SAMPLE QUESTION PAPER

BLUEPRINT

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

S. No.	Chapter	VSA/ AR/ Case Based (1 mark)	SA-I (2 marks)	SA-II (3 marks)	LA (5 marks)	Total
1.	Electrostatics	1(1)	2(4)	–	1(5)	**7(16)**
2.	Current Electricity	1(1)	1(2)	1(3)	–	
3.	Magnetic Effects of Current and Magnetism	1(1)	2(4)	1(3)	–	**8(17)**
4.	Electromagnetic Induction and Alternating Current	3(6)	–	1(3)	–	
5.	Electromagnetic Waves	1(1)	–	1(3)	–	**8(18)**
6.	Optics	4(7)	1(2)	–	1(5)	
7.	Dual Nature of Radiation and Matter	2(2)	1(2)	–	–	**6(12)**
8.	Atoms and Nuclei	1(1)	1(2)	–	1(5)	
9.	Electronic Devices	2(2)	1(2)	1(3)	–	**4(7)**
	Total	**16(22)**	**9(18)**	**5(15)**	**3(15)**	**33(70)**

Subject Code : 042

PHYSICS

Time allowed : 3 hours ***Maximum marks : 70***

(i) All questions are compulsory. There are 33 questions in all.

(ii) This question paper has five sections: Section A, Section B, Section C, Section D and Section E.

(iii) Section A contains ten very short answer questions and four assertion reasoning MCQs of 1 mark each, Section B has two case based questions of 4 marks each, Section C contains nine short answer questions of 2 marks each, Section D contains five short answer questions of 3 marks each and Section E contains three long answer questions of 5 marks each.

(iv) There is no overall choice. However internal choice is provided. You have to attempt only one of the choices in such questions.

SECTION - A

All questions are compulsory. In case of internal choices, attempt any one of them.

1. Write the expression for the de-Broglie wavelength associated with a charged particle having charge 'q' and mass 'm', when it is accelerated by a potential V.

OR

Which phenomenon best supports the theory that matter has a wave nature?

2. If A is the angle of prism, r angle of refraction, then what is the condition for minimum deviation?

3. Define one tesla using the expression for the magnetic force acting on a particle of charge 'q' moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$.

4. An electric dipole with dipole moment 4×10^{-9} C m is aligned at 30° with the direction of a uniform electric field of magnitude 5×10^{4} N C^{-1}. Calculate the magnitude of the torque acting on the dipole.

5. Draw the graph showing variation of the value of the induced emf as a function of rate of change of current flowing through an ideal inductor.

6. Name the phenomenon which shows the quantum nature of electromagnetic radiation.

OR

Define the term 'stopping potential' in relation to photoelectric effect.

7. Define 'quality factor' of resonance in series LCR circuit. What is its SI unit?

8. Assuming the nuclei to be spherical in shape, how does the surface area of a nucleus of mass number A_1, compare with that of a nucleus of mass number A_2.

OR

The gravitational force between a H-atom and another particle of mass m will be given by Newton's law: $F = G\frac{M.m}{r^2}$, where r is in km. What is the value of M?

9. In double-slit experiment using light of wavelength 600 nm, the angular width of a fringe formed on a distant screen is 0.1°. What is the spacing between the two slits?

10. What types of charge carriers are there in a (i) n-type semiconductor (ii) p-type semiconductor ?

OR

Is the ratio of number of holes and number of conduction electrons in a n-type extrinsic semiconductor more than, less than or equal to 1 ?

For question numbers 11, 12, 13 and 14, two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(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 and R is also false

11. **Assertion (A) :** Light is a transverse wave but not an electromagnetic wave.
Reason (R) : Maxwell showed that speed of electromagnetic waves is related to the permittivity of the medium through which it travels.

12. **Assertion (A) :** Bending a wire does not affect electrical resistance.
Reason (R) : Resistance of wire is proportional to resistivity of material.

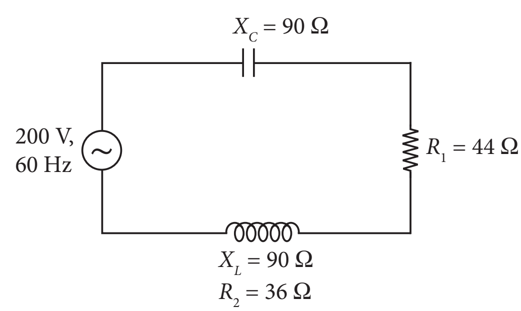
13. **Assertion (A) :** No interference pattern is detected when two coherent sources are infinitely close to each other.
Reason (R) : The fringe width is inversely proportional to the distance between the two slits.

14. **Assertion (A) :** An n-type semiconductor has a large number of electrons but still it is electrically neutral.
Reason (R) : An n-type semiconductor is obtained by doping an intrinsic semiconductor with a pentavalent impurity.

SECTION - B

Questions 15 and 16 are Case Study based questions and are compulsory. Attempt any 4 sub parts from each question. Each question carries 1 mark.

15. A series LCR circuit consist of series combination of a resistance, a inductor and a capacitance. A similar series LCR circuit is shown in figure. The given series LCR circuit is connected across a 200 V, 60 Hz line consisting of a capacitive reactance 30 Ω, a non-inductive resistor of 44 Ω and a coil of inductive reactance 90 Ω and resistance 36 Ω.



