PHYSICS

Simplified

DR. M. BALASUBRAMANIAN

SINGHAL LAW PUBLICATIONS

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Syllabus

Chapter I: Law of Motion: Force and Inertia, Law of inertia or Newton's first law of motion, Newton's Second law of motion, Newton's third law of motion and it's applications, Basic forces in nature, Weight of body in lift, Equilibrium of concurrent forces, Lami's Theorem Friction: Cause of friction, Types of friction, Laws of friction, Angle of friction and repose, Centripetal and centrifugal force, velocity of vehicle on curved leveled and banked road.

Chapter II: Work, Energy & Power: Work, Conservative force, Power, Kinetic Energy, Work energy theorem, Potential Energy, Conservation of gravitational P.E. into K.E., P.E. of spring. Collisions: Types of collision, elastic collision in 1D & 2D, Inelastic collision in 1D, Perfectly inelastic collision in 1D.

Chapter III: Electricity & electromagnetism: Electric charge, Electron theory of electrification, Frictional electricity, Properties of electric charge, Coulomb's Law, Superposition Principle, Electric field intensity, Electric Lines of forces. Electrostatics: Line integral of electric field, Electrostatic potential, State & Proof of Gauss's theorem. Capacitance: Principle of Capacitor, Parallel and spherical capacitors, Grouping of capacitors and their capacitance, Effect of dielectric in capacitors. Current Electricity: Current, Ohm's Law, Resistance, Grouping of resistance, Krichoff's rule, Wheatstone bridge, Slide Wire Bridge.

Chapter IV: Structure of Atom: Thomson's atomic model, Rutherford's alpha scattering experiment and atomic model, Postulates of Bohr's Model. Semiconductors: Energy bands in solids, Difference between metals, insulators and semi conductors, Current carriers in semiconductors, Intrinsic semiconductor, Doping, Extrinsic semiconductors, Formation of p-n junction, Biasing of p-n junction, Light emitting diode. Transistors: Action of n-p-n & p-n-p transistors, Advantages of transistors, Integrated Circuit.

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Some Important Units and Equations

The Fundamental Units: Each physical quantity has a standard unit and the unit indicates the size of the quantity .We follow ***System International*** *units*. Here the basic units which we use in this book are given in the table. The derived units are explained whenever required.

Fundamental ***quantity***	***Unit***	***Symbol***
Length	*Metre*	*M*
Mass	*kilogram*	*Kg*
Time	*second*	*S*
Electric current	*ampere*	*A*

The following are the basic equations that we are going to apply.

$$v = u \pm at$$

$$v^2 = u^2 \pm 2as$$

$$S = ut \pm \frac{1}{2}at^2$$

Where

U is the initial velocity
V is the final velocity
t is time
S is displacement or distance
a is acceleration

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CHAPTER

1 LAWS OF MOTION

Introduction

In this chapter we are going to see 'Dynamics'- a branch of physics which deals with motion of a particle. Newton not only described the cause and motion of the particles on the earth but also described the motion of the heavenly bodies.

1.1 Newton's First law of Motion

It states that every body continues in its state of rest or of uniform motion in a straight line unless it is compelled by an external force to change that state.

This means an object at rest continues to remain in a state of rest or an object in uniform motion continues to remain in a state of uniform motion, unless it is acted upon by an external force.

That is a body on it its own cannot change its state of rest or its state of uniform motion along a straight line.

This inability of a body to change its state of rest or its state of uniform motion by itself is called inertia.

Newton's first law defines the concept of **inertia** so it is called law of inertia.

Measure of Inertia : Inertia is an inherent property of all the objects. Mass is the measure of inertia. More force is required to move a heavier body than a lighter body from its state of rest. Thus, the more the mass, more the inability of the object to change its state and hence more inertia. Hence mass is the measure of inertia. There are three types of Inertia

1. Inertia of rest
2. Inertia of motion
3. Inertia of direction

Try not to become a man of success, but rather try to become a man of value.

— Albert Einstein

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Inertia of rest

The inability of the object to change its state of rest by itself is called inertia of rest.

Examples:

a. A person standing in a bus falls backward when the bus suddenly starts moving. This is because the feet of the person start moving along the bus as it is in contact with the floor of the bus. The upper portion of the person continues to remain stationary due to inertia. Therefore the standing person falls back.

b. The dust particles are removed from a carpet by beating it with a stick. If the carpet is hung vertically and beaten with a stick, the carpet moves and the dust particles at rest fall vertically downwards.

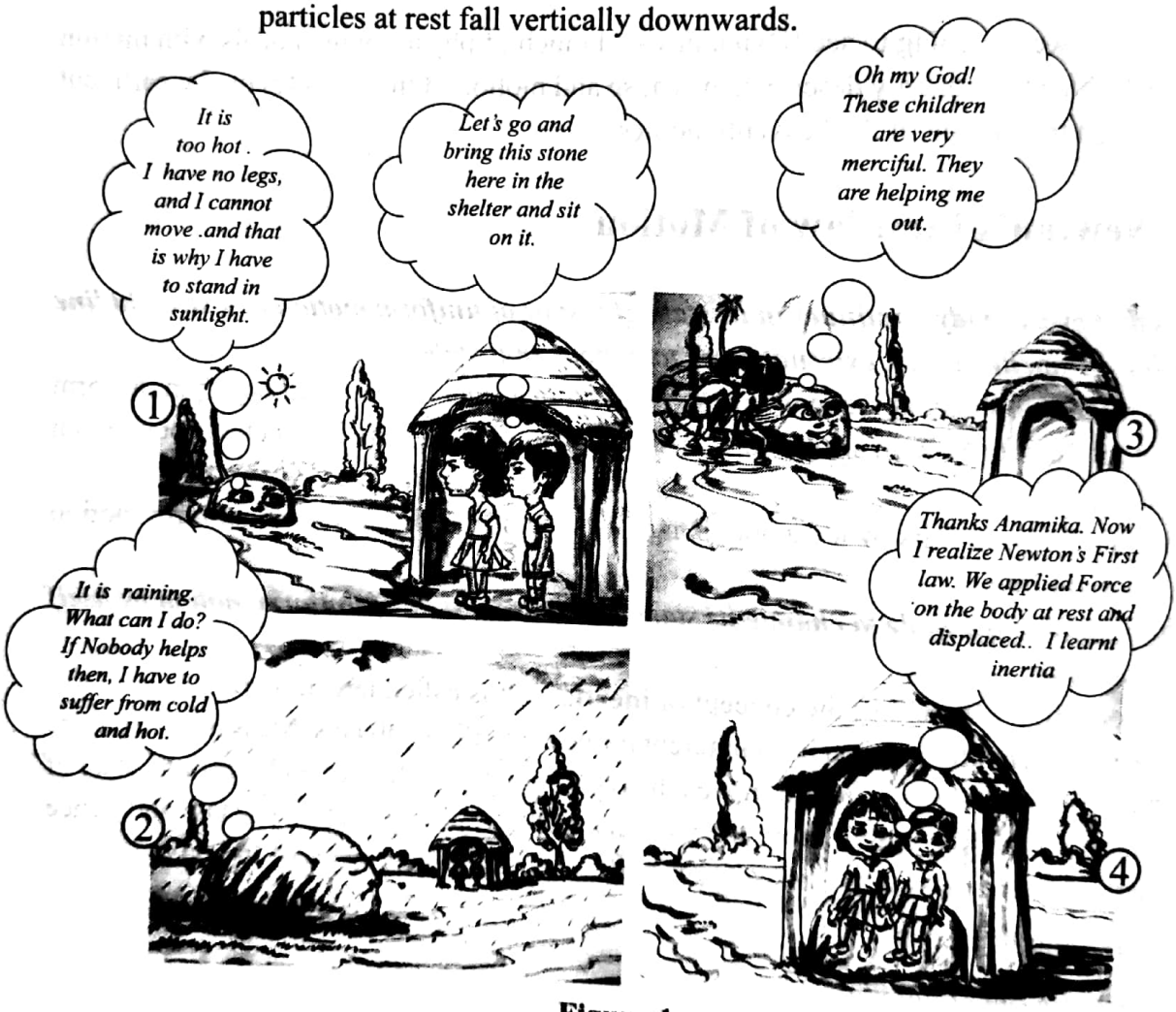

Figure:1

Look at the sky. We are not alone. The whole universe is friendly to us and conspires only to give the best to those who dream and work.

—Dr. A.P.J.Abdul Kalam

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Inertia of motion

The inability of the object to change its state of motion by itself is called inertia of motion.

Examples:

a. A person standing in a moving bus falls forward, when the bus stops suddenly. This is because the feet come to rest as soon as the bus stops where as the upper portion of the body continues to move due to inertia of motion. So the person falls in forward direction.

b. An athlete running in a race will continue to run some distance even after reaching the finishing line.

Inertia of direction

The inability of the object to change its direction of motion by itself is called inertia of direction.

Examples:

a. When a bus moving in a straight line takes a left turn, the passengers are thrown right.

b. When a knife is sharpened by a rotating disc, the sparks move tangentially to the rotating disc.

Force

From Newton's first law we learn that to change the state of rest or uniform motion of an object, some external agency called force is required.

Force can be defined as that which acting on a body changes or tends to change the state of rest or of uniform motion of the body. A force may be a push or pull.

Momentum

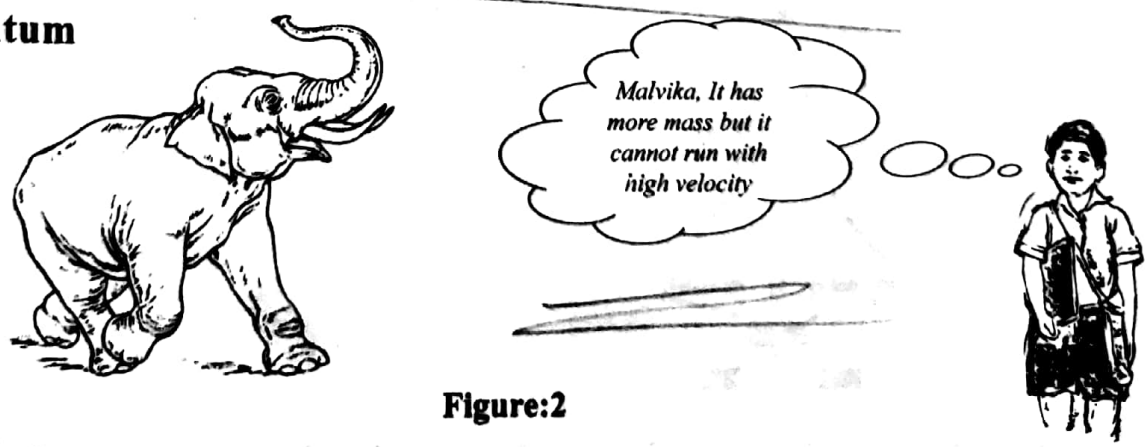

Figure:2

I can calculate the motion of heavenly bodies, but not the madness of people.

— ***Isaac Newton***

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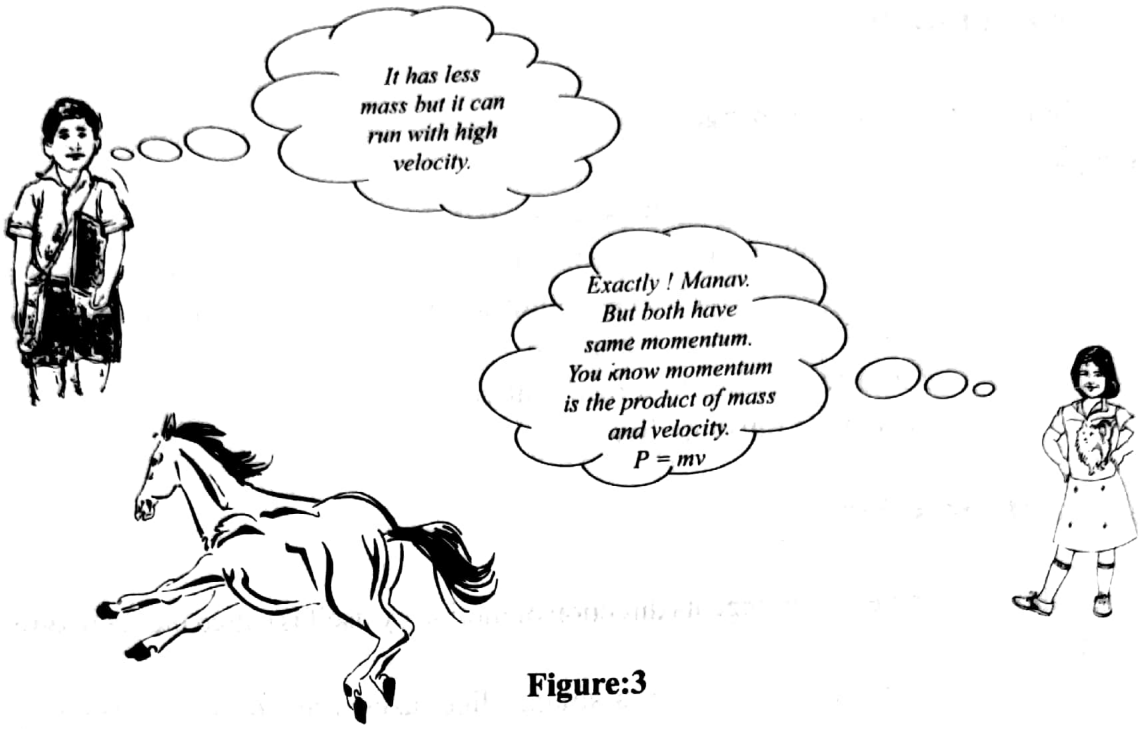
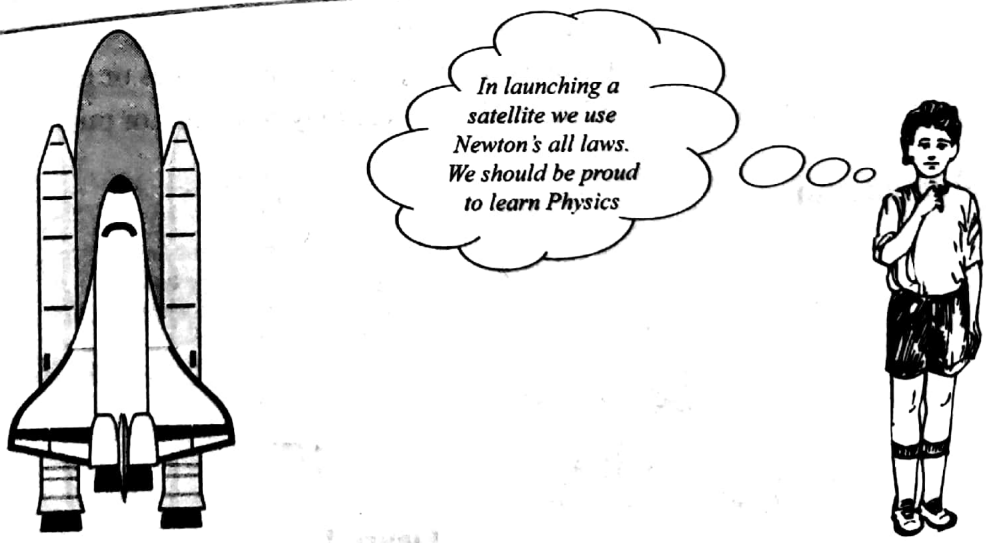


Figure:3

It is known practically that the force required to stop a moving object (for example a lean boy and fat boy) depends on mass and velocity of the object. Here we introduce one new term called "momentum" for a moving object.

The momentum of the body is defined as the product of mass and velocity. If m is the mass of the body and v is the velocity of the body the momentum of the body is given by P = mv.

Momentum is a vector quantity because velocity is the vector quantity.



Look deep into nature, and then you will understand everything better.

— Albert Einstein

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1.2 Newton's Second Law

Newton's second law states that the rate of change of momentum of a body is directly proportional to the external force applied on it and the change in momentum takes place in the direction of the applied force.

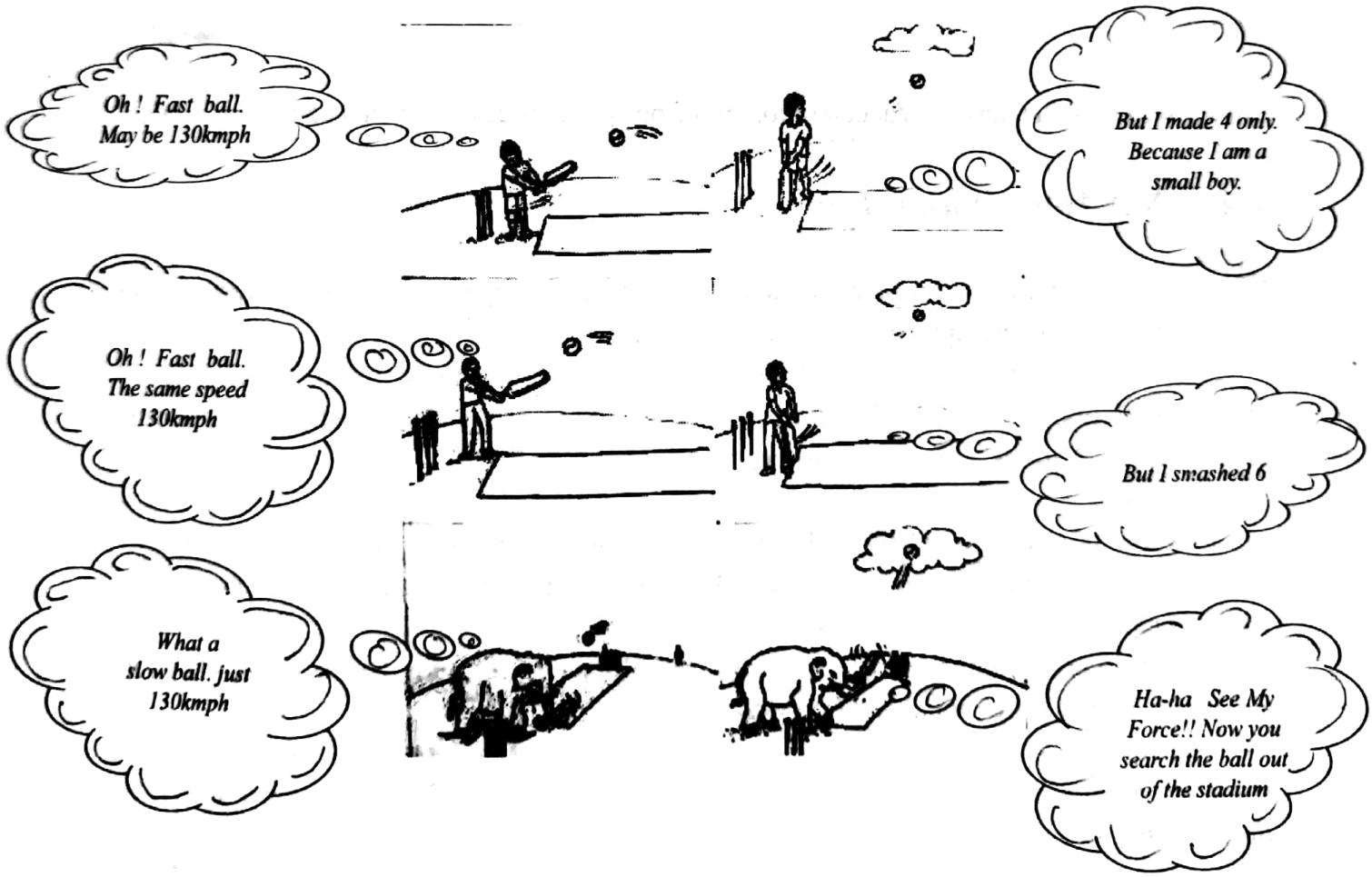
If p is the momentum of a body and F is the external force acting on it, then according to Newton's second law,

$$F \alpha \frac{dp}{dt}$$

$$F = k\frac{dp}{dt}$$

Where k is the constant and force is taken in such a way that k = 1. Now F can be written as

$$F = \frac{dp}{dt}$$



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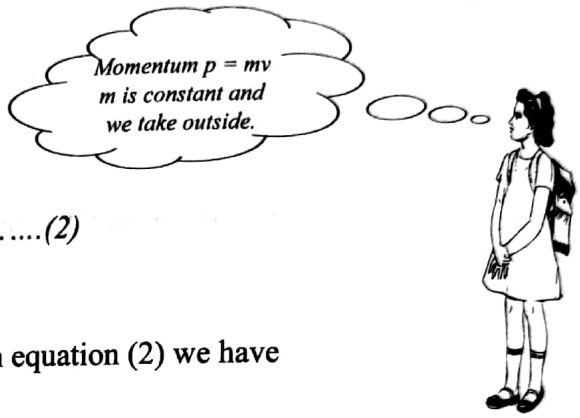
1.3 Measure of Force

If m is the mass of the body and v is its velocity, then the momentum $p = mv$.
According to Newton's second law

$$F = \frac{dp}{dt} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Substituting the value for " p" in above equation, we have

$$F = \frac{d(mv)}{dt}$$



$$F = \frac{mdv}{dt} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Since acceleration $a = \frac{dv}{dt}$ and substituting in equation (2) we have
$F = ma$

Thus if we know the mass and acceleration of the body, the force acting on it can be calculated.

1.4 Newton's Third Law

When one body exerts a force on a second body, the second body simultaneously exerts a force equal in magnitude and opposite in direction on the first body.

According to Newton's third law all forces between two objects exist in equal magnitude and opposite direction: if one object A exerts a force F_A on a second object B, then B simultaneously exerts a force F_B on A, and the two forces are equal and opposite:

$F_A = -F_B$

This law is also referred to as the *action-reaction law*, with F_A is called the "action" and F_B the "reaction". The action and the reaction are simultaneous, and it does not matter which is called the *action* and which is called *reaction*;

Thus, to every action , there is always equal and opposite reaction. That is forces of action and reaction are always equal and opposite.

If you're changing the world, you're working on important things. You're excited to get up in the morning.

— *Larry Page*

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Example:

a. The swimmer pushes the water in the backward direction with a certain force, the water pushes the swimmer in the forward direction with an equal and opposite force.

b. When a bullet is fired from a rifle , the bullet moves with some force in forward direction and the rifle moves in backward direction with equal force.

Concept of inertial mass

From Newton's second law:-

$$F = ma$$

$$a = \frac{F}{m}$$

i.e. Magnitude of acceleration is inversely proportional to mass of the body.

Larger the mass of a body, smaller is the acceleration produced in it by a given forces. Thus mass of the body is the measure of the opposition offered by the body to change in velocity.

Thus mass of the body is the measure of its inertia.

Such a mass which accounts for linear inertia of the body is called inertial mass of the body.

$$\text{If } a = 1,\ F = m$$
$$= mi$$
$$= \textbf{Inertial mass.}$$

Thus inertial mass of a body is the force required to produce unit acceleration of the body

1.5 Second law is the Real Law of motion

First law is contained in the second law : According to Newton's second law, the external force (F) applied on a body of mass m and the acceleration (a) produced, are related by

$$F = ma$$

If no external force acts on the body, $F = 0$ then

$$ma = 0$$

As we know mass cannot be equal to zero, $m \neq 0$

$$a = 0$$

Thus there will be no acceleration in the body if no external force is applied .This means that a body at rest will remain at rest and a body in uniform motion will continue moving uniformly along the same straight line in the absence of an external force .This is exactly, what Newton's first law states. Hence Newton's first law is contained in the second law

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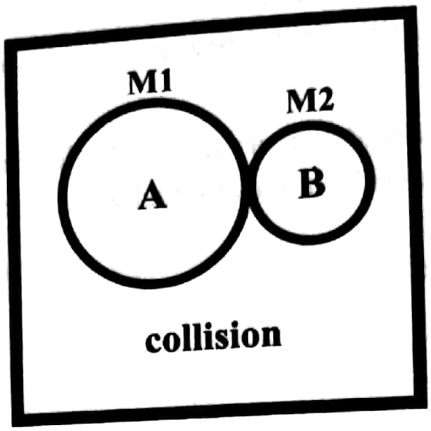
Third law is contained in the second law



Consider two bodies A and B in an isolated system.
Let the two bodies collide themselves and during collision,
Let the body A exerts a force F_1 on a body B for a time Δt.
Let the body B exerts a force F_2 on a body A for the same time Δt
According to Newton's second law,

Change in linear momentum $= F.t$
Change in linear momentum of $B = F_1 . \Delta t$
Change in linear momentum of $A = F_2 . \Delta t$
Total change in linear momentum of A and $B = F_1 . \Delta t + F_2 . \Delta t$
As no external force is acting on the isolated system, the change in momentum is zero.

Thus $F_1.\Delta t + F_2.\Delta t = 0$
Or $F_1 . \Delta t = - F_2.\Delta t$
Or $F_1 = - F_2$
Or Action = - Reaction.

i.e. action is equal and opposite to reaction and thus third law ~~is~~ contained in the second law.

Hence both first law and third law are derived from **Second law**. **So Newton's second law is the real law of motion.**

1.6 Concurrent Forces

If many forces are acting at one point then that forces are called Concurrent Forces.

Consider three forces F_1, F_2 and F_3 are acting at one point O as shown in fig. The resultant of F_1 and F_2 is R.

If F_3 is equal to R then the net force acting at the point O is equal to zero.

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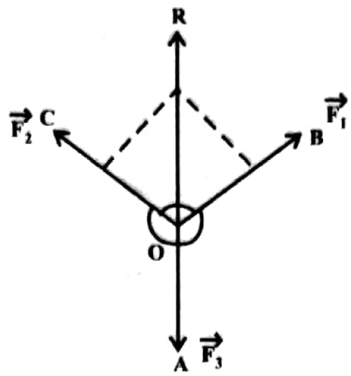
i.e. $F_1 + F_2 + F_3 = 0$

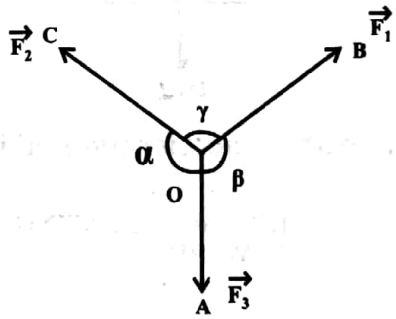


1.7 Lami's Theorem

Lami's theorem is an equation relating the magnitudes of three coplanar, concurrent and non-collinear forces, which keeps an object in static equilibrium, with the angles directly opposite to the corresponding forces.

As per Lami's theorem, three forces acting at a point are in equilibrium, if each force is proportional to the Sine of the angle between the other two forces.

Consider three concurrent forces F_1, F_2 and F_3 acting at the point 'O' are in equilibrium. Let α be the angle opposite to force F_1, β be the angle opposite to force F_2 and γ the angle opposite to force F_3 then , according to Lami's theorem we have,



$$\frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma}$$

1.8 Apparent loss of weight in Lift

Let us consider a boy standing on a weighing machine placed inside a lift.

Let 'm' be the mass of the boy. The weight $W = mg$

The weight acts downwards on the machine. As a result reaction acts upwards.

This reaction is measured as apparent weight of the boy.

We will discuss this apparent weight in five different cases.

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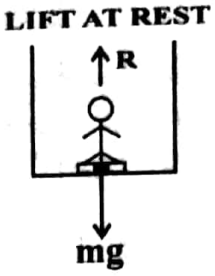
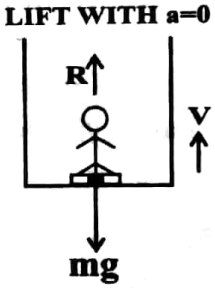
Case 1: When the lift is at Rest.



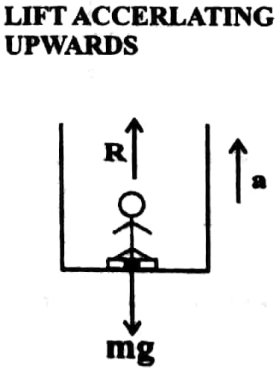
The acceleration of the boy = 0
The net force acting on the boy = 0
From fig 1, $R - mg = 0$
Or $R = mg$
That is the apparent weight is equal to actual weight.

Case 2: when the lift is moving with uniform velocity in upward direction.

For uniform velocity , the acceleration of the boy is zero.Therefore the apparent weight is equal to actual weight. .i.e. mg.



Case 3: when the lift is moving with an acceleration 'a' in upward direction.



If the lift is moving with an acceleration 'a' means, force acting the boy $F = ma$
Then $R = m(g + a)$

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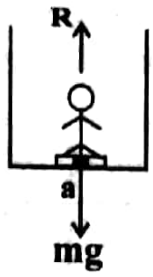
Therfore the apparent weight is greater than actual weight.

Case 4: when the lift is moving with an acceleration 'a' in downward direction.

LIFT ACCERLATING DOWNWARDS



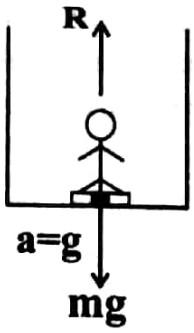
If the lift is moving downward with an acceleration 'a' means, force acting on the boy $F=-ma$

Then $R=m(g-a)$

Therfore the apparent weight is less than actual weight

Case 5: when the lift is moving with an acceleration 'g' in downward direction. It is called free fall of the lift .i.e. when the rope of the lift is broken, then the lift falls freely just like a ball falling freely.

LIFT IN FREE FALL



Then $R = m(g-g)$

$R = 0$

That is the apparent weight is zero. This is called weightlessness of the object.

1.9 Types of friction

There are three types of friction:

1. Static Friction
2. Limiting Friction
3. Kinetic Friction

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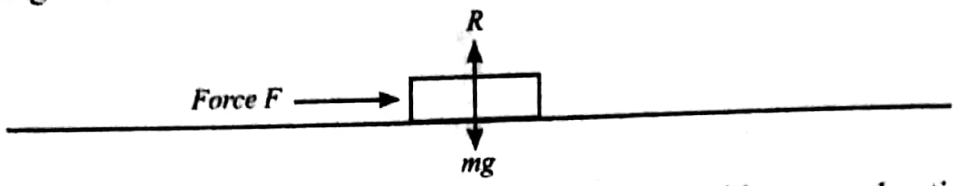
1.10 Static Friction

Consider a body of mass m on a horizontal surface. The weight of the body mg is balanced by the normal reaction R. i.e.

$$R = mg$$

Suppose a small force F is applied on the body along horizontal direction to move the body as shown in figure..



Now according to Newton's second law the body should move with an acceleration 'a' due to applied external force F and 'a' is given by

$$a = \frac{F}{m}$$

From practical day to day experience we know that this small applied force can not move the body. This means that an opposing force equal to applied force is there due to which only the body is not moving. This opposing force acting along the surface of the body in contact with the horizontal surface in a direction opposite to the applied force is called static friction. Thus static friction is the opposing force that comes into play between the surfaces of contact of the two bodies, when one body tends to slide over the surface of another, but actual motion is not yet started.

1.11 Limiting Friction

When the applied force is increased, a stage comes at which the body is just at verge of moving over the other. The static friction at this stage is maximum. This maximum value of static friction is called ***limiting friction***. And it can be defined as follows:

Limiting friction is the maximum opposing force that comes into play, when one body is just at the verge of moving over the surface of the other body.

Laws of limiting friction

The limiting static friction obeys the following laws, which are based on experimental observations.

1. The value of limiting static friction between two bodies is directly proportional to the normal reaction between them. Consider a body is lying on a horizontal surface and if R is the normal reaction and F is the limiting static friction

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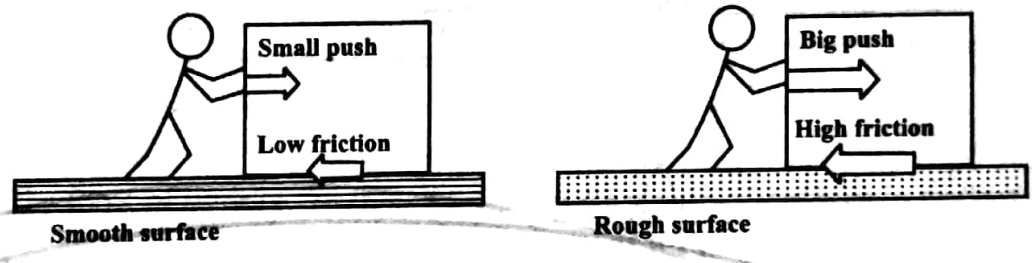
Then $F \propto R$

$$F = \mu R$$

The constant 'μ' is known as coefficient of static friction.

Thus coefficient of static friction is defined as the ratio of limiting friction to the normal reaction.

1. The value of limiting friction is independent of the area of the surfaces in contact as long as the normal reactions remains the same.
2. The force of friction is opposite to the direction in which the body starts moving on applying the force.
3. The value of limiting static friction depends upon the nature of the two surfaces in contact and their state of roughness or smoothness.

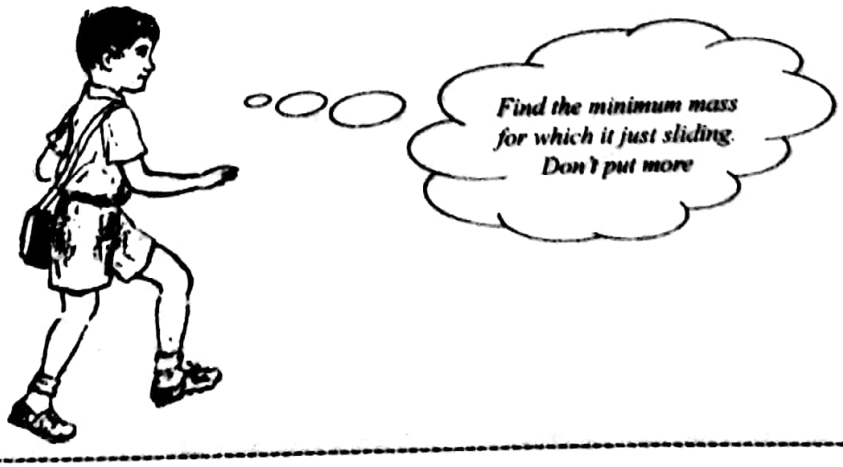


1.12 Experimental verification of the laws

First Law: The limiting friction is directly proportional to Normal Reaction ($F \propto R$).

A rectangular block 'A' of weight mg with a hook on one side is placed on a horizontal table.

A string is attached to the hook. The other end of the string is passed over the pulley and a pan is attached to it as shown in Fig.



Fools ignore complexity. Pragmatists suffer it. Some can avoid it. Geniuses remove it.

— ***Alan Perlis***

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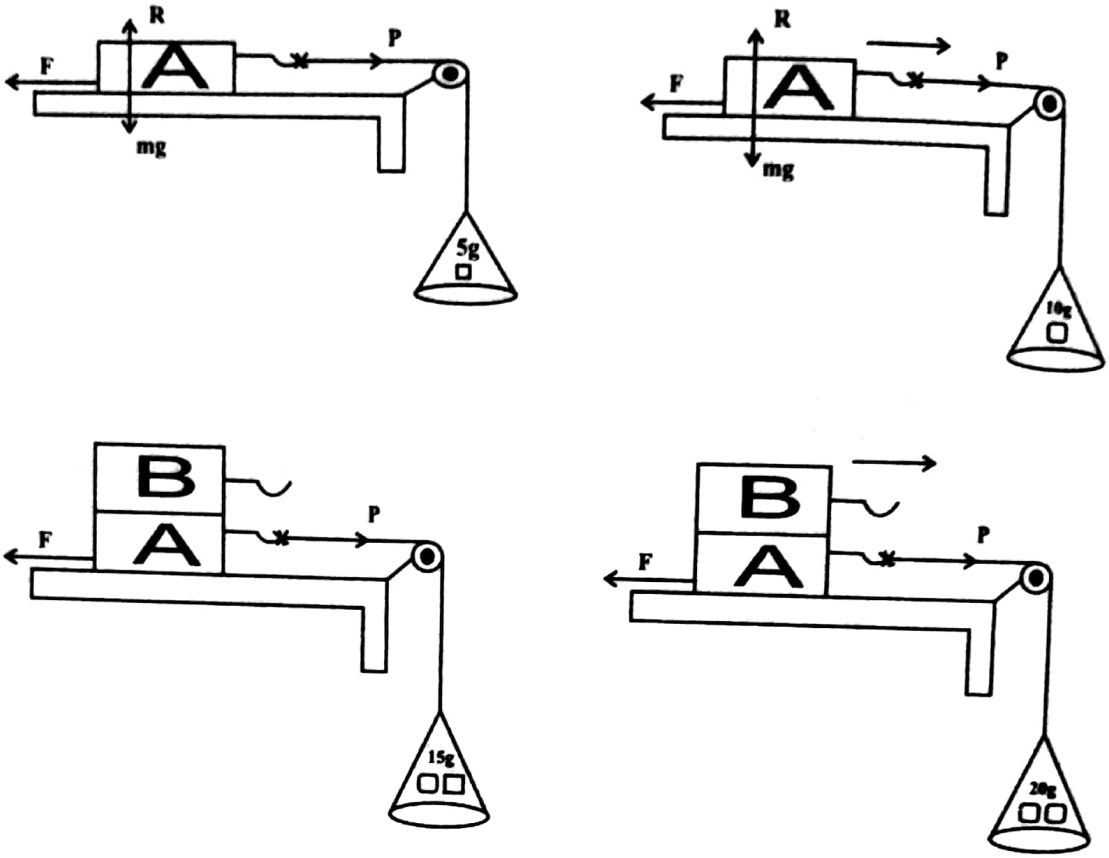

From a weight box, weights are added in the pan till the block just begins to move. The applied force P (weight of pan+ weight in the pan) gives the measure of the force of limiting friction (F).

i.e., $F=P$ and $R=mg$ (W)

Now another identical block 'B' is placed over the block 'A'. The weight is doubled and normal reaction is doubled. The experiment is repeated by adding the weights in the pan, till the system of two blocks just begins to slide. It will be 2P i.e. twice as that of first observation.

Clearly the normal reaction is equal to the weight 2W.

This experiment verifies that the limiting friction is directly proportional to normal reaction.

Second Law: To verify that limiting static friction is independent of area of the surfaces in contact.

Join the two blocks A and B and place them on the table as shown in fig. The experiment is repeated by adding weights in the pan. It is found that the limiting friction is same as in the case when the block B is placed over the block A.

The total normal reaction is same in both the cases but the area of contact is double in the second case.

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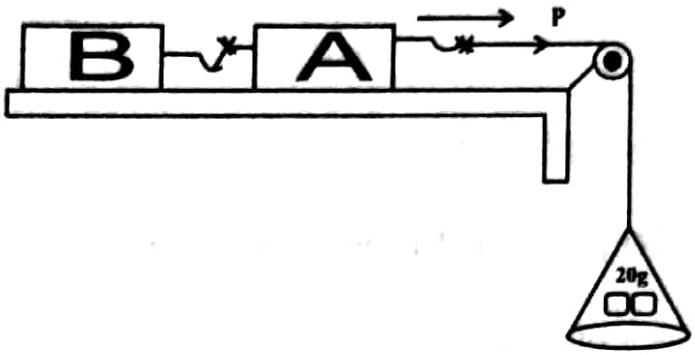


This proves the limiting friction is independent of area of contact.

Third Law: To verify that limiting friction depends on the nature of the surfaces in contact. Make one surface of A smooth and well-polished and the opposite surface of A very rough. Repeat the above experiment and the force of limiting friction is determined when

a. The rough surface is in contact with the table.

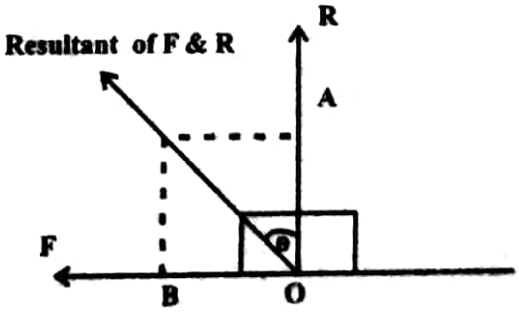
b. The smooth surface is in contact with the table.

It is observed that the limiting fiction is less for smooth surface than rough surface is in contact with the table.

Hence the force of limiting friction depends on the nature of surfaces in contact.

1.13 Angle of Friction

The angle of friction is defined as the angle which the resultant of the limiting friction (F) and the normal reaction (R) makes with the normal reaction.



In the fig the resultant of the limiting friction and normal reaction R makes an angle θ with the normal reaction.

$$\tan\theta = \frac{OB}{OA} = \frac{F}{R} \qquad \text{.....(1)}$$

But $$\mu = \frac{F}{R} \qquad \text{.....(2)}$$

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From Equation 1 and 2

$$\boxed{\text{Tan } \theta = \mu}$$

Thus co-efficient of limiting friction is equal to the tangent of the angle of friction.

1.14 Angle of Repose or Angle of Sliding

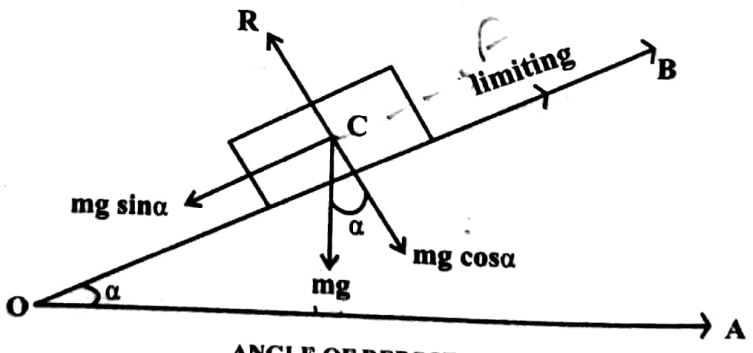
Angle of repose or angle of sliding is defined as the minimum angle of inclination of a plane with the horizontal, such that a body placed on it just begins to slide.

Consider an inclined plane, whose inclination with horizontal is gradually increased till the body placed on its surface just begins to slide down. If 'α' is the inclination at which the body just begins to slide down, then α is called the angle of repose.

The body is under the action of the following forces:

1. The weight Mg of the body acting vertically downwards. This is resolved into two components.
   a. Mg cos α acting perpendicular to inclined plane
   b. Mg sin α acting along the inclined plane.
2. The limiting friction F acting along the inclined plane in the upward direction. In magnitude, it is equal to the component of mg acting along the inclined plane.

$$F = Mg \sin \alpha \quad \text{.....} (1)$$



ANGLE OF REPOSE

3. The normal reaction R is acting at right angle to the inclined plane in the upward direction. It is equal to Mgcos α.

$$R = Mg \cos \alpha \quad \text{.....} (2)$$

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Dividing 1 by 2, we have

$$\frac{F}{R} = \frac{Mg \sin a}{Mg \cos a}$$

$$\frac{F}{R} = \tan \alpha \quad \text{.....(3)}$$

We know,

$$\frac{F}{R} = \mu \quad \text{.....(4)}$$

Therefore, from 3 and 4:

$$\mu = \tan \alpha \quad \text{.....(5)}$$

Therefore, the coefficient of static friction is equal to the tangent of the angle of repose.
We know Angle of Friction

$$\tan \theta = \mu \quad \text{.....(6)}$$

From equation 5 and 6:

$$\alpha = \theta \quad \text{.....(7)}$$

i.e. the angle of repose is equal to the angle of friction.

A year spent in artificial intelligence is enough to make one believe in God.

— Alan Perlis

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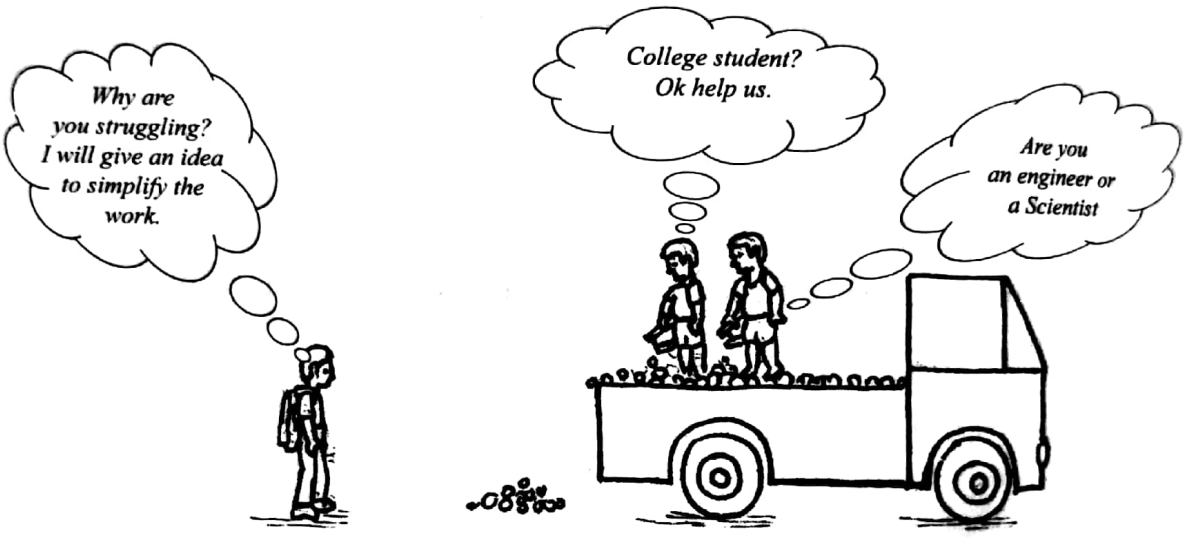

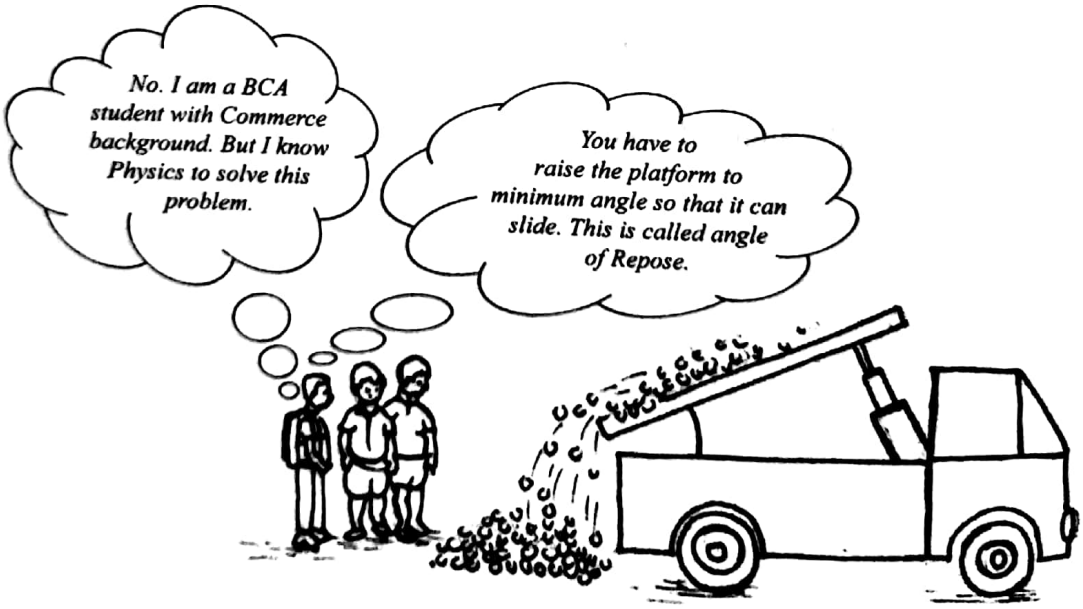

A ship in port is safe, but that's not what ships are built for.

