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Physics (Theory)–2008

Code No. 55/1/2

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

1. Name the part of the electromagnetic spectrum of wavelength 10^2 m and mention its one application.

Radio waves; radio signals like AM radio

1. An electron and alpha particle have the same kinetic energy. How are the de–Broglie wavelengths associated with them related?

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$$

$$\frac{\lambda_1}{\lambda_2} = \sqrt{\frac{m_2E_2}{m_1E_1}} = \sqrt{\frac{m_2}{m_1}}$$

$$\frac{\lambda_e}{\lambda_\alpha} = \sqrt{\frac{m_\alpha}{m_e}} = \sqrt{\frac{4m_p}{m_e}}$$

Masses are given in question paper, substitute values and calculate.

3.A converging lens of refractive index 1.5 is kept in a liquid medium having same refractive index. What would be the focal length of the lens in this medium?

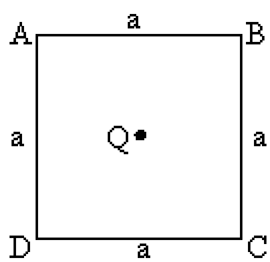
Ans
Infinite

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

$$\frac{1}{f} = 0 \text{ as n2 = n1}$$

f is infinite

2. A 500 μC charge is at the centre of a square of side 10 cm. Find the work done in moving a charge of 10 μ C between two diagonally opposite points on the square.



Work done = $q(V_2 - V_1)$. As potential at the two diagonally opposite points is same work done will be zero.

5. The plot of the variation of potential difference across a combination of three identical cells in series, versus current is as shown below. What is the emf of each cell?

2V.

$\varepsilon = V - Ir$

When I = 0, then ε=V

$\varepsilon = 6V$

emf of each cell is 2V

6. How does the angular separation of interference fringes change, in Young's experiment, if the distance between the slits is increased?

$\theta = \dfrac{\lambda}{d}$; so if d is increased then angular separation will decrease.

7. What is the direction of the force acting on a charged particle *q*, moving with a velocity $\vec{v}$ in a uniform magnetic filed $\vec{B}$?

F is perpendicular to both velocity vector and magnetic field vector.

8. State the reason, why heavy water is generally used as a moderator in a nuclear reactor.

It helps to slow down the neutrons so that the probability of their participating in a nuclear reaction increases. Since heavy water has a mass that is comparable with neutrons they are effective in slowing down the neutrons.

9. A nucleus $^{23}_{10}Ne$ undergoes β–decay and becomes $^{23}_{11}Na$. Calculate the maximum kinetic energy of electrons emitted assuming that the daughter nucleus and anti–neutrino carry negligible kinetic energy.

$$Ne_{10}^{23} \rightarrow Na_{11}^{23} + \beta_{-1}^{0} + Energy$$

22.994466u - 22.989770u = 0.004696u
Energy = 0.004696u x 931.5 MeV = 4.374 MeV

10. Distinguish between an intrinsic semiconductor and P–type semiconductor. Give reason, why a P–type semiconductor crystal is electrically neutral, although $n_h >> n_e$?

An intrinsic semiconductor has a few free electrons and an equal number of holes. Its conductivity is temperature dependant and increases with an increase in temperature. A p-type semiconductor is doped with an element from the 3rd group to increase its conductivity. So the number of holes in this semiconductor is much larger than the number of electrons. It is electrically neutral, as charged particles are not added to make the semiconductor p-type. When a semiconductor is doped, atoms are added to it and then no charges are removed or added.So they cannot make the material charged.

11. Draw a ray diagram of an astronomical telescope in the normal adjustment position. State two drawback of this type of telescope.
See diagram from book
Drawbacks: Limit to its resolving power which means the smallest distance between objects that can be clearly seen.
Spherical aberration and chromatic aberration of its lenses.

