PHYSICS – 2024
Semiconductor Electronics

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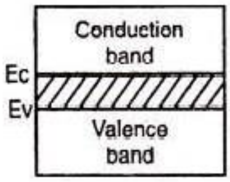
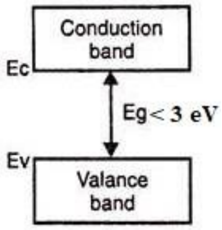
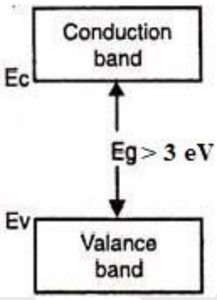
On the basis of energy bands distinguish between a conductors (metals), semiconductor and an insulator.

CONDUCTORS	SEMICONDUCTORS	INSULATORS
		
It has low resistivity	It has moderate resistivity	It has high resistivity
They allow current to pass through it	Their electrical properties lies between that of conductors and insulators	They don't allow current to pass through it
conductivity decreases with increase in temperature	conductivity increases with increase in temperature	Their conductivity is zero
Conductivityis due to free electrons	Conductivity is due to both electrons and holes	No electrons or holes for conductivity.
Conduction band is completely filled with electrons at above 0K	Conduction band is partially filled with electrons above 0K	Conduction band is completely empty

Distinction between Intrinsic and Extrinsic semiconductor

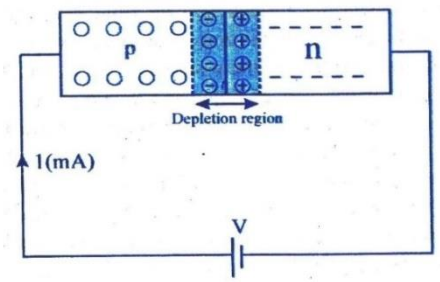
	Intrinsic semiconductor		Extrinsic semiconductor
1	These are pure semiconductor	1	These are doped semiconductors
2	Conductivity is due both electrons and holes.	2	Conductivity is mainly due to majority charge carriers.
3	Conductivity is low.	3	Conductivity is high.
4	$n_e = n_h$	4	$n_e \neq n_h$
5	Conductivity depends on the temperature.	5	Conductivity depends on the temperature and also doping level.

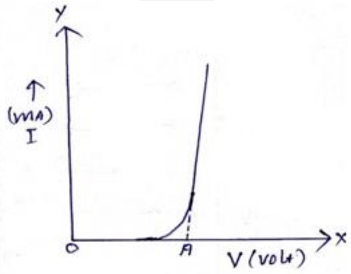
Distinguish between p – type and n – type semiconductors.

p – type semiconductor		n – type semiconductor	
1	Trivalent dopants are used	1	Pentavalent dopants are used
2	It has acceptor impurity	2	It has donor impurity
3	The majority charge carriers are holes	3	The majority charge carriers are electrons
4	The minority charge carriers are electrons	4	The minority charge carriers are holes
5	Acceptor energy level is slightly above the top of the valence band.	5	Donar energy level is slightly below the bottom of the conduction band .
6	$n_h >>> n_e$	6	$n_e >>> n_h$

Forward biasing of diode : -

The diode is said to be forward biased when p –side is connected to +ve terminal and n – side is connected to –ve terminal of the battery.

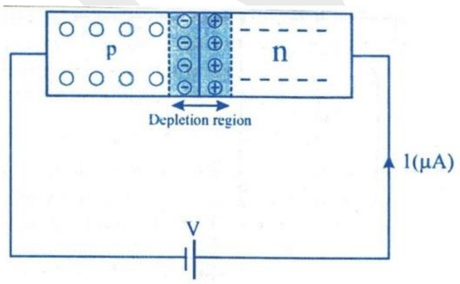


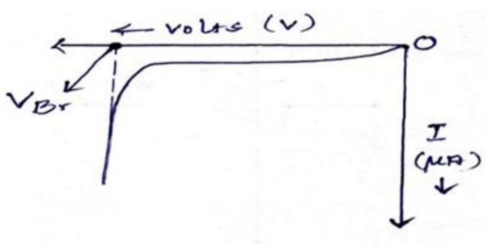


During forward bias

- The width of depletion region decreases and
- Junction potential decreases
- The charge carriers cross the junction and electric current flows through the circuit.
- Forward bias offers negligibly small resistance and hence the diode conducts.
- Current is due to majority charge carriers.

Reverse biasing of diode : -





The diode is said to be forward biased when p –side is connected to –ve terminal and n – side is connected to +ve terminal of the battery.

