Class: XII

SESSION : 2022-2023

SUBJECT: PHYSICS (THEORY)

SAMPLE QUESTION PAPER - 23

with SOLUTION

Maximum Marks: 70 Marks **Time Allowed**: 3 hours.

General Instructions:

(1) There are 35 questions in all. All questions are compulsory

(2) This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.

(3) Section A contains eighteen MCQ of 1 mark each, Section B contains seven questions of two marks each, Section C contains five questions of three marks each, section D contains three long questions of five marks each and Section E contains two case study based questions of 4 marks each.

(4) There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.

5. Use of calculators is not allowed.

Section A

1. A wire of resistance R is stretched till its length is double of the original wire. Then, the resistance of the stretched wire is: **[1]**

a) 8R b) 4R

c) 2R d) 16R

2. A stationary swimmer S inside a liquid of refractive index μ_1 is at a distance d from a fixed point P inside a liquid. A rectangular block of width t and refractive index μ_2 $(\mu_2 < \mu_1)$ is now placed between S and P. Now S will observe P to be at a distance: **[1]**

a) $d - t\left[1 - \frac{\mu_2}{\mu_1}\right]$ b) $d + t\left[\frac{\mu_1}{\mu_2} - 1\right]$

c) $d - t\left[\frac{\mu_1}{\mu_2} - 1\right]$ d) $d + t\left[1 - \frac{\mu_2}{\mu_1}\right]$

3. One serious drawback of semiconductor devices is, that: **[1]**

a) they do not last for long time b) they pollute the environment

c) they are costly d) they cannot be used to withstand high voltage

4. The difference in the variation of resistance with temperature in a metal and a semiconductor arises essentially due to the difference in: **[1]**

a) scattering mechanism with temperature b) crystal stmcture

c) number of charge carriers with temperature

d) type of bonding

5. When a dielectric slab is removed electric field becomes 4.8×10^5 V/m. If the original field was 6×10^5 V/m, the dielectric constant of dielectric material is: [1]

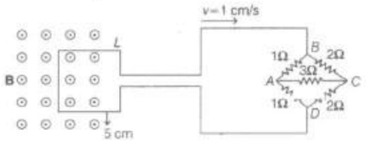
a) 0.8

b) 2

c) 7.6

d) 8

6. The figure shows a square loop L of side 5 cm which is connected to a network of resistances. The whole setup is moving towards right with a constant speed of 1 cm s^{-1}. At some instant, a part of L is in a uniform magnetic field of 1 T, perpendicular to the plane of the loop. If the resistance of L is 1.7 Ω, the current in the loop at that instant will be close to [1]



a) 150 μA

b) 60 μA

c) 115 μA

d) 170 μA

7. The scale of a galvanometer of resistance 100Ω contains 25 divisions. It gives a deflection of one division on passing a current of $4 \times 10^{-4} A$. The resistance in ohms to be added to it so that it may become a voltmeter of range 2.5 volt is [1]

a) 100

b) 250

c) 300

d) 150

8. For ionising, an excited hydrogen atom, the energy required (in eV) will be [1]

a) more than 13.6 eV

b) a little less than 13.6

c) 13.6

d) 3.4 or less

9. The phenomenon of rotation of plane polarised light is called: [1]

a) dichroism

b) double refraction

c) optical activity

d) Kerr effect

10. In n-type semiconductors, majority charge carriers are [1]

a) holes

b) protons

c) electrons

d) neutrons

11. An electric dipole has a pair of equal and Opposite point charges q and - q separated by a distance 2x. The axis of the dipole is defined as: [1]

a) perpendicular to the line joining the two charges drawn at the centre and pointing downward direction

b) direction from negative charge to positive charge

c) direction from positive charge to negative charge

d) perpendicular to the line joining the two charges drawn at the centre and pointing upward direction

12. The threshold wavelength for a metal having work function W_0 is λ_0. What is the threshold wavelength for a metal whose work function is $\frac{W_0}{2}$? **[1]**

a) $4\lambda_0$

b) $\frac{\lambda_0}{4}$

c) $2\lambda_0$

d) $\frac{\lambda_0}{2}$

13. Why is the refractive index in a transparent medium greater than one? **[1]**

a) Because the speed of light in a vacuum is always greater than speed in a transparent medium

b) Frequency of wave changes when it crosses the medium

c) Because the speed of light in a vacuum is always less than speed in a transparent medium

d) None of these

14. The fact that light is a transverse wave phenomenon derives its evidential support from the observation that: **[1]**

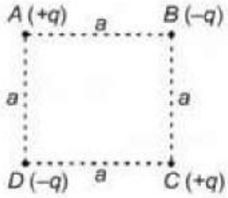
a) light can be diffracted

b) light shows polarising effects

c) light is a wave motion

d) light is characterised by interference

15. There are four point charges +q, -q, +q and -q are placed at the corners A, B, C, and D respectively of a square of side a. The potential energy of the system is $\frac{1}{4\pi\varepsilon_0}$ times. **[1]**



a) $\frac{q^2}{a}(-4+\sqrt{2})$

b) $\frac{-4\sqrt{2q^2}}{a}$

c) $\frac{q^2}{2a}(-4+\sqrt{2})$

d) $\frac{4q^2}{a}$

16. **Assertion (A):** Neutrons penetrate matter more readily as compared to protons. **[1]**
Reason (R): Neutrons are slightly more massive than protons.

a) Both A and R are true and R is the correct explanation of A.
b) Both A and R are true but R is not the correct explanation of A.
c) A is true but R is false.
d) A is false but R is true.

17. **Assertion (A):** It is necessary to use satellites for long distance T.V. transmission. **[1]**
Reason (R): The television signals are low frequency signals.

a) Both A and R are true and R is the correct explanation of A.
b) Both A and R are true but R is not the correct explanation of A.
c) A is true but R is false.
d) A is false but R is true.

18. **Assertion (A):** The tangent galvanometer can be made more sensitive by increasing the number of turns of its coil. **[1]**
Reason (R): Current through galvanometer is inversely proportional to the number of turns of coil.

a) Both A and R are true and R is the correct explanation of A.
b) Both A and R are true but R is not the correct explanation of A.
c) A is true but R is false.
d) A is false but R is true.