(i) Calculate the total impedance of the circuit.
(a) 1000 Ω (b) 100 Ω (c) 3600 Ω (d) 4900 Ω

(ii) Calculate the current flowing in the circuit.
(a) 1 A (b) 5 A (c) 2 A (d) 10 A

(iii) What is the impedance of the coil?
(a) 97 Ω (b) 87 Ω (c) 100 Ω (d) 110 Ω

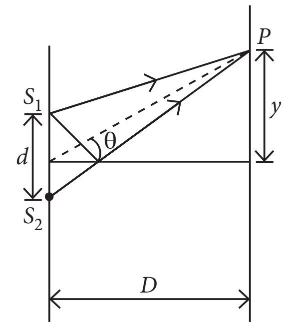
(iv) What is the pontential difference across the coil?

(a) 194 V (b) 186 V (c) 180 V (d) 190 V

(v) Calculate the power dissipiated in the coil.

(a) 100 W (b) 122 W (c) 130 W (d) 144 W

16. In Young's experiment, a source of light illuminates two parallel slits in an otherwise opaque surface. The light passing through the two slits is observed on a distant screen. When the widths of the slits are significantly greater than the wavelength of the light, the rules of geometrical optics hold. The light casts two shadows, and there are two illuminated regions on the screen. However, as the slits are narrowed in width, the light diffracts into the geometrical shadow and the light waves overlap on the screen. The superposition principle determines the resulting intensity pattern on the illuminated screen. Constructive interference occurs whenever the difference in paths from the two slits to a point on the screen equals an integral number of wavelengths. This path difference guarantees that crests from the two waves arrive simultaneously. Destructive interference arises from path differences that equal a half-integral number of wavelengths.



(i) When the screen is moved away from the plane of the slits, the fringe width will

(a) increases (b) decrease (c) remains unchanged (d) can not say

(ii) If the source is replaced by another source of shorter wavelength then the fringe width will

(a) increases (b) decrease (c) remains unchanged (d) can not say

(iii) If the separation between the two slits is decreased, the fringe width will

(a) increases (b) decrease (c) remains unchanged (d) can not say

(iv) Young's double slit experiment, if the width of 4^{th} bright fringe is 2×10^{-2} cm, then the width of 6^{th} bright fringe will be

(a) 10^{-2} cm (b) 3×10^{-2} cm (c) 2×10^{-2} cm (d) 1.5×10^{-2}

(v) If two slits in young's double slit experiment are of unequal width, then

(a) fringe width will change with the order of the fringes

(b) bright fringes will have unequal brightness

(c) the fringe will not appear

(d) the dark fringes are not perfectly dark.

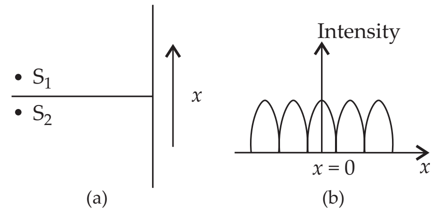
SECTION - C

All questions are compulsory. In case of internal choices, attempt anyone.

17. Two large parallel plane sheets have uniform charge densities $+\sigma$ and $-\sigma$. Determine the electric field (i) between the sheets, and (ii) outside the sheets.

18. What is photoelectric effect? Explain the effect of increase of (i) frequency (ii) intensity of incident radiation on photoelectrons emitted by a phototube.

19. Two source S_1 and S_2 of intensity I_1 and I_2 are placed in front of a screen [figure (a)]. The pattern of intensity distribution seen in the central portion is given by figure (b).



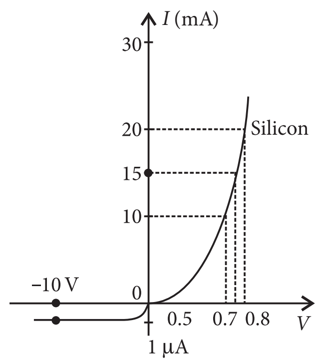
Give reason, why S_1 and S_2 will have the same intensity.

OR

Consider the diffraction pattern for a small pinhole. What effect does the size and intensity of the image will have as the size of the hole is increased?

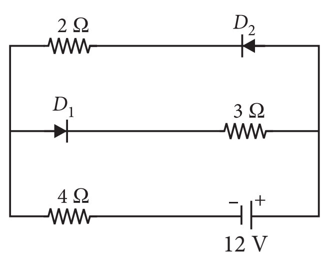
20. Plot a graph showing potential energy of a pair of nucleons as a function of their separation. Also mention two important conclusions from the graph regarding the nature of nuclear forces.

21. The *V-I* characteristic of a silicon diode is as shown in the figure. Calculate the resistance of the diode at (i) $I = 15$ mA and (ii) $V = -10$ V



OR

The circuit shown in the figure has two oppositely connected ideal diodes connected in parallel. Find the current flowing through each diode in the circuit.

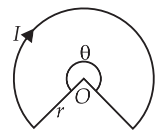


22. A compass needle, free to turn in a vertical plane orients itself with its axis vertical at a certain place on the earth. Find out the values of (i) horizontal component of earth's magnetic field and (ii) angle of dip at the place.

23. 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 $\vec{r}_2$, respectively in an external electric field $\vec{E}$.

24. A steady current flows in a metallic conductor of non-uniform cross-section. Which of these quantities is constant along the conductor: current, current density, electric field, drift speed?

25. A circular segment of radius *r* and angle θ carries current *I* as shown in figure. What is the value of magnetic field at the centre *O* of segment?



OR

Show that outside the toroid magnetic field at any point in the open space is zero.

SECTION - D

All questions are compulsory. In case of internal choices, attempt anyone.

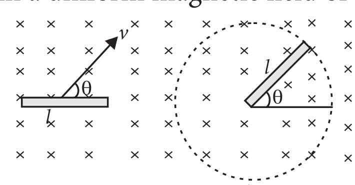
26. Draw *V-I* characteristics of a *p-n* junction diode. Answer the following questions, giving reasons.

