Physics

Academic Year: 2012-2013 Marks: 70
Date: March 2013

Question 1: Select and write the most appropriate answer from the given alternatives for each sub-question [7]

Question 1.1: The moment of inertia of a thin uniform rod of mass M and length L, about an axis passing through a point, midway between the centre and one end, perpendicular to its length is ..... [1]

(a) $\frac{48}{7} ML^2$
(b) $\frac{7}{48} ML^2$
(c) $\frac{1}{48} ML^2$
(d) $\frac{1}{16} ML^2$

Solution:
(b) $\frac{7}{48} ML^2$

Question 1.2: 'n' droplets of equal size of radius r coalesce to form a bigger drop of radius R. The energy liberated is equal to.................. [1]
(T =Surface tension of water)
$(a) 4\pi R^2 T\left[n^{\frac{1}{3}} - 1\right]$
$(b) 4\pi r^2 T\left[n^{\frac{1}{3}} - 1\right]$
$(c) 4\pi R^2 T\left[n^{\frac{2}{3}} - 1\right]$
$(d) 4\pi r^2 T\left[n^{\frac{2}{3}} - 1\right]$

Solution:
(a) $4\pi R^2 T\left[n^{\frac{1}{3}} - 1\right]$

Question 1.3: The buckling of a beam is found to be more if ___. [1]

(a) the breadth of the beam is large.
(b) the beam material has large value of Young's -modulus.
(c) the length of the beam is small.
(d) the depth of the beam is small.·

Solution: (d) the depth of the beam is small

Question 1.4: When a transverse wave on a string is reflected from the free end, the phase change produced is .... **[1]**

(a) zero rad
(b) $\frac{\pi}{2}$ rad
(c) $\frac{3\pi}{4}$ rad
(d) π rad

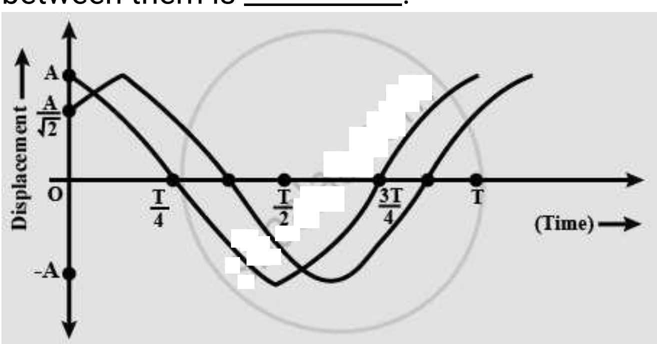
Solution: (a) zero rad

Question 1.5: The number of degrees of freedom for a rigid diatomic molecule is................ **[1]**

(a) 3
(b) 5
(c) 6
(d) 7

Solution: (b) 5

Question 1.6: Two particles perform linear simple harmonic motion along the same path of length 2A and period T as shown in the graph below. The phase difference between them is __________. **[1]**



Zero rad
$\frac{\pi}{4}$ rad
$\frac{\pi}{2}$ rad
$\frac{3\pi}{4}$ rad

Solution:

$\frac{\pi}{4} rad$

Let the equation of waves be Asin(ωt + Φ)

For wave with peak at t = 0, the equation becomes,

y = Asin(ωt + 90°)

For the wave with displacement $\frac{A}{\sqrt{2}} at\ t = 0$

$$\frac{A}{\sqrt{2}} = A\sin(\Phi)$$

$\Rightarrow \Phi = 45° = \frac{\pi}{4}$

Hence this is the phase difference between the waves.

Question 1.7: The light from the Sun is found to have a maximum intensity near the wavelength of 470 nm. Assuming the surface of the Sun as a black body, the temperature of the Sun is ____________. **[1]**

[Wien's constant b = 2 .898 x 10^{-3}mK]

5800 K

6050 K

6166 K

6500 K

Solution: The light from the Sun is found to have a maximum intensity near the wavelength of 470 nm. Assuming the surface of the Sun as a black body, the temperature of the Sun is **6166 K.**

Explanation:

Given: λ_m= 470nm = 4.70×10^{-7}m b = 2.898×10^{-3}mK

From Wien's displacement law,

$T\lambda_m$ = b

We get, temperature of sun

$T = \frac{b}{\lambda_m}$

$\therefore T = \frac{2.898 \times 10^{-3}}{4.70 \times 10^{-7}} = 6166\ K$

Question 2 | Attempt any SIX : **[12]**

Question 2.1: State Kepler's law of orbit and law of equal areas. **[2]**

Solution 1: Ist law (Law of orbit) : The orbital path in the solar system is an ellipse with sun as one focus.

2nd law (Law of equal area) : The radius vector joining the centre of the planet to the centre of sun traces out equal area in equal intervals of time.

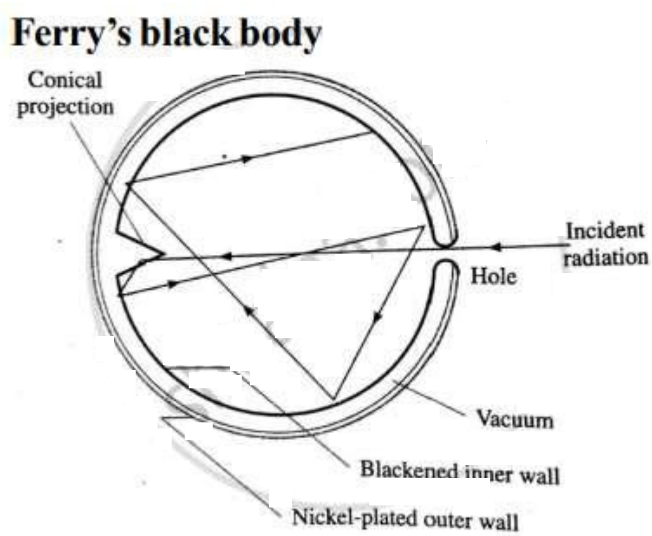
i.e. The area velocity of the planet is constant

Question 2.2: All planet revolves around the sun in the elliptical orbit, the sun as one of its focus. **[2]**

The line joining sun and planet sweeps the equal area in equal time interval i.e. A real velocity is constant.

