SAMPLE QUESTION PAPER

BLUE PRINT

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	3(6)	1(2)	1(3)	–	**8(16)**
2.	Current Electricity	2(2)	–	1(3)	–	
3.	Magnetic Effects of Current and Magnetism	1(1)	1(2)	–	1(5)	**9(17)**
4.	Electromagnetic Induction and Alternating Current	4(4)	1(2)	1(3)	–	
5.	Electromagnetic Waves	1(1)	1(2)	–	–	**8(18)**
6.	Optics	1(1)	3(6)	1(3)	1(5)	
7.	Dual Nature of Radiation and Matter	1(1)	–	–	–	**4(12)**
8.	Atoms and Nuclei	1(4)	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. What is the function of a photodiode?

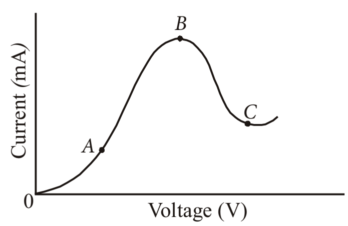
2. Can the potential function have a maximum or minimum value in free space?

3. In a half wave rectifier circuit operating from 50 Hz mains frequency, what would be the fundamental frequency in the ripple?

4. A steady current flows in a metallic conductor of non-uniform cross-section. Which of the following quantities is/are constant along the length of conductor : current, current density, drift speed?

OR

The graph shown in the figure represents a plot of current versus voltage for a given semiconductor. Identify the region, if any, over which the semiconductor has a negative resistance.



5. Why is the penetrating power of gamma rays very large?

OR

Welders wear special goggles or face masks with glass windows to protect their eyes from electromagnetic radiations. Name the radiations and write the range of their frequency.

6. Define the term 'coherent sources' which are required to produce interference pattern in Young's double slit experiment.

7. A magnetic needle, free to rotate in a vertical plane, orients itself vertically at a certain place on the Earth. What are the values of

   (i) horizontal component of Earth's magnetic field and

   (ii) angle of dip at this place?

OR

At a place, the horizontal component of earth's magnetic field is B and angle of dip is 60°. What is the value of horizontal component of the earth's magnetic field at equator?

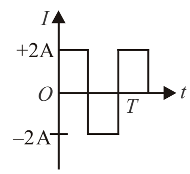
8. In a series *LCR* circuit, the voltages across an inductor, a capacitor and a resistor are 30V, 30V and 60V respectively. What is the phase difference between the applied voltage and the current in the circuit.

9. Which process causes depletion region in a *p-n* junction?

OR

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

10. Calculate the rms value of the alternating current shown in the figure.



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) :** Faraday's laws are consequences of conservation of energy.
    Reason (R) : In a purely resistive A.C. circuit, the current lags behind the e.m.f.

12. **Assertion (A) :** Voltmeter is connected in parallel with the circuit.
    Reason (R) : Resistance of a voltmeter is very large.

13. **Assertion (A) :** Charge never flows from a condenser of higher capacity to the condenser of lower capacity.
    Reason (R) : Flow of charge between two bodies connected by a thin wire is determined by the charges on them.

14. **Assertion (A) :** The possibility of an electric bulb fusing is higher at the time of switching on and off.
    Reason (R) : Inductive effects produce a surge at the time of switch-off and switch-on.

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. Niels Bohr introduced the atomic Hydrogen model in 1913. He described it as a positively charged nucleus, comprised of protons and neutrons, surrounded by a negatively charged electron cloud. In the model, electrons orbit the nucleus in atomic shells. The atom is held together by electrostatic forces between the positive nucleus and negative surroundings.

(i) In the Bohr model of the hydrogen atom, discrete radii and energy states result when an electron circles the atom in an integer number of

(a) de Broglie wavelengths (b) wave frequencies

(c) quantum numbers (d) diffraction patterns.

(ii) Which of the following was explained by the Bohr atom?

(a) Atomic spectra.

(b) The fact that most of the mass of an atom is in the nucleus.

(c) Nuclear fission.

(d) The photoelectric effect.

(iii) In Bohr's model of the hydrogen atom, the radius of an orbit ______.

(a) is proportional to n^2

(b) is smallest for the highest energy state

(c) increases when a photon of light is emitted from an excited atom

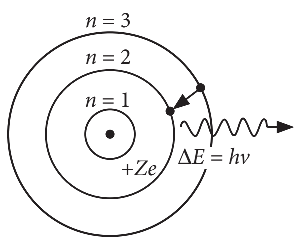
(d) can have any value that is larger than the ground-state radius

(iv) The energy associated with the first orbit in the hydrogen atom is -2.17×10^{-18} J atom^{-1}. What is the energy associated with the fifth orbit?

(a) -8.77×10^{-20} J atom^{-1} (b) -9.34×10^{-20} J atom^{-1}

(c) -7.65×10^{-20} J atom^{-1} (d) -8.77×10^{-24} J atom^{-1}

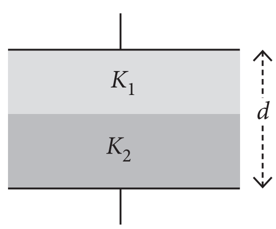
(v) Suppose the energy required to remove all the three electrons from a lithium atom in the ground state is 'E' electron volt. What will be the energy required (in electron volt) to remove two electrons from the lithium atom in the ground state?



(a) $2E/3$ (b) $E - 13.6$ (c) $E - 27.2$ (d) $E - 122.4$

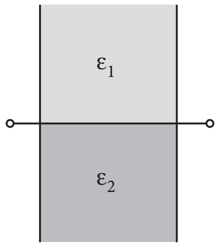
16. When the capacitor is connected to the battery, the energy stored in the air-filled capacitor is $U = \frac{1}{2}CV^2$, and the charge on each plate is $q = CV$. When the capacitor is filled with the dielectric material, its capacitance becomes kC, where k is the dielectric constant of the material. This increases the charge stored on each plate to kCV. The additional charge of $(k - 1)CV$ came through the battery, which did some work, given by $\Delta qV = (k - 1)CV^2$.

