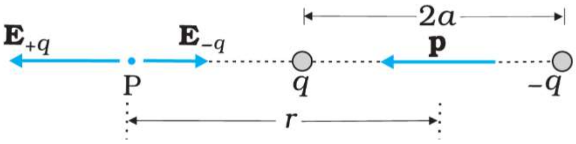
39.CHAPTER_1: ELECTRIC CHARGES AND FIELDS

1. Derive the expression for Electric Field at a point on the axial line of an electric dipole.

Consider an electric dipole of dipole moment $p = 2aq$.

Let P be a point on the axial line of the electric dipole at a distance r from the centre of a dipole.

The magnitude of electric field at P, due to charges +q and −q of dipole is given by



$$E_{+q} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}$$

$$E_{-q} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}$$

Since E_{+q} and E_{-q} are in opposite direction, therefore net electric field at P is

$$E = E_{+q} - E_{-q}$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2} - \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}$$

$$E = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{(r-a)^2} - \frac{q}{(r+a)^2}\right]$$

$$E = \frac{q}{4\pi\varepsilon_0}\left[\frac{4ar}{(r-a)^2(r+a)^2}\right]$$

$$E = \frac{1}{4\pi\varepsilon_0}\left[\frac{2pr}{(r^2-a^2)^2}\right]$$

For $r \gg a$,

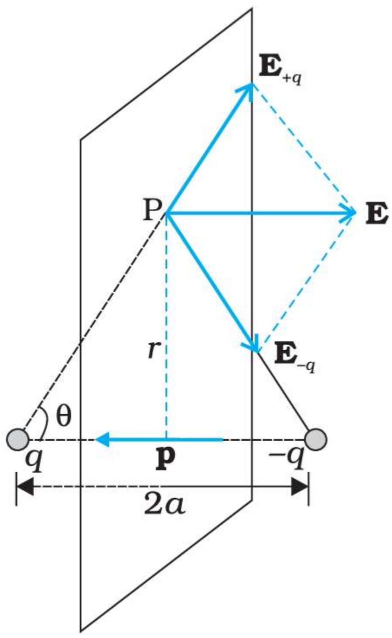
$$E = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$$

2. Derive the expression for Electric Field at a point on the equatorial line of an electric dipole.

Consider an electric dipole of dipole moment $p = 2aq$.

Let P be a point on the equatorial line of the electric dipole at a distance r from the centre of a dipole.

The magnitude of electric field at P, due to charges +q and −q of dipole is given by



$$E_{+q} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)}$$

$$E_{-q} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)}$$

Here $E_{+q} = E_{-q}$ in magnitude

$$E_{+q} = E_{-q} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2 + a^2)}$$

The components of fields E_{+q} and E_{-q}, normal to the dipole axis are equal and opposite and hence they get cancel. The field components along the dipole axis are get add up.
Therefore, the net electric field at P is, $E = E_{+q}cos\theta + E_{-q}cos\theta$

$$E = 2E_{+q}cos\theta$$

$$E = 2\frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2 + a^2)}\frac{a}{\sqrt{(r^2 + a^2)}}$$

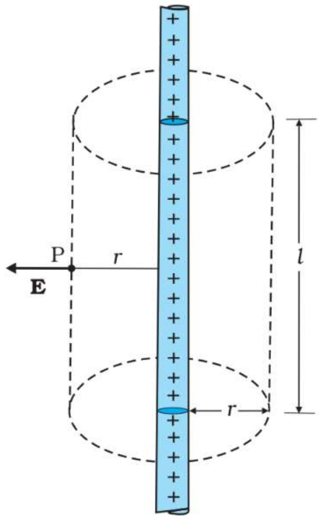
$$E = \frac{1}{4\pi\varepsilon_0}\frac{p}{(r^2 + a^2)^{3/2}}$$

For $r \gg a$,

$$E = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$$

3. State Gauss's law in electrostatics. Obtain an expression for electric field due to uniformly charged long straight wire using Gauss's law.

Statement: "The total electric flux through a closed surface in free space is equal to $\frac{1}{\epsilon_0}$ times the net charge enclosed by the surface.



