All India CBSE Board 2020 Solved Paper

GENERAL INSTRUCTIONS

(i) *This question paper comprises four sections - A, B, C and D.*

(ii) *There are 37 questions in the question paper. All questions are compulsory.*

(iii) *Section A : Q. no.* ***1*** *to* ***20*** *are very short-answer questions and carry* ***1*** *mark each.*

(iv) *Section B : Q. no.* ***21*** *to* ***27*** *are short-answer questions and carry* ***2*** *marks each.*

(v) *Section C : Q. no.* ***28*** *to* ***34*** *are long-answer questions and carry* ***3*** *marks each.*

(vi) *Section D : Q. no.* ***35*** *to* ***37*** *are also long answer questions and carry* ***5*** *marks each.*

(vii) *There is no overall choice. However, an internal choice has been provided in* ***two*** *questions of* ***one*** *mark,* ***two*** *questions of* ***two*** *marks,* ***one*** *questions of* ***three*** *marks and all the* ***three*** *questions of* ***five*** *marks weightage. You have to attempt only one of the choices in* ***such*** *questions.*

(viii) *However, separate instructions are given with each section and question, wherever necessary.*

(ix) *Use of calculators and log tables is not permitted.*

(x) *You may use the following values of physical constants wherever necessary.*

$c = 3 \times 10^{8}$ m/s

$h = 6.63 \times 10^{-34}$ Js

$e = 1.6 \times 10^{-19}$ C

$\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}

$\varepsilon_0 = 8.854 \times 10^{-12}\ C^2\ N^{-1}\ m^{-2}$

$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^{9}\ N\ m^2\ C^{-2}$

Mass of electron (m_e) = 9.1×10^{-31} kg

Mass of neutron = 1.675×10^{-27} kg

Mass of proton = 1.673×10^{-27} kg

Avogadro's number = 6.023×10^{23} per gram mole

Boltzmann constant = $1.38 \times 10^{-23}\ JK^{-1}$

SECTION A

Note: ***Select the most appropriate option from those given below each question:***

1. If the net electric flux through a closed surface is zero, then we can infer

(a) no net charge is enclosed by the surface.

(b) uniform electric field exists within the surface.

(c) electric potential varies from point to point inside the surface.

(d) charge is present inside the surface.

2. An electric dipole consisting of charges $+q$ and $-q$ separated by a distance L is in stable equilibrium in a uniform electric field $\vec{E}$. The electrostatic potential energy of the dipole is

(a) qLE (b) zero

(c) $-qLE$ (d) $-2\,qEL$

3. A potentiometer can measure emf of a cell because

(a) the sensitivity of potentiometer is large.

(b) no current is drawn from the cell at balance.

(c) no current flows in the wire of potentiometer at balance.

(d) internal resistance of cell is neglected.

4. Two resistors R_1 and R_2 of 4 Ω and 6 Ω are connected in parallel across a battery. The ratio of power dissipated in them, $P_1 : P_2$ will be

(a) 4 : 9 (b) 3 : 2

(c) 9 : 4 (d) 2 : 3

5. The magnetic dipole moment of a current carrying coil does ***not*** depend upon

(a) number of turns of the coil.

(b) cross-sectional area of the coil.

(c) current flowing in the coil.

(d) material of the turns of the coil.

6. Larger aperture of objective lens in an astronomical telescope
(a) increases the resolving power of telescope.
(b) decreases the brightness of the image.
(c) increases the size of the image.
(d) decreases the length of the telescope.

7. A biconvex lens of glass having refractive index 1.47 is immersed in a liquid. It becomes invisible and behaves as a plane glass plate. The refractive index of the liquid is
(a) 1.47 (b) 1.62
(c) 1.33 (d) 1.51

8. For a glass prism, the angle of minimum deviation will be smallest for the light of
(a) red colour. (b) blue colour.
(c) yellow colour. (d) green colour.

9. Which of the following statements is ***not*** correct according to Rutherford model ?
(a) Most of the space inside an atom is empty.
(b) The electrons revolve around the nucleus under the influence of coulomb force acting on them.
(c) Most part of the mass of the atom and its positive charge are concentrated at its centre.
(d) The stability of atom was established by the model.

10. Photons of energies 1 eV and 2 eV are successively incident on a metallic surface of work function 0.5 eV. The ratio of kinetic energy of most energetic photoelectrons in the two cases will be
(a) 1 : 2 (b) 1 : 1
(c) 1 : 3 (d) 1 : 4

Note: ***Fill in the blanks with appropriate answer :***

11. The magnetic field and angle of dip at a place on the earth are 0.3 G and 30°, respectively. The value of vertical component of the earth's magnetic field at the place is ___________.

12. Laminated iron sheets are used to minimize ________ currents in the core of a transformer.

13. The number of turns of a solenoid are doubled without changing its length and area of cross-section. The self-inductance of the solenoid will become __________ times.

14. According to Bohr's atomic model, the circumference of the electron orbit is always an ________ multiple of de Broglie wavelength.

OR

In β-decay, the parent and daughter nuclei have the same number of _____________

15. A ray of light on passing through an equilateral glass prism, suffers a minimum deviation equal to the angle of the prism. The value of refractive index of the material of the prism is ________.

Note: ***Answer the following :***

16. Write the mathematical form of Ampere-Maxwell circuital law.

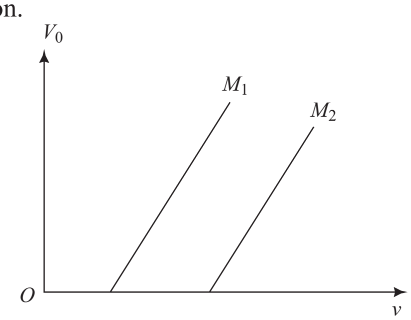
17. How does an increase in doping concentration affect the width of depletion layer of a *p-n* junction diode?

18. The nuclear radius of $^{27}_{13}\text{Al}$ is 3.6 fermi. Find the nuclear radius of $^{64}_{29}\text{Cu}$.

OR

A proton and an electron have equal speeds. Find the ratio of de Broglie wavelengths associated with them.

19. The variation of the stopping potential (V_0) with the frequency (ν) of the light incident on two different photosensitive surfaces M_1 and M_2 is shown in the figure. Identify the surface which has greater value of the work function.



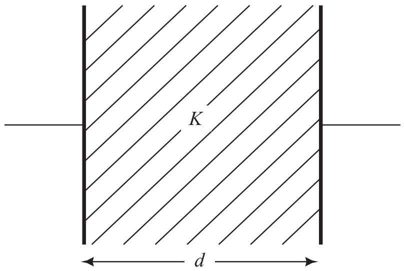
20. Why cannot we use Si and Ge in fabrication of visible LEDs?