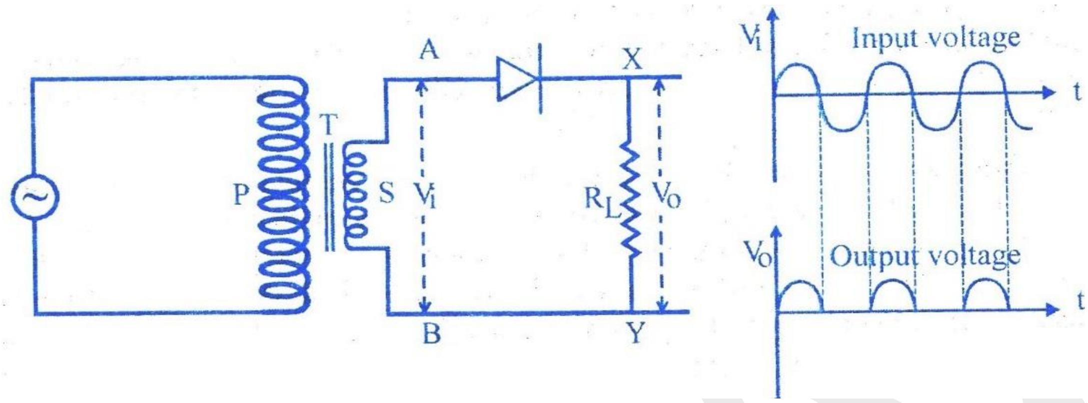
During reverse bias

- The width of depletion region increases
- Junction potential increases
- Reverse bias offers high resistance
- Current is due to minority charge carriers.

1. **Half wave rectifier: -**

A device which converts AC to DC is called a **rectifier** and the process is called **rectification.**

It is a device which converts only one half cycle of ac into dc.



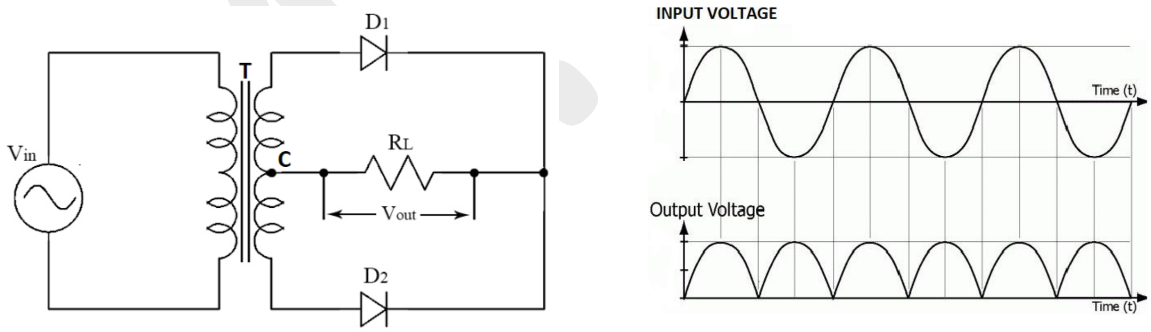
During the positive half cycle of input AC voltage i.e. When 'A' is +ve the diode is forward biased and it conducts. As a result current flows through the R_L and produces output across it.

During negative half cycle of input A.C voltage i.e. when 'A' is – ve the diode is reverse biased so it does not conduct. So we can't get the output. The input and output wave forms of half wave rectifier are as shown in figure.

2. **Full wave rectifier: -**

A device which converts AC to DC is called a **rectifier** and the process is called **rectification.**

Full wave rectifier is a device which converts both the half cycles of ac into dc.



During the positive half cycle of input AC voltage, A is positive and B is negative the diode D_1 is forward biased so D_1 conducts. The diode D_2 is in reverse biased and hence D_2 does not conduct. As a result the current I flows through R_L and produces output across the R_L.

During the negative half cycle of input AC voltage, A is negative and B is positive the diode D_1 is reverse biased so D_1 does not conducts. The diode D_2 is in forward biased and hence D_2 conducts. As a result the current I flows through R_L and produces output across the R_L.

