PRE-MEDICAL : ENTHUSIAST COURSE (ALL PHASE)

PHYSICS SOLUTION

Section – A

1. (C) Find $C_{eq.}$ & Q, then apply V = Q/C **[1]**

2. (C) $\frac{B}{8} = \frac{\mu_0 NIR^2}{2(R^2+x^2)^{\frac{3}{2}}}$ **[1]**

3. (D) $V = \frac{kp\cos\theta}{r^2}$ **[1]**

4. (B) $\mu = \frac{V_d}{E}$ **[1]**

5. (B) Given $\frac{\mu_2}{\mu_1} = 1$, from $\frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \Rightarrow \boxed{f = \infty}$ **[1]**

6. (B)Use, $\sin i_c = \frac{\mu_2}{\mu_1}$ & $\mu = \frac{c}{v}$ **[1]**

7. (B) $A = \sqrt{A_1^2 + A_2^2}$ **[1]**

8. (A) $\frac{1}{2}\frac{B^2}{\mu_0}$ as both are energy density. **[1]**

9. (C) **[1]**

10. (D) **[1]**

11. $R = \rho\frac{l}{A} = \rho\frac{l^2}{Al} = \frac{\rho}{V}l^2$, V is volume which does not change in stretching.

$\therefore \frac{R_2}{R_1} = \frac{l_2^2}{l_1^2} = \frac{(2l_1)^2}{l_1^2} = 4 \Rightarrow \therefore R_2 = 4R_1 = 4 \times 10 = 40\ \Omega$ **[1]**

OR

$\frac{1}{n} = T = 2\pi\sqrt{\frac{I}{MB}}$ **[1]**

12. (0.2A) Find $\frac{d\phi}{dt}$, i.e., E then I by using R. **[1]**

13. As we know that,

$\lambda = \frac{12.27}{\sqrt{V}}Å = \frac{12.27}{\sqrt{100}}Å \Rightarrow \boxed{\lambda = 1.227Å}$ **[1]**

14. Increases with decrease in temperature. **[1]**

15. Given that : $E = 3.3 \times 10^{-20}$ J, $h = 6.6 \times 10^{-34}$ Js, ν = ?

As we know that, $\boxed{E = h\nu}$

$\therefore \nu = \frac{E}{h} = \frac{3.3\times10^{-20}}{6.6\times10^{-34}} \Rightarrow \nu = 5 \times 10^{13}$ Hz **[1]**

16. Foucault discovered that whenever mag. flux is changed for a solid state mass (e.g. metallic block, sheet etc) then currents in the form of eddies get generated in its whole volume following Lenz's law producing heating effect in it.

Uses : (a) In induction furnace. (b) In electromagnetic damping. **[1]**

17. According to Rayleigh's criteria, scattering $\alpha \frac{1}{\lambda^4}$ **[1]**

Since colour 'RED' possess the longest wave length, its scattering is least, so it is used in danger signals.

18. The total decay rate of a radioactive sample is called activity of the sample. The S.I. unit of activity is 'becquerel'. **[1]**

19. **Given :** $R_0 = 1.2 \times 10^{-15}$m, A = 8

As we know that

$\boxed{R = R_0 A^{\frac{1}{3}}}$,

$\therefore R = 1.2 \times 10^{-15} \times (8)^{1/3}$

$= 1.2 \times 10^{-15} \times (2)^{3 \times \frac{1}{3}}$

$\boxed{R = 2.4 \times 10^{-15}\ \text{m}}$ **[1]**

20. Two properties of nuclear force are -

(1) It is mainly an attractive force.

(2) It is the strongest fundamental force in nature. **[1]**

OR

Two applications of ultra-violet rays are —

(i) They are used to preserve food stuff and make drinking water free from bacteria, as these rays can kill bacteria, germs etc.

(ii) They are used for sterilizing the surgical instruments. **[1]**

Section – B

21. Given that, $R_S = 18\Omega$, $R_p = 4\Omega$

$R_1 = ?$, $R_2 = ?$

As we know that,

$R_S = R_1 + R_2$

$18\Omega = R_1 + R_2$ ...(1)

$R_P = \frac{R_1 R_2}{R_1 + R_2}$

As we have, $4 = \frac{R_1 R_2}{18}$ $\therefore R_1 R_2 = 4 \times 18 = 72\Omega$

Also, $(R_1 - R_2)^2 = (R_1 + R_2)^2 - 4R_1R_2$

$= (18)^2 - 4 \times 72$

$= 324 - 288 = 36$

$\therefore R_1 - R_2 = \sqrt{36} = 6\Omega$ ....(2)

From eqn. (l) & (2), we get

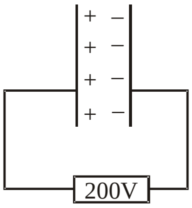
$R_1 + R_2 = 18$

$R_1 - R_2 = 6$

$2R_1 = 24$

$R_1 = \frac{24}{2} = 12\Omega$, $\therefore R_2 = 18 - 12$, $R_2 = 6\Omega$ **[2]**

22.



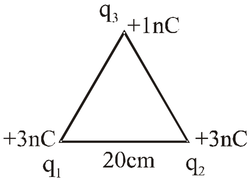
Given $6cm^{2} = A$, $d = 2 \times 10^{-3}$m

From $C = \left(\frac{\varepsilon_0 A}{d}\right) = \frac{8.85\times10^{-12}\times6\times10^{-4}}{2\times10^{-3}}$

$= 8.85 \times 10^{-12} \times 3 \times 10^{-1} = 2.7 \times 10^{-12}$ F

Now, $Q = CV = 2.7 \times 10^{-12} \times 200 \Rightarrow Q = 5.4 \times 10^{-10}$ C **[2]**

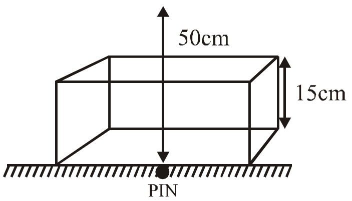
23.