SECTION B

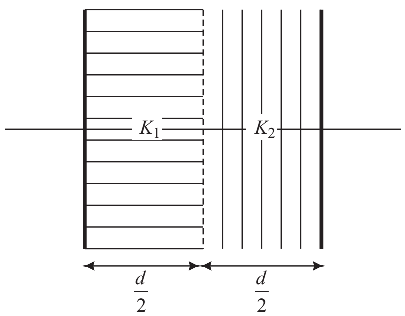
21. Explain the principle of working of a meter bridge. Draw the circuit diagram for determination of an unknown resistance using it.

22. The space between the plates of a parallel plate capacitor is completely filled in two ways. In the first case, it is filled with a slab of dielectric constant K. In the second case, it is filled with two slabs of equal thickness and dielectric constants K_1 and K_2 respectively as shown in the figure.

The capacitance of the capacitor is same in the two cases. Obtain the relationship between K, K_1 and K_2.



(Case 1)



(Case 2)

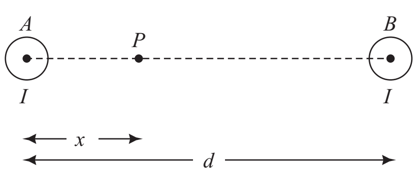
23. Define the term 'Half-life' of a radioactive substance. Two different radioactive substances have half-lives T_1 and T_2 and number of undecayed atoms at an instant N_1 and N_2, respectively. Find the ratio of their activities at that instant.

24. Define wavefront of a travelling wave. Using Huygens principle, obtain the law of refraction at a plane interface when light passes from a denser to rarer medium.

OR

Using lens maker's formula, derive the thin lens formula $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$ for a biconvex lens.

25. Two long straight parallel wires A and B separated by a distance d, carry equal current I flowing in same direction as shown in the figure.



(a) Find the magnetic field at a point P situated between them at a distance x from one wire.

(b) Show graphically the variation of the magnetic field with distance x for $0 < x < d$.

26. Using Bohr's atomic model, derive the expression for the radius of n^{th} orbit of the revolving electron in a hydrogen atom.

OR

(a) Write two main observations of photoelectric effect experiment which could only be explained by Einstein's photoelectric equation.

(b) Draw a graph showing variation of photocurrent with the anode potential of a photocell.

27. Explain the terms 'depletion layer' and 'potential barrier' in a *p-n* junction diode. How are the (a) width of depletion layer, and (b) value of potential barrier affected when the *p-n* junction is forward biased?

SECTION C

28. (a) Two cells of emf E_1 and E_2 have their internal resistances r_1 and r_2 respectively. Deduce an expression for the equivalent emf and internal resistance of their parallel combination when connected across an external resistance R. Assume that the two cells are supporting each other.

(b) In case the two cells are identical, each of emf $E = 5$ V and internal resistance $r = 2\Omega$, calculate the voltage across the external resistance $R = 10\ \Omega$.

29. (a) Write an expression of magnetic moment associated with a current (I) carrying circular coil of radius r having N turns.

(b) Consider the above mentioned coil placed in YZ plane with its centre at the origin. Derive expression for the value of magnetic field due to it at point $(x, 0, 0)$.

OR

(a) Define current sensitivity of a galvanometer. Write its expression.

(b) A galvanometer has resistance G and shows full scale deflection for current I_g.

(i) How can it be converted into an ammeter to measure current upto I_0 ($I_0 > I_g$)?

(ii) What is the effective resistance of this ammeter?

30. A resistance R and a capacitor C are connected in series to a source $V = V_0 \sin \omega t$.

Find :

(a) The peak value of the voltage across the (i) resistance and (ii) capacitor.

(b) The phase difference between the applied voltage and current. Which of them is ahead?

31. What is the effect on the interference fringes in Young's double slit experiment due to each of the following operations? Justify your answers.

(a) The screen is moved away from the plane of the slits.

(b) The separation between slits is increased.

(c) The source slit is moved closer to the plane of double slit.

32. (a) Write the expression for the speed of light in a material medium of relative permittivity ε_r and relative magnetic permeability μ_r.

(b) Write the wavelength range and name of the electromagnetic waves which are used in (i) radar systems for aircraft navigation, and (ii) Earth satellites to observe the growth of the crops.

33. The nucleus ${}^{235}_{92}\text{Y}$, initially at rest, decays into ${}^{231}_{90}\text{X}$ by emitting an α-particle

$$ {}^{235}_{92}\text{Y} \longrightarrow {}^{231}_{90}\text{X} + {}^{4}_{2}\text{He} + \text{energy}. $$

The binding energies per nucleon of the parent nucleus, the daughter nucleus and α-particle are 7.8 MeV, 7.835 MeV and 7.07 MeV, respectively. Assuming the daughter nucleus to be formed in the unexcited state and neglecting its share in the energy of the reaction, find the speed of the emitted α-particle. (Mass of α-particle = 6.68×10^{-27} kg)

34. (a) Draw circuit diagram and explain the working of a zener diode as a dc voltage regulator with the help of its I-V characteristic.

(b) What is the purpose of heavy doping of *p*- and *n*-sides of a zener diode?

SECTION D

35. (a) Using Gauss law, derive expression for electric field due to a spherical shell of uniform charge distribution σ and radius R at a point lying at a distance x from the centre of shell, such that

(i) $0 < x < R$, and

(ii) $x > R$.

(b) An electric field is uniform and acts along $+x$ direction in the region of positive x. It is also uniform with the same magnitude but act in $-x$ direction in the region of negative x. The value of the field is $E = 200$ N/C for $x > 0$ and $E = -200$ N/C for $x < 0$. A right circular cylinder of length 20 cm and radius 5 cm has its centre at the origin and its axis along the x-axis so that one flat face is at $x = +10$ cm and the other is at $x = -10$ cm.

Find:

(i) The net outward flux through the cylinder.

(ii) The net charge present inside the cylinder.

OR

(a) Find the expression for the potential energy of a system of two point charges q_1 and q_2 located at $\vec{r}_1$ and , respectively in an external electric field $\vec{E}$.

(b) Draw equipotential surfaces due to an isolated point charge $(-q)$ and depict the electric field lines.

(c) Three point charges $+1\ \mu C$, $-1\ \mu C$ and $+2\ \mu C$ are initially infinite distance apart. Calculate the work done in assembling these charges at the vertices of an equilateral triangle of side 10 cm.

36. (a) Derive the expression for the torque acting on the rectangular current carrying coil of a galvanometer. Why is the magnetic field made radial ?

(b) An α-particle is accelerated through a potential difference of 10 kV and moves along x-axis. It enters in a region of uniform magnetic field $B = 2 \times 10^{-3}$ T acting along y-axis. Find the radius of its path. (Take mass of α-particle = 6.4×10^{-27} kg)

OR

(a) With the help of a labelled diagram, explain the working of a step-up transformer. Give reasons to explain the following :

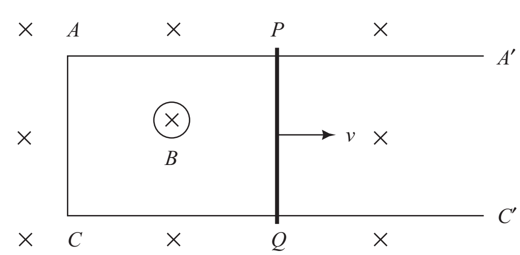
(i) The core of the transformer is laminated.

