Class XII Session 2025-26
Subject - Physics
Sample Question Paper - 4

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

General Instructions:

1. There are 33 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.
3. All the sections are compulsory.
4. **Section A** contains sixteen questions, twelve MCQ and four Assertion Reasoning based of 1 mark each, **Section B** contains five questions of two marks each, **Section C** contains seven questions of three marks each, **Section D** contains two case study based questions of four marks each and **Section E** contains three long answer questions of five marks each.
5. There is no overall choice. However, an internal choice has been provided in one question in Section B, one question in Section C, one question in each CBQ in Section D and all three questions in Section E. You have to attempt only one of the choices in such questions.
6. Use of calculators is not allowed.

Section A

1. Hole is **[1]**

a) A vacancy created when an electron leaves a covalent bond.
b) Gap between valence band and conduction band
c) Particle similar to that of electron
d) An anti-particle of electron.

2. Thermo emf ε (in volts) of a certain thermocouple is found to vary with θ (in ^{o}C) according to equation E = 20θ - $\frac{\theta^2}{20}$, where θ is the temperature of the hot function, the cold function being kept at 0° C. Then, the neutral temperature of the thermocouple is: **[1]**

a) 100°C
b) 340°C
c) 200°C
d) 300°C

3. For a glass prism, the angle of minimum deviation will be smallest for the light of **[1]**

a) blue colour
b) yellow colour
c) red colour.
d) green colour

4. The susceptibility of a magnetic substance is found to depend on temperature and the strength of the magnetising field. The material is a: **[1]**

a) diamagnet
b) superconductor

c) paramagnet

d) ferromagnet

5. A series combination of n_1 capacitors, each of value C_1 is charged by a source of potential difference 4V. When another parallel combination of n_2 capacitors, each of value C_2, is charged by a source of potential difference V, it has the same (total) energy stored in it, as the first combination has. The value of C_2, in terms of C_1, is then: **[1]**

a) $\frac{2C_1}{n_1 n_2}$

b) $16\frac{n_2}{n_1}C_1$

c) $2\frac{n_2}{n_1}C_1$

d) $\frac{16C_1}{n_1 n_2}$

6. Magnetic field due to a straight solenoid at any point inside it is B = μ_0 ni. Magnetic field at the end of the solenoid is **[1]**

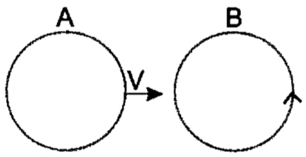
a) $\frac{B}{4}$

b) 2B

c) $\frac{B}{2}$

d) B

7. There are two coils A and B as shown in the figure. A current starts flowing in B as shown, when A is moved towards B and stops when A stops moving. The current in A is counter clockwise. B is kept stationary when A moves. We can infer that **[1]**



a) there is a constant current in the counterclockwise direction in A.

b) there is a constant current in the clockwise direction in A.

c) there is no current in A.

d) there is a varying current in A.

8. The intensity of magnetic field is H and the moment of a magnet is M Maximum potential energy is: **[1]**

a) 4 MH

b) MH

c) 2 MH

d) 3 MH

9. The maximum number of possible interference maxima for slit separation equal to twice the wavelength in Young's double-slit experiment is: **[1]**

a) three

b) zero

c) five

d) infinite

10. Two point charges q_1 and q_2 are at separation r. The force acting between them is given by $F = K\frac{q_1 q_2}{r^2}$. The constant K depends upon **[1]**

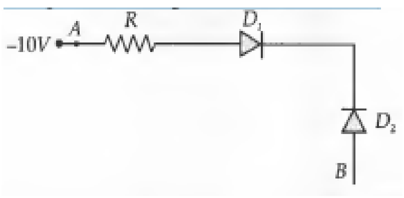
a) neither on only on the system of units nor on only on medium between charges

b) only on medium between charges

c) only on the system of units

d) both on only on the system of units and only on medium between charges

11. In the given Fig., assuming the diodes to be ideal, **[1]**



a) D_1 and D_2 are both forward biased and hence current flows from A to B.

b) D_2 is forward biased and D_1 is reverse biased and hence no current flows from B to A and vice versa.

c) D_1 and D_2 are both reverse biased and hence no current flows from A to B and vice versa.

d) D_1 is forward biased and D_2 is reverse biased and hence current flows from A to B

12. The relationship between angle of incidence i, prism of angle A and angle of minimum deviation for a triangular prism is **[1]**

a) $2A + \delta_m = i$

b) $A + \delta_m = 2i$

c) $A + \frac{\delta_m}{2} = i$

d) $A + \delta_m = i$

13. **Assertion (A):** If frequency of incident light is doubled, the kinetic energy of photoelectron is also doubled. **[1]**

Reason (R): The kinetic energy of photoelectron is directly proportional to frequency of incident light.

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.

14. **Assertion:** If a conducting medium is placed between two charges, then electric force between them becomes zero. **[1]**

Reason: Reduction in a force due to introduced conductor is proportional to its dielectric constant.

a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

c) Assertion is correct statement but reason is wrong statement.

d) Assertion is wrong statement but reason is correct statement.

15. **Assertion (A):** When a tiny circular obstacle is placed in the path of light from a distant source, a bright spot is seen at the centre of the shadow of the obstacle. **[1]**

Reason (R): Wave diffracted from the edges of circular obstacle interfere constructively at the centre of the shadow resulting in the formation of a bright spot.

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.

16. **Assertion (A):** An alternating current does not show any magnetic effect. **[1]**

Reason (R): Alternating current varies with time.

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.