(i) Why is the current under reverse bias almost independent of the applied potential upto a critical voltage?

(ii) Why does the reverse current show a sudden increase at the critical voltage?

Name any semiconductor device which operates under the reverse bias in the breakdown region.

27. Calculate the rate at which the flux linked with the generated area changes with time when a rod of length l is (i) translated (ii) rotated clockwise in a uniform magnetic field of induction B as shown in figure.



(a) (b)

OR

A metallic rod of length 'l' is rotated with a uniform angular speed ω, with one end hinged at the centre and the other end at the circumference of a circular metallic ring of radius $R = l$, about an axis passing through the centre and perpendicular to the plane of the ring. A constant and uniform magnetic field B parallel to the axis is present everywhere. Deduce the expression for the emf induced in the rod. If r is the resistance of the rod and the metallic ring has negligible resistance, obtain the expression for the power generated.

28. A straight wire of length L is bent into a semi-circular loop. Use Biot-Savart law to deduce an expression for the magnetic field at its centre due to the current I passing through it.

29. State the underlying principle of meter bridge. Draw the circuit diagram and explain how the unknown resistance of a conductor can be determined by this method.

30. **(a)** How are electromagnetic waves produced?

(b) How can you say that electromagnetic waves carry energy and momentum?

OR

Answer the following questions:

(a) Name the *e.m.* waves which are suitable for radar systems used in aircraft navigation. Write the range of frequency of these waves.

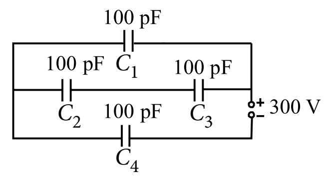
(b) If the Earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now? Explain.

(c) An *e.m.* wave exerts pressure on the surface on which it is incident. Justify.

SECTION - E

All questions are compulsory. In case of internal choices, attempt anyone.

31. Obtain the equivalent capacitance for the following network. For a 300 V supply, determine the charge and voltage across each capacitor.



OR

A capacitor is charged to potential V_1. The power supply is then disconnected and the capacitor is then connected in parallel to another capacitor (uncharged).

(a) Derive the expression for the common potential of the combination of capacitors.

(b) Show that the total energy of combination is less than the sum of the energy stored in them before they were connected.

32. **(a)** Draw a labelled schematic ray diagram of astronomical telescope in normal adjustment.

(b) Which two aberrations do objectives of refracting telescope suffer from? How are these overcome in reflecting telescope?

OR

Obtain lens makers formula using the expression

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{(n_2 - n_1)}{R}$$

Here the ray of light propagating from a rarer medium of refractive index (n_1) to a denser medium of refractive index (n_2) is incident on the convex side of spherical refracting surface of radius of curvature R

33. **(a)** Using Bohr's theory of hydrogen atom, derive the expression for the total energy of the electron in the stationary states of the atom.

(b) If electron in the atom is replaced by a particle (muon) having the same charge but mass about 200 times as that of the electron to form a muonic atom, how would (i) the radius and (ii) the ground state energy of this be affected?

OR

In the study of Geiger-Marsden experiment on scattering of α-particles by a thin foil of gold, draw the trajectory of α-particles in the coulomb field of target nucleus. Explain briefly how one gets the information on the size of the nucleus from this study.

From the relation $R = R_0 A^{1/3}$, where R_0 is constant and A is the mass number of the nucleus, show that nuclear matter density is independent of A.

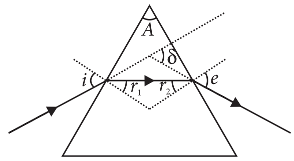
SOLUTIONS

1. $\lambda = \dfrac{h}{\sqrt{2mqV}}$

OR

Wave nature of matter was proved by de Brogile when accelerated electrons showed differaction by metal foil in the same manner as *X*-ray diffraction.

2. As $r_1 + r_2 = A$
At minimum deviation,
$r_1 = r_2 = r$
$\therefore \quad 2r = A$



3. One tesla is defined as the magnitude of magnetic field which produces a force of 1 newton when a charge of 1 coulomb moves perpendicularly in the region of the magnetic field at a velocity of 1 m/s.

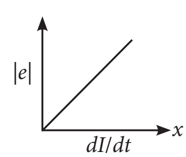
$F = qvB \Rightarrow B = \dfrac{F}{qv}$ or $1\text{ T} = \dfrac{1\text{ N}}{(1\text{ C})(1\text{ m/s})}$

4. Torque on dipole is, $\tau = pE \sin 30°$

or $\quad \tau = 4 \times 10^{-9} \times 5 \times 10^4 \times \dfrac{1}{2}$ or $\tau = 10 \times 10^{-5}$

or $\quad \tau = 1 \times 10^{-4}$ N m.

5. The graph showing the variation of the value of induced emf as a function of rate of change of current in an ideal inductor is given here.



6. Photoelectric effect shows the quantum nature of electromagnetic radiation.

OR

For a given frequency of incident radiation stopping potential is that minimum negative potential given to anode for which the photoelectric current becomes zero. It is denoted by V_s. For a given frequency of the incident radiation, the value of stopping potential is different for different metals but it is independent of the intensity of the incident light.

7. The quality factor (Q) of resonance in series *LCR* circuit is defined as the ratio of voltage drop across inductor (or capacitor) to the applied voltage,

i.e., $Q = \dfrac{V_L}{V_R} = \dfrac{I_0 X_L}{I_0 R} = \dfrac{\omega_0 L}{R} = \dfrac{1}{\omega_0 CR}$

It is an indicator of sharpness of the resonance.
Quality factor has no unit.