Section B

19. Carbon and silicon are known to have similar lattice structures. However, the four bonding electrons of carbon are present in second orbit while those of silicon are present in its third orbit. How does this difference result in a difference in their electrical conductivities? **[2]**

20. Define ionization energy. How would the ionization energy change when electron in hydrogen atom is replaced by a particle of mas 200 times that of the electron but having the same charge? **[2]**

21. In a centre trap full wave rectifier, the load resistance $R_L = 1\ k\Omega$. Each diode has a forward bias dynamic resistance of 10Ω. The voltage across half the secondary winding is 220 sin 314t. Find **[2]**
   i. the peak value of current
   ii. the dc value of current and
   iii. the rms value of current

22. A plane e.m. wave is propagating in the x-direction has a wavelength of 6.0 mm. The electric field is in the y-direction and its maximum magnitude is $33\ Vm^{-1}$. Write suitable equations for the electric and magnetic fields as a function of x and t. **[2]**

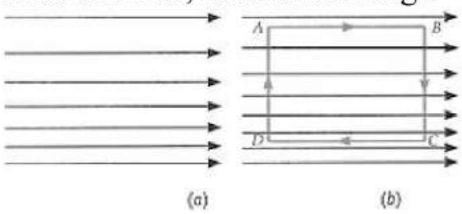
OR

The magnetic field of a beam emerging from a filter facing a floodlight is given by $B_0 = 12 \times 10^{-8} \sin(1.20 \times 10^7 z - 3.60 \times 10^{15} t)$ T. What is the average intensity of the beam?

23. i. Write two main observations of the photoelectric effect experiment which could only be explained by Einstein's photoelectric equation. **[2]**

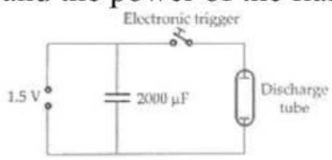
ii. Draw a graph showing the variation of photocurrent with the anode potential of a photocell.

24. Is it possible to create an electric field in which all the lines of force are parallel lines and whose density increases gradually in a direction perpendicular to the lines of force, as shown in Fig.? **[2]**



OR

In a camera-flash circuit (Fig.), 2000 μF capacitor is charged by a 1.5 V cell. When a flash is required, the energy stored in the capacitor is discharged by means of a trigger T through a discharge tube in 0.1 milliseconds. Find the energy stored in the capacitor and the power of the flash.



25. The nucleus $^{23}_{10}Ne$ decays by β^- emission. Write down the β -decay equation and determine the maximum kinetic energy of the electrons emitted. Given that: $m\left(^{23}_{10}Ne\right) = 22.994466$ u and $m\left(^{23}_{11}Na\right) = 22.989770$ u. **[2]**

Section C

26. It is found experimentally that 13.6 eV energy is required to separate a hydrogen atom into a proton and an electron. Compute the orbital radius and the velocity of the electron in a hydrogen atom. **[3]**

27. Two sources S_1 and S_2 emitting light of wavelength 600 nm placed 0.1 mm apart. A detector is moved on the line S_1P which is perpendicular to S_1S_2. **[3]**

i. What would be the minimum and maximum path difference at the detector as it is moved along the line S_1P.

ii. Locate the position of farthest minimum detected.

28. Name the parts of the electromagnetic spectrum which is **[3]**

i. suitable for RADAR systems in aircraft navigations.

ii. used to treat muscular strain.

iii. used as a diagnostic tool in medicine.

Write in brief, how these waves can be produced.

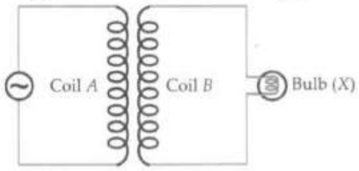
OR

State clearly how a microwave oven works to heat up a food item containing water molecules. Why are microwaves found useful for the raw systems in aircraft navigation?

29. Deduce an expression for the mutual inductance of two long coaxial solenoids but having different radii and different number of turns. **[3]**

OR

Figure given below shows an arrangement by which current flows through the bulb (X) connected with coil B, when a.c. is passed through coil A.
Explain the following observations:



i. Bulb lights up.
ii. Bulb gets dimmer if the coil 'B' is moved upwards.
iii. If a copper sheet is inserted in the gap between the coils how the brightness of the bulb would change?

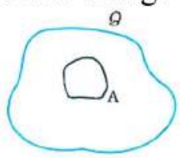
30. A short bar magnet placed with its axis at 30° with a uniform external magnetic field of 0.16 T experiences a torque of magnitude 0.032 J. **[3]**

a. Estimate the magnetic moment of the magnet.
b. If the bar were free to rotate, which orientations would correspond to its
   i. stable, and
   ii. unstable equilibrium?

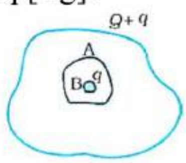
What is its potential energy in the field for cases (i) and (ii)?

Section D

31. a. A conductor A with a cavity as shown in fig is given a charge Q. Show that the entire charge must appear on the outer surface of the conductor. **[5]**



b. Another conductor B with charge q is inserted into the cavity keeping B insulated from A. Show that the total charge on the outside surface of A is Q + q [fig].



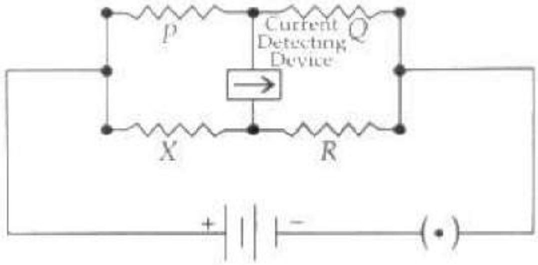
c. A sensitive instrument is to be shielded from the strong electrostatic fields in its environment. Suggest a possible way.

OR

i. Use Gauss's law to show that due to a uniformly charged spherical shell of radius R, the electric field at any point situated outside the shell at a distance r from its center is equal to the electric field at the same point, when the entire charge on the shell was concentrated at its center. Also plot the graph showing the variation of an electric field with r, for $r \leq R$ and $r \geq R$.

ii. Two-point charges of +1 μC and +4 μC is kept 30 cm apart. How far from the +1 μ C charge on the line joining the two charges, will the net electric field be zero?