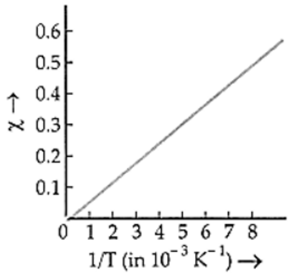
c) A is true but R is false.

d) A is false but R is true.

Section B

17. Find the wavelength of the electromagnetic waves of frequency 4×10^9 Hz in free space. Give its two applications. **[2]**

18. Find Curie constant for chromium potassium alum from its χ vs. $\frac{1}{T}$ graph shown in figure. **[2]**



OR

A bar magnet of magnetic moment M is aligned parallel to the direction of a uniform magnetic field B. What is the work done, to turn the magnet, so as to align its magnetic moment:

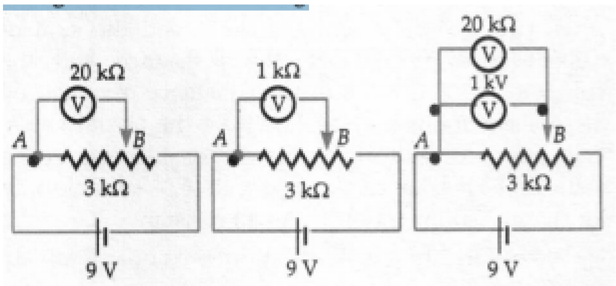
i. opposite to the field direction and
ii. normal to the field direction?

19. When the voltage drop across a p-n junction diode is increased from 0.70 V to 0.71 V, the change in the diode current is 10 mA. What is the dynamic resistance of the diode? **[2]**

20. Which level of the double ionised lithium (Li^{2+}) has the same energy as the ground state energy of the hydrogen atom? Compare the orbital radius of the two levels. **[2]**

21. a. battery of emf 9 V and negligible internal resistance is connected to a 3k Ω resistor. The potential drop across a part of the resistor (between points A and B in Fig. is measured by **[2]**

i. a 20 k Ω voltmeter;
ii. a 1 kΩ voltmeter.
iii. both the voltmeters are connected across AB. In which case would you get the
1. highest,
2. lowest reading?



b. Do your answers to this problem alter if the potential drop across the entire resistor is measured ? What if the battery has non-negligible resistance?

Section C

22. A cell of emf ε and internal resistance r is connected across a variable resistance R. Plot graphs showing the variation of **[3]**

i. ε and R,
ii. terminal p.d. V with R. Predict from the second graph under which V becomes equal to ε.

23. The maximum kinetic energy of the photoelectrons emitted is doubled when the wavelength of light incident on the photosensitive surface changes from λ_1 to λ_2. Deduce expressions for the threshold wavelength and work function for the metal surface in terms of λ_1 and λ_2. **[3]**

24. Distinguish between n-type and p-type semiconductors on the basis of energy band diagrams. **[3]**

25. Draw a plot showing the variation of binding energy per nucleon with mass number A. Write two important conclusions which you can draw from this plot. Explain with the help of this plot, the release in energy in the **[3]**

processes of nuclear fusion and fission.

26. An electron is in the third excited state in a hydrogen atom. It undergoes transitions to the lower energy states. **[3]**

a. What is the maximum number of spectral lines that can be emitted?

b. Calculate the minimum wavelength of the spectral lines emitted.

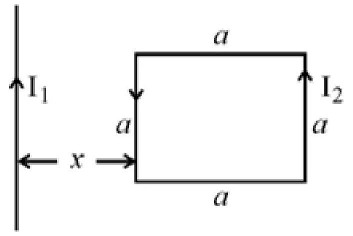
27. A plane wavefront is incident on a surface separating two media of refractive indices n_1 and n_2 ($> n_1$). With the help of a suitable diagram, explain its propagation from the rarer to denser medium. Hence, verify Snell's law. **[3]**

28. Define mutual inductance between a pair of coils. Derive an expression for the mutual inductance of two long coaxial solenoids of the same length wound one over the other. **[3]**

OR

a. Define mutual inductance and write its S.I. unit.

b. A square loop of side **a** carrying a current I_2 is kept at distance x from an infinitely long straight wire carrying a current I_1 as shown in the figure. Obtain the expression for the resultant force acting on the loop.



Section D

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

All the known radiations from a big family of electromagnetic waves which stretch over a large range of wavelengths. Electromagnetic wave include radio waves, microwaves, visible light waves, infrared rays, UV rays, X-rays and gamma rays. The orderly distribution of the electromagnetic waves in accordance with their wavelength or frequency into distinct groups having widely differing properties is electromagnetic spectrum.

(a) Which wavelength of the Sun is used finally as electric energy?
radio waves, infrared waves, visible light, microwaves

a) infrared waves
b) radio waves
c) microwaves
d) visible light

(b) Which of the following electromagnetic radiations have the longest wavelength?
X-rays, γ-rays, microwaves, radiowaves

a) γ-rays
b) X-rays
c) microwaves
d) radiowaves

(c) Which one of the following is not electromagnetic in nature?
X-rays, gamma rays, cathode rays, infrared rays

a) infrared rays
b) gamma rays
c) cathode rays
d) X-rays

OR

The decreasing order of wavelength of infrared, microwave, ultraviolet and gamma rays is

a) microwave, gamma rays, infrared, ultraviolet
b) infrared, microwave, ultraviolet, gamma rays.

c) gamma rays, ultraviolet, infrared, microwave

d) microwave, infrared, ultraviolet, gamma rays

(d) Which of the following has minimum wavelength?