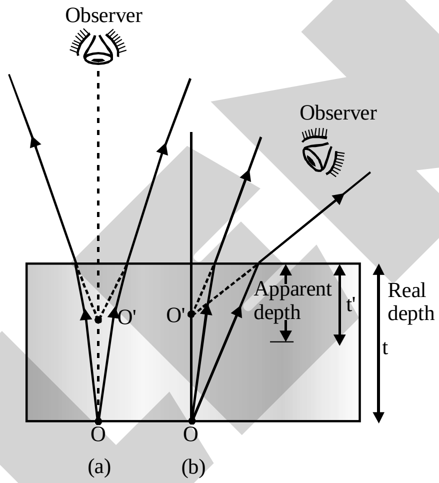


Total work done, $W = U = \frac{kq_1q_3}{r} + \frac{kq_2q_3}{r}$

$U = \frac{kq_3}{r}(q_1+q_2) = \frac{9\times10^9\times10^{-9}}{20\times10^{-2}}(6\times10^{-9}) = \frac{900}{20}\times6\times10^{-9} = 2.7 \times 10^{-7}$ J **[2]**

24.





Here, t = Real depth = 15 cm

t' = Apparent depth

$\mu = 1.5$

So, $t' = \frac{t}{\mu} = \frac{15\text{cm}}{1.5} = 10\text{cm}$

$\therefore$ Image is viewed at $t - t'$

$= (15 - 10)$cm $= 5$ cm

[2]

25. **Work function—** The minimum amount of energy required to eject an electron from the surface of a metal is called its work function.

Threshold frequency—Photo-electrons can not come out from the surface of a metal if the frequency of the incident light is less than a particular minimum value. This minimum frequency is called threshold frequency. **[2]**

26.

$$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta} A_2 \xrightarrow{\gamma} A_3$$

$$^{238}_{92}U \xrightarrow{\alpha} {}^{234}_{90}U + {}^{4}_{2}He \xrightarrow{\beta} {}^{234}_{91}U + {}_{-1}e^{\circ} + \nu$$

$$\downarrow \gamma$$

$$^{234}_{91}U$$

So, atomic no. is 91 & mass no. is 234 for A_3. **[2]**

OR

According to quantum theory, the energy of a photon is given by, $E = h\nu$ ...(i)

Einstein's relation between Energy (E) & momentum (p) is given as-

$E = \sqrt{p^2c^2 + m_0^2c^4}$

& photon is mass less ($m_0 = 0$)

$\therefore$ E = pc

or $h\nu = pc$

$\therefore \quad p = \dfrac{h}{\left(\dfrac{c}{\nu}\right)} = \dfrac{h}{\lambda}$ ...(ii)

or $\lambda = \dfrac{h}{p}$

So, according to De-Broglie, if a wave behaves like a particle, then a particle (matter) must behave like a wave.

$\lambda = \dfrac{h}{p}$ ..(iii)

27. Following are the advantages of LED—
(1) LEDs are manufactured easily.
(2) LEDs have low cost.
(3) LEDs work at low voltage as compared to the incandescent bulb.
(4) No warm up time is required.
(5) They can emit monochromatic light as well as bright light. **[2]**

OR

Intrinsic Semiconductor	**Extrinsic Semiconductor**
1. Pure semiconductor	**1.** Doped semiconductor
2. $n_e = n_h$	**2.** $n_e \neq n_h$
3. Electrical conductivity is low	**3.** Electrical conductivity is high.
4. Resistivity is higher.	**4.** Resistivity is lower.

Section – C

28. **Wheatstone bridge—** It is an arrangement of four resistances connected with galvanometer in the form of a bridge. It is used to find unknown resistance accurately.

Principle — No electric current passed through galvanometer for balanced bridge. ($I_g = 0$)

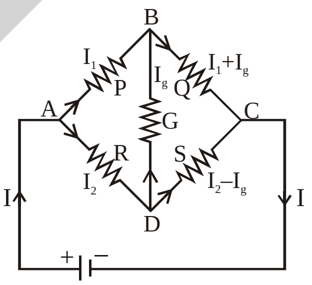
$\dfrac{P}{Q} = \dfrac{R}{S}$ ....(i)

or PS =QR ....(ii)

Working—There are three resistances P, Q and R but S is unknown. With the help of known resistance unknown resistance can be determined, R is known resistance.

If no electric current is passing through a galvanometer, the bridge is said to be balanced.

Construction—



In loop ABDA

$I_1P - I_gG - I_2R = 0$ ...(3)

For balanced bridge, $I_g = 0$

$\therefore \quad I_1P - I_2R = 0$

$I_1P = I_2R$

$\dfrac{I_1}{I_2} = \dfrac{R}{P}$ ...(4)

In loop BCDB,

$(I_1 + I_g)Q - S(I_2 - I_g) + I_gG = 0$ ...(5)

For balanced bridge, $I_g = 0$

$\therefore$ $I_1Q - I_2S = 0$

$I_1Q = I_2S$

$$\frac{I_1}{I_2} = \frac{S}{Q} \quad ...(6)$$

Equating eq^n (4) & (6)

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

or $$\frac{R}{S} = \frac{P}{Q} \quad ...(7)$$

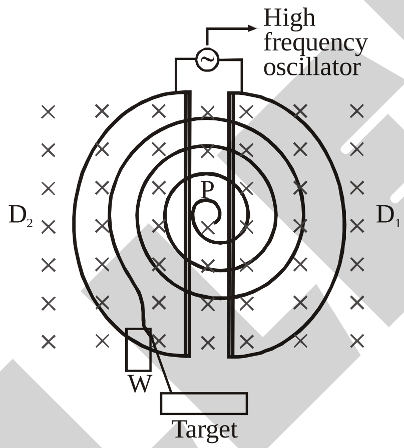
Equation (7) is the condition for a balanced wheatstone bridge. **[3]**

29. **Cyclotron—**Cyclotron is a device which is used to accelerate charged particles such as proton, α-particle etc. to acquire sufficient amount of energy to carry out different nuclear disintegration reactions.

Principle—

It is the practical application of cross-fields, where 'T' of an accelerating particle is independent of its radius & velocity.

Construction—



Let us consider two metallic chambers D_1 and D_2. D_1 is called left D and D_2 is called right D. Both the dees are connected through high frequency oscillator called HFO.

The main function of HFO is to control the acceleration of positive charge particle by changing the polarity in alternative manner. In hollow space, magnetic material is filled which produces the magnetic field.