8. $\dfrac{S_{A_1}}{S_{A_2}} = \dfrac{4\pi R_1^2}{4\pi R_2^2} = \left(\dfrac{R_1}{R_2}\right)^2 = \left(\dfrac{R_0 A_1^{\,3}}{R_0 A_1^{\,3}}\right) = \left(\dfrac{A_1}{A_2}\right)^6$

OR

Here, M = Mass of Hydrogen atom

$= m_{\text{proton}} + m_{\text{electron}} - \dfrac{B}{c^2}$

where B is binding energy of H-atom which is 13.6 eV.

9. Angular width, $\theta = \dfrac{\lambda}{d}$

$0.1 = \dfrac{0.1}{180}\pi \text{ rad} = \dfrac{6 \times 10^{-7}}{d}$

$\therefore \quad d = \dfrac{6 \times 10^{-7} \times 180}{0.1 \times \pi} = 3.44 \times 10^{-4}$ m

10. (i) electrons (ii) holes

OR

Less than 1.

11. (d) : The speed of em waves in free space is given by $c = \dfrac{1}{\sqrt{\mu_0 \varepsilon_0}}$

where $\mu_0 = 4\pi \times 10^{-7}$ N s^2/C^2 is permeability constant of vacuum and $\varepsilon_0 = 8.85419 \times 10^{-12}$ C^2/ N m^2 is the permittivity of free space. After substituting these value, the value of c ($= 2.99792 \times 10^8$ m/s) which is same as the speed of light in vacuum. From this it is concluded that light is an electromagnetic wave.

12. (b) : Resistance of wire, $R = \rho \dfrac{l}{A}$.

where ρ is resistivity of material which does not depend on the geometry of wire. Since when wire is bended, resistivity, length and area of cross-section do not change, therefore resistance of wire also remains same.

13. (a) : When d is negligibly small, fringe width β which is proportional to $1/d$ may become too large. Even a single fringe may occupy the whole screen. Hence the pattern cannot be detected.

14. (b) : A n-type semiconductor is formed by doping pure germanium or silicon crystal with suitable impurity atoms of valency five. As the impurity atoms take the position of Ge atom in germanium crystal, its four electrons form covalent bonds by sharing electrons with the neighbouring four atoms of germanium whereas the fifth electron is left free. Since the atom on the whole is electrically neutral, the n-type semiconductor is also neutral.

15. (i) (b) : $Z=\sqrt{(R_1+R_2)^2+(X_L-X_C)^2}$

$=\sqrt{(44+36)^2+(90-30)^2}=100\ \Omega$

(ii) (c) : Current, $I=\dfrac{V}{Z}=\dfrac{200}{100}=2\text{ A}$

(iii) (a) : Impedance of the coil, $Z_L=\sqrt{R_2^2+X_L^2}$

$=\sqrt{(36)^2+(90)^2}=97\ \Omega$

(iv) (a) : Potential difference across the coil, $V_L = IZ_L$
$= 2 \times 97 = 194$ V

(v) (d) : Power dissipated in the induction coil, $P = I^2R_2$
$= (2)^2 \times 36 = 144$ W

16. We have that $\beta=\dfrac{D\lambda}{d}$

(i) (a) : When the screen is moved away from the plane of the slits, D increases. Hence, fringe width will increase.

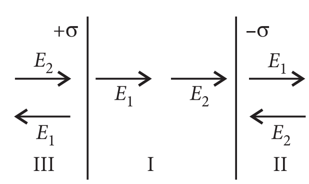
(ii) (b)

(iii) (a) : When separation between the two sources is decreased, d decreases. Hence, fringe width will increase.

(iv) (c) : Fringe width is independent of the order of fringe.

(v) (d) : When the slits are of unequal widths,
$I_1 \neq I_2 \therefore\ A \neq B$
$I_{min} = (A - B)^2 \neq 0$
i.e., the dark fringes are not perfectly dark.

17. The direction of electric field in various regions is given as follows :



$E_1=E_2=\dfrac{\sigma}{2\varepsilon_0}$

(i) $E_{net}=|\vec{E_1}+\vec{E_2}|=\dfrac{\sigma}{2\varepsilon_0}+\dfrac{\sigma}{2\varepsilon_0}=\dfrac{\sigma}{\varepsilon_0}$

(ii) $E_{net}=E_1-E_2=\dfrac{\sigma}{2\varepsilon_0}-\dfrac{\sigma}{2\varepsilon_0}=0$

18. The photoelectric effect is the emission of electrons or free carriers when light incident on a material. The emitted electrons are called photoelectrons.

(i) On increasing frequency υ of incident radiation, energy of photons increases and hence kinetic energy with which photoelectrons are emitted also increases.

(ii) On increasing intensity of incident radiation, number of photons in incident radiation and hence number of photoelectrons emitted also increases.

19. The intensity distribution pattern seen in the central position is given by same intensities, having constant phase difference and same wavelength as

$I = I_1 + I_2 + 2\sqrt{I_1I_2}\cos\phi$.

If $\cos\phi$ remains constant with time, total intensity at any point will be constant.

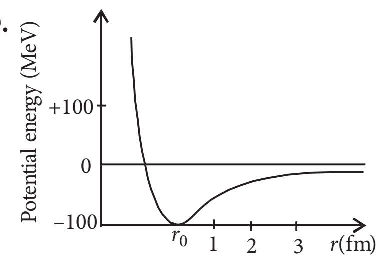
OR

We know that

$\beta=\dfrac{2D\lambda}{a}$ for central width hence as size of pinhole increases, size of image decreases.

Light distribution is now in smaller area therefore intensity increases.

20.



From the above plot, following conclusions can be drawn.

(i) Nuclear forces are short range forces.