(ii) Thick copper wire is used in windings.

(b) A conducting rod PQ of length 20 cm and resistance 0.1 Ω rests on two smooth parallel rails of negligible resistance AA' and CC'. It can slide on the rails and the arrangement is positioned between the poles of a permanent magnet producing uniform magnetic field $B = 0.4$ T. The rails, the rod and the magnetic field are in three mutually perpendicular directions as shown in the figure. If the ends A and C of the rails are short circuited, find the

(i) external force required to move the rod with uniform velocity $v = 10$ cm/s, and

(ii) power required to do so.



37. (a) Draw the ray diagram of an astronomical telescope when the final image is formed at infinity. Write the expression for the resolving power of the telescope.

(b) An astronomical telescope has an objective lens of focal length 20 m and eyepiece of focal length 1 cm.

(i) Find the angular magnification of the telescope.

(ii) If this telescope is used to view the Moon, find the diameter of the image formed by the objective lens. Given the diameter of the Moon is 3.5×10^6 m and radius of lunar orbit is 3.8×10^8 m.

OR

(a) An object is placed in front of a concave mirror. It is observed that a virtual image is formed. Draw the ray diagram to show the image formation and hence derive the mirror equation $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$.

(b) An object is placed 30 cm in front of a plano-convex lens with its spherical surface of radius of curvature 20 cm. If the refractive index of the material of the lens is 1.5, find the position and nature of the image formed.

Solutions

SECTION A

1. Option (a) is correct.

According to Gauss's theorem

$$\phi = \frac{\Sigma q_{en}}{\varepsilon_0}$$

So, net charge enclosed by the surface is zero if the net electric flux through a closed surface is zero.

2. Option (c) is correct.

Potential energy of a dipole in external field U is

$$U = -\vec{P} \cdot \vec{E}$$

for stable equilibrium $\theta = 0°$

$$U = -p\, E \cos 0° = -pE$$

$$\therefore \quad U = -qLE$$

3. Option (b) is correct.

4. Option (b) is correct.

$$P_1 = \frac{V^2}{R_1} \text{ and } P_2 = \frac{V^2}{R_2}$$

$$\frac{P_1}{P_2} = \frac{R_2}{R_1} = \frac{6}{4} = \frac{3}{2}$$

5. Option (d) is correct.

6. Option (a) is correct.

7. Option (a) is correct.

8. Option (a) is correct.

Angle of minimum deviation δ.

$$\delta = (\mu - 1)A$$

Now $\lambda_{red} > \lambda_{violet}$

$\therefore \quad \mu_{red} < \mu_{violet}$

So δ_{red} is smallest.

9. Option (d) is correct.

10. Option (c) is correct.

$K.E.$ = Photon energy – Work function.

$$\therefore \quad \frac{K.E_1}{K.E_2} = \frac{1-0.5}{2-0.5} = \frac{0.5}{1.5} = \frac{1}{3}$$

11. Vertical component of magnetic field B_V is

$$B_V = B \sin \delta$$

Given $B = 0.3$

$$\delta = 30°$$

$$B_V = 0.3 \sin 30°$$

$$B_V = 0.15 \text{ G}$$

12. Eddy currents.

13. Self-inductance of *a* long solenoid

$$L = \frac{\mu_0 N^2 A}{l}$$

$$\therefore \quad L \propto N^2$$

So, the self inductance of the solenoid will become *4 times*.

14. Integral multiple

OR

Nucleons (neutrons + protons)

15. Here $A = 60°$ $\delta = 60°$

$$\mu = \frac{\sin \frac{A+\delta}{2}}{\sin \frac{A}{2}}$$

$$\mu = \frac{\sin 60°}{\sin 30°}$$

$$\therefore \quad \mu = \sqrt{3}.$$

16. Mathematical form of ampere-Maxwell circuital law

$$\oint_l \vec{B}.\overrightarrow{dl} = \mu_0 \left[I + \varepsilon_0 \frac{d\phi_E}{dt} \right]$$

17. An increase in doping concentration decrease the width of depletion layer of *a p-n* junction diode.

18.

$$R = R_0 A^{1/3}$$

$$\frac{R_2}{R_1} = \left(\frac{A_2}{A_1}\right)^{1/3}$$

$$\Rightarrow \quad R_2 = R_1 \left(\frac{A_2}{A_1}\right)^{1/3}$$

$$R_2 = 3.6 \left(\frac{64}{27}\right)^{1/3} = 3.6 \left(\frac{4}{3}\right)$$

$$\Rightarrow \quad R_2 = 4.8 \text{ fermi}$$

OR

de Broglie wavelength $\lambda = \frac{h}{P} = \frac{h}{mv}$

$$\frac{\lambda_p}{\lambda_e} = \frac{h/m_pV_p}{h/m_eV_e}$$

Given $V_p = V_e$

$$\therefore \quad \frac{\lambda_p}{\lambda_e} = \frac{m_e}{m_p}$$

19. From the graph, we can conclude that M_2 will have greater value of work function due to higher value of threshold frequency.

20. For visible LEDs, the band gap of semiconductor must be within 1.8 eV to 3 eV. But the band gap of Ge and Si is less than 1.8 eV. So, they cannot be used to fabricate visible LEDs.

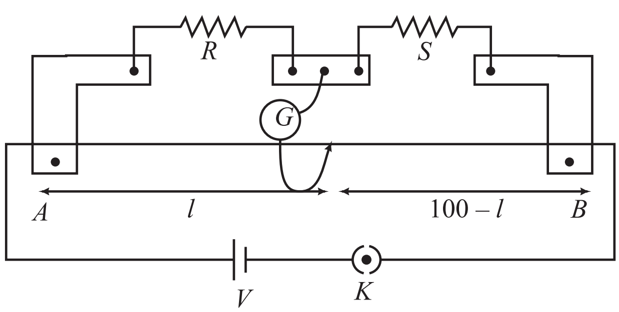
SECTION B

21. Working principle of meter bridge:

The working principle of meter bridge is based on wheatstone bridge. It is an arrangement of four resistances used to determine one of these resistances quickly in terms of the remaining three resistances.

When the bridge is balanced,

$\frac{R}{S} = \frac{l}{100-l}$; l = balanced length.