32. i. Obtain the condition under which the current flowing, in the current detecting device, used in the circuit shown in the figure, becomes zero. **[5]**



ii. Describe briefly the device, based on the above question. Draw a circuit diagram for this device and discuss, in brief, how it is used for finding an unknown resistance.

33. a. Define magnifying power of a reflecting type telescope. Write its expression. **[5]**

b. A small telescope has an objective lens of focal length 150 cm and an eyepiece of focal length 5 cm. If this telescope is used to view a 100 m high tower 3 km away, find the height of the final image when it is formed 25 cm away from the eyepiece.

OR

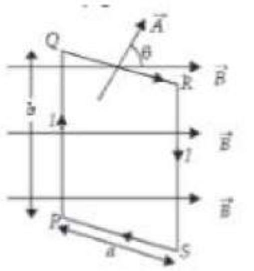
i. Draw a ray diagram for the formation of the image of a point object by a thin double convex lens having radii of curvatures R_1 and R_2 and hence, derive lens maker's formula.

ii. Define power of a lens and give its SI unit. If a convex lens of length 50 cm is placed in contact coaxially with a concave lens of focal length 20 cm, what is the power of the combination?

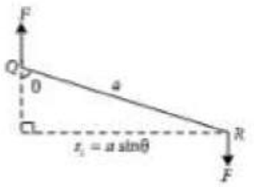
Section E

34. **Read the text carefully and answer the questions:** **[4]**

When a rectangular loop PQRS of sides a and b carrying current I is placed in uniform magnetic field $\vec{B}$, such that area vector $\vec{A}$ makes an angle θ with the direction of the magnetic field, then forces on the arms QR and SP of loop are equal, opposite and collinear, thereby perfectly cancel each other, whereas forces on the arms PQ and RS of loop are equal and opposite but not collinear, so they give rise to torque on the loop.



Force on side PQ or RS of loop is F = IbB sin 90^o = IbB and perpendicular distance between two non-collinear forces is r_1 = a sin θ



So, torque on the loop, $\tau = IAB\sin\theta$

In vector form torque, $\vec{\tau} = \vec{M} \times \vec{B}$

where $\vec{M} = NI\vec{A}$ is called magnetic dipole moment of current loop and is directed in direction of area vector $\vec{A}$ i.e., normal to the plane of loop.

(i) A circular loop of area 1 cm^2, carrying a current of 10 A is placed in a magnetic field of 0.1 T perpendicular to the plane of the loop. Calculate the torque acting on the loop due to the magnetic field.

(ii) Write the relation between magnetic moment and angular velocity of the coil.

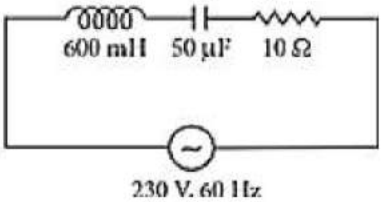
(iii) A current loop is lying in a magnetic field, what are conditions for it to be in stable and unstable equilibrium?

OR

How does the magnetic moment of a current I carrying circular coil of radius r and number of turns N varies with radius of the coil?

35. **Read the text carefully and answer the questions:** **[4]**

In an a.c. circuit, values of voltage and current change every instant. Therefore, the power of an a.c. circuit at any instant is the product of instantaneous voltage (E) and instantaneous current (I). The average power supplied to a pure resistance R over a complete cycle of a.c. is P = $E_v I_\gamma$. When the circuit is inductive, the average power per cycle is $E_v I_v \cos\phi$



In an a.c. circuit, 600 mH inductor and a 50 μF capacitor are connected in series with 10 Ω resistance. The a.c. supply to the circuit is 230 V, 60 Hz.

(i) What will be the value of average power transferred per cycle to the resistance?

(ii) What will be the value of the average power transferred per cycle to the capacitor?

(iii) What will be the total power transferred per cycle by all three circuit elements?

OR

What will be the electrical energy spent in running the circuit for one hour?

SOLUTION

Section A

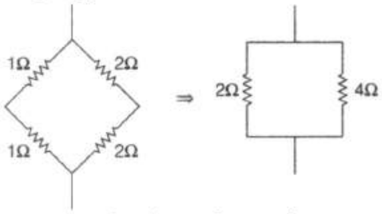
1. **(b)** 4R
   Explanation: Resistance R of a wire of length l and radius r with specific resistance K for its material is given by:
   $R = Kl/\pi r^2$ ...(i)
   As the wire is stretched, there is no change in its mass M. But $M = \pi r^2 ld$,
   So, $\pi r^2 = M/ld$
   Hence, $R = \frac{Kl}{M/ld} = \left(\frac{Kd}{M}\right) l^2$ ...(ii)
   Let the resistance of the stretched wire be R'; then
   $R' = \left(\frac{Kd}{M}\right)(2l)^2 = 4R$
2. **(b)** $d + t\left[\frac{\mu_1}{\mu_2} - 1\right]$
   Explanation: The refractive index of the block relative to medium surrounding is:
   $\mu = \frac{\mu_2}{\mu_1}$
   When the block is introduced, P will appear to move towards S through a distance t'.
   Where $t' = t\left[1 - \frac{1}{\mu}\right]$
   $= t\left[1 - \frac{\mu_1}{\mu_2}\right] < 0$
   Apparent distance from S to P
   = d - t'
   $= d + t\left[\frac{\mu_1}{\mu_2} - 1\right]$
3. **(d)** they cannot be used to withstand high voltage
   Explanation: We know that conductivity of semiconductors is affected by varying the voltage (as resistivity of semiconductor devices decreases with increase in temperature). Therefore, the serious drawback of semiconductor devices is that they cannot be used to withstand high voltage.
4. **(c)** number of charge carriers with temperature
   Explanation: Metal has number of free electrons while semiconductor has not at room temperature. The difference in the variation of resistance with temperature in metal and semiconductor is caused due to difference in the variation of the number of charge carriers with temperature.
5. **(a)** 0.8
   Explanation: By using,
   $K = \frac{E_{\text{without dielectric}}}{E_{\text{with dielectric}}} = \frac{4.8 \times 10^5}{6 \times 10^5} = 0.8$
6. **(d)** 170 μA
   Explanation:
   Induced emf in the conductor of length L moving with velocity of 1 cm/s in the magnetic field of 1T is given by
   V = BLv ......(i)

If equivalent resistance of the circuit is Req, then current in the loop will be

$i=\frac{V}{R_{\text{eq}}}=\frac{BLv}{R_{\text{eq}}}$ .....(ii)

Now, given network is a balanced Wheatstone bridge $\left(\frac{P}{Q}=\frac{R}{S}\right)$.