Question 2.3: Draw a neat labelled diagram for Ferry's perfectly black body. **[2]**

Solution: Ferry's perfectly black body



Question 2.4: A mass M attached to a spring oscillates with a period of 2 seconds. If the mass is increased by 2 Kg, the period increases by 1 second. Find the initial mass, assuming that Hooke's law is obeyed. **[2]**

Solution: Mass (M) = ?

Time period of a oscillating mass m attached to a spring is given by:

Time period is given by , $T = 2\pi\sqrt{\frac{M}{K}}$

where, T is the period, m is the mass and k is the spring constant.

$T_1 = 2s$,

$T_2 = 2 + 1 = 3s$,

$m_2 = m_1 + 2$

$T_1 = 2\pi\sqrt{\frac{M}{K}}$ ....(i)

$T_2 = 2\pi\sqrt{\frac{M+2}{K}}$ ....(ii)

From (i) and (ii)

$$\frac{2}{3} = \sqrt{\frac{M}{M+2}}$$

Squaring both the sides,

$$\frac{4}{9} = \frac{M}{M+2}$$

$\Rightarrow 4(m + 2) = 9m$
$\Rightarrow 4m + 8 = 9m$
$\Rightarrow 5m = 8$
$\therefore M = 1.6$ Kg
The initial mass attached to the spring is 1.6 Kg.

Question 2.5: Differentiate between free and forced vibrations. **[2]**

Solution:

Sr. No	Free vibrations	Forced vibrations
1	Free vibrations are produced when a body is disturbed from its equilibrium position and released.	Forced vibrations are produced by an external periodic force of any frequency.
2	To start free vibrations only, the force is required initially.	Continuous external periodic force is required. If external periodic force sis stopped, then forced vibrations also stop.
3	The frequency of free vibrations depends on the natural frequency.	The frequency of forced vibrations depends on the frequency of the external periodic force.
4	Energy of the body remains constant in the absence of friction, air resistance, etc.	Energy of the body is maintained constant by the external periodic force.

	Due to damping forces, total energy decreases.	
5	Amplitude of vibrations decreases with time.	Amplitude is small but remains constant as long as external periodic force acts on it.
6	Vibrations stop sooner or later depending on the damping force.	Vibrations stop as soon as external periodic force is stopped.

Question 2.6: The surface tension of water at 0ºc is 75·5 dyne/cm. Find surface tension of water at 25°C. [α for water = 0·0021/°C] **[1]**

Solution: Given, T_0 = 75.5 dyne/cm, α = 0.0027, θ = 25°C

Thus, $T = T_0 (1 - \alpha\theta)$

$= 75.5 [1 - (0.0027)(25)]$

$= 75.5 [1 - 0.0675]$

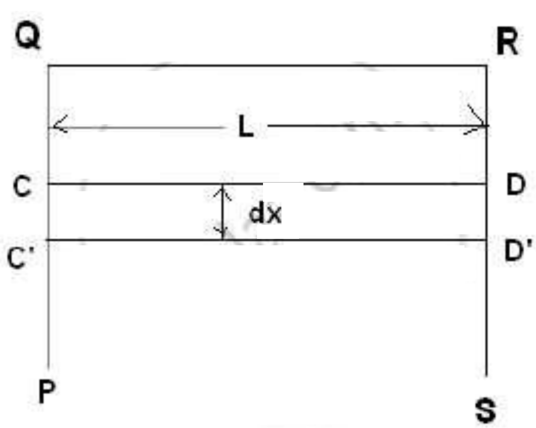
$= 75.5(0.9325)$

= 70.40 dyne/cm

Thus, the surface tension of water at 25°C is 70.40 dyne/cm.

Question 2.7: Derive the relation between surface tension and surface energy per unit area. **[1]**

Solution: Surface tension tries to decrease the surface area of a liquid. For increasing surface area, the work has to be done against the surface tension and it is stored in the surface molecules in the form of potential energy



Consider a rectangular frame PQRS having a movable wire CD. Let QR = CD = L. If a soap film is formed on the frame CQRD, then the surface tension will try to pull the

wire inward by a force F . $\text{Surface tension} = \dfrac{\text{Force}}{\text{free Length}}$

F = Surface tension x Free length

$\therefore$ F = T (2L)
If the wire is pulled out to CD" role="presentation" style="position: relative;" data-mce-style="position: relative;">D^D through distance 'dx'
$\therefore$ Work done = F. dx
$\therefore$ W = T (2Ldx)
$\therefore$W = T (2Ldx)

But increase in area = dA = 2Ldx
Surface energy is defined as the work done per unit area to increase the free surface area, under isothermal condition.

$$\therefore Surfacee \neq r \geq y = \frac{\text{Work done}}{\text{Free surface area}} = \frac{W}{\text{dA}} = \frac{T(2Ldx)}{2Ldx} = T$$

$\therefore$ Surface energy is equal to surface tension

Question 2.8: A wheel of moment of inertia 1 Kgm^2 is rotating at a speed of 40 rad/s. Due to friction on the axis, the wheel comes to rest in 10 minutes. Calculate the angular momentum of the wheel, two minutes before it comes to rest. **[1]**

Solution: I = 1 kgm^2, c = 40 rad/s,

t_1 = 600s, t_2 = 10 - 2 = 8 min = 480 s

L = ?