12.Calculate the distance of an object of height *h* from a concave mirror of focal length 10 cm, so as to obtain a real image of magnification 2.

f = -10cm, m = -v/u = -2
u = ?; v = 2u

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

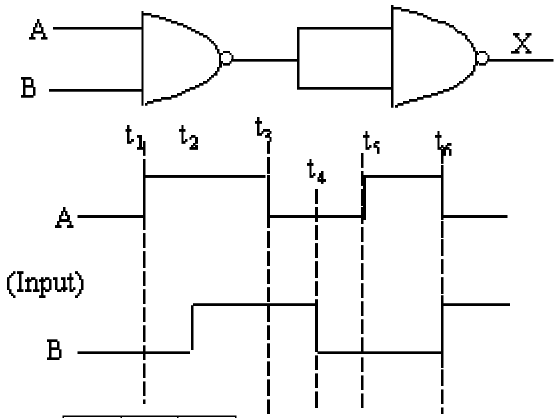
$$\frac{1}{f} = \frac{1}{2u} + \frac{1}{u}$$

$$\frac{1}{f} = \frac{3}{2u}$$

$$f = -10$$

$$u = -15cm$$

13. . Draw the output wave form at X, using the given inputs A, B for the logic circuit shown below. Also identify the gate.



A	B	X
1	0	0
1	1	1
0	1	0
0	0	0
1	0	0

AND gate

14. A transmitting antenna at the top of a tower has a height of 36 m and the height of the receiving antenna is 49 m. What is the maximum distance between them, for satisfactory communication in the LOS mode? (Radius of earth = 6400 km)

$$\sqrt{2hR_T} + \sqrt{2hR_R} = \sqrt{2\times 6400\times 1000\times 36m} + \sqrt{2\times 6400\times 1000\times 49m} =$$
$$= 21.4km + 25.3km = 46.7km$$

15. Derive an expression for the potential energy of an electric dipole of the dipole moment $\vec{P}$ in an electric field $\vec{E}$

$$U = \int \tau . d\theta$$
$$U = \int pE\sin\theta d\theta = \left[pE\cos\theta\right]_{90}^{\theta} = -pE\cos\theta = -\vec{p}.\vec{E}$$

16. Define magnetic susceptibility of a material. Name two elements, one having positive susceptibility and the other having negative susceptibility. What does negative susceptibility signify?

$M = \chi H$ where M is the magnetization of the material and H is magnetic intensity. It is a measure of how a material behaves in an external field.

Paramagnetic and ferromagnetic substances example iron have positive susceptibility and diamagnetic substances example copper have negative susceptibility.

17. The oscillating magnetic field in a plane electromagnetic wave is given by

$$B_y = (8\times10^{-6})\sin[\,2\times10^{11}t + 300\pi x]T$$

(i) Calculate the wavelength of the electromagnetic wave.

(ii) Write down the expression for the oscillating electric field.

$$i)k = 300\pi$$

$$k = \frac{2\pi}{\lambda}$$

$$\lambda = \frac{2\pi}{300\pi} = \frac{1}{150}m$$

$$ii)E_z = 8\times10^{-6}\times3\times10^{8}\sin(2\times10^{11} + 300\pi x)V/m$$

18.

$$P = \frac{1}{T}\int VIdt = \frac{1}{T}\int V_0 \cos \omega t I_0(-\sin \omega t)dt = 0$$

or

Prove that an ideal inductor does not dissipate power in an a.c. circuit.

OR

Derive an expression for the self-inductance of a long air-cored solenoid of length *l* and number of turns N.

$$L = \frac{\Phi}{i}$$

$$B = \mu_0 ni$$

Total flux linked with the coil = NBA=N$\mu_0 niA$

$$L = \frac{\mathrm{N}\mu_0 niA}{i} = \mathrm{N}\mu_0 nA = \mathrm{N}\mu_0\frac{N}{l}A = \mu_0\frac{N^2}{l}A$$

19. Prove that the current density of a metallic conductor is directly proportional to the drift speed of electrons.

OR

Define conductivity of a conductor. Explain the variation of conductivity with temperature in (a) good conductors (b) ionic conductors.