(i) What is the value of total capacitance if two dielectric slabs are introduced between the plates of the capacitor as shown?



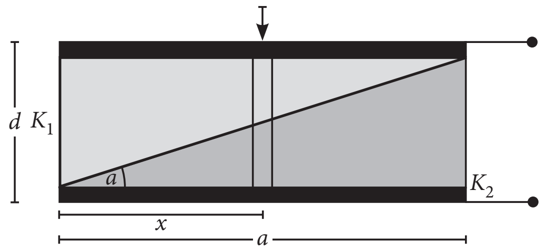
(a) $\dfrac{2\varepsilon_0 A K_1 K_2}{(K_1 + K_2)d}$ (b) $\dfrac{\varepsilon_0 A(K_1 + K_2)}{2d}$ (c) $\dfrac{\varepsilon_0 A K_1 K_2}{(K_1 + K_2)d}\log\dfrac{K_2}{K_1}$ (d) $\dfrac{\varepsilon_0 A}{d}\left(\dfrac{K_1}{2} + \dfrac{K_2 K_3}{K_2 + K_3}\right)$

(ii) What is the value of total capacitance if two dielectric slabs are introduced between the plates of the capacitor as shown?



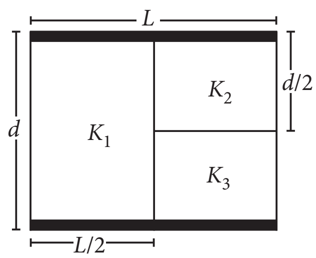
(a) $\frac{2\varepsilon_0 AK_1K_2}{(K_1+K_2)d}$ (b) $\frac{\varepsilon_0 A(K_1+K_2)}{2d}$ (c) $\frac{\varepsilon_0 AK_1K_2}{(K_1+K_2)d}\log\frac{K_2}{K_1}$ (d) $\frac{\varepsilon_0 A}{d}\left(\frac{K_1}{2}+\frac{K_2K_3}{K_2+K_3}\right)$

(iii) What is the value of total capacitance if two dielectric slabs are introduced between the plates of the capacitor as shown?



(a) $\frac{2\varepsilon_0 AK_1K_2}{(K_1+K_2)d}$ (b) $\frac{\varepsilon_0 A(K_1+K_2)}{2d}$ (c) $\frac{\varepsilon_0 AK_1K_2}{(K_1+K_2)d}\log\frac{K_2}{K_1}$ (d) $\frac{\varepsilon_0 A}{d}\left(\frac{K_1}{2}+\frac{K_2K_3}{K_2+K_3}\right)$

(iv) What is the value of total capacitance if two dielectric slabs are introduced between the plates of the capacitor as shown?



(a) $\frac{2\varepsilon_0 AK_1K_2}{(K_1+K_2)d}$ (b) $\frac{\varepsilon_0 A(K_1+K_2)}{2d}$ (c) $\frac{\varepsilon_0 AK_1K_2}{(K_1+K_2)d}\log\frac{K_2}{K_1}$ (d) $\frac{\varepsilon_0 A}{d}\left(\frac{K_1}{2}+\frac{K_2K_3}{K_2+K_3}\right)$

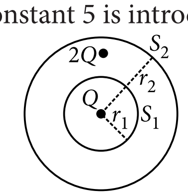
(v) Two identical conducting plates of plate area A are separated by a distance d to form a parallel plate air capacitor. Now a metal sheet of thickness $d/3$ is inserted between the plates of the capacitor. The ratio of capacitance before the insertion of plate and after the insertion of plate is

(a) 2:3 (b) 1:1 (c) 3:1 (d) 4:1

SECTION - C

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

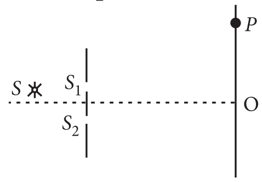
17. A sphere S_1 of radius r_1 encloses a net charge Q. If there is another concentric sphere S_2 of radius $r_2 (r_2 > r_1)$ enclosing charge $3Q$, find the ratio of the electric flux through S_1 and S_2. How will the electric flux through sphere S_1 change if a medium of dielectric constant 5 is introduced in the space inside S_1 in place of air?



OR

A slab of material of dielectric constant K has the same area as that of the plates of a parallel plate capacitor but has the thickness $d/2$, where d is the separation between the plates. Find out the expression for its capacitance when the slab is inserted between the plates of the capacitor.

18. The figure shows a modified Young's double slit experimental set-up. Here $SS_2 - SS_1 = \lambda/4$.



(a) Write the condition for constructive interference.

(b) Obtain an expression for the fringe width.

19. Draw energy band diagram of p and n type semiconductors. Also write two differences between p and n type semiconductors.

OR

Energy gap in a $p - n$ photodiode is 2.8 eV. Can it detect a wavelength of 600 nm? Justify your answer.

20. A fish in a water tank sees the outside world as if it (the fish) is at the vertex of a cone such that the circular base of the cone coincides with the surface of water. Given the depth of water, where fish is located, being 'h' and the critical angle for water-air interface being 'i_c', find out by drawing a suitable ray diagram the relationship between the radius of the cone and the height 'h'.

21. An ordinary moving coil ammeter used in d.c. cannot be used to measure an alternating current even if its frequency is low. Explain why?

