2023	12	25

TS-P5

SEAT NUMBER

IIT INSPIRE
ACADEMY OF SCIENCE
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XI & XII Science (CBSE/state)
IIT- JEE (Mains + Advance)
NEET, MH-CET , NDA
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Branches : Chhatrapati Sq., Mangalmurti Sq.

(4 Pages)

calculator is not allowed.
5. All symbols having their usual meanings unless otherwise stated.
6. For each MCQ, correct answer must be written along with its alphabet.
7. Evaluation of each MCQ would be done for the first attempt only.

Physical Constants:
(1) $\pi=3.142$ (2) $g=10\,m/s^2$ (3) $h=6.63\times10^{-34}\,J.s$ (4) $c=3\times10^8\,m/s$
(5) $e=1.6\times10^{-19}\,C$ (6) $\varepsilon_0=8.85\times10^{-12}\,C^2/N.m^2$ (7) $\mu_0=4\pi\times10^7\,T.m/A$,
(8) $\sigma=5.7\times10^{-8}\,W/m^2K^4$

SECTION-A

Q.1 Select and write the correct answers to the following questions: [10]

1) **When seen from below, the blades of a ceiling fan are seen to be revolving anticlockwise and their speed is decreasing. Select correct statement about the directions of its angular velocity and angular acceleration._________ (1)**
Ans:
a) Angular velocity upwards, angular acceleration downwards.

2) **Two capillary tubes of radii 0.3 cm and 0.6 cm are dipped in the same liquid. The ratio of heights through which the liquid will rise in the tubes is (1)**
Ans:
b) 2:1

3) **If $a=0.72$ and $r=0.24$, then the value of t_r is (1)**
Ans:
b) 0.04

4) **Thermal equilibrium implies the equality of (1)**
Ans:
d) temperature

5) **A parallel plate capacitor is charged and then isolated. The effect of increasing the plate separation on charge, potential, capacitance respectively are - (1)**

Ans:

d) constant, increases, decreases

6) **Intensity of magnetic field of the earth at a point inside a hollow iron box is ___ (1)**

Ans:

d) zero

7) **A 50 mH coil carries a current of 2 ampere. The energy stored in joules is (1)**

Ans:

b) 0.1

8) **The wavelength of matter is independent of (1)**

Ans:

d) charge

9) **A transistor act as an open switch when it is in: (1)**

Ans:

a) the cut off region

10) **If q is a charge on the capacitor and C is a capacitance, then energy stored in capacitor is (1)**

Ans:

c) $\frac{q^2}{2C}$

Q.2 Answer the following questions in one sentence: [8]

(1) Write the mathematical equation representing a progressive wave travelling in the negative x-direction with constant speed v. (1)

Ans:

$y(x,t) = A\sin(kx + \omega t)$

(2) What is a galvanometer? (1)

Ans:

A galvanometer is a device used to detect weak electric current in the circuit.

(3) State the expression for the magnetic field produced by a current in a circular arc of wire. (1)

Ans:

$B = \frac{\mu_0}{4\pi}\frac{I}{r}\theta, when\, \theta\, is \in radians$

(4) What is Gyromagnetic ration? (1)

Ans:

Gyromagnetic ration is defined as the ration of orbital magnetic moment to angular momentum.

$\frac{m_{orb}}{L} = \frac{-e}{2m_e}$

(5) State Lenz's Law. (1)

Ans:

When magnetic flux linked with conductor(coil) changes, emf is induced in the coil in such a direction so as to oppose the cause which produced.

(6) What is SI unit and dimension of X_L. **(1)**

Ans:

SI unit is ohm

Dimension is $[M^1 L^2 T^{-3} I^{-2}$¿

(7) Can microwave be used in the experiment on photoelectric effect? **(1)**

Ans:

No, it is not possible to obtain photoelectric effect using microwaves.