Theory—

Necessary centripetal force is provided by lorentz magnetic force.

$$F_C = F_B \quad ...(1)$$

$$\frac{mv^2}{r} = qvB\sin\theta \,(\theta = 90°) \quad ...(2)$$

$$\frac{mv^2}{r} = qvB \Rightarrow \boxed{v = \frac{qBr}{m}} \quad ...(3)$$

$$\textbf{Time period} = \frac{\text{Distance}}{\text{Speed}} = \frac{2\pi r}{v} = \frac{2\pi r}{qBr/m} \quad ....(4)$$

$$\Rightarrow \boxed{T = \frac{2\pi m}{qB}} \quad ...(5)$$

Eqn (5) is the general expression for time period of cyclotron.

Cyclotron frequency (ν) —

The reciprocal of time period is called cyclotron's frequency (ν). It is represented by (ν).

$$\nu = \frac{1}{T} \quad ...(6)$$

Using eq(5)

$$\boxed{\nu = \frac{qB}{2\pi m}} \quad ...(7)$$

Cyclotron's signal frequency —

It can be defined as,

$$\omega = \frac{2\pi}{T} \quad ....(8)$$

Using equation (5)

$$\omega = 2\pi \times \frac{qB}{2\pi m}$$

$$\boxed{\omega = \frac{qB}{m}} \quad ...(9)$$

Energy acquired by charge particle —

$$E = K.E = \frac{1}{2}mv^2 \quad ...(10)$$

Using equation (3)

$$E = \frac{1}{2}m\left(\frac{qBr}{m}\right)^2 \Rightarrow \boxed{E = \frac{q^2B^2r^2}{2m}} \quad ...(11)$$

For maximum energy of charged particle radius must be max.

$$\boxed{E_{max} = \frac{1}{2}\frac{q^2B^2r^2{}_{max}}{m}} \quad ...(12)$$

Hence, energy of particle is maximum at pheriphery. **[3]**

30. **Power of A.C.—**The instantaneous power of AC circuit can be defined as the product of instantaneous emf and instantaneous current

Let us consider.

$$\varepsilon = \varepsilon_0 \sin\omega t \quad ....(1)$$

$$I = I_0 \sin(\omega t + (\phi) \quad ....(2)$$

So, corresponding power,

$P = \varepsilon I = \varepsilon_o I_o \sin\omega t \sin(\omega t + \phi)$

$$P = \frac{\varepsilon_o I_o}{2}\left[\cos(-\phi) - \cos(2\omega t + \phi)\right]$$

$$P = \frac{\varepsilon_o I_o}{2}\cos\phi - \frac{\varepsilon_o I_o}{2}\cos(2\omega t + \phi)$$

Now take average on both the sides,

$$P_{av} = \frac{\varepsilon_o I_o}{2}\cos\phi - 0 \qquad \boxed{\because \text{avg. value of } \cos(2\omega t + \phi) = o}$$

$$P_{av} = \frac{\varepsilon_o}{\sqrt{2}}\frac{I_o}{\sqrt{2}}\cos\phi$$

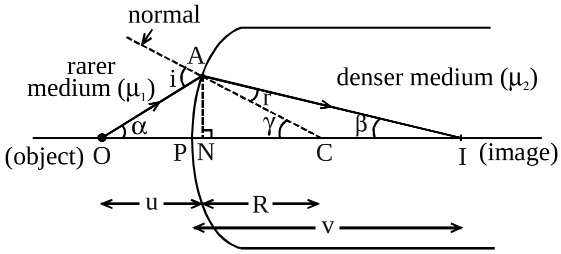
or $P_{av} = \varepsilon_{rms} I_{rms} \cos\phi$ **[3]**

31. **Refraction through spherical surface**

Assumtions :

1. The spherical surface must be very thin.
2. The object must be a point object and should lie on principle axis.
3. The angle made by object, image and normal must be very-very small.

Convex surface—Real image



In ΔAOC

$i = \alpha + \gamma$ - (1)

In ΔAIC

$\gamma = r + \beta \Rightarrow r = \gamma - \beta$ - (2)

If α, β and γ are very small, then

$\alpha \approx \tan\alpha$ $\beta \approx \tan\beta$ and $\gamma \approx \tan\gamma$

from eq. (1) and(2)

$i = \tan\alpha + \tan\gamma$ - (3)

$r = \tan\gamma - \tan\beta$ - (4)

From snell's law

$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} \Rightarrow \mu_1 \sin i = \mu_2 \sin r$ $\left\{\begin{array}{l}\text{angle } i \text{ and } r \text{ are very small, then}\\ \sin i \approx i \text{ and } \sin r \approx r\end{array}\right.$

$\mu_1 i = \mu_2 r$

From eq. (3) and (4)

$\mu_1(\tan\alpha + \tan\gamma) = \mu_2(\tan\gamma - \tan\beta)$

$\mu_1\left(\frac{AN}{OP} + \frac{AN}{PC}\right) = \mu_2\left(\frac{AN}{PC} - \frac{AN}{PI}\right)$

$\mu_1\left(\frac{1}{OP} + \frac{1}{PC}\right) = \mu_2\left(\frac{1}{PC} - \frac{1}{PI}\right)$

$\left\{\begin{array}{l}\text{from figure,}\\ \tan\alpha = \frac{AN}{ON} \approx \frac{AN}{OP}\\ \tan\beta = \frac{AN}{NI} \approx \frac{AN}{PI}\\ \tan\gamma = \frac{AN}{NC} \approx \frac{AN}{PC}\end{array}\right.$

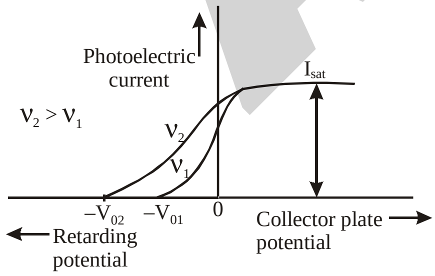
Applying sign convention -

OP = –u, PC = +R and PI = v

$\mu_1\left(-\frac{1}{u} + \frac{1}{R}\right) = \mu_2\left(\frac{1}{R} - \frac{1}{v}\right) \Rightarrow \boxed{\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}}$

[3]

32. (a)



(b) Albert Einstein explained the various laws of photoelectric emission on the basis of Plank's quantum theory. According to Plank's quantum theory, light radiations consist of tiny packets of energy called photon.