$\omega_2 = \omega_1 + \alpha\, t_1$

0 = 40 + 600 α

$\therefore \alpha = \frac{-1}{15}$ rad/s^2

$\omega_3 = \omega_1 + \alpha\, t_2$

$= 40 - \frac{1}{15} \times 480$

$\therefore \omega_3$ = 8 rad/s

L = I ω_3

= 1 × 8 = 8 Kgm^2 /s

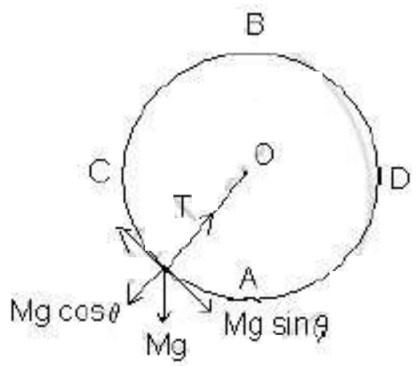
The angular momentum of the wheel, two minutes before it comes to rest would be 8 Kgm^2/s.

Question 3: Attempt any THREE : **[9]**

Question 3.1: A particle of mass m, just completes the vertical circular motion. Derive the expression for the difference in tensions at the highest and the lowest points. **[3]**

Solution: Consider a body of mass 'M' moving in a vertical circle of radius 'R'. At any position P, the forces are acting body are weight Mg vertically downward and tension 'T' towards centre. Centripetal force $F_C = T - Mg\cos\theta$

$T = FC + Mg\cos\theta$



The body is moving such that it can move in a vertical circle.

At position B : $\theta = 180^{\circ}, \cos\theta = -1. T_B = F_C - Mg$

$$\therefore T_B = \frac{MV_B^2}{R} - Mg$$

$$\therefore T_B = \frac{MgR}{R} - Mg$$

$$\therefore T_B = 0$$

At position A : $\theta = 0^{\circ}, \cos\theta = 1, T_B = F_C - Mg$

$$T_A = F_C + Mg$$

$$\therefore T_A = \frac{MV_A^2}{R} + Mg$$

$$\therefore T_A = \frac{5MgR}{R} + Mg$$

$$\therefore T_A = 6Mg$$

Difference in tension $T_B - T_A = 6$ Mg

Question 3.2: The Earth is rotating with angular velocity ω about its own axis. R is the radius of the Earth. If $R\omega^2 = 0 \cdot 03386$ m/ s^2, calculate the weight of a body of mass 100 gram at latitude 25°. ($g = 9{\cdot}8 m/s^2$). **[3]**

Solution:

Weight W $= m\left(g - R\omega^2 \cos^2 \phi\right)$

$\therefore\ W = 0.1\left(9.8 - 0.03386 \times \cos^2 25\right)$

$\therefore W = 0.1(9.8 - 0.0278)$

$\therefore W = 0.9772N$

Question 3.3: Derive an expression for kinetic energy, when a rigid body is rolling on a horizontal surface without slipping. Hence find kinetic energy for a solid sphere. **[3]**

Solution: Total Rolling kinetic energy = Translational K. E. + Rotational K. E.

$= \frac{1}{2}MV^2 + \frac{1}{2}I\omega^2$

But

$\omega = \frac{V}{R}$

$\text{Total Rolling K.E} = \frac{1}{2}MV^2 + \frac{1}{2}I\left(\frac{V^2}{R^2}\right)$

$\text{for solid sphere} I = \frac{2}{5}MR^2$

$\text{Total Rolling K.E.} = \frac{1}{2}MV^2 + \frac{1}{2}\frac{2MR^2}{5}\left(\frac{V^2}{R^2}\right)$

$= \frac{1}{2}MV^2 + \frac{1}{5}MV^2$

$= \frac{7}{10}MV^2$

Question 3.4: A steel wire-of diameter 1 x 10^{-3}m is stretched by a force of 20 N. Calculate the strain energy per unit volume. (Y steel= 2 x 1011 N /m^2) **[3]**

Solution: D = 1 x 10^{-3} m
∴ r = 5 x 10^{-4} m

A = πr^2 = 3.14 x $(5 \times 10^{-4})^2$
F = 20 N, Y = 2 x 10^{11} N/m^2

Now,

u = $\frac{1}{2} \times \text{stress} \times \text{strain}$

= $\frac{1}{2} \times \frac{(\text{stress})^2}{Y}$

$\Rightarrow$ u = $\frac{1}{2} \frac{F^2}{A^2 y}$

u = $\frac{1}{2}\left[\frac{20}{\left[3.14 \times \left(5 \times 10^{-4}\right)\right]^2} \text{ \^{} } 2 \times \frac{1}{2 \times 10^{11}}\right]$

u = 1621 Joule

Question 4 | Attempt any one of the following : **[7]**

Question 4.1: Define an ideal simple pendulum. **[7]**

Solution: An ideal simple pendulum - An ideal simple pendulum consists a point mass suspended from a perfectly rigid support by weightless, inextensible and perfectly flexible fibre.

Question 4.1: Show that, under certain conditions, simple pendulum performs the linear simple harmonic motion.

Solution: Practical simple pendulum – In practice a small but heavy sphere can be regarded as point mass and a light string whose weight is negligible compared with weight of the bob can be taken as a weightless fibre.

Suppose that a simple pendulum of length 'L' is displaced through a small angle θ and released.

It oscillates two sides of its equilibrium position. At displaced position, force acting on the bob are (1) its weight mg (2) the tension T in the string. Resolved 'mg' into two components 'mg sinθ' to ⊥ the string and 'mg cos θ' parallel to the string.

The component 'mg cosθ' is balanced by the tension in the string. The component 'mg sinθ' is unbalanced. This acts as restoring force.

F = - mg sinθ -ve sign indicates that force is opposite.
But θ is very small, sinθ = θ

$$F=-mg\theta \text{ and } \theta=\frac{X}{L}$$

$$\therefore\ F=-\frac{mgX}{L}$$

$$F=-\left(\frac{mg}{L}\right)X$$

But $F=ma_{cc}$

$$\therefore ma_{cc}=-\left(\frac{mg}{L}\right)X$$

$$a_{cc}=-\left(\frac{g}{L}\right)X$$

$$a_{cc}\alpha(-X)$$

The motion of simple pendulum is linear S.H.M.

$$a_{\ cc}=-\left(\frac{g}{L}\right)X$$

Condition for simple pendulum: (1) Bob must be small but heavy sphere.
(2) It must be suspended by light string.
(3) It must be supported by rigid support.
(4) Amplitude must be very small.