(ii) For a separation greater than r_0, the nuclear forces are attractive and for separation less than r_0, the nuclear forces are strongly repulsive.

21. (i) From the given curve, we have
voltage, $V = 0.8$ volt for current, $I = 20$ mA
voltage, $V = 0.7$ volt for current, $I = 10$ mA
$\Rightarrow\ \Delta I = (20 - 10)\text{mA} = 10 \times 10^{-3}$ A
$\Rightarrow\ \Delta V = (0.8 - 0.7) = 0.1$ V

$\therefore$ Resistance, $R=\dfrac{\Delta V}{\Delta I}$

$\Rightarrow\ R=\dfrac{0.1}{10\times10^{-3}} \Rightarrow R = 10\ \Omega$

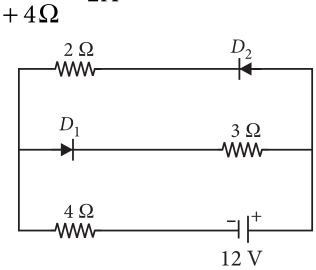
(ii) For $V = -10$ V, we have
$I = -1\ \mu\text{A} = -1 \times 10^{-6}$ A

$\Rightarrow\ R=\dfrac{10}{1\times10^{-6}}=1.0\times10^{7}\ \Omega$

OR

Diode D_1 is reverse biased, so it offers an infinite resistance. So no current flows in the branch of diode D_1. Diode D_2 is forward biased, and offers negligible resistance in the circuit. So current in the branch

$I=\dfrac{V}{R_{eq}}=\dfrac{12\text{V}}{2\Omega+4\Omega}=2\text{A}$



22. (i) As, horizontal component of earth's magnetic field, $B_H = B\cos\delta$

Putting $\delta = 90°$, $B_H = 0$

(ii) For a compass needle aligned vertically at a certain place, angle of dip, $\delta = 90°$.

23. The work done in bringing charge q_1 in the external electric field at a distance $\vec{r}_1 = q_1V(r_1)$. Work done in bringing charge q_2 in the external electric field at a distance $\vec{r}_2 = q_2V(r_2)$.

The work done in moving q_2 against the force of q_1

$$= \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r_{12}}$$

where r_{12} is the distance between q_1 and q_2.

∴ Potential energy of the system

$$q_1V(r_1) + q_2V(r_2) + \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r_{12}}$$

24. The current will be constant.

Current density, $J = \frac{I}{A}$ will not be constant in non-uniform cross-section.

The electric field E is also variable in non uniform cross-section.

$J = \sigma E$

$$\frac{I}{A} = \sigma E \Rightarrow E = \frac{I}{\sigma A}. \text{ So } E \propto \frac{1}{A}$$

Drift speed also changes in non uniform cross-section.

$J = nev_d$

$$v_d = \frac{I}{Ane}, \text{ so } v_d \propto \frac{1}{A}$$

25. According to Biot-Savart's law, the magnetic field due to a small circular current element of length Δl at centre O is

$$\Delta B = \frac{\mu_0 I \Delta l \sin 90°}{4\pi r^2}$$

while the magnetic field due to straight portions will be zero (since $\sin\theta = 0$)

∴ Total magnetic field at centre O is

$$B = \frac{\mu_0 I}{4\pi r^2}\Sigma\Delta l = \frac{\mu_0 I}{4\pi r^2}r\theta \qquad (\because \Sigma\Delta l = r\theta)$$

$$= \frac{\mu_0 I\theta}{4\pi r}$$

OR

Let us consider a coplanar loop in the open space of exterior of toroid. Here, each turn of toroid threads the loop two times in opposite directions.

Therefore, net current threading the loop

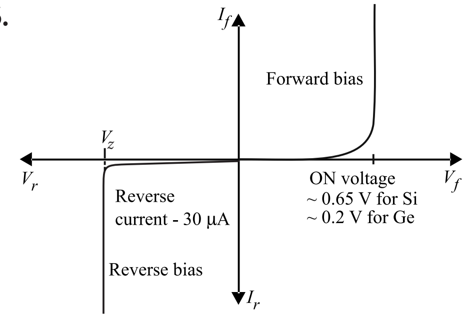
$= \quad NI - NI = 0$

∴ By Ampere's circuital law

$$\oint_{\text{loop 3}} \vec{B}\cdot\vec{dl} = \mu_0(NI - NI) = 0 \Rightarrow B = 0$$

Thus, there is no magnetic field in the open space inside and outside the toroid.

26.



(i) The reverse current is due to minority charge carriers and even a small voltage is sufficient to sweep the minority carriers from one side of the junction to the other side of the junction. Here the current is not limited by the magnitude of the applied voltage but is limited due to the concentration of the minority carrier on either side of the junction.

(ii) At critical voltage/breakdown voltage, a large number of covalent bonds break, resulting in availability of large number of charge carriers.

Zener diode operates under the reverse bias in the breakdown region.

27. (i) Component of velocity perpendicular to the rod = $v \sin\theta$.

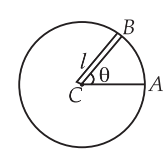
Therefore, in time t, area traversed = $l \times v\sin\theta \times t$

∴ $\phi = B(l \times v\sin\theta \times t)\cos 0° = Blvt\sin\theta$

$$\frac{d\phi}{dt} = Blv\sin\theta$$

(ii) If θ is the angle between the rod and the radius of the circle CA at time t, the area of the sector ACB is given by

∴ Area swept, $A = \pi l^2 \times \left(\frac{\theta}{2\pi}\right) = \frac{1}{2}l^2\theta$



$$\phi = B\left(\frac{1}{2}l^2\theta\right)\cos 0° = \frac{1}{2}Bl^2\theta$$

$$\frac{d\phi}{dt} = \frac{1}{2}Bl^2\frac{d\theta}{dt} = \frac{1}{2}Bl^2\omega$$

OR

In one revolution change of area $dA = \pi l^2$.