One quantum of light radiation is called a photon which travels with the speed of light.

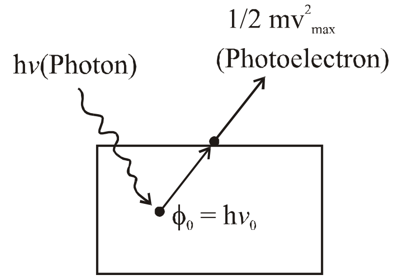
The energy of a photon is given by

$E = h\nu$

where, h is Planck's constant and ν is the frequency of light radiation.

When a photon of energy $h\nu$ falls on a metal surface, the energy divides in following two ways:

ALLEN



Metal
Emission of photoelectron by a metal when a photon is absorbed by it

(i) A part of energy is used to overcome the surface barrier to come out as photoelectron from metal surface. This part of energy is called work function. It is expressed as $\phi_0 = h\nu_0$.

(ii) The remaining part of the energy is used in giving a velocity v to the emitted photoelectron. This is equal to the maximum kinetic energy of the photoelectrons $\left(\frac{1}{2}mv^2_{max}\right)$, where m is the mass of the photoelectrons. According to the law of conservation of energy,

$$h\nu = \phi_0 + \frac{1}{2}mv^2_{max} = h\nu_0 + \frac{1}{2}mv^2_{max}$$

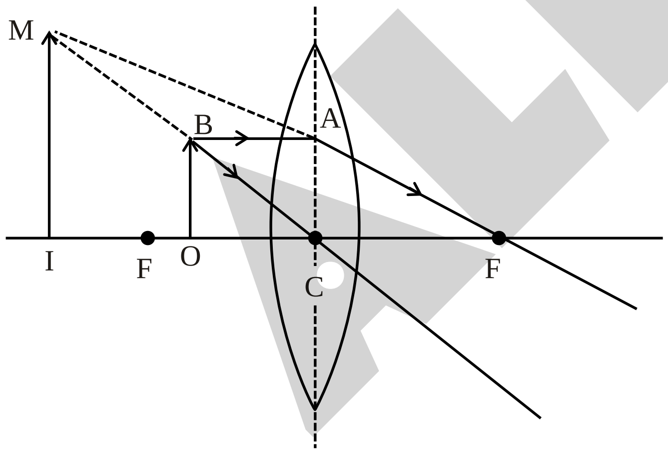
$\therefore$ $\boxed{\frac{1}{2}mv^2_{max} = K_{max} = h\nu - \phi_0}$ This equation is called Einstein's photoelectric equation.

The features of Photo electric emission which cannot be explained by wave theory

(i) Below a certain frequency (Threshold) there is no photo emission.

(ii) Spontaneous emission of photo-electrons. **[3]**

33.



As per the above figure

Δ ICM $\simeq$ OCB (similar)

$\therefore \frac{OB}{IM} = \frac{OC}{IC}$ .....(i)

Also, $\Delta CFA \simeq \Delta IFM$(similar)

$\therefore \frac{CA}{IM} = \frac{CF}{IF} = \frac{CF}{IC + CF}$ .....(ii)

$\because$ CA = OP

$\therefore$ Equation(2) can be written as :

$$\frac{OB}{IM} = \frac{CF}{IC + CF} \quad .....(iii)$$

From (i) & (iii)

$$\frac{OC}{IC} = \frac{CF}{IC + CF} \Rightarrow \frac{-u}{-v} = \frac{f}{-v + f} \Rightarrow \frac{u}{v} = \frac{f}{f - v}$$

uf – uv = vf

Divide by uvf

$$\frac{1}{v} - \frac{1}{f} = \frac{1}{u} \Rightarrow \frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$ **[3]**

OR

As $\Delta ABC \simeq A'B'C$

So $\frac{AB}{A'B'} = \frac{CB}{CB'}$

Again $\Delta ABP \simeq \Delta A'B'P$

$$\frac{AB}{A'B'} = \frac{PB}{PB'}$$

Proceeding as above, $\frac{CB}{CB'} = \frac{PB}{PB'}$

Measuring all distance from P, we get CB = PC – PB

CB' = PC + PB'

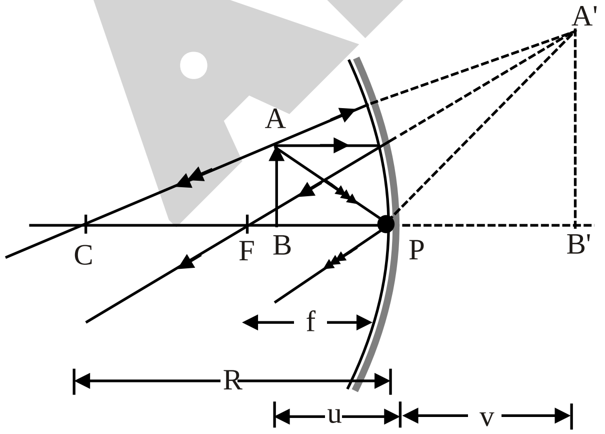
$$\therefore \frac{PC - PB}{PC + PB'} = \frac{PB}{PB'}$$

Using new cartesian sign conventions,

PB = – u, PB' = v, PC = – R

$$\frac{-R + u}{-R + v} = \frac{-u}{v} \Rightarrow uR - uv = -vR + uv$$

uR + vR = 2 uv



Dividing both sides by u υ R, we get

$$\frac{1}{v} + \frac{1}{u} = \frac{2}{R} \Rightarrow \boxed{\frac{1}{f} = \frac{1}{v} + \frac{1}{u}}$$

Which is the required mirror formula.

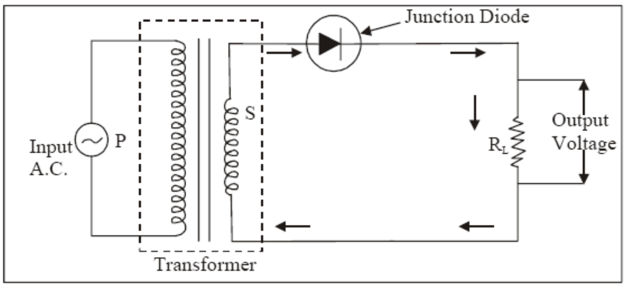
34. Application of a p-n junction diode as a half wave rectifier:

A device which converts alternating current (a.c.) into direct current (d.c.) is known as rectifier and the process is known as rectification.