22. Capacitance of capacitor in case I

$$C_1 = \frac{K\varepsilon_0 A}{d}.$$

For, case 2, the capacitor are connected in series. Therefore equivalent capacitance would be

$$\frac{1}{C_2} = \frac{1}{\frac{K_1\varepsilon_0 A}{d/2}} + \frac{1}{\frac{K_2\varepsilon_0 A}{d/2}}$$

$$\frac{1}{C_2} = \frac{d}{2\varepsilon_0 A}\left[\frac{1}{K_1} + \frac{1}{K_2}\right]$$

$$C_2 = \frac{2\varepsilon_0 A}{d}\left[\frac{K_1K_2}{K_1 + K_2}\right]$$

Given that $C_1 = C_2$

$$\therefore \quad \frac{k\varepsilon_0 A}{d} = \frac{2\varepsilon_0 A}{d}\left[\frac{K_1K_2}{K_1 + K_2}\right]$$

$$\boxed{K = \left[\frac{2K_1K_2}{K_1 + K_2}\right]}$$

23. *Half-life:* The time-interval in which one half of the radioactive nuclei originally present in radioactive sample disintegrate is called half-life of the radioactive substance.

Activity $R = \lambda N$

$$\therefore \quad \frac{R_1}{R_2} = \frac{\lambda_1}{\lambda_2} \times \frac{N_1}{N_2}$$

We know that,0

$$\lambda = \frac{0.693}{T_{1/2}}$$

$$\therefore \quad \frac{\lambda_1}{\lambda_2} = \frac{(T_{1/2})_2}{(T_{1/2})_1}$$

$$\Rightarrow \quad \frac{R_1}{R_2} = \frac{(T_{1/2})_2}{(T_{1/2})_1} \times \frac{N_1}{N_2}$$

24. *Wavefront: A* locus of the points which oscillates in the same phase is called a wavefront. Thus, *a* wavefront is defined as *a* surface of constant phase.

Law of refraction at rarer medium

Consider a plane wavefront AB incident on a plane surface, separating two media 1 and 2. Let v_1 and v_2 be the velocities of light in the two media with $v_2 > v_1$. The wavefront first strikes at point A and then at the successive points towards C. According to Hugyen's principle, from each point on AC, the secondary wavelets start growing in the second medium with speed v_2.

Let $BC = v_1 t$

and $AD = v_2 t$

where t = time taken to travel from B to C and from A to D.

The tangent plane CD drawn from point C over the hemisphere of radius v_2t will be our new refracted wavefront.

From ΔABC, we have

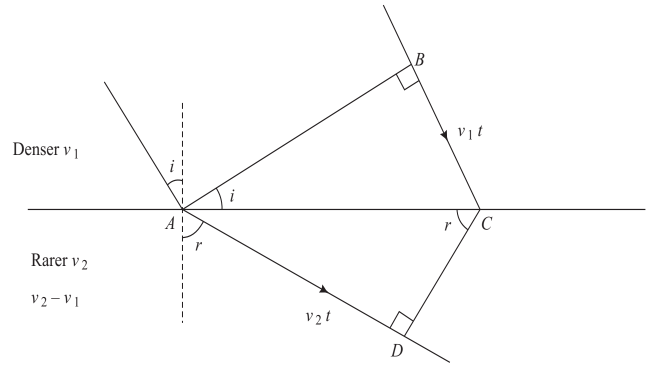
$$\sin i = \frac{BC}{AC}$$

and from ΔADC we have

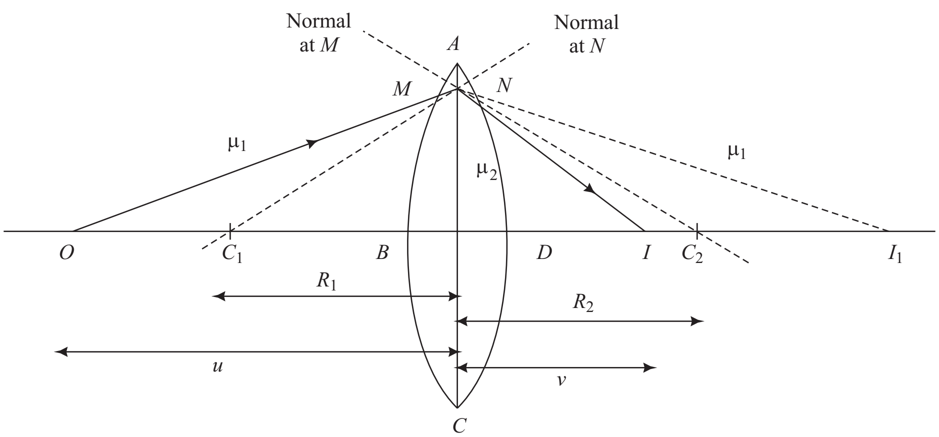
$$\sin r = \frac{AD}{AC}$$

$$\therefore \quad \frac{\sin i}{\sin r} = \frac{BC}{AD} = \frac{v_1 t}{v_2 t}$$

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \mu = \text{constant.}$$



OR



For refraction at surface ABC, we have

$$\frac{\mu_2}{v_1} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R_1} \qquad ...(1)$$

For refraction at surface ADC, we have

$$\frac{\mu_1}{v} - \frac{\mu_2}{v_1} = \frac{\mu_1 - \mu_2}{R_2} \qquad ...(2)$$

adding equation (1) and (2), we get

$$\frac{\mu_1}{v} - \frac{\mu_1}{u} = (\mu_2 - \mu_1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\frac{1}{v} - \frac{1}{u} = \left[\frac{(\mu_2 - \mu_1)}{\mu_1}\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \qquad ...(3)$$

If the object is placed at infinity ($u = \infty$), the image will be formed at the focus, *i.e.* $v = f$

Therefore

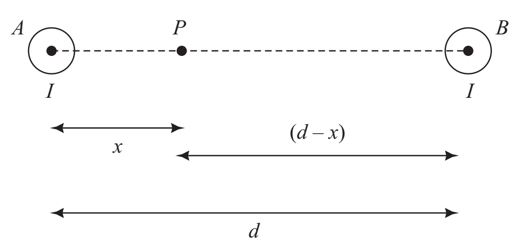
$$\frac{1}{f} - \frac{1}{\infty} = (\mu_{21} - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\frac{1}{f} = (\mu_{21} - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \qquad ...(4)$$

From eq. (3) and (4), we have

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \rightarrow \text{Thin lens formula.}$$

25.