22. State de Broglie hypothesis. Is it applicable for moving electron of hydrogen atom ?

OR

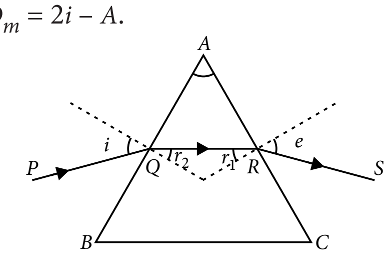
Calculate the de-Broglie wavelength of the electron orbiting in the $n = 2$ state of hydrogen atom.

23. How does the angle of dip vary as one moves from the equator towards the north pole? If the horizontal component of earth's magnetic field at a place where the angle of dip is 60° is 0.4×10^{-4} T, calculate the vertical component and the resultant magnetic field of earth at that point.

24. Figure shows a ray of light passing through a prism. If the refracted ray QR is parallel to the base BC, show that

(i) $r_1 = r_2 = A/2$,

(ii) angle of minimum deviation, $D_m = 2i - A$.



25. When the oscillating electric and magnetic fields are along the x-and y-direction respectively,

(i) point out the direction of propagation of electromagnetic wave.

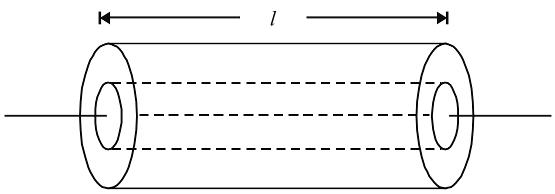
(ii) express the velocity of propagation in terms of the amplitudes of the oscillating electric and magnetic fields.

(iii) Write the expression of energy density and momentum carried by the electromagnetic waves.

SECTION - D

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

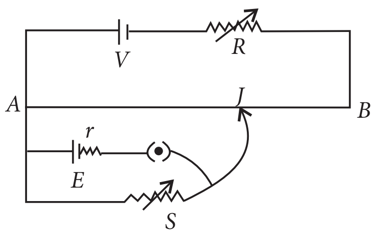
26. Figure shows two long coaxial solenoids, each of length 'l'. The outer solenoid has an area of cross-section A_1 and number of turns per unit length n_1. The corresponding values for the inner solenoid are A_2 and n_2. Write the expression for self inductance L_1, L_2 of the two coils and their mutual inductance M. Hence show that $M < \sqrt{L_1 L_2}$.



OR

State Lenz's law. A metallic rod held horizontally along east-west direction, is allowed to fall under gravity. Will there be an emf induced at its ends? Justify your answer.

27. State working principle of potentiometer. Explain how the balance point shifts when value of resistor R increases in the circuit of potentiometer, given below.



28. **(a)** Two slits in Young's double slit experiment are illuminated by two different lamps emitting light of the same wavelength. Will you observe the interference pattern? Justify your answer.

(b) In Young's double slit experiment using monochromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ, is K units. Find out the intensity of light at a point where path difference is $\lambda/3$.

OR

(a) In a single slit diffraction pattern, how does the angular width of the central maximum vary, when

(i) aperture of slit is increased?

(ii) distance between the slit and the screen is decreased?

(b) How is the diffraction pattern different from the interference pattern obtained in Young's double slit experiment?

29. Two identical spheres A and B, each having a charge of 6×10^{-8}C, are separated by 60 cm. A third uncharged sphere C of the same size is brought in contact with sphere A, then brought in contact with sphere B and finally removed from both. What is the new force of repulsion between A and B?

30. Suggest an idea to convert a full wave rectifier to a half wave rectifier by changing the connecting wires. Draw the diagram and explain your answer.

SECTION - E

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

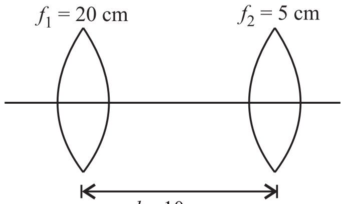
31. **(a)** Define magnifying power of a telescope. Write its expression.

(b) A small telescope has an objective lens of focal length 150 cm and an eye piece 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

(a) Define power of a lens. Write its units. Deduce the relation $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$ for two thin lenses kept in contact coaxially.

(b) Two converging lens of focal length 20 cm and 5 cm are kept at a distance of 10 cm in air, find the equivalent power of the combination.



32. Draw the magnetic field lines due to a current passing through a long solenoid. Use Ampere's circuital law, to obtain the expression for the magnetic field due to the current I in a long solenoid having n number of turns per unit length.

OR

(a) How is a toroid different from a solenoid ?

(b) Use Ampere's circuital law to obtain the magnetic field inside a toroid.

(c) Show that in an ideal toroid, the magnetic field (i) inside the toroid and (ii) outside the toroid at any point in the open space is zero.

33. A slow neutron strikes a nucleus of $_{92}U^{235}$ splitting it into lighter nuclei of barium and krypton and releasing three neutrons. Write the corresponding nuclear reaction. Also calculate the energy released in this reaction. Given that $m(_{92}U^{235})$ = 235.043933 a.m.u., $m(n^1)$ = 1.008665 a.m.u. $m(_{56}Ba^{141})$ = 140.917700 a.m.u. and $m(_{36}(Kr^{92})$ = 91.895400 a.m.u.

OR

(a) Why is the binding energy per nucleon found to be constant for nuclei in the range of mass number (A) lying between 30 and 170?

(b) When a heavy nucleus with mass number A = 240 breaks into two nuclei, A = 120, energy is released in the process. Why?

SOLUTIONS

1. Photodiode is used to detect the light signal and to measure light intensity.

2. No, potential function cannot have a maximum or minimum value in free space.

For that to happen $\frac{dV}{dr} = 0$ or $E = 0$ which is not so in free space.

3. As the output voltage obtained in a half wave rectifier circuit has a single variation in one cycle of ac voltage, hence the fundamental frequency in the ripple of output voltage would be = 50 Hz.