Nucleus

Properties of Nuclear forces:

- strong attractive forces
- short range forces
- Nuclear forces are charge independent
- Nuclear forces are spin dependent
- Nuclear forces are exchange forces
- Nuclear forces are saturated forces

Differences between nuclear fission and nuclear fusion

	Nuclear Fission		Nuclear Fusion
➢	Nucleus of a heavy element splits into two lighter nuclei.	➢	Two lighter nuclei fuse to form a heavier nucleus.
➢	It can take place at all temperature	➢	It requires very high temperature
➢	Energy released per fission is high	➢	Energy released per fusion is low
➢	Energy released per nucleon is low	➢	Energy released per nucleon is high
➢	Radioactive waste will be there	➢	No radioactive waste.
➢			

Atoms

Postulates of Bohr's theory OR Bohr's atom model

1) The electrons revolve only in certain orbits called stationary orbits without the emission of radiant energy.
2) The angular momentum of an electron in the stationary orbits is an integral multiple of $h/2\pi$

   i.e., $L = \frac{nh}{2\pi}$
3) An electron emits energy only when it jumps from outer stationary orbit to inner stationary orbits.

   i.e. $E = E_2 - E_1$

   $h\nu = E_2 - E_1$

   where ν=frequency of emitted radiation.

Limitations of Bohr's theory (Drawbacks)

1) Bohr's theory is applicable only to hydrogen and hydrogen like atoms
2) It could not explain the fine structure of spectral lines.
3) It could not explain relative intensities of spectral lines.
4) It could not explain elliptical orbits of electron
5) It could not explain Stark effect.
6) It could not explain Zeeman Effect.
7) It could not explain wave nature of electrons.

Dual Nature of Radiation and Matter

Types of electron emission:

1. **Thermionic emission** 2. **Photo emission**
3. **Field emission** 4. **Secondary emission**

Laws of photoelectric effect or observations of photo electric effect:

- **i)** The photoelectron emission is an instantaneous process.
- **ii)** For a given metal, there exists a certain minimum frequency of the incident radiation below which no emission of photoelectrons takes place. This minimum frequency is called threshold frequency.
- **iii)** Above the threshold frequency,photoelectric currentis directly proportional to the intensity of incident radiation.
- **iv)** Above the threshold frequency, the maximum kinetic energy photoelectrons is directly proportional to frequency of the incident radiation.
- **v)** Photoelectric current just becomes zero at a particular negative voltage called stopping potential.
- **vi)** Above the threshold frequency, the stopping potential is directly proportional to frequency of the incident radiation.

Einstein's Explanation of Photoelectric effect:

$$\therefore \frac{1}{2}mV_{max}^2 = \mathrm{h}\nu - h\nu_0 \rightarrow (1)$$

Here m is the mass of the electron

V_{max} is the maximum velocity of the photoelectron.

Einstein's explanation on photoelectric effect

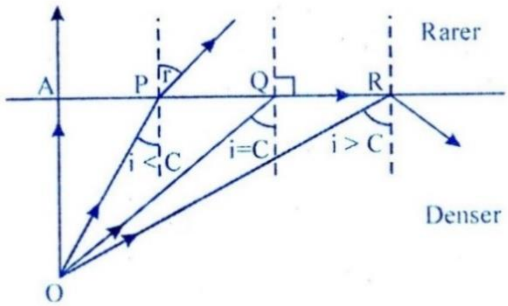
1. The photoelectron emission is an instantaneous process.
2. If $\nu = \nu_0$,From equation (1) $KE_{max} = 0$. Photoelectric effect is just possible.
3. If $\nu > \nu_0$,From equation (1) KE_{max} is positive. Photoelectric effect is possible.
4. If $\nu < \nu_0$,From equation (1) KE_{max} is negative. Photoelectric effect is not possible.
5. Above the threshold frequency, photoelectric current is directly proportional to the intensity of incident radiation.
6. Above the threshold frequency, the maximum kinetic energy photoelectrons are directly proportional to frequency of the incident radiation.

Properties of Photons:

- Rest mass of a photon is zero.
- All photons travels with speed of light in space.
- All photons travels in a straight line.
- Photons are electrically neutral.
- Each photon has energy $E = h\nu$
- Photons are not deflected by electric field or magnetic field.

Ray Optics and Optical Instruments

Total internal reflection [TIR]



Conditions for TIR: -

- ✓ The ray of light must travel from optically denser medium into rarer medium.
- ✓ The angle of incidence in the denser medium must be greater than critical angle

Applications of TIR: -

1) Sparkling of diamond 2)Formation of mirages 3) In optical fibres

OPTICAL FIBRE

It works on the principle of **TIR.**

Applications of Optical fibres: -

1) Used in the field of communications
2) Used in endoscopy to examine the inner parts of human body
3) They are used to transmit light signal and two-dimensional pictures.
4) Optical sensor fibres are used to measure temperature, pressure and rate of flow of liquids.