Consider a long straight wire with uniform linear charge density λ. Let P be a point at a distance r from the wire. Consider an imaginary cylinder of length ℓ and radius r.
Total electric flux through Gaussian cylinder is

$$\phi = \int Edscos\theta$$

$$\phi = E\int ds = E(2\pi rl) \dots\dots\dots\dots (1)$$

From Gauss's law,

$$\phi = \frac{Q}{\epsilon_0} = \frac{\lambda l}{\epsilon_0} \dots\dots\dots\dots (2)$$

From (1) and (2)

$$E(2\pi rl) = \frac{\lambda l}{\epsilon_0}$$

$$E = \frac{\lambda}{2\pi\,\epsilon_0\,r}$$

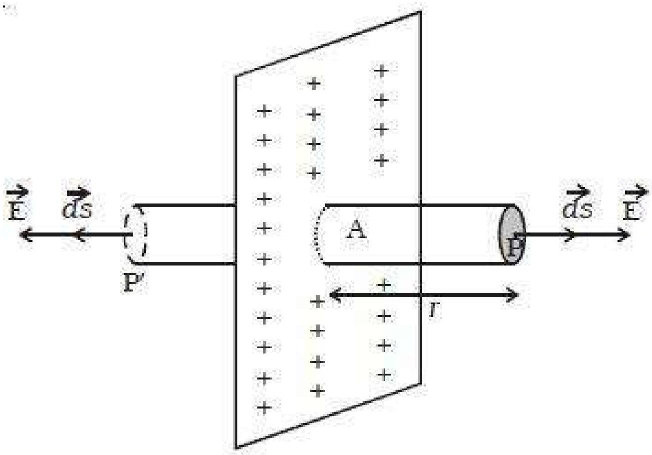
4. Obtain an expression for electric field due to a uniformly charged infinite plane sheet.

Consider an infinite thin plane sheet of surface charge density σ.

Imagine a Gaussian cylinder of cross-sectional area A.

Total electric flux through the cylinder is:

$$\phi = \phi_1 + \phi_2 + \phi_3$$



But,

$$\phi_1 = \phi_2 = EA$$

And

$$\phi_3 = 0$$

Therefore,

$$\phi = EA + EA + 0 = 2EA \ldots\ldots\ldots (1)$$

From Gauss's law,

$$\phi = \frac{Q}{\epsilon_0} = \frac{\sigma A}{\epsilon_0} \ldots\ldots\ldots\ldots (2)$$

From (1) and (2)

$$2EA = \frac{\sigma A}{\epsilon_0}$$

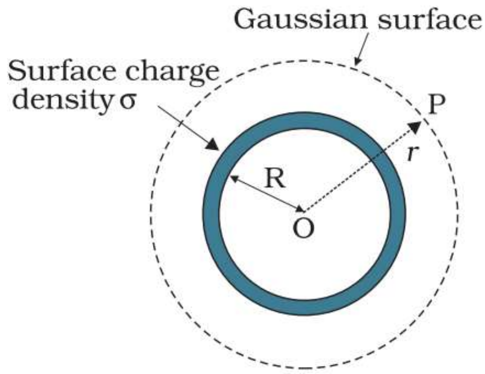
$$E = \frac{\sigma}{2\,\epsilon_0}$$

5. State Gauss's law in electrostatics. Derive expression for electric field due to a uniformly charged thin spherical shell at a point outside the shell.

Statement: "The total electric flux through a closed surface in free space is equal to $\frac{1}{\epsilon_0}$ times the net charge enclosed by the surface.

Consider a spherical shell of radius R with a charge q. P is a point at distance r from O. Imagine Gaussian sphere with centre O and radius r.