$i = neAv_d;$

$.i = jA$

$j = \frac{i}{A} = \frac{neAv}{A} = nev_d$

Or

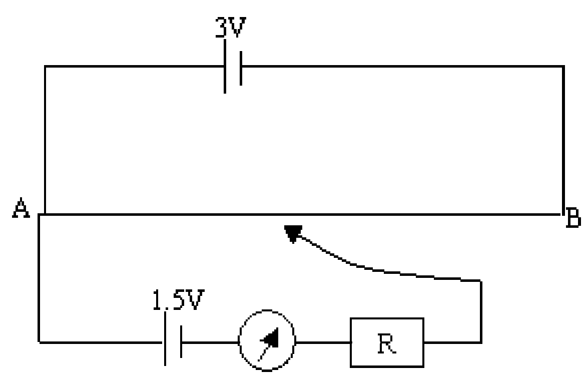
$\vec{j} = \sigma\vec{E}$

$\sigma = \frac{1}{\rho}$

where j is the current density and E is the electric field.

With increase in temperature in good conductors the conductivity decreases. With increase in temperature the average speed of electrons increases. This decreases the time between collisions hence resistivity increases or conductivity decreases. In ionic conductors conductivity will increase as mobility of ions will increase.

20. A potentiometer wire of length 1m is connected to a driver cell of emf 3V as shown in the figure. When cell of 1.5 V emf is used in the secondary circuit, the balance point is found to be 60 cm. On replacing this cell and using a cell of unknown emf, the balance point shifts to 80 cm.



$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$$

$$\frac{1.5}{x} = \frac{60}{80}$$

No, a balance point will not be reached and current will flow for all positions of the jockey.

No, it does not affect the balance point as at balance, as the current through the circuit with R is zero at balance.

21. An electromagnetic wave of wavelength λ is incident on a photosensitive surface of negligible work function. If the photo-electrons emitted from this surface have the de –Broglie wavelength λ_1, prove that $\lambda = \left(\frac{2mc}{h}\right)\lambda_1^2$.

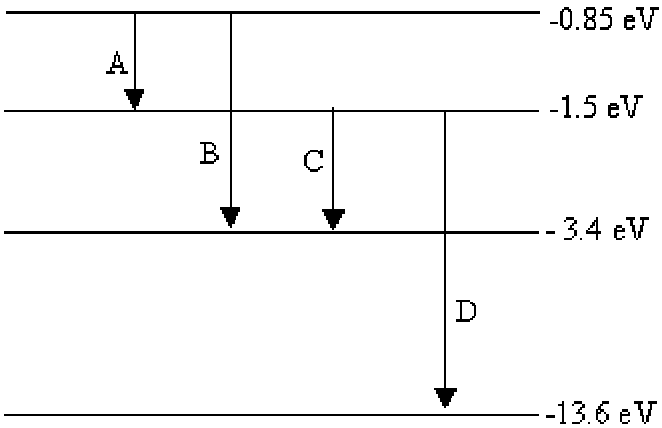
$$E = h\frac{c}{\lambda} - h\frac{c}{\lambda_0}$$

$$E = h\frac{c}{\lambda}$$

$$p = \sqrt{2mE} = \sqrt{2mh\frac{c}{\lambda}}$$

$$\lambda_1 = \frac{h}{p} = \frac{h}{\sqrt{2mh\frac{c}{\lambda}}}$$

22. . The energy level diagram of an element is given below. Identify, by doing necessary calculations, which transition corresponds to the emission of a spectral line of wavelength 102.7 nm.