Wave Optics

Differences between interference and diffraction

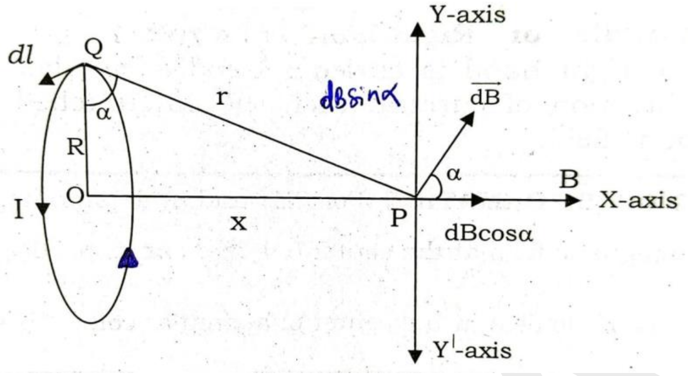
Interference	Diffraction
* Intensity of all bright fringes are equal.	* Intensity of all the bright fringes are not equal
* Numbers of fringes observed more	* Numbers of fringes observed less
* Intensity of all dark fringes are zero	* Intensity of all dark fringes are not zero
* The width of all the fringes is same	* The width of all the fringes is not same

Uses of polaroids

1. They are used to view 3D pictures.
2. They are used to study optical properties of metals.
3. Polaroids are used as sun glasses.
4. They are used in windows of vehicles.

Moving Charges and Magnetism

1. Derive an expression for the magnetic field strength at any point on the axis of a circular current loop using Biot-Savart's law.



The magnetic field at P due to the current element AB is given by

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

$$since\ \theta\ = 90^0\ ,\ \text{Sin}90^0 = 1$$

$$\therefore dB = \frac{\mu_0}{4\pi}\frac{I\ dl}{r^2}$$

Here Y – components of magnetic field will be cancel out. But X – components of magnetic field are added up

$$\therefore \quad B = \sum dB\cos\alpha$$

$$B = \sum \frac{\mu_0}{4\pi}\frac{I\ dl}{r^2}\cos\alpha$$

$$B = \frac{\mu_0}{4\pi}\frac{I\ \cos\alpha}{r^2}\sum dl$$

But $\sum dl = 2\pi R$,

$$B = \frac{\mu_0}{4\pi}\frac{I\ \cos\alpha}{r^2}\ 2\pi R$$

$$B = \frac{\mu_0}{4\pi}\frac{2\pi IR\ \cos\alpha}{r^2}$$

In triangle POQ $\cos\alpha = \frac{R}{r}$

$$\therefore \quad B = \frac{\mu_0}{4\pi}\frac{2\pi IR}{r^2}\ \text{x}\ \frac{R}{r}$$

$$B = \frac{\mu_0}{4\pi}\frac{2\pi IR^2}{r^3}$$

In triangle POQ

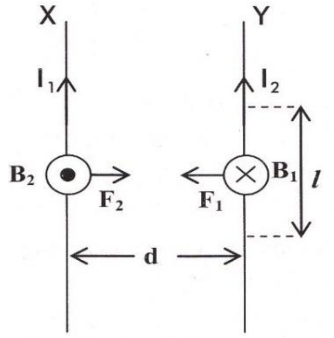
$$r^2 = R^2 + \text{x}^2 ==> r = (R^2 + \text{x}^2)^{1/2}\ and\ r^3 = (R^2 + \text{x}^2)^{3/2}$$

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

For N turns

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

2. **Derive the expression for the force between two straight parallel conductors carrying current in same direction and hence define ampere.**



Magnetic field due to the current I_1 is

$$B_1 = \frac{\mu_0 I_1}{2\pi\, d} \text{------(1)}$$

The force on a segment l of conductor Y is given by,

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

$$since\ \theta = 90^0 \text{ , } \sin 90^0 = 1$$

$$F_1 = B_1 I_2 l \text{ -----(2)}$$

(1) in (2) ==>

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

Similarly $F_2 = \frac{\mu_0 I_1 I_2\, l}{2\, \pi\, d}$

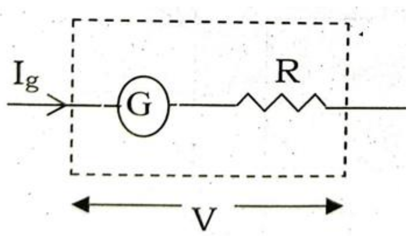
Therefore, the force of attraction or the force of repulsion is given by

$$F = \frac{\mu_0 I_1 I_2 l}{2\, \pi\, d}$$

Definition of ampere

'Ampere' is the current which when flows through two infinitely long straight parallel conductors separated by a distance 1m, placed in free space causes a force of 2×10^{-7} Nm^{-1} between them.