X-rays, ultraviolet rays, γ-rays, cosmic rays

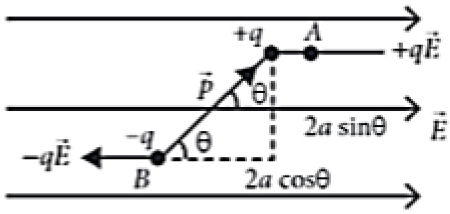
a) ultraviolet rays

b) X-rays

c) cosmic rays

d) γ-rays

30. When electric dipole is placed in uniform electric field, its two charges experience equal and opposite forces, which cancel each other and hence net force on electric dipole in uniform electric field is zero. However these forces are not collinear, so they give rise to some torque on the dipole. Since net force on electric dipole in uniform electric field is zero. so no work is done in moving the electric dipole in uniform electric field. However some work is done in rotating the dipole against the torque acting on it. **[4]**



i. The dipole moment of a dipole in a uniform external field $\vec{E}$ is $\vec{P}$. Then find the torque $\vec{\tau}$ acting on the dipole.

ii. An electric dipole consists of two opposite charges, each of magnitude 1.0 μC separated by a distance of 2.0 cm. The dipole is placed in an external field of 10^5 NC^{-1}. Then find the maximum torque on the dipole.

iii. Find the θ when torque on a dipole in uniform electric field is minimum.

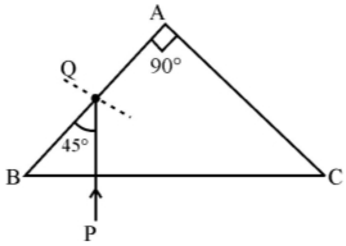
iv. What is the net force F and torque τ on the dipole when an electric dipole is held at an angle in a uniform electric field?

v. An electric dipole of moment p is placed in an electric field of intensity E. The dipole acquires a position such that the axis of the dipole makes an angle θ with the direction of the field. Assuming that the potential energy of the dipole to be zero when θ = 90^o, Find the torque and the potential energy of the dipole.

Section E

31. a. Draw the ray diagram showing refraction of ray of light through a glass prism. Derive the expression for the refractive index μ of the material of prism in terms of the angle of prism A and angle of minimum deviation δ_m. **[5]**

b. A ray of light PQ enters an isosceles right angled prism ABC of refractive index 1.5 as shown in figure.

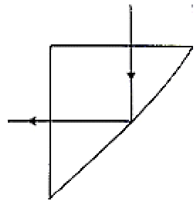


i. Trace the path of the ray through the prism.

ii. What will be the effect on the path of the ray if the refractive index of the prism is 1.4?

OR

A ray of light incident normally on one of the faces of a right angled isosceles prism is found to be totally reflected as shown.



i. What is the minimum value of the refractive index of the material of the prism?

ii. When the prism is immersed in water, trace the path of the emergent ray for the same incident ray indicating the values of all the angles. (μ of water = $\frac{4}{3}$).

32. i. A. Why does the electric field inside a dielectric slab decrease when kept in an external electric field? **[5]**

B. Derive an expression for the capacitance of a parallel plate capacitor filled with a medium of dielectric constant K.

ii. A charge q = 2 μC is placed at the centre of a sphere of radius 20 cm. What is the amount of work done in moving 4 μC from one point to another point on its surface?

iii. Write a relation for polarisation $\vec{P}$ of a dielectric material in the presence of an external electric field.

OR

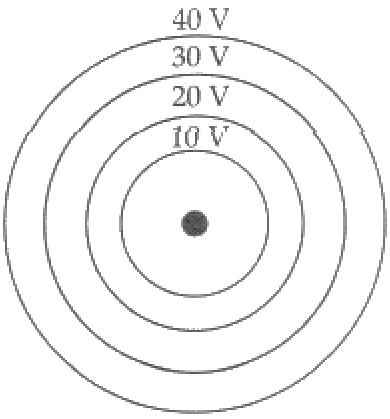
i. Two isolated metal spheres A and B have radii R and 2R respectively, and the same charge q. Find which of the two spheres have greater:

a. capacitance and

b. energy density just outside the surface of the spheres

ii. a. Show that the equipotential surfaces are closed together in the regions of a strong field and far apart in the regions of a weak field. Draw equipotential surfaces for an electric dipole,

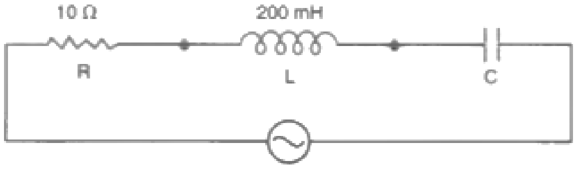
b. Concentric equipotential surfaces due to a charged body placed at the centre are shown. Identify the polarity of the charge and draw the electric field lines due to it.



33. In the following circuit, calculate: **[5]**

i. the capacitance of the capacitor, if the power factor of the circuit is unity,

ii. the Q-factor of this circuit. What is the significance of the Q-factor in ac circuit? Given the angular frequency of the ac source to be 100 rad/s. Calculate the average power dissipated in the circuit.



OR

A 25.0 pF capacitor, a 0.10 H inductor and a 25.0 ohm resistor are connected in series with an ac source whose emf is

$E = 310 \sin 314t$.

i. What is the frequency of the emf?

ii. Calculate

a. the reactance of the circuit

b. the impedance of the circuit and

c. the current in the circuit.

Solution

Section A

1. **(a)** A vacancy created when an electron leaves a covalent bond.
   Explanation:
   A **hole** is the absence of an electron in a particular place in an atom.