∴ Change in magnetic flux

$d\phi = \vec{B}\cdot d\vec{A} = BdA\cos 0°$

$= B\pi l^2$

Period of revolution = T

Induced emf (ε) = $\frac{B\pi l^2}{T} = B\pi l^2\upsilon$

Induced current, $I = \dfrac{\varepsilon}{r} = \dfrac{B\pi l^2 \upsilon}{r}$

Power, $P = \varepsilon I = \dfrac{B^2 \omega^2 l^4}{4r}$ $\qquad (\because \omega = 2\pi\upsilon)$

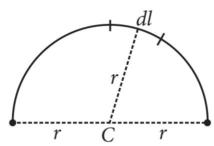
28. Let length L is bent into semi-circular loop.

Length of wire = Circumference of semi circular wire

$\Rightarrow L = \pi r$

$$r = \frac{L}{\pi} \qquad \text{...(i)}$$

Considering a small element dl on current loop. The magnetic field dB due to small current element Idl at centre C,



$$dB = \frac{\mu_0}{4\pi} \frac{Idl \sin 90°}{r^2} \qquad [\because I\vec{dl} \perp \vec{r}, \therefore \theta = 90°]$$

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

$\therefore$ Net magnetic field at C due to semi-circular loop,

$$B = \int_{\text{semicircle}} \frac{\mu_0}{4\pi} \frac{Idl}{r^2}$$

$$B = \frac{\mu_0}{4\pi} \frac{I}{r^2} \int_{\text{semicircle}} dl \; ; \; B = \frac{\mu_0}{4\pi} \cdot \frac{I}{r^2} L$$

But, $r = \dfrac{L}{\pi}$

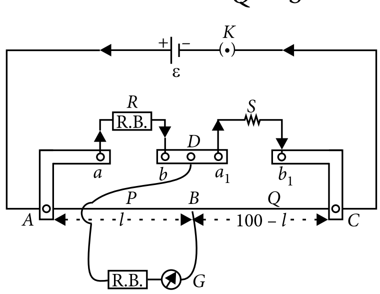
$$B = \frac{\mu_0}{4\pi} \cdot \frac{IL}{(L/\pi)^2} = \frac{\mu_0}{4\pi} \times \frac{IL}{L^2} \times \pi^2$$

$$\Rightarrow B = \frac{\mu_0 I \pi}{4L}$$

29. Metre bridge : It is the simplest practical application of the Wheatstone bridge that is used to measure an unknown resistance.

Principle : Its working is based on the principle of Wheatstone bridge.

When the bridge is balanced, $\dfrac{P}{Q} = \dfrac{R}{S}$



Measurement of unknown resistance by a metre bridge.

Working : After taking out a suitable resistance R from the resistance box, the jockey is moved along the wire AC till there is no deflection in the galvanometer. This is the balanced condition of the Wheatstone bridge. If P and Q are the resistance of the parts AB and BC of the wire, then for the balanced condition of the bridge, we have

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

Let total length of wire AC = 100 cm and $AB = l$ cm, then $BC = (100 - l)$ cm. Since the bridge wire is of uniform cross-section, therefore,

resistance of wire $\propto$ length of wire

or $\dfrac{P}{Q} = \dfrac{\text{resistance of } AB}{\text{resistance of } BC} = \dfrac{\sigma l}{\sigma(100 - l)} = \dfrac{l}{100 - l}$

where σ is the resistance per unit length of the wire.

Hence, $\dfrac{R}{S} = \dfrac{l}{100 - l}$ or $S = \dfrac{R(100 - l)}{l}$

Knowing l and R, unknown resistance S can be determined.

30. (a) : An oscillating or accelerated charge is supposed to be source of an electromagnetic wave. An oscillating charge produces an oscillating electric field in space which further produces an oscillating magnetic field which in turn is a source of electric field. These oscillating electric and magnetic field hence, keep on regenerating each other and an electromagnetic wave is produced.

(b) Electromagnetic waves or photons transport energy and momentum. When an electromagnetic wave interacts with a small particle, it can exchange energy and momentum with the particle. The force exerted on the particle is equal to the momentum transferred per unit time. Optical tweezers use this force to provide a non-invasive technique for manipulating microscopic-sized particles with light.

OR

(a) Microwaves are suitable for the radar system used in aircraft navigation. Range of frequency of microwaves is 10^8 Hz to 10^{11} Hz.

(b) If the Earth did not have atmosphere, thenthere would be absence of green house effect of the atmosphere. Due to this reason, the temperature of the earth would be lower than what it is now.

(c) An *e.m.* wave carries momentum with itself and given by

$$p = \frac{\text{Energy of wave } (U)}{\text{Speed of the wave } (c)}$$

When it is incident upon a surface it exerts pressure on it.