Question 4.1: A train blows a whistle of frequency 640 Hz in air. Find the difference in apparent frequencies of the whistle for a stationary observer, when the train moves towards and away from the observer with the speed of 72 Km/hour. [Speed of sound in air = 340 m/s.]

Solution:

$$N_1=N\left(\frac{V}{V-V_s}\right)$$

$$V_s=72$$

$$N_1=640\left(\frac{340}{340-20}\right)$$

$$N_1=680Hz$$

$$N_2=N\left(\frac{V}{V+v_s}\right)$$

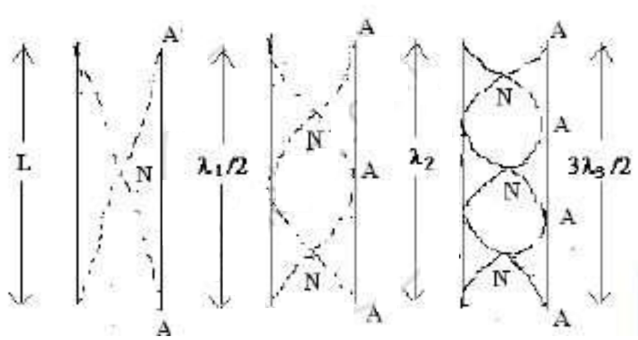
$$V_s=72$$

$$N_2 = 640\left(\frac{340}{340+20}\right)$$

$$N_2 = 604.4Hz$$

Question 4.2: With a neat labelled diagram, show that all harmonics are present in an air column contained in a pipe open at both the ends. Define end correction. **[7]**

Solution: Stationary waves are produced due to the superposition of two identical simple harmonic progressive waves traveling through the same part of the medium in opposite direction. In the case of pipe open at both ends, the air molecules near the open end are free to vibrate, hence they vibrate with maximum amplitude. Therefore the open end becomes an antinode.



The simplest mode of vibration is the fundamental mode of vibration. (in above fig a) In this case one node & two antinodes are formed. If λ_1 be the corresponding wavelength &

$$\text{L be length of the pipe } \mathrm{L} = \frac{\lambda_1}{2}$$

$$\lambda_1 = 2\mathrm{L}$$

If n_1 be corresponding frequency and v be velocity of sound in air $v = \mathbf{n}_1\boldsymbol{\lambda}_1$

$$\mathrm{n}_1 = \frac{\mathrm{v}}{\lambda_1}$$

$$n_1 = \frac{\mathrm{v}}{2\mathrm{L}} \text{......(1)}$$ This is called 1st harmonic.

The next possible mode of vibration is called the 1st overtone. (in above fig) In this case, two nodes and three antinodes are formed. If λ_2 and n_2 be the corresponding wavelength and frequency,

$L = \lambda_2$

$\lambda_2 = L$

But

v $n_2\lambda_2$ i.e = $\lambda_2 = \frac{v}{\lambda_2}$ $n_2 = \frac{\mathbf{v}}{\mathbf{L}}$

This is called 2nd harmonic.

The next possible mode of vibration is called 2nd overtone.(in above fig c) In this case three nodes & four antinodes are formed. If λ_3 and n_3 be the corresponding wavelength & frequency,

$$L = 3\frac{\lambda_3}{2}$$

$$\lambda_3 = \frac{2L}{3}$$

$$v = n_3\lambda_3$$

i.e

$$n_3 = \frac{v}{\lambda_3}$$

$n_3 = 3\frac{\mathbf{v}}{2}L$.

This is called 3rd harmonic.

$$n_1 : n_2 : n_3 :: 1 : 2 : 3$$

Thus in case of pipe open at both end, all harmonics are present.
In this case, the node is forming at the closed-end i.e. at the water surface & antinode is forming at the open end. But antinode is not formed exactly at the open end but slightly outside it since air molecules are free to vibrate. The correction has to be applied is called end correction.

Question 4.2: Calculate the kinetic energy of 10 gram of Argon molecules at 127°C. [Universal gas constant R = 8320 J/k mole K. Atomic weight of Argon = 40]

Solution: Given:

R = 8320 J/k mole K

M_0 = 40

T = 127°C = 127 + 273 = 400K

To find:

K.E for 10g = ?

Formula:

$$K.E = \frac{3RT}{2M_o} \times M$$

Solution:

$$K.E = \frac{3RT}{2M_o} \times M$$

$$K.E = \frac{3 \times 8320 \times 400 \times 0.01}{2 \times 40}$$

K.E = 1248J

The kinetic energy of 10 grams of Argon molecules at 127°C is 1248J of Argon.

Question 5 | Select and write the most appropriate answer from the given alternatives for each sub-question: **[7]**

Question 5.1: In the diffraction pattern due to a single slit of width 'd' with incident light of wavelength 'λ', at an angle of diffraction θ. the condition for first minimum is .... **[1]**

(a) $\lambda \sin\theta = d$

(b) $d \cos\theta = \lambda$

(c) $d \sin\theta = \lambda$

(d) $\lambda \cos\theta = d$

Solution: (c) $d \sin\theta = \lambda$

Question 5.2: Kirchhoff's junction law is equivalent to .... **[1]**

(a) conservation of energy.

(b) conservation of charge

(c) conservation of electric potential

(d) conservation of electric flux

Solution: (b) conservation of charge

Question 5.3: Let 'p' and 'E' denote the linear momentum and energy of emitted photon respectively. If the wavelength of incident radiation is increased ___. **[1]**

(a) both p and E increase

(b) p increases and E decreases

(c) p decreases and E increases

(d) both p and E decrease.