So, equivalent resistance of the Wheatstone bridge is



$R_W=\frac{2\times4}{2+4}=\frac{8}{6}=\frac{4}{3}\Omega$

Again, resistance of conductor is 1.7 Ω.

So, effective resistance will be

$R_{\text{eq}}=\frac{4}{3}+1.7=\frac{4}{3}+\frac{17}{10}$

$R_{\text{eq}}=\frac{40+51}{30}=\frac{91}{30}\simeq 3\Omega$

By putting given values of R_{eq}, B and v in

Eq. (ii), we have

$i=\frac{(1)\left(5\times10^{-2}\right)\times10^{-2}}{3}$

[here, L = 5×10^{-2}m, v = 1 cm/s = 10^{-2} m/s]

$i=\frac{5\times10^{-4}}{3}=1.67\times10^{-4}\text{A}$

$i=167\mu\text{A}\approx170\mu\text{A}$

7. **(d)** 150

   Explanation: $R=\frac{V}{I_g}-G$

   V = 2.5 V ; G = 100 Ohm ; $I_g\ =0.01\ A$

   On solving we get,

   R = 150 Ohm
8. **(d)** 3.4 or less

   Explanation: The energy of the electron is -3.4 eV in first excited state and the magnitude is less for higher excited states.
9. **(c)** optical activity

   Explanation: The phenomenon of rotation of plane-polarized light is called optical activity.
10. **(c)** electrons

    Explanation: The more abundant charge carriers are called majority carriers, which are primarily responsible for current transport in a piece of semiconductor. In n-type semiconductors, they are electrons, while in p-type semiconductors, they are holes.
11. **(b)** direction from negative charge to positive charge

    Explanation: The torque acting on a dipole in a uniform external field $\vec{E}$ is $\vec{\tau}=\vec{P}\times\vec{E}$ or PE sin θ and its direction is perpendicular to E and also P (P = q2x, where 2x is the distance between the positive and negative charges).
12. **(c)** $2\lambda_0$

    Explanation: Work function, $W_0=\frac{hc}{\lambda_0}$ (where λ_0 is the threshold wavelength) or $W_0 \propto \frac{1}{\lambda_0}$

$\therefore \quad \frac{W_0}{W_0'} = \frac{\lambda_0'}{\lambda_0}$

or $\frac{W_0}{W_0/2} = \frac{\lambda_0'}{\lambda_0}$ or $\lambda_0' = 2\lambda_0$

13. **(a)** Because the speed of light in a vacuum is always greater than speed in a transparent medium

    Explanation: $\{\mu v\}_{vacuum} = \{\mu v\}_{medium}$

    $\Rightarrow \mu_{medium} = \frac{speedoflightinvacuum}{speedoflightingivenmedium}$

    Here refractive index of the medium is inversely proportional to the speed of light in the medium. As the refractive index of vacuum is 1, the speed of light is always greater in vacuum as compared to transparent medium. Hence, the refractive index of a transparent medium is always greater than one.
14. **(b)** light shows polarising effects

    Explanation: light shows polarising effects
15. **(a)** $\frac{q^2}{a}(-4+\sqrt{2})$

    Explanation: $\frac{q^2}{a}(-4+\sqrt{2})$
16. **(b)** Both A and R are true but R is not the correct explanation of A.

    Explanation: Both A and R are true but R is not the correct explanation of A.
17. **(c)** A is true but R is false.

    Explanation: The television signals being of high frequency are not reflected by the ionosphere. So the T.V. signals are broadcasted by tall antenna to get large coverage, but for transmission over large distance satellites are needed. That is why, satellites are used for long distance T.V. transmission.
18. **(b)** Both A and R are true but R is not the correct explanation of A.

    Explanation: In tangent galvanometer the current through the coil is given by I = $\frac{2a}{N\mu_0}$. B_H tan θ.

    Where a = radius of coil, N = number of turns, θ = deflection of the needle. Tan $\theta \propto \frac{N}{a}$. So for the same current passing through the coil, by reducing its radius or by increasing number of turns of coil we can increase the sensitivity of tangent galvanometer.

Section B

19. The energy required to take out an electron from Si atom is much smaller than that in the case of C atom. Hence the number of free electrons for conduction in Si is quite significant but negligibly small for C. Consequently the conductivity of silicon is much greater than that of carbon.
20. Ionisation energy is defined as the energy required to free an electron from the ground state of an atom.

    I.E. $= E_\infty - E_1 = \frac{2\pi^2 mk^2e^4}{h^3} \Rightarrow$ I.E. $\propto m$

    Thus the I.E. will become 200 times that of the electron.
21. The voltage across half the secondary winding is V = 200 sin 314t
    i. Peak value of voltage, V_0 = 220 V

    $\therefore$ Peak value of current is

$I_0 = \frac{V_0}{r_d + R_L} = \frac{220}{10+1000} = 0.2178$ A = 217.8 mA

ii. d.c. value of current,

$I_{dc} = \frac{2I_0}{\pi} = 2 \times 0.637 \times 217.8 = 138.66$ mA

iii. rms value of current is

$I_{rms} = \frac{I_0}{\sqrt{2}} = 0.707 \times 217.8 = 154$ mA

22. Here $\lambda = 6.0$ mm $= 6 \times 10^{-3}$ m,

$E_0 = 33$ Vm^{-1}

$\omega = 2\pi\nu = \frac{2\pi c}{\lambda} = \frac{2\pi \times 3 \times 10^8}{6 \times 10^{-3}} = \pi \times 10^{11}$ rad s^{-1}

$B_0 = \frac{E_0}{c} = \frac{33}{3 \times 10^8} = 1.1 \times 10^{-7}$T

The equation for the electric field along y-axis can be written as

$E = E_y = E_0 \sin\omega\left(t - \frac{x}{c}\right)$

$= 33\sin\pi \times 10^{11}\left(t - \frac{x}{c}\right) \mathrm{Vm}^{-1}$

The equation for the magnetic field along z-axis can be written as

$B = B_Z = = B_0 \sin\omega\left(t - \frac{x}{t}\right)$

$= 1.1 \times 10^{-7} \sin\pi \times 10^{11}\left(t - \frac{x}{c}\right)$ tesla.