— Grace Hopper

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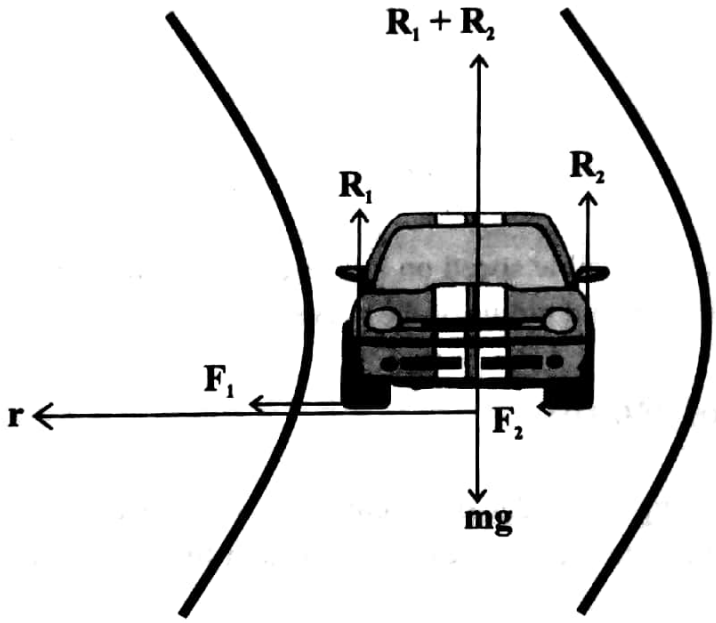
1.15 Velocity of Vehicle on Curved Road

Consider a vehicle of weight *mg* going around on a curved path of radius r. Let v be the velocity of the vehicle. While negotiating the curved path , the wheels of the vehicle have a tendency to leave the curved path and regain the straight line path. Frictional force between the tyres of the vehicle and the road opposes this tendency of the wheels. This frictional force acts towards the centre of the circular path and provides necessary centripetal force.

Let F_1 and F_2 be the forces of friction of inner wheels and outer wheels of the vehicle.

Let R_1 and R_2 be the normal reaction of the road on the wheels.

Let μ be the coefficient of friction between tyres and the road.



According to the figure

$R_1+R_2=$ mg

And

$$F_1+F_2 = \frac{mv^2}{r} \qquad \text{.....(1)}$$

We know F = μR and we can write

$F_1=\mu R_1$

$F_2=\mu R_2$

One man's constant is another man's variable.

—Alan Perlis

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Then total centripetal force will be

$F_1+F_2 = \mu(R_1+R_2)$

Substitute $(R_1+R_2) = mg$

$F_1+F_2 = \mu mg$ .....(2)

From equation 1 and 2, we have

$$\frac{mv^2}{r} = \mu mg$$

Therefore,

$v^2 = \mu gr$

$v = (\mu rg)^{1/2}$

Where v is the maximum possible speed on a leveled curved road and this velocity depends on the coefficient of friction and radius of the curve.

1.16 Banking of Roads

The phenomenon of raising outer edge of the curved road above the inner edge so as to provide necessary centripetal force to the vehicles to take a safer turn is called banking of road.

Explanation

The maximum velocity with which a vehicle can go round a level road without skidding depends upon coefficient of friction μ and the value of 'μ' decreases:

1. When the road is smooth or
2. The tyres of the vehicle are worn out or
3. The road is wet.

Thus force of friction is not reliable source for providing required centripetal force.

Especially in hilly areas where the vehicle has to move constantly along the curved track, the maximum speed at which it can run will be very low. If any attempt is made to run it at a greater speed, the vehicle is likely to skid and go out of track. In order that the vehicle can go round the curved track at a reasonable speed without skidding, the sufficient centripetal force is managed for it by raising the outer edge of the track a little above the inner edge. It is called banking of the circular track or Banking of Roads.

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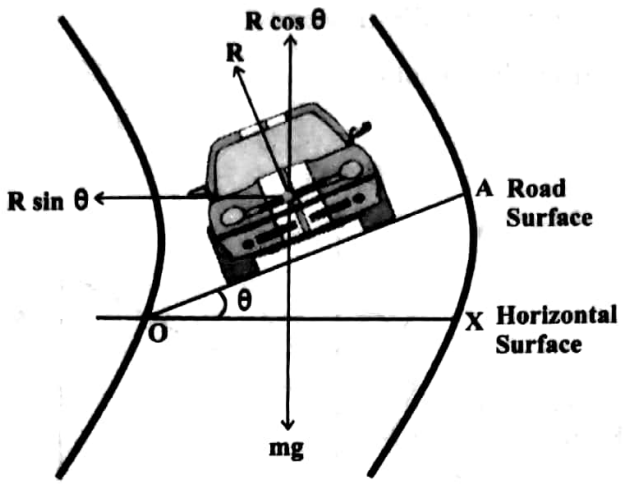
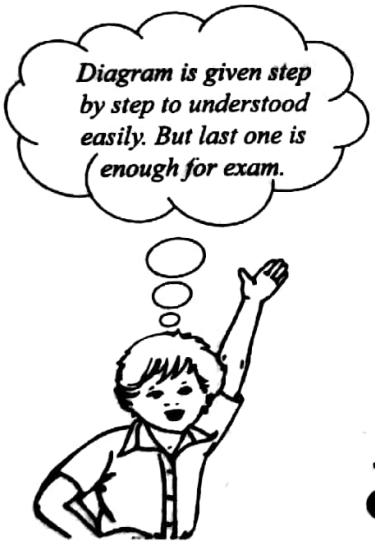
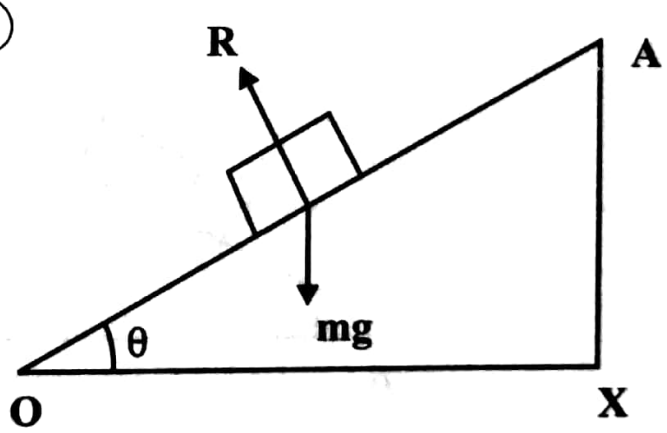


Expression For Velocity

In figure OX is the horizontal line; OA is the level of banked curved road, whose outer edge has been raised. **Angle XOA=angle of banking**.





Two forces acting on the vehicle are shown in figure:

1. Weight Mg of vehicle acting vertically downwards.
2. Normal reaction 'R' of the banked road acting upwards in a direction perpendicular to OA.

We can only see a short distance ahead, but we can see plenty there that needs to be done.

— Alan Turing

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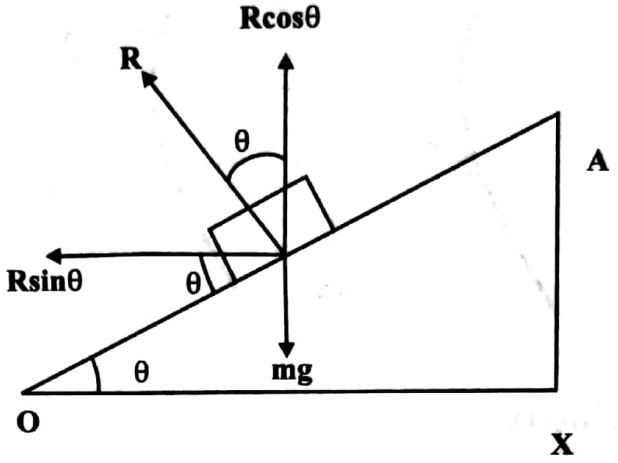
Resolving R into horizontal and vertical components we have

a. $R\cos\theta$ along vertically upwards.

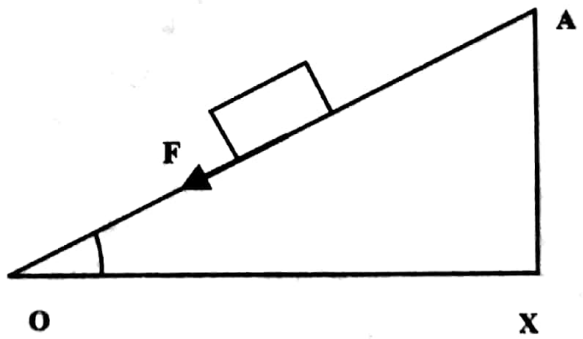
b. $R\sin\theta$ along horizontal.

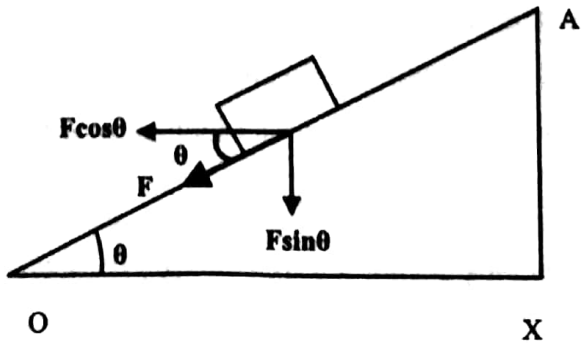


3. Force of friction 'F' between banked road and tyres acting along AO. It is resolved into two components

a. $F\cos\theta$ along horizontal.

b. $F\sin\theta$ along vertically vertically downwards.





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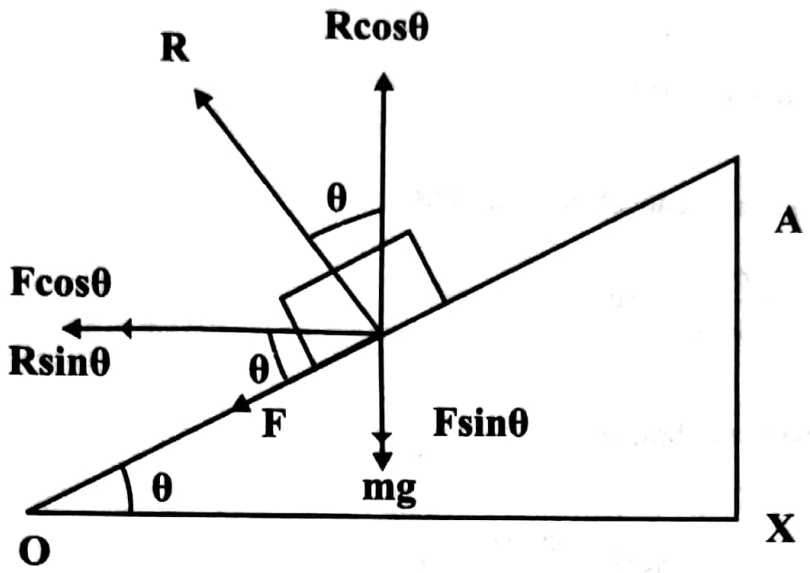
Now all the forces are together can be drawn in one diagram as follows



Now Equating the forces:

$$R\cos\theta = Mg + F\sin\theta \qquad \text{.....(1)}$$

The horizontal components of R and vertical component of F give centripetal force.

$$R\sin\theta + F\cos\theta = \frac{Mv^2}{r} \qquad \text{.....(2)}$$

We know:

$$F = \mu R \qquad \text{.....(3)}$$

Substituting equation 3 in 1:

$$R\cos\theta = Mg + \mu R\sin\theta$$

$$R\cos\theta - \mu R\sin\theta = Mg$$

$$R(\cos\theta - \mu\sin\theta) = Mg \qquad \text{.....(4)}$$

Substituting F value in Equation 2:

$$R\sin\theta + \mu R\cos\theta = \frac{Mv^2}{r}$$

$$R(\sin\theta + \mu\,\text{os}\,\theta) = \frac{Mv^2}{r} \qquad \text{.....(5)}$$

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Dividing equation 5 by equation 4:

$$\frac{R(\sin\theta+\mu\cos\theta)}{R(\cos\theta-\mu\sin\theta)}=\frac{Mv^2}{rMg}$$

Rearranging to get v^2 and cancelling R and M

$$v^2=\frac{(\sin\theta+\mu cos\theta)}{(cos\theta-\mu sin\theta)}\times rg$$

Taking $\cos\theta$ outside the bracket:

$$v^2=\frac{\cos\theta\left\{\left(\frac{\sin\theta}{\cos\theta}\right)+\mu\right\}}{\cos\theta\left\{1-\mu\frac{\sin\theta}{\cos\theta}\right\}}\times rg$$

$$v^2=\frac{(\tan\theta+\mu)}{(1-\mu\tan\theta)}\times rg$$

$$v^2=\left[\frac{(\tan\theta+\mu)}{(1-\mu\tan\theta)}\right]\times rg$$

$$v=(rg)^{\frac{1}{2}}\left[\frac{(\tan\theta+\mu)}{(1-\mu\tan\theta)}\right]^{\frac{1}{2}}$$

Thus comparing the velocity of the vehicle $v=(\mu r g)^{1/2}$ along normal curved road and above velocity we observe that velocity of banked road is greater than normal curved road.

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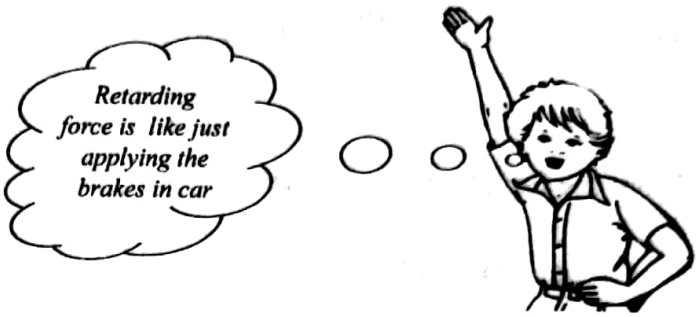
1.17 Numerical Problems

1. A body of mass 100 kg is moving is with a speed of 20m/s. A Retarding force of 100N is applied to it. How long does the body take to stop?

Given Data:

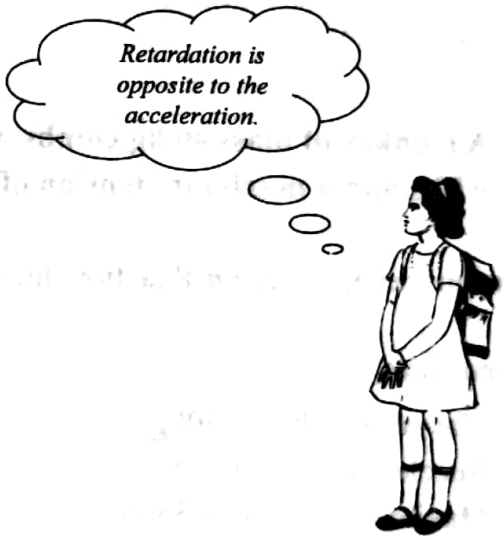
Retarding force =100 N
Mass of body =100 kg
Initial Velocity =20m/s
Final velocity = 0



Solution:

We Know Force F = m .a
Since the force is bringing the body to rest, in the above formula 'a' is called retardation and we take it as negative.

Retardation $a = \frac{F}{m}$



Retardation $a = \frac{100}{100} = -1m/s^2$

We know $v = u + at$

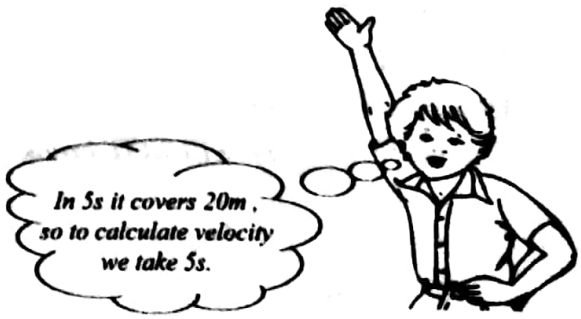
$0 = 20 - 1 \times t$
$t = 20s.$

The body will take 20 seconds to stop due to the applied retarding force.

2. A force acts for 2s on a body of mass 5 kg initially at rest, after which the force ceases to act. The body travels 20m in the next 5s. Find the magnitude of the force.

Given Data:

Mass of body= 5kg
Initial velocity = 0
Distance travelled by the body = 20 m
Time taken by the body to travel 20m = 5s



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Time of force acting on the body = 2 s
Force = ?

Solution:

The velocity $v = \frac{20m}{5s} = 4\ m/s$

From the Equation, $v = u + at$

$4 = 0 + a \times 2$

$a = 4/2 = 2\ m/s^2$.

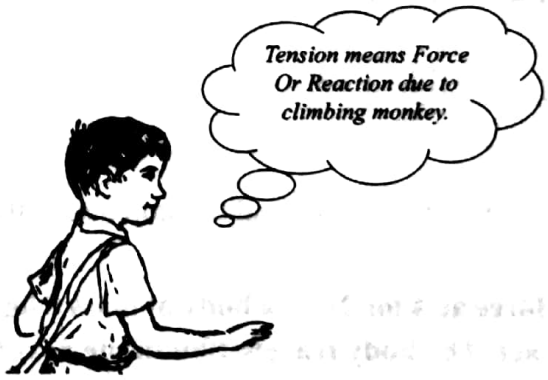
Now, $F = m.a$
$= 5 \times$
$F = 10\ N$.

3. A monkey of mass 40 kg climbs with an acceleration of 2.2 m/s² on a rope which can withstand a maximum tension of 550 N. Will the rope break ? (g = 9.8)

Tension means Force Or Reaction due to climbing monkey.

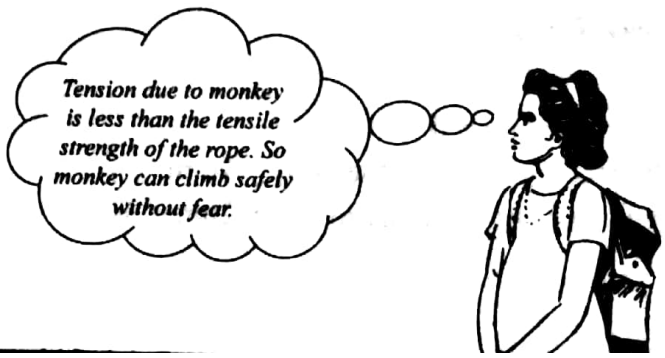
Given Data

Mass of monkey = 40kg
Acceleration = 2.2 m/s²
Maximum Tension = 550N



Solution

Tension T = M (g + a)
T = 40 (9.8 + 2.2)
T = 40 x 12
T = *480 N.*
Hence, 550 N > 480 N
Therefore, *the rope will NOT break.*



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4. While launching a rocket of mass 10^5 kg, a force of 10^7 N is applied for 20s. What will be the speed attained by the rocket at the end of 20s?

Given Data

Mass m = 10^5 kg
Force f = 10^7 N
Time = 20 s

Solution

Acceleration $a = \frac{f}{m} = 10^7 / 10^5 = 100\ m/s^2$

From the Equation, v = u + at
v = 0 + 100 x 20
Speed = *2000 m/s.*

5. A constant force acting on a body of mass 7 kg changes its speed from 2m/s to 7m/s in 10 s, the direction of motion of the body remaining unchanged . Find the magnitude of the force.

Given Data

Mass of body=7kg
Initial velocity=2m/s
Final velocity=7m/s
Time = 10 s

Solution

From the Equation, v = u + at
Substituting the values,
7 = 2 + 10*a
a = 0.5 m/s²
Now, F = ma
= 7 * 0.5
F = *3.5 N.*

We can calculate by following other method also.

According to Second law, $Force\ F = \frac{dp}{dt}$

Change in momentum = 7 x (7 – 2)
= 35 Kg m/s

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$$Force\ F = \frac{dp}{dt} = \frac{35}{10}$$

Force F= 3.5 N.

6. A man of mass 60 kg stands in a lift. Determine the apparent weight of the man when lift starts moving upward with an acceleration of $2m/s^2$. (g = 10). Also find the apparent weight when it moves downward with an acceleration of $2m/s^2$.

Given Data

Mass m =60 kg

Acceleration of the lift in upward direction = $2m/s^2$

Solution:

(a) The apparent weight of the man when lift starts moving upward with acceleration

$W_1 = M(g + a)$

$= 60(10 + 2)$

$= 720\ N.$

(b) The apparent weight of the man when lift starts moving downward with an acceleration

$W_2 = M(g - a)$

$W_2 = 60(10 - 2)$

$W_2 = 480$ N.

7. A boy throws a ball of mass 400 gm on a wall with a speed of $15ms^{-1}$. It bounces back with the same speed. Calculate the impulse.

Solution:

Given Data:

Mass of the ball = 400gm = 400×10^{-3}kg = 0.4 kg

Speed of the ball $v_1 = 15ms^{-1}$

When the ball bounces back the speed $v_2 = -15ms^{-1}$

{Here instead of speed, it is a velocity and when it bounces its direction is opposite. So we have to take it negative.}

Impulse I = Mass $[v_1 . v_2]$

Impulse I = $0.4 \times [15-(-15)]$

Impulse I = 0.4×30

Impulse I = 12 kg ms^{-1}

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8. A block weighing 200 N is pushed along a surface. If it takes 80 N to get the block moving and 40 N to keep the block moving at a constant velocity, what are the coefficients of friction μ_s and μ_k?

Given Data:

Weight of the block = 200 N
Force required to just move = 80 N
Force required to keep moving = 40 N
Coefficients of friction μ_s and μ_k?

Solution

i) $F = \mu_s R$
R is equal to the weight of the block, so R = 200 N.
Substituting these values in the formula.
$80 = \mu_s \times 200$

$$\mu_s = \frac{80}{200}$$

Coefficient of Static Friction $\mu_s = 0.4$

ii) $f = \mu_k \times R$
μ_k is the coefficient of kinetic friction and the force required to maintain a constant velocity is given as 40 N.
$40 = \mu_k \times 200$
$\mu_k = 0.2$

The two coefficients of frictions are $\mu_s = 0.4$ and $\mu_k = 0.2$.

9. Calculate the force of friction acting on a 15 kg block sliding on a concrete floor of μ=0.6 .

Given Data

Mass = 15 kg
g = 10 approximately.
Force F ?

Solution:

$F = \mu R$
Here R = mg = 15 x 10

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F= 0.6 x (15x10)
F = 90 N.

10. A man needs to apply a force of 190N to move a 95kg table to a different location in the Hall. What is the coefficient of static friction between the table and the floor?

Given Data

Mass = 95 *kg*
Force = 190 *N*

Solution:

We know
F= μR
R= mg
Here g is taken as 10 approximately.
R = 95 x 10 = 950 N
Now,
190 N = μ (950)

$$\mu = \frac{190}{950}$$

μ = 0.2

The coefficient of static friction between the table and the floor, μ = 0.2

11. A bullet of mass 0.05 kg is fired with a speed of 100 ms^{-1} and it penetrates a wooden block. The bullet is stopped after travelling a distance of 40 cm. Determine the resistance force exerted by the block on the bullet to bring halt.

Given Data

Mass of the bullet m =0.05kg
Initial velocity u = 100ms^{-1}
Final velocity v = 0
Distance travelled by the bullet s =40cm = 0.4m

Solution

We know $v^2 - u^2 = 2as$
Substituting the values we have,

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$0-(100)^2 = 2a \times 0.40$

$a = -12500\ ms^{-1}$

i.e. Retardation $a = 12500\ ms^{-1}$

Hence, Retarding force = mass x retardation

$F = 0.05 \times 12500$

$F = 625N$

12. A cyclist moving with a speed of $5ms^{-1}$ has seen nails on the road. He applies the breaks and brings the cycle to halt in 5s. Calculate the retardation.

Given Data:

Initial Velocity of the cyclist = $5ms^{-1}$

Final velocity of the cyclist = 0

Time taken t = 5 s

Solution:

We know $v = u + at$

$a.t = v-u$

$a.5 = -5$

$a = -1ms^{-2}$

Hence, retardation = $-1\ ms^{-2}$

13. The coefficient of friction between the road and the wheels of a bike is 0.5. The bike starts from rest and acquires a speed of 20m/s. What is minimum distance the bike covered?. (Take $g=10\ m/s^2$)

Given Data:

Coefficient of friction = 0.5

Initial velocity = 0

Final velocity = 20m/s

Distance covered ?

Solution:

Coefficient of friction $\mu = \frac{f}{R} = \frac{ma}{mg} = \frac{a}{g}$

$a = \mu g$

$a = 0.5 \times 10$

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$a = 5m/s^2$

Using $v^2 - u^2 = 2as$

$(20)^2 - 0 = 2 \times 5 \times S$

$$S = \frac{400}{10} = 40\ m$$

The minimum distance covered by the bike is 40 m.

14. A block lying on a floor of a truck remains stationary, while the truck is accelerated. The coefficient of static friction between the block and the truck's floor is 0.25. Calculate the acceleration of the truck.

Take $g=10m/s^2$

Given Data:

Coefficient of friction = 0.25.

$g=10m/s^2$

Solution:

$F = Ma$ 1

$F = \mu R$.....2

Since $R = Mg$,

$F = \mu(Mg)$.....3

$Ma=M\mu g$

$a=\mu g$

$a = 0.25 \times 10=2.5m/s^2$

The acceleration of the truck is $2.5m/s^2$.

15. A rectangular box of mass 2 kg is placed on a ground. The coefficient of static friction between the box and ground is 0.5. If a boy applies some force to displace the box , Find the magnitude of force .($g=10\ m/s^2$)

Given Data:

Mass of the box = 2 kg

Friction = 0.5

Solution: $$\mu = \frac{f}{R} = \frac{f}{mg}$$

$f=\mu mg$

$f=0.5x2x10$

$f=10\ N$

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CHAPTER

2 WORK, ENERGY AND COLLISION

2.1 Work

In day-to-day life, the term work is used to refer to any form of activity that requires the exertion of mental or muscular efforts. In physics, work is said to be done by a force when the body is displaced actually through some distance in the direction of applied force.

Work done by force is equal to the product of the force and the displacement of the object in the direction of force.

If under a constant force F the object is displaced through a distance **s**, and θ is the angle from the straight line path of the object then work done by the force is

$$W = \vec{F}.\vec{s}$$

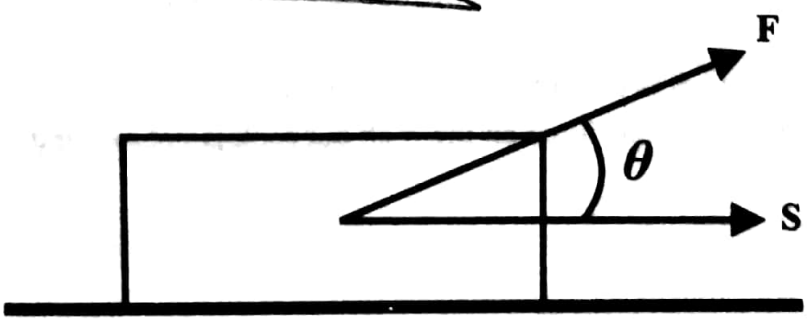
$$W = F.s\cos\theta$$

If F and s are in the same direction then $\theta = 0$.

$$W = F \times s$$

Thus work done by force is the dot product of the force and the displacement.

Work is a scalar quantity. It's SI unit **is joule** .



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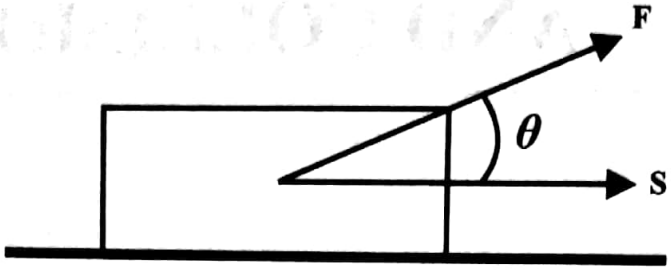
Positive work done

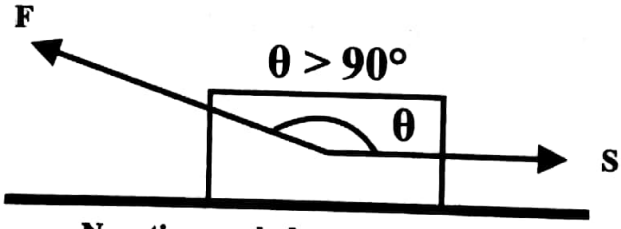
Work done is positive when θ is less than 90°.



1. When an object falls freely due to gravity , then $\theta = 0$, and cos θ =0. Therefore work done by gravity is positive
2. Stretching force is positive in case of a spring is stretching.

Negative work done

Work done is negative when θ is more than 90°.



Negative work done by a force F

Example:

1. When an object is thrown up, its motion is opposed by gravitational force.
   When θ is equal to 180°
   Cos 180° = -1.

Hence work done by gravity on a object thrown upwards is negative

Work done is zero : when θ is equal to 90.i.e. cos90 = 0.
When we push the rock, we exert force on the rock but rock is not moving.
Therefore work done is zero.

2.2 Energy

Energy of a body is its capacity of doing work.
It is a scalar quantity. Its SI unit is joule.

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There are several types of energies, such as mechanical energy (Kinetic energy and Potential energy), chemical energy, light energy, heat energy, sound energy, nuclear energy, electric energy etc.

2.3 Kinetic Energy

The kinetic energy of a body is the energy possessed by a body by virtue of its motion.

Example:

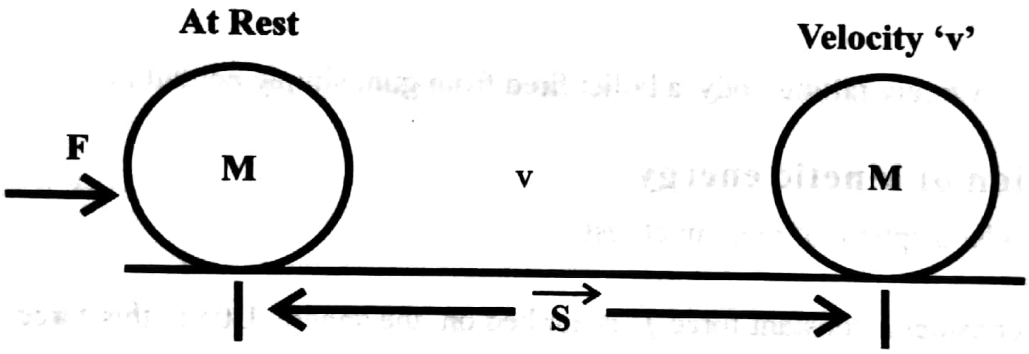
A freely falling body, a bullet fired from gun, simple pendulum.

Expression of kinetic energy

Let us consider a sphere of mass m at rest.

Let us consider a constant force is applied on the sphere. Due to this force the spere is moving with a velocity along the direction of force.

Let s be the displacement of the sphere.



We know work done W = F. s .....(1)

If ' a' is the acceleration of sphere then by Newton's second law

F = m.a .....(2)

Substituting Equation (2) in Equation (1)

W = m.a.s .....(3)

We know, $v^2 = u^2 + 2as$

Since the sphere initially is at rest u = 0.

Acceleration $a = \frac{v^2}{2s}$

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Substituting the value of 'a' in equation (3)

$$W = m \times \frac{v^2}{2s} s$$

Cancelling s we have ,

$$W = \frac{mv^2}{2}$$

This work done on the sphere is a measure of kinetic energy acquired by sphere.

$$\text{Kinetic Energy (K.E)} = \frac{mv^2}{2} \quad \text{..... (4)}$$

2.4 Kinetic Energy in another form

The kinetic energy of a body is the energy possessed by a body by virtue of its motion.

Example:

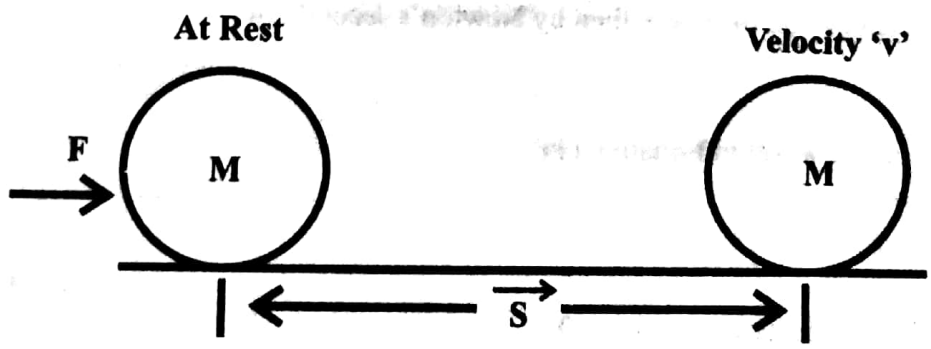
A freely falling body, a bullet fired from gun, simple pendulum.

Expression of kinetic energy

Let us consider a sphere of mass m at rest.

Let us consider a constant force $\vec{F}$ is applied on the sphere. Due to this force, the sphere is moving with a velocity along the direction of force.

Let $\vec{ds}$ be the displacement of the sphere.



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We know work done dW = $F.ds$ .....(1)

If 'a' is the acceleration of sphere then by Newton's second law

$F = m \, . \, a$ .....(2)

Substituting equation 2 in 1, we have,

$dW = ma.ds$

But , Acceleration $a = \frac{dv}{dt}$

$$dW = m\frac{dv}{dt} \times ds$$

$$dW = m \times dv\frac{ds}{dt}$$

We know, Velocity $v = \frac{ds}{dt}$

$$dW = m.v.dv$$

The work done on the sphere in order to increase its velocity from 0 to v is given by

$$W = \int_0^v m.v.dv$$

$$W = m\int_0^v .v.dv$$

$$W = \left[m\frac{v^2}{2}\right]$$

This work done W is equal to kinetic energy of any object moving with velocity v and mass m.

Example:

A freely falling body, a bullet fired from gun, simple pendulum.

2.5 Work energy theorem

The work done by a force acting on a body during its displacement is equal to the change in kinetic energy of the body during that displacement.

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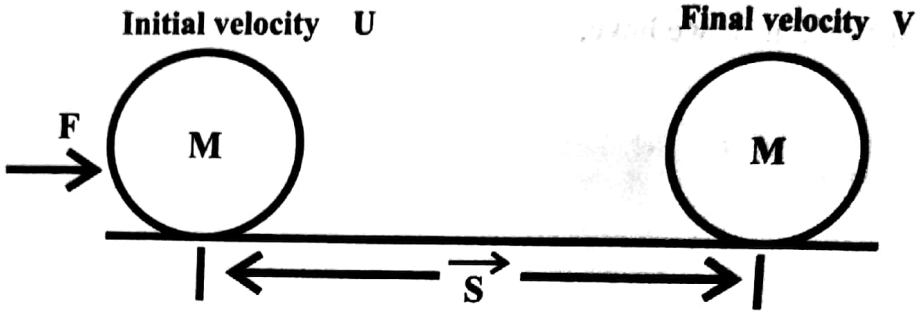
Let us consider a sphere of mass m at rest.

Let us consider a constant force $\vec{F}$ is applied on the sphere. Due to this force, the sphere is moving with a velocity along the direction of force.

Let $\vec{ds}$ be the displacement of the sphere.



We know work done dW = $\vec{F}.\ \vec{ds}$ ..... (1)

In scalar form when angle is zero.

$dW = F.\ ds$ .....(2)

If ' a' is the acceleration of sphere then by Newton's second law

$F = m\ .\ a$ .....(3)

Substituting the value of F in equation (2)

$dW = ma.\ ds$

But acceleration $a = \dfrac{dv}{dt}$

$$dW = m\frac{dv}{dt} \times dS$$

Rearranging ds & dv

$$dW = m \times dv\frac{ds}{dt}.$$

But velocity $v = \dfrac{ds}{dt}$

The work done on the sphere in order to increase its velocity from U to V is given by

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$$dW = m.v\ .dv$$

$$W = \int_u^v m.v.dv$$

Integrating from initial velocity to final velocity, Here initial velocity = 0.

$$W = m\int_0^v v.dv$$

$$W = m\frac{v^2}{2}$$

This work done W by the force increases its initial velocity U to final velocity V is given by

Work done $W = m\int_u^v vdv$

$$W = \left[m\frac{v^2}{2}\right]_u^v$$

Applying the limits u to v we have

$$W = m\left[\frac{v^2}{2} - \frac{u^2}{2}\right]$$

Thus work done by force acting on a body during its displacement is equal to the change in the kinetic energy of the body.

2.6 Potential energy

The potential energy of a body is defined as the energy possessed by the body by virtue of its position. Depending upon the nature of the force operating in the system, the potential energy can be of different types:

1. **Gravitational Potential Energy**: A system of two material bodies exerting gravitational attractive force on each other possesses gravitational P.E. Gravitational P.E. of a system is always negative.
2. **Electrostatic Potential Energy.** : The potential energy of a system of two electric charges is called electrostatic P.E.

   In the case of like charges the electrostatic P.E. is positive.

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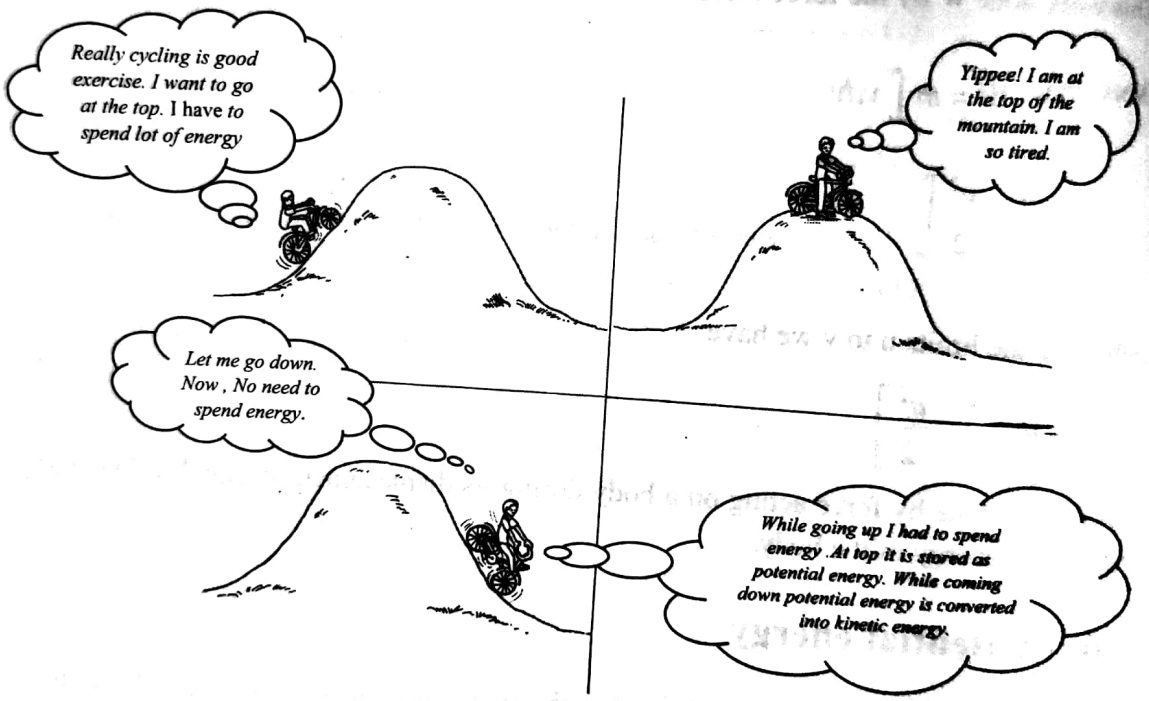
In case of two unlike charges it is negative.

3. **Elastic Potential Energy** : When a mass attached to a spring is displaced from its equilibrium position, restoring force is set up in the spring due to the property of elasticity.

The work done against the restoring force set up due to elasticity is stored in the system in the form of its elastic potential energy.

Examples:

1. Water stored in reservoir.
2. A Wound Spring
3. Stretched Rubber.
4. Velocity on releasing the bow.



2.7 Gravitational Potential Energy

Consider a body of mass M is lying at point A on the surface of the earth. It will be attracted towards the centre of the earth with a force Mg equal to the weight of the body. Here 'g' is the acceleration due to gravity on surface of the earth.

In order to move the body up from point A to B with zero acceleration, a force Mg has to be applied on the body in upward direction. If the body is moved through a height 'h' then

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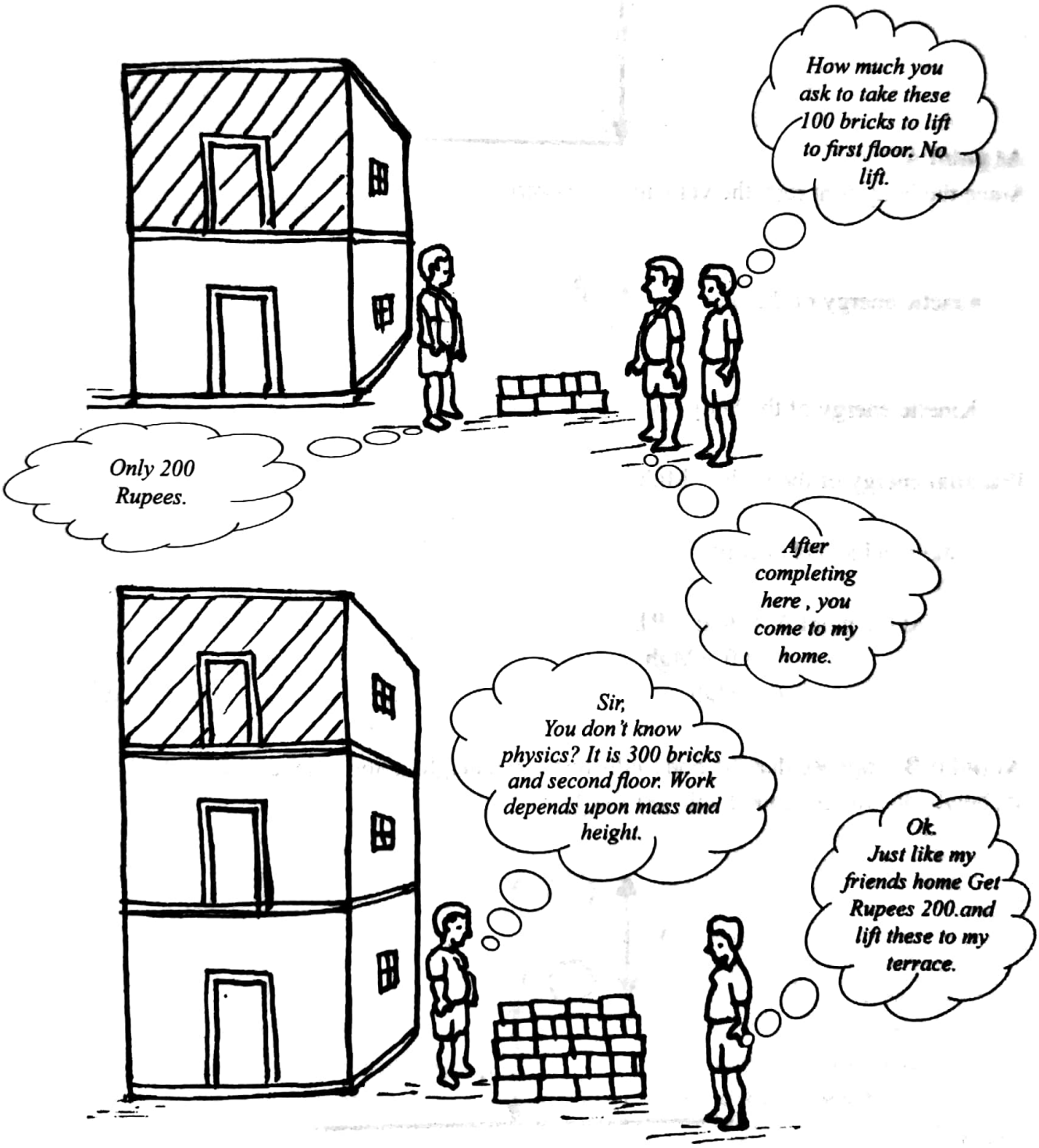
Work done W = Force X distance

W= mgh

here F = ma. And height =h

This work done is stored inside the body as its gravitational potential energy at the point B

P.E.= Mgh



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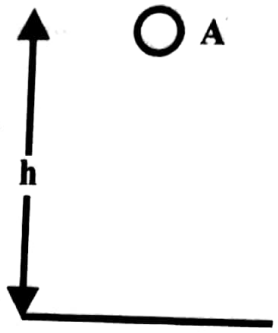
2.8 Conservation of Gravitational P.E. into K.E.