4. Total current remains the same, current density $J = \frac{I}{A}$, J changes with change in area, drift speed $v_d = \frac{I}{Ane}$ also changes.

OR

Region BC of the graph has a negative slope, hence in region BC semiconductor has a negative resistance.

5. γ-rays are electromagnetic waves of very large energy, so they passes through the matter with less number of collisions with atoms or molecules of matter, thereby penetrating more into it.

OR

Ultraviolet radiations produced during welding are harmful to eyes. Special goggles or face masks are used to protect eyes from UV radiations. UV radiations have a range of frequency between 10^{14} Hz – 10^{16} Hz.

6. Two sources are said to be coherent, if they emit light waves of same frequency or wavelength and of a stable phase difference.

7. (i) Zero, (ii) 90°

OR

Given: $B_H = B$, $\delta = 60°$; $B_H = B_T \cos\delta$

$B = \frac{B_T}{2} \Rightarrow B_T = 2B$

At equator $\delta = 0$

$\therefore \quad B_{Heq} = B_T \cos\delta \Rightarrow B_{Heq} = 2B$

8. As $V_L = V_C = 30$ V, so the series LCR circuit is in resonance and hence the applied voltage and current in the circuit are in same phase.

9. Diffusion of electrons and holes across the junction.

OR

LED's must have band gap in the order of 1.8 eV to 3 eV but Si and Ge have band gap less than 1.8 eV.

10. 2 A, because magnitude of current is constant at 2 A.

11. (c) : Faraday's laws involve conservation of mechanical energy into electrical energy. This is in accordance with the law of conservation of energy. In pure resistance, the e.m.f. is in phase with the current.

12. (a) : A voltmeter is always connected in parallel. This has ofcourse a large resistance.

13. (d) : Charge flows from a body at higher potential to the body at lower potential. A condenser of higher capacity may be at higher potential. So the charge may flow from it to the condenser of lower capacity, which may be at lower potential. Therefore, both assertion and reason are wrong.

14. (a) : The bulb fuses when potential difference across it becomes more than 220 volt.
At on and off hour, inductive effect may produce a surge in voltage and the bulb may be fused under higher voltage.

15. (i) (c)

(ii) (a) : Atomic spectra could be explained by Bohr's model.

(iii) (a)

(iv) (a) : Energy of n^{th} Bohr's orbit of hydrogen atom.

$$E_n = \frac{-2.17\times10^{-18}}{n^2} \text{ J/atom}$$

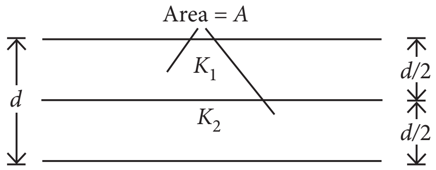
For fifth orbit, $E_n = \frac{-2.17\times10^{-18}}{5^2}$

$= -8.68 \times 10^{-20}$ J/atom

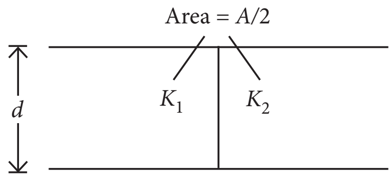
(v) (d) : The energy of the electron in a hydrogen like atom in the ground state is = – 13.6 Z^2 eV.
Since for lithium $Z = 3$, the third electron has energy equal to – 13.6 × 9 eV = 122.4 eV.
The energy needed to remove two electrons from the lithium atom in the ground state is therefore equal to (E –122.4) eV.

16. (i)(a): When the two dielectric slabs fill the space between two plates of the capacitor as shown in figure (a). It behaves series combination of two subcapacitors. Each subcapacitor has plate area A and plate separation $d/2$. The capacitor of capacitor given by

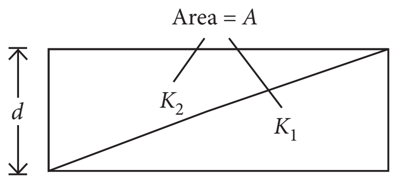
$$C = \frac{2\varepsilon_0 K_1 K_2}{(K_1 + K_2)d}$$



(a)



(b)



(c)

(ii) (b) : When two dielectric slabs fill the space between the two plates of the capacitor as shown in figure (b), it behaves as parallel combination of two sub-capacitors. Each sub-capacitor has plate area $A/2$ and plate separation d. The capacitance of capacitor is given by

$$C = \frac{\varepsilon_0 A(K_1 + K_2)}{2d}$$

(iii) (c) : When two dielectric slabs fill the space between the two plates of the capacitors as shown in figure(c), it behaves as series combination of two sub-capacitors. Each sub-capacitor has plate area A, plate separation d and the two dielectric slabs gradually varying thicknesses filling the space between the plate. The capacitance of the capacitor is given by

$$C = \frac{\varepsilon_0 A K_1 K_2}{(K_1 - K_2)d} \log_e \frac{K_2}{K_1}$$

(iv) (d)

(v) (a) : Capacitance of capacitor before inserting metal plate is $C = (\varepsilon_0 A)/d$ And after the insertion of any dielectric plate filling the capacitor partially is

$C = (\varepsilon_0 A)/[(d–t)+t/K]$

We know that K for a metal is infinite thus

$C = (\varepsilon_0 A)/(d–t)$

Here $t = d/3$ thus

$C' = (3\varepsilon_0 A)/2d = \frac{3}{2} C$

$C : C' = 2 : 3$

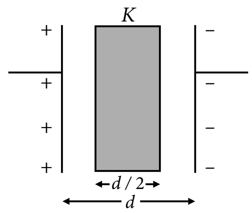
17. Electric flux, $\phi_1 = \frac{Q}{\varepsilon_0}$, $\phi_2 = \frac{3Q}{\varepsilon_0}$