OR

The standard equation of magnetic field can be expressed as $B = B_0 \sin \omega t$.

We are given equation

$B = 12 \times 10^{-8} \sin(120 \times 10^7 z - 3.60 \times 10^{15} t)$T

On comparing this equation with standard equation, we get

$B_0 = 12 \times 10^{-8}$ T and

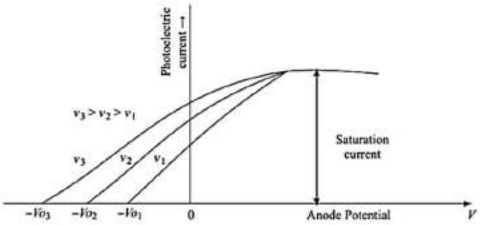
The average intensity of the beam is given by :-

$I_{\mathrm{av}} = \frac{1}{2}\frac{B_0^2}{\mu_0} \cdot c = \frac{1}{2} \times \frac{\left(12 \times 10^{-8}\right)^2 \times 3 \times 10^8}{4\pi \times 10^{-7}}$

$= 1.71$ W/m^2

23. i. The two main observation of the photoelectric effect experiment which could only be explained by Einstein's photoelectric equations are:
    a. The photoelectric emission is an instantaneous process
    b. For a given photosensitive material, there exists a certain minimum cutoff frequency below which no photoelectrons are emitted, howsoever high is the intensity of incident radiations. This frequency is called the threshold frequency.
    c. The reverse potential at which the photo-current stops (stopping potential) is independent of the intensity of light. Therefore, no matter how intense your source of light is, it can’t defeat the stopping voltage.

ii.



24. No. This is not possible because the work done in carrying a test charge along a closed path ABCDA, as shown in Fig. (b), will not be zero. More work is done along CD, less along AB, zero along BC and DA. But in an electric field, work done is essentially zero as it is a conservative field.

OR

Here C = 2000 μF = 2 × 10^{-3} F, V = 1.5 V

Energy stored in the capacitor,

U = $\frac{1}{2}$ CV^2 = $\frac{1}{2}$ × 2 × 10^{-3} × $(1.5)^2$ = 2.25 × 10^{-3} J

Time during which capacitor is discharged for producing flash,

t = 0.1 millisecond = 0.1 × 10^{-3} s = 10^{-4} s

Power of flash,

$P = \frac{U}{t} = \frac{2.25 \times 10^{-3}}{10^{-4}}$ = 22.5W

25. The β -decay of ${}_{10}^{23}Ne$ may be represented as ${}_{10}^{23}Ne \rightarrow_{11}^{23} Na - e_{-1}^{0} + \overline{\nu} + Q$

Ignoring the rest mass of antineutrino $(\overline{\nu})$ and electron

Mass defect, $\Delta m = m\left({}_{10}^{23}Ne\right) - m\left({}_{11}^{23}Na\right)$

= 22.994466 - 22.989770

= 0.004696 u

$Q = 0.004696 \times 931\ MeV$ = 4.372 MeV

As ${}_{11}^{23}Na$ is very massive, this energy of 4.3792 MeV, is shared by e^{-} and $\overline{\nu}$ pair. The maximum K.E. of e^- = 4.372 MeV, when energy carried by $\overline{\nu}$ is zero.

Section C

26. Total energy of the electron in hydrogen atom is –13.6 eV = –13.6 × 1.6 × 10^{-19} J = –2.2 × 10^{-18} J.

Thus from Eq., we have

$-\frac{e^2}{8\pi\varepsilon_0 r}$ = E

This gives the orbital radius

$r = -\frac{e^2}{8\pi\varepsilon_0 E} = -\frac{\left(9\times10^{9}\mathrm{Nm}^2/\mathrm{C}^2\right)\left(1.6\times10^{-19}\mathrm{C}\right)^2}{(2)\left(-2.2\times10^{-18}\mathrm{J}\right)}$

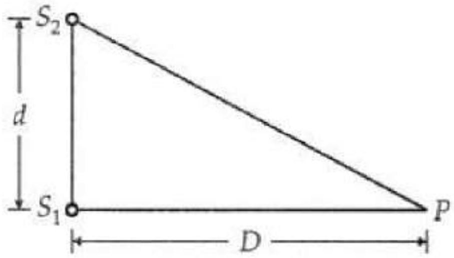
= 5.3 × 10^{-11} m

The velocity of the revolving electron can be computed from Eq. with m = 9.1 × 10^{-31} kg,

$\frac{1}{2}mv^2 = \frac{e^2}{4\pi\epsilon_0 r^2}$ thus velocity of electron is given by :-

$v = \frac{e}{\sqrt{4\pi\varepsilon_0 m r^2}} = \mathbf{2.2} \times \mathbf{10^6 m/s}$

27. i. The situation is shown in Fig. The path difference is minimum when the detector is at a large distance from S_1. Then the path difference is near to zero.



The path difference is maximum when the detector lies at point S_1.

$\therefore$ Maximum path difference = S_1S_2 = 0.1 mm

ii. The farthest minimum will occur at a point P for which the path difference is $\frac{\lambda}{2}$

Let S_1P = D. Then

$p = S_2P - S_1P = \frac{\lambda}{2}$

or $\sqrt{D^2 + d^2} - D = \frac{\lambda}{2}$

or $D^2 + d^2 = \left(D + \frac{\lambda}{2}\right)^2$

or $d^2 = D\lambda + \frac{\lambda^2}{4}$

or $D = \frac{d^2}{\lambda} - \frac{\lambda}{4} = \frac{\left(0.1\times10^{-3}\right)^2}{600\times10^{-9}} - \frac{600\times10^{-9}}{4}$

$= \frac{1}{60} - 150 \times 10^{-9} = \simeq \frac{1}{60}$ m = 1.7 cm

28. i. The EM waves suitable for radar systems are microwaves. These rays are produced by special vacuum tubes, namely klystrons, magnetrons and Gunn diodes.

ii. Infrared waves are used to treat muscular strain. These rays are produced by hot bodies and vibration of molecules and atoms. For example, hot charcoal emits infrared radiation not the visible light to give the sensation of heat.