3. **How can a moving coil galvanometer be converted into a voltmeter? Explain with the diagram.**



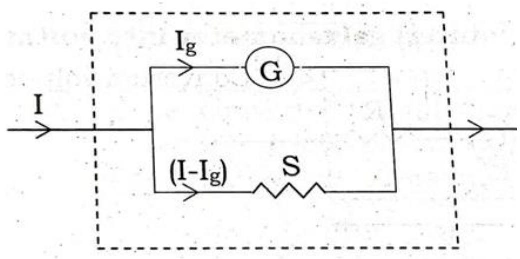
A galvanometer can be converted into a voltmeter by connecting high résistance in series with it.

From Ohm's law, $V = I_g\,(G + R)$

$$G + R = \frac{V}{I_g}$$

$$\mathbf{R} = \frac{V}{I_g} - G$$

4. **Explain with the circuit diagram how to convert a galvanometer into an ammeter.**



A galvanometer can be converted into an ammeter by connecting a low resistance in parallel with it.

$\therefore Potential\ difference\ across\ S = Potential\ difference\ across\ G$

$$(I - Ig)\ S = Ig\ G$$

$$\mathbf{S} = \frac{I_g G}{I - I_g}$$

5. **<u>Expression for magnetic field at a point inside the current carrying solenoid</u>**

$$B = \mu_0\, nI$$

Where,

μ_0 is the permeability of free space,
n is the number of turns per unit length of the solenoid,
I is the current in the solenoid.

Magnetism and Matter

Properties of magnetic field lines [Magnetic lines of force]

1) They form closed loops.
2) They do not intersect each other.
3) They do not pass through the superconductors.
4) They can pass through conductors and insulators.
5) The tangent drawn at any point on the field line represents the direction of magnetic field at that point.

Gauss' law in magnetism:
The net magnetic flux through any closed surface is always zero.

i.e, $\sum \vec{B}.\overrightarrow{dA} = 0$

Properties of Diamagnetic materials

1) They are repelled by the magnets.
2) They do not obey Curie's law.
3) Magnetization is low and negative.
4) Their relative permeability is less than 1.
5) Their susceptibility is low and negative.

Properties of paramagnetic materials:

1) They are weakly attracted by the magnets.
2) They obey Curie's law.
3) Their Magnetisation is low and positive.

4) Their relative permeability is slightly more than 1.
5) Their susceptibility is low and positive.

Properties of Ferromagnetic materials:

1) They are strongly attracted by magnets.
2) They obey curie's law above curie temperature.
3) Their magnetization is large and positive.
4) Their relativity permeability is much more than 1
5) Their susceptibility is high and positive.

Alternating Current

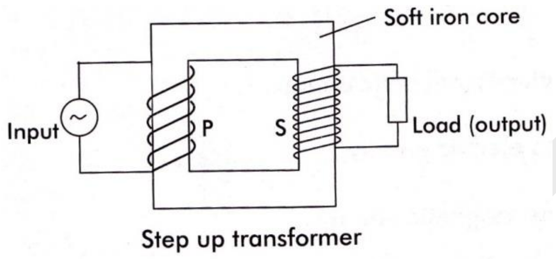
Transformer

It is a device used to step up or step down the alternating voltage.

Principle of transformer

Mutual induction

Construction of transformer



Step up transformer

Sources of energy losses in a transformer

1) Loss due to heating
2) Loss due to flux leakage
3) Loss due to eddy currents
4) Loss due to hysteresis.

Electric Charges and Fields

Basic properties of electric charge:

1) Charge is additive.
2) Charge is conserved.
3) Charge is quantized.

Coulombs law

Coulomb's law states that 'the force between two point charges is directly proportional to product of magnitudes of charges and inversely proportional to square of the distance between them'.

$$F = \frac{1}{4\pi\epsilon_o}\frac{q_1 q_2}{r^2},$$

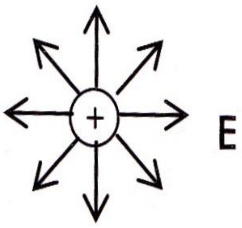
q_1 and q_2 are the point charges , r – distance between them

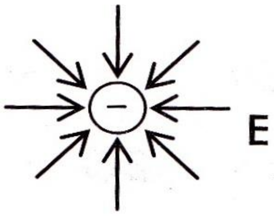
ϵ_o → permitivity of free space

Properties of electric field lines.