Consider a body of mass M lying at rest at the point 'A' at a height 'h' above the ground.



At point A:
Since the body is at rest, the velocity "v "is zero.

Kinetic energy of the body = $\frac{M(0)^2}{2}$

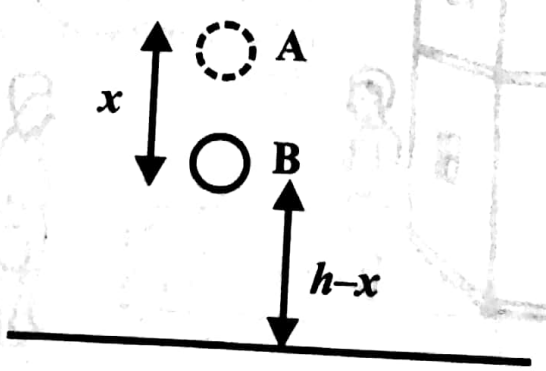
Kinetic energy of the body = 0

Potential energy of the body = Mgh

Total mechanical energy

At the point A = K.E + P.E
= 0 + Mgh
E = Mgh .....(1)

At point B: Suppose that the body falls through a height x and reaches the point B. Its height above the ground will be (h-x).



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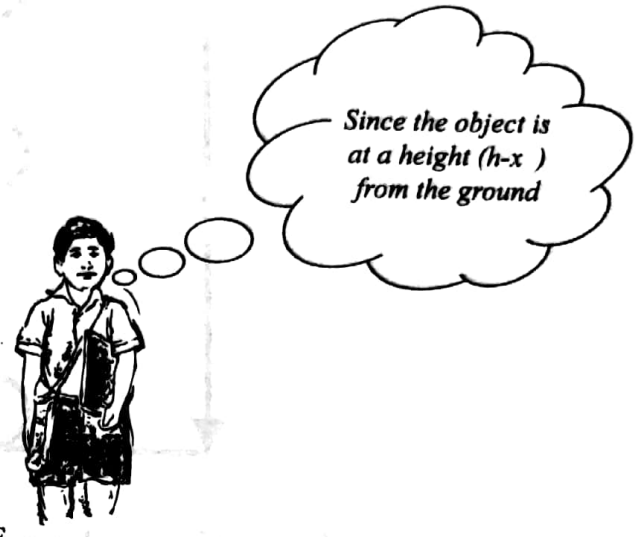
Let v be the velocity of the body at the point B.

We know $v^2 - u^2 = 2as$

Here $u = 0$ and $a = g$

Therefore $v^2 = 2gx$ ..... (2)

$$\text{Kinetic Energy} = \frac{Mv^2}{2}$$



$$\text{Sub (2), Kinetic Energy} = \frac{M.2gx}{2}$$

$$\text{Kinetic Energy} = Mgx$$

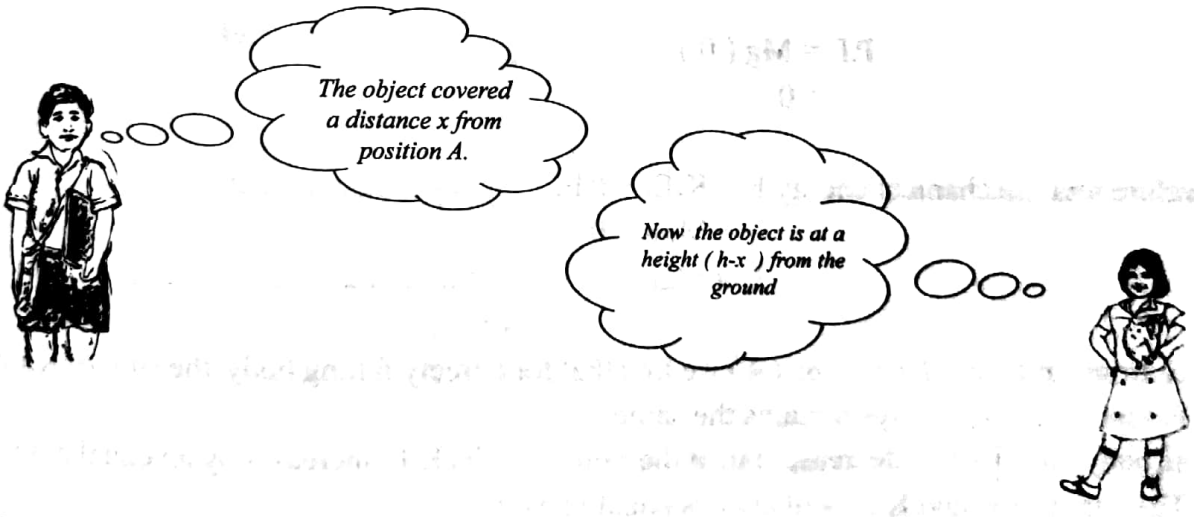
$$\text{Potential Energy} = Mg\,(h-x)$$

Therefore total mechanical energy = K.E. + P.E.

$$E = Mgx + Mg\,(h-x)$$
$$= Mgx + Mgh - Mgx$$

Cancelling Mgx and $-Mgx$, we have

Total energy = Mgh ..... (3)



The important thing is not to stop questioning. Curiosity has its own reason for existing. Anyone who has never made a mistake has never tried anything new.

— *Einstein*

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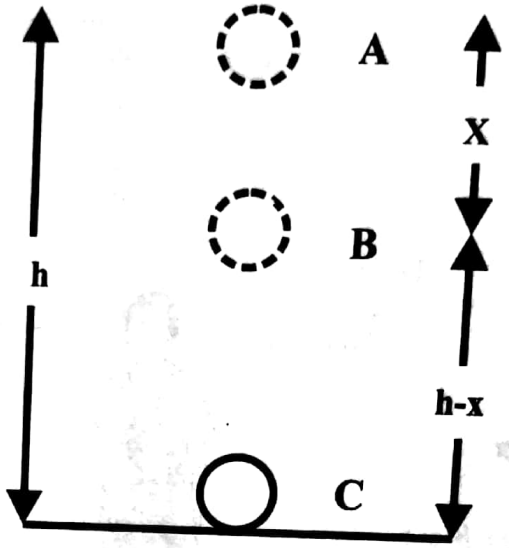
At point C : When the body finally reaches point ' C ' on the ground, its height above the ground is zero. Let V be the velocity acquired by the body on reaching the ground.



Then, using the equation $v^2 - u^2 = 2as$, Here $u = 0$ and s= height h

$$v^2 - 0 = 2gh$$

$$v^2 = 2gh$$

Kinetic energy $= (M.2gh)/2$

Therefore $K.E. = Mgh$

$$P.E = Mg(0)$$
$$= 0$$

Therefore total mechanical energy $E = K.E. + P.E.$

$$= Mgh + 0$$

$$E = Mgh \qquad \text{.....(4)}$$

Hence from equation (1), (3) & (4) we find that for a freely falling body, the sum of Kinetic and Potential energy always remains the same.

As the body falls, its P.E. decreases but at the same time its K.E. increases by an equal amount. The sum of P.E and K.E. will always equal to Mgh .

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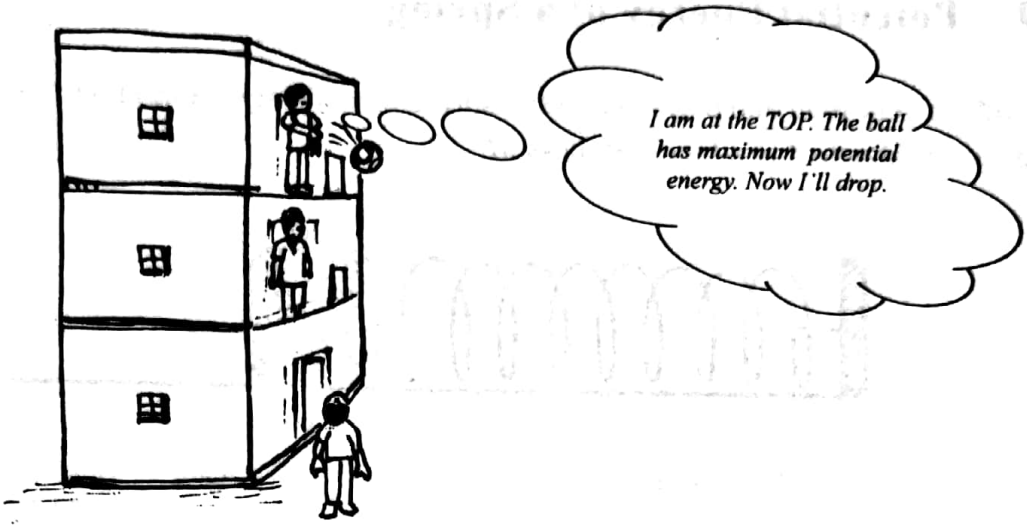

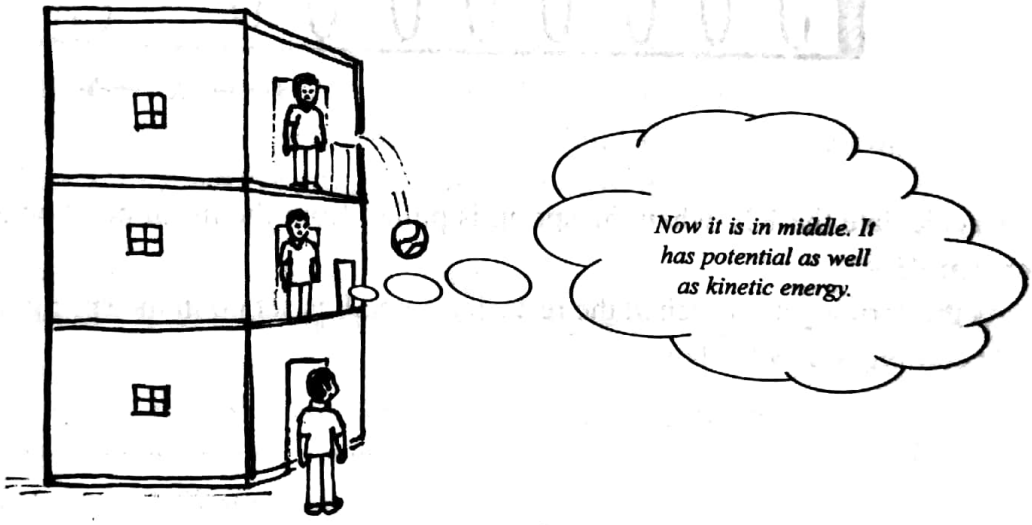

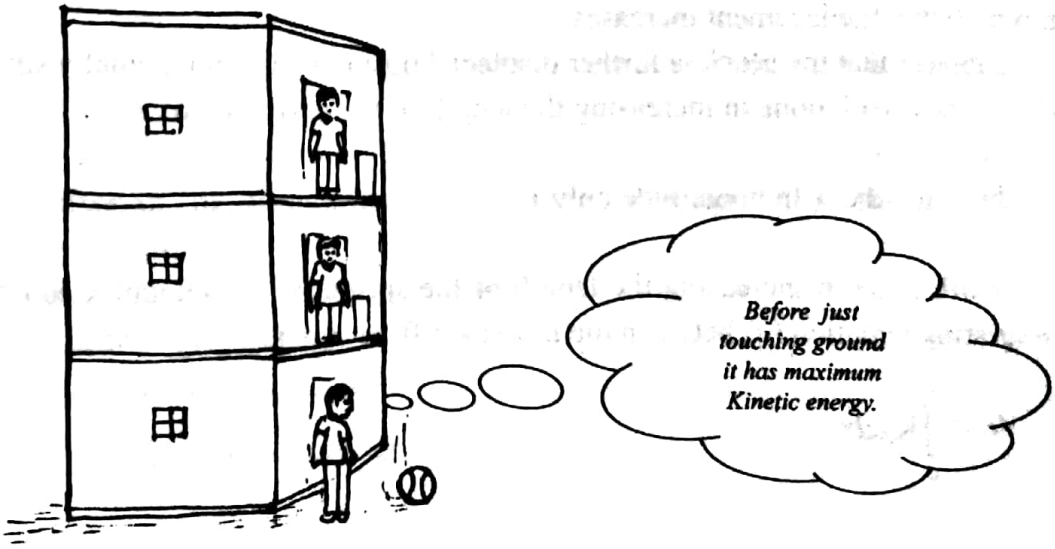

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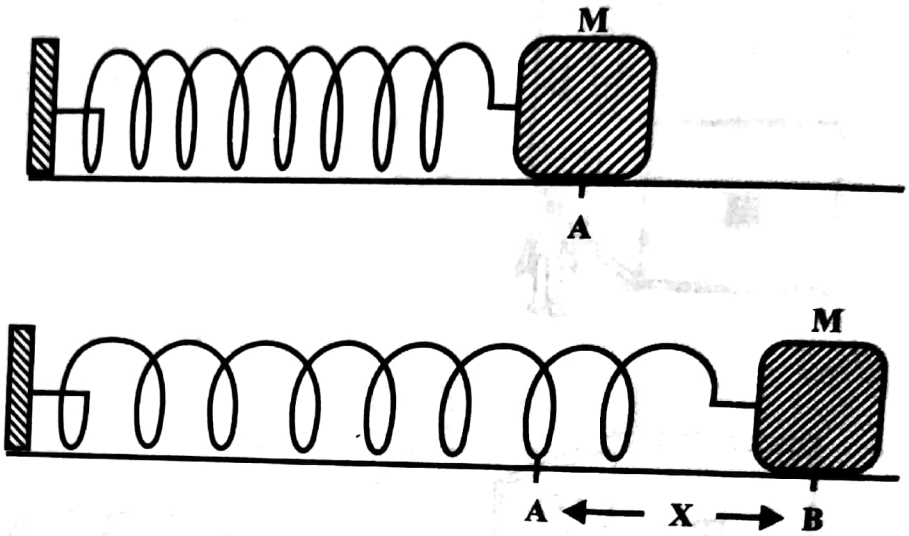
2.9 Potential Energy of a Spring

Consider a very light and perfectly elastic spring fixed firmly at one end to a rigid support. The other end is attached to a block of mass *M*.



Let us calculate the P.E. when the spring is pulled from the mean position *A* up to a point *B* such that $AB = x$

As the spring gets stretched the restoring force F is set up in the spring due to elasticity.

According to Hook's law

$F \propto x$

or $F = -K\ x$ ..... (1)

Where K is called force constant.

The negative sign shows that the restoring force acts in a direction opposite to the direction in which the displacement increases.

Suppose that the block is further displaced through an infinitesimally small distance dx. Then small work done in increasing the length of the spring by dx is

$dw = F.dx$

$dw = Kx.dx$ (In magnitude only) ..... (2)

The work done in increasing the length of the spring by an amount x can be calculated by integrating equation (2) between the limits x = 0 to x = x.

$$W = \int_0^x Kx dx$$

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$$= K \cdot \int_0^x x\,dx$$

$$= K\left[\frac{X^2}{2}\right]_0^x$$

$$= K\left[\frac{X^2}{2} - 0\right]$$

$$W = \frac{Kx^2}{2}$$

This work done is stored in the system as its potential energy at the point *B*

2. 10 Collision

Collision between two bodies is said to occur if physically strike against each other or if the path of the motion of one is influenced by the other. In physics, the term collision does not necessarily mean that a particle actually strikes. Two particles may not even touch and yet they are said to collide if one particle influences the motion of the other.

The collisions between two bodies are of following three types

(a) Elastic collision : If both momentum and K.E of the system are conserved then it is called elastic collision.

Example: In daily life, the collisions between two glass or preferably ivory balls may be taken as elastic collisions.

Characteristics of elastic collisions:

- The momentum is conserved.
- kinetic energy is conserved.
- The mechanical energy is not converted into any other form such as sound, heat, light energy.

(b) Inelastic collision: The momentum of the system is conserved but the K.E is not conserved in inelastic collisions.

The K.E lost appears in some other form of energy such as heat, sound etc

Characteristics of inelastic collision:

- The momentum is conserved.
- The kinetic energy is not conserved

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(c) Perfectly inelastic collision: Those collision in which the colliding bodies stick together after the collision and then move with a common velocity are called perfectly inelastic collision.

Example: A bullet fired into wooden block and moving with it.

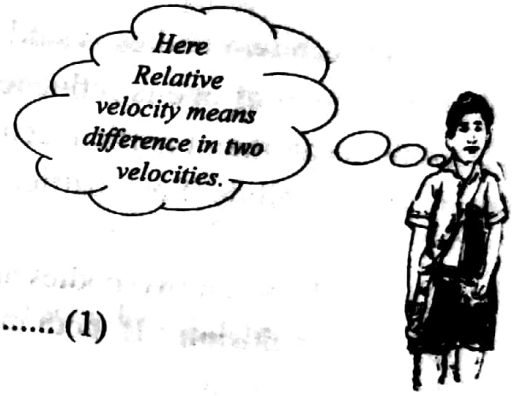
2.11 Coefficient of Restitution

The coefficient of restitution gives important idea about the nature of collision, whether energy is conserved or not conserved in the collision.

The coefficient of restitution is defined as the ratio of velocity of separation to the velocity of approach of the colliding bodies.

It is denoted by 'e'. Let us consider two bodies namely A and B of masses m_1 and m_2 moving with initial velocities u_1 and u_2 respectively along a straight line collide. After collision their respective velocities become v_1 and v_2 and they continue to move in the same straight line.

Then their relative velocity before collision is $u_1 - u_2$



Relative velocity after collision is $v_2 - v_1$

$$e = \frac{v_2 - v_1}{u_1 - u_2} \quad \text{.....(1)}$$

1. **For an elastic collision e = 1**

$$u_1 - u_2 = v_2 - v_1$$

Therefore, Velocity of separation is equal to velocity of approach.

2. **For an inelastic collision 0 < e < 1**

From equation (1) we have

$$0 < \frac{v_2 - v_1}{u_1 - u_2} < 1$$

(a) When $e = 0$, the collision is called Perfectly inelastic collision.

In this case $v_1 = v_2$

That means after collision both the bodies stick together and move with same velocity.

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2.12 Elastic Collision in One Dimension

The elastic collision in one dimension is a collision in which kinetic energy and momentum are conserved before and after collision and both the bodies continue to move in same straight line before and after collision.

Let *P* denotes momentum and *KE* denotes kinetic energy, then in one dimension elastic collision,

1. P (before collision) = P (after collision)
2. KE (before collision) = KE (after collision)

Let us consider two bodies namely A and B of masses m_1 and m_2.

Let u_1 and u_2 be their velocities respectively along a straight line and let us assume they collide. After collision their respective velocities become v_1 and v_2 and they continue to move in the same straight line.

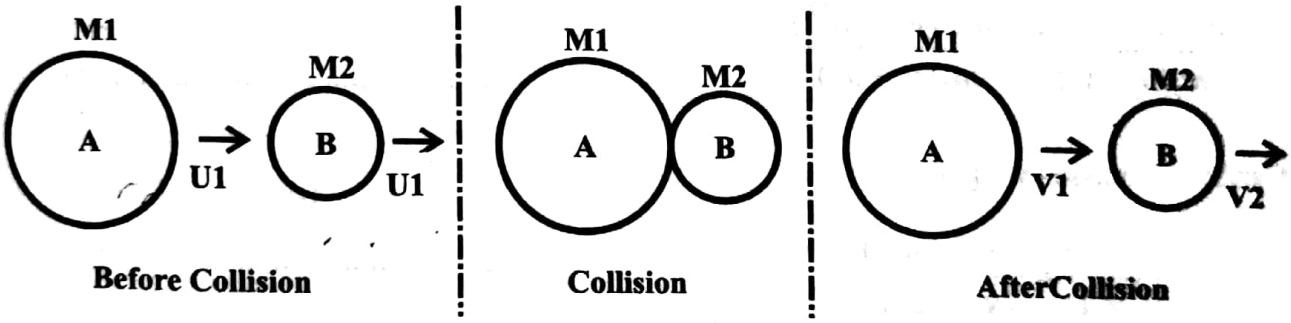

Fig: The two bodies A and B suffer head on collision.

From the law of conservation of momentum

Total momentum before collision = Total momentum after collision

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2 \quad \text{.....(1)}$$

Rearranging equation (1), keeping momentum of body A in LHS and keeping momentum of body B in RHS

$$m_1u_1 - m_1v_1 = m_2v_2 - m_2u_2$$

$$m_1(u_1 - v_1) = m_2(v_2 - u_2) \quad \text{.....(2)}$$

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From the law of conservation of kinetic energy

$$\frac{1}{2}m_1u_1^2+\frac{1}{2}m_2u_2^2=\frac{1}{2}m_1v_1^2+\frac{1}{2}m_2v_2^2 \quad \text{.....(3)}$$

Rearranging equation (3), keeping kinetic energy of the body A in LHS and keeing kinetic energy of body B in RHS

$$\frac{1}{2}m_1u_1^2-\frac{1}{2}m_1v_1^2=\frac{1}{2}m_2v_2^2-\frac{1}{2}m_2u_2^2 \quad \text{.....(4)}$$

Cancelling 1/2 and taking masses common we have,

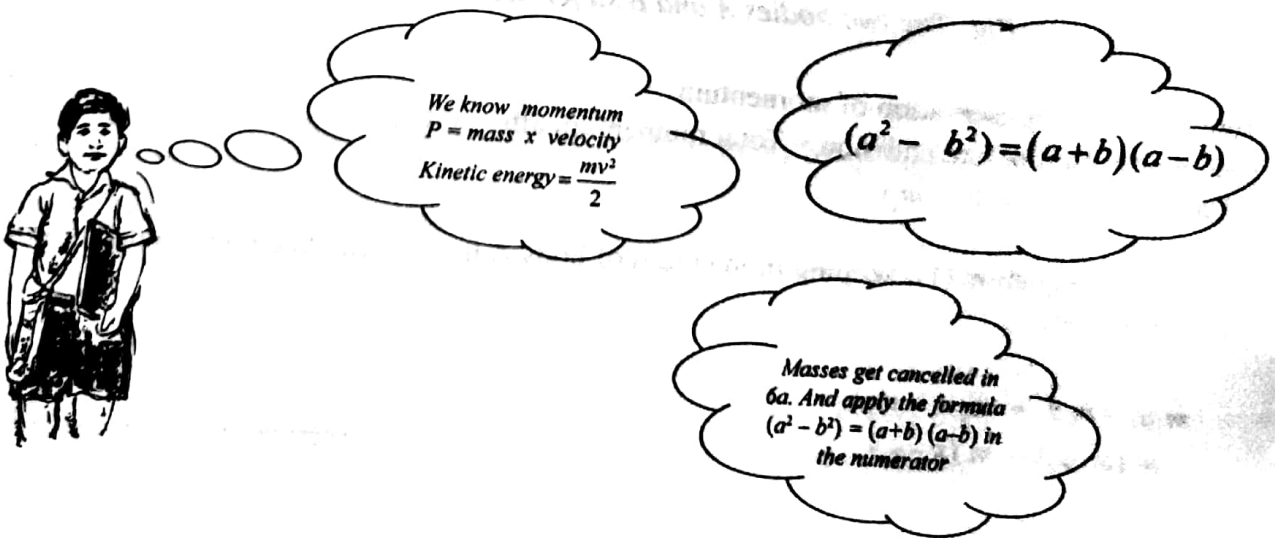
$$m_1(u_1^2-v_1^2)=m_2(v_2^2-u_2^2) \quad \text{.....(5)}$$

Dividing equation 5 and 2 we get

$$\frac{m_1(u_1^2-v_1^2)}{m_1(u_1-v_1)}=\frac{m_2(v_2^2-u_2^2)}{m_2(v_2-u_2)} \quad \text{.....(6)}$$

Canceling masses we get,

$$\frac{(u_1^2-v_1^2)}{(u_1-v_1)}=\frac{(v_2^2-u_2^2)}{(v_2-u_2)} \quad \text{.....(6a)}$$



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$$\frac{(u_1+v_1)(u_1-v_1)}{(u_1-v_1)} = \frac{(u_2+v_2)(v_2-u_2)}{(v_2-u_2)}$$

Cancelling,

(u_1-v_1) and (v_2-u_2) we get,

$$(u_1+v_1)=(u_2+v_2) \quad \text{.....(7)}$$

Rearranging velocities before collision and after collision,

$$(u_1-u_2)=(v_2-v_1) \quad \text{.....(8)}$$

The difference in initial velocities .i.e. u_1-u_2 is called velocity of approach.
The difference in final velocities v_2-v_1 is called velocity of separation.
Collision will occur only if $u_1>u_2$

After the collision the two bodies will separate only if $v_2 > v_1$
Thus velocity of approach = velocity of separation
In one dimensional elastic collision relative velocity of approach is equal to relative velocity of separation.

From equation (7)

$$(u_1+v_1)=(u_2+v_2)$$

$$v_2=u_1-u_2+v_1 \quad \text{.....(8a)}$$

Substituting equation (8) in equation (1)

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2(u_1-u_2+v_1)$$

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2u_1-m_2u_2+ m_2 v_1$$

Taking v_1 common in the right side

$$m_1u_1 + m_2u_2 = (m_1+ m_2) v_1 + m_2u_1- m_2u_2$$

$$m_1u_1 + m_2u_2-m_2u_1+m_2u_2 = (m_1 + m_2) v_1$$

$$(m_1-m_2) u_1 +2 m_2u_2 = (m_1 + m_2) v_1$$

$$v_1 = \frac{(m_1-m_2)u_1+2m_2u_2}{(m_1+m_2)} \quad \text{.....(9)}$$

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From equation (8)

$$v_1 = v_2 - u_1 + u_2 \quad \text{.....(10)}$$

Substitute equation 10 in equation 1,

$$m_1u_1 + m_2u_2 = m_1(v_2 - u_1 + u_2) + m_2v_2$$

$$m_1u_1 + m_2u_2 = m_1v_2 - m_1u_1 + m_1u_2 + m_2v_2$$

$$m_1u_1 + m_2u_2 = (m_1 + m_2)v_2 - m_1u_1 + m_1u_2$$

$$m_1u_1 + m_2u_2 + m_1u_1 - m_1u_2 = (m_1 + m_2)v_2$$

$$(m_2 - m_1)u_2 + 2m_1u_1 = (m_1 + m_2)v_2$$

$$v_2 = \frac{(m_2 - m_1)u_2 + 2m_1u_1}{(m_1 + m_2)} \quad \text{.....(11)}$$

The above equations are general and we can apply for particular cases as follows.

Case 1: When both the masses are equal, i.e. $m_1 = m_2 = m$

Then from equation (9)

$$v_1 = \frac{0 + 2mu_2}{(m + m)}$$

$$v_1 = \frac{2mu_2}{2m}$$

$$v_1 = u_2 \quad \text{.....(11a)}$$

Similarly if we take equation 10 and apply the condition- When both the masses are equal, i.e. $m_1 = m_2 = m$

$$v_2 = u_1 \quad \text{.....(12)}$$

From Equation 11 and 12, we observe that when two elastic objects of equal masses collide directly, then they exchange velocities.

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Case2: when one object is at rest, what will happen when another object hits?

For this case let us consider the second object is at rest. Then $u_2 = 0$.

Substituting $u_2 = 0$ in equation 9 and 11 we have,

$$v_1 = \frac{(m_1 - m_2)u_1}{(m_1 + m_2)} \quad \text{.....(13)}$$

$$v_2 = \frac{2m_1 u_1}{(m_1 + m_2)} \quad \text{.....(14)}$$

Case 3: When the bodies are identical in shape as well as on all nature, i.e.

$m_1 = m_2 = m$ and $u_2 = 0$

From equation 13 and 14 we have,

$V_1 = 0$

$V_2 = U_1$

When the object A collides with other identical object B at rest, the object A comes to rest and object B moves with velocity of A.

Case 4: When the mass of B is very large as compared to that of A then,

$m_2 >> m_1$, then we can write

$m_1 - m_2 = -m_2$

$m_1 + m_2 = m_2$

From equation 13 & 14

$v_1 = -u_1$

$v_2 = 0$

When a bouncing ball hits the wall, it bounces back with same speed with opposite direction.

Case 5: When the mass of B is negligibly small as compared to A, then $m_1 >> m_2$

Now, $m_1 - m_2 = m_1$

$m_1 + m_2 = m_1$

From equation (13 & 14)

$v_1 = u_1$

$v_2 = 2u_1$.

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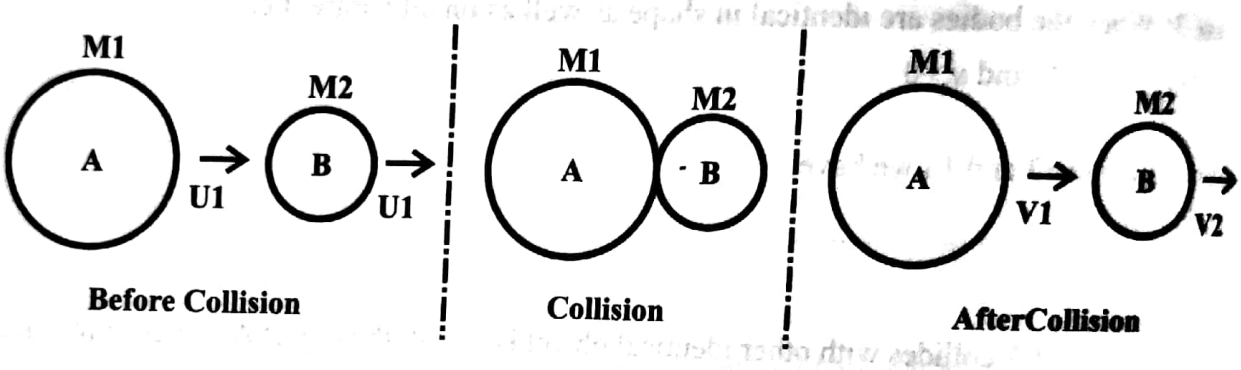
The object at rest,whose mass is negligible compared to first one, moves two times the velocity of first object.

2.13 Inelastic collision in one dimension

The Collision in which there is a loss of energy and momentum only conserved and objects are moving in one direction before and after collision is called inelastic collision.

Let us consider two bodies namely A and B of masses m_1 and m_2 moving with initial velocities u_1 and u_2 respectively along a straight line collide. After collision their respective velocities become v_1 and v_2 and they continue to move in the same straight line.



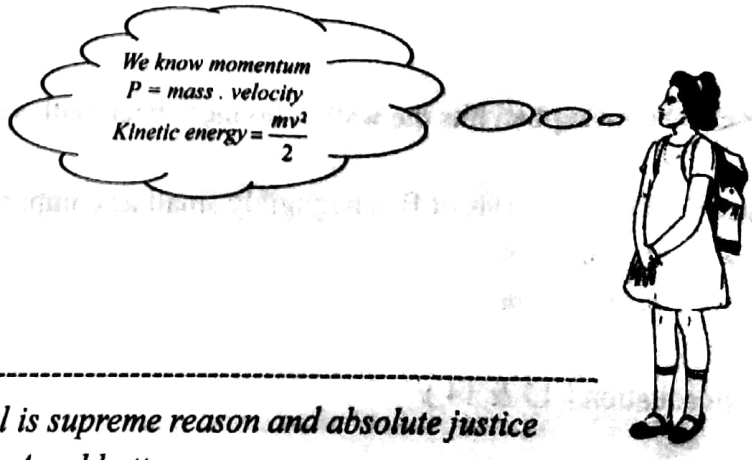
The two bodies A and B suffer head on collision.

From the law of conservation of momentum
Total momentum before collision = Total momentum after collision

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2 \qquad \text{.....(1)}$$

Rearranging equation (1), keeping momentum of body A in LHS and keeping momentum of body B in RHS

$$m_1u_1 - m_1v_1 = m_2v_2 - m_2u_2$$



The universal medicine for the soul is supreme reason and absolute justice
— Aryabhatta

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Velocity of approach and velocity of separation can be related with coefficient of restitution

as $e = \dfrac{(v_2 - v_1)}{(u_1 - u_2)}$ or (cross multiplying and rearranging)

$$v_2 = v_1 + e(u_1 - u_2) \qquad \text{.....(2)}$$

Substituting the value of v_2 from equation 1 in equation (2)

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2[v_1 + e(u_1 - u_2)]$$

multiplying m_2 in second part of RHS,

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_1 + m_2 . e(u_1 - u_2)$$

Taking v_1 as common,

$$m_1u_1 + m_2u_2 = v_1(m_1 + m_2) + m_2 . e(u_1 - u_2)$$

Rearranging .i.e. bringing $v_1(m_1 + m_2)$ to LHS and others RHS

$$v_1(m_1 + m_2) = m_1u_1 + m_2u_2 - m_2 . e(u_1 - u_2)$$

Multiplying $m_2 . e$ with u_1 and u_2

$$v_1(m_1 + m_2) = m_1u_1 + m_2u_2 - m_2eu_1 + m_2eu_2$$

Arranging u_1 and u_2 as common,

$$v_1(m_1 + m_2) = (m_1 - em_2)u_1 + m_2u_2(1 + e)$$

Taking $(m_1 + m_2)$ to denominator,

$$v_1 = \frac{[(m_1 - em_2)u_1 + m_2u_2(1 + e)]}{(m_1 + m_2)} \qquad \text{.....3}$$

From eq.2

$$v_1 = v_2 - e(u_1 - u_2) \qquad \text{.....4}$$

Substitute the value of v_1 from equation 4 in equation1 , we have

$$v_2 = \frac{[(m_2 - em_1)u_2 + m_1u_1(1 + e)]}{(m_1 + m_2)} \qquad \text{.....5}$$

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V_1 and V_2 are final velocities of A and B.

Case 1: e = 0.

When the coefficient of restitution is Zero (e = 0), then the collision is called Perfectly inelastic collision.

$$V_1 = \frac{(m_1u_1 + m_2\ u_2)}{(m_1 + m_2)}$$

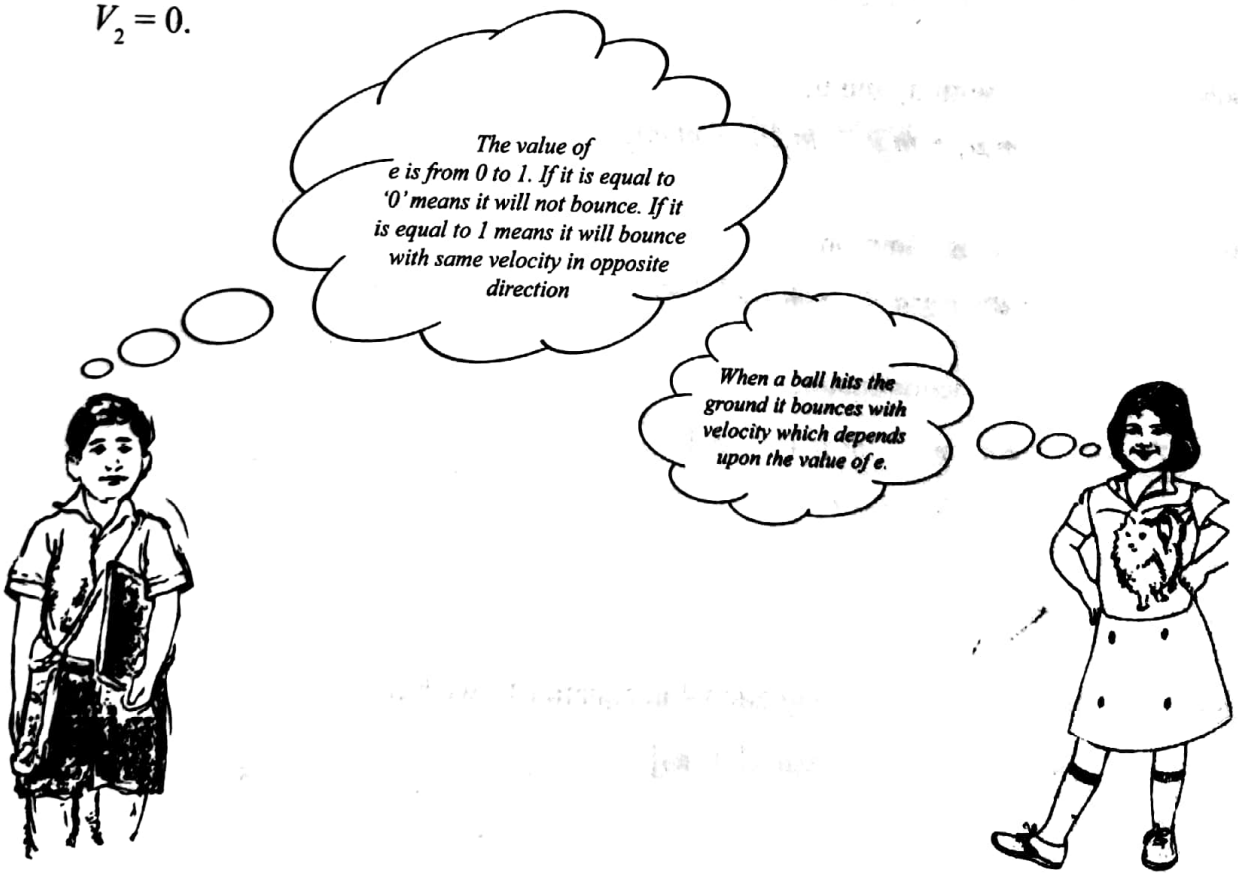
$$V_2 = \frac{(m_1u_1 + m_2\ u_2)}{(m_1 + m_2)}$$

Both V_1 and V_2 are same, which means both the bodies stick togather and move with common velocity.

Case 2: When the mass of first object is negligible compared to second one, we have

$$V_1 = -eu_1 ..$$

$$V_2 = 0.$$



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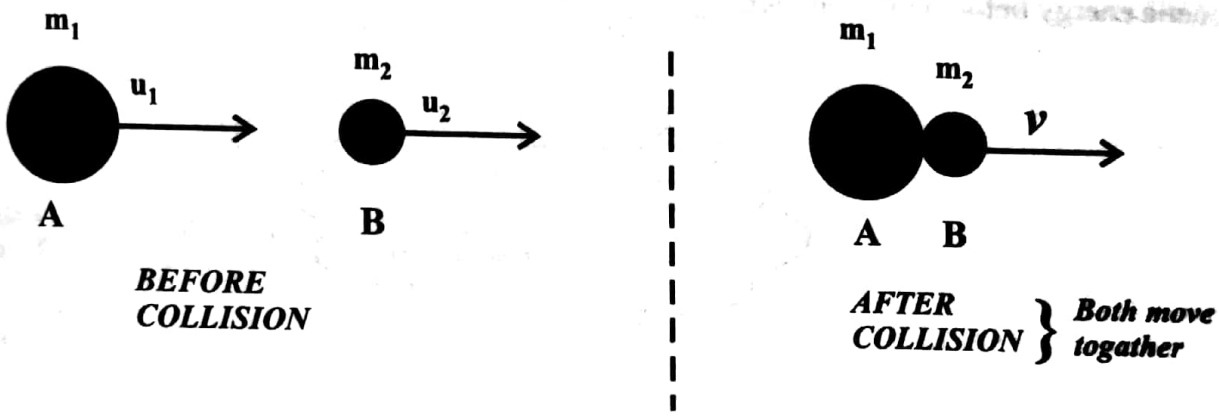
2.14 Perfectly Inelastic Collision

When the two colliding bodies stick together and move as a single body with a common velocity after the collision, then the collision is said to be perfectly inelastic in nature.

For eg. when a bullet is fired from a gun and it strikes a wooden block, the bullet gets embedded in the block and they both move with a common velocity



Consider two spheres A and B of masses m_1 and m_2 moving with initial velocities u_1 and u_2 collide perfectly inelastically.

After the collision, they stick together and move with a common velocity v.

As we know linear momentum is conserved in both the cases of collision, we have,

Momentum before collision = Momentum after collision

$$m_1u_1 + m_2u_2 = (m_1 + m_2)\, v$$

A good designer must rely on experience, on precise, logic thinking; and on pedantic exactness. No magic will do.

— ***Niklaus Wirth***

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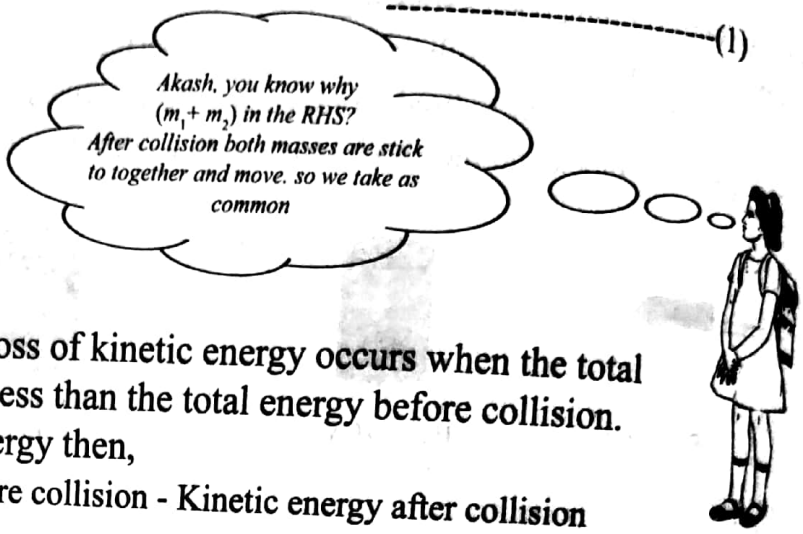
NOW v can be written as

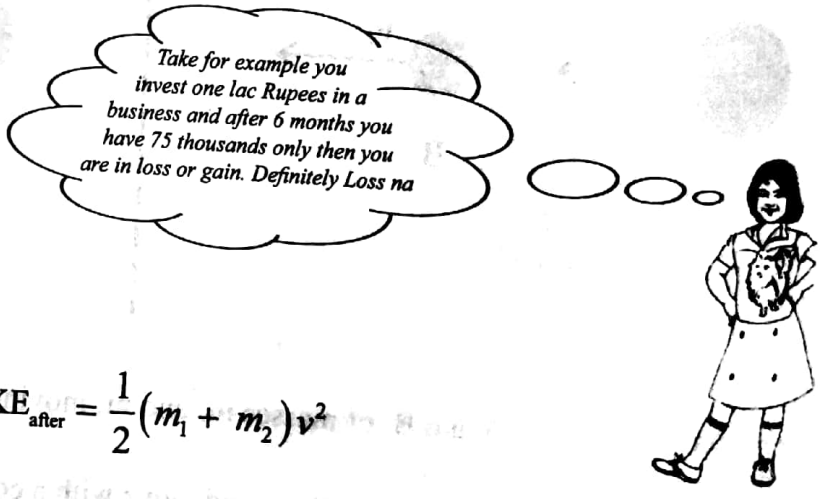
$$\text{Or, } v = \frac{m_1u_1 + m_2u_2}{m_1 + m_2} \quad \text{----------(1)}$$



Loss of Kinetic Energy: Loss of kinetic energy occurs when the total energy after the collision is less than the total energy before collision. If ΔKE is Loss of kinetic energy then,

ΔKE = Kinetic energy before collision - Kinetic energy after collision

Kinetic energy before collision $KE_{before} = \left[\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2\right]$



Kinetic energy after collision $KE_{after} = \frac{1}{2}(m_1 + m_2)v^2$

$$\Delta KE = KE_{before} - KE_{after}$$

$$= \left[\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2\right] - \frac{1}{2}(m_1 + m_2)v^2 \quad \text{.....(2)}$$

Substituting the value of v from equation (1) in equation (2)

$$\Delta KE = \left[\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2\right] - \frac{1}{2}(m_1 + m_2)\left[\frac{m_1u_1 + m_2u_2}{m_1 + m_2}\right]^2$$

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$$\Delta KE = \left[\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2\right] - \frac{1}{2}(m_1+m_2)\left[\frac{m_1^2u_1^2 + m_2^2u_2^2 + 2m_1u_1\,m_2u_2}{(m_1+m_2)^2}\right]$$

$$\Delta KE = \left[\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2\right] - \frac{1}{2}\left[\frac{m_1^2u_1^2 + m_2^2u_2^2 + 2m_1u_1\,m_2u_2}{(m_1+m_2)}\right]$$

$$\Delta KE = \frac{\left[(\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2)(m_1+m_2)\right] - \frac{1}{2}\left[m_1^2u_1^2 + m_2^2u_2^2 + 2m_1u_1\,m_2u_2\right]}{(m_1+m_2)}$$

$$\Delta KE = \frac{\left[(m_1^2u_1^2 + m_2^2u_2^2 + m_1m_2u_1^2 + m_1m_2u_2^2)\right] - \left[m_1^2u_1^2 + m_2^2u_2^2 + 2m_1u_1\,m_2u_2\right]}{2(m_1+m_2)}$$

Cancelling $m_1^2u_1^2 + m_2^2u_2^2 - m_1^2u_1^2 - m_2^2u_2^2$ we get

$$\Delta KE = \frac{\left[(m_1m_2u_1^2 + m_1m_2u_2^2)\right] - +2m_1u_1\,m_2u_2}{2(m_1+m_2)}$$

$$\Delta KE = \frac{\left[(m_1m_2u_1^2 + m_1m_2u_2^2\right] - 2m_1u_1\,m_2u_2}{2(m_1+m_2)}$$

$$\Delta KE = \frac{m_1.m_2\left[u_1^2 + u_2^2 - 2u_1u_2\right]}{2(m_1+m_2)}$$

$$\Delta KE = \frac{[m_1.m_2][u_1 - u_2]^2}{2(m_1+m_2)}$$

Case 1: When the target is at rest ie $u_2 = 0$

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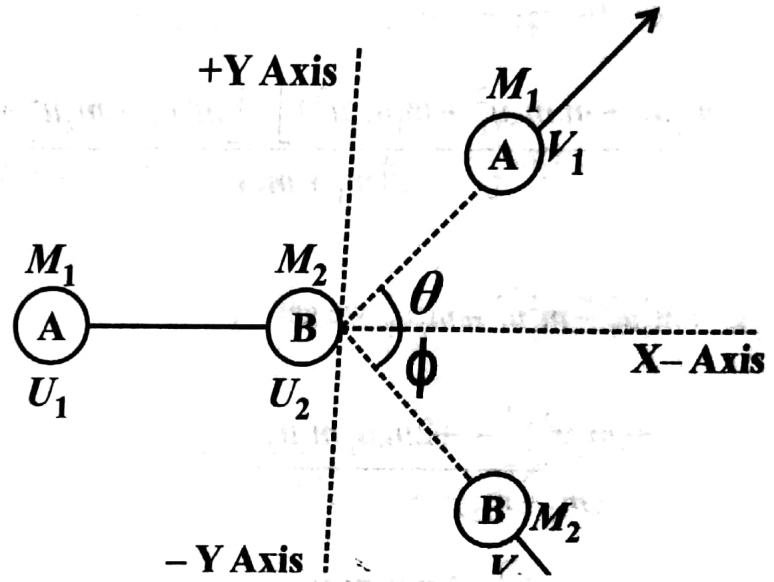
$$\Delta KE = \frac{m_1.m_2 \quad u_1^{\ 2}}{2(m_1 + m_2)}$$

Case 2: When the target mass is very large, then

$$\Delta KE = \frac{m_1 u_1^2}{2}$$

2.15 Elastic Collision in Two Dimensions

If both the spheres move in X axis or Y axis or Z axis only then the collision is called one dimension collision. If the particles are moving in $X-Y$ plane, we require two coordinates to locate the particles then it is called two dimension collision.