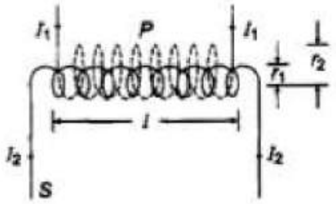
iii. X-rays are used as a diagnostic tool in medicine. These rays are produced when high energy electrons emitted from cathode are stopped suddenly on a metal (anode) of high atomic number in an X-ray tube.

OR

In a microwave oven, the frequency of the microwaves is selected to match the resonant frequency of water molecules. This leads to the vibrations of these water molecules. As these vibrations increase with time, the temperature increases leading to the production of heat and this is the heat that is responsible for the cooking of food in the oven. So any food containing water molecules inside can be heated by a microwave oven.

Microwaves are short-wavelength radio waves, with the frequency of the order of 300 MHz to 300 GHz. Due to the short wavelengths, they have high penetrating power with respect to the atmosphere and less diffraction in the atmospheric layers. So, these waves are suitable for the RADAR (Radio Detection And Ranging) systems used in aircraft navigation.

29. Let coaxial solenoid P is wound over an another solenoid.



Let l = length of both solenoid

r_1 and r_2 = radii of P and S

$A_2 = \pi r_2^2$ [area of secondary coil, S]

Magnetic induction in solenoid, P

$B_1 = \mu_0 n_1 I_1$

where, $n_1 = \frac{N_1}{l}$

∴Total flux linked with solenoid S,

$\phi_2 = B_1 A_2 N_2$

$\Rightarrow \quad \phi_2 = B_1 \left(\pi r_2^2\right) N_2 = (\mu_0 n_1 I_1) \pi r_2^2 N_2$

$\phi_2 = \left(\mu_0 \frac{N_1}{l} I_1\right) \pi r_2^2 N_2$

$\Rightarrow \quad \phi_2 = \frac{\mu_0 \pi I_1 N_1 N_2 r_2^2}{l}$ ...(i)

But $\phi_2 = M I_1$

were, M = coefficient of mutual induction

$\Rightarrow M I_1 = \frac{\mu_0 \pi N_1 N_2 r_2^2}{l} I_1 \Rightarrow M = \frac{\mu_0 \pi N_1 N_2 r_2^2}{l}$

OR

i. Bulb lights up due to the induced current set up in coil B because of alternating current in coil A.
ii. Bulb gets dimmer when coil B is moved upwards because the flux linked with coil B decreases and induced current also decreases.
iii. When the copper sheet is inserted, eddy currents are set up in it which oppose the passage of magnetic flux. The induced emf in coil B decreases. This decreases the brightness of the bulb.

30. a. Here $\theta = 30^o$, B = 0.16T, τ = 0.032 J

Magnetic moment,

$m = \frac{\tau}{B \sin \theta} = \frac{0.032}{0.16 \times \sin 30^\circ} = 0.40 \text{ JT}^{-1}$

b. Potential energy of the dipole in a magnetic field $\vec{B}$ is given by

$U = -\vec{m} \cdot \vec{B} = -mB \sin \theta$

i. The bar will be in stable equilibrium when its magnetic moment $\vec{m}$ is parallel to $\vec{B}$ ($\theta = 0°$). Its potential energy is then minimum and is given by

$U_{min} = -mB \cos 0^o = -mB$

$= -0.40 \times 0.16 = -0.064$ J

ii. The bar will be in unstable equilibrium when $\vec{m}$ is antiparallel to $\vec{B}$ (θ =180°). Its potential energy is then maximum and is given by

$U_{max} = -mB \cos 180^o = + mB = +0.064$ J

Section D

31. a. Let us consider a Gaussian surface that is Iying wholly within a conductor and enclosing the cavity. The electric field intensity E inside the charged conductor is zero. Let q is the charge inside the conductor and $\in_o$ is the permittivity of free space. According to Gauss's law,

Flux, $\phi = \overrightarrow{E}.\overrightarrow{ds} = \frac{q}{\epsilon_0}$

Here, E = 0

$\frac{q}{\epsilon^0} = 0$

$\therefore \epsilon_o \neq 0$

$\therefore$ q = 0

Therefore, the charge inside the conductor is zero.

The entire charge Q appears on the outer surface of the conductor.

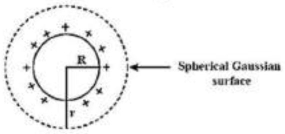
b. The outer surface of conductor A has a charge of amount Q. Another conductor B having charge +q is kept inside conductor A and it is insulated from A. Hence, a charge of the amount -q will be induced in the inner surface of conductor A and +q is induced on the outer surface of conductor A. Therefore, the total charge on the outer surface of conductor A is Q+q.

c. A sensitive instrument can be shielded from the strong electrostatic field in its environment by enclosing it fully inside a metallic surface. A closed metallic body acts as an electrostatic shield.

OR

i. Let Surface charge density of spherical shell = λ

Radius = R, Consider Spherical Gaussian surface of radius = r



from Gauss Law

$\phi = \frac{q_{in}}{\epsilon_0}$

$= \frac{\lambda \times 4\pi r^2}{\in_0}$

$\phi = \frac{4\pi\lambda R^2}{\epsilon_0}$ ...(i)

Also, $\phi = \overrightarrow{E} \cdot \overrightarrow{A} = E\left(4\pi r^2\right)$ ...(ii)

From equation (i) and (ii)

$E\left(4\pi r^2\right) = \frac{4\pi\lambda R^2}{\epsilon_0}$

$E = \frac{\lambda R^2}{\in_0 r^2}$ ...(iii)

$\therefore \lambda = \frac{\theta}{4\pi R^2}$ or $\lambda R^2 = \frac{\theta}{4\pi}$

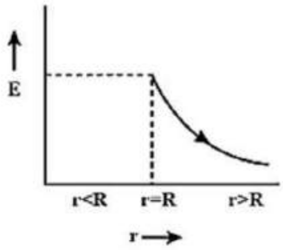
$E = \frac{\theta}{4\pi\epsilon_0 r^2}$ ......(iv) hence, From equation (iv)

Electric field only depend on charge enclosed and location of point.