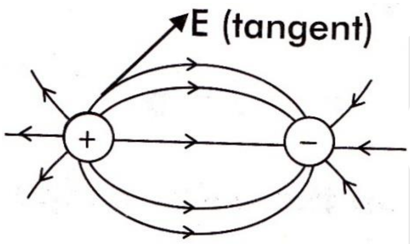
a) They do not form closed loops.
b) They do not intersect each other.
c) They do not pass through a conductor
d) They are normal to the surface of a charged conductor.
e) Electric field lines start from a positive charge and end on negative charge.

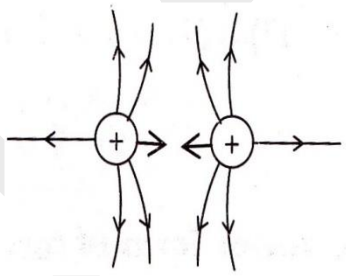
Electric field lines in case of a positive point charge(q>0) and negative point charge(q<0)





Electric field lines in case of a pair of equal and opposite charges(Dipole) and a pair of equal positive charges





Gauss law in electrostatics

"The total electric flux through any closed surface in free space is equal to $\frac{1}{\varepsilon_o}$ times the net charge enclosed by that surface".

Let q be the total charge enclosed by the surface,

$\emptyset = \frac{q}{\varepsilon_o}$ where $\epsilon_o \rightarrow$ permitivity of free space

CURRENT ELECTRICITY

Ohm's Law

Statement:

The current in a metallic conductor is directly proportional to the potential difference applied across its ends, provided the temperature & other physical conditions of the conductor are kept constant.

i.e. $V \propto I$

$=> I = \frac{V}{R}$.

I be the current, V be the potential difference, R is the resistance

Limitations of Ohm's Law

1) It is not applicable for metallic conductors at very low and very high temperatures.
2) It is not applicable for semiconductors, diodes.

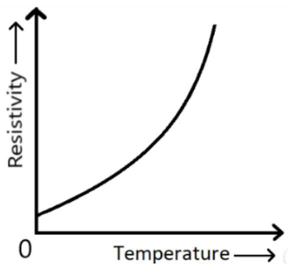
3) Ohm's law fails, if the current varies non-linearly with voltage.
4) Ohm's law fails, if the relation between voltage and current is not unique.

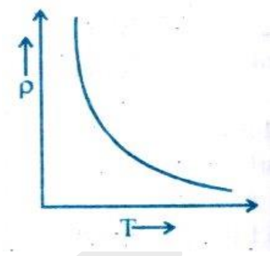
Factors on which the resistance of a conductor depend

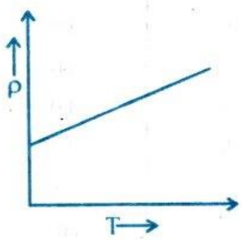
1) Length of the conductor
2) Area of cross section of the conductor
3) Nature of the conductor
4) Temperature of the conductor

Temperature –resistivity graph

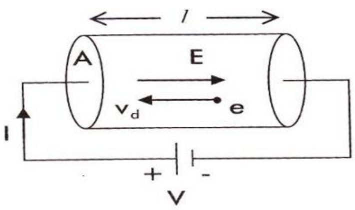
a) Conductor(**copper**) b)semiconductor(**Ge/Si**) c)Alloys**(Manganin** and **Constantan)**







Obtain the exression for 'drift velocity' of electrons in terms of 'relaxation time'.



WKT V = u + at

In the absence of electric field u = 0

In the presence of electric field V = V_d and t = τ

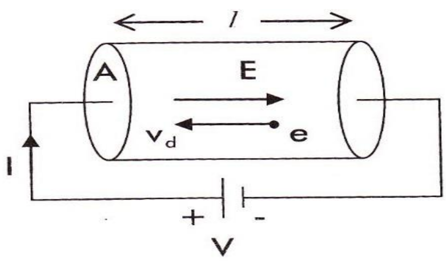
$$V_d = a\tau$$

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

⇨ $$V_d = \frac{-eE}{m}\tau$$

Relation between current density and conductivity of conductor

Derive the relation $\vec{J} = \sigma \vec{E}$



WKT $I = \frac{V}{R}$ – – –>(1)