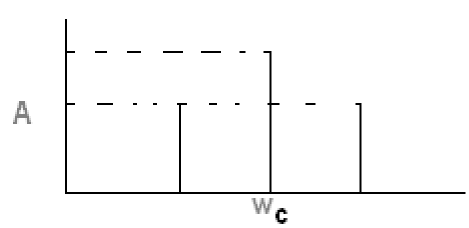
$$a) h\nu = E_1 - E_2$$

$$h\frac{c}{\lambda} = E_1 - E_2$$

$$E_1 - E_2 = h\frac{c}{\lambda} = \frac{6.626\times10^{-34}\times3\times10^{8}}{102.7\times10^{-9}} J = \frac{6.626\times10^{-34}\times3\times10^{8}}{102.7\times10^{-9}\times1.6\times10^{-19}} eV = 12eV$$

Ans is **D**

23. . Draw a plot of the variation of amplitude versus ω for an amplitude modulated wave. Define modulation index. State its importance for effective amplitude modulation.



Amplitude of side bands is $\frac{\mu A_i}{2}$

Modulation index = $\text{mod}\,ulation \text{ index} = \frac{\text{amplitude of message signal}}{amplitude \text{ of carrier wave}}$.

In practice this is kept less than 1 to avoid distortion.

24. How is a wave front defined? Using Huygen's construction draw a figure showing the propagation of a plane wave reflecting at the interface of the two media. Show that the angle of incidence is equal to the angle of reflection.

It is a surface of constant phase. Proof is given in book NCERT page 357 part II

25. A coil of number of turns N, area A, is rotated at a constant angular speed ω, in a uniform magnetic field B, and connected to a resistor R. Deduce expressions for:

(i) Maximum emf induced in the coil

(ii) Power dissipation in the coil

$$\varepsilon = -\frac{d\Phi}{dt}$$

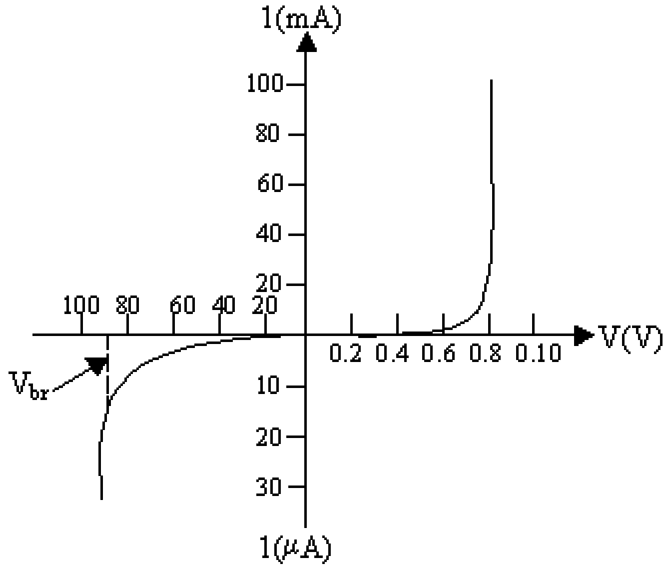
$$\Phi = NBA\cos\theta = NBA\cos\omega t$$

$$\varepsilon = -\frac{d\Phi}{dt} = NBA\omega\sin\omega t$$

Maximum E = NBAω

$$Power = I^2R = \frac{V^2}{R} = \frac{(\mathrm{NBA}\omega)^2}{R}$$

26i) . The figure below shows the V-I characteristic of a semiconductor diode

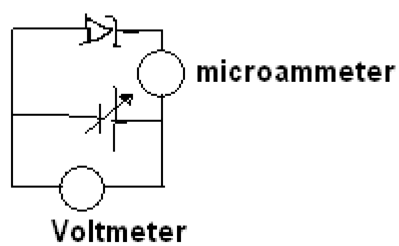


(i) **Identify the semiconductor diode used.**

(ii) Draw the circuit diagram to obtain the given characteristic of this device.

(iii) Briefly explain how this diode can be used as a voltage regulator

Zener diode



Across the zener diode voltage remains constant even though the current through it changes. Example if the input voltage decreases, the current through the series resistor in the circuit decreases and through the zener diode also decreases. The voltage across the series resistor will decrease but the voltage across the zener diode will not change. Thus the zener diode acts as a voltage regulator.