(8) Two charge of magnitudes -4Q and +2Q are located at points (2a, 0) and (5a, 0) respectively. What is the electric flux due to these charges through a sphere of radius 4a with its centre at the origin? **(1)**

Ans:

According to Gauss' theorem,

$$flux, \phi = \frac{Total\, charges \in a\, closed\, surface}{\varepsilon_0}$$

$$\therefore \phi = \frac{-4Q}{\varepsilon_0}$$

SECTION-B

Attempt any eight of the following questions: **[16]**

Q.3 State the characteristics of circular motion. **(2)**

Ans:

1. It is an accelerated motion: As the direction of velocity changes at every instant, it is an accelerated motion.
2. It is a periodic motion: During the motion, the particle repeats its path along the same trajectory. Thus, the motion is periodic.

Q.4 How much work is required to form a bubble of 2 cm radius from the soap solution having surface tension 0.07 N/m. **(2)**

Ans:

$T = 0.07\, N/m, r = 2\, cm \times 10^{-2}\, m$

W =?

$W = T \times (dA)$

¿$T \times 2(4\pi r^2)$

¿0.07×2¿

¿$7 \times 32\pi \times 10^{-6}$

¿$7.038 \times 10^{-4}\, J$

Q.5 At what temperature will oxygen molecules have same rms speed as helium molecules at STP (Molecular masses of oxygen and helium are 32 and 4 respectively). **(2)**

Ans:

$T_{He} = 273\, K$

$T_{O2} = ?$

$V_{O2} = V_{He}$

$M_{O2} = 32$

$M_{He} = 4$

$$V_{Rms}=\sqrt{\frac{3RT}{M}}, hence$$
$$\frac{T_{O2}}{M_{O2}}=\frac{T_{He}}{M_{He}}$$
$$\frac{T_{O2}}{32}=\frac{273}{4}$$
$$T_{O2}=273\times 8$$
$$\therefore T_{O2}=2184\,K$$

Q.6 Define linear simple harmonic motion. (2)

Ans:

Linear S.H.M: Linear periodic motion in which the restoring force (acceleration) acting on a body is directly proportional to its displacement from the mean position and is always directed towards the mean position is called linear S.H.M.

Q.7 What are stationary waves? Why they are called stationary waves? (2)

Ans:

1. When two identical progressive waves both (transverse or longitudinal) travelling along the same path in opposite directions interfere with each other by superposition of waves, resultant waves obtained in the form of loops is called a stationary wave.
2. Stationary waves are called standing wave because the resultant harmonic disturbance of the particles does not travel in any direction and there is no transport of energy.

   There are two types of stationary waves:

1. **Transverse Stationary Waves:**
   Eg: Vibration of stretched strings (guitar, sitar, veena, etc)
2. **Longitudinal Stationary Waves:**
   Eg: Vibration of air columns in organ pipe and flute

Q.8 What are coherent sources? How are they produced? (2)

Ans:

Two sources, which emit waves of the same frequency having a constant phase difference, independent of time, are called coherent sources.

Methods to produce coherent sources:

1. **Division of wavefront:** A wavefront is divided into two or more parts using biprism, slits, mirrors, lens etc. The well known method is Young's double slit method.
2. **Division of amplitude:** An amplitude is divided into two or more parts by partial reflection. E.g. Young's double slits.

Q.9 In a double slit arrangement, the slits are separated by a distance equal to 100 times the wavelength of light passing through the slits (2)

a) What is the angular separation in radius between the central maximum and an adjacent maximum?

b) What is the distance between these maxima on a screen 50.0 cm from the slits?

Ans:

$$\theta_1=\frac{\lambda}{a}=\frac{\lambda}{100\,\lambda}=0.01\,rad.$$
$$x_1=\frac{\lambda D}{a}=\frac{\lambda\times 50}{100\,\lambda}$$
¿ $0.5\,cm$

Q.10 State any two sources of errors in meter bridge experiment. Explain how they can be minimized. **(2)**

Ans:

Error due to non-uniformity of wire:

1. If the wire is not uniform, the resistance per unit length will not be same everywhere. So, there will be an error in the value of unknown resistance.
2. The wire must be uniform and should have same cross-sectional area throughout the length.