Let us consider two perfectly elastic bodies A and B of masses M_1 and M_2 moving along X-axis with velocities U_1 and U_2 respectively. The elastic collision in two dimension is a collision in which kinetic energy and momentum are conserved before and after collision and both the bodies continue to move in different directions with respect to original axis.

Let P denotes momentum and KE denotes kinetic energy then in one dimension elastic collision,

1. P (before collision) = P (after collision)
2. KE (before collision) = KE (after collision)

If $U_1 > U_2$ then the bodies will undergo collision.

Real programmers can write assembly code in any language.

— Larry Wall

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After The Collision

The two bodies A and B move with velocities V_1 and V_2 making angles θ and Φ with the X-axis respectively.

As the collision is perfectly elastic, Kinetic Energy should be conserved.

$$\frac{1}{2}M_1U_1^2 + \frac{1}{2}M_2U_2^2 = \frac{1}{2}M_1V_1^2 + \frac{1}{2}M_2V_2^2 \quad \text{.....(1)}$$

After collision the bodies move in different directions and the momentum is conserved along X and Y axis.

The X component of momentum of "A"= $M_1V_1\cos\theta$

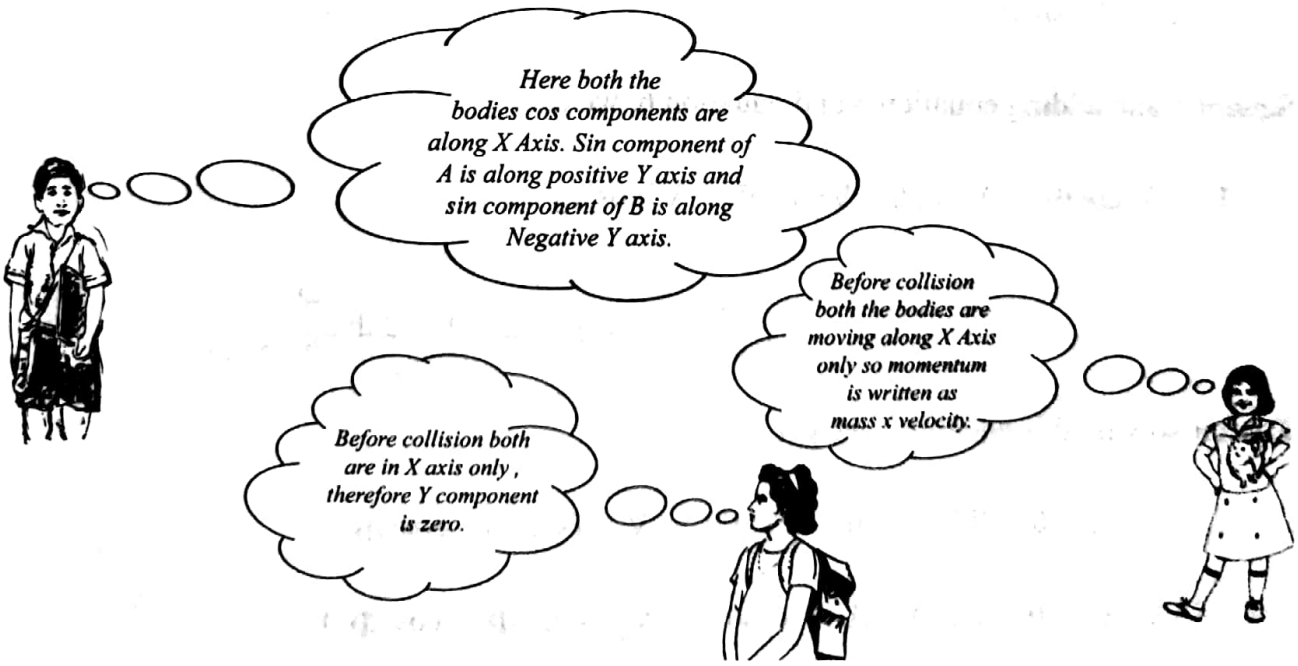
The X component of momentum of "B"= $M_2V_2\cos\Phi$

The Y component of momentum of "A" = $M_1V_1\sin\theta$

The Y component of momentum of "B" = $-M_2V_2\sin\Phi$

The Y component of "B" is in the negative Y axis. so we have to put negative sign.
Applying the law of conservation of momentum along X-axis,

$$M_1U_1 + M_2U_2 = M_1V_1\cos\theta + M_2V_2\cos\Phi \quad \text{.....(2)}$$



Applying the law of conservation of momentum along Y-axis,

$$0 + 0 = M_1V_1\sin\theta - M_2V_2\sin\Phi$$

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Here before collision the bodies travel in X axis only. Therefore the Y component is taken as zero.

$$M_1V_1\sin\theta = M_2V_2\sin\Phi \quad \text{.....(3)}$$

If we take the mass of the two elastic bodies to be equal, such that $M_1 = M_2 = M$ and the second body at rest , that is $U_2 = 0$.

From equations 1,2 and 3 we have,

$$U_1^2 = V_1^2 + V_2^2$$

$$U_1 = V_1\cos\theta + V_2\cos\Phi$$

$$V_1\sin\theta = V_2\sin\Phi$$

Keeping V_2 in R.H.S., We rearrange the equations into

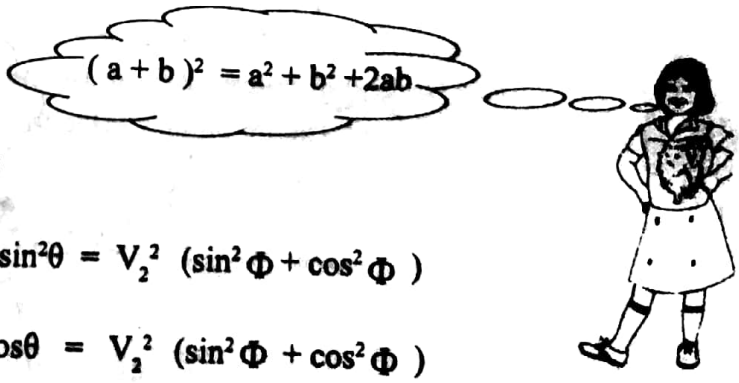
$$U_1^2 - V_1^2 = V_2^2 \quad \text{.....(4)}$$

$$U_1 - V_1\cos\theta = V_2\cos\Phi \quad \text{.....(5)}$$

$$V_1\sin\theta = V_2\sin\Phi \quad \text{.....(6)}$$

Squaring and adding equation 5 and equation 6, we get

$$(U_1 - V_1\cos\theta)^2 + V_1\sin^2\theta = V^2\sin^2\Phi + V^2\cos^2\Phi$$



Further solving this equation , we get

$$U_1^2 + V_1^2\cos^2\theta - 2U_1V_1\cos\theta + V_1^2\sin^2\theta = V_2^2\ (\sin^2\Phi + \cos^2\Phi)$$

$$U_1^2 + V_1^2(\cos^2\theta + \sin^2\theta) - 2U_1V_1\cos\theta = V_2^2\ (\sin^2\Phi + \cos^2\Phi)$$

Since $(\sin^2\Phi + \cos^2\Phi) = 1$ we have

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$$U_1^2 + V_1^2 - 2U_1V_1\cos\theta = V_2^2 \quad \text{..... (7)}$$

Comparing equations 4 and 7, RHS is equal therefore we equate LHS

$$U_1^2 + V_1^2 - 2U_1V_1\cos\theta = U_1^2 - V_1^2$$

Cancelling U_1^2 and bringing V_1^2 in LHS we have

$$2V_1^2 = 2U_1V_1\cos\theta$$

$$V_1 = U_1\cos\theta \quad \text{..... (8)}$$

Substitute the values of equation 8 in equation 4, we get

$$U_1^2\ (1-\cos^2\theta) = V_2^2 \qquad [1-\cos^2\theta = \sin^2\theta]$$

$$U_1^2(\sin^2\theta) = V_2^2$$

Taking square root we get,

$$V_2 = U_1\sin\theta \quad \text{..... (9)}$$

Substituting equation 8 and 9 in equation 6, we get

$\cos\theta = \sin\Phi$

Cosθ can be written as $\sin(90-\theta)$ then

$\sin(90-\theta) = \sin\Phi$

$90 - \theta = \Phi$

$\theta + \Phi = 90$

We conclude that if a body collides with another body of same mass which is at rest, then the two bodies move at right angles to each other after the collision.

Simplicity is prerequisite for reliability.

— Edsger W. Dijkstra

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2.16 Numerical Problems

1. A truck of mass 10000 kg moving with a speed of 10 m/s strikes a stationary truck of same mass. After the collision, the two trucks get stick to each other and move together with a common velocity v. Calculate the velocity of the truck after the collision?

Solution

Given Data: $m_1 = 10000\ kg$, $u_1 = 10\ m/s$, $m_2 = 10000kg$, $u_2 = 0$

The two bodies stick together and move with same velocity, so it is perfectly inelastic collision.
Therefore,

$$(m_1 + m_2).v = m_1 . u_1 + m_2 . u_2$$

$$(10000 + 10000)\ v = 10000 . 10 \qquad \{\text{since } u_2 \text{ is zero}\}$$

$$20000 . v = 10000 . 10$$

$$v = (10000.10)/20000$$
$$v = 5\ m/s$$

Therefore, velocity after collision is 5 m/s.

2. A sphere of mass m is moving with a velocity of 20 m/s. The kinetic energy of the sphere is 800 J. Find the mass of the sphere.

Solution

Given Data: mass = m , velocity(v) = 20 m/s , $KE = 800\ J$
Therefore,

$$KE = \frac{mv^2}{2}$$

$$800 = ½ . m.20.20$$

$$800 = ½ . m . 400$$

$$m = (800.2)/400$$

$$m = 1600/400 \Rightarrow m = 4\ kg$$

Therefore, the mass of the body is 4 kg.

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CHAPTER

3 ELECTRICITY

3.1 Introduction

All the substances are made of atoms. The atoms consist of protons, neutrons and electrons. The protons and electrons in addition to gravitational force have some additional force which is called electrostatic force. This electrostatic force is a peculiar property for electrons and protons and so these are called electric charges.

A proton is positive charge and an electron is negative charge.

3.2 Frictional Electricity

The electricity developed on objects when they are rubbed with some other material is called frictional electricity.

- If a glass rod is rubbed with silk cloth, it acquires positive charge while silk cloth acquires an equal amount of negative charge.
- If an ebonite is rubbed with fur, it acquires negative charge while fur becomes positive charge.
- While rubbing charges are not created and are transferred from one material to another.
- Atom as a whole is neutral. When glass is rubbed, electrons in the glass rod acquire energy and move to silk cloth. Thus silk becomes negative and glass becomes positive.
- This classification of positive and negative charges was given by the Scientist Benjamin Franklin.

3.3 Properties of Electric Charge

1. Like charges repel each other and unlike charges attract each other.
2. The magnitude of elementary negative or positive charge is same and is equal to 1.6×10^{-19} C.

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3. Additive nature of charges: If you add two point charges q_1 and q_2, then the total charge is obtained by simply adding q_1 and q_2, i.e., charges add up like real numbers .i.e. 2+3=5 Or 3-2 =1.

   Charge is a scalar quantity; it has magnitude but no direction, just like mass.

   For Example:

$$q = q_1 + q_2 + q_3 + q_4 + q_5$$

$$q = (+14) + (-22) + (-2) + (+10) + (+5)$$

$$q = +5C$$

   Therefore, the total charge of the system is +5C and it is positively charged.

4. Charge is conserved: According to the law of conservation of charge, charges cannot be created or destroyed. However, a charge can be transferred from one body to other.

5. Quantization of charge: The charge of any object is equal to multiples of 'n' of the elementary charge. This is known as quantization of charge. It is given by

   $+q = +ne$ -----For proton

   $-q = n(-e)$ -----For electron

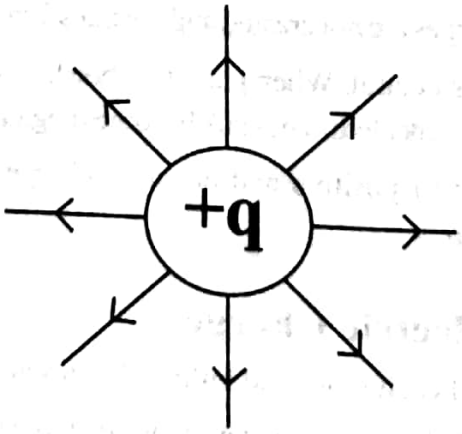
   Where,

   q = electric charge of any object or body

   n = any integer- positive or negative

   $-e$ = charge carried by single electron.

   e = charge carried by single proton.



Lines of force due to positive charge and these are radially outward.

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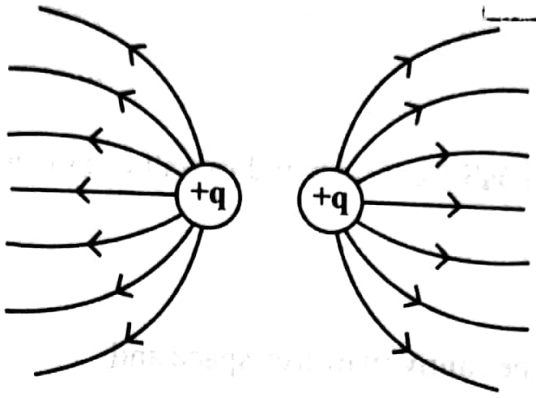


Fig : Repulsion between two positive charges

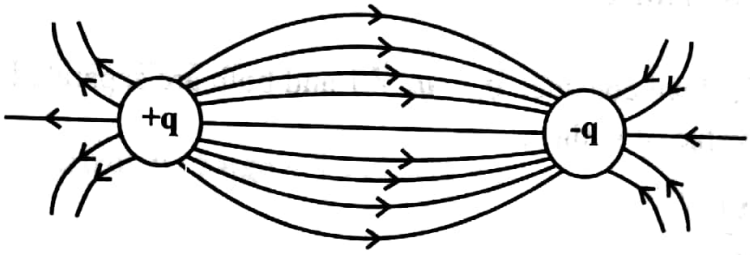
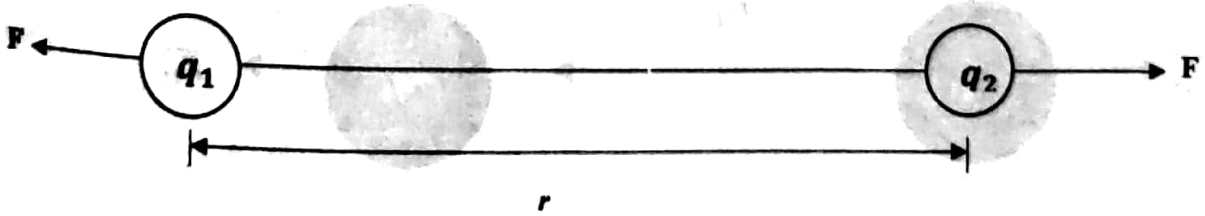


Fig :Attraction between positive and negative charges.

3.4 Coulomb's Law

According to Coulomb's Law, the force attraction or repulsion between two charged objects is directly proportional to the product of the magnitude of charges and is inversely proportional to the square of the distance between them. This force acts along the straight line joining the two charges.

Consider two charges q_1 and q_2 separated by a distance r as shown in fig.



Then, according to Coulomb's law,

$$F \propto \frac{q_1 q_2}{r^2}$$

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$$F = k\frac{q_1 q_2}{r^2} \qquad \text{..... (1)}$$

Where k is the proportionality constant and its value is given by,

$$K = \frac{1}{4\pi\varepsilon o}$$

Where εo is known as permittivity of free space and

$$\varepsilon o = 8.54\times10^{-12} C^2 N^{-1} m^{-2}$$

$$K = \frac{1}{4\pi\varepsilon_o} = 9\times10^9 \text{Nm}^2\text{C}^{-2}$$

In the equation (1) , If we consider $q_1 = q_2 = 1$ and both are separated by one meter length and substituting the value of k then,

$$F = (9 \times 10^9)\ \frac{1x1}{1^2}$$

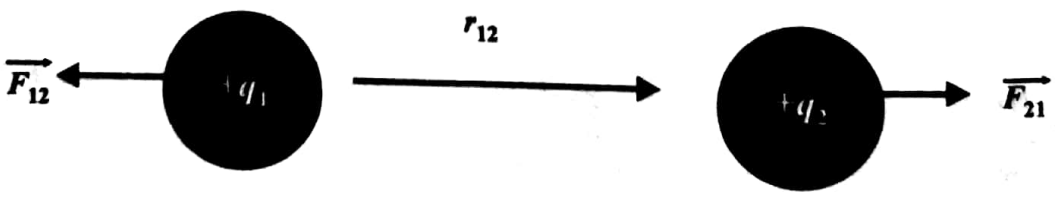
$$F = 9 \times 10^9 \text{ N.}$$

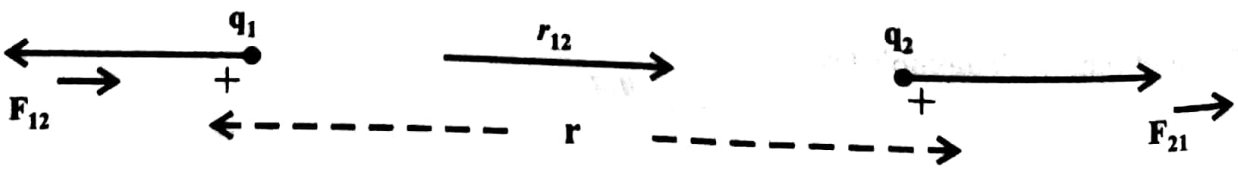
Now we can define coulomb as,

One Coulomb is defined as the quantity of charge, which when placed at a distance of 1 metre in air or vacuum from an equal and similar charge, experiences a repulsive force of 9×10^9 N.

Vector Representation

When two positive charges are placed at a distance r





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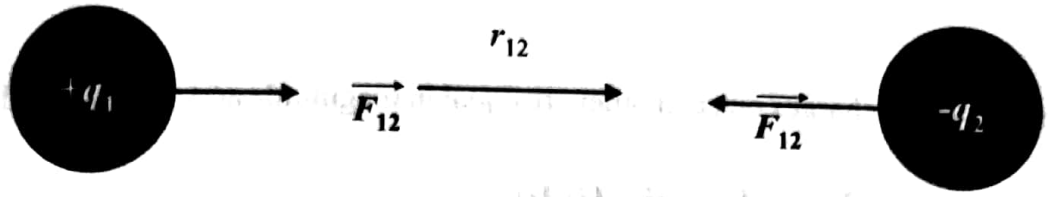
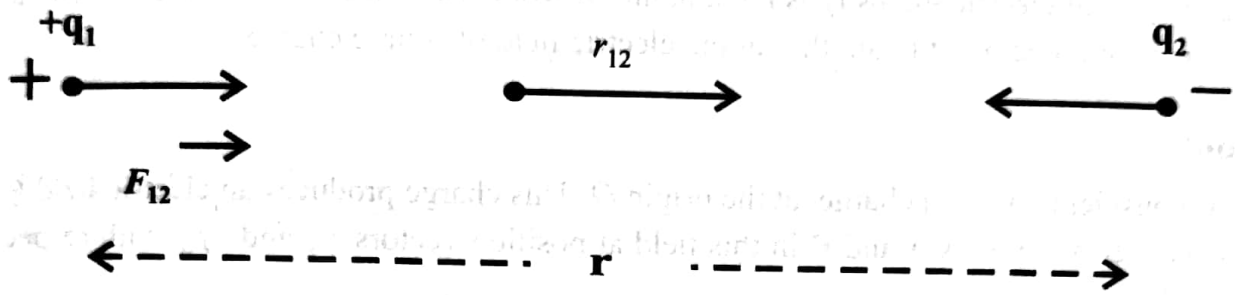
When one positive charge and one negative charge are placed at a distance r





If $\overrightarrow{F_{21}}$ is the force exerted on charge q_1 by charge q_2,

$$\overrightarrow{F_{21}} = k\frac{q_1 \cdot q_2}{\vec{r}_{12}^{\,2}}\hat{r}_{12}$$

where $\hat{r}_{12}$ is the unit vector from q_1 to q_2.

If $\overrightarrow{F_{12}}$ is the force exerted on charge q_2 by charge q_1,

$$\overrightarrow{F_{12}} = k\frac{q_1 q_2}{\vec{r}_{21}^{\,2}}\hat{r}_{21}$$

where $\hat{r}_{21}$ is the unit vector from q_2 to q_1 .

Both $\hat{r}_{21}$ and $\hat{r}_{12}$ have the same magnitude, and are oppositely directed So we can write as follows,

or $$\overrightarrow{F_{12}} = k\frac{q_1 \cdot q_2}{\vec{r}_{21}^{\,2}}(-\hat{r}_{12})$$

or $$\overrightarrow{F_{12}} = -k\frac{q_1 \cdot q_2}{\vec{r}_{21}^{\,2}}(\hat{r}_{12})$$

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or $$\overrightarrow{F_{12}} = -\overrightarrow{F_{21}}$$

So, the forces exerted by charges on each other are equal in magnitude and opposide in direction

3.5 Line integral of electric field

Line integral of electric intensity is the amount of work done on a unit positive test charge in moving it from one point to another in the electric field of source charge.

Proof

Let us consider a unit +q charge at the origin *O*. This charge produces an electric field $\overline{E}$.

Consider two points A and B in this field at position vectors $\overline{r}_A$ and $\overline{r}_B$ with respect to origin *O*.

Let a point P lies on the line of AB.

Force on charge q_0 at P is

$$F = q_0 \ \overline{E} \qquad \text{.....(1)}$$

Where $\overline{E}$ is the electric intensity at P due to charge q and is given by

$$\overline{E} = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}\overline{r} \qquad \text{.....(2)}$$

Let the charge q_o be moved from P to Q through a small distance $PQ = dl$ then small amount of work done in moving charge q_0 from P to Q is given by

$$dW = \overline{F}.dl$$

Substituting $\overline{F} = q_o \ \overline{E}$ from equation (1)

$$dW = q_o \overline{E}\ .\overline{dl}\ .$$

$$dW = q_o \ E\ dl \cos\theta \qquad \text{.....(3)}$$

(Where θ is the angle between E and dl.)

dl $\cos\theta$ = dr and substitute this in equ 3, we get

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$$dW = q_o E\, dr$$

Substituting E value,

$$dW = \frac{1}{4\pi\varepsilon_0}\frac{qq_o}{r^2}dr$$

Total work done in moving the charge q_0 from A to B, integrate above eq.

$$\text{i.e. } \int_A^B dW = W_{AB} = \int_{\bar{r}A}^{\bar{r}B} \frac{1}{4\pi\varepsilon_0}\frac{qq_o}{r^2}dr$$

$$W = \frac{qq_0}{4\pi\varepsilon_0}\left[\frac{1}{\bar{r}_A} - \frac{1}{\bar{r}_B}\right]$$

$$\text{Work done} = \frac{qq_o}{4\pi\varepsilon_o}\left[\frac{1}{\bar{r}_A} - \frac{1}{\bar{r}_B}\right]$$

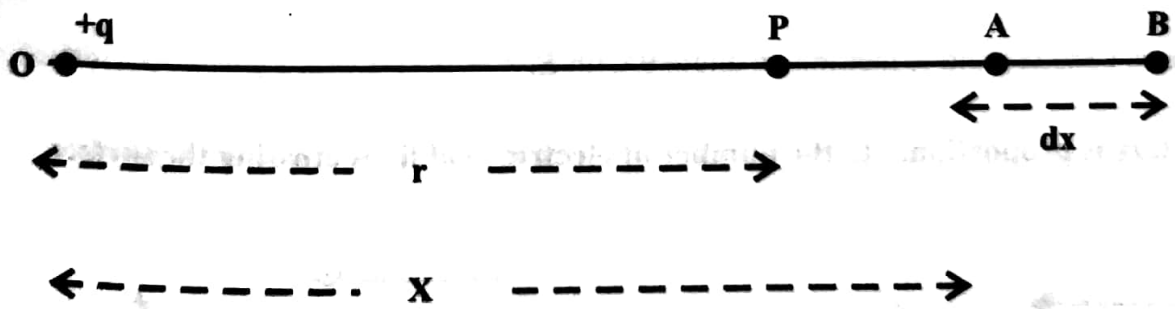
3.6 Electric Potential

The electric potential in an electric field at a point is defined as the amount of work done in moving a unit positive charge from infinity to that point against the electric force.

Consider an isolated point charge +q at a point O.

Consider a point P at a distance r from +q.

Consider two points A and B at a distance x and $x + dx$ from the point O.



The potential difference between A and B is,

$$dV = -E\, dx$$

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The electric field at point is E and is given by,

$$E = \frac{q}{4\pi\varepsilon_0 x^2}$$

The negative sign indicates that the work done is against the electric force.

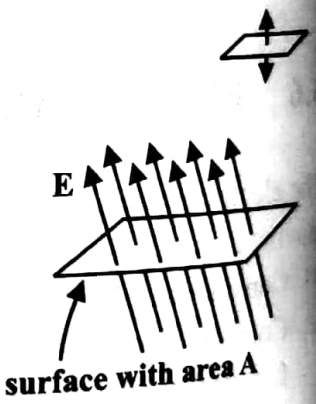
The electric potential at a point P due to charge +q is the total work done in moving a u positive charge from infinity to that point

$$V = \int_{\infty}^{r} \frac{q}{4\pi\varepsilon_0 x^2} dx$$

The potential $V = \dfrac{q}{4\pi\varepsilon_0 r}$

3.7 Flux (Φ)

The electric flux is defined as total number of electric lines of force crossing through the given area. It is denoted by the symbol Φ.



The electric flux Φ through a surface S is defined as

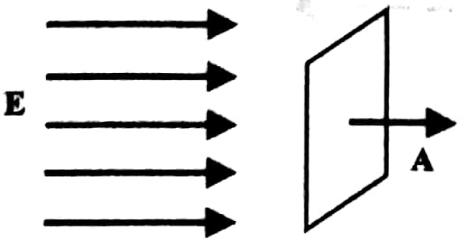
$$\Phi = \oint E.ds$$

Where E is electric field.

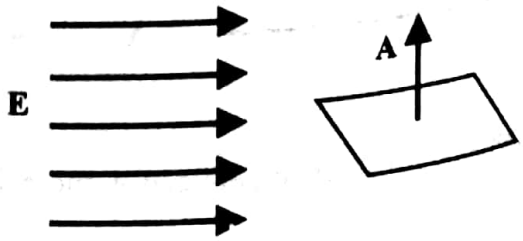
$\oint$ is the surface integral of closed surface S and ds is the small area.

Here E is constant and is making an angle θ with E.

Thus flux is proportional to the number of electric field lines crossing the surface.



θ=0, cosθ = 1, Φ max



θ=90°, cosθ = 0, Φ = 0

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3.8 Gauss's Law

Guass law relates the flux through any closed surface and the net charge enclosed within the surface.

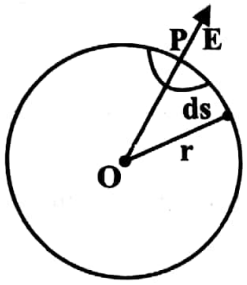
The law states that the total flux of electric field E over any closed surface is $\frac{1}{\varepsilon_0}$ times the net charge enclosed by the surface. If the closed surface encloses an electric charge q, then by Gauss law the total electric flux through the closed surface is given by

$$\Phi = \frac{q}{\varepsilon_o}$$

Where ε_0 is absolute permittivity of free space.

Proof of Gauss's Law

Consider a point charge q at the centre of a sphere.



Let r be the radius of the sphere.
Let E be the electric field a point P on the surface of the sphere.

Then $E = \frac{q}{4\pi\varepsilon_0 r^2}$

The electric flux through a closed surface $\Phi = \oint E ds$

Substituting E value, $\Phi = \frac{q}{4\pi\varepsilon_o r^2}\oint ds$

The surface area $\oint$ ds of the sphere is $4\pi r^2$

Now, $\Phi = \frac{q}{4\pi\varepsilon_0 r^2} 4\pi r^2$

Cancelling $4\pi r^2$, we get

$$\Phi = \frac{q}{\varepsilon_o}$$

Hence proved.

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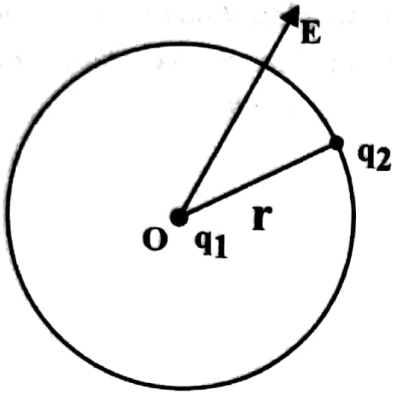
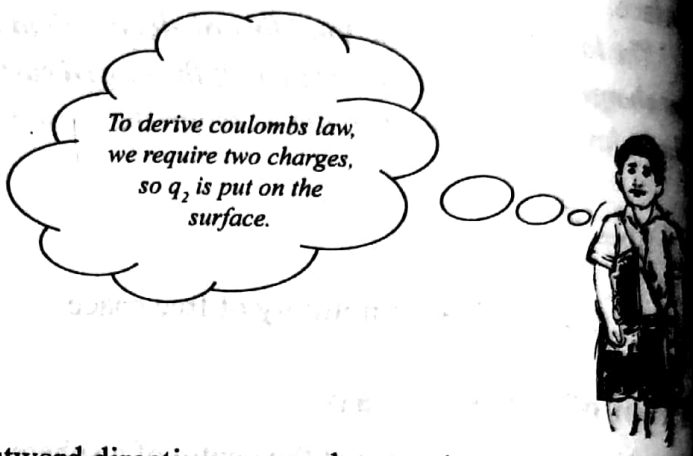
3.9 Coulomb's law from Gauss's law

Consider a charge q_1 at the centre of a sphere of radius r.





Field of a positive charge is in radially outward direction everywhere and magnitude of electric field intensity is same for all points at a distance r from the charge.

We know $\Phi = \oint E ds$ .....(1)

Here **E** is constant at all points on the surface and $\oint ds$ = Surface area of the sphere and is equal to $4\pi r^2$

i.e $\oint ds = 4\pi r^2$

Substituting this in (1)

$\Phi = E4\pi r^2$ .....(2)

But From Gauss's law $\Phi = \dfrac{q_1}{\varepsilon_0}$ .....(3)

Equating 2 and 3 we have

$$\frac{q_1}{\varepsilon_0} = E4\pi r^2$$

Or $E = \dfrac{q_1}{4\pi r^2 \varepsilon_0}$ .....(4)

Force acting on point charge q_2 at distance r from point charge q_1 is

$F = q_2 E$ .....(5)

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Substituting for E from (4)

$$F = \frac{q_1 q_2}{4\pi r^2 \varepsilon_0}$$

Thus we obtained Coulomb's law from Gauss's law.

3.10 Electric Field due to an infinite long straight charged conductor

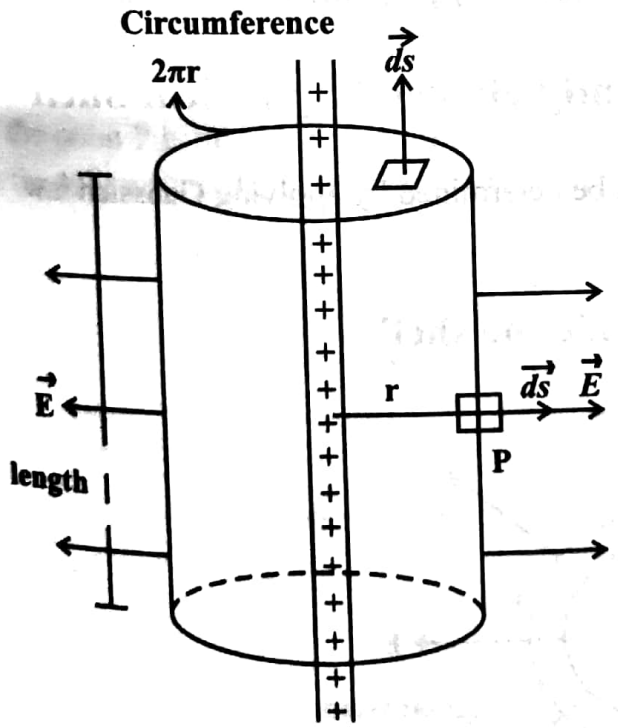
Consider an uniformly charged wire of infinite length .

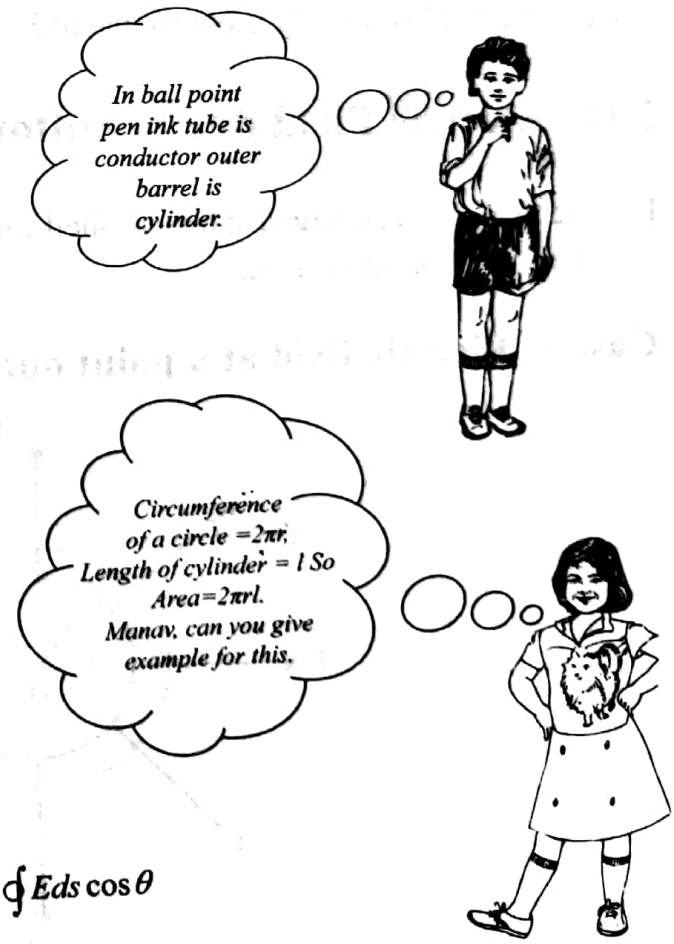
Let λ be linear charge density of the wire. Let P be the point at a distance r from the wire. Let E be the electric field at a point P.

Consider a cylinder of length l and radius r , closed at both ends by a plane caps normal to the axis of the wire. This imaginary cylinder is called Guassian surface.

Consider a small area ds on the Guassian surface. By symmetry the magnitude of electric field will be same at all points on curved surface. The electric field is radially outward.

The electric field E and small area ds are along same direction.





The electric flux through curved surface $\Phi = \oint E ds \cos\theta$

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When $\theta = 0$, $cos\theta = 1$ then we have

$$\Phi = \oint Eds$$

$\oint$ is the surface area of the curved area and is equal to $2\pi rl$

The total flux through Guassian surface $\Phi = E2\pi rl$
The net charge enclosed by Guassian surface is $q = \lambda l$
By Guass law

$$E2\pi rl = \frac{\lambda l}{\varepsilon_0}$$

$$E = \frac{\lambda l}{2\pi rl\varepsilon_0}$$

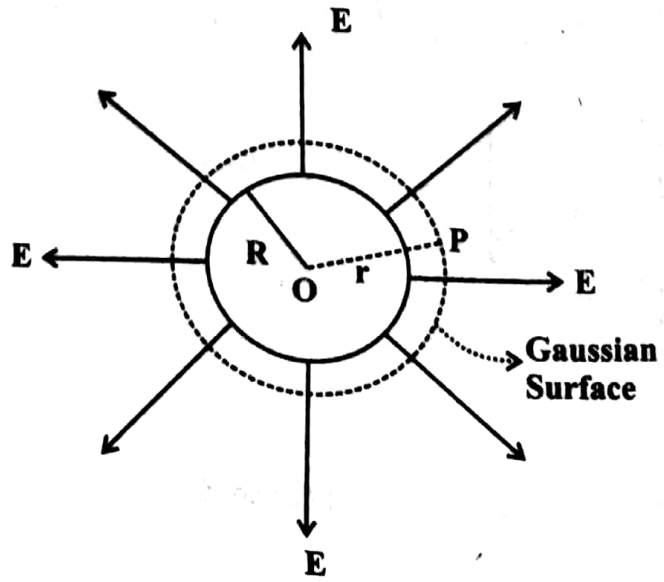
Electric field $E = \dfrac{\lambda}{2\pi r\varepsilon_0}$

The electric field is directly proportional to λ and inversely proportional to distance r.

3.11 Electric Field due to uniformly charged Spherical Shell

Electric field due to charged spherical shell can be determined by applying Gaussian law. There are three cases in it.

Case 1: Electric field at a point outside the shell



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Consider a charged spherical shell of radius R.
Let P be the point outside the shell at which we have to determine the electric field.
Let 'r' is the distance of the point 'P' from the centre of the shell.
Now construct an imaginary Gaussian surface of radius r.
The electric field is normal to the surface.

The flux $\Phi = \oint E ds$

The surface area of sphere $\oint ds = 4\pi r^2$

Now $\Phi = E4\pi r^2$ ..... (1)

By Gauss' law $= \Phi = \frac{q}{\varepsilon_0}$ ..... (2)

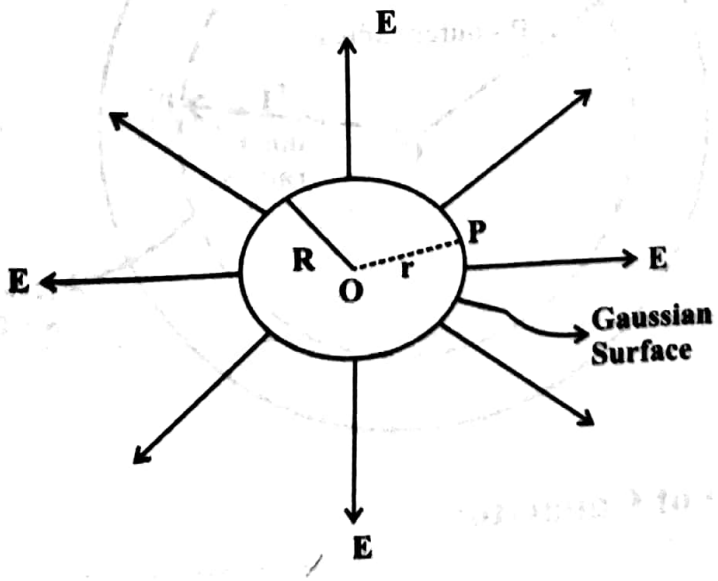
Equating Equation 1 & 2 we have,

$$E.4\pi r^2 = \frac{q}{\varepsilon_0}$$

$$E = \frac{q}{4\pi r^2 \varepsilon_0}$$

Case 2: Electric field at a point on the surface of the shell

If the point P is on the surface of the spherical shell , then R = r. That is Guassian surface is on the spherical surface itself as shown in fig.



$$E = \frac{q}{4\pi R^2 \varepsilon_0}$$

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Case 3: Electric field at a point inside the shell.

Consider a point P inside the shell at a distance r_1 from the centre of the shell. Let us construct a imaginary Gaussian surface with radius r_1 as shown in fig.

The flux $\Phi = \oint E ds$

The surface area of sphere $\oint ds = 4\pi r_1^2$

Now $\Phi = E4\pi r_1^2$ ..... (3)

By Gauss' law $= \Phi = \dfrac{q}{\varepsilon_0}$ ..... (4)

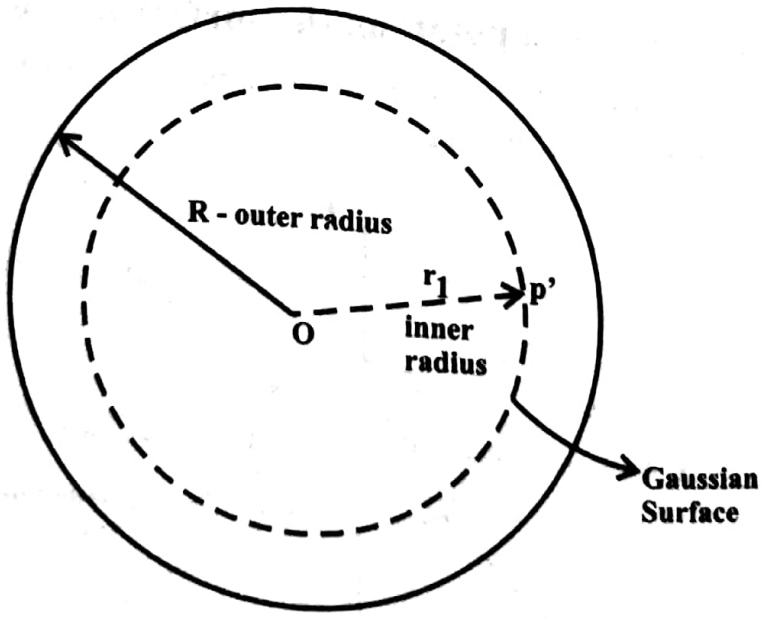
Equating Equation 3 & 4 we have,

$$E4\pi r_1^2 = \frac{q}{\varepsilon_0}$$

Since charge is on the surface only and inside the Gaussian surface no charge is there i.e. q=0

Therefore $E = 0$.

Field inside the charged spherical shell is zero.



3.12 Principle of Capacitor

Consider an insulated charged conductor A.
Let the charge in the conductor be 'q'.