27.An inductor 200 mH,, capacitor 500μF, resistor 10Ω are connected in series with a 100V, variable frequency a.c. source. Calculate the

(i) frequency at which the power factor of the circuit is unity;

(ii) current amplitude at this frequency;

(iii) Q-factor

Power factor is unity at resonance as $\phi = 0$

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

Substitute values and calculate

At resonance Z = R

$$i = \frac{V}{R} = \frac{100}{10}$$

$$Q = \frac{\omega L}{R}$$

Substitute values and calculate

28. (a) For a ray of light travelling from a denser medium of refractive index n_1 to rarer medium of refractive index n_2, prove that $\frac{n_2}{n_1} = \sin i_c$, where i_c is the critical angle of incidence for the media.

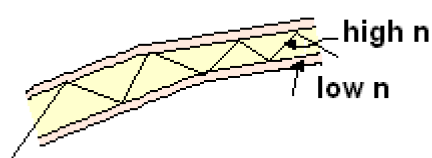
(b) Explain with the help of a diagram, how the above principle is used for transmission of video signals using optical fibres.

OR

(a) What is plane polarized light? Two polaroids are placed at 90^0 to each other and the transmitted intensity is zero. What happens when one more Polaroid is placed between these two, bisecting the angle between them? How will the intensity of transmitted light vary on further rotating the third Polaroid?

(b) If a light beam shows no intensity variation when transmitted through a Polaroid which is rotated, does it mean that the light is unpolarized? Explain briefly.

$$\frac{n_2}{n_1} = \frac{\sin i}{\sin r} = \frac{\sin i_c}{\sin 90^0} = \sin i_c$$

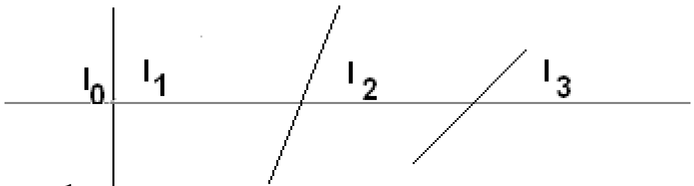


OR

In plane polarized light the electric field vector is confined to a plane. This plane is perpendicular to the direction of the light.

Intensity is no longer zero. A certain component of light that is transmitted by first polarizer is transmitted by second polarizer.

As the light reaching the first sheet is unpolarized, the transmitted light will be one-half that of the incident light.



$$I_1 = \frac{1}{2} I_0$$

$$I_2 = I_1 \cos^2\theta = \frac{1}{2} I_0 \cos^2 45^0 = \frac{1}{4} I_0$$

$$I_3 = I_2 \cos^2\theta = \frac{1}{4} I_0 \cos^2 45^0 = \frac{1}{8} I_0$$

angle is 45 degrees as the Polaroid bisects the angle between the two polaroids.

The intensity will vary in proportion to $\cos^2\theta$ on rotating the Polaroid.

Yes, in unpolarized light the electric vector is not in any particular direction so for all orientations the intensity will appear to be half. So it is not possible to distinguish between the directions.

29. (a) Using Gauss' law, derive an expression for the electric field intensity at any point outside a uniformly charged thin spherical shell of radius R and charge density σC /m^2. Draw the field lines when the charge density of the sphere (i) positive, (ii) negative.

(b) A uniformly charged conducting sphere of 2.5 m in diameter has a surface charge density of 100 μC/m^2. Calculate the

(i) charge on the sphere

(ii) total electric flux passing through the sphere

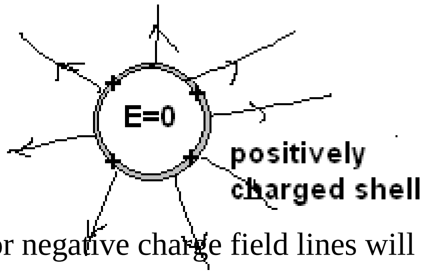
OR

(a) Derive an expression for the torque experienced by an electric dipole kept in a uniform electric field.

(b) Calculate the work done to dissociate the system of three charges placed on the vertices of a triangle as shown:

Here q = 1.6 × 10^{-10}C.