2. **(c)** 200°C
   Explanation:
   $\varepsilon = 20\theta - \frac{\theta^2}{20} \Rightarrow \frac{d\varepsilon}{d\theta} = 20 - \frac{\theta}{10}$
   At $\theta = \theta_n$, $\frac{d\varepsilon}{d\theta} = 0$
   $\therefore 20 - \frac{\theta_n}{10} = 0$
   or $\theta_n = 200^\circ\mathrm{C}$

3. **(c)** red colour.
   Explanation:
   For a glass prism, the angle of minimum deviation will be smallest for the light of red color.
   As wavelength of red color is maximum among all, hence, $\mu \propto \frac{1}{\lambda}$, hence $\mu$is smaller. As μ decreases, angle of deviation decreases.

4. **(c)** paramagnet
   Explanation:
   The susceptibility of a paramagnetic substance depends both on the temperature and strength of the magnetising field.

5. **(d)** $\frac{16C_1}{n_1 n_2}$
   Explanation:
   $\frac{1}{2}C_p V^2 = \frac{1}{2}C_s(4V)^2$
   or $\frac{1}{2}n_2 C_2 V^2 = \frac{1}{2}\frac{C_1}{n_1}(4V)^2$
   or $C_2 = \frac{16C_1}{n_1 n_2}$

6. **(c)** $\frac{B}{2}$
   Explanation:
   Magnetic field at the end of a current carrying solenoid is half of the magnetic field inside it.

7. **(a)** there is a constant current in the counterclockwise direction in A.
   Explanation:
   there is a constant current in the counterclockwise direction in A.

8. **(b)** MH
   Explanation:
   MH

9.

(c) five

Explanation:

According to the condition for interference maxima,

d $\sin\theta$ = n λ

Here, d = 2 λ

$\therefore$ 2 $\lambda\sin\theta$ = n λ

or n = 2 $\sin\theta$

For number of interference maxima to be maximum

$\sin\theta$ = 1

$\therefore$ n = 2 $\times$ 1 = 2

The interference maxima will occur, when

n = 0, $\pm$ 1 and $\pm$ 2

Hence, the maximum number of possible interference maxima = 5

10.

(d) both on only on the system of units and only on medium between charges

Explanation:

both on only on the system of units and only on medium between charges.

11.

(b) D_2 is forward biased and D_1 is reverse biased and hence no current flows from B to A and vice versa.

Explanation:

In circuit, A is at -10V and B is at 0V. So B is positive than A. So D_2 is in forward bias and D_1 is in reverse bias so no current flows from A to B or B to A.

12.

(b) A + δ_m = 2i

Explanation:

For refraction through prism,

$i_1 + i_2 = \delta + A$ and $r_1 + r_2 = A$

For minimum deviation,

$i_1 = i_2 = i$ and $r_1 = r_2 = r$

So, i = $\frac{(A+\delta_m)}{2}$

$\therefore$ A + δ_m = 2i

13.

(d) A is false but R is true.

Explanation:

A is false but R is true.

14. **(a)** Assertion and reason both are correct statements and reason is correct explanation for assertion.

Explanation:

The dielectric constant of any material is:

K = $\frac{E_0}{E} = \frac{F_0/q}{F/q} = \frac{F_0}{F}$ or F = $\frac{F_0}{K}$

Where, F_0 is force when conductor is not present between the charges. F is the force after the introduction of the conductor between the charges. Since, the dielectric constant of a conducting medium is infinity, therefore, F = 0.

15. **(a)** Both A and R are true and R is the correct explanation of A.

Explanation:

Both A and R are true and R is the correct explanation of A.

16.

(d) A is false but R is true.

Explanation:

Like direct current, an alternating current also produces a magnetic field. But the magnitude and direction of the field go on changing continuously with time.

Section B

17. Wavelength,

$\lambda = \frac{c}{v} = \frac{3\times10^8}{4\times10^9} = \frac{3}{40}$ m = 0.075 m

These are microwaves which are used

i. in radar systems for aircraft navigation.
ii. in microwave ovens.

18. According to Curie's law,

$\chi = \frac{C}{T}$

$\therefore$ C = χT

From the given graph, when χ = 0.50,

$\frac{1}{T} = 8.0 \times 10^{-3}$ K^{-1}

or T = 125 K

$\therefore$ C = 0.50 $\times$ 125 K = 62.5 K

OR

The work done in turning a dipole from orientation θ_1 to θ_2 in field B is given by

W = -MB (cos θ_2 - cos θ_1)

i. Here, θ_1 = 0^o and θ_2 = 180^o

$\therefore$ W = - MB (cos 180^o - cos 0^o)

= -MB (-1 - 1) = 2 MB

ii. Here, θ_1 = 0^o and θ_2 = 90^o

$\therefore$ W = - MB (cos 900^o - cos 0^o) = MB

19. For a p-n junction diode, the dynamic resistance is given by:

r = $\frac{\Delta V}{\Delta I}$

Given that:

ΔV = 0.71 - 0.70 = 0.01 V = 10^{-2} V

ΔI = 10^{-3} $\times$ 10A = 10^{-2} A

$\therefore$ r = $\frac{10^{-2}}{10^{-2}}$ = 1Ω

20. $E = \frac{2\pi^2 mk^2e^4}{h^2} \cdot \frac{Z^2}{n^2}$ i.e; $E_n \propto \frac{Z^2}{n^2}$

Let $E_n\left(\text{Li}^{2+}\right) = E_1(\text{H})$

$\therefore \left[\frac{Z^2}{n^2}\right]_{Li^{2+}} = \left[\frac{Z^2}{n^2}\right]_H$

or $\frac{3^2}{n^2} = \frac{1^2}{1^2}$ or n = 3

21. a. The voltmeter, which has maximum resistance, will draw minimum current and allow maximum current to flow through resistor AB. Consequently, there will be maximum potential difference across AB.