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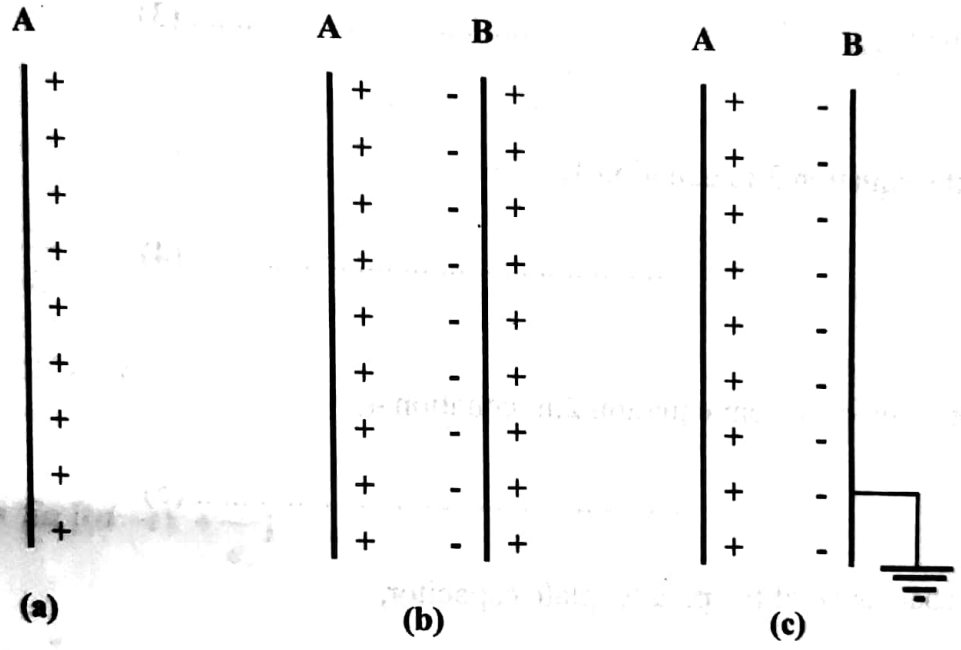
Let the potential of the conductor be V.

Now when another metal plate B of same dimension is brought near to A, negative charges are induced on the side of B near to A. An equal amount of positive charge is induced on other side of B.

Due to negative charge of B , the potential of A decreases. If potential is decreased then capacitance of A is increased according to the following equation.

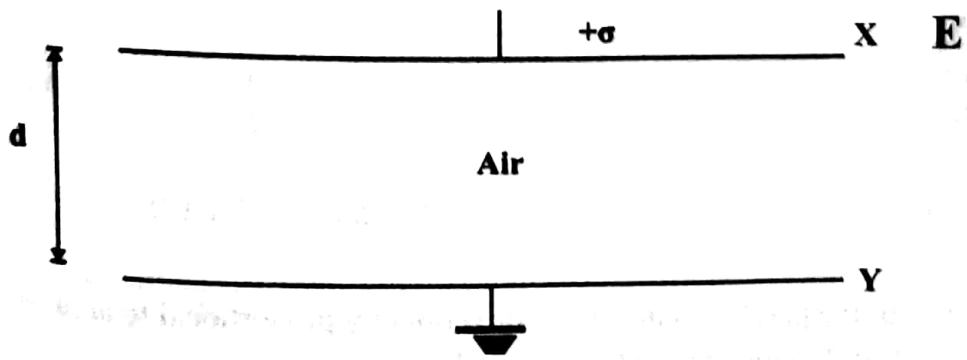
Capacitance $C = \frac{q}{V}$

If the plate B is earthed , positive charges are neutralized. Now the capacitance of A is increased more.



3.13 Parallel Plate capacitor

Consider two conducting plates X and Y kept parallel to each other.



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Let A be the area of the plate. Let d be the distance between the plates.
Let +q be the charge given to the plate X and σ be the surface charge density.
The plate Y is earthed.
Due to charge +q and –q , an electric field E_o is set up between the plates.
Let V be the potential difference between the plates.
Then

$$V = E_o.d \quad \text{..... (1)}$$

$$q = \sigma A$$

$$\sigma = \frac{q}{A} \quad \text{..... (2)}$$

Electric field $E_o = \frac{\sigma}{\varepsilon_0}$ ..... (3)

Substituting the equation 3 in equation 1,

$$V = \frac{\sigma}{\varepsilon_0} d \quad \text{..... (4)}$$

Substitute the value of σ from equation 2,in equation 4,

$$V = \frac{qd}{A\varepsilon_0} \quad \text{..... (5)}$$

If C_o is the capacitance of the parallel plate capacitor,

Then $C_o = \frac{q}{V}$ ..... (6)

Substituting the value of V from 5 ,

$$C_o = \frac{q}{\frac{qd}{A\varepsilon_0}}$$

$$C_o = \frac{\varepsilon_0}{d} A \quad \text{..... (7)}$$

The capacitance of the parallel plate capacitor is directly proportional to area of the plate and inversely proportional to distance between the plates.

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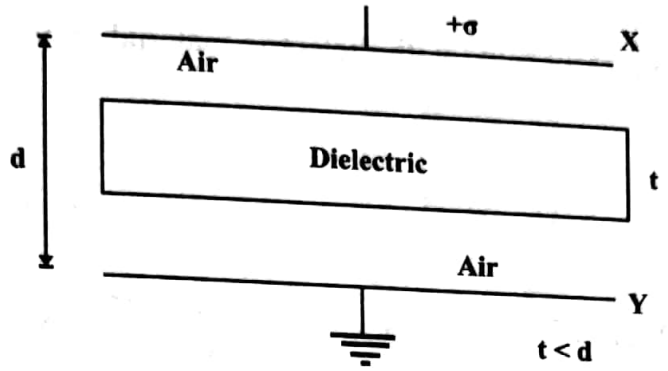
Parallel plate capacitor with dielectric material:

Let us introduce a dielectric material of thickness't' between the parallel plate capacitor as shown in fig.



Let E_o be the electric field when air is completely filled between the plates .
Let E be the electric field after dielectric material is introduced.
Potential difference between the plates $V = E.t + E_o(d-t)$ ..... (8)

But $E = \frac{E_o}{\varepsilon_r}$ ..... (9)

Now $V = \frac{E_o}{\varepsilon_r} t - E_o\,(d-t)$ ..... (10)

$V = Eo\,[(d-t) + \frac{t}{\varepsilon_r}]$ ..... (11)

But $Eo = \frac{q}{\varepsilon_0 A}$ ..... (12)

$V = \frac{q}{\varepsilon_0 A}[(d-t) + \frac{t}{\varepsilon_r}]$ ..... (13)

We know capacitance $C = \frac{q}{V}$ ..... (14)

Substituting the value of V from equation 13,

$$C = \frac{q}{\frac{q}{\varepsilon_0 A}[(d-t) + \frac{t}{\varepsilon_r}]}$$ ..... (15)

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$$C = \frac{\varepsilon_0 A}{[(d-t)+\frac{t}{\varepsilon_r}]} \quad \text{..... (16)}$$

If the capacitor is completely filled with dielectric material only then d = t and substituting this in equation 16,

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d} \quad \text{..... (17)}$$

Comparing equation 7 and 17 we observe that by introducing dielectric material of value ε_r. The capacitance increases by ε_r.

$$Or\ C = \varepsilon_r . C_o$$

3.14 Spherical Capacitor

A spherical capacitor consists of two concentric spherical shells as shown in fig. Let a and b be the radius of the inner and outer shells respectively.

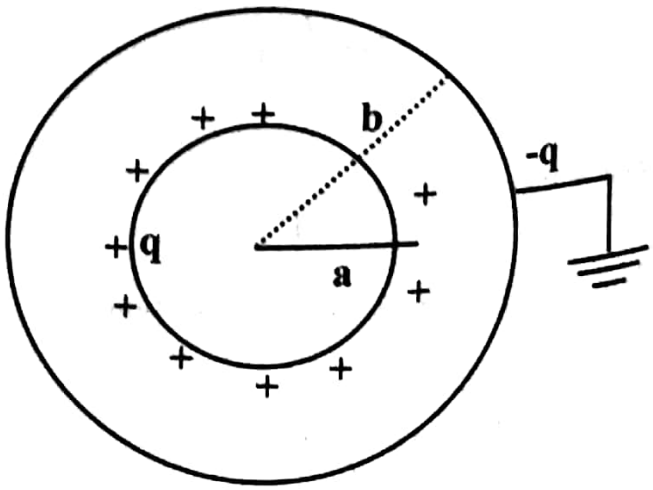
The outer shell is earthed.

The potential difference between the two shells can be found by following method.

$$V = \int_a^b dv$$

$$V = \int_a^b E.dr$$

$$V = \int_a^b \frac{q}{4\pi\varepsilon_0 r^2}.dr$$



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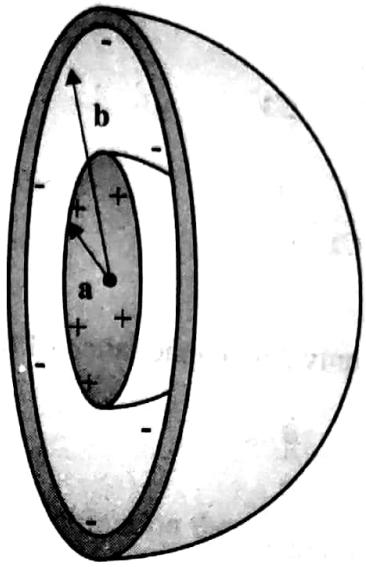
$$V = \frac{q}{4\pi\varepsilon_0 r^2}\left[\frac{b-a}{ab}\right]$$



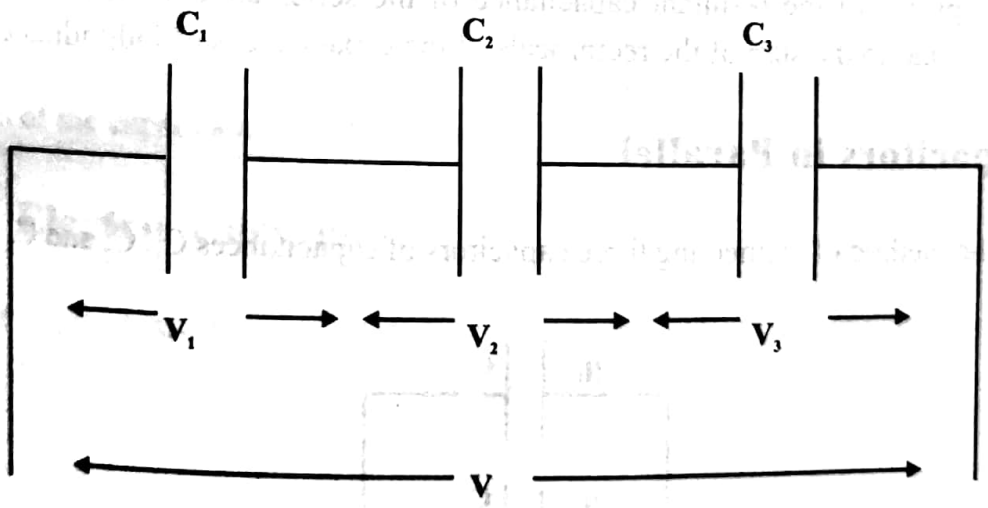
We know $C = \frac{q}{V}$

Substituting the value of V

$$C = 4\pi\varepsilon_0\left[\frac{ab}{b-a}\right]$$

3.15 Capacitors in Series

Fig shows the method of connecting three capacitors C_1, C_2, C_3 in series.



Let V_1, V_2 and V_3 be the potential differences across the plates of the three capacitors .If V is the potential difference across the series combination, then

$V = V_1 + V_2 + V_3$ 1

From the definition of the capacitance

$$V_1 = \frac{q}{C_1},\ V_2 = \frac{q}{C_2},\ V_3 = \frac{q}{C_3}$$

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$$V = \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3}$$

$$V = q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right] \quad \text{.....2}$$

Let 'C' be the equivalent capacitance of the series combination,

Therefore, $V = \frac{q}{c}$ 3

From equation 2 and 3

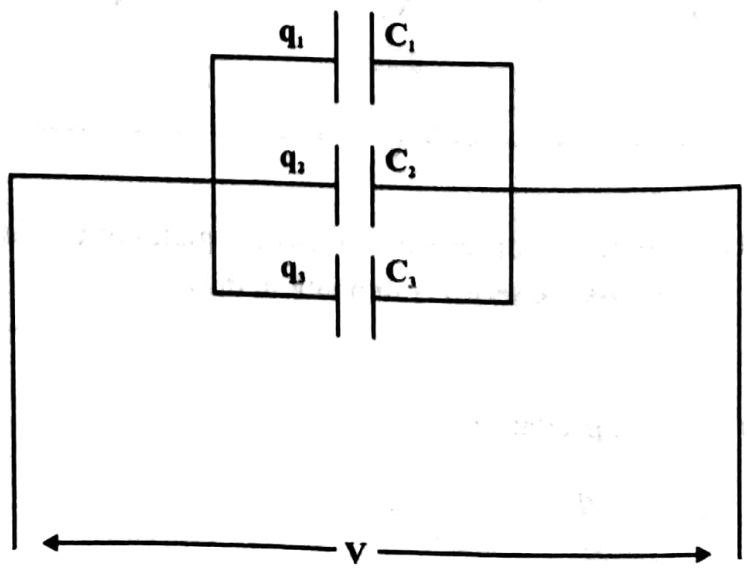
$$\frac{q}{C} = q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right]$$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Thus the reciprocal of the resultant capacitance of the series combination of a number of capacitors is equal to the sum of the reciprocals of the capacitances of individual capacitors.

3.16 Capacitors in Parallel

Fig shows the method of connecting three capacitors of capacitances C_1, C_2 and C_3 in parallel.



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If q_1, q_2 and q_3 are the values of charges on capacitors and V is the potential difference then

$$q_1=C_1V,\quad q_2=C_2V,\quad q_3=C_3V$$

Total charge on the parallel combination of capacitors

$$q=q_1+q_2+q_3$$

$$=C_1V+C_2V+C_3V$$

$$q=V[C_1+C_2+C_3] \qquad \text{..... 1}$$

If C is the equivalent capacitance of the parallel combination then

$$q=CV \qquad \text{..... 2}$$

From equation 1 and 2

$$CV=V[C_1+C_2+C_3]$$

$$C=C_1+C_2+C_3$$

The equivalent capacitance of the parallel combination of a number of capacitors is equal to the sum of the capacitances of the individual capacitors.

3.17 Electric Current

The current is defined as rate of flow of charges through any section of a conductor. If 'q' is the net charge flowing through the conductor in a time 't' then

$$I=\frac{q}{t}$$

Here q is in Coulomb, t is in seconds and unit of current is Ampere.

$$\text{Ampere } (A) = \frac{1 \text{ Coulomb}}{1 \text{ second}}$$

The current flowing through a wire is one ampere, if one Coulomb of charge flows through the wire in one second.

Current is a scalar quantity and direction of current is taken as from positive terminal of cell or battery.

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3.18 Drift velocity

Drift velocity is defined as the velocity with which free electrons in a conductor get drifted towards positive terminal, when external electric field is applied.

Consider a conductor XY connected to a battery as shown in fig. In a conductor free electrons are randomly move here and there inside due to thermal energy. And this motion will not produce any current, since there is no net flow in any direction. As soon as external field is connected, the electrons experience a force F = eE.

Due to this force, electrons acquire an acceleration 'a' in a time't". Now velocity of the electrons is called drift velocity and is given by,

Drift velocity $v_d = a.t$

The force $F = m.a$

But $F = e.E$

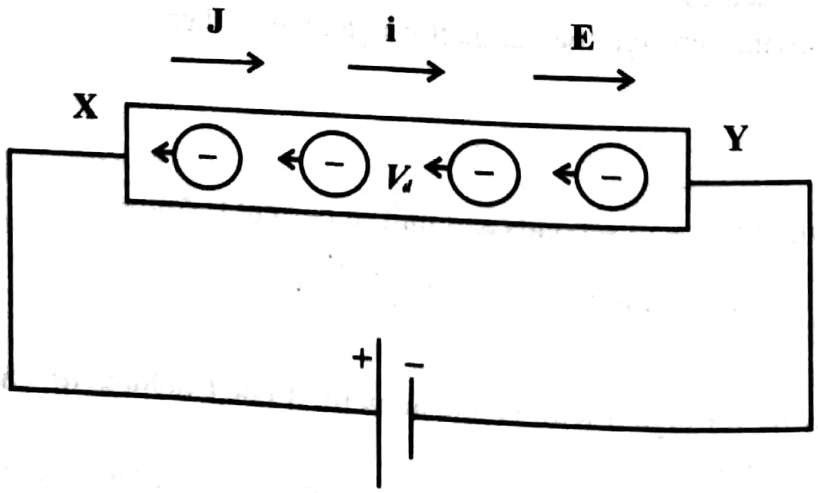
$eE = m.a$

$$a = \frac{eE}{m}$$

Now, $v_d = \frac{eE}{m} t$

Here $\mu = \frac{eE}{m}$ is called mobility and is the velocity acquired per unit electric field.

Thus the drift velocity is proportional to electric field.



Current Carrying Conductor

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3.19 Relation between Drift velocity and Electric Current

Consider a conductor XY of length l and area of cross section A.
Let n be the number of free electrons per unit volume in the conductor.
Let the electric field applied is E.
The total number of conducting electrons in the conductor $q = n.A.l.e$

The time taken by the electrons $= \frac{\text{Distance}}{\text{velocity}} = \frac{l}{v_d}$

Current $I = \frac{q}{t}$

$$I = \frac{n.A.l.e}{\frac{l}{v_d}}$$

$$I = n.A.e.\ v_d$$

The current flowing through the conductor is proportional to drift velocity.

3.20 Ohm's Law

Ohm's law states that the steady current flowing through a conductor is directly proportional to the potential difference between two ends of the conductor.

$V \propto I$

$V = IR$

Where R is proportionality constant and is called electric Resistance of the conductor. It depends on the nature and dimension of the conductor.

3.21 Resistance of a conductor

The resistance of a conductor is defined as ratio of potential difference between the conductor and the current flowing through it.

The Resistance $R = \frac{V}{I}$.

The unit of resistance is Ohm and it is denoted by Ω.

The resistance of a conductor is said to be one ohm, if one ampere current flows through it when the applied the potential difference is one volt.

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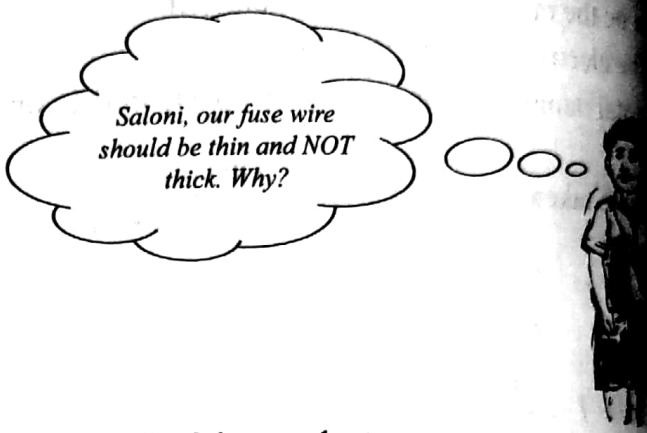
Electrical resistivity:

The resistance of a conductor is directly proportional to the length of the conduc
l and inversely proportional to area of cross section A of the conductor.

$$R \alpha \frac{l}{A}$$



$$R = \rho \frac{l}{A}$$

Where ρ is called Specific resistance of the material of the conductor.

If l=1 m, $A = 1m^2$, then $\rho = R$

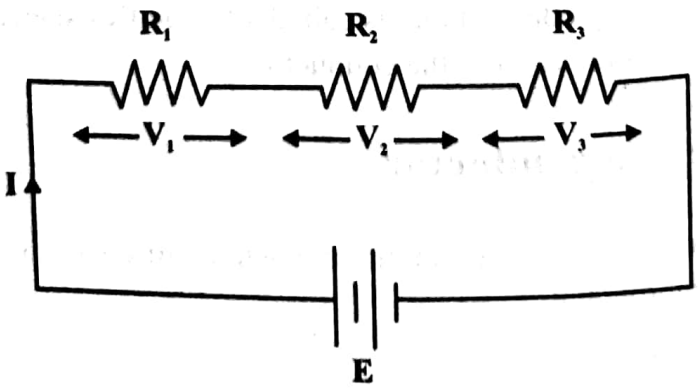
The resistivity of the material is defined as the resistance offered by the conductor of u length to current flow when area of cross section is one square metre.

3.22 Resistors in series

Two or more resistors are said to be connected in series, if same current passes through e of them.

Fig. shows the series combination of three resistors having resistances R_1, R_2 and R_3 battery of e.m.f E is connected across the combination. Current I flows through each of the

Let V_1, V_2 and V_3 the potential difference across the resistors R_1, R_2 and R_3 respectively.



According to ohm's low

$$V_1 = IR_1,\ V_2 = IR_2,\ V_3 = IR_3$$

$$Also,\ V = V_1 + V_2 + V_3$$

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$$V = IR_1 + IR_2 + IR_3$$
$$V = I\left(R_1 + R_2 + R_3\right) \quad - \quad (1)$$

If R_s is the equivalent resistance of the series combination of resistor, then the resistance R_s will allow the same current I to flow through it, when the battery of e.m.f. E is connected across it.

$$V = IR_s - (2)$$

From 1and 2

$$IR_s = I(R_1+R_2+R_3)$$
$$Or \quad R_s = R_1+R_2+R_3$$

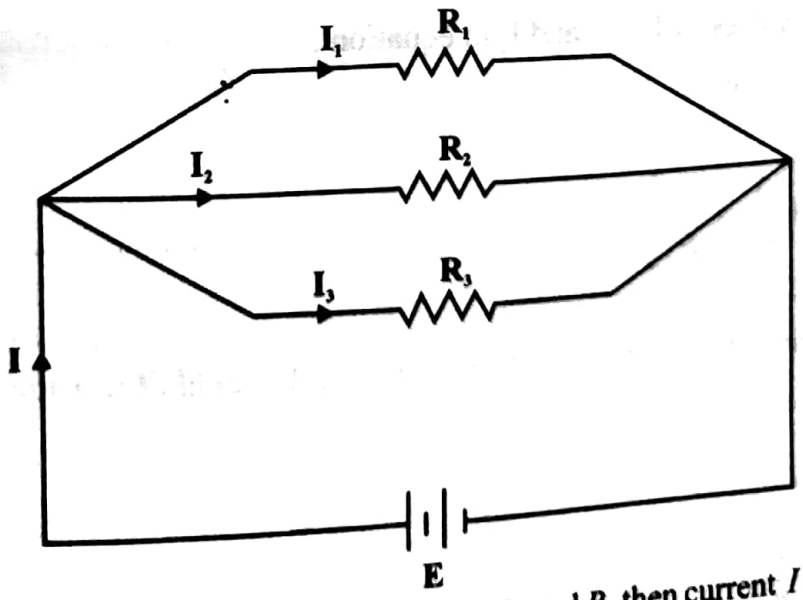
Thus when the resistors are connected in series, equivalent resistance of the series combination is equal to sum of individual

3.22 Resistors in parallel

Two or more resistors are said to be connected in parallel, if potential difference across each of them is equal to the applied potential difference.

Fig show the parallel combination of three resistors having resistances R_1, R_2 and R_3.

If a battery of emf E is connected across the parallel combination, the potential difference across each resistor will be equal to V.



If I_1, I_2 and I_3 are the currents through the resistances R_1, R_2 and R_3 then current I can be given by

$$I = I_1+I_2+I_3 \quad \text{.....(1)}$$

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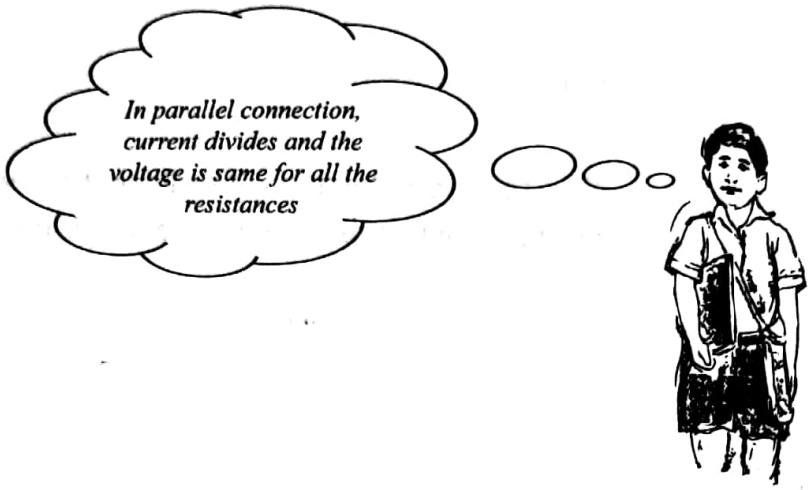

The potential difference across each resistor is V.
Then

$$V = I_1R_1, \quad I_1 = \frac{V}{R_1}$$

$$V = I_2R_2,$$

$$I_2 = \frac{V}{R_2}$$

$$V = I_3R_3,$$

$$I_3 = \frac{V}{R_3}$$

Substituting the values of I_1, I_2, and I_3 in equation ,

$$I = \frac{V}{R1} + \frac{V}{R2} + \frac{V}{R3}$$

$$I = V\left[\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}\right] \quad \text{.....(2)}$$

If R_p is the equivalent resistance of the parallel combination of resistors R_1, R_2 and R_3

Then

$$V = I R_p$$

Or $$I = \frac{V}{Rp} \quad \text{.....(3)}$$

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From equation 2 and 3,

$$\frac{V}{Rp} = V\left[\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}\right]$$

The Equivalent Resistance $\frac{1}{Rp} = \left[\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}\right]$

Thus when resistors are connected in parallel, reciprocal of equivalent resistance of the parallel combination is equal to the sum of the reciprocals of individual resistances.

It is clear that the value of equivalent resistance is always less than the value of smallest individual resistance.

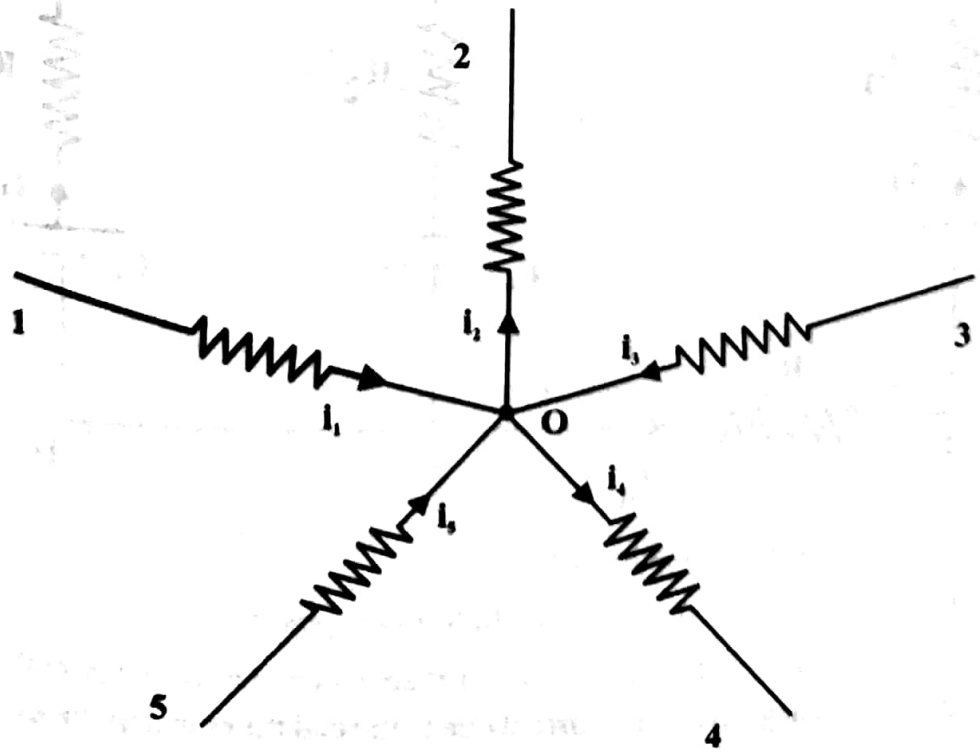
3.23 Kirchoff's first law

It states that the algebraic sum of the currents meeting at a point in an electrical circuit is always zero. It is also called junction law.

This law is based upon the fact that in an electrical circuit, a point can neither act as a source of charge nor the charge can accumulate at that point.

Explanation

Consider a point O in an electrical circuit at which currents I_1, I_2, I_3, I_4 and I_5 are flowing through five resistances in the direction as shown in fig.



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The following sign convention is adopted.

1. The current flowing in a resistance towards the junction is taken as positive.
2. The current flowing away from the junction is taken as negative.

Accordingly, currents I_1, I_3 and I_5 are positive. Currents I_2 and I_4 are negative.
According to Kirchhoff's first (junction) law

$$I_1 - I_2 + I_3 - I_4 + I_5 = 0$$

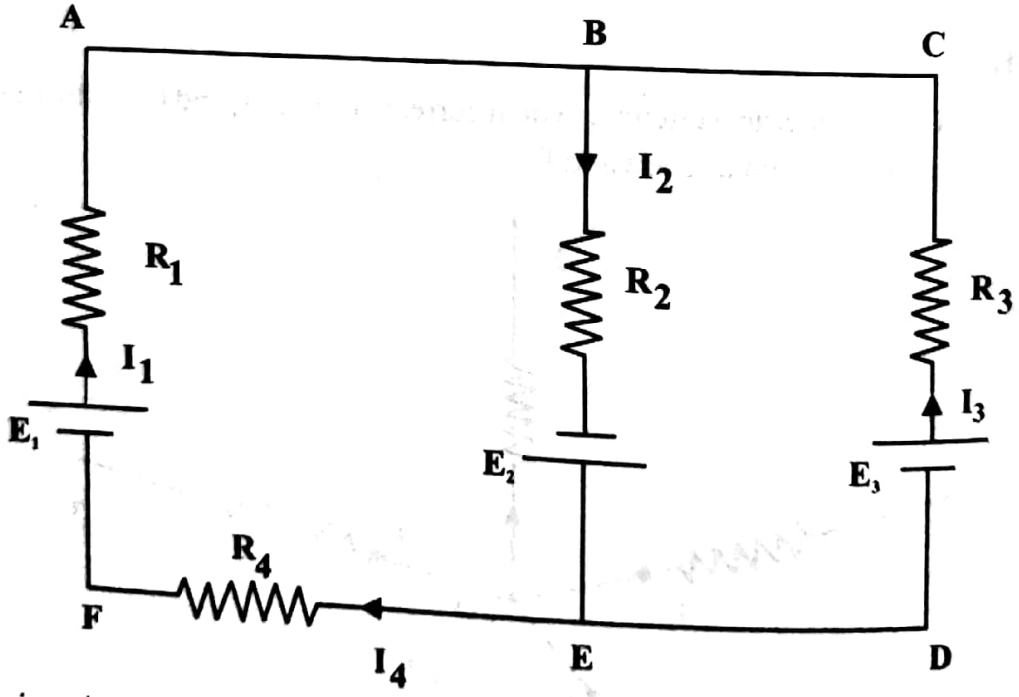
3.24 Kirchoff's second law

It states that in any closed part of an electrical circuit, the algebraic sum of the emf's is equ to the algebraic sum of the products of the resistances and currents flowing through them. It also called voltage law. This law is based upon the law of conservation of energy.

Explanation

Consider a closed circuit ABCDEFA containing two cells of emf E_1 and E_3 and three resistance R_1, R_3 and R_4 as shown in fig.

t



The following sign conventions are adopted.

1. The current flowing in clockwise direction is positive.
2. The emf of a cell is taken positive, if it sends current in the circuit in clockwise direction and negative if the current due to the cell flows in anticlockwise direction.

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Let us consider the closed part ABCDEFA of the electrical circuit

The cell E_1 sends current in clockwise direction and ,So is positive.

The cell E_3 sends current in anticlockwise direction, so E_3 is negative.

The total emf of closed part ABCDEFA = E_1-E_3.

In closed part ABCDEFA, currents I_1 and I_4 flow in clockwise direction, and are taken as positive. I_3 in anti-clockwise direction and is taken as negative.

In the closed circuit ABCDEA, According Kirchhoff's law

$$E_1 - E_3 = I_1R_1 + I_2R_2 - I_3R_3$$

Similarly, for the closed part ABEFA

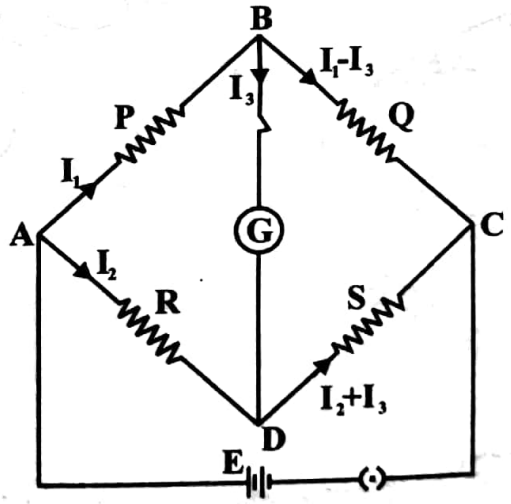
$$E_1 + E_2 = I_1R_1 + I_2R_2 + I_4R_4$$

3.25 Wheatstone Bridge

An important application of Kirchoff's law is the Wheatstone's bridge.

Four resistances P, Q, R and S are connected to form a closed network as shown in fig. A tapping key and galvanometer G are connected between two points B and D.

A battery of emf E and a key are connected between points A and C.



When the plug is inserted in the key , the current I enters the network at point A.

At A current divides into two parts. One part I_1 flows through resistance P and the part I_2 flows through resistance R.

At the point B current again divides into two parts.

When pressing the key near the galvanometer, current I_3 flows through galvanometer.

Now according to Kirchhoff's law, current (I_1-I_3) will flow through resistance Q.

Currents I_2 and I_3 join at the point D.

Current I_2+I_3 passes through resistance S.

Let us consider that current flowing in "clockwise" direction is positive.

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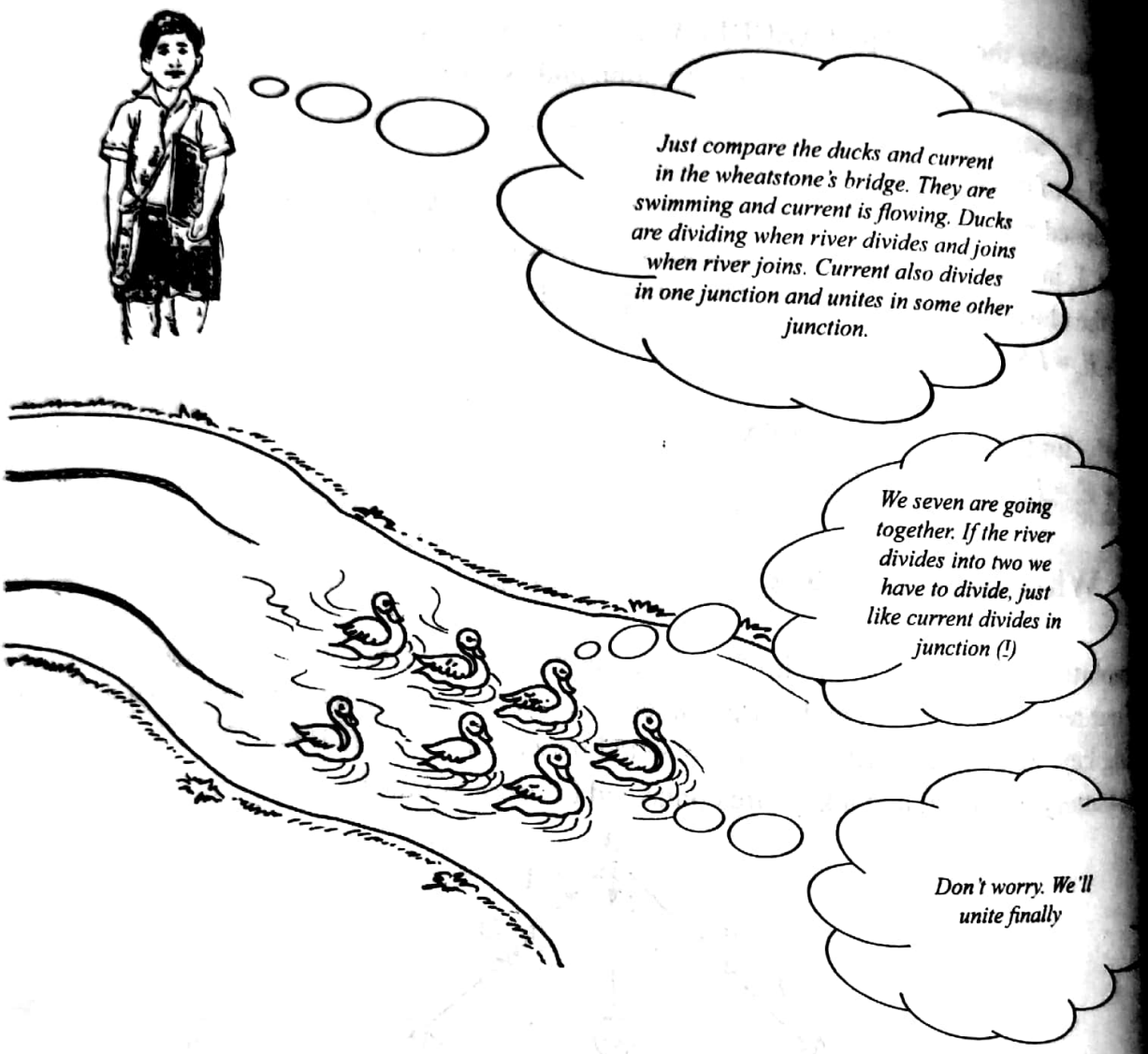

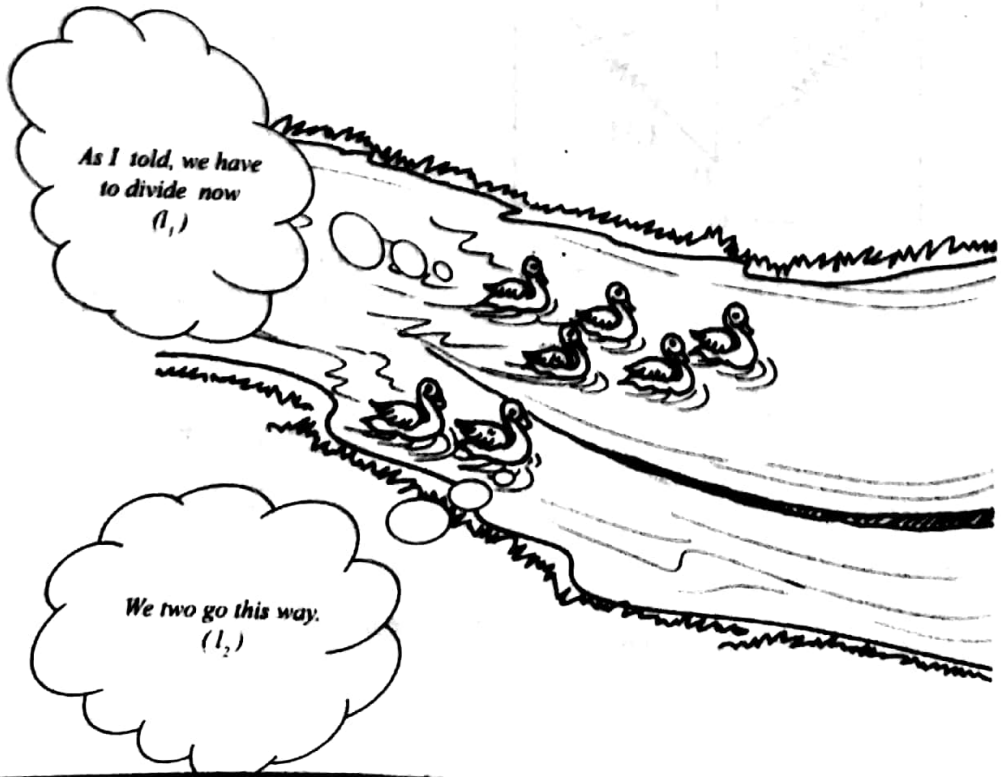

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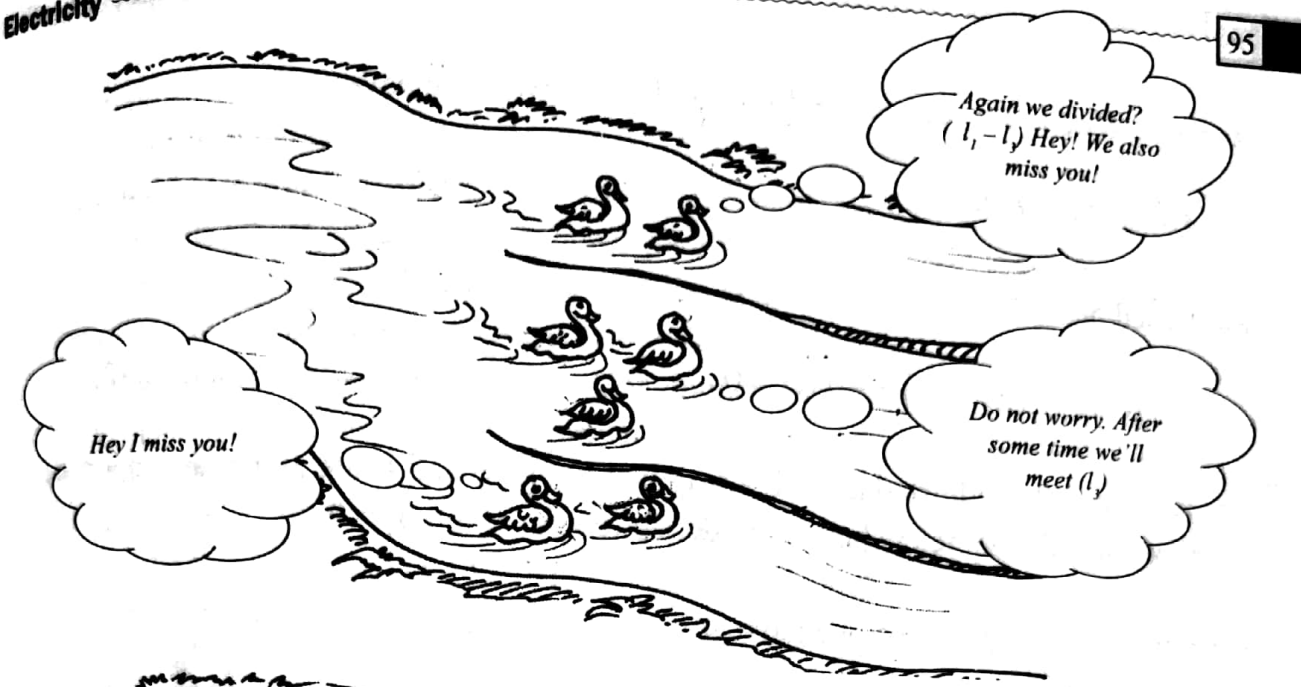

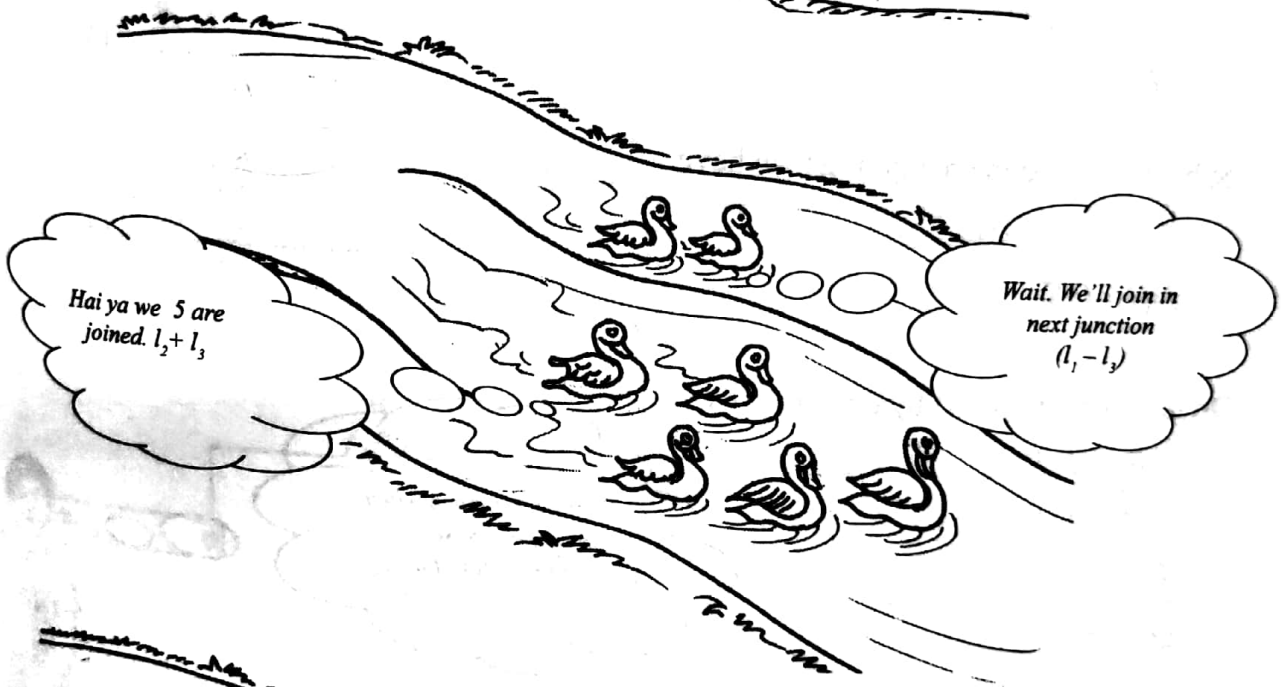

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Applying Kirchoff's voltage law for closed part ABDA we have

$$I_1P + I_3G - I_2R = 0 \quad \text{.....(1)}$$

For closed part BCDB,

$$(I_1 - I_3)Q - (I_2 + I_3)S - I_3G = 0 \quad \text{.....(2)}$$

The resistance R is adjusted in such a way that points B and D are at the same potential.
Now the galvanometer shows null deflection..i.e. $I_3 = 0$

Substitute this in equation 1, we have

$$I_1P - I_2R = 0$$

$$I_1P = I_2R \quad \text{.....(3)}$$

Substitute $I_3 = 0$ in equation (2) we have

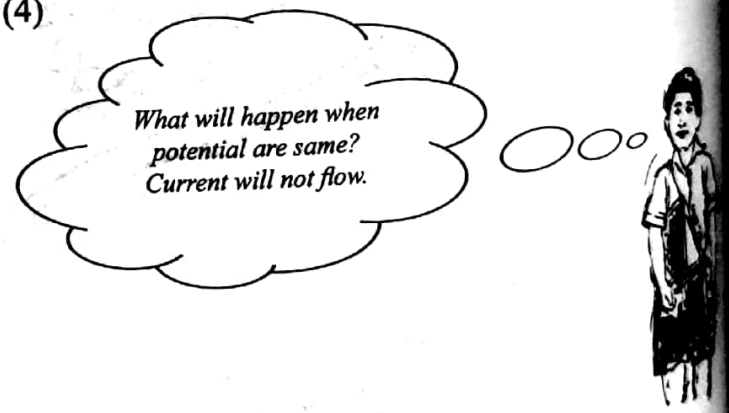
$$I_1Q - I_2S = 0 \quad \text{.....(4)}$$

$$I_1Q = I_2S$$

Dividing equation (3) by equation (4)

$$\frac{I_1P}{I_1Q} = \frac{I_2R}{I_2S}$$

$$\frac{P}{Q} = \frac{R}{S}$$



Under this condition no current flows through the galvanometer.
And this is the condition to balance the bridge.