31. (i) For equivalent capacitance, circuit can be simplified as

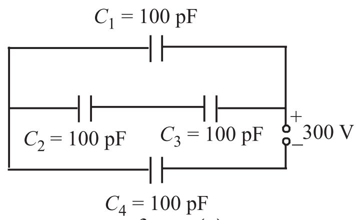


figure (a)

C_2 and C_3 are in series, so their equivalent capacitance is

$$C' = \frac{100}{2} = 50 \text{ pF}$$

(ii)

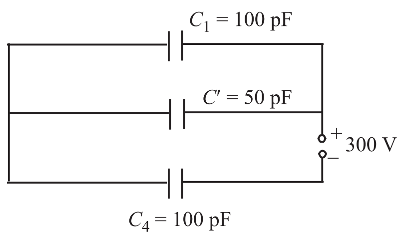


figure (b)

C_1 and C' are parallel, so their equivalent capacitance is $C'' = C_1 + C' = 100 + 50 = 150$ pF

(iii)

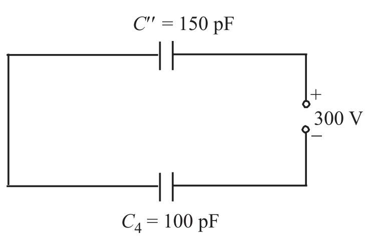


figure (c)

C'' and C_4 are in series

$$C_{eq} = \frac{150 \times 100}{250} \text{ pF}$$

$C_{eq} = 60$ pF

In figure (c) charge on each capacitor is same, as both in series

$Q = C_{eq}.V = 60 \times 10^{-12} \times 300 = 18 \times 10^{-9}$ C

Potential drop across 100 pF capacitor

$$V_4 = \frac{Q}{C_4} = \frac{18 \times 10^{-9}}{100 \times 10^{-12}}$$

$V_4 = 180$ volt

Potential drop across 150 pF capacitor,

$$V'' = \frac{Q}{C''} = \frac{18 \times 10^{-9}}{150 \times 10^{-12}} = 120 \text{ V}$$

In figure (b) in parallel, potential remains the same, hence for capacitance of 100 pF and 50 pF, potential is same

i.e., $V_1 = V' = V''$ or $V_1 = V' = 120$ volts

So, $Q_1 = C_1V_1 = 100 \times 10^{-12} \times 120 = 12 \times 10^{-9}$ C

and $Q' = C'V' = 50 \times 10^{-12} \times 120 = 6 \times 10^{-9}$ C

In figure (a) both 100 pF capacitor in series will have same charge as on equivalent 50 pF.

i.e., $Q_2 = Q_3 = Q'$ or $Q_2 = Q_3 = 6 \times 10^{-9}$ C

So, potential difference across each is

$$V_2 = V_3 = \frac{6 \times 10^{-9} \text{ C}}{100 \times 10^{-12} \text{ F}} = 60 \text{ volt}$$

OR

(a) Let the capacitor of capacitance C_1 be charged to potential V_1, then charge stored on it is $Q_1 = C_1V_1$. Now this capacitor after disconnecting is connected to another uncharged capacitor of capacitance C_2, then charge will flow from one to another until potential on both is same. Let it is V.

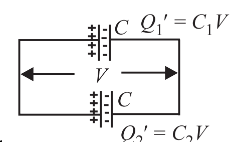
$Q_1 = C_1V_1$

or $C_1V_1 = C_1V + C_2V$

or $C_1V_1 = (C_1 + C_2)V$

Common potential is $V = \dfrac{C_1V_1}{C_1 + C_2}$

(b) Loss in energy on connecting



$$= \frac{1}{2}(C_1 + C_2)V^2 - \frac{1}{2}C_1V_1^2$$

$$\Delta U = \frac{1}{2}(C_1 + C_2)\left[\frac{C_1^2V_1^2}{(C_1 + C_2)^2}\right] - \frac{1}{2}C_1V_1^2$$

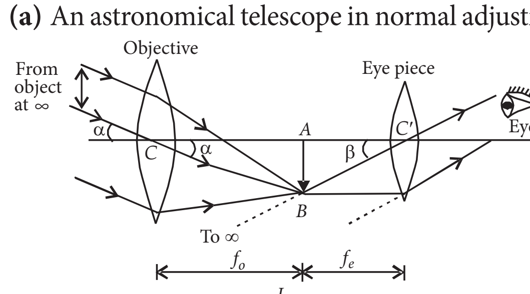
$$\Delta U = \frac{1}{2}\frac{C_1^2V_1^2}{(C_1 + C_2)} - \frac{1}{2}C_1V_1^2 = \frac{1}{2}C_1V_1^2\left[\frac{C_1}{C_1 + C_2} - 1\right]$$

$$= \frac{1}{2}C_1V_1^2\left[\frac{C_1 - C_1 - C_2}{C_1 + C_2}\right]$$

or $\Delta U = -\dfrac{C_1C_2V_1^2}{2(C_1 + C_2)}$

As ΔU is negative, so, it indicates some energy is lost due to connection.

32. (a) An astronomical telescope in normal adjustment.



It is used to see distant objects.

It consists of two lenses:

Objective of large aperture and large focal length f_o.

Eyepiece of small aperture and short focal length f_e.

Magnifying power: It is the ratio of the angle subtended at the eye, by the final image, to the angle which the object subtends at the lens, or the eye.

(b) Refracting telescope suffer from chromatic and spherical aberrations.

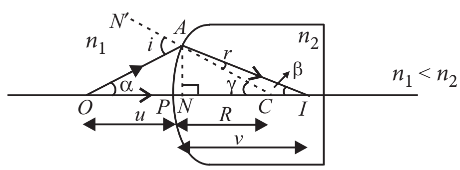
Chromatic aberration : The inability of a lens in which image formed by white object is coloured and blurred. This inability of lens to form a clear image is known as chromatic aberration.

Spherical aberration : The inability of a lens to form a point image of an object is called spherical aberration. In the reflecting-type telescope, the objective lens is replaced by the concave parabolic mirror of a large aperture required for observing fainter objects. The use of parabolic mirror makes the resolving power of the telescope high. The parabolic mirrors are free from chromatic and spherical aberrations.

OR

Refraction at convex spherical surface :

When object is in rarer medium and image formed is real.