Take a gaussian surface inside the shell and outside it. Prove that inside field is zero and outside it is as if entire charge is placed at the center of the spherical shell.
For positive charge field lines will be outward



For negative charge field lines will be inward

b) Charge on sphere = $\sigma(A) = (100 \times 10^{-6} C / m^2)4\pi(d/2)^2 m^2$

Calculate and find the charge.

Since it is a conducting sphere all the charges will reside on the surface of the sphere and field inside the sphere will be zero. Flux passing through the sphere is zero. Flux outside the sphere, leaving the surface of the sphere is kq/r.

OR

a) $$\tau = force \times (perpendicular \text{ distance between forces})$$
$$\tau = qE(2a\sin\theta) = \vec{p} \times \vec{E}$$

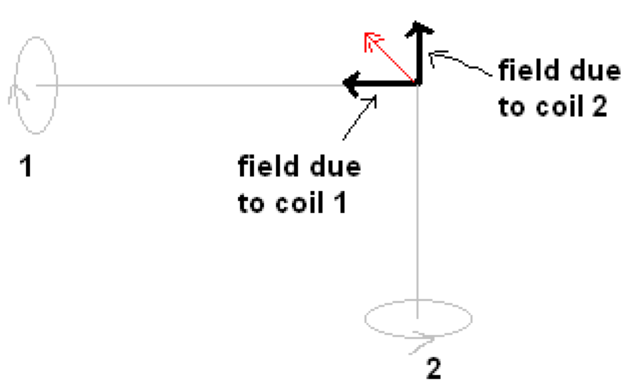
b) $$U = \frac{kq(-4q)}{10 \times 10^{-2}} + \frac{kq(+2q)}{10 \times 10^{-2}} + \frac{k(+2q)(-4q)}{10 \times 10^{-2}}$$

Substitute values and calculate.

30.

. (a) Using Biot-Savart's law, derive an expression for the magnetic field at the centre of a circular coil of radius R, number of turns N, carrying current i.

See derivation in NCERT book for field along the axis. Then take special case for center of coil.



Field due to coil 1 is
$$B_1 = B_2 = \frac{\mu_0 I R^2}{2(x^2+R^2)^{3/2}}$$
$$\text{Resultant} = \sqrt{2}B_1 = \sqrt{2}\frac{\mu_0 I R^2}{2(x^2+R^2)^{3/2}}$$

Draw a schematic diagram of a cyclotron. Explain its underlying principle and working, stating clearly the function of the electric and magnetic fields applied on a charged particle.

Deduce an expression for the period of revolution and show that it does not depend on the speed of the charged particle. Or

See diagram from NCERT book

Principle; It is a machine that uses crossed electric and magnetic fields to accelerate charged particles to high energies. It uses the principle that the frequency of revolution of the charged particle is independent of its velocity. This frequency depends on charge to mass ratio of the charged particle. So once it is adjusted the charged particle will experience a force due to the electric field at just the right instant to accelerate it.

Working At resonance the charged particle crosses the gap between the dees at just the right time so that the alternating voltage that is applied between the dees, accelerates it. A magnetic field acts perpendicular to the plane of the dees. An electric field is applied between the gap of the dees by an oscillator that is connected to the dees. Charged particles are released at the center of the dees and as they move the electric field accelerates them. They stay in a circular path due to the magnetic field. To exit the particles they are deflected by a magnetic field.

Function of electric and magnetic fields

Electric field applies a force in the direction of velocity. The force accelerates the particle and increases its velocity.

Magnetic field applies a force on the charged particle in a direction perpendicular to its velocity. So it does not change the velocity of the particle. It helps to keep the particle confined to the dees so that it can be accelerated to high velocities.

$$F = qv \times B$$
$$\frac{mv^2}{r} = qvB$$
$$v = r\omega$$
$$\omega = \frac{qB}{m}$$
$$T = \frac{2\pi}{\omega} = \frac{2\pi m}{qB}$$

This is independent of the velocity of the charged particle.