Total electric flux through the Gaussian surface is



$$\phi = \int Eds\cos\theta$$

$$\phi = E\int ds = E(4\pi r^2) \ldots\ldots\ldots (1)$$

$$\phi = \frac{Q}{\epsilon_0} \ldots\ldots\ldots (2)$$

From (1) and (2)

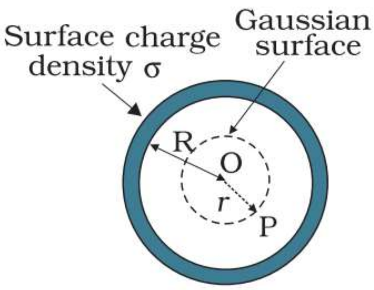
$$E(4\pi r^2) = \frac{Q}{\epsilon_0}$$

$$E = \frac{1}{4\pi\,\epsilon_0}\frac{Q}{r^2}$$

Electric field on the surface,

$$E = \frac{1}{4\pi\,\epsilon_0}\frac{Q}{R^2}$$

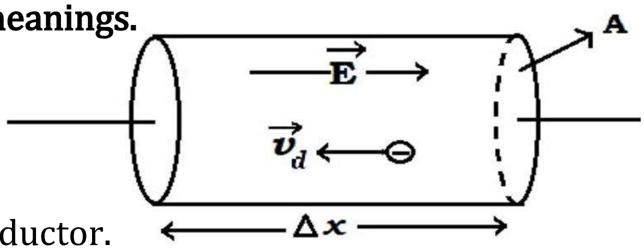
Electric field inside the sphere, $E = 0$



40.CHAPTER_3: CURRENT ELECTRICITY

1. **Derive the expression for conductivity of a conductor. (OR)**

   Derive $\sigma = \frac{ne^2\tau}{m}$ where symbols have usual meanings.



Consider a conductor carrying steady current.
Let, Δx – length of a element of a conductor
A - uniform cross sectional area of conductor
n - number density of free electrons in the conductor.

Total number of free electrons in the element is,

$$N = (Charge\ density)(volume\ ) = n(A\Delta x)$$

Magnitude of charge due to these electrons is,

$$\Delta q = (nA\Delta x)e \ldots\ldots\ldots (1)$$

If Δt is the time taken by this charge to pass through the element of conductor, then current through the conductor is,

$$I = \frac{\Delta q}{\Delta t} = \frac{nA\Delta xe}{\Delta t} = nAe\left(\frac{\Delta x}{\Delta t}\right)$$

But $\frac{\Delta x}{\Delta t} = v_d$ the drift velocity (magnitude) of conduction electrons

$$I = neAv_d \ldots\ldots\ldots (2)$$

Magnitude of drift velocity is,

$$v_d = \frac{eE\tau}{m}$$

$$\therefore I = neA\left(\frac{eE\tau}{m}\right)$$

$$\frac{I}{A} = ne^2\frac{E\tau}{m}$$

$$J = \frac{ne^2E\tau}{m} \ldots\ldots\ldots (3)$$

We know that,

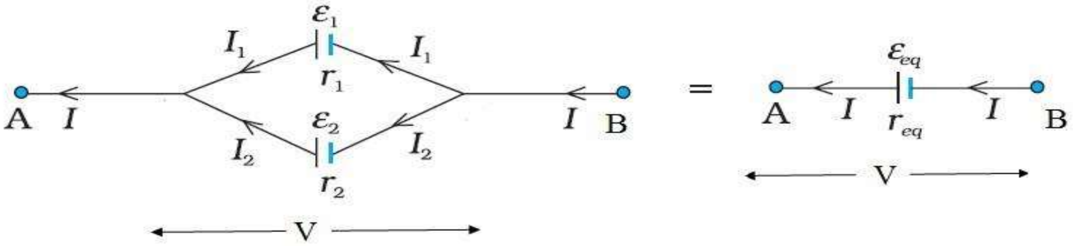
$$J = \sigma E \ldots\ldots\ldots (4)$$

From equation (3) and (4) we get

$$\sigma = \frac{ne^2\tau}{m}$$

2. **Derive the expressions for equivalent emf and equivalent internal resistance of parallel combination of two cells.**

Consider two sources of emf (cells) connected in parallel as shown in figure.