Error due to contact resistance:

1. The points where the wire is joined to the copper strips, the contact resistance is developed which produces an error in the value of unknown resistance X.
2. The experiment should be repeated by interchanging the resistance in left and right gaps.

Error due to non-exact coincidence with zero and 100cm mark of scale:

1. The ends of the wire must coincide with 0 and 100cm mark on the meter scale.
2. The value of resistance from the resistance box should be chosen such that the null point is near the center of the wire, i.e., between 35cm and 65cm.

Error due to sliding of jockey on the wire:

Due to sliding of the jockey, heat is produced due to friction. Thus, the area of wire can be deformed and resistance of the wire may change.

To minimize this error, jockey is tapped on the wire.

Q.11 A circular coil of conducting wire has 500 turns and an area $1.26 \times 10^{-4} m^2$ **is enclosed by the coil. Calculate the magnetic moment of the coil if a current of** $100\,\mu A$ **is passed through.** **(2)**

Ans:

$Data: N = 500\; I = 100 \times 10^{-6} A$

$A = 1.26 \times 10^{-4} m^2$

$\mu = NIA$

¿ $500 \times 100 \times 10^{-6} \times 1.26 \times 10^{-4}$

$\mu = 6.30 \times 10^{-6} Am^2 \vee J/T$

Q.12 State the disadvantages of eddy currents and how to minimise these disadvantages. **(2)**

Ans:

Disadvantages: Eddy currents produce large amount of heat and hence, loss of electrical energy. To minimise this effect

1. Insulated or laminated iron cores are used which minimizes the magnitude of eddy currents.
2. By reducing the surface area of the metal plate, magnitude of eddy currents is reduced.

Q.13 A capacitor draws 20 A current at 240 V, 50 Hz. Find the capacitive reactance and the capacitance of the capacitor. **(2)**

Ans:

$Data: i_{rms} = 20\,A, e_{rms} = 240\,V, f = 50\,Hz, X_C = ?, C = ?$

$(1)\; X_C = \frac{e_{r.m.s.}}{i_{r.m.s.}}$

¿ $\frac{240}{20}$

¿ $12\,\Omega$

$(2)\; X_C = \frac{1}{\omega C}$

$$¿\frac{1}{2\pi f.C}$$

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

$$¿\frac{1}{2\times 3.142\times 50\times 12}$$

$$¿\frac{1}{1200\times 3.142}$$

$$¿2.652\times 10^{-4}$$

$$\therefore X_C=12\Omega$$

$$C=2.652\times 10^{-4}F$$

Q.14 Show that linear momentum of an electron in Bohr stable orbit is inversely proportional to principal quantum number. **(2)**

Ans:

Let m_e *= mass of the electron*

v_n *= Velocity of electron ∈* n^{th} *stable orbit*

r_n *= radius of its* n^{th} *stable orbit*

Z *= atomic number ofthe itom*

Z_e *= total positive charge on the nucleus*

n *= positive integer called the principal quantum number of the electron.*

ε_0 *= permittivity of free space*

$-e$ *= charge onthe electron*

P_n *= linear momentum of an electron orbiting ∈* n^{th} *stable orbit*

$¿1^{st}\wedge 2^{nd}$ *Bohr' spostulate we get ,*

$$V_n=\frac{Ze^2}{2\varepsilon_0 hn}$$

$\therefore$ *Linear momentum* P_n *∈ thee stable orbit is given by*

$$P_n=m_e V_n$$

$$P_n=\frac{m_e Ze^2}{2\varepsilon_0 hn}$$

$$P_n=\frac{m_e Ze^2}{2\varepsilon_0 hn}\ Z=1\ \text{for hydrogen atom}$$

$$\therefore P_n=\left(\frac{m_e e^2}{2\varepsilon_0 h}\right)=\frac{1}{n}$$

$$\therefore P_n\propto\frac{1}{2}\left(m_e e^2,\varepsilon_0\wedge h=constant\right)$$