Field at P due to wire at A

$$\vec{B}_A = \frac{\mu_0 I}{2\pi x} \text{ (upward)}$$

Field at P due to wire at *B*

$$\vec{B}_B = \frac{\mu_0 I}{2\pi(d-x)} \text{ (downward)}$$

Therefore, total field at *P*

$$\vec{B} = \vec{B}_A + \vec{B}_B$$

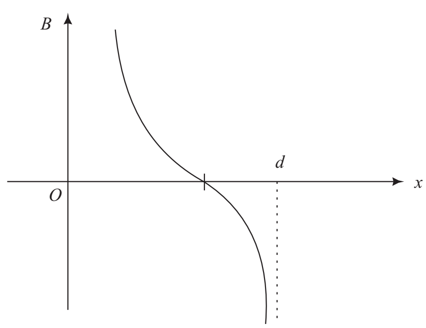
$$\vec{B} = \frac{\mu_0 I}{2\pi x} - \frac{\mu_0 I}{2\pi(d-x)}$$

$$\vec{B} = \frac{\mu_0 I}{2\pi}\left[\frac{1}{x} - \frac{1}{d-x}\right]$$

$$\vec{B} = \frac{\mu_0 I}{2\pi}\left[\frac{d-x-x}{x(d-x)}\right]$$

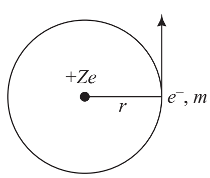
$$\vec{B} = \frac{\mu_0 I(d-2x)}{2\pi x(d-x)} \text{ upward.}$$

(b)



26. The electrostatic force of attraction between nucleus and the electron is

$$F = \frac{KZe.e}{r^2}$$



$$F = \frac{KZe^2}{r^2}$$

To keep the electron in its orbit, the centripetal force on the electron must be equal to the electrostatic attraction. Therefore,

$$\frac{mv^2}{r} = \frac{KZe^2}{r^2}$$

$$\Rightarrow \quad r = \frac{KZe^2}{mv^2} \quad ...(1)$$

m = mass of electron

v = speed of electron

According to Bohr's quantisation condition for angular momentum,

$$L = mvr = \frac{nh}{2\pi}$$

$$r = \frac{nh}{2\pi mv} \quad ...(2)$$

From (1) and (2)

$$v = \frac{2\pi KZe^2}{nh}$$

Putting the value of v in eqn (2), we get

$$\boxed{r = \frac{n^2h^2}{4\pi^2 mKZe^2}}$$

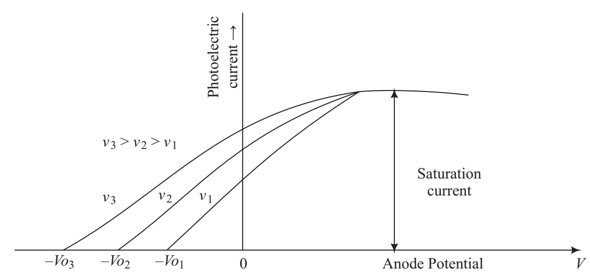
OR

(a) The two main observation of photoelectric effect experiment which could only be explained by Einstein's photoelectric equations are:

(i) The photoelectric emission is an instantaneous process

(ii) For a given photosensitive material, there exist a certain minimum cut-off frequency below which no photoelectrons are emitted, howsoever high is the intensity of incident radiations. This frequency is called threshold frequency.

(b)



27. *Potential barrier:* The accumulation of negative charges in the *p*-region and positive charges in the *n*-region sets up a potential difference across the junction. This act as a barrier and is called barrier potential.

Depletion layer: It is a layer of immobile ion formed near the p-n junction by diffusion of majority charge carriers and electron hole recombination.

(a) Width of depletion layer decreases in forward bias.

(b) The value of potential barrier reduces in forward bias.

SECTION C

28. (a) From the circuit, we can write

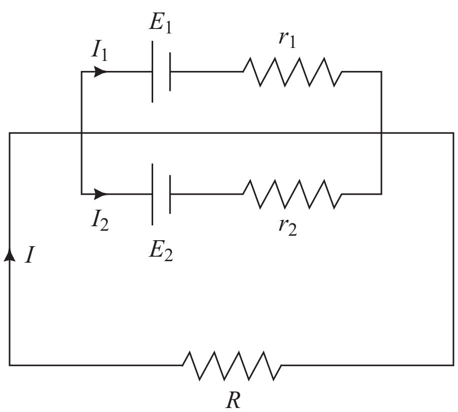
$$V_1 = E_1 - I_1 r_1 \quad ...(1)$$

$$V_2 = E_2 - I_2 r_2 \quad ...(2)$$

Since E_1 and E_2 are parallel

$$V_1 = V_2 = V$$

and $$I = I_1 + I_2$$



From (1),

$$I_1 = \frac{E_1 - V}{r_1}$$

From (2)

$$I_2 = \frac{E_2 - V}{r_2}$$

Similarly, for equivalent cell

$$I = \frac{E_{eq} - V}{r_{eq}}$$

$$\therefore \quad I = I_1 + I_2$$

$$\frac{E_{eq} - V}{r_{eq}} = \left(\frac{E_1}{r_1} + \frac{E_2}{r_2}\right) - V\left[\frac{1}{r_1} + \frac{1}{r_2}\right]$$

$$\frac{E_{eq}}{r_{eq}} - V\left[\frac{1}{r_{eq}}\right] = \left[\frac{E_1 r_2 + E_2 r_1}{r_1 r_2}\right] - V\left[\frac{1}{r_1} + \frac{1}{r_2}\right]$$

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

and $$E_{eq} = r_{eq}\left[\frac{E_1 r_2 + E_2 r_1}{r_1 r_2}\right]$$

$$\boxed{E_{eq} = \left[\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}\right]}$$

(b) Given $E_1 = E_2 = 5$ V

$$r_1 = r_2 = 2\ \Omega$$

$$\therefore \quad E_{eq} = \frac{5 \times 2 + 5 \times 2}{2 + 2} = \frac{20}{4} = 5 \text{ V}$$

$$r_{eq} = \frac{r_1 r_2}{r_1 + r_2} = \frac{4}{4} = 1\ \Omega$$

$$I = \frac{E_{eq}}{R + r_{eq}} = \frac{5}{10 + 1} = \frac{5}{11} \text{ A}$$

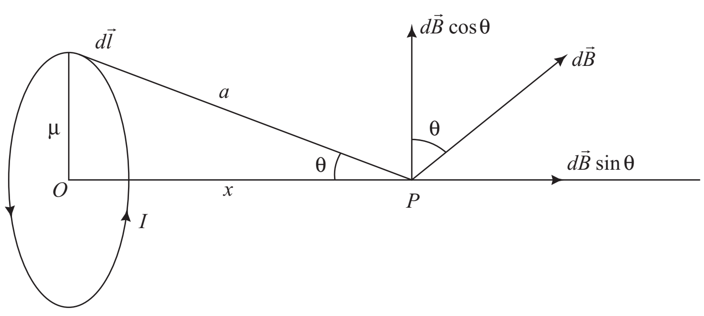
Voltage across $R \Rightarrow V = IR$

$$V = \frac{5}{11} \times 10 = \frac{50}{11} \text{ V}$$

29. (a) Magnetic moment associated with a current carrying circular coil of radius r having N turns,

$$\vec{M} = NI(\pi r^2)\,\hat{n}$$

(b)



From Biot-savart law, the magnetic field at point $P(x, 0, 0)$ due to current element $\vec{dl}$,

$$\vec{dB} = \frac{\mu_0}{4\pi}\frac{I\,dl\sin 90°}{a^2}$$

Now, the vertical component $d\vec{B}\cos\theta$ will cancel out for entire coil. So,

$$\vec{B} \text{ at } P \Rightarrow B = \int dB\sin\theta$$

$$B = \frac{\mu_0 I}{4\pi a^2}\sin\theta\int dl$$

Now $\int dl = 2\pi r$

$$\therefore \quad B = \frac{\mu_0 I}{4\pi a^2}\times\frac{r}{a}\times 2\pi r \qquad \left[\because \sin\theta = \frac{r}{a}\right]$$

$$B = \frac{\mu_0 I r^2}{2a^3}$$

$$\vec{B} = \frac{\mu_0 I r^2}{2(r^2+x^2)^{3/2}}\hat{i}.$$

For coil having N turns,

$$\vec{B} = \frac{\mu_0 I N r^2}{2(r^2+x^2)^{3/2}}\hat{i}.$$

OR

(a) Current sensitivity

It is defined as the deflection produced in the galvanometer when a unit current flows through it.