3.26 Slide Wire Bridge or Metre Bridge

Principle: It uses the wheatstone Bridge condition for balancing as given by the equation.

$$\frac{P}{Q} = \frac{R}{S}$$

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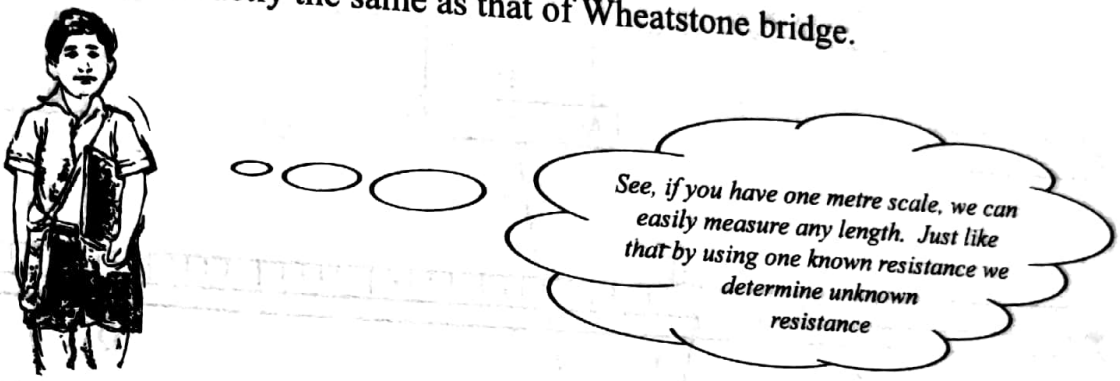
Description

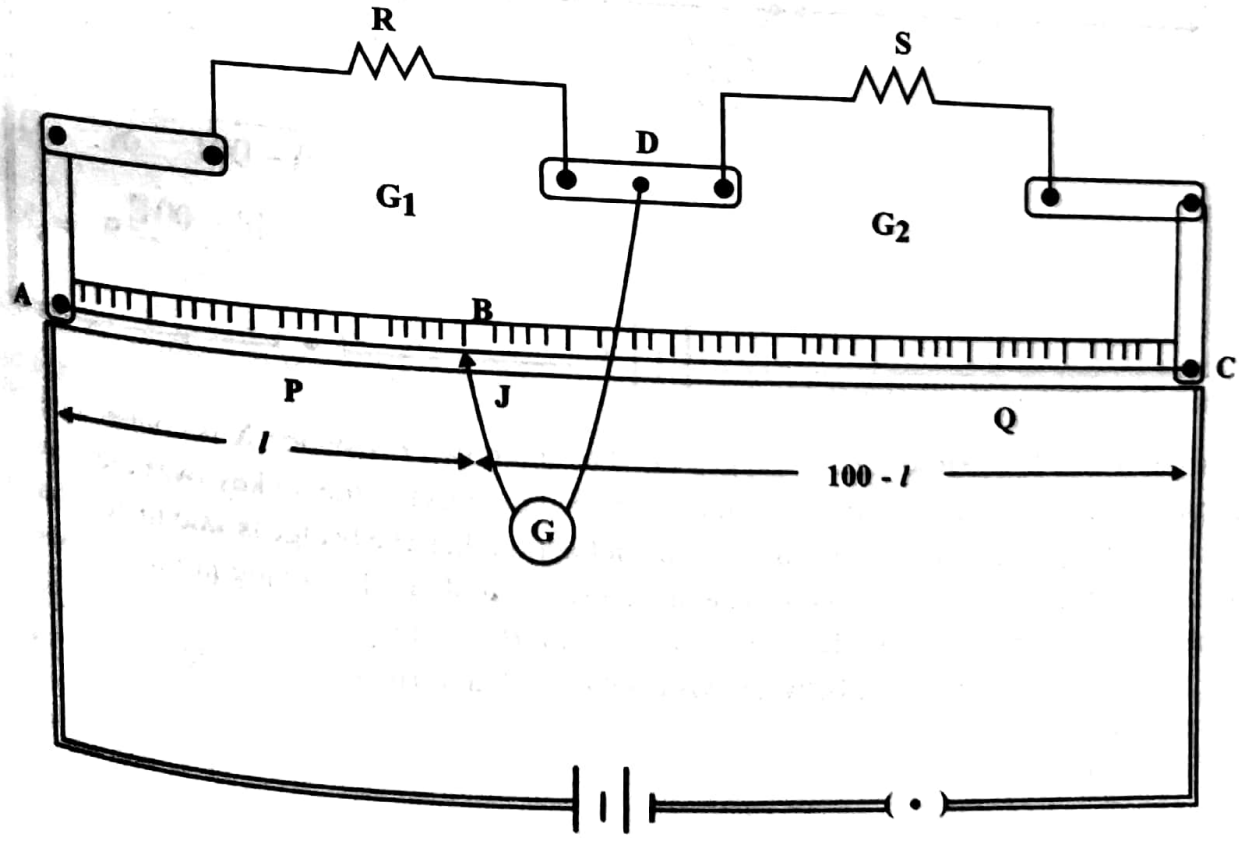
It consists of a wooden board, over which two 'L' shaped copper strips are fixed as shown in picture. Constantan wire AC of one metre in length is stretched between two copper stripes. A metre scale is also fixed on the wooden board parallel to the length of the wire.

Another copper strip is fixed on the wooden board to provide two gaps G_1 and G_2. A resistance box R and the unknown resistance S are connected between two gaps G_1 and G_2. One terminal of a sensitive galvanometer G is connected to the terminal D, provided on the central copper strip and the other of terminal of galvanometer is connected to jockey (J) through high resistance *HR*.

The jockey can slide over the wire and can make contact at any point on the wire AC. Across the two ends of wire a Leclanche cell is connected.

The circuit is now exactly the same as that of Wheatstone bridge.





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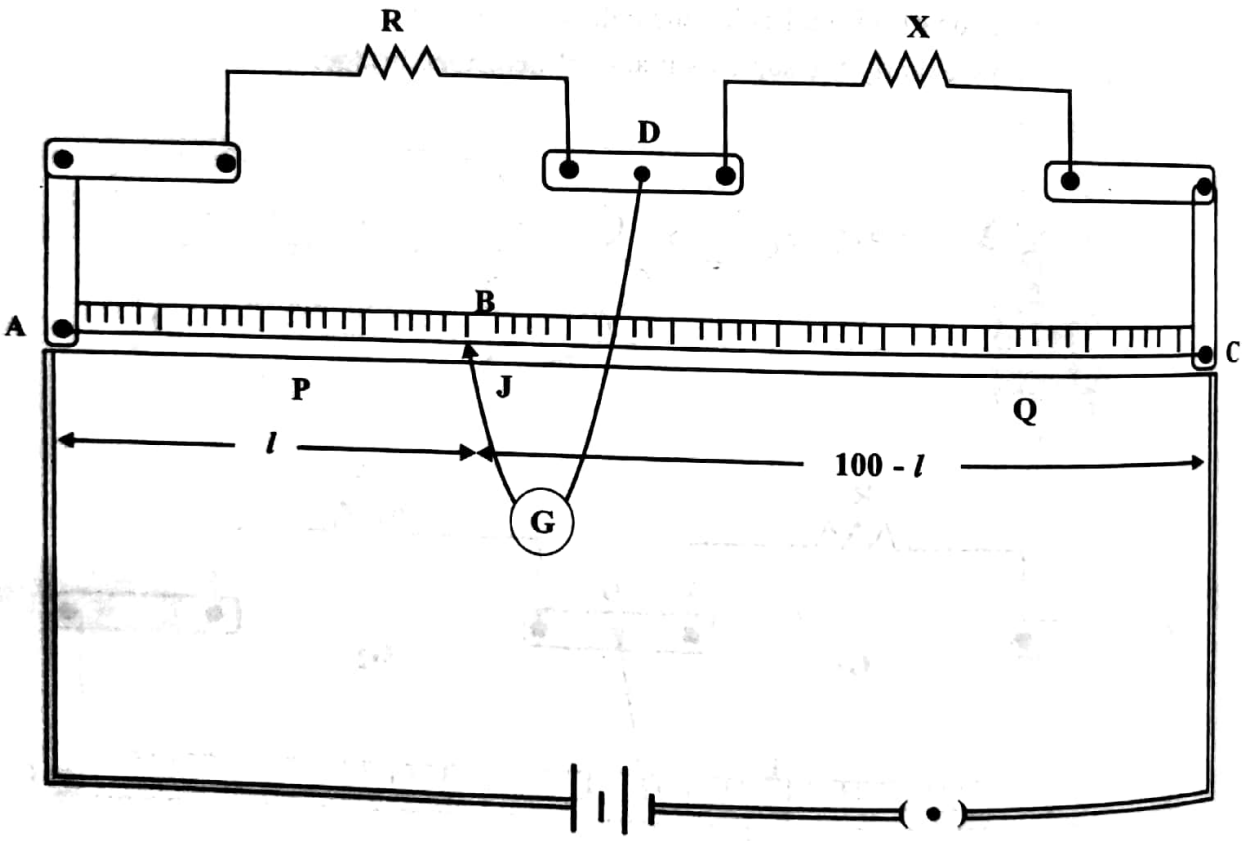
The resistance of the wire between two point A and B represents ratio arm P and that of wire between B and C represents Q. Here B is the position of jockey in balanced state of the bridge. Therefore when the bridge is balanced,

$$\frac{P}{Q} = \frac{R}{S}$$

Application of Meter bridge

I. To measure an unknown resistance:



Resistance box R is introduced in the gap G_1 .The unknown resistance X is connected in the gap G_2 as shown in fig. The bridge can be balanced by moving the jockey over the wire AC.

When the galvanometer does not give any deflection then the bridge is said to be balanced. To balance the bridge resistance R is adjusted so as to obtain balancing point. Suppose the bridge is balanced at the point B. Then, AB = l and BC = $100 - l$

The resistance of the wire between AB is taken as P and BC is taken as Q.

$P \propto l$

$Q \propto 100 - l$

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From the principle of Wheatstone bridge

$$\frac{P}{Q} = \frac{R}{X} = \frac{l}{100-l}$$

$$X = \frac{R[100-l]}{l}$$

Knowing the value of R and l, the value of unknown resistance x can be found.

II. To compare two unknown resistances: For comparing two unknown resistances R_1 and R_2 the circuit as shown in fig. is arranged. First the resistance R_1 is connected in place of unknown resistance X. The jockey is moved over the bridge wire gently and by adjusting the value of R, the balancing point is obtained.

The bridge is said to be balanced, when the jockey is at a point B on the wire such that galvanometer does not give any deflection.

Now, AB $= l_1$, BC $= 100 - l_1$

AB is the ratio arm P, BC is the ratio arm Q.

$P \alpha\ l_1$

$Q \alpha\ 100 - l_1$

From the principle of Wheatstone bridge

$$\frac{P}{Q} = \frac{R}{R_1} = \frac{l_1}{100-l_1}$$

$$R_1 = R\frac{[100-l_1]}{l_1} \quad \text{..... (1)}$$

Now the experiment is repeated with the other unknown resistance R_2. If l_2 is the balancing length then,

$$R_2 = R\frac{[100-l_2]}{l_2} \quad \text{..... (2)}$$

Dividing equation 1 and 2 we have

$$\frac{R_1}{R_2} = \frac{l_2}{l_1}\frac{(100-l_1)}{(100-l_2)}$$

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By finding the values l_1 and l_2 the ratio of $\frac{R_1}{R_2}$ can be found.

I. To measure the unknown temperature: We know that resistance of a conductor increases with increase of temperature. The resistance of a conductor at temp θ is given by

$$R = R_0(1+\alpha\theta) \quad \text{..... (1)}$$

When R_0 is resistance of the conductor at 0^0C and α is the temp. coefficient of resistance of the conductor.

From equation (1) we have

$$R - R_0 = R_0 \alpha \theta \quad \text{..... (2)}$$

$$\text{If } R_{100} - R_0 = R_0 \alpha\, 100 \quad \text{..... (3)}$$

Dividing (2) by (3)

$$\theta = \frac{(R - R_0)100}{(R_{100} - R_0)} \quad \text{..... (4)}$$

Using the above equation, the unknown temperature can be found.

The resistance is immersed in ice and bridge is balanced and resistance is R_0 and now the resistance is immersed in steam and bridge is balanced and resistance is found as R_{100}.

Then resistance is immersed in the unknown temp and the resistance is found as R. Then substituting the value of R_0, R_{100} and R in equation (4) the unknown temp can be found.

Numerical Problems

1. **Three capacitors of 2μF, 3μF and 4μF are connected in series . Calculate the effective capacitance. Also calculate the effective capacitance when they are connected in parallel.**

Solution:

Two capacitors of capacitances 3μF and 4μF are connected in parallel. Calculate the effective capacitance of two capacitors.

Solution

Two capacitors C_1 and C_2 be 3μF and 4μF. The two are connected in parallel as shown in figure

Let C_p is the effective value of parallel capacitors.

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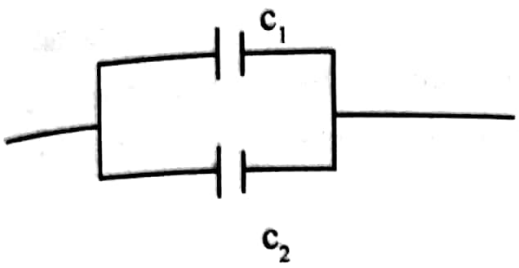
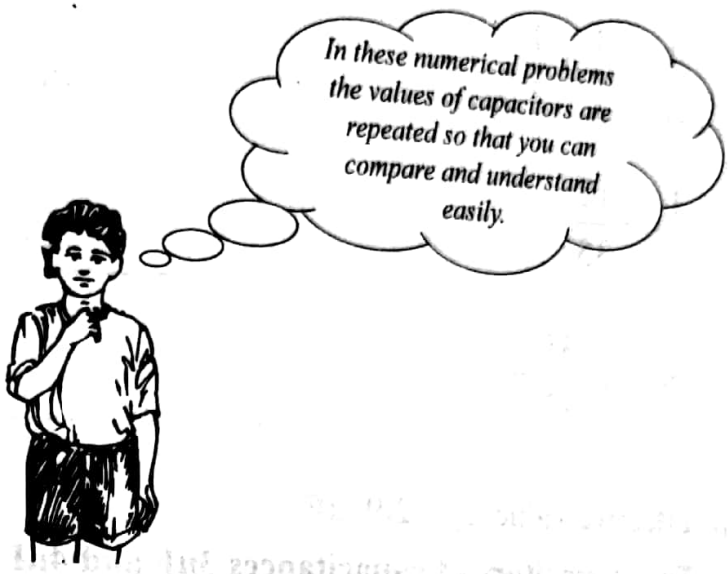


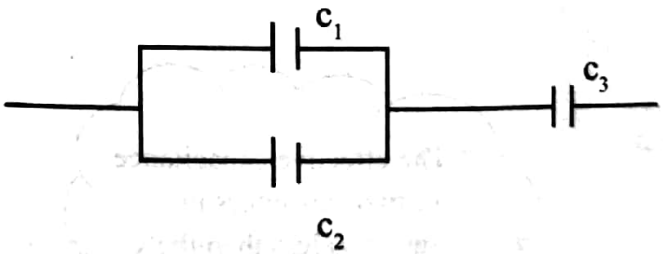


$C_p = C_1 + C_2$
$C_p = 3\mu F + 4\mu F$
$C_p = 7\ \mu F$

2. Two capacitors of capacitances 3μF and 4μF are connected in parallel. The combination is connected in series with another capacitor of capacitance 5μF. Calculate the effective capacitance of three capacitors.

Solution

Two capacitors C_1 and C_2 be 3μF and 4μF. The two are connected in parallel. C_p is the effective value of parallel capacitors and the third C_3 is connected in series as shown in figure .



$C_p = C_1 + C_2$
$C_p = 3\mu F + 4\mu F$
$C_p = 7\ \mu F$

Now the combination (C_p) is connected in series.
The effective capacitance of three capacitors is given by

Here $$\frac{1}{C_E} = \frac{1}{C_p} + \frac{1}{C_3}$$

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$$\frac{1}{c_E} = \frac{1}{7} + \frac{1}{5}$$

$$\frac{1}{c_E} = \frac{12}{35}$$

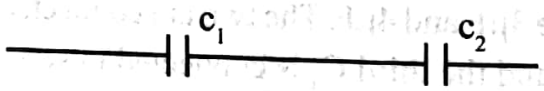
$$Or\, c_E = \frac{35}{12}\mu F$$

The effective value $C_E = 2.91\mu F$

3. Two capacitors of capacitances 3μF and 4μF are connected in series. Calculate the effective capacitance of two capacitors.

Solution

Two capacitors C_1 and C_2 be 3μF and 4μF. And are connected in series as shown in fig. C_s is the effective value of series capacitors.



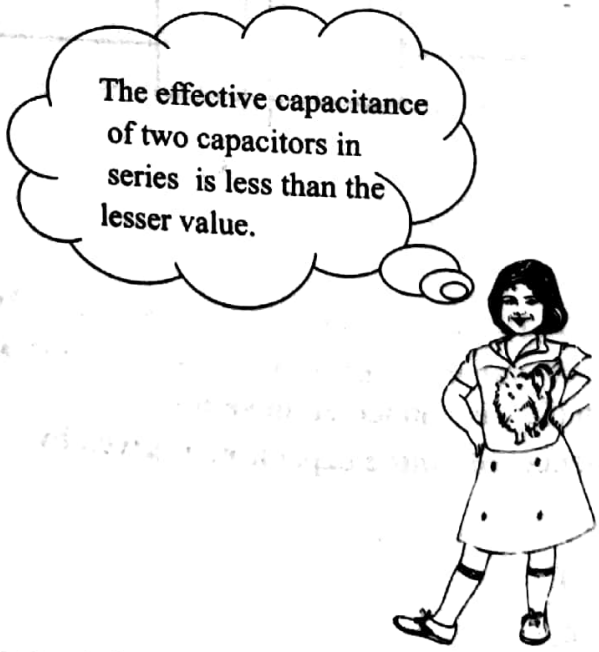
$$\frac{1}{c_s} = \frac{1}{c_{s1}} + \frac{1}{c_2}$$

$$\frac{1}{c_s} = \frac{1}{c_s} + \frac{1}{4_s}$$

$$\frac{1}{c_s} = \frac{7}{12}$$

$$c_s = \frac{12}{72}$$

$$c_s = 1.71\mu F$$



4. Two capacitors of capacitances 3μF and 4μF are connected in series. The combination is connected in parallel with another capacitor of capacitance 5μF. Calculate the effective capacitance of three capacitors.

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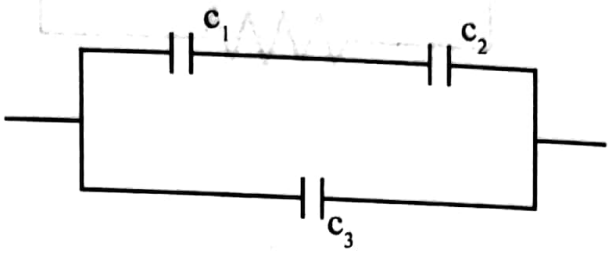
Solution

Two capacitors C_1 **and** C_2 **be** 3μF and 4μF. And are connected in series as shown in fig. C_s is the effective value of series capacitors.



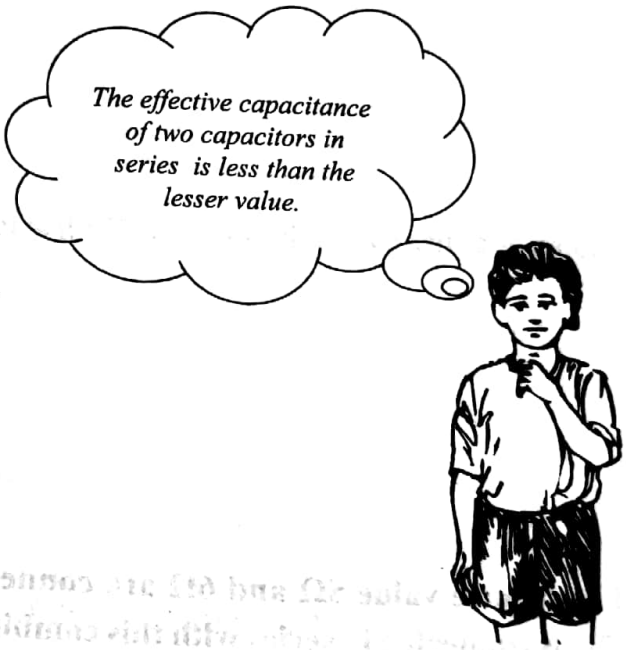
$$\frac{1}{c_s}=\frac{1}{c_1}+\frac{1}{c_2}$$

$$\frac{1}{c_s}=\frac{1}{3}+\frac{1}{4}$$

$$\frac{1}{c_s}=\frac{7}{12}$$

$$c_s=\frac{12}{72}$$

$$c_s=1.71\mu F$$



Now the combination is connected in parallel with another capacitor of value 5μF as shown in figure.

$$C_E=c_s+c_3$$

$$C_E=1.71+5$$

$$C_E=6.71\mu F.$$

5. Two resistors of resistance value 5Ω and 6Ω are connected in parallel. Calculate the effective value of two resistors.

Solution

Two resistors R_1 and R_2 be 5Ω and 6Ω and are connected in parallel as shown in figure

Let C_p is the effective value of parallel resistors.

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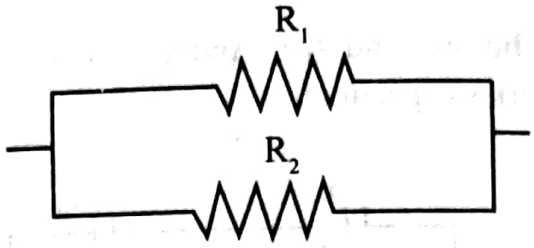


$$\frac{1}{R_s}=\frac{1}{R_1}+\frac{1}{R_2}$$

$$\frac{1}{R_s}=\frac{1}{5}+\frac{1}{6}$$

$$\frac{1}{R_s}=\frac{11}{30}$$

$$R_S=\frac{30}{11}$$

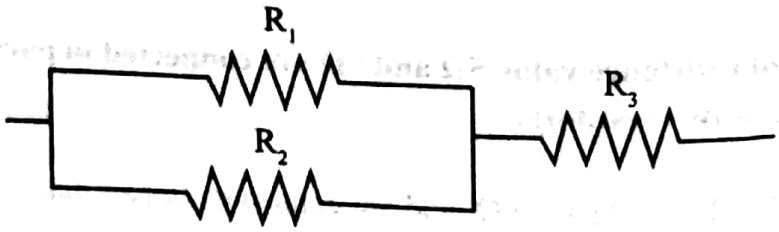
$$R_S=2.72\Omega$$

6. Two resistors of resistance value 5Ω and 6Ω are connected in parallel. A resistor of resistance value 7Ω is connected in series with this combination. Calculate the effective value of three resistors.

Solution

First we have to calculate the effective value of resistors in series and then the effective value of three values.

Two resistors R_1 and R_2 be 5Ω and 6Ω and are connected in parallel as shown in figure Let C_p is the effective value of parallel resistors.



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$$\frac{1}{R_s}=\frac{1}{R_1}+\frac{1}{R_2}$$

$$\frac{1}{R_s}=\frac{1}{5}+\frac{1}{6}$$

$$\frac{1}{R_s}=\frac{11}{30}$$

$$R_S=\frac{30}{11}$$

$$R_S=2.72\Omega$$

This R_S is connected in parallel with R_3 and the effective value is calculated as follows.

$$R_E=R_S+R_3$$

$$R_E=2.72+7$$

$$R_E=9.72\Omega$$

The effective resistance value of three resistors is 9.72Ω.

7. Two resistors of resistance value 5Ω and 6Ω are connected in series. Calculate the effective resistance value of two resistors.

Solution

Two resistors R_1 and R_2 be 5Ω and 6Ω and are connected in series as shown in figure
Let C_s is the effective value of series resistors.

$$R_s=R_1+R_2$$

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$R_S = 5 + 6$

$R_S = 11\Omega$

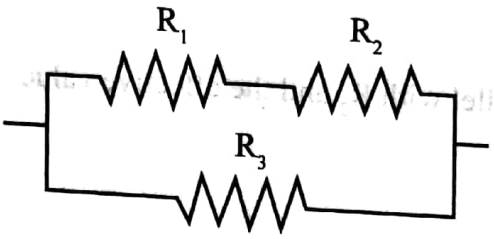
8. Two resistors of resistance value 5Ω and 6Ω are connected in series. A resistor of resistance value 7Ω is connected in parallel with this combination. Calculate the effective value of three resistors.

Solution

First we have to calculate the effective value of resistors in series and then the effective value of three values.

Two resistors R_1 and R_2 be 5Ω and 6Ω and are connected in series as shown in figure

Let R_s is the effective value of series resistors.



$R_S = R_1 + R_2$

$R_S = 5 + 6$

$R_S = 11\Omega$

Now this combination is connected in parallel with R_3.

$$\frac{1}{R_E} = \frac{1}{R_s} + \frac{1}{R_3}$$

$$\frac{1}{R_E} = \frac{1}{11} + \frac{1}{7}$$

$$\frac{1}{R_E} = \frac{18}{77}$$

The effective resistance of three resistors $R_E \frac{77}{18} = 4.27\Omega$

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9. A parallel plate capacitor with air medium has capacitance of 16μF.Determine its value when the distance between the plates are reduced by half.

Given Data

Capacitance Co = 16μF

Distance is reduced to half of original value.

New Capacitance Value =?

Solution

We know $C_o = \frac{\varepsilon_0}{d} A$

Here A= Area of the plate

d= distance between the plates.

Now let us assume new capacitance as C1 and substitute d/2

$$C_1 = \frac{\varepsilon_0}{d/2} A$$

$$C_1 = \frac{\varepsilon_0}{d} A$$

$$C_1 = 2C_o$$

$$C_o = 16\mu F$$

So $C_1 = 2 \times 16$

$$C_1 = 32\mu F$$

The capacitance increases two times of its original value when distance is reduced by half.

10. A parallel plate capacitor with air medium has capacitance of 16μF.Determine its value when the distance between the plates are reduced by one fourth of its original value.

Given Data

Capacitance Co = 16μF

Distance is reduced to one fourth of original value.

New Capacitance Value =?

Solution

We know $C_o = \frac{\varepsilon_0}{d} A$

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Here A= Area of the plate
d= distance between the plates.
Now let us assume new capacitance as C1 and substitute d/4

$$C_1 = \frac{\varepsilon_0}{d/4} A$$

$$C_1 = 4\frac{\varepsilon_0}{d} A$$

$$C_1 = 4C_o$$

$$C_o = 16\mu F$$

$$So \quad C_1 = 4 \times 16$$

$$C_1 = 64\mu F$$

The capacitance increases four times of its original value when distance is reduced by half.

11. A parallel plate capacitor with air medium has capacitance of 16μF.Determine its value when the distance between the plates are reduced by half and area is doubled.

Given Data

Capacitance Co = 16μF
Distance is reduced to half of original value.
Area is doubled.
New Capacitance Value =?

Solution

We know $C_o = \frac{\varepsilon_0}{d} A$

Here A= Area of the plate
d= distance between the plates.
Now let us assume new capacitance as C_1 and substitute d/2 and 2A.

$$C_1 = \frac{\varepsilon_0 . 2A}{\frac{d}{2}}$$

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$$C_1 = 4\frac{\varepsilon_0}{d}A$$

$$C_1 = 4C_o$$

$$C_o = 16\mu F$$

So $C_1 = 4\times16$

$$C_1 = 64\mu F$$

12. The capacitance increases four times of its original value when distance is reduced by half and area is doubled.

A parallel plate capacitor with air medium has capacitance of 12μF.Determine its value when the distance between the plates is filled with dielectric medium of value10.

Given Data

Capacitance Co = 12μF

The space is filled with dielectric of k = 10.

New Capacitance Value =?

Solution

We know $C = \frac{K\varepsilon_o A}{d}$

Here k= dielectric constant.

A= Area of the plate

d= distance between the plates.

$C = KC_o$

The capacitance with air space is and is given as 12.

i.e. Co = 12μF

So C = 10x12

C = 120

The capacitance increases ten times of its original value when space is filled with k of value 10.

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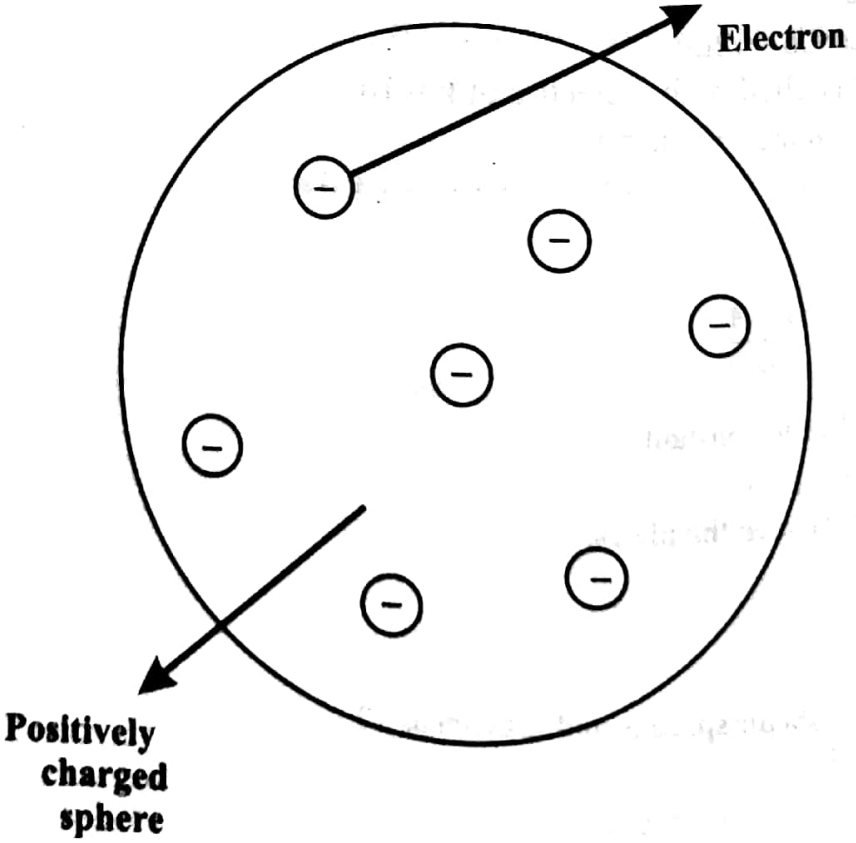
CHAPTER

4 STRUCTURE OF ATOM AND SEMICONDUCTORS

4.1 Thomson Atom Model

From the study of discharge of electricity through gases, it became clear that atom consists of positive and negative charges.

J.J Thomson gave explanation about the arrangement of positive charge and electrons inside the atom. According to him, an atom is a sphere of positive charge having a radius of the order 10^{-10} m. The positive charge is uniformly distributed over the entire sphere. The electrons are embedded in the sphere of positive charge as shown in fig.



The total positive charge of the atom is equal to the total negative charge of the electrons, so that every atom is electricity neutral.

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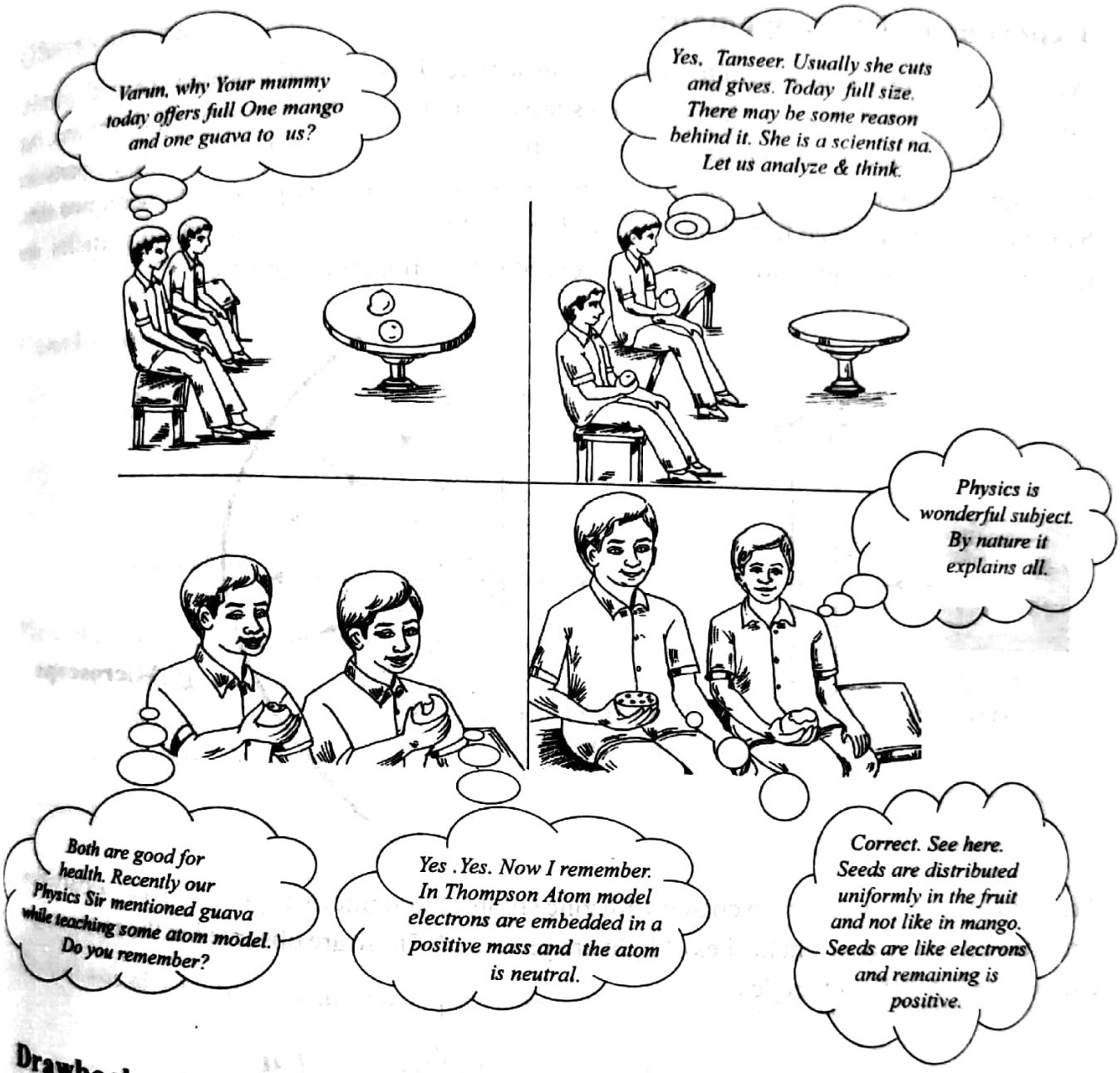

Drawbacks of Thomson atom model

1. It could not explain the spectral lines of hydrogen atom and other atoms.
2. It could not account for the scattering of α-particles through large angle in the case of Rutherford's α-ray scattering experiment.

4.2 Rutherford's α-particle scattering experiment:

Rutherford studied the scattering of α-particles by a thin gold foil which led to discovery of atomic nucleus. An α-particle is a helium nucleus containing two protons and two neutrons. They are emitted by many radioactive elements.

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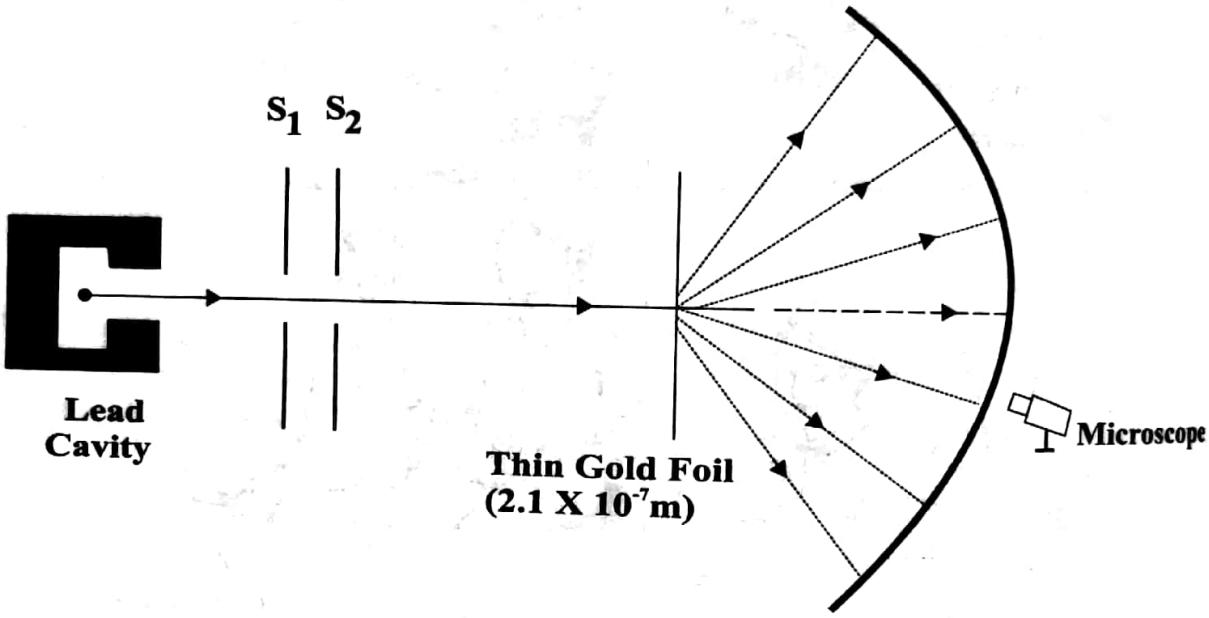
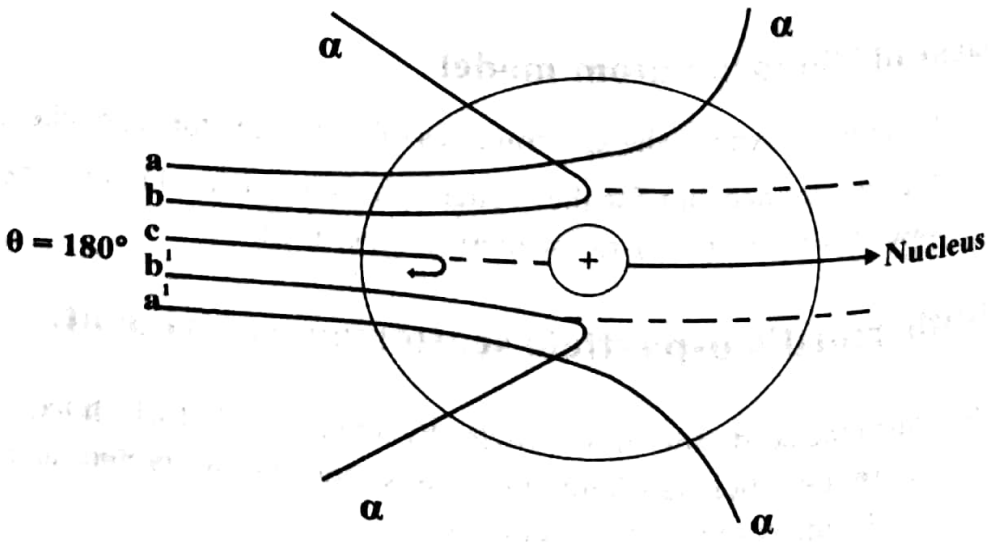
Experimental Arrangement:

A radioactive material like bismuth which emits α-particles is placed in a lead box with narrow opening as shown in fig..... . The α-particles are emitted from the source in all directions, but only a narrow beam emerges from the lead box through the opening. The remaining α-particles are absorbed in the lead box. The α-particles are made narrow by passing through two slits. Now the beam is allowed to fall on a thin gold foil of thickness 2×10^{-7} m. The α-particles are scattered in different directions and are observed by the rotatable detector.



The detector consists of screen coated with zinc sulphide and microscope. When the α-particles strike the screen, tiny bright flashes of light are produced. These are observed in the microscope and counted at different angles.



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Observations

1. Most of the α-particles pass straight through the gold foil without appreciable deflection. This observation led to the conclusion that atom has lot of space as shown in fig.
2. A large number of α-particles suffered fairly large deflections.
3. One particle in every in 8000 particles deflects by nearly 180°.

Conclusion

1. Since most of the α-particles passed through the foil, the atom has a lot of empty spaces in it.
2. Since the high velocity and heavy α-particles are deflected even through 180°, the whole of positive charge of atom must be concentrated in a tiny central core of each atom. This tiny central core is named as nucleus.

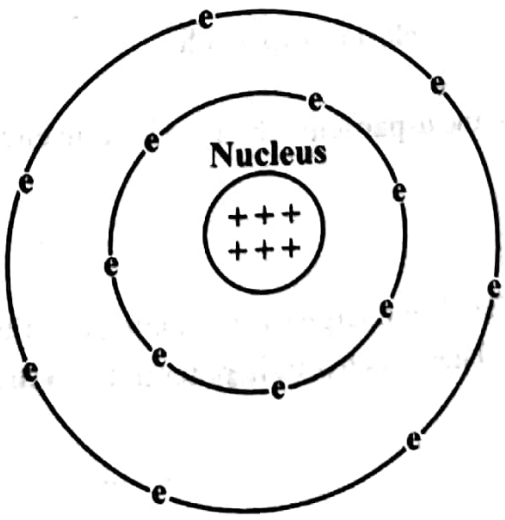
The scattering of α-particles through different angles was explained with the help of the fig..

1. Since the nucleus is concentrated at the centre and particles travel directly towards it, are repulsed and deflected back through 180° and retrace their original path.
2. α-particles which pass through close to the nucleus are deflected at greater angles.
3. α-particles which pass through at a large distance undergo small deflection.

4.3 Rutherford's Atom Model

On the basis of α-particles scattering experiment Rutherford proposed the atom model as below:

e--Electrons are revolving



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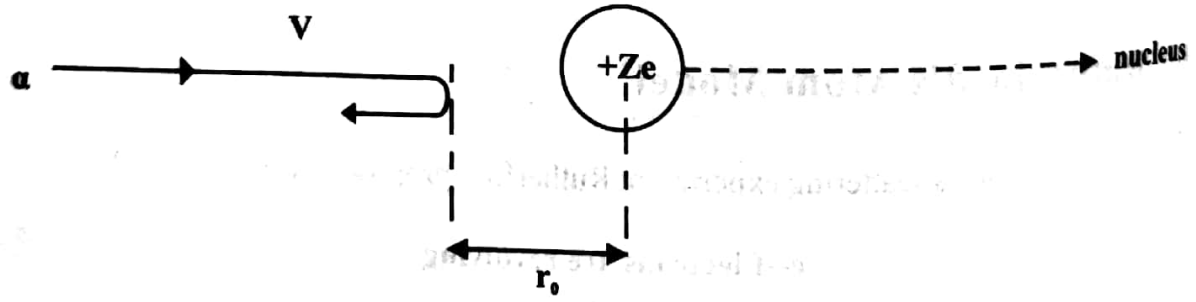
1. Every atom consists of a tiny central core called the nucleus.
2. The positive charge and almost entire mass of the atom are concentrated in the nucleus.
3. The size of the nucleus is of the order of 10^{-14} m.
4. The size of the atom is of the order of 10^{-10} m.
5. The nucleus is surrounded by certain number of electrons.
6. The total negative charge of the electron is equal to the positive charge of nucleus. Therefore atom is neutral.
7. The electrons revolve around the nucleus in various orbits as planets revolve around the sun.
8. The centripetal force required by the electron for revolution is provided by the electrostatic force of attraction between the electrons and the nucleus.