In case (i), resistance of voltmeter, $R_y = 20\text{k}\Omega$

In case (ii),$R_V = 1\text{k}\Omega$

In case (iii),$\frac{1}{R_V} = \frac{1}{20} + \frac{1}{1} = \frac{1+20}{20}$ or $R_V = \frac{20}{21}\text{k}\Omega$

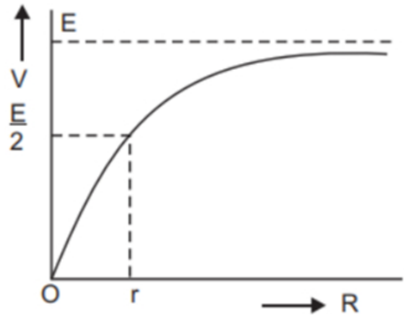
1. As the resistance of voltmeter is maximum in case (i), it will show maximum reading.
2. As the resistance of voltmeter is minimum in case (iii), it will show lowest reading.

b. In all cases, the voltmeter reading will be same if the battery has negligible internal resistance. But if the internal resistance is non-negligible, then the answers will be similar to those in (a).

Section C

22. When $R \to 0$, $V = 0$ When $R = r$, $V = \frac{E}{2}$ When $R = \infty$, $V = E$

The graph is shown in fig.



23. Given that

Initial kinetic energy of photoelectrons is given by = K_1

Final kinetic energy of photoelectrons is given by $K_2 = 2K_1$

Wavelength of light changes from λ_1 to λ_2

Let the threshold frequency is ν_0 and work function is ϕ_0

Now, we know that:-

$\frac{hc}{\lambda} = \phi_0 + KE$

$\frac{hc}{\lambda_1} = \phi_0 + K_1$ ...(i)

$\frac{hc}{\lambda_2} = \phi_0 + K_2$ ...(ii)

$K_2 = 2K_1$

$\frac{hc}{\lambda_2} = \phi_0 + 2K_1$ ...(iii)

$\frac{2hc}{\lambda_1} = 2\phi_0 + 2K_1$ (eq (i) $\times$ 2)

$\frac{2hc}{\lambda_1} - \frac{hc}{\lambda_2} = \phi_0$

$\Rightarrow \phi_0 = hc\left(\frac{2\lambda_2 - \lambda_1}{\lambda_1\lambda_2}\right)$

We know

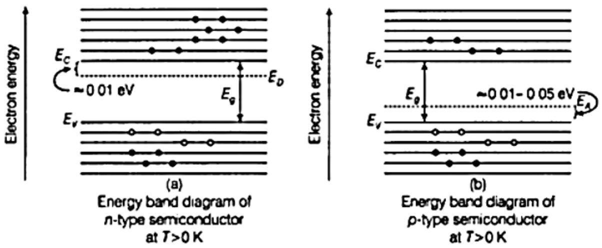
work function is given by $\phi_0 = \frac{hc}{\lambda_0}$

$\frac{hc}{\lambda_0} = hc\left(\frac{2\lambda_2 - \lambda_1}{\lambda_1\lambda_2}\right)$

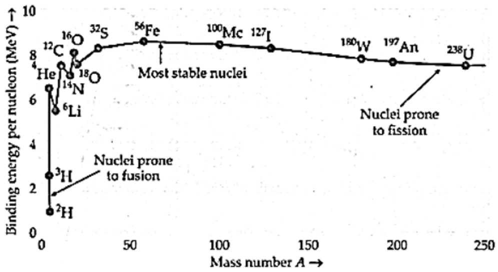
$\frac{1}{\lambda_0} = \frac{2\lambda_2 - \lambda_1}{\lambda_1\lambda_2}$

$\lambda_0 = \frac{\lambda_1\lambda_2}{2\lambda_2 - \lambda_1}$

24. In an n-type semiconductor, the donor energy level E_D is slightly below the bottom E_C of the conduction band and electrons from this level move into the conduction band with a very small supply of energy. Fermi-level shifts towards the conduction band where a higher number of electrons are available for conduction. In an n-type semiconductor, the energy gap decreases.



In a p-type semiconductor, the acceptor energy level E_A is above the top E_V of the valence band, therefore with a small supply of energy, the electrons can jump from the valence band to the acceptor energy level. Fermi levels shift closer to the valence bond because holes are the majority carriers. In a p-type semiconductor, the energy band increases.

25. 

Binding energy per nucleon as a function of mass number A.

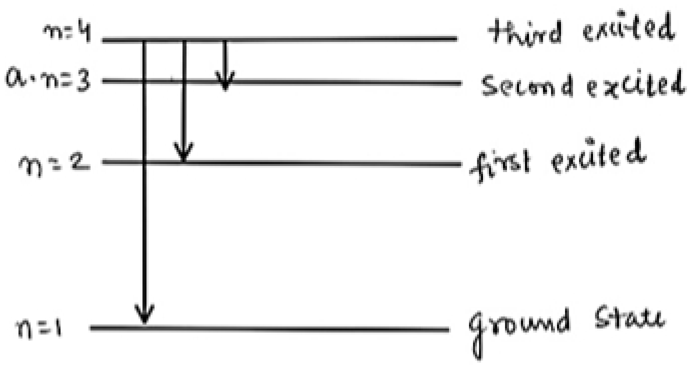
Two important conclusions from this graph are:

i. Nuclear forces non-central and short ranged force.

ii. Nuclear forces between proton-neutron and neutron-neutron are strong and attractive in nature.