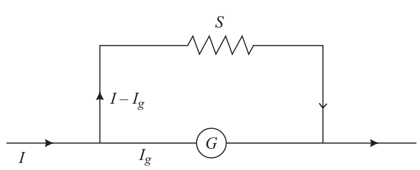
Current sensitivity $I_C = \dfrac{NBA}{K}$

Where N = no. of turns in the coil

B = Magnetic field

A = area of coil of galvanometer.

(b) (i)



Galvanometer can be converted into ammeter by connecting a shunt (small resistance) S with parallel to galvanometer.

As galvanometer and shunt are connected in parallel, so,

Potential across G = Potential across the S

$$I_g G = (I - I_g)S$$

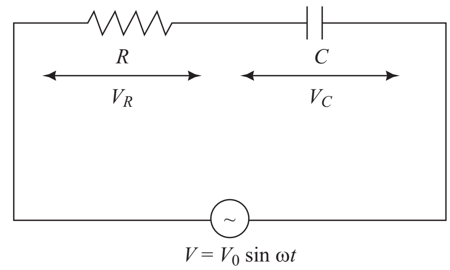
$$\therefore \quad S = \frac{I_g}{I - I_g}G.$$

(ii) Effective resistance of this ammeter will be

$$\frac{1}{R_A} = \frac{1}{G}+\frac{1}{S}$$

$$R_A = \frac{GS}{G+S}.$$

30. (a)



Total impedance of circuit

$$Z = \sqrt{R^2 + X_C{}^2}$$

$\therefore$ Current in circuit

$$I = \frac{V_0}{\sqrt{R^2 + X_C^2}}$$

Peak voltage across

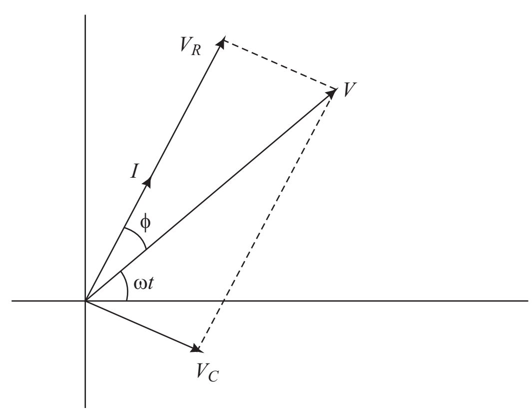
(i) Resistance R

$$V_R = IR = \frac{V_0 R}{\sqrt{R^2 + X_C^2}}$$

(ii) Capacitor C

$$V_C = I X_C$$

$$= \frac{V_0 X_C}{\sqrt{R^2 + X_C^2}}$$



(b) $\tan\phi = \dfrac{V_C}{V_R} \Rightarrow \phi = \tan^{-1}\left(\dfrac{V_C}{V_R}\right) = \tan^{-1}\left(\dfrac{X_C}{R}\right)$

$\therefore$ Phase difference between V and I is $\tan^{-1}\left(\frac{X_C}{R}\right)$

31. (a) Fringe width $\beta = \frac{\lambda D}{d}$

Since $\beta \propto D$, the fringe width will increase, as screen is moved away.

(b) $\beta \propto \frac{1}{d}$, therefore fringe width will decrease, as separation between slits is increased.

(c) Let s be the width of the source slit and S its distance from plane of two slit. For interference fringes to be distinctly seen, the condition

$$\frac{s}{S} < \frac{\lambda}{d}$$

should be satisfied, otherwise, the interference patterns produced will overlap.

32. (a) Velocity of light v will be

$$v = \frac{1}{\sqrt{\mu_0 \mu_r \varepsilon_0 \varepsilon_r}}$$

Now, since $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

$$\therefore \quad v = \frac{c}{\sqrt{\mu_r \varepsilon_r}}$$

(b) (i) Microwaves – 0.3 m to 10^{-3} m

(ii) Infrared – 5×10^{-3}m to 10^{-6} m

33. Total B.E of ${}^{235}_{92}\text{Y} = 7.8 \times 235 = 1833\ MeV$

Total B.E of ${}^{231}_{90}\text{X} = 7.835 \times 231 = 1809.9\ MeV$

Total B.E of ${}^{4}_{2}\text{He} = 7.07 \times 4 = 28.28\ MeV$

Energy released in the decay, Q

$Q = B.E$ of $X + B.E$ of He – $B.E$ of Y

$= 1809.9 + 28.28 - 1833$

$= 5.18$ MeV

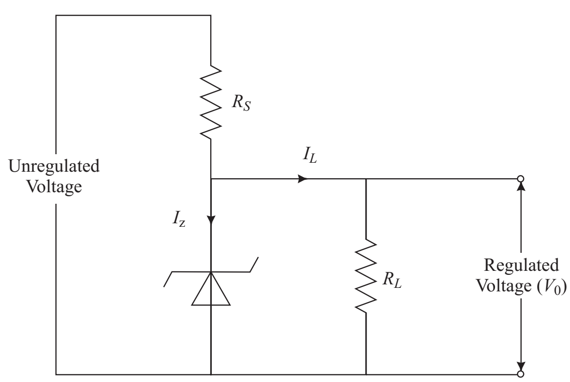
$K.E$ of a particle, $\frac{1}{2}mv^2 = Q$

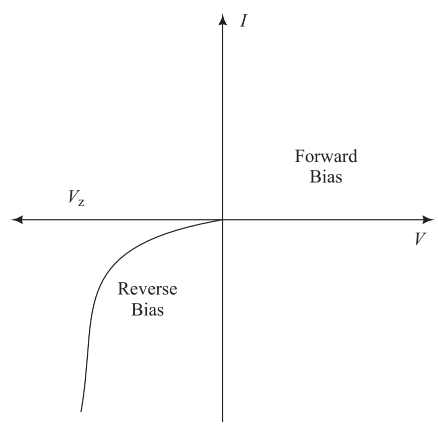
$$\therefore \text{ Speed, } \quad v = \sqrt{\frac{2Q}{m}}$$

$$v = \sqrt{\frac{2 \times 5.18 \times 1.6 \times 10^{-13}}{6.68 \times 10^{-27}}}$$

$$v = 1.58 \times 10^{7}\ ms^{-1}$$

34. (a)