Solution: (d) both p and E decreases

Question 5.4: The nuclei having same number of protons but different number of neutrons are called ___. **[1]**

(a) isobars

(b) a-particles
(c) isotopes
(d) y-particles

Solution: (c) isotopes

Question 5.5: In case of transistor oscillator, to obtain sustained oscillations, the product of voltage gain without feedback and feedback factor should be ________. **[1]**
zero
less than 1
one
infinity

Solution: In case of transistor oscillator, to obtain sustained oscillations, the product of voltage gain without feedback and feedback factor should be **One.**

Question 5.6: The process of regaining of information from carrier wave at the receiver is called .... **[1]**
(a) modulation
(b) transmission
(c) propagation
(d) demodulation

Solution: (d) demodulation

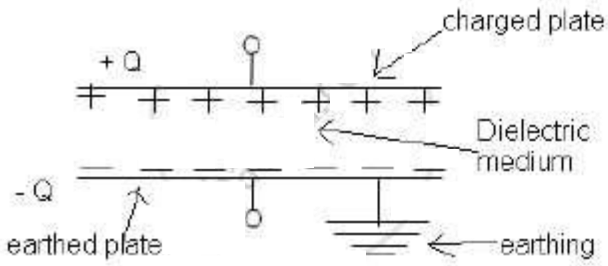
Question 5.7: Reactance of a coil is 157 Ω. On connecting the coil across a source of frequency 100 Hz, the current lags behind e.m.f. by 45°. The inductance of the coil is .... **[1]**
(a) 0·25 H
(b) 0·5 H
(c) 4 H
(d) 314H

Solution: (a) 0·25 H

Question 6: Attempt any SIX : [12]

Question 6.1: Draw a neat labelled diagram of a parallel plate capacitor completely filled with dielectric. **[2]**

Solution: Parallel plate capacitor



Question 6.2: A point is situated at 7cm and 7·2 cm from two coherent sources. Find the· nature of illumination at the point if wavelength of light is 4000A. **[2]**

Solution:

Path difference = 7.2 cm – 7 cm = 0.2 cm

$$\frac{\text{Path diffrence}}{\lambda} = \frac{0.2}{4000 \times 10^{-8}} = 5000$$

path difference is integral multiple of λ

∴ It is bright point

Question 6.3: Obtain the expression for current sensitivity of moving coil galvanometer. **[2]**

Solution: The sensitivity (i.e. current sensitivity) of a galvanometer is defined as the angle of deflection per unit current flowing through it.
If d θ is change in the deflection produced by a small change in the current dI, sensitivity (S) of the galvanometer is given by

$$S = \frac{d\theta}{dI}$$

The current I flowing through a moving coil galvanometer is given by

$I = \frac{k}{nAB}\theta$ Where θ is the angle of deflection, N is its turns, A is area, B is magnetic induction & k is the couple per unit twist.

$$\theta = \frac{NAB}{k} I$$

$$\frac{d\theta}{dI} = \frac{NAB}{k}$$

$$S = \frac{NAB}{k}$$

Question 6.4: In a cyclotron, magnetic field of 3·5Wb/m2 is used to accelerate protons. What should be the time interval in which the electric field between the Dees be reversed? **[2]**
(Mass of proton = 1· 67 x 10^{-27}Kg, Charge on proton =1·6x10^{-19}c).

Solution: B = 3.5 Wb/m^2 , m_P = 1.67 × 10^{-27} Kg,

e = 1.6 × 10^{-19} C,

t = ?

$$t = \pi \frac{m_p}{Bq_p}$$

$$t = \frac{3.142 \times 1.67 \times 10^{-27}}{3.5 \times 1.6 \times 10^{-19}}$$

$$= \frac{3.142 \times 1.67}{3.5 \times 1.6} \times 10^{-8}$$

= [log (3.142) + log (1.67) - log (3.5) - log (1.6)] × 10^{-8}

= [0.4972 + 0.2227 - 0.5441 - 0.2041] × 10^{-8}

= [antilog (- 0.0283)] × 10^{-8} s

= 0.9369 × 10^{-8} s

= 9.369 × 10^{-9} s

The does should be reversed within time interval of 9.369 × 10^{-9} S.

Question 6.5: Define magnetization. State its formula and S.I. unit. **[2]**

Solution: The net magnetic dipole moment per unit volume is called as the magnetization of the sample.

$$\text{Magnetization} = \frac{\text{Net magneticmoment}}{\text{Volume}}$$

It is vector quantity.

Unit A/m and Dimension $[M^0L^{-1}T^0I^1]$

$$\therefore M_z = \frac{M_{\text{net}}}{\text{Volume}}$$

Unit (A / m) and dimensions $[L^{-1}M^0T^0I^1]$

Question 6.6: Electrostatic energy of $3{\cdot}5 \times 10^{-4}$ J is stored in a capacitor at 700 V. What is the charge on the capacitor? **[2]**

Solution:

$U = 3.5 \times 10^{-4} J$, $V = 700V$

$$U = \frac{1}{2} Q V$$

$$Q = \frac{2U}{V}$$

$$= \frac{2 \times 3.5 \times 10^{-4}}{700}$$

$$Q = 10^{-6} C$$

Question 6.7: What is space wave propagation? **[2]**

Solution: Space wave propagation: When the radio waves from the transmitting antenna propagate along the space surrounding the earth to reach the receiving antenna, either directly or after reflection from the ground or in the troposphere, the wave propagation is called Space wave propagation.

Question 6.7: State three components of space wave propagation.

Solution: The space wave has three components:

(a) Direct wave : Along path (a), radio waves reach receiving antenna directly.

(b) Ground reflected wave: The radio waves reach the receiving antenna after reflection from ground.