Principle— A junction diode conducts only under forward biased and it does not conduct under reverse biased. This fact makes the junction diode to work as a rectifier.

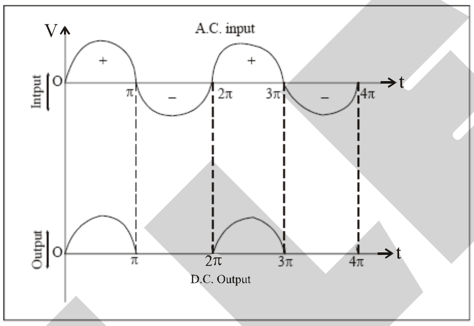
Junction diode as a half wave rectifier :

The rectifier which converts only one half of a.c. cycle into d.c. is called half wave rectifier.



Working—When positive half of an a.c. cycle comes, the upper end of the secondary coil becomes positive and lower end becomes negative i.e., the junction diode is forward biased and conducts by flowing a current so, an output voltage is obtained across the load resistance R_L.

Now, when negative half of a.c. cycle comes, upper end of the secondary coil becomes negative and lower end becomes positive. So the junction diode is reverse biased and does not conduct. Therefore, no output is obtained across the load resistance R_L.



Since only half portion of an a.c. (signal) is obtained as an output in the form of d.c., the junction diode is called half wave rectifier. **[3]**

Section – D

35. **(a)** If dielectric slab is not placed in between the plates its capacitance-

$$\boxed{C_0 = \frac{\varepsilon_0 A}{d}} \qquad \text{....(i)}$$

Here, A = area of the plate

d = the distance between the two plates, ε_0 = permittivity of free space

Initial electric field is E_0.

When, dielectric slab is placed between the two plates having dielectric constant "K"

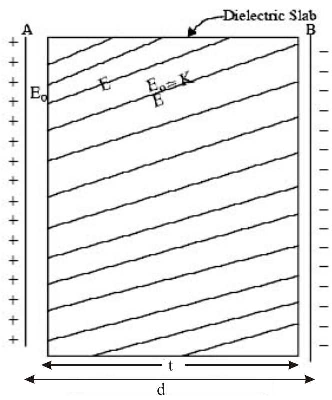
$$E_m = \frac{\sigma}{\varepsilon} = \frac{Q}{A\varepsilon}$$

$$\& \; V_m = E_m d \Rightarrow \therefore V_m = \frac{Q}{A\varepsilon} d$$

$$\Rightarrow C_m = \frac{Q}{V_m} \Rightarrow C_m = \frac{\varepsilon A}{d}$$

$$C_m = \frac{\varepsilon_0 K A}{d}$$

$$C_m = KC_0$$



Conclusion — If a dielectric slab is placed in between two plates of ppc, its capacitance increases 'K' times. **[3]**

(b) Capacitor is either fully charged or fully discharged.

There is no any condition in between the two.

Fully charged means q = Qand fully discharged means q = 0

Charging of a capacitor is a continuous process. Therefore, small work done in terms of electrostatic potential,

$$dw = V.dq \qquad ....(1)$$

By definition of capacitance

$$q = CV \qquad ....(2)$$

$$V = \frac{q}{C} \qquad ...(3)$$

Using in equation (1)

$$dw = \frac{q}{C}.dq \qquad ....(4)$$

Therefore, total work done in complete charging of a capacitor,

$$\int_0^w dw = \int_0^Q \frac{q\,dq}{C} \Rightarrow W = \frac{1}{C}\int_0^Q q.dq$$

$$= \frac{1}{C}\left[\frac{q^2}{2}\right]_0^Q \Rightarrow W = \frac{1}{2C}\left[q^2\right]_0^Q$$

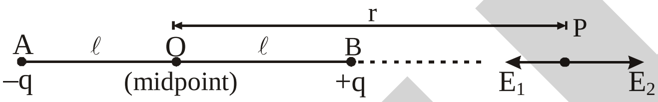
$$\therefore \qquad W = \frac{Q^2}{2C}$$

This work done is stored in the form of electrostatic potential energy of a capacitor.

$$\therefore \qquad U = \frac{1}{2}.\frac{Q^2}{C}$$ **[2]**

OR

(a) Electric field on the axial line of an electric dipole.



$\overrightarrow{E_1}$ is the electric field due to (–ve) charge which is acting inward while electric field $\overrightarrow{E_2}$ due to (+ve) charge is acting outward.

$$AP = (r + \ell) \qquad ...(1)$$

$$BP = (r - \ell) \qquad ...(2)$$

$$E_1 = \frac{1}{4\pi\epsilon_0} \times \frac{q}{(AP)^2} \qquad ...(3)$$

Using equation (1)

$$E_1 = \frac{1}{4\pi\epsilon_0} \times \frac{q}{(r+\ell)^2} \qquad ...(4)$$

then, $$E_2 = \frac{1}{4\pi\epsilon_0} \times \frac{q}{(BP)^2} \qquad ...(5)$$

Using equation (2)

$$E_2 = \frac{1}{4\pi\epsilon_0} \times \frac{q}{(r-\ell)^2} \qquad ...(6)$$

Since $E_2 > E_1$

∴ Total electric field at point 'P' -

$$E = E_2 - E_1 \qquad ...(7)$$

$$= \frac{1}{4\pi\epsilon_0} \times \frac{q}{(r-\ell)^2} - \frac{1}{4\pi\epsilon_0} \times \frac{q}{(r+\ell)^2}$$

$$=\frac{q}{4\pi\epsilon_0}\left(\frac{(r+\ell)^2-(r-\ell)^2}{(r+\ell)^2(r-\ell)^2}\right)$$

$$=\frac{q}{4\pi\epsilon_0}\left[\frac{r^2+\ell^2+2r\ell-r^2-\ell^2+2r\ell}{(r^2-\ell^2)^2}\right]$$

$$=\frac{1}{4\pi\epsilon_0}\frac{2.(2\ell q)r}{(r^2-\ell^2)^2} \quad ...(8)$$

But, $2\ell q = p$ ...(9)

$$=\frac{1}{4\pi\epsilon_0}\frac{2pr}{(r^2-\ell^2)^2} \quad ...(10)$$

Eqn. (10) is the general eqn. for electric field on the axial line of electric dipole.