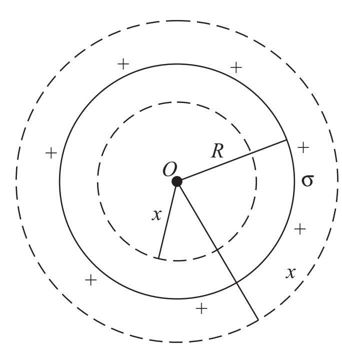


Working of a zener diode as voltage regulator: If the input voltage increases, the current through R_S and Zener diode also increases. This increases the voltage drop across R_S without any change in the voltage across the zener diode. This is because in the breakdown region, Zener voltage remains constant even though current through the Zener diode changes. Similarly, if the input voltage decreases, the voltage across R_S decreases without any change in the voltage across the Zener diode. Thus any increase/decrease of the input voltage results in increase/decrease of the voltage drop across R_S without any change in voltage across Zener diode. Hence the Zener diode act as voltage regulator.

(b) Due to heavy doping of P and n sides, the width of junction layer is small and the barrier field is high.

SECTION D

35. (a)



(i) $0 < x < R$

As x lies inside the shell, the charge enclosed by the gaussian surface is zero

$$q = 0$$

Flux through the Gaussian surface

$$\phi = E \times 4\pi x^2$$

Applying Gauss's theorem,

$$\phi = \frac{q}{\varepsilon_0}$$

$$E \times 4\pi x^2 = 0$$

$$\therefore \quad E = 0$$

(ii) $x > R$

The total charge q inside the gaussian surface is the charge on the shell of radius R and area $4\pi R^2$.

$$\therefore \quad q = 4\pi R^2 \sigma$$

Flux through gaussian surface

$$\phi = E \times 4\pi x^2$$

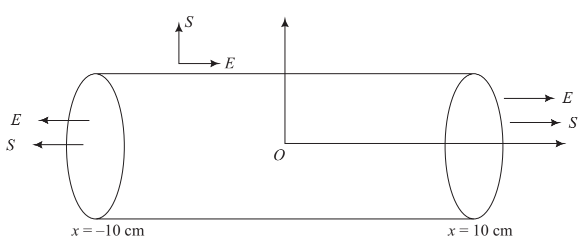
Applying gauss theorem,

$$\phi = \frac{q}{\varepsilon_0}$$

$$E \times 4\pi x^2 = \frac{4\pi R^2 \sigma}{\varepsilon_0}$$

$$E = \frac{\sigma R^2}{\varepsilon_0 x^2}$$

(b)



(i) Outward flux through left face is

$$\phi = \vec{E}.\Delta\vec{S}$$

$$= -200 \times \pi(0.05)^2 \left(-\hat{i}\right)\hat{i}$$

$$= +1.57\ Nm^2C^{-1}.$$

Outward flux through right face

$$\phi = \vec{E}.\Delta\vec{S}$$

$$= 200 \times \pi(0.05)^2\ \hat{i}.\hat{i}$$

$$\phi = +1.57\ Nm^2C^{-1}$$

Flux through the side of the cylinder

$$\phi = E\Delta S \cos 90° = 0$$

$\therefore$ Net outward flux through the cylinder

$$\phi = 1.57 + 1.57$$

$$= 3.14\ Nm^2C^{-1}$$

(ii) The net charge inside the cylinder

$$q = \varepsilon_0 \phi_E$$

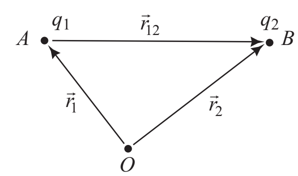
$$= 8.854 \times 10^{-12} \times 3.14$$

$$q = 2.78 \times 10^{-11}\ C$$

OR

(a) Work done to bring q_1 from ∞ in external electric field $\vec{E}$

$$w_1 = q_1\ V(\vec{r}_1)$$



Work done to bring q_2 in external electric field $\vec{E}$ and of field of q_2

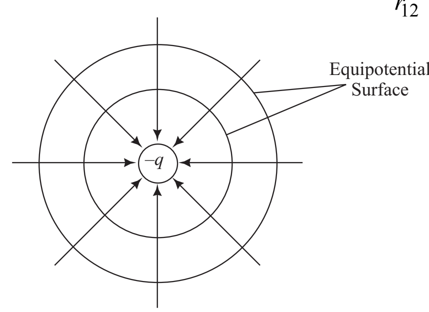
$$w_2 = q_2 V(\vec{r}_2) + \frac{Kq_1q_2}{r_{12}}$$

Potential energy of system

$$U = w_1 + w_2$$

$$= q_1 V(\vec{r}_1) + q_2 V(\vec{r}_2) + \frac{Kq_1q_2}{r_{12}}$$

(b)



(c) Potential energy of the system

$$U = U_{12} + U_{23} + U_{13}$$

$$U = \frac{1}{4\pi\varepsilon_0 r}[q_1q_2 + q_2q_3 + q_1q_3]$$

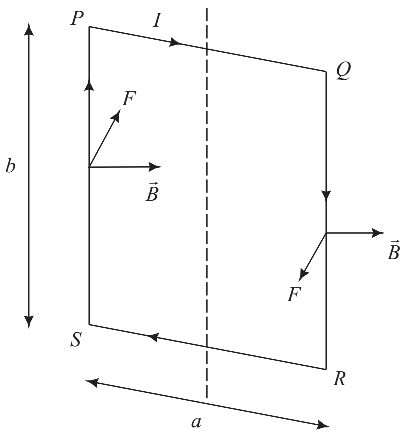
$$U = \frac{9\times10^9}{10\times10^{-12}}$$

$$[+1 \times -1 + (+1) \times (+2) + (-1)(+2)] \times 10^{-12}$$

$$U = 9 \times 10^{-2}\ (-1 + 2 - 2)$$

$$U = -0.09\ J$$

36. (a)



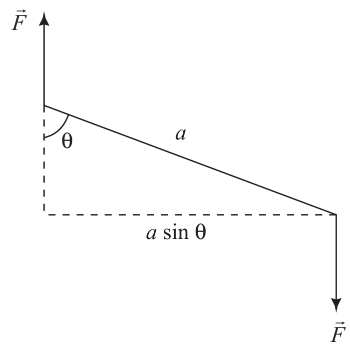
As we can see from figure,

I = current flowing through coil $PQRS$

a, b = sides of rectangular coil $PQRS$

$A = ab$ = area of the coil

N = number of turns in the coil.