Therefore charge with either on canter or surface enclose charge by Gaussian surface (r > R) will not change

$\therefore$ Hence it is proved.

Case(1) If r < R



this graph shows the variation of electric field with radius r

Charge enclose, $q_{in} = 0$

$E = 0$

Case(2) If r > R

$E = \frac{\theta}{4\pi\epsilon_o r^2}$

ii. Given that,

First point charge = +1 μC

Second point charge = +4 μC

Distance = 30 cm

Let us consider the net electric field zero at x distance from first charge.

Using formula of electric field

$E_X = E_{30\text{-}x}$

$\frac{kq_1}{r^2} = \frac{kq_2}{r'^2}$

Put the value into the formula

$\frac{1\times10^{-6}}{x^2} = \frac{4\times10^{-6}}{(30-x)^2}$

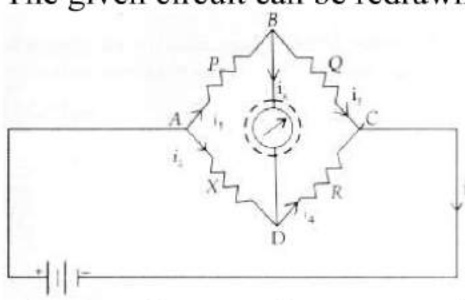
$\frac{(30-x)^2}{x^2} = \frac{4\times10^{-6}}{1\times10^{-6}}$

$\frac{30-x}{x} = \sqrt{\frac{4}{1}}$,

30 - x = 2x

x = 10 cm

32. i. The given circuit can be redrawn as shown :



It is, therefore, a Wheatstone Bridge. Therefore, we have to find the bridge balance condition

Using Kirchhoff's laws, we get (when $i_g = 0$)

$i_1 = i_3$

and $i_2 = i_4$

For the loop ABDA, we have

$-i_1P + i_2X = 0$ or $i_1P = i_2X$

For the loop BCDB, we have,

$-i_3Q + i_4R = 0$ or $i_3Q = i_4R$

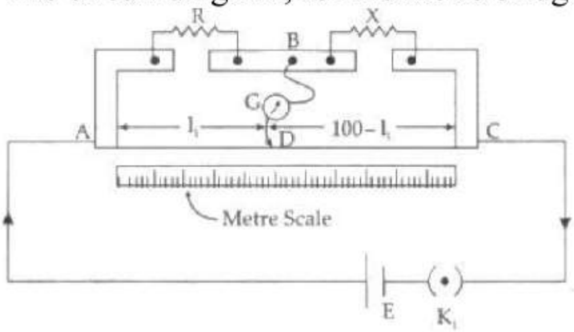
Dividing we get,

$\frac{i_1 P}{i_3 Q} = \frac{i_2 X}{i_4 R}$

or $\frac{P}{Q} = \frac{X}{R}$ ($\because i_1 = i_3$ and $i_2 = i_4$)

ii. A simple device, based on the above condition, is the metre bridge. It has a (uniform cross-section) wire of length 1 m stretched out between two thick metallic clamps. It has two gaps for connection a resistance box and the unknown resistance.

The circuit diagram, for the metre bridge, is shown here.



We move the jockey, on the wire of the meter bridge, till we find a point at which the deflection in G, is zero, we can have(value of R is known to us)

$\frac{R}{l_1} = \frac{X}{l_2}$

or X = $R\left(\frac{l_2}{l_1}\right)$

Knowing R, and finding l_1 and $l_2 = (100 - l_1)$, we can easily calculate X. (Unknown resistance)

33. a. Magnifying power of reflecting type telescope is the ratio of the angle subtended at the eye by the image to the angle subtended at the unaided eye by the object. Mathematically, we can write

m = $\frac{f_0}{f_e}$ Or $m = \frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$

where, f_o is the focal length of the objective, f_e is the focal length of the eye-piece.

b. Using, the lens equation for objective lens,

$\frac{1}{f_0} = \frac{1}{v_0} - \frac{1}{u_0}$

$\Rightarrow \frac{1}{150} = \frac{1}{v_0} - \frac{1}{-3\times10^5}$

$\Rightarrow \frac{1}{150} - \frac{1}{3\times10^5} = \frac{1}{v_o}$

$\Rightarrow v_o = \frac{3\times10^5}{1999} = 150$ cm

Hence, magnification due to the objective lens is given by,

$m_o = \frac{\mathbf{v_o}}{\mathbf{u_o}} = \frac{150\times10^{-2}}{3000} = \frac{10^{-2}}{20}$

$\Rightarrow m_o = 0.05 \times 10^{-2}$

Now, using lens formula for eye-piece, we get

$\frac{1}{f_e} = \frac{1}{v_e} - \frac{1}{u_e}$

$\Rightarrow \frac{1}{5} = \frac{1}{-25} - \frac{1}{u_e}$

$\Rightarrow u_e = \frac{-25}{6}$ cm

Therefore, magnification due to eyepiece $m_e = \frac{-25}{-\frac{25}{6}} = 6$ cm

Hence, total magnification, $m = m_e \times m_o$

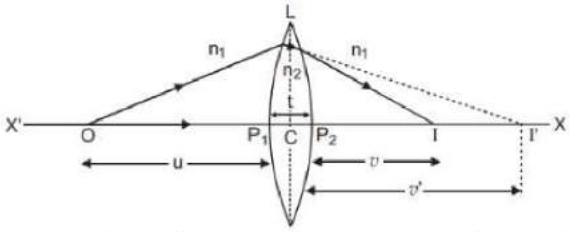
$m = 6 \times 5 \times 10^{-4}$

$= 30 \times 10^{-4}$

So, size of final image = $30 \times 10^{-4} \times 100$ m = 30 cm

OR

i. Consider the figure. Suppose L is a thin lens. The thickness of lens is t, which is very small. O is a point object on the principal axis of the lens. The distance of O from pole P_1 is u. The first refracting surface forms the image of O at I' at a distance v' from P_1.



From the refraction formula at spherical surface:

$\frac{n_2}{v'} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1}$ ....(i)

The image I' acts as a virtual object for second surface and after refraction at second surface, the final image is formed at I. The distance of I from pole P_2 of second surface is v. The distance of virtual object (I') from pole P_2 is (v' - t).