But $R = \frac{\rho l}{A}$ ∴ (1)

$$I = \frac{V}{\rho\frac{l}{A}} = \frac{VA}{\rho l}$$

$$\frac{I}{A} = \frac{1}{\rho}\left(\frac{V}{l}\right) - - -> (2)$$

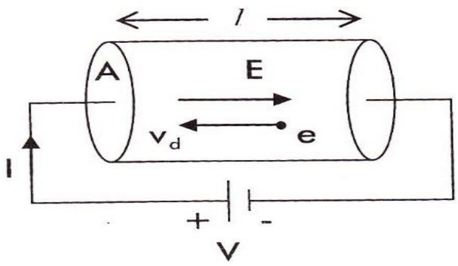
But $\frac{I}{A} = J,\quad \frac{V}{L} = E \; and \; \frac{1}{\rho} = \sigma$

$$\therefore (2) ==> J = \sigma E$$

Expression for conductivity of a material in terms of relaxation time

Or

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



We have J = σE

$==> \sigma = \frac{J}{E}$

But $J = \frac{I}{A}$, $\therefore \sigma = \frac{I}{AE}$

But I = $n\ A\ v_d e$

$$\therefore \sigma = \frac{n\ A\ v_d e}{A\ E}$$

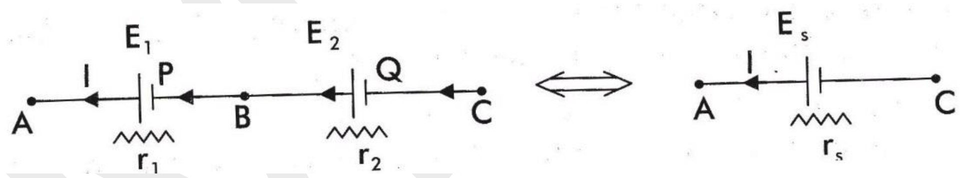
$$==> \sigma = \frac{n\ v_d e}{E}$$

But $\quad v_d = \frac{Ee\tau}{m}$

$$\therefore \sigma = \frac{n\ e}{E}\left(\frac{Ee\tau}{m}\right)$$

$$==> \sigma = \frac{n\ e^2\tau}{m}$$

Two cells of different emf's and different internal resistances are connected in series. Find the expressions for the equivalent emf and equivalent internal resistance of the combination.



Potential difference between the points A and C is given by

$V = V_1 + V_2$ - - - - > (4)

$V = (E_1 - I\ r_1) + (E_2 - I\ r_2)$

$V = E_1 - I\ r_1 + E_2 - I\ r_2$

$V = E_1 + E_2 - I\ r_1 - I\ r_2$

$V = (E_1 + E_2) - I\ (r_1 + r_2)$ ------ (5)

FROM (figure – 2)

We get, $V = E_s - I\ r_s$ ----- (6)

On comparing (5) and (6), we get,

$E_S = E_1 + E_2$ and $r_s = r_1 + r_2$

Two cells of different emf's and different internal resistances are connected in parallel. Find the expression for the equivalent emf and equivalent internal resistance of the combination.

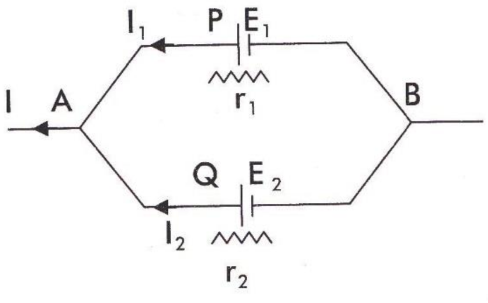


Figure-1

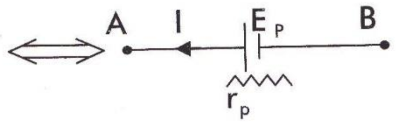


Figure-2

The total current, $I = I_1 + I_2$ ---- (1)

$E = V + I r$

$=> V = E - I r$

$$I = \frac{E - V}{r}$$

BUT $I_1 = \frac{E_1 - V}{r_1}$ ……..(2)

$I_2 = \frac{E_2 - V}{r_2}$ ……… (3)

(1)=> $I = \frac{E_1 - V}{r_1} + \frac{E_2 - V}{r_2}$

$I = \frac{E_1 r_2 - V r_2 + E_2 r_1 - V r_1}{r_1 r_2}$

$$I(r_1 r_2) = E_1 r_2 + E_2 r_1 - V(r_1 + r_2)$$

$$V(r_1 + r_2) = E_1 r_2 + E_2 r_1 - I(r_1 r_2)$$

$$V = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}\right) - I\left(\frac{r_1 r_2}{r_1 + r_2}\right) \text{ ----- (5)}$$