Explanation of Nuclear Fission: When a heavy nucleus ($A \geq 235$ say) breaks into two lighter nuclei (nuclear fission), the binding energy per nucleon increases i.e, nucleons get more tightly bound. This implies that energy would be released in nuclear fission.

Explanation of Nuclear Fusion: When two very light nuclei ($A \leq 10$) join to form a heavy nucleus, the binding is energy per nucleon of fused heavier nucleus more than the binding energy per nucleon of lighter nuclei, so again energy would be released in nuclear fusion.

26. 

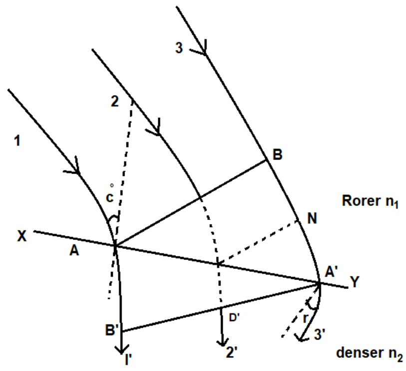
as $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$\frac{1}{\lambda_{\min}} = R\left(\frac{1}{1^2} - \frac{1}{4^2}\right) = \frac{15R}{16}$

$\lambda_{\min} = \frac{16}{15R} = \frac{16}{15 \times 1.09 \times 10^7}$

$= 0.978 \times 10^{-7}$ m

= 97.8 nm

27. 

Let XY be interface of two mediums and c_1 and c_2 are velocity of light is rarer and denser medium respectively.

Then, refractive index of denser medium relative to rarer medium $\mu = \frac{c_1}{c_2}$

Also, according to Huygens principle, every point of plane wavefront AB acts as a source of secondary wavelet. Let the secondary wavelets takes time t from B to strike at XY surface at A'

$BA' = c_1 \times t$

in same time t wavelet from A travels with speed c_2 and strikes B'

$AB' = c_2 \times t$

In $\triangle AA'B$

sin i = $\frac{BA'}{AA'} = \frac{C_1 t}{AA'}$

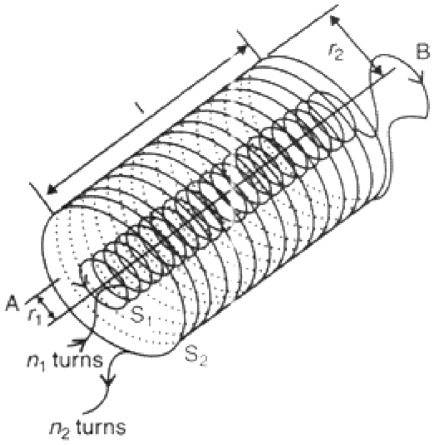
In △AA'B'

sin r = $\frac{AB'}{AA'} = \frac{C_2 \times t}{AA'}$

$\frac{\sin i}{\sin r} = \frac{c_1}{c_2} = \mu = \frac{n_2}{n_1}$ This verifies the snell's law of refraction.

28. i. Mutual inductance is numerically equal to the induced emf in the secondary coil when the current in the primary coil changes by unity.

ii. in the question mutual inductance of two long coaxial solenoids of same length l wound one over the other is given by:-



Let a current I_2 flow in the secondary coil

∴ $B_2 = \frac{\mu_0 N_2 i_2}{l}$

∴ Flux linked with the primary coil = $\frac{\mu_0 N_2 N_1 A_1 i_2}{l}$

= $M_{12} i_2$

Hence, $M_{12} = \frac{\mu_0 N_2 N_1 A_1}{l}$

$\mu_0 n_2 n_1 A_1 l \left(n_1 = \frac{N_1}{l}; n_2 = \frac{N_2}{l}\right)$

OR

a. **Mutual inductance**: It is the property of the coils that enables it to oppose the changes in the current in another coil. Its S.I unit is Henry (H).

b. Force on the part of the loop which is parallel to infinite straight wire and at a distance x from it.

$F_1 = \frac{\mu_0}{2\pi} \frac{I_1 I_2 a}{x}$ (away from the infinite straight wire)

Force on the part of the loop which is at a distance (x + a) from it

$F_2 = \frac{\mu_0}{2\pi} \frac{\mathbf{I_1 I_2} a}{\mathbf{(x+a)}}$ (towards the infinite straight wire)

Net force $F = F_1 - F_2$

$F = \frac{\mu_0 I_1 I_2 a}{2\pi} \left[\frac{1}{x} - \frac{1}{x+a}\right]$

$F = \frac{\mu_0}{2\pi} \frac{I_1 I_2 a^2}{x(x+a)}$

Section D

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

All the known radiations from a big family of electromagnetic waves which stretch over a large range of wavelengths. Electromagnetic wave include radio waves, microwaves, visible light waves, infrared rays, UV rays, X-rays and gamma rays. The orderly distribution of the electromagnetic waves in accordance with their wavelength or frequency into distinct groups having widely differing properties is electromagnetic spectrum.

(i) **(a)** infrared waves

Explanation:

Infrared rays can be converted into electric energy as in solar cell.

(ii) **(d)** radiowaves

Explanation:

Radiowaves have longest wavelength.

(iii) **(c)** cathode rays

Explanation:

Cathode rays are invisible fast moving streams of electrons emitted by the cathode of a discharge tube which is maintained at a pressure of about 0.01 mm of mercury.

OR

(d) microwave, infrared, ultraviolet, gamma rays

Explanation:

$\lambda_{\text{micro}} > \lambda_{\text{infra}} > \lambda_{\text{ultra}} > \lambda_{\text{gamma}}$

(iv) **(d)** γ-rays

Explanation:

γ-rays have minimum wavelength.