The ratio of the electric flux, $\frac{\phi_1}{\phi_2} = \frac{1}{3}$

If a medium of dielectric constant 5 is filled in the space inside S_1, the flux inside S_1

$$\phi_1' = \frac{Q}{5\varepsilon_0} = \frac{\phi_1}{5}$$

OR



Capacitance of a capacitor partially filled with a dielectric

$$C = \frac{\varepsilon_0 A}{d - t + \frac{t}{K}} = \frac{\varepsilon_0 A}{d - \frac{d}{2} + \frac{d}{2K}} = \frac{2\varepsilon_0 AK}{d(K+1)}$$

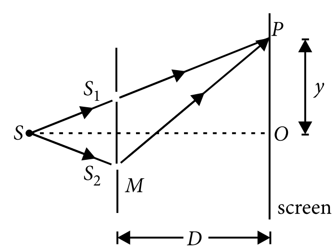
18. (a) Given : $SS_2 - SS_1 = \frac{\lambda}{4}$

Now path difference between the two waves from slit S_1 and S_2 on reaching point P on screen is

$\Delta x = (SS_2 + S_2P) - (SS_1 + S_1P)$

or $\Delta x = (SS_2 - SS_1) + (S_2P - S_1P)$

or $\Delta x = \frac{\lambda}{4} + \frac{yd}{D}$, where d is the slits separation.



For constructive interference at point P, path difference, $\Delta x = n\lambda$ or $\frac{\lambda}{4} + \frac{yd}{D} = n\lambda$

or $\frac{yd}{D} = \left(n - \frac{1}{4}\right)\lambda$ ...(i)

where $n = 0, 1, 2, 3,...,$

(b) From equation (i), $y_n = \left(n - \frac{1}{4}\right)\frac{\lambda D}{d}$

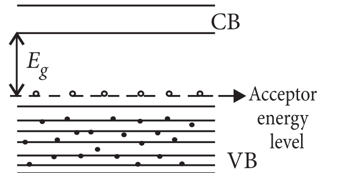
and $y_{n-1} = \left(n - 1 - \frac{1}{4}\right)\frac{\lambda D}{d}$

The fringe width is given by separation of two consecutive bright fringes.

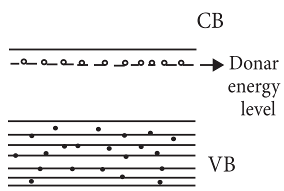
$$\beta = y_n - y_{n-1} = \left(n - \frac{1}{4}\right)\frac{\lambda D}{d} - \left(n - 1 - \frac{1}{4}\right)\frac{\lambda D}{d} = \frac{\lambda D}{d}$$

19.

Energy band diagram for p-type semiconductor



Energy band diagram for n-type semiconductor



Differences between p-type and n-type semiconductor :

S. No.	*p*-type semiconductor	*n*-type semiconductor
1.	Density of holes >> density of electron	Density of electron >> density of holes
2.	Formed by doping trivalent impurity atoms to a pure or intrinsic semiconductor.	Formed by doping pentavalent impurity atoms to pure or intrinsic semiconductor.

OR

Energy of photon, $E = \frac{hc}{\lambda}$

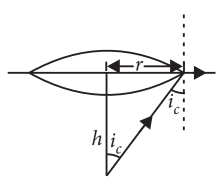
$$= \frac{6.62 \times 10^{-34} \times 3 \times 10^{8}}{600 \times 10^{-9} \times 1.6 \times 10^{-19}} \text{ eV} = 2.07 \text{ eV}$$

As $E < E_g$ (2.8 eV), so photodiode cannot detect this photon.

20. Radius, $r = h \tan i_c$

$$= h\frac{\sin i_c}{\cos i_c}$$

$$r = h\frac{1/\mu}{\sqrt{1 - \frac{1}{\mu^2}}} \Rightarrow r = \frac{h}{\sqrt{\mu^2 - 1}}$$



21. In alternating current, both magnitude and direction of current changes with time, which makes the needle of ordinary moving coil ammeter oscillate even with low frequency of A.C. Hence it can not be used to measure alternating current.

22. de-Broglie hypothesis : It states that a moving particle sometimes acts as a particle or a wave associated with moving particle which controls the particle in every respect. The wave associated with moving particle is called matter wave or de-Broglie wave whose wavelength is given by

$$\lambda = \frac{h}{mv}$$

where m and v are the mass and velocity of the particle and h is Planck's constant.

Yes, it is applicable for moving electron of hydrogen atom.

OR

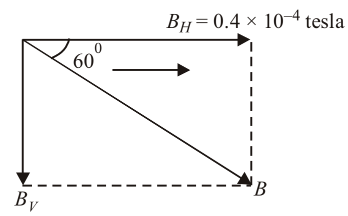
Kinetic energy of the electron in the second state of hydrogen atom

$$E_K = \frac{13.6 \text{ eV}}{n^2} = \frac{13.6 \text{ eV}}{4} = 3.4 \times 1.6 \times 10^{-19} \text{ J}$$

de Broglie wavelength $\lambda = \frac{h}{\sqrt{2mE_K}}$

$$= \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 3.4 \times 1.6 \times 10^{-19}}} = 0.67 \text{ nm}$$

23. As one moves from the equator towards north pole, angle of dip increases such that north pole of the bar magnet bends downwards.



$$\tan 60° = \frac{B_V}{B_H}$$

$$B_V = \sqrt{3}\, B_H = \sqrt{3} \times 0.4 \times 10^{-4} \text{ tesla}$$

$$B_{net} = \sqrt{B_H{}^2 + B_V{}^2} = 0.4 \times 10^{-4} \times 2$$
$$= 0.8 \times 10^{-4} \text{ tesla}$$