In ΔOAC, $i = \alpha + \gamma$

and in ΔAIC, $\gamma = r + \beta$ or $r = \gamma - \beta$

$\therefore$ By Snell's law $^1n_2 = \frac{\sin i}{\sin r} \approx \frac{i}{r} = \frac{\alpha + \gamma}{\gamma - \beta}$

or $\frac{n_2}{n_1} = \frac{\alpha + \gamma}{\gamma - \beta}$ or $n_2\gamma - n_2\beta = n_1\alpha + n_1\gamma$

or $(n_2 - n_1)\gamma = n_1\alpha + n_2\beta$ ...(i)

As α, β and γ are small and P and N lie close to each other,

So, $\alpha \approx \tan\alpha = \frac{AN}{NO} \approx \frac{AN}{PO}$

$\beta \approx \tan\beta = \frac{AN}{NI} \approx \frac{AN}{PI}$

$\gamma \approx \tan\gamma = \frac{AN}{NC} \approx \frac{A}{P}$

On using them in equation (i), we get

$$(n_2 - n_1)\frac{AN}{PC} = n_1\frac{AN}{PO} + n_2\frac{AN}{PI}$$

or $\frac{n_2 - n_1}{PC} = \frac{n_1}{PO} + \frac{n_2}{PI}$ ...(ii)

where, $PC = +R$, radius of curvature

$PO = -u$, object distance

$PI = +v$, image distance

So $\frac{n_2 - n_1}{R} = \frac{n_1}{-u} + \frac{n_2}{v}$ or $\frac{n_2 - n_1}{R} = \frac{n_2}{v} - \frac{n_1}{u}$

This gives formula for refraction at spherical surface when object is in rarer medium.

33. (a) According to Bohr's postulates, in a hydrogen atom, as single electron revolves around a nucleus of charge $+e$. For an electron moving with a uniform speed in a circular orbit of a given radius, the centripetal force is provided by coulomb force of attraction between the electron and the nucleus. The gravitational attraction may be neglected as the mass of electron and proton is very small.

So, $\frac{mv^2}{r} = \frac{ke^2}{r^2}$ $\left(\text{Where, } k = \frac{1}{4\pi\varepsilon_0}\right)$

or $mv^2 = \frac{ke^2}{r}$ ...(i)

where, m = mass of electron

r = radius of electronic orbit

v = velocity of electron

Again, by Bohr's second postulates

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

where, n = 1, 2, 3...... or $v = \frac{nh}{2\pi mr}$

Putting the value of v in eq. (i)

$$m\left(\frac{nh}{2\pi mr}\right)^2 = \frac{ke^2}{r} \Rightarrow r = \frac{n^2h^2}{4\pi^2kme^2} \quad \text{...(ii)}$$

Kinetic energy of electron,

$$E_k = \frac{1}{2}mv^2 = \frac{ke^2}{2r} \quad \left(\because \frac{mv^2}{r} = \frac{ke^2}{r^2}\right)$$

Using eq. (ii) we get

$$E_k = \frac{ke^2}{2}\frac{4\pi^2kme^2}{n^2h^2} = \frac{2\pi^2k^2me^4}{n^2h^2}$$

Potential energy of electron,

$$E_p = -\frac{k(e)\times(e)}{r} = -\frac{ke^2}{r}$$

Using eq. (ii), we get

$$E_p = -ke^2 \times \frac{4\pi^2kme^2}{n^2h^2} = -\frac{4\pi^2kme^4}{n^2h^2}$$

Hence, total energy of the electron in the n^{th} orbit

$E = E_p + E_k$

$$= -\frac{4\pi^2k^2me^4}{n^2h^2} + \frac{2\pi^2k^2me^4}{n^2h^2} = -\frac{2\pi^2k^2me^4}{n^2h^2} = -\frac{13.6}{n^2}\text{ eV}$$

When the electron in a hydrogen atom jumps from higher energy level to the lower energy level, the difference of energies of the two energy levels is emitted as a radiation of particular wavelength. It is called a spectral line.

(b) (i) $\because$ Radius $r = \frac{n^2h^2\varepsilon_0}{\pi me^2}$ or $r \propto \frac{1}{m}$

$\therefore$ When we increase the mass 200 times, the radius reduces to 200 times.

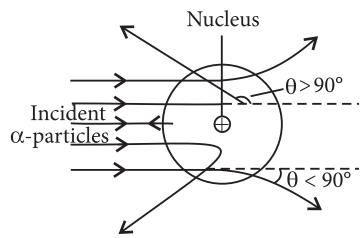
(ii) Similarly, ground state energy for hydrogen,
$E = \frac{-me^4}{8\varepsilon_0^2 n^2 h^2}$

i.e. $E \propto m$

$\therefore$ when we increase the mass 200 times, the ground state energy also increases by a factor 200.

OR

Trajectory of α-particles in coulomb field of target nucleus shows that only a small fraction of the number of incident α-particles (1 in 8000) rebound back.



This shows that the number of α-particles undergoing head-on collision is small. This implies that the entire positive charge of the atom is concentrated in a small volume. So, this experiment is an important way to determine an upper limit on the size of nucleus.

$$\text{Density of nucleus} = \frac{\text{mass of nucleus}}{\text{volume}}$$

$$\rho = \frac{A \times 1\,\text{amu}}{\frac{4}{3}\pi R^3}$$

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

$$\text{Density } \rho = \frac{A \times 1\,\text{amu}}{\frac{4}{3}\pi R_0^3 A} = \frac{1\,\text{amu}}{\frac{4}{3}\pi R_0^3}$$

$\rho = 2.97 \times 10^{17}$ kg m^{-3}

so, nuclear density is constant irrespective of mass number or size.

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