(c)Tropospheric wave: The radio waves reach the receiving antenna after reflection from troposphere

Question 6.8: Find the value of energy of electron in eV in the third Bohr orbit of hydrogen atom. **[2]**
(Rydberg's constant (R) = $1{\cdot}097 \times 10^{7} m^{-1}$, Planck's constant (h) =$6{\cdot}63 \times 10^{-34}$ J-s, Velocity of light in air (c) = 3×10^{8} m/ s.)

Solution: $R = 1.097 \times 10^{7}\ m^{-1}$

$h = 6.63 \times 10^{-34}$ J - s,

$c = 3 \times 10^{8}$ m/s

$n = 3$

$e = 1.6 \times 10^{-19}$ C,

$E_3 = ?$

$$E = \frac{-6.63 \times 10^{-34} \times 1.097 \times 10^{7} \times 3 \times 10^{8}}{9 \times 1.6 \times 10^{-19}}$$

$$= \frac{-6.63 \times 1.097 \times 3}{9 \times 1.6}$$

$$= -[\log(6.63) + \log(1.097) + \log(3) - \log(9) - \log(1.6)]$$

$$[0.8215 + 0.0402 + 0.4771 - 0.9542 - 0.2041]$$

$$[\text{antilog}(0.1805)]$$

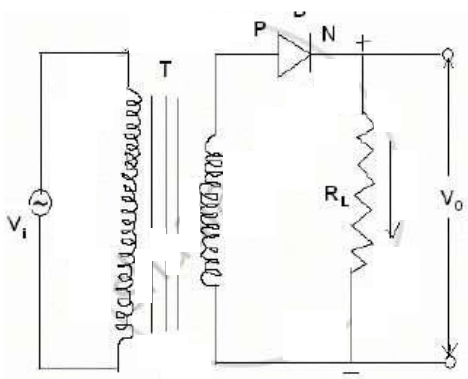
= 1.515 eV

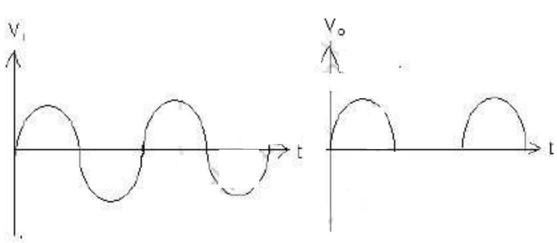
The value of energy of electron in the third bohr orbit of hydrogen atom is 1.515 eV.

Question 7 | Attempt any THREE : [9]

Question 7.1: With the help of neat labelled circuit diagram explain the working of half wave rectifier using semiconductor diode. Draw the input and output waveforms. [3]

Solution: A device which converts A.C. to D.C. is called rectifier. In this case output exists only for half cycle hence it is called half wave rectifier. Construction: The circuit diagram of a half wave rectifier using a junction diode is as shown in fig. The alternating voltage source is connected to the primary coil of a transformer. The secondary coil is connected to the diode in series with a resistance RL called the load resistance





T=Transformer

D=Diode

V0=output voltage

v1=input voltage

RL=load resistance

Working: In first cycle of input voltage, the anode of the diode is positive potential w.r.t. cathode. Hence the diode is in forward-biased. Hence it conduct current. The current flows through load resistance giving voltage drop iRL. This voltage drop is called output voltage. During next half cycle the anode of diode is in negative potential w.r.t. Hence it is in reversed-biased. Hence it does not conduct the current. Hence current does not flow through load resistance giving no P.D. across it. Hence output voltage is unidirectional. It is called as D.C.

Question 7.2: A cell balances against a length of 200 cm on a potentiometer wire, when it is shunted by a resistance of 8Ω. The balancing length reduces by 40 cm, when it is shunted by a resistance of 4 Ω. calculate the balancing length when the cell is in open circuit. Also calculate the internal resistance of the cell. **[3]**

Solution: Given: $R_1 = 8\Omega$, $l_2 = 200cm$,

$R_2 = 4\Omega$, $l'_2 = 160cm$

Balancing length (l_1) = ?

Internal resistance of the cell (r) = ?

$$r = R\left(\frac{l_1 - l_2}{l_2}\right)$$

From first condition ,

$$r = 8\left(\frac{l_1 - 200}{200}\right) \quad ......(1)$$

From first condition ,

$$r = 4\left(\frac{l_1 - 160}{160}\right) \quad .....(2)$$

From equation (1) and (2),

we get

$$8\left(\frac{l_1-200}{200}\right)=4\left(\frac{l_1-160}{160}\right)$$

$$\therefore \frac{l_1-200}{25}=\frac{l_1-160}{40}$$

$$\therefore 25l_1-4000=40l_1-8000$$

$$\therefore 15l_1=4000$$

$$\therefore l_1=266.67cm$$

From equation (1) we get,

Internal resistance,

$$r=8\left(\frac{l_1 200}{200}\right)=\frac{266.67-200}{25}$$

$$\therefore r=2.667\ \Omega$$

Question 7.3: State the law of radioactive decay. **[3]**

Solution: Law of radioactive decay:
The number of nuclei undergoing the decay per unit time is proportional to the number of unchanged nuclei present at that instant.

If 'N' is the number of nuclei present at any instant 't', 'dN' is the number of nuclei that disintegrated in short interval of time 'dt', then according to decay law,

$$-\frac{dN}{dt}\propto N$$

$$\therefore \frac{dN}{dt}=-\lambda N$$

Where, λ is known as decay constant or disintegration constant. The negative sign indicates disintegration of atoms.

Question 7.3: Derive the mathematical expression for law of radioactive decay for a sample of a radioactive nucleus

Solution: In any radioactive sample which undergoes α, β or γ-decay, it is found that the number of nuclei undergoing decay per unit time is proportional to the total number of nuclei in the sample.

If N is the number of nuclei in the sample and ΔN undergoes decay in time Δt, then we have

$$\frac{\Delta N}{\Delta t} \propto N$$

$$\therefore \frac{\Delta N}{\Delta t} = \lambda N$$

Where λ is called the radioactive decay constant or disintegration constant.

