distance greater than 2f from the lens.

3. The images formed by concave lenses

A) are always real. B) are always virtual. C) could be real or virtual; it depends on whether the object distance is smaller or greater than the focal length. D) could be real or virtual, but always real when the object is placed at the focal point

4. A converging lens of focal length 10.0 cm forms images of objects placed

(A) 30.0 cm,

(B) 10.0 cm, and

(C) 5.00 cm from the lens.

In each case, construct a ray diagram, find the image distance and describe the image.

4.2. Determination of the magnification of optical instruments

Duration: 3 hrs

Learning outcome 4.2 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Apply clearly the Magnification of microscope in physics
2. Apply clearly the Magnification of telescope in physics

Resources

Equipment	Tools	Materials
PPE, whiteboard, chalkboard, optical benc, optical slides, computer, projector, textbooks	Compute, projector, textbooks, scientific calculator	Chalks, Markers, Candles, lens, lens holders.

Advance preparation:

Trainer shows magnifying glass

Trainer shows the telescope, periscope and microscope where they are available.

Magnification refers to the act of visually enlarging an object, meaning that the object itself doesn't become physically larger but only larger in appearance. This notion of magnification can arise in either of two forms: **microscopic** magnification is what we use when we make small objects appear larger, while **telescopic** magnification makes distant objects appear closer (and thus clearer and more defined).

4.2.1. Magnification of microscope

The overall magnification of a microscope is the product of the magnifications produced by the two lenses. The image formed by the objective lens is a factor greater than the object itself.

$$m_o = \frac{h_i}{h_o} = \frac{d_i}{d_o} = \frac{\ell - f_e}{d_o},$$

where d_o and d_i are the object and image distances for the objective lens, is the , l distance between the lenses and we ignored the minus sign which only tells us that the image is inverted.

We set $d_i = l - f_e$ which is exact only if the eye is relaxed, so that the image I_i is at the eyepiece focal point F_e. If we assume that the eye is relaxed, the eyepiece angular magnification M_e is

$$M_e = \frac{N}{f_e},$$

Where N = 25 cm the near point for the normal eye. Since the eyepiece enlarges the image formed by the objective, the overall angular magnification M is the product of the magnification of the objective lens M_o, times the angular magnification M_e of the eyepiece lens.

$$M = M_e m_o = \left(\frac{N}{f_e}\right)\left(\frac{\ell - f_e}{d_o}\right) \approx \frac{N\ell}{f_e f_o}.$$

When f_o and f_e are small compared to l so $l - f_e = l$ and the object is near F_o so $d_o \approx f_o$

Example:

Two thin converging lenses of focal lengths $f_1 = 10.0$ cm and $f_2 = 20.0$ cm are separated by 20.0 cm. An object is placed 30.0 cm to the left of lens 1. Find the position and the magnification of the final image.

Solution:

The location of the image formed by lens 1 is found from the thin lens equation:

$$\frac{1}{p_1} + \frac{1}{q_1} = \frac{1}{f}$$

$$\frac{1}{30.0 \text{ cm}} + \frac{1}{q_1} = \frac{1}{10.0 \text{ cm}}$$

$$q_1 = +15.0 \text{ cm}$$

The magnification of this image is

$$M_1 = -\frac{q_1}{p_1} = -\frac{15.0 \text{ cm}}{30.0 \text{ cm}} = -0.500$$

The image formed by this lens acts as the object for the second lens. Thus, the object distance for the second lens is 20.0 cm - 15.0 cm = 5.00 cm. We again apply the thin lens equation to find the location of the final image:

$$\frac{1}{5.00 \text{ cm}} + \frac{1}{q_2} = \frac{1}{20.0 \text{ cm}}$$

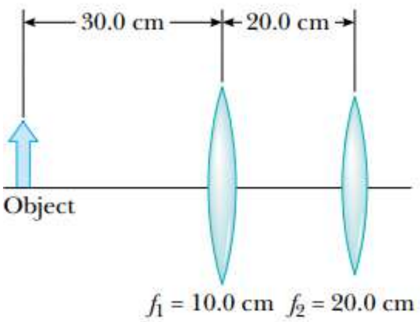
$$q_2 = -6.67 \text{ cm}$$

The magnification of the second image is

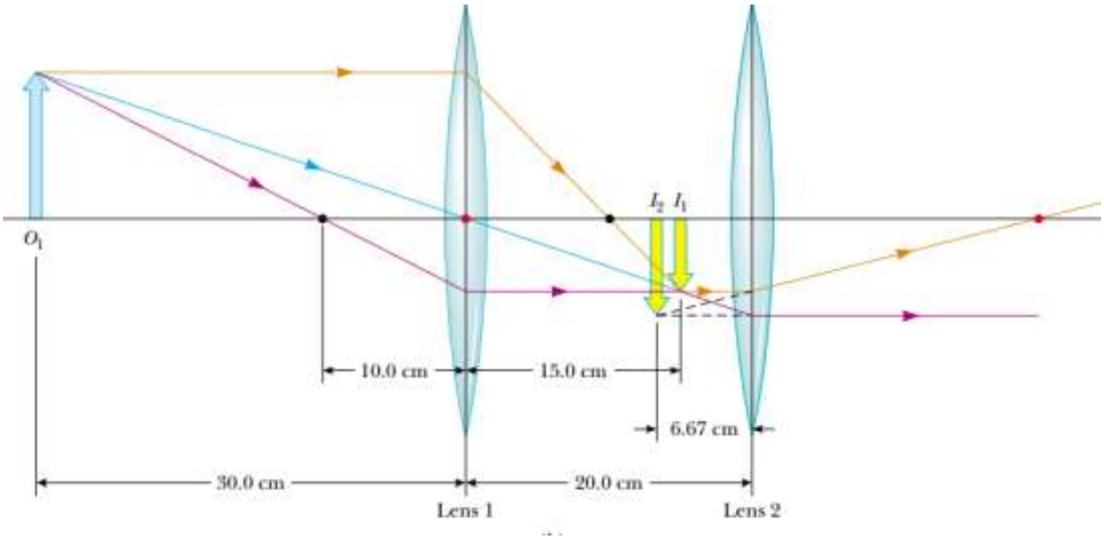
$$M_2 = -\frac{q_2}{p_2} = -\frac{(-6.67 \text{ cm})}{5.00 \text{ cm}} = +1.33$$

Thus, the overall magnification of the system is

$$M = M_1 M_2 = (-0.500)(1.33) = -0.667$$



(a)



4.2.3 Magnification of telescope

That is, the eyepiece magnifies the image I_1 formed by the objective lens to produce a second, greatly magnified image I_2, which is virtual and inverted. If the viewing eye is relaxed, the eyepiece is adjusted so the image I_2 is at infinity. Then the real image I_1 is at the focal point of the eyepiece, and the distance between the lenses is $f_0 + f_e$ for an object at infinity.

$$M = \frac{\theta'}{\theta} = \frac{h/f_e}{h/f_0} = -\frac{f_0}{f_e}$$

We inserted a minus sign to indicate that the image is inverted. To achieve a large magnification, the objective lens should have a long focal length and the eyepiece a short focal length.

For a telescope in normal adjustment, the separation of the objective and the eye piece is $F_0 + f_e$.

Example:

The largest optical refracting telescope in the world is located at the Yerkes Observatory in Wisconsin,

It is referred to as a “40-inch” telescope, meaning that the diameter of the objective is 40 in., or 102 cm. The objective lens has a focal length of 19 m, and the eyepiece has a focal length of 10 cm.

(*a*) Calculate the total magnifying power of this telescope.

(*b*) Estimate the length of the telescope.

The length of the telescope is the distance between the two lenses.

Solution

a) $M=-\frac{f_0}{f_e}=-\frac{19m}{0.10m}=-190\times$

b) For relaxed eye, the image I_1 is at the focal point of both the eyepiece and the objective lenses. The distance between the two lenses is thus $f_0+f_e\approx 19m$ which essentially the length of the telescope.

Theoretical learning Activity

1. You have heard that there are some heavenly and distant earthly bodies that cannot be seen by our naked eyes. How did the people know that there exist such bodies?

Which instrument do you think is used to see these bodies and to observe what takes place on these bodies?

Why do you think it is difficult to see distant objects using our eyes?

2. (i) Hold a convex lens of focal length 5cm close to your eye.

(ii) Hold another lens of focal length 20cm at an arm's length.

iii) Use the lens combination to view distant objects.

iv) Adjust the distance of the farther lens until the image is clear (take care not to drop the lenses). What type of image do you see?

3. Trainees in pair perform the following multiple choice questions:

i) What type of lens is a magnifying glass?

A) converging B) diverging C) spherical D) cylindrical.

ii) A refracting telescope has a magnification m. If the objective focal length is doubled and the eyepiece focal length is halved, what is the new magnification? A) 4m B) 2m C) m/2 D) m/

iii) The objective of a telescope has a focal length of 200 cm and its eyepiece has a focal length of 1.0 cm. What is the magnification of this telescope when viewing an object at infinity? A) 20 B) 0.0050 C) 200 D) none of the given answers

Practical learning Activity

In group of two trainees, the trainer provides 2 lenses to trainees and guides them to form a telescope.