4.4 Distance of closest approach

An α-particle directed towards the centre of the nucleus will move close up to a distance r_o. At this point due to repulsive force, the α-particle is deflected back. At this moment the kinetic energy of the α-particle is converted into electrostatic potential energy. This distance r_o is known as the distance of closest approach.



closest approach

Let m and v be the velocity of the α-particle. Then the kinetic energy of the α-particle is given by

$$E_k = \frac{mv^2}{2} \qquad \text{..... (1)}$$

Charge of the α-particle is 2e. The charge of the nucleus of the atom is Ze and here Z is the atomic number of the atom. Then electrostatic potential at a distance r_o is given by

$$Ep = \frac{2e.Ze}{4\pi\varepsilon_o r_o} \qquad \text{..... (2)}$$

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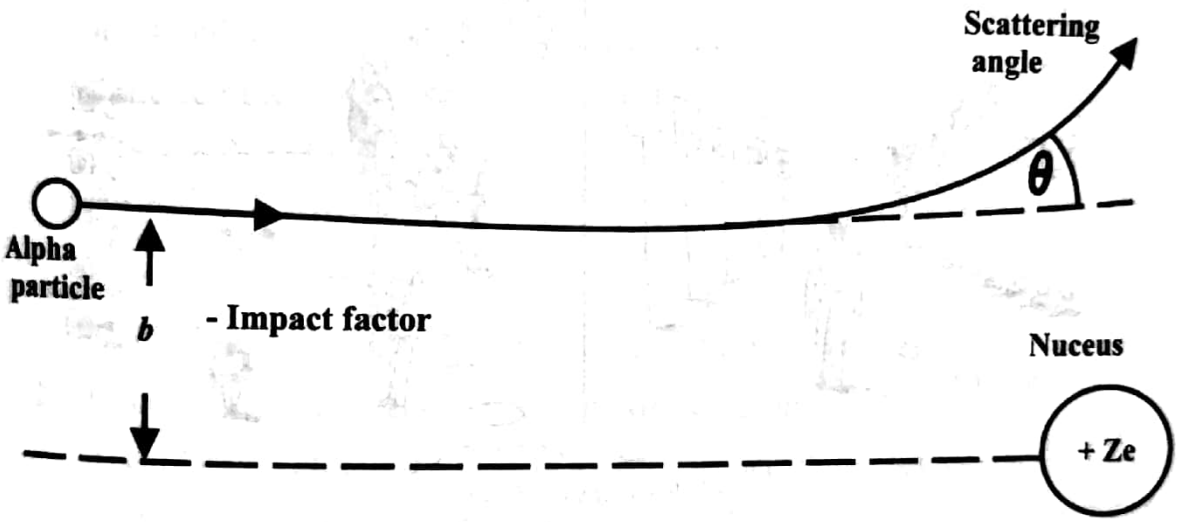
Equating 1 & 2 we have

$$r_o = \frac{4ze^2}{4\pi\varepsilon omv^2}$$

At this point the kinetic energy of the α-particle is equal to potential energy and it is deflected back.

4.5 Impact parameter

It is defined as the perpendicular distance of the α-particle from centre of the nucleus when the α-particle is far away from the atom. It is denoted by the letter b and is related to scattering angle Θ by following relation.



Impact parameter $b = Ze^2.(\cot\theta/2)/4\pi\varepsilon_o E_K$

1. If b is large, the angle of scattering is small.
2. If b is small, the angle of scattering is large.
3. If b = 0, then $\cot\Theta/2 = 0$

   and

   $\Theta/2 = 90^o$

   Hence, $\Theta = 180^o$

Thus if a particle has an impact parameter equal to zero, then it will be deflected through 180°. i.e., it retraces its original path.

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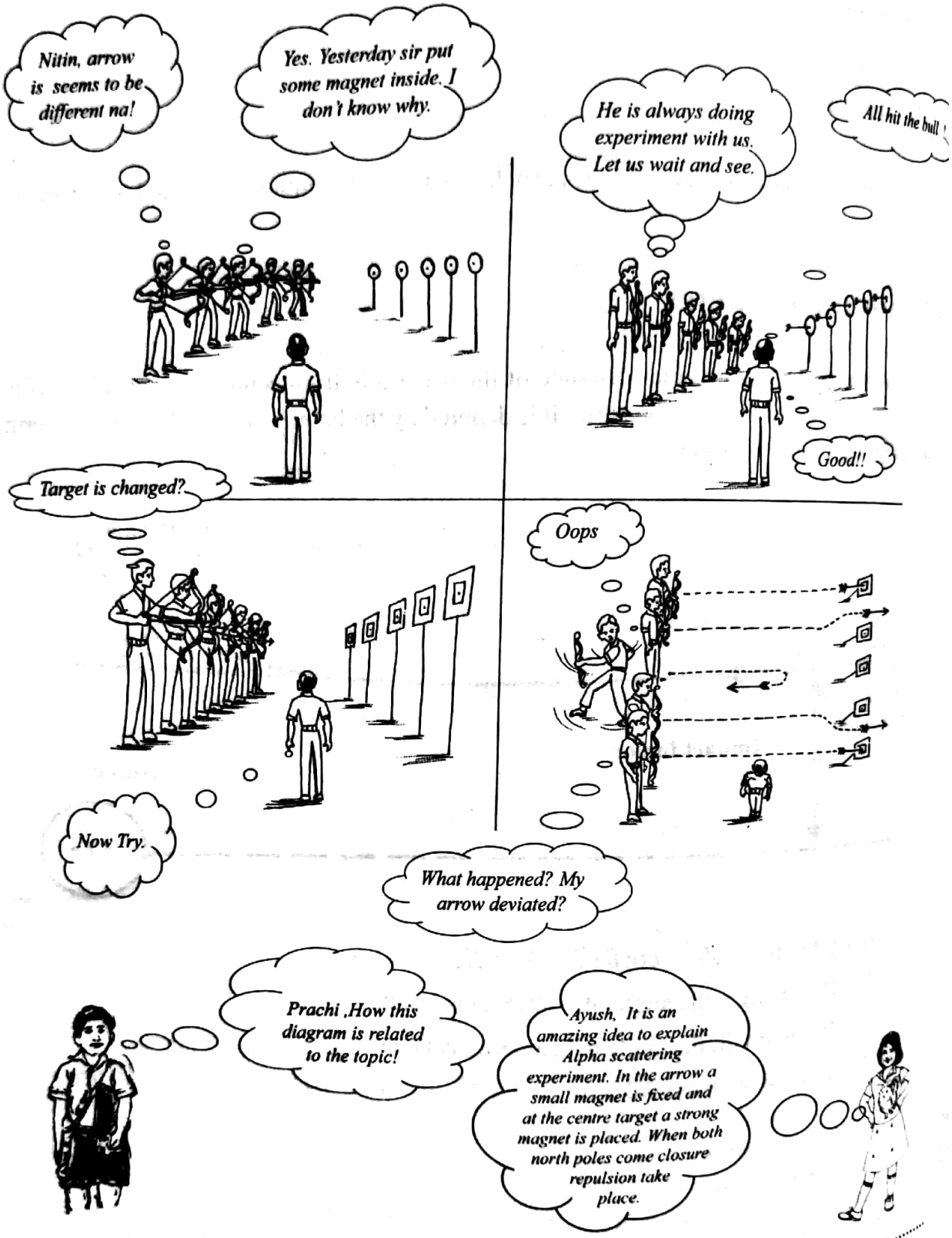

A person who never made a mistake never tried anything new.

— *Albert Einstein*

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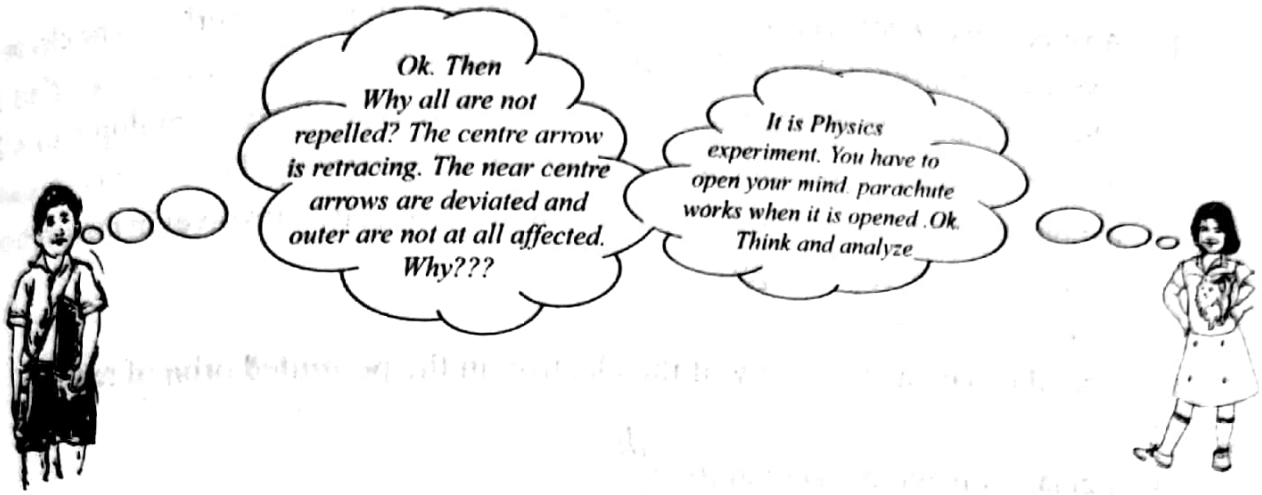

Drawback of Rutherford's atom model

Following two are the drawbacks of Rutherford's model:

1. It couldn't explain the stability of the atom.

   The electrons revolving in the circular orbit experience a centripetal acceleration. According to electromagnetic theory, an accelerated electric charge must radiate energy in the form of electromagnetic wave. Therefore, if the accelerated electrons lose energy by radiation, the energy of the electron continuously decreases and it must spiral down into the nucleus as shown in fig Thus, the atom cannot be stable. Thus this model could not explain the stability the atom.

2. It couldn't explain the line spectrum of hydrogen atom.

   According to classical electromagnetic theory, the accelerating electron must radiate energy at a frequency proportional to the angular velocity of the electron when the electron spiral towards the nucleus the angular velocity tends to become infinity and hence the frequency of the emitted energy will tend to infinity. As a result one should get a continuous spectrum with all possible wavelengths. But experiments show only line spectrum of fixed wavelength.

4.6 Bohr atom model

In 1993, Neils Bohr modified Rutherford's atom model to explain the stability of the atom and line spectrum of the atom. He combined classical ideas and early quantum concepts. He proposed the following postulates.

Nothing happens until something moves.

— *Albert Einstein*

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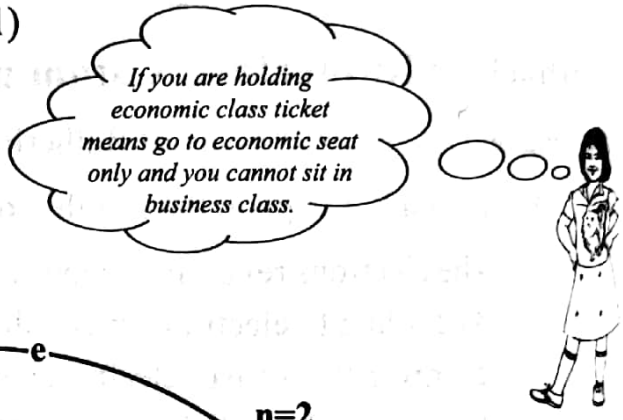
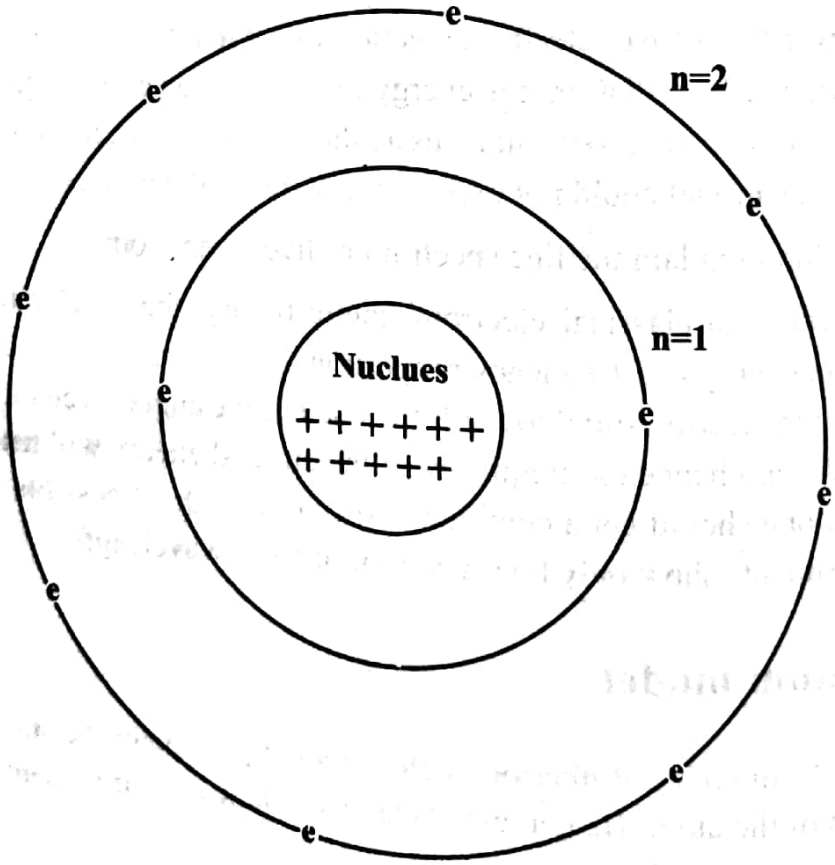
1. An electron *cannot* revolve around the nucleus in all possible orbits. The electrons *can* revolve around the nucleus only in those *allowed or permissible* orbits for which the angular momentum of the electron is an integral multiple of $h/2\pi$. (Here h is Planck's constant and is equal to 6.626×10^{-34}Js). These orbits are called stationary orbits or non-radiating orbits. When an electron revolves in these orbits,it does not radiate any energy.

If m and v are the mass and velocity of the electron in the permitted orbit of radius *r*,

then the angular momentum is equal to $\frac{nh}{2\pi}$

$$mvr = \frac{nh}{2\pi} \qquad \text{.....(1)}$$





Where n is called principal quantum number and has the integral values1, 2,3,4.....n and equation (1) is called quantization condition.

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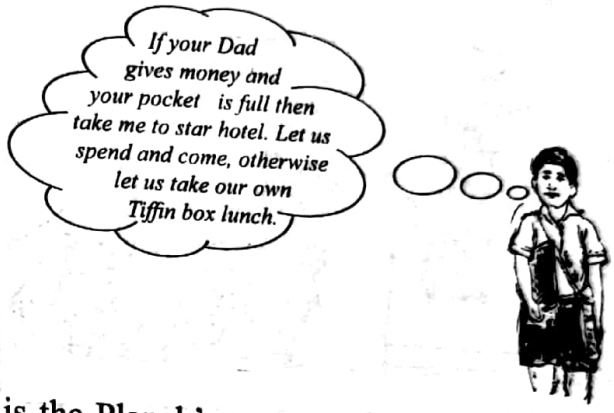
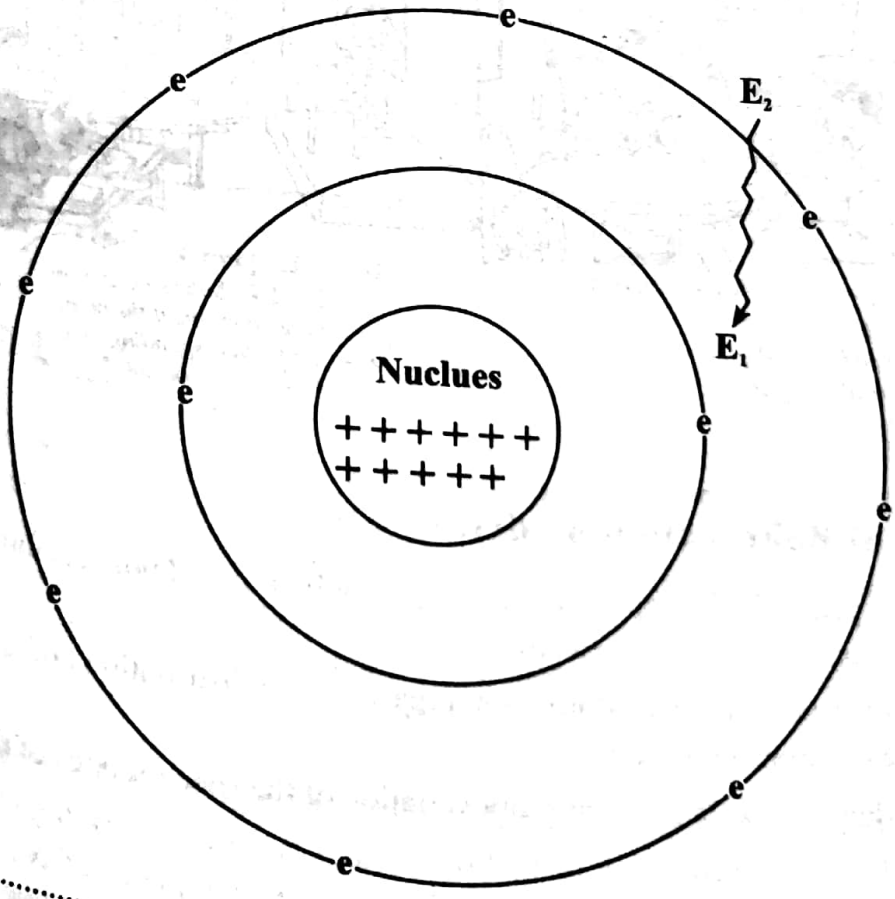
2. An atom radiates energy, only when an electron jumps from a stationary orbit of higher energy to an orbit of lower energy. If the electron jumps from an orbit of energy E_2 to an orbit of energy E_1, a photon of energy $h\gamma$ is emitted.

$$E_2 - E_1 = h\gamma \qquad \text{.....(2)}$$

$$or\ \gamma = \frac{E_2 - E_1}{h}$$



Here γ is the frequency of the radiation and h is the Planck's constant. Equation (2) is the Bohr's atom frequency condition.



I am the master of my failure... If I never fail how will I ever learn."

— Sir C.V. Raman

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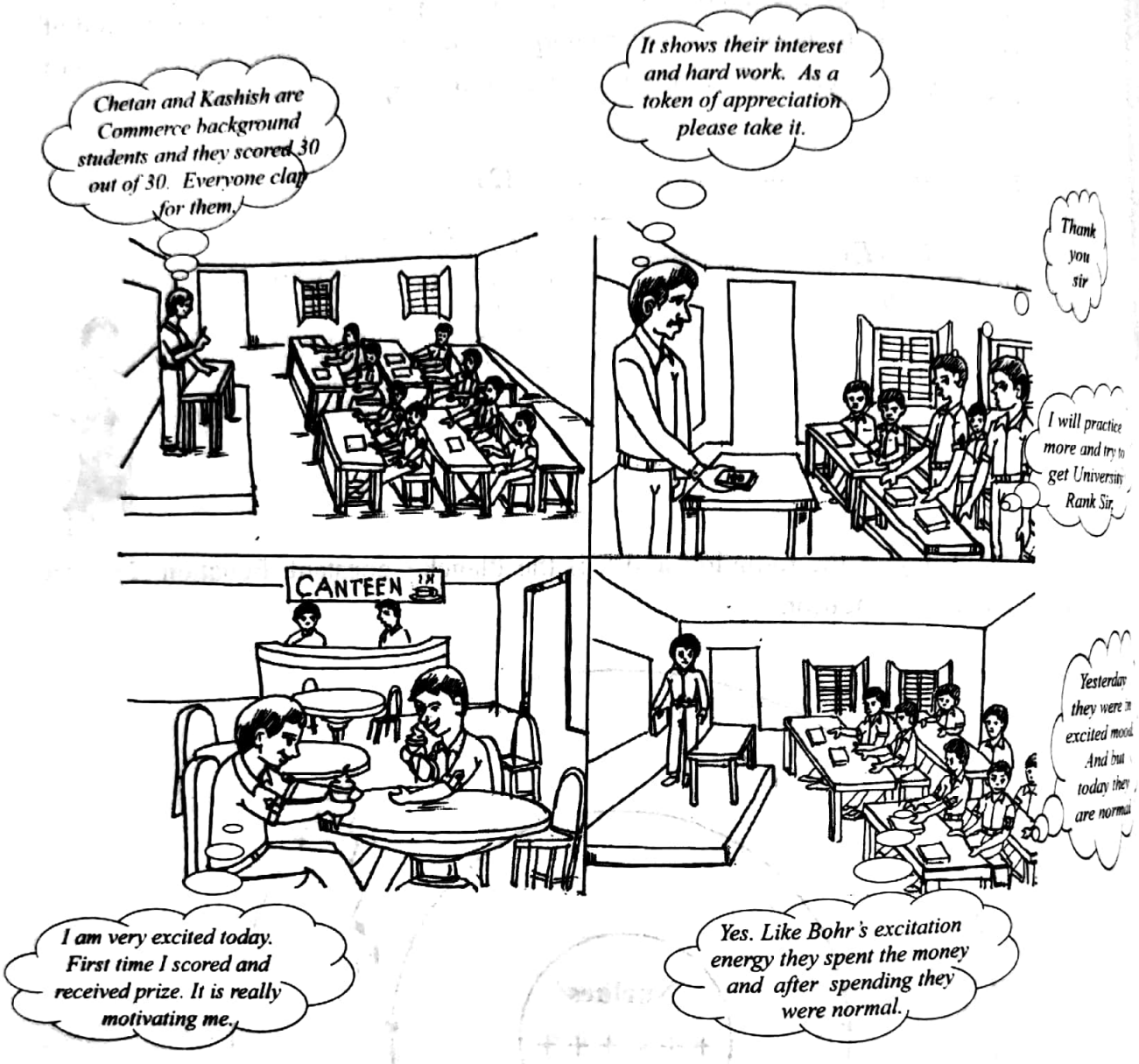

Drawbacks of Bohr's atom model:

1. It explains the line spectra of hydrogen only. It could not account for the spectra of atoms having many electrons.
2. It does not give any information regarding the distribution and arrangements of the electrons in the atom.
3. It does not explain the intensity variation of the spectral lines of the elements.
4. When the spectral line of hydrogen atom is observed by highly sophisticated spectrometers, it is found that a single line is composed of two or more close components. This is known as the fine structure of spectral lines. Bohr's atom model could not explain this fine structure of spectral lines.

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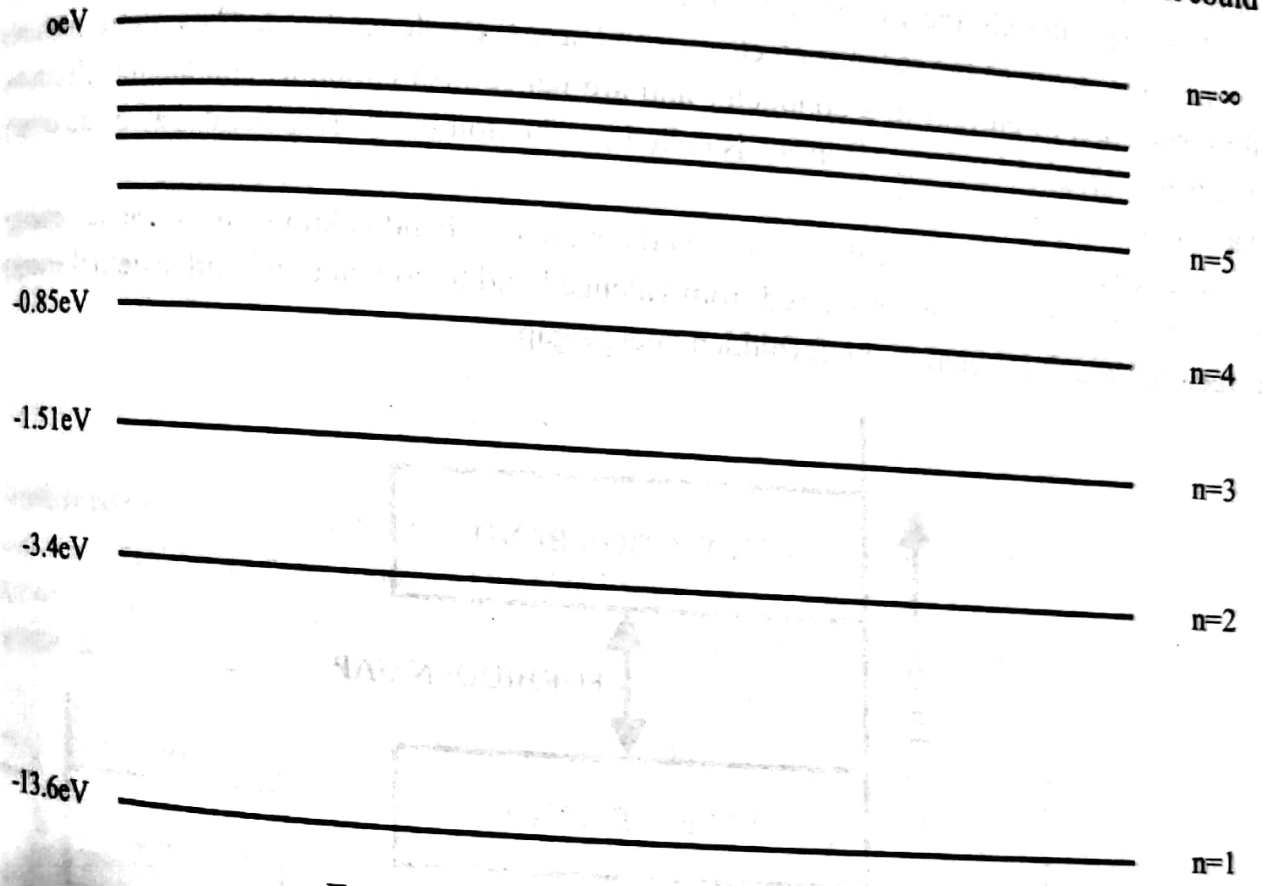
5. When electric or magnetic field is applied to the atom, each of the spectral line splits into several lines. The splitting of spectral lines due to electric fields is called strak effect and due to magnetic fields is called Zeeman effect. Bohr's model could not explain these effects.



Energy level diagram for hydrogen atom

4.7 Energy Bands in solids

In the case of a single isolated atom, there are various discrete energy levels. In solids, the atoms are arranged in a systematic space lattice and each atom is influenced by neighboring atoms. The closeness of atoms results in the intermixing of electrons of neighboring atoms. Due to this, number of permissible energy levels increases. Hence in the case of a solid, instead of a single energy level associated with single atom, there will be bands of energy levels. A set of such closely packed energy levels is called an energy band.

4.8 Valence Band, Conduction Band And Forbidden Enrgy Gap

The atoms of a solid are arranged in a regular repeated geometric pattern and the electrons of the atom revolve around the nucleus in certain permitted energy levels. The electrons in the inner shells are strongly bound to the nucleus.

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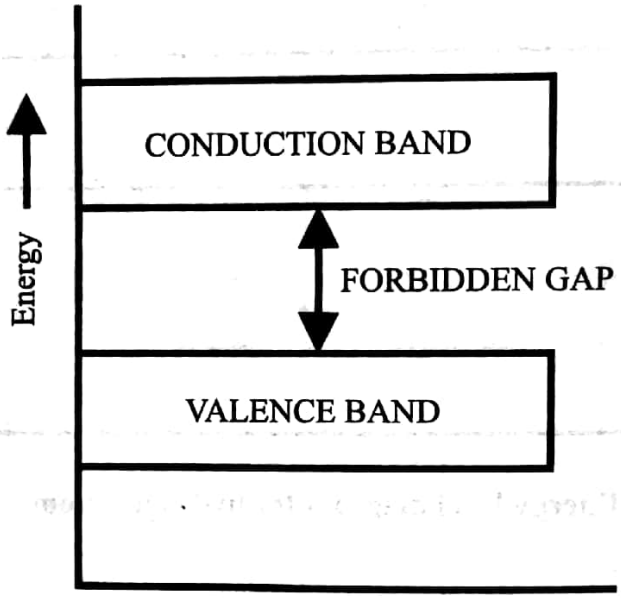
A band which is occupied by the valence electrons or a band having highest energy is defined as valence band. The valence band is partially or completely filled. This band can never be empty.

In some materials, the valence electrons are loosely attached to the nucleus. Even at room temperature, some of the valence electrons can leave the valence band. They are responsible for conduction of current in a conductor and are henceforth called as conduction electrons. The band occupied by these electrons is called conduction band. This band may be an empty band or partially filled band.

The separation between valence band and conduction band is known as forbidden energy gap. If an electron is to be transferred from valence band to conduction band, external energy is required which is equal to the forbidden energy gap.



4.9 Insulators, Semiconductors And Conductors

Insulators: In an insulator, the forbidden energy gap is very large. In general, the forbidden energy gap is more than 3eV and almost no electrons are available for conduction. Therefore, a very large amount of energy must be supplied to a valence electron to enable it to move to the conduction band. In the case of materials like glass, the valence band and conduction band is of the order of 10 eV. If the electron is supplied with high energy, it can jump across the forbidden gap. When the temperature is increased, some electrons will move to the conduction band. This is the reason, why certain materials, which are insulators at room temperature become conductors at high temperature. The resistivity of insulator approximately lies between 10^{11} and $10^{16}\Omega$ m.

Semiconductors: In semiconductors, the forbidden gap is very small. Germanium and silicon are the best example of semiconductors. The forbidden gap energy is of the order of

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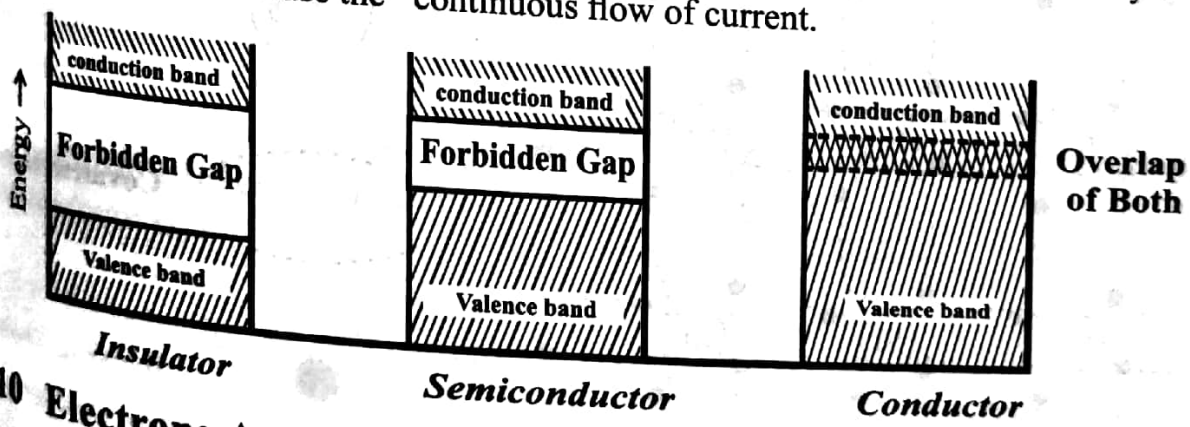
0.7eV for Ge and 1.1eV for Si. There are no electrons in the conduction band. The valence band is completely filled at 0K. With a small amount of energy that is supplied, the electrons can easily jump from the valence band to the conduction band. For example, if the temperature is raised, the forbidden gap is decreased and some electrons are liberated into the conduction band. The conductivity of a semiconductor is of the order of 10^{2} Mho m^{-1}.

Conductors: In the conductors, there is no forbidden gap is available, the valence and conduction band overlap each other. The electrons from valence band freely enter into the conduction band. Due to the overlapping of the valence and conduction bands, a very low potential difference can cause the continuous flow of current.



4.10 Electrons And Holes In Semiconductors

Consider pure silicon crystal. It has four electrons in its outer or valence orbit. These electrons are known as valence electrons. When two atoms of silicon are brought close to each other, a covalent bond is formed between the atoms. If some additional energy is received, one of the electrons contributing to a covalent bond breaks and it is free to move in the crystal lattice.

While coming out of the bond, a hole is said to be created at its place, which is usually represented by an open circle. An electron from the neighboring atom can break the covalent bond and can occupy this hole, creating a hole at another place. Since an electron has a unit negative charge, the hole is associated with a unit positive charge. The importance of hole is that, it may serve as a carrier of electricity in the same manner as the free electrons, but in the opposite direction.

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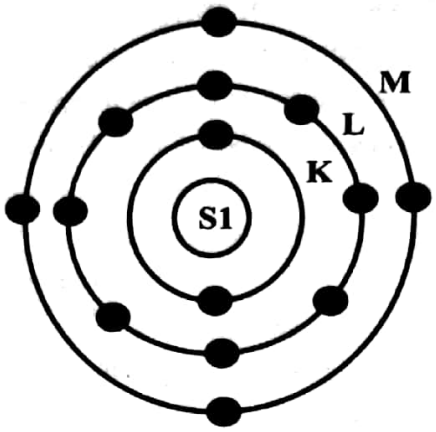

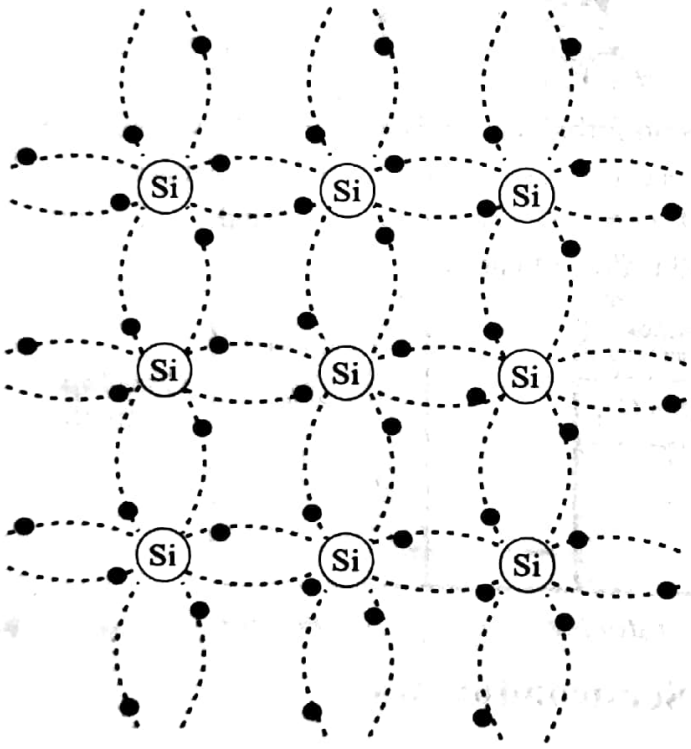

4.11 Intrinsic Semiconductor

A semiconductor which is pure and contains no impurity is known as an intrinsic semiconductor. In an intrinsic semiconductor, the number of free electrons and holes are equal. Common examples of intrinsic semiconductors are pure germanium and silicon. The forbidden energy gap is so small that even at ordinary room temperature, there are many electrons which possess sufficient energy to cross the forbidden energy gap and enter into the conduction band. Schematic band diagram of an intrinsic semiconductor at room temperature is represented in fig.

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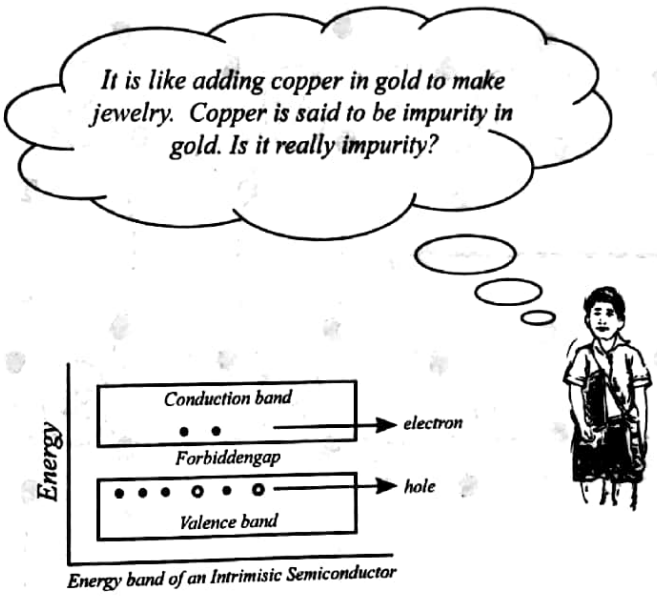
4.12 Doping A Semiconductor

Electrons and holes can be generated in a semiconductor crystal with heat energy or light energy. But in these cases, the conductivity remains very low. The efficient and convenient method of generating free electrons and holes is to add very small amount of selected impurity inside the crystal.

The impurity to be added is of the order of 100 ppm(parts per million) . ***The process of addition of a very small amount of impurity into an intrinsic semiconductor is called doping. The impurity atoms are called dopants. The semiconductor containing impurity atoms is knows as impure or doped or extrinsic semiconductor.***

Usually, the doping material is either pentavalent atoms (bismuth, antimony, phosphorus, arsenic which have five valence electron) or trivalent atoms (aluminium, gallium, indium, boron which have three valence electrons)

The pentavalent doping atom is known as donor atom, since it donates one electron to the conduction band of pure semiconductor. The trivalent atom is called an acceptor atom, because it accepts one electron from the pure semiconductor atom



Energy band of an Intrimisic Semiconductor

4.13 Extrinsic Semiconductor

An extrinsic semiconductor is one in which an impurity with a valency higher or lower than valency of the pure semiconductor is added, so as to increase the electrical conductivity of the semiconductor.

Depending upon the type of impurity atoms added, an extrinsic semiconductor can be classified as N- type or P-type.

4.14 N-type semiconductor

When a small amount of pentavalent impurity such as arsenic is added to a pure germanium semiconductor crystal, the resulting crystal is called N-type semiconductor .

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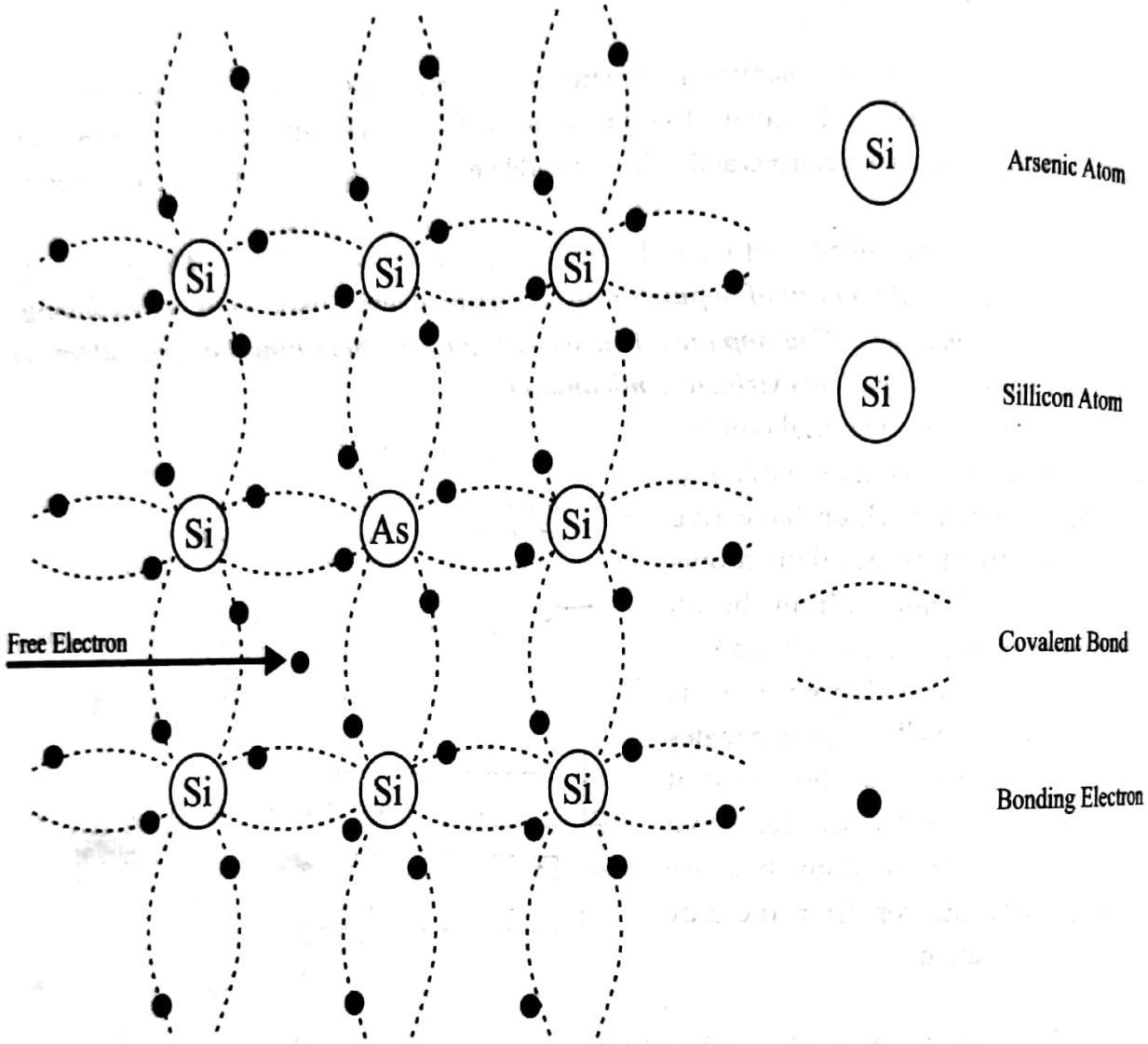

The crystal structure obtained when pentavalent arsenic impurity is added with pure silicon crystal is shown in fig.. The four valence electrons of arsenic atom form covalent bond with electrons of neighboring four silicon atoms. The fifth electron of arsenic atom is loosely bound. This electron can move about almost as freely as an electron in a conductor and hence it will be the carrier of current.

Each impurity atom donates one free electron to the semiconductor. These impurity atoms are called donors.

4.15 P-type semiconductor

When a small amount of trivalent impurity (such as indium, boron or gallium) is added to a pure semiconductor crystal, the resulting semiconductor is called P-type semiconductor.

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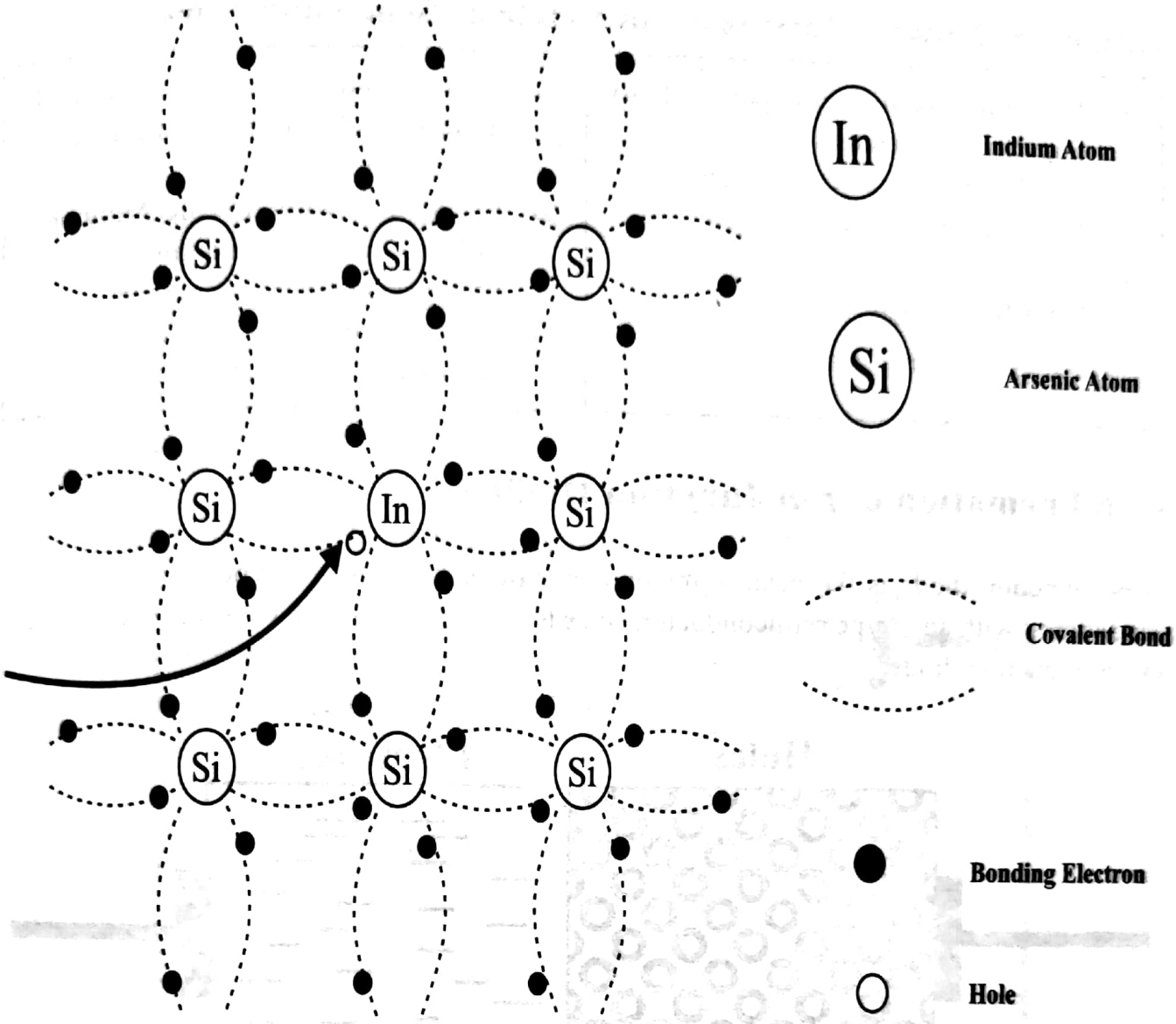

The crystal structure obtained, when trivalent indium impurity added with pure silicon crystal is shown in fig. The three valence electrons of the indium atom form covalent bonds with valence electron of three neighborhood silicon atoms. In the fourth covalent bond, only one valence electron is available from silicon atom and there is deficiency of one electron which is called as a hole. Hence for each indium atom added, one hole is created. Since the holes can accept electrons from neighborhood, the impurity is called acceptor. The hole may be filled by the electron from a neighboring atom, creating a hole in that position from where the electron moves. This process continues and the hole moves about in a random manner due to thermal effects. Since the hole is associated with a positive charge moving from one position to another, this is called as P-type semiconductor.