The change in the number of nuclei in the sample is dN = −ΔN in time Δt, i.e. in the limit dt → 0. Thus, the rate of change of N is

$$\frac{dN}{dt} = -\lambda N$$

$$\therefore \frac{dN}{N} = -\lambda dt$$

Now, integrating both the sides, we get

$$\int_{N_0}^{N} \frac{dN}{N} = -\lambda \int_{t_0}^{t} dt$$

$$\therefore \ln N - \ln N_0 = -\lambda(t-t_0)$$

Here, N_0 is the number of radioactive nuclei in the sample at some arbitrary time t_0 and N is the number of radioactive nuclei at any subsequent time t. Setting $t_0 = 0$ and rearranging, we get

In

$\therefore N(t) = N_0 e^{-\lambda t}$

This is the law of radioactive decay.

Question 7.4: The photoelectric work function for a metal is 4.2 eV. If the stopping potential is 3V, find the threshold wavelength and maximum kinetic energy of emitted electrons. **[3]**
(Velocity of light in air = 3×10^8 m/s,
Planck's constant = $6{\cdot}63 \times 10^{-34}$ J -s,
Charge or electron = $1{\cdot}6 \times 10^{-19}$ C)

Solution:

$$\phi_0 = \frac{hc}{\lambda_0}$$

$$\lambda_0 = \frac{hc}{\phi_0}$$

$$\phi_0 = 4.2ev = 4.2 \times 1.6 \times 10^{-19}J = 6.72 \times 10^{-19}J$$

$$\lambda_0 = \frac{hc}{\phi_0} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{6.72x10^{-19}}$$

$$\lambda_0 = 2.960 \times 10^{-7}m$$

λ_0 = 2960 A^0

(K. E.)max = e Vs = 1.6 x 10^{-19} x 3

(K. E.)max = 4.8 x 10^{-19} J = 3 e V

Question 8 | Attempt any one : **[7]**

Question 8.1: State Faraday's laws of electromagnetic induction. **[7]**

Solution: (1) **Faraday's first law of electromagnetic induction** states that whenever a conductor is placed in the varying magnetic field, electromagnetic fields are induced known as induced emf. If the conductor circuit is closed, a current is also induced which are called induced current.

(2) **Faraday's second law of electromagnetic induction** states that
the induced emf in a coil is equal to the rate of change of flux linkage. Here the flux is nothing but the product of the number of turns in the coil and flux connected with the coil.

The formula of Faraday's law is given below :

$$\mathbf{e} = \mathbf{N} \times \frac{d\Phi}{dt}$$

Where,

e is the induced voltage
N is the number of turns in the coil
Φ is the magnetic flux
t is the time

If dΦ is change in magnetic flux in time dt, the induced e.m.f. is given by

$$e \alpha \frac{d\varphi}{dt}$$

$$\therefore e = k\frac{d\varphi}{dt}$$

$$\text{if} \quad d\varphi = 1wb, dt = 1s \quad \text{then} \quad e = 1V$$

$$\therefore k = 1$$

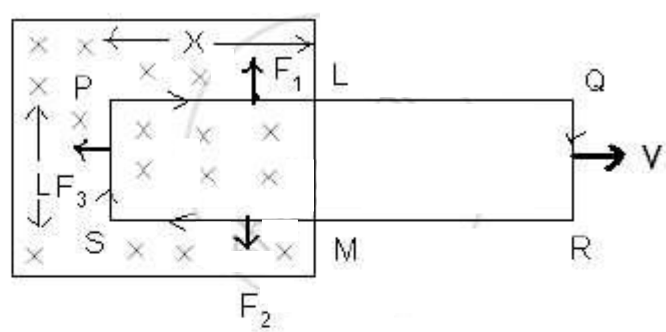
$$\therefore e = \frac{d\varphi}{dt}$$

Question 8.1: State Lenz's Law. **[7]**

Solution: Lenz's law: It is stated that the direction of induced e.m.f. is always in such direction that it opposes the change in magnetic flux.

$$e = \frac{d\varphi}{dt}$$

Consider a rectangular metal coil PQRS. Let 'L' be the length of the coil. It is placed in a partly magnetic field 'B'. the direction of magnetic field is perpendicular to paper and into the paper. The 'x' part of the coil is in magnetic field at instant t. If the coil is moved towards right with a velocity v = dx/dt with help of external agent like hand. The magnetic flux through the coil is Φ= BA = BLx ∴Φ = B Lx ----(1) There is relative motion of a current through the coil. Let 'i' be current through the coil.



Three forces acts on the coil.
F_1 on conductor PL ∴ F1 = Bix, vertically upward.
F_2 on conductor MS ∴ F2 = Bix, vertically downward.
F_3 on conductor SP ∴ F3 = BiL towards left.
F_1 & F_2 are equal and opposite and also in a same lines. They will cancel each other, F_3 is a resultant force. The external agent has to do work against this force.

∴ F3 = - Bil -ve sign indicates that force is opposite to dx.
If dx is displacement in time dt, then work done dw = F3 dx

∴ dw = - BiL dx

This power is an electrical energy 'ei' where 'e' is an induced e.m.f.

$$\therefore ei = -\frac{Bildx}{dt}$$

$$\therefore e = -\frac{BLdx}{dt}$$

$$\therefore e = -BLv$$

$$\therefore e = -\frac{d}{dt}(BLx)$$

$$\therefore = e = -\frac{d\varphi}{dt} \text{ from eq (1)}$$

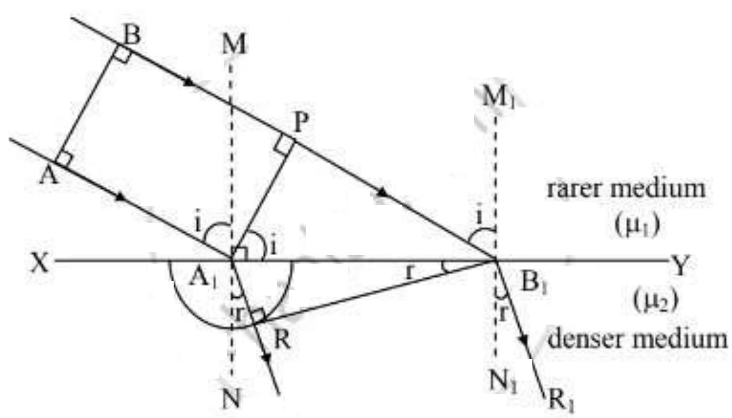
Solution 2: The Lenz's law states that the direction of induced current is such that it opposes the cause which produces it.