Let, $\in_1$ and $\in_2$ - emf of two cells and r_1 and r_2 - Internal resistance of two cells

I_1 and I_2 – Currents through the branches of cells $\in_1$ and $\in_2$ respectively

I – Net current in the branch AB,

The total current due to this combination of cells is

$$I = I_1 + I_2 \ldots\ldots\ldots (1)$$

Terminal potential difference across the first cell, $V = \in_1 - I_1 r_1$

$$I_1 = \frac{\in_1 - V}{r_1}$$

similarly,

$$I_2 = \frac{\in_2 - V}{r_2}$$

$$(1) \Rightarrow I = \frac{\in_1 - V}{r_1} + \frac{\in_2 - V}{r_2}$$

$$I = \frac{\in_1}{r_1} + \frac{\in_2}{r_2} - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right) \ldots\ldots\ldots (2)$$

If the combination of cells is replaced by an equivalent cell of emf $\in_{eq}$ and internal resistance r_{eq} then terminal potential difference of that cell is,

$$V = \in_{eq} - I r_{eq}$$

$$I = \frac{\in_{eq}}{r_{eq}} - \frac{V}{r_{eq}} \ldots\ldots\ldots (3)$$

From equation (2) and (3),

$$\frac{\in_{eq}}{r_{eq}} = \frac{\in_1}{r_1} + \frac{\in_2}{r_2}$$

$$\Rightarrow \in_{eq} = \left(\frac{\in_1}{r_1} + \frac{\in_2}{r_2}\right) r_{eq}$$

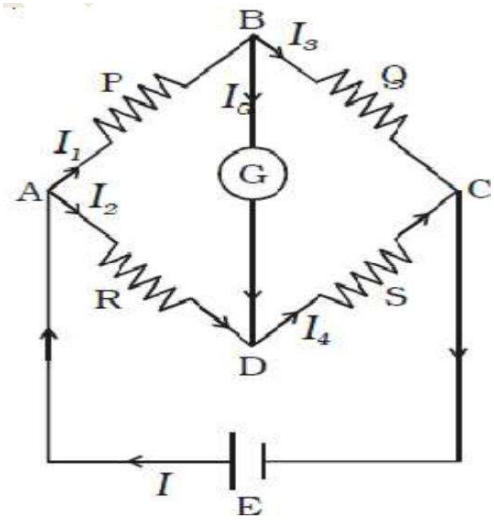
and

$$\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2}$$

3. **Deduce the balancing condition for Wheat stone's network using Kirchhoff's rules.**

The figure shows a Wheatstone bridge consisting of four resistances P, Q, R and S.

If the current through the galvanometer is zero then the network is said to be balanced.



At balanced state of network i.e.

$$I_g = 0$$

Applying Kirchhoff's node rule for nodes B and D, we get,

$$I_1 = I_3 \text{ and } I_2 = I_4 \ldots\ldots\ldots (1)$$

Applying Kirchhoff's second law to the mesh ABDA,

$$I_1 P + 0 - I_2 R = 0$$

$$I_1 P = I_2 R \ldots\ldots\ldots (2)$$

Applying Kirchhoff's second law to the mesh BCDB,

$$I_3 Q - I_4 S - 0 = 0$$

$$I_3 Q = I_4 S \ldots\ldots\ldots (3)$$

Dividing equation (2) by (3)

$$\frac{I_1 P}{I_3 Q} = \frac{I_2 R}{I_4 S}$$

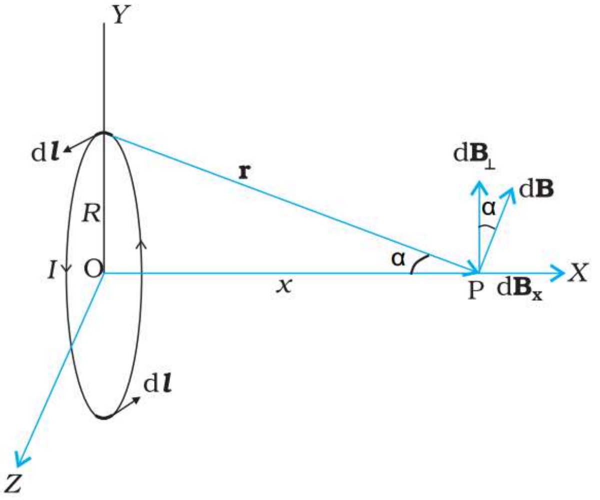
Using equation (1), the above equation becomes to

$$\frac{P}{Q} = \frac{R}{S}$$

This is the condition for balance of Wheatstone network.