FROM figure -2

We get, $V = E_p - I r_p ----(6)$

On comparing (5) and (6), we get,

$E_p = \frac{E_1 r_2 + E_2 r_1}{(r_1 + r_2)}$ ----(7)

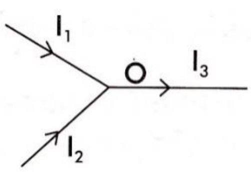
$r_p = \frac{r_1 r_2}{r_1 + r_2}$ -----(8)

Kirchhoff's junction rule.(KCL)

Statement: The sum of the currents entering the junction is equal to the sum of the currents leaving the junction.

Explanation:

$I_1 + I_2 = I_3$



Kirchhoff's junction rule is the consequence of Law of conservation of charge

Kirchhoff's loop rule or mesh rule (KVL)

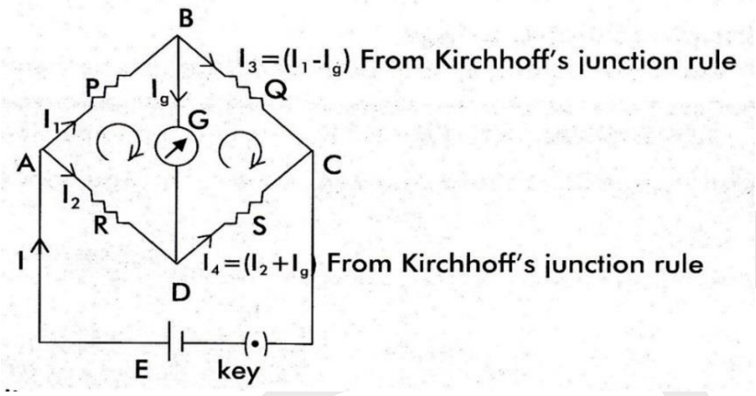
Statement

The algebraic sum of the emf's and the changes in potential around any closed loop in an electrical network is zero.

i.e, $\sum E + \sum IR = 0$

Kirchoff's loop rule is the consequence of law of conservation of energy.

Condition for balance of Wheatstone bridge using Kirchhoff's rules.



On applying KVL rule to the loop ABDA, we get

$$-I_1P - I_gG + I_2R = 0 \quad \longrightarrow (1)$$

On applying KVL rule to the loop BCDB, we get

$$-(I_1 - I_g)Q + (I_2 + I_g)S + I_gG = 0 \longrightarrow (2)$$

But for balance of network, $I_g = 0$

$$\therefore I_1P = I_2R \text{------}(3)$$

$$I_1Q = I_2S \text{-----}(4)$$

$$\frac{(3)}{(4)} \Rightarrow \frac{I_1P}{I_1Q} = \frac{I_2R}{I_2S}$$

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

ELECTROSTATIC POTENTIAL AND CAPACITANCE

Expression for capacitance of a parallel plate capacitor without any dielectric medium between the plates. (or parallel plate air capacitor)

$$C = \frac{\varepsilon_0 A}{d}$$

Factors on which the capacitance of parallel plate capacitor depends

1) Directly proportional to the area of the plates.
2) Inversly proportional to the distance between the plates.
3) Directly proportional to the dielectric constant of the medium between the plates.

ELECTROMAGNETIC INDUCTION

Faraday's laws of electromagnetic induction

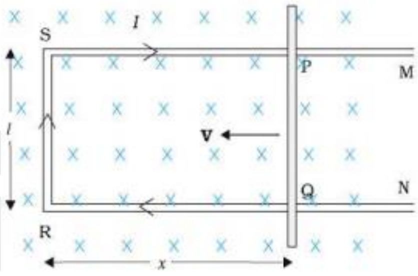
The magnitude of induced emf in a circuit is directly proportional to the rate of change of magnetic flux linked with the circuit.

i.e. $e = -\frac{d\phi}{dt}$

Derive an expression for motional e.m.f induced in a conductor moving perpendicular to the uniform magnetic field.

Magnetic flux enclosed by the loop PQRS is $\phi_B = BA$

$= BLx$



∴ Induced emf

$$e = -\frac{d\phi}{dt}$$

$$e = -\frac{d(B\,L\,x)}{dt}$$

$$\therefore \frac{dX}{dt} = -V$$

e = BLV

Lenz's law

It is the consequence of law of conservation of energy and it gives the polarity of the induced emf.