30. i. $\vec{\tau} = \vec{P} \times \vec{E}$

As τ = either force $\times$ perpendicular distance between the two forces

= qaE sin θ or τ = PE sin θ

or $\vec{P} \times \vec{E}$ ($\because$ qa = P)

ii. The maximum torque on the dipole in an external field is given by

τ = pE = q(2a) $\times$ E

Here, q = $1\mu C = 10^{-6} C$, 2a = 2 cm = 2×10^{-2} m, E = 10^5 NC^{-1}, τ = ?

$\therefore \tau = 10^{-6} \times 2 \times 10^{-2} \times 10^5 = 2 \times 10^{-3}$ Nm

$\therefore$ the maximum torque on the dipole 2×10^{-3} Nm.

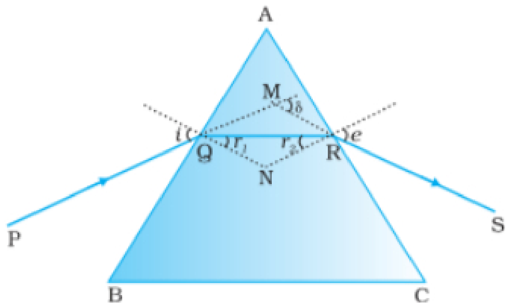
iii. When θ is 0 or 180^o, the τ is minimum, which means the dipole moment should be parallel to the direction of the uniform electric field.

iv. The net force is zero and torque acts on the dipole, trying to align p with E.

v. Torque, τ = pE sin θ and potential energy U = -pE cos θ

Section E

31. a. i.



ii. Derivation

From the above figure

$\angle$A + $\angle$QNR = 180^o (i)

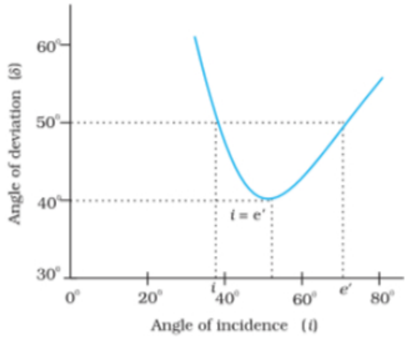
In ΔQNR $r_1 + r_2$ + $\angle$QNR = 180^o (ii)

Comparing equation (i) and (ii) we get

$r_1 + r_2$ = A (iii)

Total deviation produced δ = $(i - r_1) + (e - r_2)$

$\delta = i + e - (r_1 + r_2) = i + e - A$ (iv)



From the above graph of δ vs i we can find when δ becomes minimum i.e. δ_m

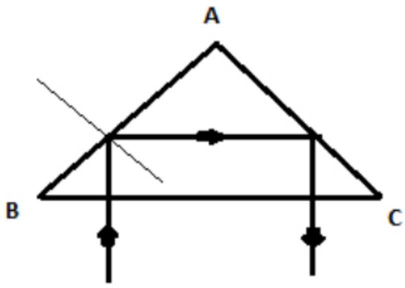
i = e and $r_1 = r_2$

From (iv) i = $\frac{(A+\delta_m)}{2}$

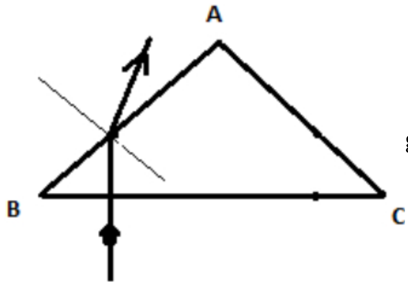
and from (iii) r = $\frac{A}{2}$

$\mu = \frac{\sin i}{\sin r} = \frac{\sin^{(A+\delta m)/2}}{\sin \frac{A}{2}}$

b. i.



ii. For μ = 1.4 total internal reflection will not occur according to the figure that we have

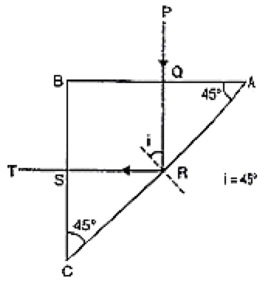


gg

OR

i. ABC is the section of the prism, B is a right angle. A and C are equal angles i.e. A = C = 45°.

The ray PQ is normally incident on the face AB. Hence it is normally refracted and the ray QR strikes the face AC at an angle of incidence 45°. It is given that the ray does not undergo refraction but is totally reflected at the face AC. This gives a maximum value for the critical angle as 45°.



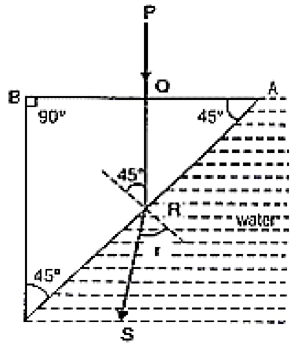
sin C = sin 45° $= \frac{1}{\sqrt{2}}$ in the limit

Since $\mu = \frac{1}{\sin C} = \frac{1}{\sqrt{2}}$

or, $\mu = \frac{1}{\sin 45}$ $or\ \mu_{\min} = \sqrt{2}$

The minimum value of refractive index $= \sqrt{2}$.

ii. When the prism is immersed in water the critical angle for the glass water interface is given by



$\sin C_1 = \frac{4/3}{\sqrt{2}} = \frac{4}{3\sqrt{2}}$

C_1 = 70.53°

The angle of incidence at R continues to be 45° and since 45° < 70.53°, refraction taking place and the refracted ray is RS.