Question 8.1: A circular coil of 250 turns and diameter 18 cm carries a current of 12A. What is the magnitude of magnetic moment associated with the coil? **[7]**

Solution: M = N I A where A =π r^2

∴ M = NI π r2
∴ M = 250 x 12 x 3.14 x 81 x10^{-4}
∴ M = 76.30 A-m^2

Question 8.2: On the basis of Huygens' wave theory of light prove that velocity of light in a rarer medium is greater than velocity of light in a denser medium. **[7]**



Refraction of light

Solution:

XY : plane refracting surface

AB : incident plane wave front

B_1R : refracted wave front

AA_1 , BB_1 : incident rays

A_1R , B_1R_1 : refracted rays

$\angle AA_1M = \angle BB_1M_1 = \angle i$: angle of incidence

$\angle RA_1N = \angle R_1B_1N_1 = \angle r$: angle of refraction

a. Let XY be the plane refracting surface separating two media rarer and denser of refractive indices μ_1 and μ_2 respectively.

b. A plane wave front AB is advancing obliquely towards XY from rarer medium. It is bounded by rays AA_1 and BB_1 which are incident rays.

c. When 'A' reaches at 'A_1' then 'B' will be at 'P'. It still has to cover distance PB_1 to reach XY.

d. According to Huygens ‘Principle, secondary wavelets will originate from A_1 and it will spread over a hemisphere in denser medium.

e. All the rays between AA_1 and BB_1 will reach XY and spread over the hemispheres of increasing radii in denser medium. The surface of tangency of all such hemisphere is RB_1. This gives rise to refracted wave front B_1R in denser medium.

f. A_1R and B_1R are refracted rays.

g. Let c_1 and c_2 be the velocities of light in rarer and denser medium respectively.

h. At any instant of time 't' , distance covered by incident wavelength from P to $B_1 = PB_1 = c_1t$
   Distance covered by secondary wave from A_1 to $R = A_1R = c_2t$.

i. From above figure,
   $\angle AA_1M + \angle MA_1P = 90°$ .....(i) and
   $\angle MA_1P + \angle PA_1B_1 = 90°$ ....(ii)
   From equation (i) and (ii) , we have,
   $\angle AA_1M = \angle PA_1B_1 = 90°$

j. Similarly ,
   $\angle NA_1R = \angle N_1B_1R_1 = r$
   We have,
   $\angle N_1B_1R_1 + \angle A_1B_1R = 90°$ ....(iii)
   and
   $\angle N_1B_1R_1 + \angle A_1B_1R = 90°$ ....(iv)
   From equations (iii) and (iv) , we have,
   $\angle N_1B_1R_1 + \angle A_1B_1R = r$

k. In Δ A_1PB_1 ,

$$\sin i = \frac{PB_1}{A_1B_1} = \frac{c_1t}{A_1B_1} \quad \text{........(v)}$$

l. In Δ A_1RB_1 ,

$$\sin r = \frac{A_1R}{A_1B_1} = \frac{c_2t}{A_1B_1} \quad \text{............(vi)}$$

m. Dividing equation (v) bt (vi), we have

$$\frac{\text{sini}}{\text{sinr}} = \frac{\frac{c_1t}{A_1B_1}}{\frac{c_2t}{A_1B_1}}$$

$$\therefore \frac{\text{sini}}{\text{sinr}} = \frac{c_1}{c_2} \quad \text{.....(vii)}$$

Also $\frac{c_1}{c_2} = \frac{\mu_2}{\mu_1} = 1\mu_2$ .....(viii)

where $1\mu_2$ = R.I. of denser medium w.r.t rarer medium.

n. From above figure ,

$\angle i > \angle r$

$\therefore$ sin i > sin r

$$\therefore \frac{\text{sini}}{\text{sinr}} > 1$$

$$\therefore \frac{\mu_2}{\mu_1} > 1 \quad \text{.........(ix)}$$

Since , $\frac{c_1}{c_2} = \frac{\mu_2}{\mu_1}$ ....[From ix]

$$\therefore \frac{c_1}{c_2} > 1$$

$$\therefore c_1 > c_2$$

Hence, velocity of light in rarer medium is greater than velocity in denser medium.

Question 8.2: In Young's experiment the ratio of intensity at the maxima and minima in the interference pattern is 36 : 16. What is the ratio of the widths of the two slits?

Solution:

$$\frac{I_{\max}}{I_{\min}} = \left(\frac{\frac{A_1}{A_2} + 1}{\frac{A_1}{A_2} - 1}\right)^2$$

$$Let \frac{A_1}{A_2} = r$$

$$\therefore \frac{I_{\max}}{I_{\min}} = \left(\frac{r+1}{r-1}\right)^2$$

$$\therefore \frac{36}{16} = \left(\frac{r+1}{r-1}\right)^2$$

$$\therefore \frac{6}{4} = \left(\frac{r+1}{r-1}\right)$$

$$\therefore r = \frac{5}{1}$$

$$\frac{A_1}{A_2} = \frac{5}{1}$$

Ratio of width $= \left(\frac{A_1}{A_2}\right)^2 = \frac{25}{1}$