24. (i) When QR is parallel to the base BC, we have

$i = e \Rightarrow \quad r_1 = r_2 = r$

We know that

$r_1 + r_2 = A \Rightarrow r + r = A$

$\therefore \quad r = A/2$

(ii) Also, we have

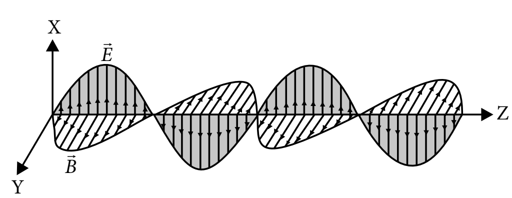
$A + D = i + e$

Substituting, $D = D_m$ and $i = e$

$A + D_m = i + i$

$\therefore \quad D_m = 2i - A$

25. (i)



Propagation of electromagnetic wave is along z-axis.
(ii) Speed of electromagnetic wave can be given as the ratio of magnitude of electric field (E_0) to the magnitude of magnetic field (B_0), *i.e.*, $c = \frac{E_0}{B_0}$

(iii) Energy density carried by the electromagnetic waves is

$u = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2\mu_0}B^2$; where E and B are electric and magnetic fields of electromagnetic waves.

Momentum of electromagnetic wave is

$p = \frac{U}{c}$; where U is the energy.

26. $L_1 = \mu_0 n_1^2 l A_1$ ...(i)

$L_2 = \mu_0 n_2^2 l A_2$ ...(ii)

$M = \mu_0 n_1 n_2 l A_2$ ...(iii)

Now, $L_1 L_2 = \mu_0^2 n_1^2 n_2^2 l^2 A_1 A_2$

or $\sqrt{L_1 L_2} = \mu_0 n_1 n_2 l \sqrt{A_1 A_2}$ ...(iv)

Dividing equation (iii) by (iv), we get

$$\frac{M}{\sqrt{L_1 L_2}} = \frac{A_2}{\sqrt{A_1 A_2}} = \frac{\sqrt{A_2^2}}{\sqrt{A_1 A_2}} = \frac{\sqrt{A_2}}{\sqrt{A_1}}$$

or $\frac{M}{\sqrt{L_1 L_2}} < 1$ $[\because A_2 < A_1]$

or $M < \sqrt{L_1 L_2}$

OR

Lenz's law states that the direction of the induced emf and the direction of induced current are such that they oppose the cause which produces them.

The rod held along east west direction will fall in a perpendicular magnetic field B_H present in N-S direction. Hence an emf will be induced in the rod following the relation for the motional emf

$\varepsilon = B_H v l$.

27. Principle of potentiometer : When a constant current flows through a wire of uniform area of cross-section, the potential drop across any length of the wire is directly proportional to the length.

Let resistance of wire AB be R_1 and its length be l then current drawn from driving cell

$$I = \frac{V}{R + R_1}$$

and hence potential drop across the wire AB will be,

$$V_{AB} = IR_1 = \frac{V}{R + R_1} \times \frac{\rho l}{a}$$

where a is the area of cross-section of the wire AB.

$$\therefore \frac{V_{AB}}{l} = \frac{V\rho}{(R + R_1)a} = \text{constant} = k$$

When R increases, current and potential difference across wire AB will be decreased and hence potential gradient k will also be decreased. Thus the null point or balance point will shift to right (towards, B) side.

28. (a) Two different lamps emit light waves which are not coherent, as they are not in same phase or not have stable phase difference. Due to this, no sustained interference pattern can be obtained on screen.

(b) Intensity at a point, $I = 4I_0 \cos^2\left(\frac{\phi}{2}\right)$

Phase difference $= \frac{2\pi}{\lambda} \times$ Path difference

At path difference λ,

Phase difference, $\phi = \frac{2\pi}{\lambda} \times \lambda = 2\pi$

$\therefore$ Intensity, $K = 4I_0 \cos^2\left(\frac{2\pi}{2}\right)$

[$\because$ Given $I = K$ at path difference λ]

$K = 4I_0$ ...(i)

At path difference $\frac{\lambda}{3}$

$$\phi' = \frac{2\pi}{\lambda} \times \frac{\lambda}{3} = \frac{2\pi}{3}$$

Intensity, $I' = 4I_0 \cos^2\left(\frac{2\pi}{6}\right)$

$= \frac{K}{4}$ (Using (i))

OR

(a) The angular width of central maximum is given by

$2\theta_0 = \frac{2\lambda}{a}$, ...(i)

where the letters have their usual meanings.

(i) Effect of slit width : From the equations (i), it follows that $\beta_0 \propto \frac{1}{a}$. Therefore, as the slit width is increased, the width of the central maximum will decrease.

(ii) Effect of distance between slit and screen (D) : From the equation (i), it follows that $2\theta_0$ is independent of D. So the angular width will remain same whatever the value of D.

(b) Difference between interference and diffraction

Experiment to observe diffraction pattern

S. No	Interference	Diffraction
1.	Interference is caused by superposition two waves starting from two coherent sources.	Diffraction is caused by superposition of a number of waves starting from the slit.
2.	All bright and dark fringes are of equal width.	Width of central bright fringe is double of all other maxima.
3.	All bright fringes are of same intensity.	Intensity of bright fringes decreases sharply as we move away from central bright fringe.
4.	Dark Fringes are perfectly dark.	Dark fringes are not perfectly dark.