41.CHAPTER_4:MOVING CHARGES AND MAGNETISM

1. **Derive the expression for magnetic field at a point on the axis of a circular current loop.**



Consider a circular coil carrying current as shown in figure.

Let, R – radius of current loop

I – current in the loop

dl – length of current element AB

x – distance of point P on the axis from the center of current loop O.

Magnetic field at P due to current element 'AB' of length 'dl' is,

$$dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$$

here, $\theta = 90^0$ so, $\sin 90^0 = 1$, $r^2 = x^2 + R^2$

$$\therefore dB = \frac{\mu_0}{4\pi}\frac{Idl}{x^2 + R^2} \ldots\ldots\ldots(1)$$

This magnetic field $\overrightarrow{dB}$ can be resolved into two components, $dB_{\perp} = dB\cos\alpha$ and $dB_{\parallel} = dB\sin\alpha$

If the magnetic field at P is summed over the entire loop,

(a) all the perpendicular components are cancelled out and

(b) the parallel components are added.

Hence the magnetic field at P due to entire current loop is,

$$B = \sum dB\sin\alpha$$

$$= \sum\left(\frac{\mu_0}{4\pi}\frac{Idl}{(x^2 + R^2)}\right)\left(\frac{R}{(x^2 + R^2)^{1/2}}\right)$$

From figure, $\sin\alpha = \frac{R}{(x^2+R^2)^{1/2}}$

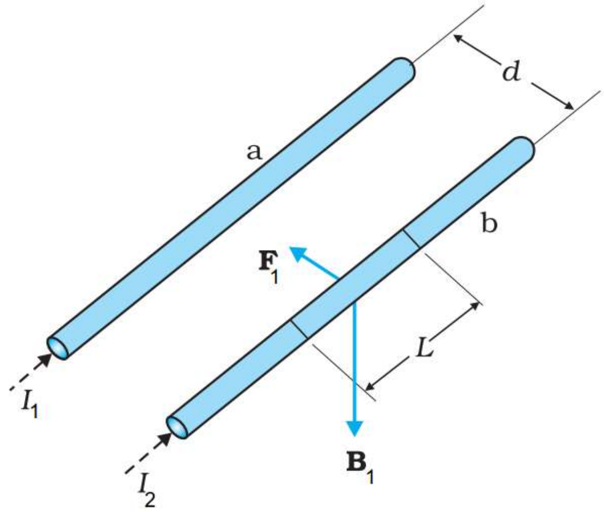
$$= \frac{\mu_0}{4\pi}\frac{IR}{(x^2 + R^2)^{3/2}}\sum dl$$

$$= \frac{\mu_0}{4\pi}\frac{IR}{(x^2 + R^2)^{3/2}}(2\pi R)$$

$$B = \frac{\mu_0}{4\pi}\frac{2\pi IR^2}{(x^2 + R^2)^{3/2}}$$

2. Derive the expression for the force between two infinitely long straight parallel conductors carrying currents and hence define ampere.

Consider two infinitely long straight parallel conductors a and b carrying currents I_1 and I_2 respectively and separated by a perpendicular distance 'd' as shown in the figure. The magnetic field at each point on conductor 'b' due to current I_1 in conductor 'a' is



$$B_1 = \frac{\mu_0 I_1}{2\pi d}$$

Now the current carrying conductor 'b' is in uniform magnetic field B_1. Hence magnetic force on the segment L of conductor 'b' is,

$$F_1 = I_2 L B_1 sin\theta$$

$\overrightarrow{F_1}$ is directed towards the conductor 'a' and here, here, $\theta = 90^0$ so, $sin90^0 = 1$.

$$F_1 = I_2 L\left(\frac{\mu_0 I_1}{2\pi d}\right)$$

$$F_1 = \frac{\mu_0 I_1 I_2 L}{2\pi d}$$

Similarly conductor 'a' also experience same magnitude of force but in opposite direction. Magnetic force on segment L of conductor 'a' is,

$$F_2 = \frac{\mu_0 I_1 I_2 L}{2\pi d}$$

The mutual force per unit length on conductors 'a' and 'b' is,

$$F = \frac{F_1}{L} = \frac{\mu_0 I_1 I_2}{2\pi d}$$

Definition of ampere: Thus "If two very long, straight, parallel conductors of negligible cross section carrying same steady current are placed 1 m apart in vacuum experience a mutual force of 2×10^{-7} newton per meter length of these conductors, then the current in each conductor is said to be 1 ampere".