Spl. Case— If $r >> \ell$ then, ...(11)

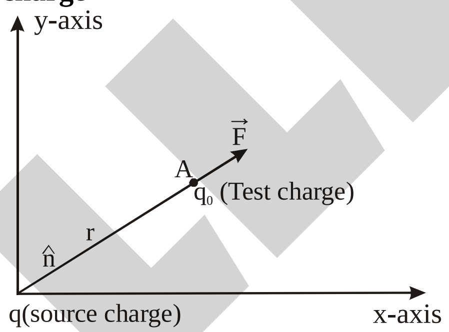
In this case "ℓ" can be neglected.

or $\ell = 0$ ...(12)

$$E_{axial}=\frac{1}{4\pi\epsilon_0}\times\frac{2pr}{r^4}$$

$$\boxed{E_{axial}=\frac{1}{4\pi\epsilon_0}\times\frac{2p}{r^3}}$$ **[3]**

(b) Electrical field due to a Point charge—



Electric field can be defined as force acting per unit test charge. Force between source charge & test charge -

$$F=\frac{1}{4\pi\epsilon_0}\times\frac{qq_0}{r^2} \quad ...(1)$$

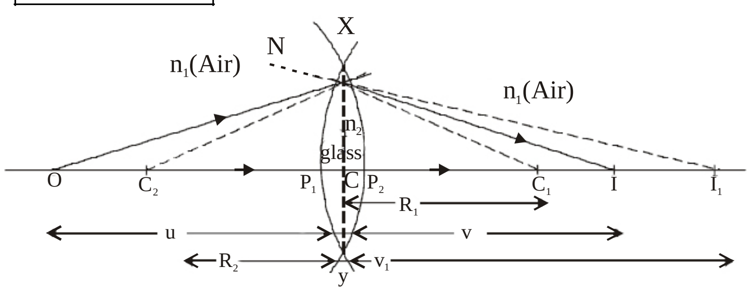
From, $E=\frac{F}{q_0}$ ...(2)

Using equation (1)

$$E=\frac{1}{4\pi\epsilon_0}\times\frac{qq_0}{q_0r^2}$$

$$\therefore \quad \boxed{E=\frac{1}{4\pi\epsilon_0}\times\frac{q}{r^2}}$$ **[2]**

36. (a)



Considering the refraction of on object an surface XP_1Y_1, the image is formed at I_1 (ie., at distance v_1)

$CI_1 = P_1I_1 = v_1$ (as the lens is thin)

$CC_1 = P_1C_1 = R_1$

$CO = P_1O = u$

It follows from the refraction due to convex spherical surface XP_1Y_1

$$\frac{n_2}{v_1} + \frac{n_1}{-u} = \frac{n_2 - n_1}{R_1} \quad ...(1)$$

Refracted ray from A suffers a second refraction on the surface XP_2Y_2 & merges along BI.

So, I is the final real image of O.

Here the object distance is,

$\therefore\ u = CI_1 \simeq P_2I_1 = v_1$ (Note : P_1P_2 is very small)

Let $CI \simeq P_2I = v$ (final image distance)

Similarly, equation for 2nd refraction, (from denser to rarer)

$$\frac{-n_2}{v_1} + \frac{n_1}{v} = \frac{n_1 - n_2}{R_2} \Rightarrow \frac{-n_2}{v_1} + \frac{n_1}{v} = \frac{-(n_2 - n_1)}{R_2} \quad ...(2)$$

Adding (1) & (2),

$$\frac{-n_1}{u} + \frac{n_1}{v} = (n_2 - n_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$n_1\left[\frac{1}{v} - \frac{1}{u}\right] = (n_2 - n_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{v} - \frac{1}{u} = \frac{(n_2 - n_1)}{n_1}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

But, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ & $\frac{n_2}{n_1} = n_{21}$

$\therefore$ $$\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$ **[3]**

(b) Given that,

$\angle A = 60°$ $\delta m = 30°$, $n = ?$

We have,

$$n = \frac{\sin\left(\frac{A + \delta m}{2}\right)}{\sin\left(\frac{A}{2}\right)} = \frac{\sin 45°}{\sin 30°}$$

$$n = \frac{\frac{1}{\sqrt{2}}}{\frac{1}{2}} = \sqrt{2} = 1.41$$ **[2]**

OR

(a) Two differences between interference and diffraction are as follows-

Interference	**Diffraction**
1. It is due to the superposition of secondary wavelets coming from two different coherent sources.	1. It is due to the superposition of secondary wavelets wavelets originating from different points of the same wavefront.
2. In interference the dark fringes are almost perfectly dark.	2. In diffraction pattern, the dark fringes are not perfectly dark.

[2]

(b) **Interference of Light—**Interference is the superposition of two light waves due to which non-uniform distribution of energy takes place in the medium. The points at which intensity of light is maximum called constructive interference while the points where intensity is minimum called destructive interference. Constructive interference is called bright fringe and destructive interference is called dark fringe.

If interference pattern is permanent on the screen then it is called sustained interference pattern. Following are the important conditions for sustained interference pattern—

1. The two light sources must emit light waves continuously.
2. The two light sources must be very-very close to each other.
3. The light waves should be of nearly same wave length.
4. The intensity of light from the two sources must be nearly same.
5. The two light sources must have zero or constant phase difference.
6. The light sources must be narrow.

CONDITIONS FOR CONSTRUCTIVE AND DESTRUCTIVE INTERFERENCE

Let us consider two light waves represented by the equations—

$$y_1 = A_1 \sin wt \quad ...(1)$$

$$y_2 = A_2 \sin (wt + \delta) \quad ...(2)$$

By definition of interference,

$$y = y_1 + y_2$$

$$= A_1 \sin wt + A_2 \sin (wt + \delta) \quad ....(3)$$

$$= A_1 \sin wt + A_2 [\sin wt. \cos \delta + \cos wt. \sin \delta)$$

$$= A_1 \sin wt + A_2 \sin wt. \cos \delta + A_2 \cos wt. \sin \delta$$

$$= [A_1 + A_2 \cos \delta] \sin wt + (A_2 \sin \delta) \cos wt ...(4)$$

Let us consider,

$$A_1 + A_2 \cos \delta = A \cos \theta \quad ...(5)$$

$$A_2 \sin \delta = A \sin \theta \quad ...(6)$$

Using in equation (4)

$$y = A \cos \theta \sin wt + A \sin \theta \cos wt$$

$$y = A [\sin wt \cos \theta + \cos wt . \sin \theta]$$

$$\boxed{y = A \sin(wt + \theta)} \quad ...(7)$$

eq^n (7) is the general eq^n for superimposed wave which is periodic.