29. Given, $q_A = q_B = 6 \times 10^{-8}$ C

When uncharged sphere C is brought in contact with sphere A, then the charge on A or C is

$$q'_A = \frac{\text{Charge on } A + \text{Charge on } C}{2} = \frac{(6\times10^{-8}+0)}{2}$$

$= 3 \times 10^{-8}$ C

When charged sphere C is brought in contact with charged sphere B, then the charge on sphere B or C is

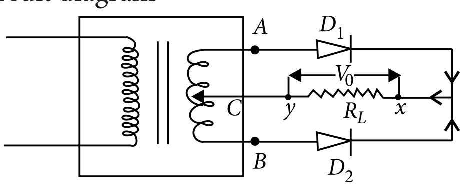
$$q'_B = \frac{(6\times10^{-8}+3\times10^{-8})}{2} = 4.5\times10^{-8}\text{ C}$$

New force between spheres A and B is

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q'_A q'_B}{r^2} = \frac{9\times10^9\times3\times10^{-8}\times4.5\times10^{-8}}{(0.6)^2}$$

$$= \frac{9\times3\times4.5\times10^{-7}}{0.36} = 3.4\times10^{-5}\text{ N}$$

30. Circuit diagram



One possible answer: Change the connection of R_L from point C to point B.

Now no current flowing through D_2 in the second half.

31. (a) When the final image is formed at least distance of distinct vision :

Magnifying power of refracting telescope (M) is defined as the ratio of the angle subtended by the image (β) at the eye to the angle subtended by the distant object at the unaided eye (α).

$$M = \frac{\beta}{\alpha}$$

We can increase the magnifying power of telescope by

(i) Increasing the focal length of the objective.

(ii) Decreasing the focal length of eyepiece.

(b) Here, $f_o = 150$ cm, $f_e = 5$ cm

Angle subtended by 100 m tall tower at 3 km is

$$\alpha = \frac{100}{3\times1000} = \frac{1}{30}\text{ rad}$$

If h is the height of image formed by the objective, then

$$\alpha = \frac{h}{f_o} = \frac{h}{150}$$

$$\therefore \frac{h}{150} = \frac{1}{30} \quad \text{or} \quad h = \frac{150}{30}\text{ cm} = 5\text{ cm}$$

Magnification produced by eyepiece

$$m_e = \left(1+\frac{D}{f_e}\right) = \left(1+\frac{25}{5}\right) = 6$$

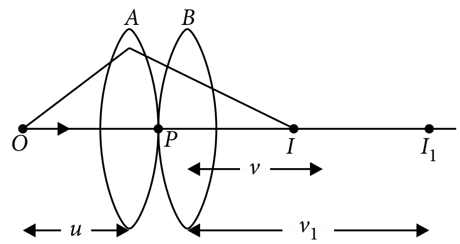
$\therefore$ Height of final image $= h \times m_e = 5 \times 6 = 30$ cm

OR

(a) Power of lens : It is the reciprocal of focal length of a lens.

$$P = \frac{1}{f} \quad (f \text{ is in metre})$$

Unit of power of lens : Dioptre



An object is placed at point O. The lens A produces an image at I_1 which serves as a virtual object for lens B which produces final image at I.

Given, the lenses are thin. The optical centres (P) of the lenses A and B coincide with each other.

For lens A, we have $\frac{1}{v_1} - \frac{1}{u} = \frac{1}{f_1}$ ...(i)

For lens B, we have $\frac{1}{v} - \frac{1}{v_1} = \frac{1}{f_2}$ ...(ii)

Adding equations (i) and (ii), $\frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2}$ ...(iii)

If two lenses are considered as equivalent to a single lens of focal length f, then

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad \text{...(iv)}$$

From equation (iii) and equation (iv), we can write

$$\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}$$

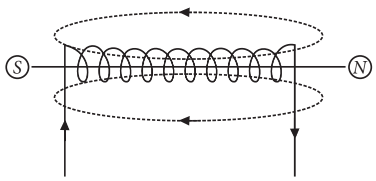
(b) Equivalent focal length of two lenses separated by a distance is given as

$$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}-\frac{d}{f_1 f_2};$$

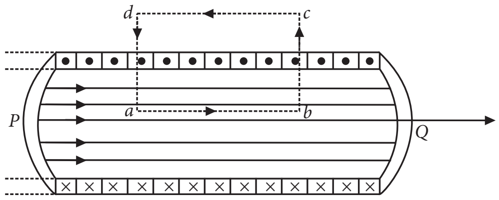
$$\frac{1}{F}=\frac{1}{0.2}+\frac{1}{0.05}-\frac{0.1}{(0.2)(0.05)}=15\ \text{m}^{-1}$$

$\Rightarrow$ Power $P=\frac{1}{F}=+15$ D

32.



Consider a rectangular amperian loop *abcd* near the middle of solenoid as shown in figure where $PQ = l$.



Let the magnetic field along the path *ab* be B and is zero along *cd*. As the paths *bc* and *da* are perpendicular to the axis of solenoid, the magnetic field component along these paths is zero. Therefore, the path *bc* and *da* will not contribute to the line integral of magnetic field B.

Total number of turns in length $l = nl$

The line integral of magnetic field induction B over the closed path *abcd* is

$$\int_{abcd}\vec{B}\cdot\vec{dl}=\int_a^b\vec{B}\cdot\vec{dl}+\int_b^c\vec{B}\cdot\vec{dl}+\int_c^d\vec{B}\cdot\vec{dl}+\int_d^a\vec{B}\cdot\vec{dl}$$

$$\because \int_a^b\vec{B}\cdot\vec{dl}=\int_a^b B\,dl\cos 0^\circ = Bl$$

and $\int_b^c\vec{B}\cdot\vec{dl}=\int_b^c B\,dl\,\cos 90^\circ = 0 = \int_d^a\vec{B}\cdot\vec{dl}$

Also $\int_c^d\vec{B}\cdot\vec{dl}=0$ $\quad$ ($\because$ Outside the solenoid, $B = 0$)

$$\therefore \int_{abcd}\vec{B}\cdot\vec{dl}=Bl+0+0+0=Bl \qquad \text{...(i)}$$

Using Ampere's circuital law

$$\int_{abcd}\vec{B}\cdot\vec{dl}=\mu_0\times \text{total current in rectangle } abcd$$

$= \mu_0 \times$ number of turns in rectangle $\times$ current

$= \mu_0 \times nl \times I = \mu_0\, nl\, I$ ...(ii)

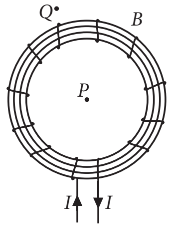
From (i) and (ii), we have

$Bl = \mu_0 nl\, I \qquad \therefore\ B = \mu_0 nI$

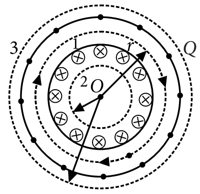
It gives magnetic field strength inside straight current carrying solenoid, directed along the axis of solenoid.