Points to Remember (Take home message)

- ✓ **Magnification** refers to the act of visually enlarging an object, meaning that the object itself doesn't become physically larger but only larger in appearance.
- ✓ Microscope magnification

$$M = M_e m_o = \left(\frac{N}{f_e}\right)\left(\frac{\ell - f_e}{d_o}\right)$$

- ✓ Telescope magnification

$$M = -\frac{f_o}{f_e}$$

Learning out come 4.2 : formative assessment

At the end of this learning outcome, the trainees should perform this formative assessment.

- ✓ A student constructs an astronomical telescope with a magnification of 10. If the telescope has a converging lens of focal length 50 cm, what is the focal length of the eyepiece? A) 2.5 cm B) 5.0 cm C) 10 cm D) 25 cm
- ✓ A student constructs an astronomical telescope with a magnification of 10. If the telescope has a converging lens of focal length 50 cm, what is the resulting length of the telescope? A) 53 cm B) 55 cm C) 60 cm D) 75 cm
- ✓ A compound microscope has an objective with a focal length of 3.00 mm and an eyepiece of focal length 6.00 cm. If the two lenses are separated by 40.0 cm, what is the total magnification? A) 27.8 B) 55.6 C) 278 D) 556
- ✓ A microscope has an objective lens of focal length 1.4 mm and an eyepiece of focal length 20 mm, adjusted for minimum eyestrain. A blood sample is placed 1.5 mm from the objective. How far apart are the lenses? A) 20 mm B) 21 mm C) 23 mm D) 41 mm

Learning outcome 4.3 Correction of Optical instrument

Duration: 3 hrs

Learning outcome 4.3 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Explain clearly the Spherical aberration
2. explain clearly the Chromatic aberrations
3. explain clearly the astigmatic aberration

Resources

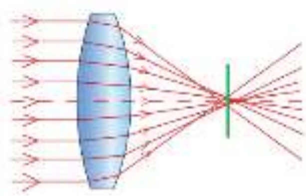
Equipment	**Tools**	**Materials**
PPE, whiteboard, chalkboard, optical benc, optical slides, computer, projector, textbooks	Compute, projector, textbooks, scientific calculator	Chalks, Markers, Candles, Water

Advance preparation:

- **Use the converging lens to show**
- **Show to the learners the diverging lens**

4.3.1 Spherical aberration

This arises in lenses of larger aperture when a wide beam of light incident on the lens, not all rays are brought to one focus. As a result, the image of the object becomes distorted. The defect is due to the fact that the focal length of the lens for rays far from the principal axis are less than for rays closer to a property of a spherical surface and as a result, they converge to a point closer to the lens.

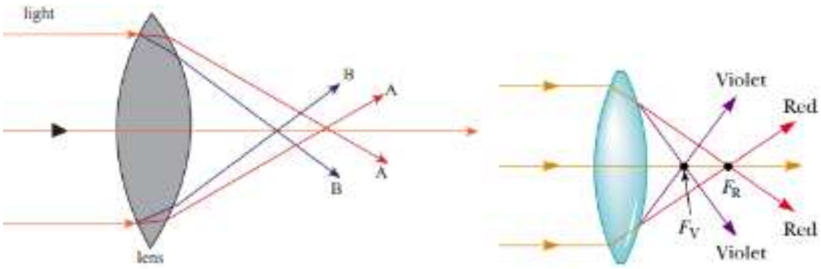


Spherical aberration can be eliminated by using a parabolic mirror instead of a spherical mirror as an objective.

However, this reduces the brightness of the image since it reduces the amount of light energy passing through the lens.

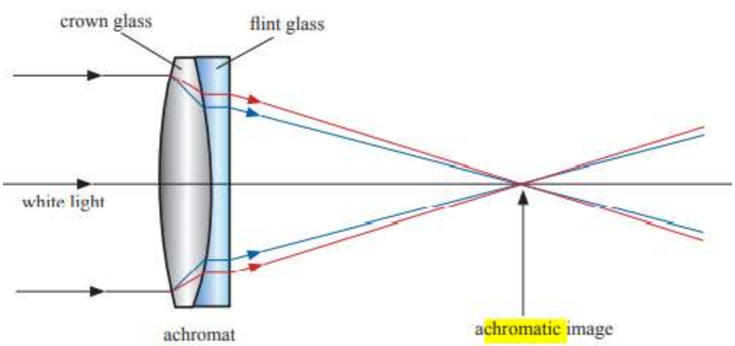
4.3.2. Chromatic aberration

Notice that the image has coloured patches. This defect where by an image formed has coloured patches is called chromatic aberration. This occurs when white light from an object falls on a lens and splits it into its component colours. These colours separate and converge to different foci, and this results into an image with coloured edges



Chromatic aberration caused by a converging lens. Rays of different wavelengths focus at different points.