42.CHAPTER_9: RAY OPTICS

1. Derive an expression for the relation between n u v and R for refraction at a spherical surface.
2. Derive Lens Maker's formula for convex lens.
3. Derive the expression for equivalent focal length of two lenses kept in contact.
4. Derive the expression for refractive index of the material of a prism in terms of an angle of prism (A) and angle of minimum deviation (D_m).

43.CHAPTER_11: DUAL NATURE OD RADIATION AND MATTER

(a) Define the following terms

1) **Work function.**
2) **Threshold frequency.**
3) **Electron volt.**
4) **Stopping potential.**

Work function of a metal surface is the minimum energy required to liberate an electron from the metal surface.

Threshold frequency of a metal surface is the minimum frequency of incident radiation below which there is no photo emission.

One **electron volt** (1 eV) is the energy gained by an electron when it is accelerated through a potential difference of one volt.

The minimum negative (retarding) potential given to the collector plate for which the photo electric current becomes zero is called the **stopping potential**.

(b) 1) Mention Einstein's photoelectric equation and explain the terms.

$$K_{max} = E - W_0 = h(\nu - \nu_0)$$

Where, E – energy of incident photon

W_0 – work function

ν & ν_0- are frequency of incident radiation and threshold frequency.

2) Write the expression for de Broglie wavelength of a particle and explain the terms.

$$\lambda = \frac{h}{mv}$$

Where, h – plank's constant m – mass of electron v – velocity of a particle.

3) Write the expression for de-Broglie wave length of electrons in terms of electric potential and explain the terms used.

$$\lambda = \frac{h}{\sqrt{2meV}}$$

Where, h – plank's constant m – mass of electron

e – charge of electron V – electric potential.

4)Write the expression for de-Broglie wave length of electrons in terms of kinetic energy and explain the terms used.

$$\lambda = \frac{h}{\sqrt{2mK}}$$

Where, h – plank's constant m – mass of electron K – kinetic energy

(c) 1) Write the experimental observations of photoelectric effect.

The experimental observations of photoelectric effect are,

- The photoelectric emission is an instantaneous process.
- For every photosensitive material, there exists a certain minimum cut-off frequency of the incident radiation below which there is no photoelectric emission.
- Above threshold frequency, the photo current is directly proportional to the intensity of incident light.
- Above the threshold frequency, saturation current is proportional to the intensity of incident radiation.

2) Using the Einstein's photoelectric equation explain any t experimental observations of photoelectric effect.