The magnetic forces on sides PQ and SR are equal, opposite and collinear, so their resultant is zero. According to Fleming's rule, the side PS experiences a normal inward force equal to $NIbB$ while the side QR experiences an equal normal outward force. The two forces on sides PS and QR are equal and opposite. They form a couple and exert a torque given by

τ = Force × Perpendicular distance

$= NIbB \times a \sin 90°$

$= NIB\,(ab)$

$\tau = NIBA$

Magnetic field is taken radial in galvanometer coil in order to create $\theta = 90°$ at every orientation of coil in the magnetic field so that current varies linearly with deflection.

(b) Radius of circular path

$$r = \frac{1}{B}\sqrt{\frac{2mV}{q}}$$

$$r = \frac{1}{2\times10^{-3}}\sqrt{\frac{2\times6.4\times10^{-27}\times10\times10^{3}}{2\times1.6\times10^{-19}}}$$

$r = 10\ m.$

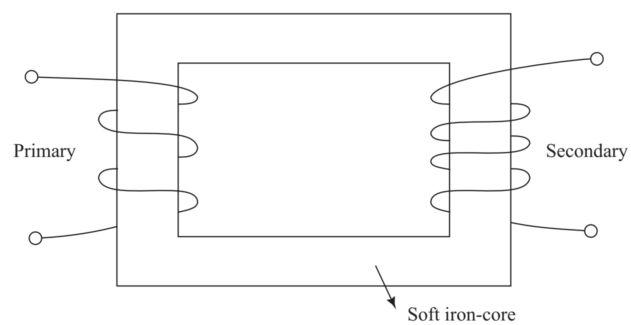
OR

Working of transformer:

As the alternating current flows through the primary, it generates an alternating magnetic flux in the core which also passes through the secondary. This changing flux sets up an induced emf in the secondary, also a self-induced emf in the primary. If there is no leakage of magnetic flux, then flux linked with each turn of the primary will be equal to that linked with each turn of the secondary.

(i) Core is laminated to block or minimise the paths of eddy current to minimise heat loss against resistance of core.

(ii) Thick copper wire is used in order to reduce the resistance of transformer coil to minimise heat loss.



STEP-UP TRANSFORMER

(b) (i) Force $F = I\,l\,B$

$$F = \left(\frac{Blv}{R}\right)lB = \frac{B^2l^2v}{R}$$

$$= \frac{(0.4)^2\times(20\times10^{-2})^2\times(10\times10^{-2})}{0.1}$$

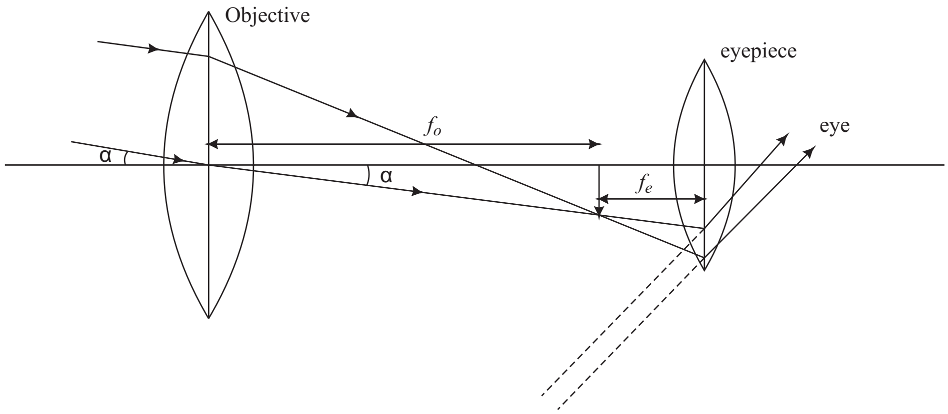
$F = 6.4\times10^{-3}\ N$

(ii) Power $P = Fv$

$= 6.4\times10^{-3}\times10\times10^{-2}$

$= 6.4\times10^{-4}$ Watt

37. (a)



Resolving power = $\frac{D}{1.22\lambda}$

(b) (i) Angular magnification

$$m = \frac{f_0}{f_e}$$

$$m = \frac{20}{0.01} = 2000$$

(ii) Let d be the diameter of the image in metres. Then angle subtended by the moon will be

$$\alpha = \frac{\text{Diameter at moon}}{\text{Radius of lunar orbit}}$$

$$= \frac{3.5\times10^6}{3.8\times10^8}$$

Angle subtended by the image formed by the objective will also be equal to α and is given by

$$\alpha = \frac{\text{Diameter of image of moon}}{f_o}$$

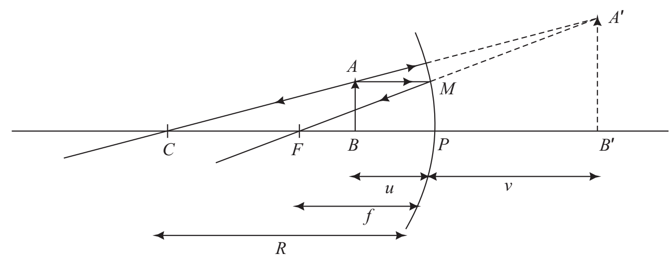
$$\alpha = \frac{d}{20}$$

$$\therefore \quad \frac{\quad}{20} = \frac{3.5\times10^6}{3.8\times10^8}$$

$$d = 0.18\ m$$

OR

(a) Consider an object AB placed on the principle axis of a concave mirror between its pole P and focus F. A virtual and errect image $A'B'$ is formed behind mirror, after reflection from concave mirror.



Here, $\Delta ABC \sim \Delta A'B'C'$,

$$\frac{AB}{A'B'} = \frac{CB}{CB'} = \frac{CP-BP}{CP+PB'} = \frac{-2f+u}{-2f+v} \quad ...(1)$$

Also, $\Delta MPF \sim \Delta A'B'F$, therefore,

$$\frac{MP}{A'B'} = \frac{FP}{FB'} = \frac{FP}{FP+PB'}$$

$$\therefore \quad \frac{AB}{A'B'} = \frac{-f}{-f+v} \quad [\because MP = AB] \quad ...(2)$$

From equation (1) and (2), we get

$$\frac{-2f+u}{-2f+v} = \frac{-f}{-f+v}$$

$$\Rightarrow \quad -fv - fu + uv = 0$$

$$uv = fv + fu$$

Dividing both sides by uvf, we get,

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

(b) Lens-maker formula,

$$\frac{1}{f} = (\mu-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$$

$$\frac{1}{f} = (1.5-1)\left[\frac{1}{20}-\frac{1}{\infty}\right]$$

$$\frac{1}{f} = \frac{0.5}{20}=\frac{1}{40}$$

$\Rightarrow$ $f = 40$ cm

Now, $\dfrac{1}{f} = \dfrac{1}{v}-\dfrac{1}{u}$

$$\frac{1}{40} = \frac{1}{v}-\frac{1}{(-30)}$$

$$\frac{1}{v} = \frac{1}{40}-\frac{1}{30}$$

$$v = \frac{-40\times 30}{10}$$

$$v = -120 \text{ cm}$$

Image is virtual, erect and enlarged in front of lens 120 cm away.