For refraction at second surface, the ray is going from second medium (refractive index n_2) to first medium (refractive index n_1), therefore from refraction formula at spherical surface

$\frac{n_1}{v} - \frac{n_2}{(v'-t)} = \frac{n_1 - n_2}{R_2}$ .....(ii)

For a thin lens, t is negligible as compared to v', therefore from (ii),

$\frac{n_1}{v} - \frac{n_2}{(v')} = -\frac{n_2 - n_1}{R_2}$ .....(iii)

Adding equations (i) and (iii), we get

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

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

If the object O is at infinity, the image will be formed at second focus i.e. if $u = \infty$, $v = f_2 = f$

Therefore from equation (iv)

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

i.e. $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ ....(v)

This is the formula of refraction for a thin lens. This formula is called Lens-Maker's Formula.

ii. **Power of a Lens:** The power of a lens is its ability to deviate the rays towards its principal axis. It is defined as the reciprocal of focal length in metres.

Power of a lens, $P = \frac{1}{f(\text{ in metres })}$ diopters $= \frac{100}{f(\text{ in cm})}$ diopters

The SI unit for power of a lens is dioptre (D).

Power of convex lens, $P_1 = \frac{1}{F_1} D = \frac{1}{0\cdot50} = 2$ D

Power of concave lens, $P_2 = \frac{1}{F_2}$D $= \frac{1}{-0\cdot20} = -5$ D

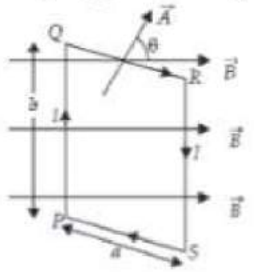
$\therefore$ Power of combination of lenses in contact

$P = P_1 + P_2 = 2 - 5 = -3$ D

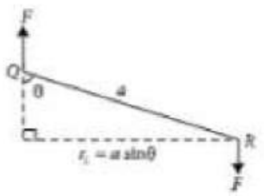
Section E

34. **Read the text carefully and answer the questions:**

When a rectangular loop PQRS of sides a and b carrying current I is placed in uniform magnetic field $\vec{B}$, such that area vector $\vec{A}$ makes an angle θ with the direction of the magnetic field, then forces on the arms QR and SP of loop are equal, opposite and collinear, thereby perfectly cancel each other, whereas forces on the arms PQ and RS of loop are equal and opposite but not collinear, so they give rise to torque on the loop.



Force on side PQ or RS of loop is F = IbB sin 90^o = IbB and perpendicular distance between two non-collinear forces is r_1 = a sin θ



So, torque on the loop, $\tau = IAB\sin\theta$

In vector form torque, $\vec{\tau} = \vec{M} \times \vec{B}$

where $\vec{M} = NI\vec{A}$ is called magnetic dipole moment of current loop and is directed in direction of area vector $\vec{A}$ i.e., normal to the plane of loop.

(i) zero

Torque on a current carrying loop in magnetic field, $\tau = IBA\sin\theta$

Here, I = 10A, B = 0.1 T, A = 1 $cm^2 = 10^{-4}$ m^2, $\theta = 0^o$

$\therefore \tau = 10 \times 0.1 \times 10^{-4} \sin 0^\circ = 0$

(ii) $M \propto \omega$

Magnetic moment, M = IA = $I\left(\pi r^2\right) = \frac{q}{T} \times \pi r^2$

As $\omega = \frac{2\pi}{T} \therefore M = \frac{q\omega r^2}{2}$ or $M \propto \omega$

(iii) It can be in equilibrium in two orientations, one stable while the other is unstable

When a current loop is placed in a magnetic field it experiences a torque. It is given by

$\vec{\tau} = \vec{M} \times \vec{B}$

where $\vec{M}$ is the magnetic moment of the loop and $\vec{B}$ is the magnetic field.

or $\tau = MB\sin\theta$ where θ is angle between M and B

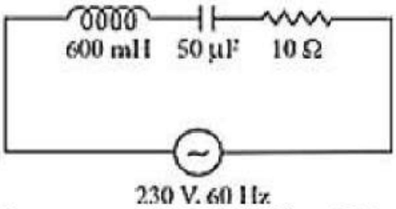
When $\vec{M}$ and $\vec{B}$ are parallel (i.e. $\theta = 0^o$) the equilibrium is stable and when they are antiparallel (i.e. $\theta = \pi$) the equilibrium is unstable.

OR

Magnetic moment, M = NIA = NI πr^2 i.e., M $\propto r^2$

35. **Read the text carefully and answer the questions:**

In an a.c. circuit, values of voltage and current change every instant. Therefore, the power of an a.c. circuit at any instant is the product of instantaneous voltage (E) and instantaneous current (I). The average power supplied to a pure resistance R over a complete cycle of a.c. is P = $E_v I_\gamma$. When the circuit is inductive, the average power per cycle is $E_v I_v \cos\phi$



In an a.c. circuit, 600 mH inductor and a 50 μF capacitor are connected in series with 10 Ω resistance. The a.c. supply to the circuit is 230 V, 60 Hz.

(i) Average power transferred per cycle to resistance is $P_v = I_v^2 R$

As $X_L = \omega L = 2\pi\nu L = 2 \times \frac{22}{7} \times 60 \times 0.6 = 226.28\ \Omega$

$X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C} = \frac{7}{2\times22/7\times60\times50\times10^{-6}}$

$= 53.03\ \Omega$

$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(10)^2 + (226.28 - 53.03)^2} = 173.53\ \Omega$

$I_V = \frac{E_v}{Z} = \frac{230}{173.53} = 1.32$ A

$P_V = I_v^2 R = (1.32)^2 \times 10 = 17.42$ W

(ii) $P_L = E_v I_v \cos\phi$

In a capacitor, phase difference, $\phi = 90^o$

$P_L = E_v I_v \cos 90^\circ$ = zero

(iii) Total power absorbed per cycle $P = P_R + P_C + P_L = 17.42 + 0 + 0 = 17.42$ W

OR

Energy spent = power $\times$ time

$= 17.42 \times 60 \times 60 = 6.2 \times 10^4$ Joule