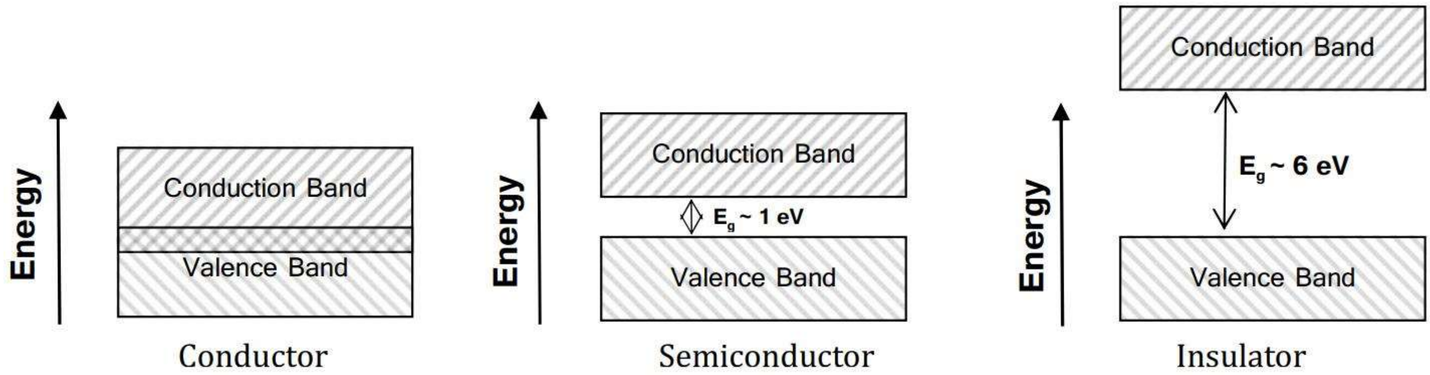
- According to Einstein's photoelectric equation, K_{max} depends linearly on frequency ν and $K_{max}$is independent of intensity of radiation.
- Since K_{max} must be non-negative, photoelectric emission is possible only if $h\nu > W_0$ or $\nu > \nu_0$. Thus, there exists a threshold frequency νo for every metal surface, below which no photoelectric emission is possible.
- Intensity of radiation is proportional to the number of photons per unit area per unit time. The greater the number of photons available, the greater is the number of electrons coming out of the metal. Therefore, (for frequencies $\nu > \nu_0$) photoelectric current is directly proportional to intensity of incident radiation.
- According to Einstein, the photoelectric effect is instantaneous process. This is because photoelectric effect process involves absorption of light quantum by single electron, which takes place instantaneously.

44.CHAPTER_14: SEMICONDUCTOR ELECTRONICS

1. **(a) Explain the formation of energy bands in solids.**
   (b) Using band theory differentiate between conductors, semiconductors and insulators.

In an *isolated atom* the electron exists in discrete energy levels. But when the atoms come together to form a solid, the outer orbits of electrons from neighbouring atoms would come very close or could even overlap. Because of this, energy levels of each electron will be very close to each other. The group of such energy levels forming continuous energy variation are called energy bands.

Conductors	**Semiconductor**	**Insulator**
Conduction and Valance band are overlapped	Conduction and Valance band are separated by small energy gap (Eg< 3 eV)	Conduction and Valance band are separated by large energy gap (Eg> 3 eV)
Conduction band is largely filled by conduction electrons	Conduction band is partially filled by conduction electrons	Conduction band is completely empty
Their electrical conductivity is very high	Their electrical conductivity lies between conductors and insulators	The electrical conductivity is not possible.
Their Conductivity *decreases* with increase in temperature	Their Conductivity *increases* with increase in temperature	Their Conductivity is *independent* of temperature
Ex: Metals and their alloys	Ex: Si, Ge	Ex: Plastic, rubber, glass



2. **(a) What is rectification?**
   (b) Explain the working of P-N junction diode as a half wave rectifier.
   (c) Draw relevant circuit diagram and wave form of a half wave rectifier.

The process of conversion of AC into DC.

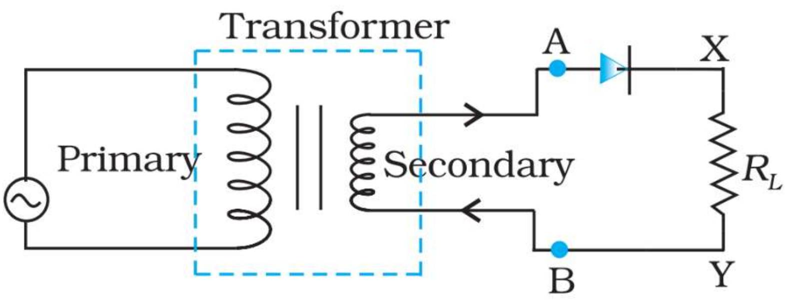
The device which converts only half cycle of AC into DC is called half wave rectifier.