The angle of refraction r is given by $\mu_g \sin i = \mu_w \sin r$

$g\mu_\omega = \frac{\sin i}{\sin r}$
$\frac{\mu_\omega}{\mu_g} = \frac{\sin i}{\sin r}$
$\sqrt{2}\sin 45^\circ = \frac{4}{3}\sin r$
$\sin r = \frac{3\sqrt{2}}{4}\sin 45^\circ = \frac{3\sqrt{2}}{4} \times \frac{1}{\sqrt{2}} = \frac{3}{4}$
$r = \sin^{-1}\frac{3}{4} = 48^\circ 36'$
$\therefore$The angle of refraction in water = $48^\circ 36'$

32. i. A. A dielectric material gets polarized when it is placed in an external electric field. The field produced due to the polarization of material reduces the effect of external electric field. Hence, the electric field inside a dielectric decreases.

B. Electric field in vacuum between the plates = E0 = $\frac{\sigma}{\varepsilon_o}$
Electric field in dielectric between the plates, E = $\frac{E_0}{K}$
Potential difference between the capacitor plates
V = Et + E_0(d - t)
where 't' is the thickness of dielectric slab.
V = $\frac{E_0}{K}\text{t} + \text{E}_0(\text{ d} - \text{t})$
V = $\frac{\sigma}{\varepsilon_o}\left[\frac{t}{K} + (\text{d} - \text{t})\right]$
V = $\frac{\sigma}{\varepsilon_o}\left[\frac{t+K(d-t)}{K}\right]$
As C = $\frac{Q}{V}$
$\Rightarrow$ C = $\frac{\varepsilon_0 AK}{t+K(d-t)}$

ii. The surface of the sphere is equipotential. So, the work done in moving the charge from one point to the other is zero.
W = q Δ V ($\because \Delta$ V = 0)
= 0

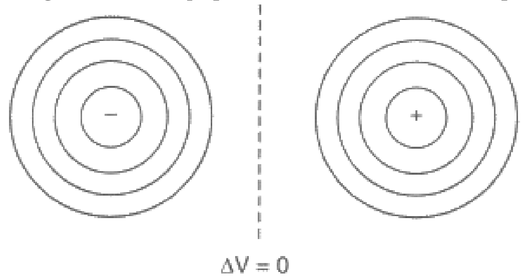
iii. P = χ E

OR

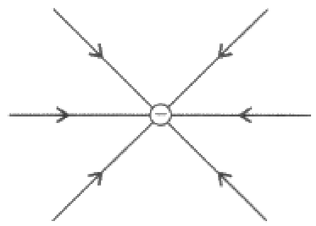
i. $C_A = 4\pi\varepsilon_0 R$, $C_B = 4\pi\varepsilon_0$ (2R) (in general form C = $4\pi \in 0r$

a. $\therefore C_B > C_A$
b. $U = \frac{1}{2}\varepsilon_0 E^2$
$E = \frac{\sigma}{\varepsilon_P} = \frac{Q}{A\varepsilon_0}$
$\therefore U \propto \frac{1}{A^2}$
$\therefore U_A > U_B$

ii. a. $E = -\frac{dV}{dr}$
For the same change in dV, E $\propto \frac{1}{dr}$
where, 'dr' represents the distance between equipotential surfaces.
Diagram of the equipotential surface due to a dipole



b. The polarity of charge: negative
The direction of the electric field is radially inward,(for a negative charge electric field lines are radially inward)



33. i. Calculation of Capacitance

As power factor is unity,

$\therefore X_L = X_C$ also L=200mH and R= 10 Ω

$\Rightarrow \omega = \frac{1}{\sqrt{LC}}$

$100 = \frac{1}{\sqrt{200\times10^{-3}\times C}}$

$10^4 \times 2 \times 10^2 \times 10^{-3} \times C = 1$

hence ca[pacitance is given by ,C = $\frac{1}{2\times10^3}$ F

$= 0.5 \times 10^{-3}$ F

= 0.5mF

ii. Q-factor of circuit and its importance Calculation of average power dissipated

Quality factor, $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

$= \frac{1}{10}\sqrt{\frac{200\times10^{-3}}{0.5\times10^{-3}}}$

$= \frac{1}{10}\times 20 = 2$

Significance: It measures the sharpness of resnance.

Average Power dissipated,

$P = V_{rms} I_{rms} \cos\phi$

$= 50 \times \frac{50}{10}\times 1$ W

= 250 watts

OR

Given, C = 25 pF = 25×10^{-6} F, L = 0.10 H, R = 25.0 ohm, E_0 = 310 V

i. E = 310 sin 314t

Comparing with the equation $E = E_0 \sin\omega t$

$\omega = 314$

$2\pi f = 314$

Frequency, $f = \frac{314}{2\pi}$ = 50 Hz

ii. a. $X_L = 2\pi f L = 2 \times 3.14 \times 50 \times 0.10 = 2 \times 3.14 \times 5 = 31.4$ ohm

$X_C = \frac{1}{2\pi f C}$

$= \frac{1}{2\times3.14\times50\times25\times10^{-6}}$ = 127.4 ohm

Thus the reactance of the circuit is,

$X_C - X_L = 127.4 - 31.4 = 96$ ohm

b. Impedance, $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$Z = \sqrt{(25)^2 + (96)^2} = 99.2$ ohm

c. Current, $I = \frac{E_{rms}}{Z}$

Now, $E_{rms} = \frac{E_o}{\sqrt{2}}$

Thus, $I = \frac{310}{\sqrt{2}\times99.2} = 2.21$ A