The separation takes place because the material of a glass of a lens has different refractive indices for each colour. The colours travel at different speeds in glass: red colour with the greatest and the violet with the least. As a result, violet is deviated most and red is the least deviated Thus, a converging lens produces a series of coloured images of an extended white object as shown in the figure above (exaggerated for clarity). Chromatic aberration can be minimised by using an achromatic lens called an achromatic doublet. This consists of a converging lens of crown glass combined with a diverging lens of flint glass cemented together with Canada balsam.



The flint glass of the diverging lens produces the same dispersion as the crown glass of the converging lens but in the opposite direction and the overall combination is converging. As a result, the achromatic combination converges the white light to one focus.

4.3.3 Astigmatic aberration

This is the defect that occurs if the curvature of the cornea varies in different directions so that rays in different planes from an object are focused in different positions by the eye and the image is distorted. A person suffering from astigmatism sees one set of lines more sharply than others. This defect is corrected by wearing corrected lenses. These help to bend the incoming rays to correct for irregular refraction.

Theoretical learning Activity

1) The farthest distance at which an eye can see objects clearly is

A) the near point.

B) the far point.

C) nearsightedness.

D) farsightedness.

Answer: B

2) If a person's eyeball is too long from front to back, the person is likely to suffer from

A) spherical aberration.

B) nearsightedness.

C) farsightedness.

D) astigmatism.

Answer: B

3) Nearsightedness can usually be corrected with

A) converging lenses.

B) diverging lenses.

C) achromatic lenses.

D) cylindrical lenses. Answer: B

4) If a person's eyeball is too short from front to back, the person is likely to suffer from

A) astigmatism.

B) spherical aberration.

C) farsightedness.

D) nearsightedness.

Answer: C

5) Farsightedness can usually be corrected with

A) cylindrical lenses.

B) achromatic lenses.

C) diverging lenses.

D) converging lenses.

Answer: D

Practical learning Activity

Trainees in groups

i) Place a white sheet of paper on a horizontal ground.

(ii) Hold a glass ruler above the paper so as to focus rays from the sun on to the paper.

(iii) Observe carefully the image formed on the sheet of paper.

(iv) Repeat the above with the convex lens. What have you observed? **Share the ideas about the observations.**

Points to Remember (Take home message)

- ✓ **Spherical aberration**: The defect is due to the fact that the focal length of the lens for rays far from the principal axis are less than for rays closer to a property of a spherical surface and as a result, they converge to a point closer to the lens.
- ✓ **Chromatic aberration** caused by a converging lens. Rays of different wavelengths focus at different points.
- ✓ **Astigmatic aberration**: This is the defect that occurs if the curvature of the cornea varies in different directions so that rays in different planes from an object are focused in different positions by the eye and the image is distorted.

Learning out come 4.3 : formative assessment

Written assessment

1. If a person's eyeball is too long from front to back, the person is likely to suffer from A) spherical aberration. B) nearsightedness. C) farsightedness. D) astigmatism

2. Spherical lenses suffer from A) both spherical and chromatic aberration. B) spherical aberration, but not chromatic aberration. C) chromatic aberration, but not spherical aberration. D) neither spherical nor chromatic aberration

3. If a person's eyeball is too short from front to back, the person is likely to suffer from

A) astigmatism. B) spherical aberration. C) farsightedness. D) nearsightedness.

References

1. Yeshu G. Deshmukh, Gayatri R. Deshmukh, Ashvini B. Nagdevte, Electrical energy generate by using turbo ventilator, International Research Journal of Engineering and Technology.

2. Giancoli, Douglas C. (2005). Physics Principles with applications 6^{th} edition. Pearson Prentice Hall. New Jersey.

3. Young, Hugh, D.; Freedman, Roger, A. (2012), Sears and Zeanmansky's University Physics: With modern physics, 13^{th} edition. New York: Addison Wesley, Pearson

4. Knight, R. D. (2016). *Physics for scientists and engineers* (4th ed.). Pearson.

5. Knight, Randall D. 2016. *Physics for Scientists and Engineers*. 4^{th} ed. Upper Saddle River, NJ: Pearson.