Taking square of eq^n (5) and (6) and then add them,

$$A_1^2 + A_2^2 \cos^2\delta + 2A_1A_2 \cos\delta + A_2^2 \sin^2\delta$$

$$= A^2 [\cos^2\theta + \sin^2\theta]$$

$$A_1^2 + 2A_1A_2 \cos \delta + A_2^2 [\cos^2\delta + \sin^2\delta] = A^2$$

$$A_1^2 + 2A_1A_2 \cos \delta + A_2^2 = A^2$$

$$A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2 \cos\delta} \quad ....(8)$$

Resultant intensity of light $I = KA^2$ ....(9)

$$= K (A_1^2 + A_2^2 + 2A_1A_2 \cos\delta)$$

$$\therefore \quad I = I_1 + I_2 + 2\sqrt{I_1 \cdot I_2} \cos\delta \quad ....(10)$$

—» **Conditions :-**

(i) For constructive interference or bright fringe :

Here intensity must be maximum so,

$$\text{For } I_{max}, \cos \delta = 1 \quad ...(11)$$

General value,

$$\delta = 2\pi n \quad ...(12)$$

By definition of periodic function.

Path difference = $\frac{\lambda}{2\pi}\times$ phase difference ...(13)

$$x=\frac{\lambda}{2\pi}\times\delta \quad ...(14)$$

$$x=\frac{\lambda}{2\pi}\times 2\pi n$$

$$\boxed{x=n\lambda} \quad ...(15)$$

eqn (15) is the required condition for constructive interference.

(ii) Conditions for destructive interference or dark fringe :
Here intensity must be minimum so,

For I_{min}, $\cos\delta = -1$ ...(16)

General value,

$$\delta = (2n+1)\pi \quad ...(17)$$

By def^n of periodic function,

Path difference = $\frac{\lambda}{2\pi}$ × phase difference ...(18)

$$x=\frac{\lambda}{2\pi}\times\delta \quad ...(19)$$

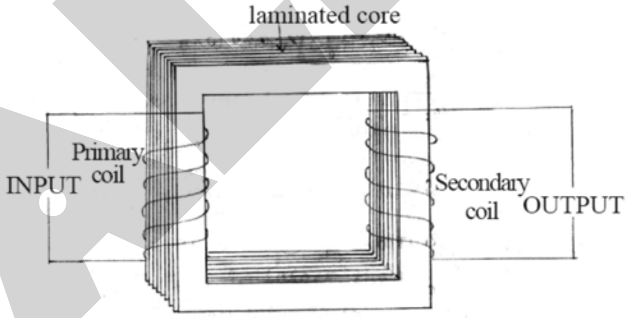
$$x=\frac{\lambda}{2\pi}\times(2n+1)\pi, \quad \boxed{x=\frac{\lambda}{2}\times(2n+1)}$$ **[3]**

This is the required condition for destructive interference.

37. **Transformer-**Transformer is a device which converts low alternating voltage (at high alternating current) into high alternating voltage (at low alternating current) and vice versa.
It does not work on D.C.

Principle - It works on the principle of "mutual induction". It states that if magnetic flux changes in primary coil, then emf is induced in secondary coil.

Construction



Transformer

Working

In a transformer there are two types of coil: Primary and Secondary.
Primary coil is attached with input whereas secondary coil is connected to output.
Through induction alternating voltage may be increased or decreased. It works on the "Coupling Method".

Theory :

According to the law of Faraday

$$\frac{d\phi}{dt}=-E \quad ....(i)$$

Let ϕ is the flux in each turn in the core at time t due to current in the primary when voltage V_p is applied to it..

Then the induced emf or voltage E_s, in the secondary with N_s turns is

$$E_s = -N_s \frac{d\phi}{dt} \quad \text{........(ii)}$$

The alternating flux ϕ also induces an emf, called back emf in the primary, which is,

$$E_p = -N_p \frac{d\phi}{dt} \quad \text{.......(iii)}$$

Eq (ii), (iii) can be written as —

$$V_s = -N_s \frac{d\phi}{dt} \quad \text{.......(iv)}$$

$$V_p = -N_p \frac{d\phi}{dt} \quad \text{.......(v)}$$

From (iv),(v)

$$\Rightarrow \boxed{\frac{V_s}{V_p} = \frac{N_s}{N_p}} \quad \text{.......(vi)}$$

$\frac{N_s}{N_p}$ is called Transformation Ratio

It is represented by K

$$K = \frac{N_s}{N_p}$$

If K > 1, then transformer is step-up Transformer.
If K < 1, then transformer is step-down Transformer.

Different Types of loses in transformer :

Flux loss—The linkage of primary to secondary coil is neither ideal nor perfect. Hence, whole magnetic flux produced in primary coil never gets linked up with the secondary coil. Hence some of the energy is lost in the form of flux, known as flux loss.

Copper loss—Due to resistance of the windings in primary and secondary coil, it opposes the current to pass through it so when current passes through the coil heat is produced. Due to heat, energy is lost which is called 'copper loss'.

Iron loss—Due to the variation in magnetic flux, eddy current is produced in the core of a transformer. When current passes small heat is produced due to Eddy current. Hence small amount of energy is lost due to heat, known as Iron loss.

Hysteresis loss—The alternating current passed through the coil which is magnetic in behaviour. During each cycle of AC, magnetisation and demagnetisation takes place. Due to this cycle, energy is lost which is called Hysteresis loss. **[5]**

OR

(a) **Mutual Induction—** Mutual induction of two coils can be defined as the generation of emf in the secondary coil due to the change in current in primary coil. Mathematically, it can be written as.

$$\phi_s \propto I_P \quad \text{....(1)}$$

$$\boxed{\phi_s = MI_P} \quad \text{...(2)}$$

M is a proportionality constant which is called mutual inductance.

$$\therefore \boxed{M = \frac{\phi_s}{I_P}} \quad \text{....(3)}$$

Hence, mutual inductance of two coils is the ratio of magnetic flux linked with the secondary coil to the current in primary coil.