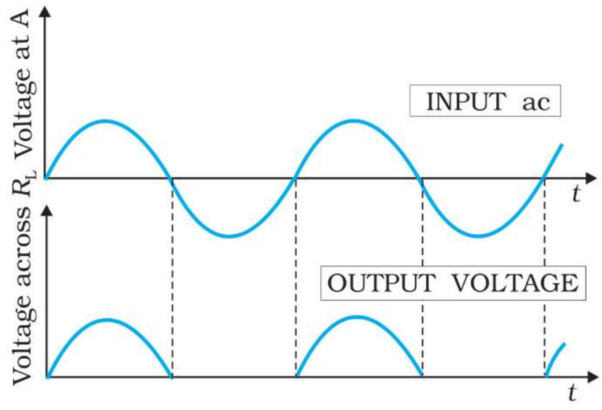
During positive half cycle of the induced ac, the end A of secondary is positive thus the diode D is forward biased. Hence the diode conducts and the output appears across R_L.

During negative half cycle of the induced ac, the end A of secondary is negative, thus the diode D is reverse biased. Hence the diode does not conduct and no output appears across R_L.

Thus, the diode conducts only positive half cycles of input ac cycle and hence it acts as half wave rectifier.

The circuit for half wave rectifier is as shown in the figure.





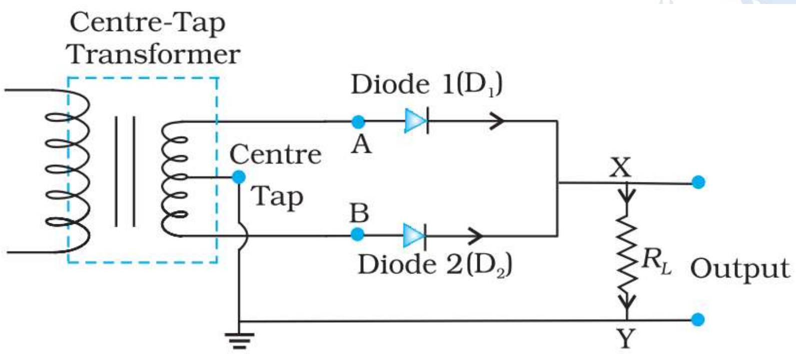
3. **(a) what is rectifier?**

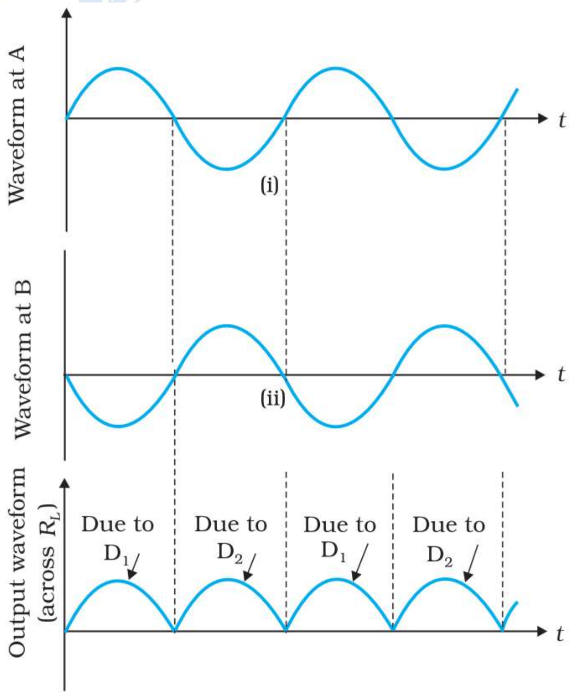
   (b) Draw relevant circuit diagram and wave form of a full wave rectifier.

   (c) Explain the working of P-N junction diode as a full wave rectifier.

A device that converts **ac into dc** is called rectifier.

A device that converts both the half cycles of ac into dc is called full wave rectifier





During positive half cycle of the ac input, the end A of secondary is positive relative to center tap and the end B is negative. Thus the diode D_1 is forward biased and D_2 is reverse biased. Hence the diode D_1 conducts and the output appears across R_L.

During negative half cycle of the ac input, the end A of secondary is negative relative to center tap and the end B is positive. Thus the diode D_1 is reverse biased and D_2 is forward biased. Hence the diode D_2 conducts and the output appears across R_L.

Thus both the halves of input AC is converted into DC and hence the device works as full wave rectifier.