In P- type semiconductor, holes are the majority charge carriers and free electrons are the minority charge carrier

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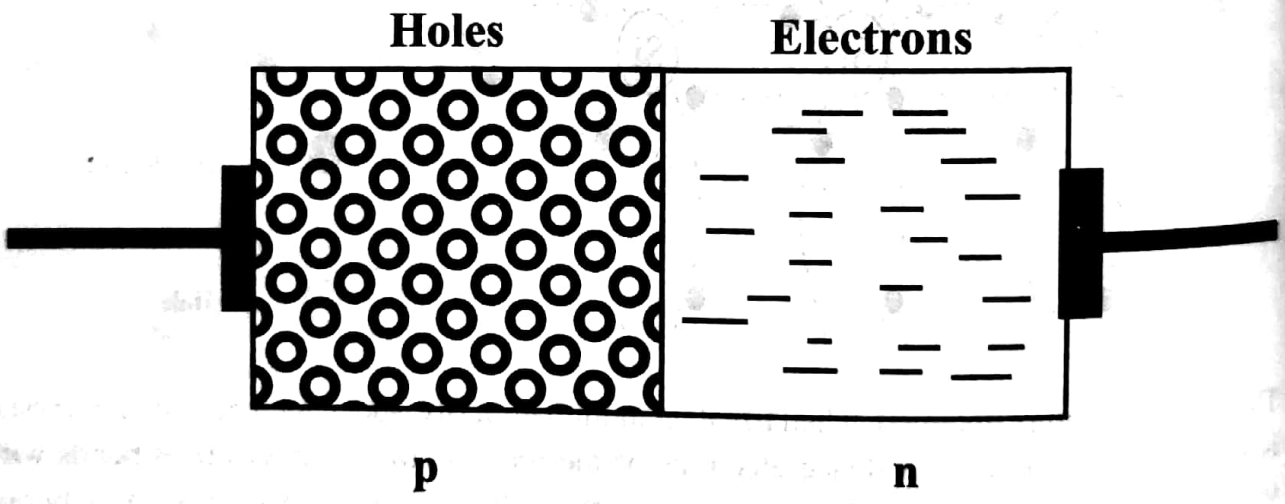
Difference between Intrinsic and Extrinsic Semiconductors

a) It is pure semiconductor and no impurity is added to it. b) Eg: Pure Silicon or Germanium c) Electrical conductivity is low. d) Electrical conductivity is a function of temperature only.	a) It is prepared by doping a small quantity of impure atoms to pure semiconductors. b) Eg: Silicon with Arsenic/Antimony, Silicon with Boron/Indium. c) Electrical conductivity is high. d) It is a function of temperature and quantity of impure atoms added.

4.16 Formation of *p-n* Junction Diode

A *p-n* junction diode is the basic semiconductor device. When a p-type semiconductor is sandwiched with an n-type semiconductor, so as to form one single device is called p-n diode OR p-n junction diode.



The line of contact of p-type semiconductor and N-type semiconductor is called p-n junction.

In p-type section holes are majority carriers and in n-type section electrons are majority carriers.

As soon as junction is formed electrons and holes cross the junction by diffusion. During this process, the electrons crossing from n-type to p- type region recombine with the holes in that region and it takes place near the junction only.

Similarly, holes crossing from p-type region to n-type region recombine with electrons in that region and it takes place near the junction only. Thus a region is formed which does not have any mobile charges very close to the junction. This region is called "depletion region'

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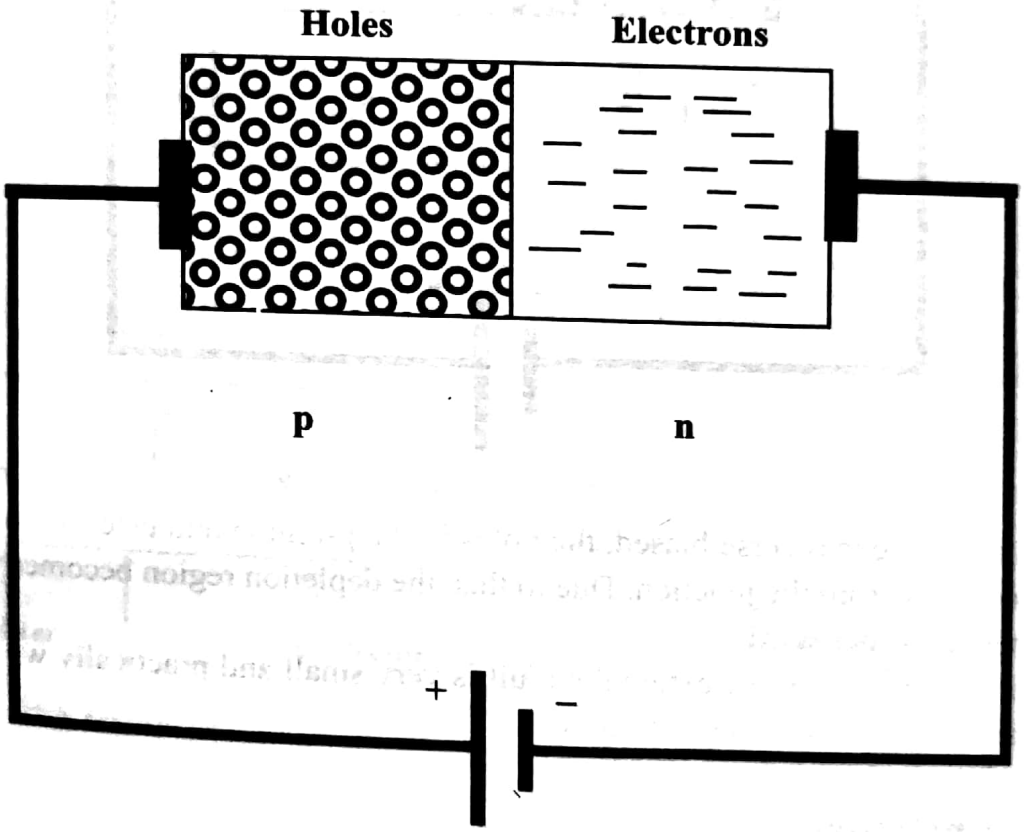
Due to this movement of charges, the p-section becomes slightly negative and n-section becomes slightly positive. This diffusion of electrons and holes continues till a potential barrier is formed. Due to this potential barrier further diffusion of charges is not possible.

For silicon the potential barrier is approximately 0.7 Volts.

4.17 Forward Biasing of p-n Junction Diode

A p-n junction diode is said to be in forward biased when the positive terminal of the external battery is connected to p-type and negative terminal of the external battery is connected to n-type of the p-n diode.

The circuit diagram is shown in figure.



When the p-n diode is forward biased, the applied positive potential repels the holes in the p-region and the negative terminal repels the electrons in the n- region. Due to this, the holes and electrons are forced to cross the junction.

If the external battery potential difference is sufficiently greater than the potential of depletion region, the depletion region disappears.

As a result, the majority carriers of p-type and n-type cross the junction in opposite direction and current flows in forward direction.

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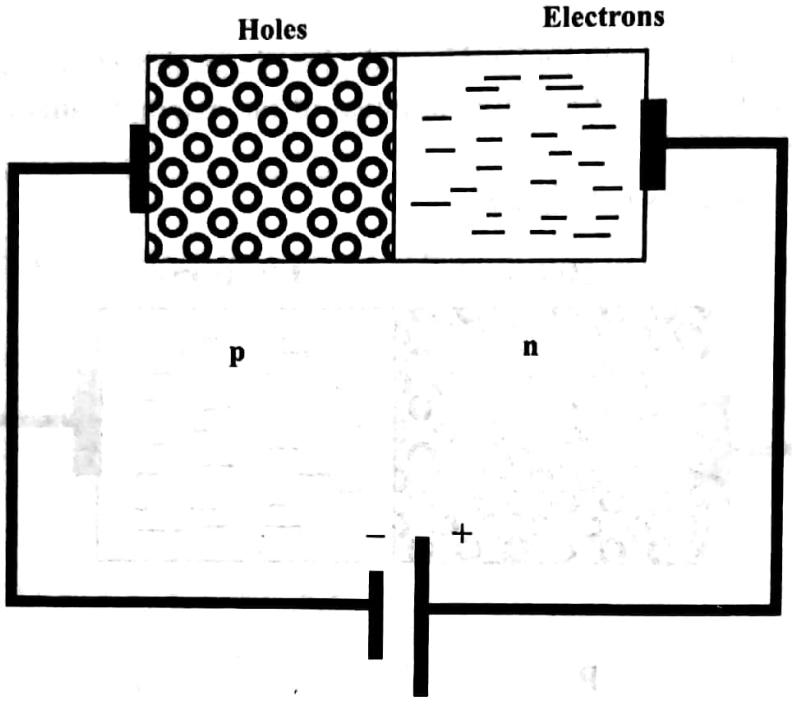
4.18 Reverse Biasing of p-n Junction Diode

A p-n junction diode is said to be in reverse biased when the negative terminal of the exte battery is connected to p-type and positive terminal of the external battery is connecte n-type of the p-n diode.

The circuit diagram is shown in figure.



When the p-n diode is reverse biased, the holes in the p-region and electrons in the n-regio are attracted away from the junction. Due to this, the depletion region becomes wider and th potential barrier is increased.

Due to this, current in the external circuit is very small and practically we are not usin reverse bias except in some special cases.

4.19 Transistors

Transistor is a semiconductor device having three sections. In the three sections the outer sections are of same type and the center section is of different type. Thus a transistor can be a n-p-n or p-n-p type.

In n-p-n transistor the n-type material is at the extreme sides and p-type material is at center as shown in figure.

In p-n-p transistor p-type material is used at the extreme sides and n-type material is at the centre as shown in figure

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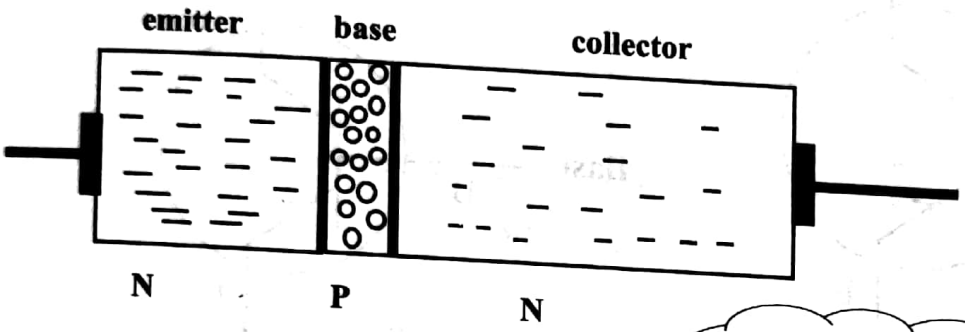
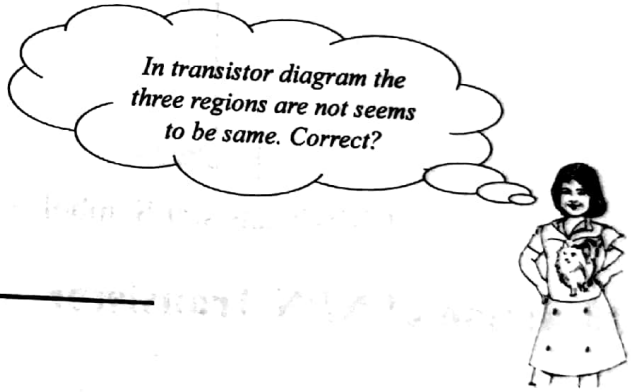
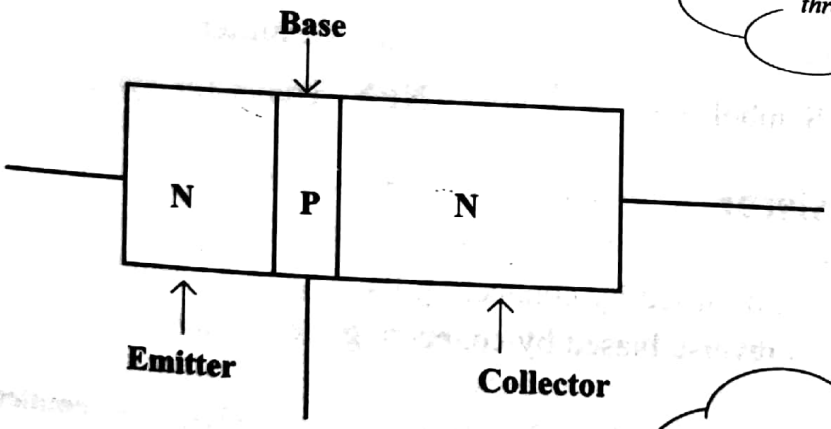
Three sections are called base, emitter and collector.

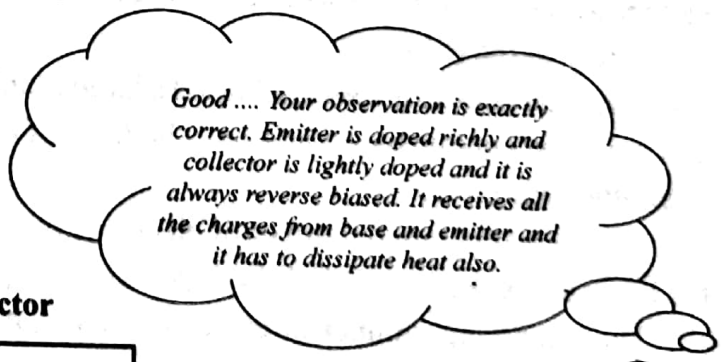
1. **Base (B):** It is a very thin layer and is lightly doped. The base forms the central region of the transistor.
2. **Emitter (E) :** Emitter is highly doped section and it supplies the majority carriers.
3. **Collector (C)** : The collector has to accept the majority charge carriers and it is lightly doped compared to emitter. Its size is larger compared to emitter.

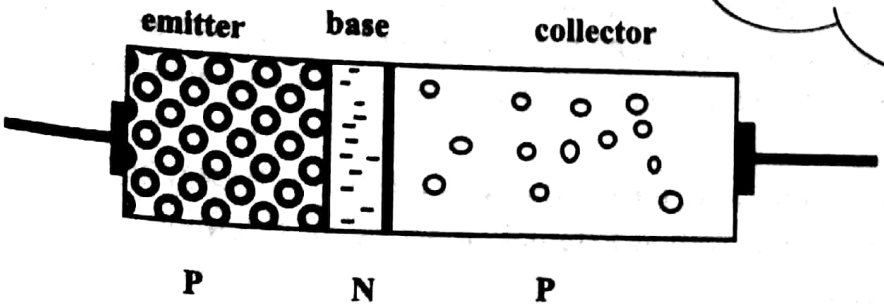






NPN transistor





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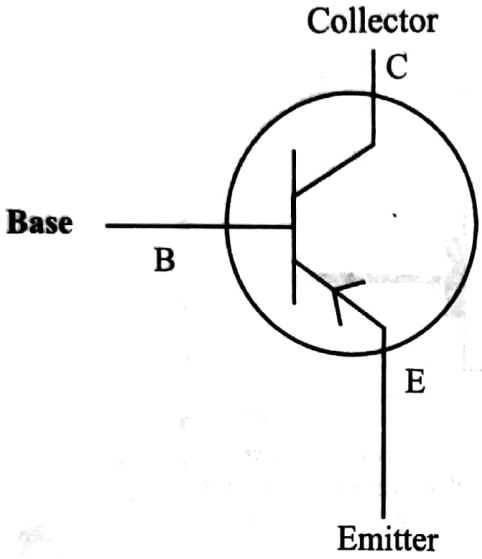
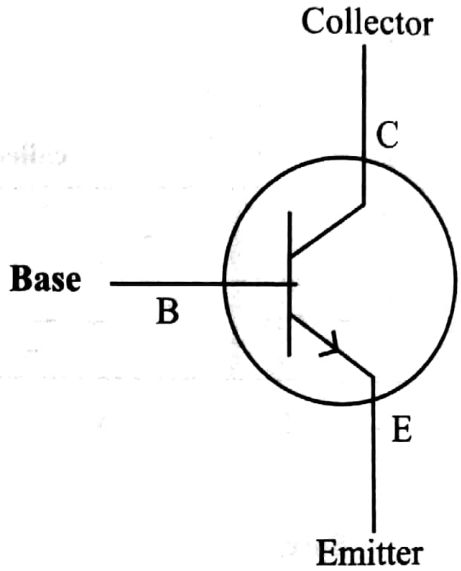
Transistor symbol

The circuit symbols of PNP and NPN transistor are shown in figure. In PNP emitter has an arrow pointing towards the base. When the PNP transistor is forward biased, the direction of the conventional current flow is from emitter to base.

NPN transistor is represented by arrow pointing away from the base. When the NPN transistor is forward biased the direction of the conventional current flow is from base to emitter.



PNP- Transistor Symbol



NPN- Transistor Symbol

4.20 Action of NPN Transistor

In NPN transistor the emitter is forward biased by connecting the negative terminal of the battery to the emitter. The collector is reverse biased by connecting the positive terminal of the battery to the collector.

Since the emitter is forward biased a large number of electrons are repelled from the emitter and cross the emitter-base junction. The flow of electrons from the emitter to base gives rise to emitter current I_E.

In base a very small number of electrons recombine with an equal number of electrons in the base. Since the base is lightly doped and thin, this number is very small.

The remaining number of electrons, which do not undergo recombination process in the base, reach the collector. These electrons are swept away by the positive terminal of the battery V_{CC} connected to the collector.

Now an equal number of electrons enter the emitter region from the battery V_{EE}. Thus the current is carried inside the transistor as well as external circuit by the electrons.

Applying Kirchoff's low we have

$$I_E = I_B + I_C$$

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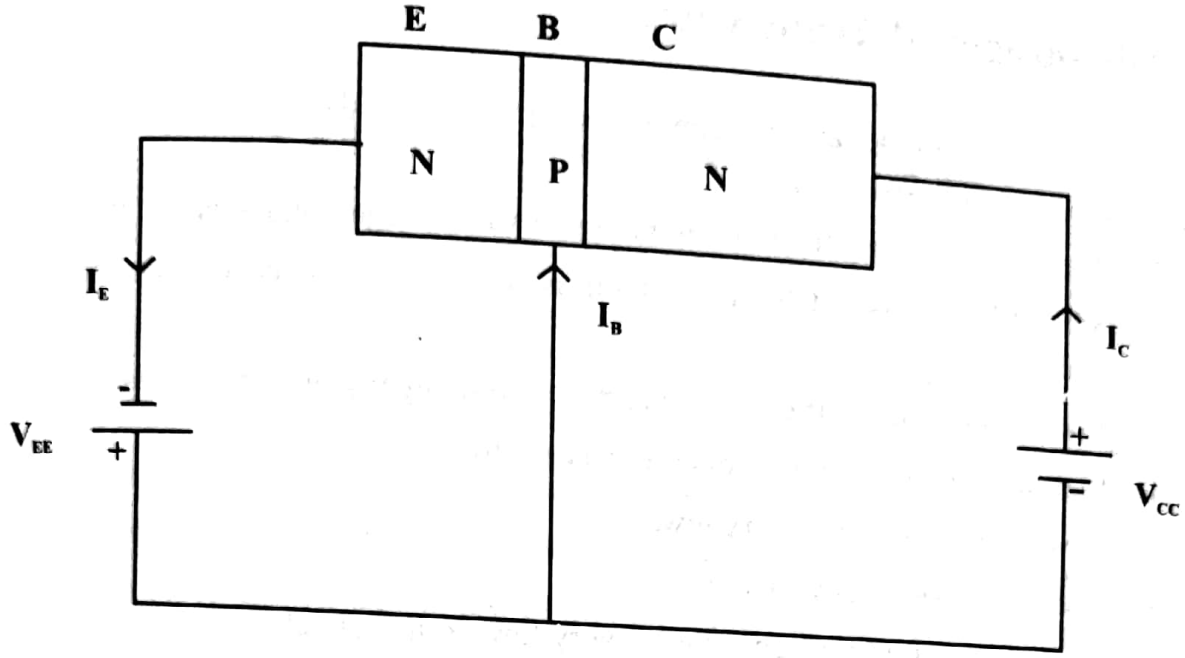

NPN Transistor Action

4.21 Action of PNP Transistor

In PNP transistor, the emitter is forward biased. That is the Positive terminal of the battery is connected to emitter of the transistor. The collector is reverse biased by connecting the negative of the battery.

Since the emitter is forward biased a large number of holes are repelled from the emitter and crosses the emitter-base junction. The flow of holes from to base gives rise to emitter current I_E.

In base a very small number of holes recombine with equal number of electrons in the base. Since the base is lightly doped and very thin, this number is very small.

The remaining numbers of holes, which do not undergo recombination process in the base, reach the collector.

These holes are neutralize by equal number of electrons flowing from the negative terminal of the battery V_{CC} into the collector.

At the same time, an equal number of electrons flow from the negative terminal of V_{EE} and reach the positive terminal of V_{CC}. The flow of holes from base to collector gives to collector current I_E. In the external circuit, it is due to the flow electrons from the negative terminal of the battery V_{CC} into the collector.

Applying Kirchoff's low we have

$$I_E = I_B + I_C$$

In PNP transistor the emitter-base junction offers very low resistance to the current and collector-base junction offers high resistance to the current due to forward and reverse biases.

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4.22 Advantages of Transistors:

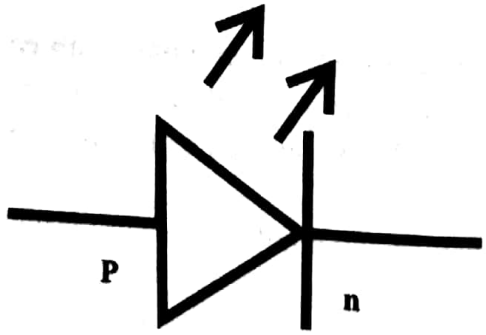
Transistors have completely replaced vacuum tubes in all the fields of electronics.

The advantages of transistors are:

1. There is no heating filament in the transistor so large voltage is not required.
2. Since filament is not there, as soon as power is switched on, transistor st working.
3. Like vacuum tubes, transistors are not producing any humming noise.
4. Size and weight of transistors are very small.
5. Power consumption is very low.
6. Cost of transistor is very low.
7. Voltage required for transistors is very low, so it is shock free.
8. Life of the transistor is long.
9. Easy to handle and reliable
10. Fixing and removing is easier.

4.23 Light Emitting Diode [LED]

Light Emitting Diode is a special type of p-n junction diode which emits light when it is forwa biased. The symbol of LED is shown in fig.



When a junction diode is forward biased, the electrons from n-region and holes from p-region cross the junction. When electron and holes recombine energy is released. Since it is a special type of diode it is manufactured with the material like Gallium Arsenide which emits light when electron and hole recombines.

The semiconductor material chosen for LED should be translucent. So when power is given to LED, it emits light. The color of light depends upon the material doped.

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QUESTION BANK

1. What is inertia? Why is Newton's first law of motion called law of inertia?
2. What is inertia? Discuss its types with one example in each case.
3. State Newton's second law of motion. Show that it gives the measure of force.
4. Prove that Newton's second law of motion is the only real law of motion
5. Define the term momentum and impulse. Obtain the relation between impulse and momentum.
6. State Newton's second law of motion and prove that impulse is equal to the change in momentum.
7. State and explain Newton's third law of motion. Give two illustration.
8. State Newton's third law of motion. Drive the law of conservation of momentum from it.
9. What is difference between mass and weight?
10. How does a weight of man standing in a lift changes, when the lift accelerate (a) upward (b) downward with an acceleration a?
11. What are concurrent forces? Obtain a condition for the equilibrium of three concurrent forces.
12. What is cause of sliding friction?
13. What is limiting friction? State the laws of limiting friction.
14. Show that $\tan\theta=\mu$, where θ is the angle of repose and μ is the coefficient of friction.
15. Define the angle of friction and angle of repose. Show that they both are numerically equal.
16. Friction is necessary evil. Explain. Give two methods to reduce friction.
17. Explain centripetal force and centrifugal force. Why centrifugal force is called a pseudo force?
18. Describe the motion of a car on levelled circular road.
19. Obtain an expression for angle of banking of curved road. Show that it is independent of the mass of the vehicle.

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20. Derive the expression for maximum speed of a vehicle on the banked road.
21. Why does a cyclist bend inwards while negotiating a curve? Explain.
22. Explain the term work. Show that work done is equal to dot product of force displacement.
23. What is meant by positive work, negative work, and zero work? Give one example of e
24. What are conservative and non-conservative forces? Explain.
25. Define work and power. State their SI units.
26. Define and derive the expression for the kinetic energy.
27. State and prove work-energy theorem.
28. Show that the total mechanical energy of a body falling freely under a gravity is conserve
29. Derive an expression for the potential energy of stretched spring.
30. What are elastic and inelastic collision? Give examples.
31. Show that in an elastic one dimension collision, the relative velocity of approach is equ to relative velocity of separation after collision.
32. Prove that when two bodies of equal masses undergo elastic collision in one dimensio their velocities are just interchanged.
33. Show that two bodies of equal masses undergoing an oblique collision move at rig angle to each other after the collision. (Two dimension)
34. Discuss briefly inelastic collision in one direction.
35. Define coefficient of restitution and discuss for three types of collisions.
36. Obtain the expression for loss of kinetic energy in case of perfectly inelastic collision in one dimension.
37. State and explain lami's theorem.
38. Discuss the various types of friction.
39. State and explain coulomb's law of force in electrostatics.
40. Give six properties of electric charge.
41. Write coulomb's law in vector form. Derive the definition of one coulomb.
42. State the principle of superposition of charges.
43. Derive an expression for electric field intensity at a point at a distance r from a point electric charge.
44. Explain the properties of electric lines of forces.
45. What is electric flux? Explain.

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46. State and prove Gauss's theorem.
47. State Gauss's theorem. How coulomb's law can be derived from it.
48. Using Gauss's theorem, obtain an expression for the electric field intensity at a point at a distance r from an infinitely long uniformly charged straight wire.
49. Derive an expression for the electric field due to uniformly charged thin spherical shell at a point (a) inside and (b) outside the shell.
50. Find an expression for line integral of electric intensity.
51. What is capacitor? Explain its principle.
52. Derive an expression for the capacitance of a parallel plate capacitor.
53. Derive an expression for the capacitance of parallel plate capacitor with dielectric as the medium between the plates.
54. What is spherical capacitor? Derive expression for its capacitance.
55. Three capacitors C_1, C_2 and C_3 are connected in series. Derive an expression for the equivalent capacitance.
56. What is resultant capacitance, when a number of capacitors are connected in parallel? Derive the expression for it.
57. What is drift velocity? Establish the relation between drift velocity and electric current.
58. State and explain Ohm's law.
59. Define resistance of a conductor. What are factors on resistance of conductor depends? Give the corresponding relation.
60. On what factor resistivity of the material depend? Why copper wires are used as connecting wires?
61. Find the total resistance, when the various resistors are connected (i) in series and (ii) in parallel.
62. State Kirchoff's laws for electric circuits and explain them giving illustrations.
63. Apply Kirchoff's laws to obtain the condition of balanced Wheatstone bridge.
64. With the help of circuit diagram, explain how a meter bridge (slide wire bridge) can be used to find the unknown resistance of a given wire.
65. Draw a circuit diagram of a meter bridge arranged to compare two resistances. Explain the principle of the experiment and give the formula used.
66. Explain Thomson's atom model.
67. Explain Rutherford's experiment on scattering of alpha particles and state the significance of the results.

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68. Describe Rutherford's model for an atom. Give its limitations.

69. Explain the following.

    (i) Distance of closest approach.

    (ii) Impact parameter.

70. What are the drawbacks of Rutherford's atom model and how did Bohr remove it.

71. State and explain the postulates of Bohr's atomic model.

72. What is meant by energy bands in solids? Draw energy band diagrams to illustrate behavior of (a) a conductor (b) a pure semiconductor (c) an insulator.

73. What is meant by doping? Explain how it changes the conductivity of the resulti extrinsic semiconductor.

74. Distinguish between intrinsic and extrinsic semiconductors.

75. What is p-n junction diode? Distinguish between forward biasing and reverse biasi in p-n junction.

76. Write a note on LED.

77. Explain the action of n-p-n and p-n-p transistors.

78. What are the advantages of transistors?

79. Write a short note of integrated circuits. Give their uses.

END TERM EXAMINATION
FIRST SEMESTER [BCA]
PHYSICS

NOTE: Attempt any five questions. Select one question from each unit including Question no. 1 which is compulsory.

Question 1.

(a) According to Newton's third law, "action and reaction are equal and opposite". Then why don't these two forces cancel each other?

(b) A boy is running with constant speed on a circular track. Is it an accelerated motion? If yes, then explain briefly the force that is acting on the boy to keep him in circular motion.

(c) A man ok mass 60 kg climbs a ladder to height 5m. Calculate the work done by the force of gravity. Take $g=10m/s^2$.

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(d) "Static friction is a self -adjusting force". Is this statement true? Justify your answer.

(e) Explain briefly elastic and perfectly inelastic collisions.

(f) Define Ohm's law. Is it a fundamental law or valid only for certain materials and devices? Justify your answer.

(g) 5J of work is done in moving a positive charge of 0.5C from one point to another. What is the potential difference between the two points?

(h) Write the two important conclusions of Rutherford's α-particle scattering experiment.

(i) Write the difference between metals, insulators and semiconductors on the basis of energy bands in solids.

(j) Name the majority and minority carriers in p-type and n-type semiconductors. (2.5*10=25)

Question 2.

(a) What is wrong with the statement, "Because the car is at rest, there are no forces acting on it"? How would you correct the statement? (4.5)

(b) A person weighs a fish on a spring scale attached to the ceiling of an elevator. Show that is the elevator accelerates upwards or downwards, the spring scale reads an apparent weight different from the fish's true weight. Justify your answers by drawing free body diagrams of the fish. (8)

Question 3.

(a) State the laws of limiting friction. (5)

(b) The outer rail of a curved railway track is generally raised over the inner. Why? Explain briefly. (7.5)

Question 4.

(a) Define work. What do you understand by negative work done by a force? (4)

(b) Does kinetic energy of a body depend upon the direction of motion? Justify your answer. (3)

(c) A toy car of mass 0.2 kg is moving with speed 10m/s. Find its kinetic energy. If the car stops due to friction, find the work done by the force of friction. (5.5)

Question 5.

(a) Define conservative force. Prove that the gravitational force is a conservative force. (6)

(b) Two identical ivory balls of mass 1 kg each, moving in opposite directions with speed

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5m/s and 10m/s collide head on. Find the velocities of the balls after the collision. Ass that the collision is perfectly elastic and one dimensional. (6

Question 6.

(a) A glass rod when rubbed with silk cloth acquires positive charge of 1.6×10^{-13} Coulom Explain it in terms of transfer of electrons. Have the electrons transferred from the gl rod to the silk cloth or from the silk cloth to the glass rod? What is the number of electro transferred? Charge of an electron=1.6×10^{-19}C. (7.

(b) Define Coulomb's Law. (2.

(c) Why no two electric field lines can intersect each other? Explain briefly. (2.

Question 7.

(a) What are the factors on which resistance of a conductor depends? Give the correspondi relationship. (4

(b) Give three identical resistors each of resistance 30 Ohms. How can they be connecte in a circuit to give a total resistance of 90 Ohms and 10 Ohms respectively? (4

(c) State and explain briefly Kirchoff's Rules. (4.5

Question 8.

(a) State the postulates of Bohr's atom model. Explain how these postulates overcome the drawbacks of Rutherford's atom model? (7.5)

(b) Explain briefly the formation of energy bands in solids. (5)

Question 9.

(a) Discuss briefly electrical conduction in semi- conductors. (4)

(b) Which biasing makes the p-n junction resistance law? Justify your answer. (3.5)

(c) What is a transistor? Write briefly the action of n-p-n transistor. (5)

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END TERM EXAMINATION
First semester [BCA]

Paper code: BCA 109
Paper Id- 20109

Subject: Basics of Physics
Time: 3 Hours
Maximum Marks: 75

NOTE: Question 1 is compulsory. Attempt one question from each unit.

Question 1.

(a) Why is Newton's first law of motion called law of inertia?

(b) Give two examples each for conservative and non-conservative force.

(c) Define angle of friction.

(d) Define an expression of power in terms of velocity and force.

(e) Explain the physical significance of coefficient of restitution.

(f) Give one example when work done by a force is (1) positive (2) negative (3) zero.

(g) Give four properties of electric charge.

(h) Define resistivity and state its S.I. unit.

(i) State Faraday's laws of electromagnetic induction.

(j) What are majority carriers (charge) in semiconductors? (10x2.5=25)

Unit -1

Question 2.

(a) What do you understand by the term 'friction'? State laws of friction. (7.5)

(b) A woman pushes a box of mass 20kg on a horizontal surface with a horizontal force of F. The

(c) Coefficients of static and kinetic friction are $\mu s=0.6$ and $\mu k=0.5$. (5)

(d) What must F be in order that she can make the start to slide?

(e) If she maintains the same force once the block starts to slide, what will be its acceleration?

Question 3.

(a) Show Newton's second law of motion and derive the equation , F=ma. (6)

(b) State and prove principle of conservation of linear momentum. (6.5)

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Unit -2

Question 4.

(a) Show that in a perfect elastic collision of two bodies of equal mass m they interchan their velocities.

(b) State the principle of conservation of energy. Prove it for the freely falling bodies. (5.

Question 5.

(c) Define coefficient of restitution. What is its physical significance?

(d) A metal ball of mass 2kg moving with a speed of 36km/h has a head –on collision wi a stationary ball of 3kg. If after collision, both the balls move together, then find the lo in kinetic energy due to collision. (6.5

Unit -3

Question 6.

(a) State Gauss's theorem. Derive an expression for electric field intensity (E) due to metallic hollow sphere of radius R at a point (a) inside the sphere (b) on the surface o the sphere (c) outside this sphere. Show graphically the variation of E with distance fro the centre of the sphere. (12.5)

Question 7.

(a) Two cells of emf 6V and 12V and internal resistances 1Ω and 2Ω respectively are connected in parallel so as to send current in the same direction through an external resistance of 15Ω.

(b) Draw the circuit diagram.

(c) Using Kirchoff's law calculate (A) Current through each branch of the circuit. (B) Potential difference across the 15Ω resistance. (8)

(d) Define resistivity and discuss its temperature dependence. (4.5)

Unit -4

Question 8.

a. State and explain Lenz's law.(5)

b. Explain the properties of semiconductors.(4)

c. State Ampere's circuital law.(3.5)

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Question 9.

(a) What is induced e.m.f.? Show that Lenz's law follows from the principle of conservation of energy. Explain magnetic Lorentz force and its applications. (12.5)

END TERM EXAMINATION
First Semester (BCA) December-2012

Paper Code: BCA109 Subject: Physics
Time: 3 Hours Maximum Marks:75

Note: Attempt any five questions. Select one question from each unit including QNo 1 which is compulsory.

Question 1.

(a) According to Newton's third law, "action and reaction are equal and opposite". Then why don't these two forces cancel each other?

(b) A boy is running with constant speed on a circular track. Is it an accelerated motion? If yes, then explain briefly the force that is acting on the boy to keep him in circular motion.

(c) A man of mass 60kg climbs a ladder of height 5m. Calculate the work done by the force of gravity. Take $g=10m/s^2$.

(d) "Static friction is a self-adjusting force". Is this statement true? Justify your answer.

(e) Explain briefly elastic and perfectly inelastic collisions.

(f) Define Ohm's law. Is it a fundamental law or valid only for certain materials and devices? Justify your answer.

(g) 5J of work is done in moving a positive charge of 0.5c from one point to another. What is the potential difference between the two points?

(h) Write the two important conclusions of Rutherford's α-particle scattering experiment.

(i) Write the difference between metals, insulators and semiconductors on the basis of energy bands in solids.

(j) Name the majority and minority carriers in p-type and n-type semiconductors.

(2.5x10=25)

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UNIT-1

Question 2.

(a) What is wrong with the statement, "Because the car is at rest, there are no forces acting on it"? How would you correct the statement? (4.5)

(b) A person weighs a fish on a spring scale attached to the ceiling of an elevator. Show that is the elevator accelerates upwards or downwards, the spring scale reads an apparent weight different from the fish's true weight. Justify your answers by drawing free body diagrams of the fish. (8)

Question 3.

(a) State the laws of limiting friction. (5)

(b) The outer rail of a curved railway track is generally raised over the inner. Why? Explain briefly. (7.5)

UNIT-2

Question 4.

(a) Define work. What do you understand by negative work done by a force? (4)

(b) Does kinetic energy of a body depend upon the direction of motion? Justify your answer. (3)

(c) A toy car of mass 0.2kg is moving with speed 10m/s. Find its kinetic energy. If the car stops due to friction, find the work done by the force of friction. (5.5)

Question 5.

(a) Define conservative force. Prove that the gravitational force is a conservative force. (6)

(b) Two identical ivory balls of mass 1kg each, moving in opposite directions with speeds 5m/s and 10m/s collide head on. Find the velocities of the balls after the collision. Assume that the collision is perfectly elastic and one dimensional. (6.5)

UNIT-3

Question 6.

(a) A glass rod when rubbed with silk cloth acquires positive charge of 1.6×10^{-13} coulombs. Explain it in terms of transfer of electrons. Have the electrons transferred from the glass rod to the silk cloth or from the silk cloth to the glass rod? What is the number of electrons transferred? Charge on an electron$=1.6 \times 10^{-19}$C. (7.5)

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(b) Define coulomb's law. (2.5)

(c) Why no two electric field lines can intersect each other? Explain briefly. (2.5)

Question 7.

(a) What are the factors on which resistance of a conductor depends? Give the corresponding relationship. (4)

(b) Give three identical resistors each of resistance 30 Ohms. How can they be connected in a circuit to give a total resistance of 90 Ohms and 10 Ohms respectively? (4)

(c) State and explain briefly Kirchoff's Rules. (4.5)

UNIT-4

Question 8.

(a) State the postulates of Bohr's atom model. Explain how these postulates overcome the drawbacks of Rutherford's atom model. (7.5)

(b) Explain briefly the formation of energy bands in solids. (5)

Question 9.

(a) Discuss briefly electrical conduction in semi-conductors. (4)

(b) Which biasing makes the p-n junction resistance law?

(c) Justify your answer. (3.5)

(d) What is a transistor? Write briefly the action of a n-p-n transistor.

END TERM EXAMINATION
First Semester (BCA)
DECEMBER 2013- JANUARY 2014

Paper code: BCA-109
Batch: 2011 onwards

Subject: Physics
Time: 3 Hours
Maximum Marks: 75

Note: Attempt any five questions, including Question No.1 which is compulsory. Select one question from each Unit.

Question 1.

(a) If a body is not at rest, then the net force acting on it can not be zero. Is this statement true or false? Justify your answer.

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(b) A man raises a body of mass 10 kg through a height of 2 metres. Find the work done against the force of gravity. Take $g=10m/s^2$

(c) Define the SI unit of power. Give its relationship with one horse power.

(d) Explain how friction helps in walking.

(e) Define Gauss's Law in Electrostatics. Explain briefly.

(f) Define intensity of electric field at a point. Write its SI unit.

(g) Explain briefly the principle of a capacitor.

(h) What is a Wheatstone bridge? Draw a circuit diagram to briefly explain it.

(i) What are energy bands in solids? Explain briefly.

(j) What are extrinsic semiconductors? Name the minority carriers in p- type semiconductors (2.5x10=25)

UNIT-I

Question 2.

(a) Define Newton's first two laws. Show that the first law can be obtained from the second law.

(b) A force of 10 N acts on a body of mass 200 g. Find the acceleration produced in the body.

(c) Define momentum. Write its SI unit. Is it a vector quantity or a scalar quantity? (5+4+3.5=12.5)

Question 3.

(a) Differentiate between static and kinetic friction.

(b) Static friction is a self adjusting force. Explain.

(c) A horizontal force of 490 N is required to slide a sledge weighing 600 kgf over a flat surface. Calculate the coefficient of friction. (4+4+4.5=12.5)

UNIT – II

Question 4.

(a) Define work and its SI unit. What is the meaning of negative work? Briefly explain.

(b) Write the expression for the potential energy of a compressed spring. Explain the various terms.

(c) Write the names of different forms of energy. Explain the law of conservation of energy. (3+5+4.5=12.5)

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Question 5.

(a) Explain elastic and inelastic collisions. Give main differences.

(b) Two identical bodies each of mass M moving with speed U_1 and U_2 along a straight line undergo a head on perfect inelastic collision. Calculate the loss in kinetic energy. (5+7.5=12.5)

UNIT – III

Question 6.

(a) Explain briefly frictional electricity.

(b) Find the force between two stationary charges each 600 micro Coulomb kept 2 meters apart in vacuum. How will the force vary if the charges are kept in a medium of dielectric constant 80?

(c) Use Gauss's law to show that the electric field inside a charge solid conducting sphere is zero.

(3+4.5+5=12.5)

Question 7.

(a) The total resistance of two resisters when connected in series is 9 Ω and when connected in parallel, Their total resistance becomes 2 Ω. Find the value of each resistance.

(b) Define Ohm's law. Is it a fundamental law? Explain briefly.

(c) State Kirchhoff's rules. Explain with the help of a circuit diagram. (3+3.5+6=12.5)

UNIT – IV

Question 8.

(a) Explain briefly the basis of Rutherford's atomic model.

(b) Why is the density of an atom less than the density of its nucleus? Explain briefly.

(c) State the Postulate of Bohr's atomic model. (5+3+4.5=12.5)

Question 9.

(a) What is a p-n junction? Explain briefly how potential barrier is caused in it.

(b) In a transistor, base is made thin and lightly doped. Why?

(c) List the advantages of integrated circuit over conventional circuit. (5+3.5+4=12.5)

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End Term Examination –December -2015

Attempt any five questions including Question No.1 which is compulsory

Question 1.

(a) State Ohm's law. Derive the laws of resistances when they are connected in

(b) Series b) Parallel

(c) What is capacitor? Explain its principle.

(d) State and explain Newton's second law of motion. Explain some of its consequences.

(e) State and explain the laws of limiting friction. How are they verified experimentally?

(f) What is meant by weight? Discuss the apparent weight of a man in a lift/elevator.

Question 2.

(a) Discuss the inelastic collision of two bodies in one dimension. Calculate the velocities of bodies after the collision. Discuss different cases.

(b) A cyclist speeding at 18 km/h on level road takes a sharp circular turn of radius 3m without reducing the speed. The coefficient of static friction is 0.1 will the cyclist slip while taking the turn.

Question 3.

(a) What is a spherical capacitor? Derive an expression for its capacitance.

(b) Three capacitors of capacitance 5,4 and 3μF are connected so that the first and second are in series and the third are in parallel with them. Calculate the capacities of the combination.

Question 4.

(a) With the help of circuit diagram explain the action of a N-P-N transistors. What are the advantages of transistors?

(b) Describe Rutherford's alpha scattering experiment.

Question 5.

(a) Obtain the condition for balancing of a Wheatstone bridge using Kirchoff's laws.

(b) A body of mass 5kg initially at arrest is subjected a force of 20N. What is the Kinetic energy acquired by the body at the end of 10 sec. ?

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Question 6.

(a) What is meant by banking of roads? Obtain an expression for the maximum speed which a vehicle can safely negotiate a curved road banked at an angle θ.

(b) How does the weight of a man standing in a lift changes when the lift accelerates:

I) Upwards

II) Downwards with an acceleration a.

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PHYSICS
Simplified

ABOUT **BOOK**

This book has been designed according to GGSIP university syllabus for BCA –Physics. All units have been categorized into chapters thus covering complete syllabus. Each [illegible] sub-topic has been elaborated upon in a lucid and easily understandable manner. Physics - Simplified as the name suggests author has taken great care in usage of language with simple sentences and easy vocabulary for in-depth learning. All technical terms have been [illegible] in [illegible] perfect possible manner which greatly contributes to better understanding [illegible]

A unique feature of the book is that not only the difficult derivations and numerical have been explained step by step for better understanding of the concept but also the diagrams.

Book serves not only the purpose of a text book but is also vital for exam preparation with the aid of question bank and previous year papers.

ABOUT **AUTHOR**

Dr. M. Balasubramanian is working in Vivekananda Institute of Professional Studies, affiliated to GGSIPU and has rich teaching experience in physics and electronics for more than 25 years. He is the recipient of excellence award in 2013 in this Institute. He has published many research papers in International Journals –Elsevier and Springer and a book-Digital Electronics.

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