If $I_P = 1A$ ...(4)

$$\boxed{M = \phi_s} \quad \text{....(5)}$$

Mutual inductance of two coils is numerically equal to the magnetic flux in secondary coil when the current in primary coil is 1 A.

According to Faraday's second law,

$$\varepsilon_s = \frac{-d\phi s}{dt} \qquad ......(6)$$

Using equation (2)

$$\varepsilon_s = \frac{-d}{dt}(MI_P)$$

$$M = \frac{\varepsilon_s}{\left(\frac{-dI_P}{dt}\right)}$$

Hence, mutual inductance of two coils is the ratio of an emf induced in the secondary coil to the rate of change of current in the primary coil.

If $$\frac{-dI_P}{dt} = 1As^{-1} \qquad .....(7)$$

$$\boxed{M = \varepsilon_s} \qquad .....(8)$$

Therefore, mutual inductance of two coils is numerically equal to the induced emf linked with secondary coil when the rate of change of current in the primary coil is $1As^{-1}$.

S.I. unit of inductance, $L = \frac{\phi}{I} = \frac{\text{weber}}{\text{ampere}} = WbA^{-1}$

$$\boxed{1\,\text{henry} = \frac{1\,\text{weber}}{1\,\text{ampere}}}$$

Solenoid— Prove that $M_{12} = M_{21} = M$

If a coil of N-turns wrapped around a soft iron core, it forms a solenoid. Two solenoids S_1 and S_2 are placed co-axially as shown in next page. The magnetic field of solenoid S_1 can be expressed as,

$$B_1 = \mu_0 n_1 I_1$$

Magnetic field of solenoid S_2.

$$B_2 = \mu_0 n_2 I_2$$

For solenoid S_1 ,N_1, is the total number of turns, n_1 is the total number of turns per unit length.

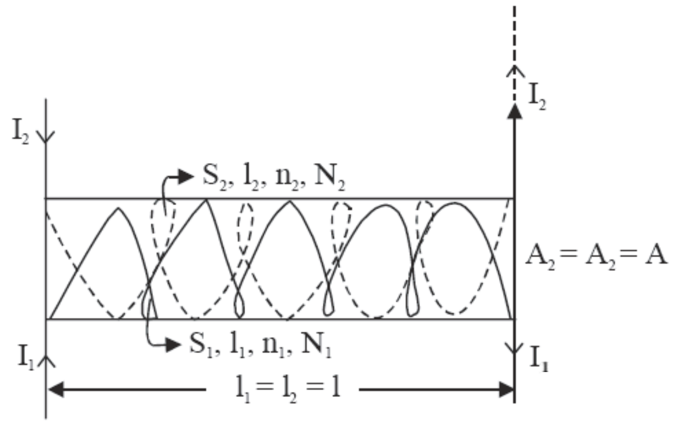
& for solenoid S_2 , N_2 is the total number of turns, n_2 is the total no. of turns per unit length.

Now,
$$B_1 = \mu_0 n_1 I_1 \qquad ...(1)$$
$$B_2 = \mu_0 n_2 I_2 \qquad ...(2)$$
$$l_1 = l_2 = l \text{ (say)} \qquad ...(3)$$
$$\left.\begin{aligned} n_1 &= \frac{N_1}{\ell_1} \\ n_2 &= \frac{N_2}{\ell_2} \end{aligned}\right\} \qquad ...(4)$$

Using in equation (1) and (2)

$$B_1 = \frac{\mu_0 N_1 I_1}{\ell} \qquad ...(5)$$

$$B_2 = \frac{\mu_0 N_2 I_2}{\ell} \qquad ....(6)$$



$\phi_1 = N_1B_2A_1$ ...(7)

$\therefore\ A_1 = A_2 = A(say)$ ...(8)

Using equation (6)

$$\phi_1 = \frac{N_1\mu_0N_2I_2}{\ell}.A_1$$

$$\boxed{\phi_1 = \frac{\mu_0N_1N_2A.I_2}{\ell}} \quad ...(9)$$

Similarly,

$$\phi_2 = N_2B_1A \quad ...(10)$$

Using equation (5)

$$\phi_2 = \frac{\mu_0N_2N_1I_1.A}{\ell}$$

$$\boxed{\phi_2 = \frac{\mu_0N_1N_2A.I_1}{\ell}} \quad ...(11)$$

By defination of mutual inductance, for primary coil

$$\phi_1\ \alpha\ I_2$$

$$\boxed{\phi_1 = M_{12}I_2} \quad ...(12)$$

Equating equation (9) and (12)

$$M_{12}I_2 = \frac{\mu_0N_1N_2AI_2}{\ell} \quad ....(13)$$

$$\therefore \quad \boxed{M_{12} = \frac{\mu_0N_1N_2A}{\ell}} \quad ....(14)$$

By def^n of mutual inductance, for primary coil.

$$\phi_2 \propto I_1$$

$$\boxed{\phi_2 = M_{21}I_1} \quad ....(15)$$

Equating equation (15) and (11)

$$M_{21}I_1 = \frac{\mu_0N_2N_1AI_1}{\ell}$$

$$\boxed{M_{21} = \frac{\mu_0N_1N_2A}{\ell}} \quad ...(16)$$

From equation (14) and (16)

$$\boxed{M_{12} = M_{21} = M}$$

Conclusion — Mutual inductance of primary wrt secondary coil is numerically equal to mutual inductance of secondary coil wrt to primary coil called mutual inductance of two coils. **[3]**

(b) Magnetic flux—It is defined as the magnetic flux is directly proportional to the number of magnetic field lines passing normally through a surface. It is denoted by ϕ.

The S.I. unit of magnetic flux is weber (Wb). **[1]**

(c) **Lenz's law of electromagnetic induction :**

It states that—"The direction of induced e.m.f or current is such that it opposes the cause which produces it. Its expression is as follows :

$$\boxed{\in = -N\frac{d\phi_B}{dt}}$$

Here. (—ve) sign shows that induced e.m.f. opposes the change in magnetic flux. It was explained by Lenz. **[1]**

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