OR

(a) A solenoid bent into the form of closed loop is called toroid. The magnetic field B has a constant magnitude everywhere inside the toroid.



(b) Let magnetic field inside the toroid is B along the considered loop (1) as shown in figure.



Applying Ampere's circuital law,

$$\oint_{\text{loop}1}\vec{B}\cdot\vec{dl}=\mu_0(NI)$$

Since, toroid of N turns, threads the loop 1, N times, each carrying current I inside the loop. Therefore, total current threading the loop 1 is NI.

$$\Rightarrow \oint_{\text{loop}1}\vec{B}\cdot\vec{dl}=\mu_0(NI)$$

$$B\oint_{\text{loop}} dl=\mu_0(NI)$$

$$B\times 2\pi r=\mu_0 NI \text{ or } B=\frac{\mu_0 NI}{2\pi r}$$

(c) (i) Magnetic field inside the open space interior the toroid. Let the loop (2) as shown in figure experience magnetic field B.

No current threads the loop 2 which lies in the open space inside the toroid.

$\therefore$ By Ampere's circuital law

$$\oint_{\text{loop }2}\vec{B}\cdot\vec{dl}=\mu_0(0)=0\Rightarrow B=0$$

(ii) Magnetic field in the space exterior of toroid. Let us consider a coplanar loop (3) 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

$= \quad NI - NI = 0$

$\therefore$ 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 interior and exterior the toroid.

33. The nuclear reaction can be represented as

$${}_{92}U^{235} + {}_0n^1 \rightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3\,{}_0n^1 + Q$$

If $m_N({}_{92}U^{235})$, $m_N({}_{56}Ba^{141})$, $m_N({}_{36}Kr^{92})$ represented masses of ${}_{92}U^{235}$, ${}_{56}Ba^{141}$ and ${}_{36}Kr^{92}$ nuclei respectively and $m({}_0n_1)$, the mass of neutron, then energy released is given by

$$Q = [m_N({}_{92}U^{235}) + m({}_0n^1) - m_N({}_{56}Ba^{141}) - m_N({}_{36}Kr^{92}) - 3m\,({}_0n^1)] \times 931.5$$

$$= [m_N({}_{92}U^{235}) - m_N({}_{56}Ba^{141}) - m_N({}_{36}Kr^{92}) - 2m\,({}_0n^1)] \times 931.5 \quad \text{....(i)}$$

If $m({}_{92}U^{235})$, $m({}_{56}Ba^{141})$ and $m({}_{36}Kr^{92})$ represent masses of ${}_{92}U^{235}$, ${}_{56}Ba^{141}$ and ${}_{36}Kr^{92}$ atoms respectively, then the equation (i) may be expressed as

$$Q = [\{m({}_{92}U^{235}) - 92m_e\} - \{m({}_{25}Ba^{141}) - 56m_e\} - m\{({}_{36}Kr^{92}) - 36\,m_e\} - 2m\,({}_0n^1)] \times 931.5$$

$$[m({}_{92}U^{235}) - m({}_{56}Ba^{141}) - m({}_{36}Kr^{92}) - 2m\,({}_0n^1)] \times 931.5$$

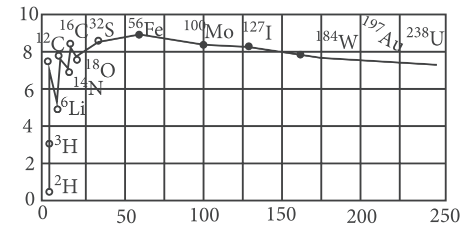
$$[235.043933 - 140.917700 - 91.895400 - 2 \times 1.008665] \times 931.5$$

$$= 0.2135 \times 931.5 = 198.88 \text{ MeV.}$$

Note : It is not mentioned in the problem as to whether the given masses are atomic masses or nuclear masses. In case, the given masses are nuclear masses, the solutions is quite simple. The problem has been solved by considering the given masses as atomic masses.

OR

(a)



The constancy of binding energy in the range $30 < A < 170$ is a consequence of the fact that the nuclear force is short ranged. Consider a particular nucleon inside a sufficiently large nucleus. It will be under the influence of only some of its neighbours, which come within the range of the nuclear force. If any other nucleon is at a distance more than the range of the nuclear force from the particular nucleon it will have no influence on the binding energy of the nucleon under consideration. If a nucleon can have a maximum of p neighbours within the range of nuclear force, its binding energy would be proportional to p. Let the binding energy of the nucleus be pk, where k is a constant having the dimensions of energy. If we increase A by adding nucleons they will not change the binding energy of a nucleon inside. Since most of the nucleons in a large nucleus reside inside it and not on the surface, the change in binding energy per nucleon would be small. The binding energy per nucleon is a constant and is approximately equal to pk.

(b) A very heavy nucleus with $A = 240$, has lower binding energy per nucleon compared to that of a nucleus with $A = 120$. When a heavy nucleus with mass number $A = 240$ breaks into two nuclei, $A = 120$, energy is released in this process.

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