SECTION-C

Attempt any eight of the following questions:
[24]

Q.15 Explain the transfer of energy between system and its environment. **(3)**

Ans:

Consider a system with temperature T_s is kept in an environment of temperature T_E. Let Q be the energy transferred between the system and the environment.

1. When the temperature of the system is less than that environment $(T_s < T_E)$, the energy flows into the system as shown in figure (a)

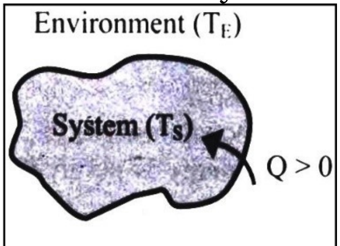


Figure (a): $T_S < T_E$

As a result, the system gains energy and Q is positive.

2. When $T_s > T_E$, the system loses energy i.e., the energy flows from system into the environment as shown in figure (b)

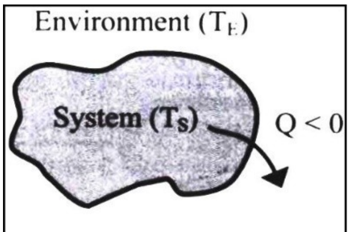


Figure (b): $T_S > T_E$

In this case, Q is negative.

3. For $T_s = T_E$, as shown in figure (c), the system and the environment are in thermal equilibrium and there is no transfer of energy i.e., $Q = 0$

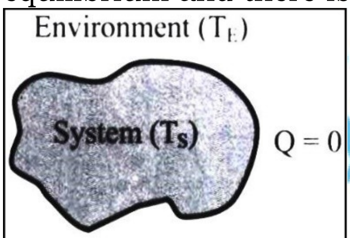


Figure (c): $T_S = T_E$

Q.16 A gas enclosed in a cylinder is expanded to double its initial volume at a constant pressure of one atmosphere. How much work is done in this process? (3)

Ans:

Given: pressure (p) ¿ 1 Atmosphere

$p = 1.01 \times 10^5\, Pa$,

$change \in volume (V_f - V_i) = 0.5$

$work\ done (W) = p(V_f - V_i)$

¿ $1.01 \times 10^5 (+0.5)$

¿ 0.505×10^5

¿ $5.05 \times 10^4\, J$

$\because V_f > V_{i,}$ *the gas inside the cylender has expanded . thus work done is positive .*

$\therefore$ *Work is done by the gas .*

Q.17 A body of mass 0.2 kg performs linear S.H.M. It experiences a restoring force of 0.2 N, when its displacement from the mean position is 4 cm. Determine (i) force constant

(ii) period of S.H.M and (iii) acceleration of the body when the displacement from the mean position is 1 cm. (3)

Ans:

(i) Force constant

$$k=\frac{F}{x}$$

$$¿\frac{(0.2)}{0.04}$$

$$k=5\,N/m$$

$$(ii)\,Period\,T=\frac{2\pi}{\omega}$$

$$¿2\pi\sqrt{\frac{m}{k}}$$

$$¿2\times3.14\sqrt{\frac{0.2}{5}}$$

$$¿0.4\,\pi s$$

$$(iii)\,Acceleraion\,a=-\omega^2 x$$

$$¿-\frac{k}{m}x$$

$$¿\frac{-5}{0.2}\times0.04$$

$$a=-1\,m/s^2$$

Q.18 State the characteristics of stationary waves. (3)

Ans:

Characteristics of Stationary Waves:

1. When two identical progressive waves travelling in opposite directions interfere with each other, they produce stationary waves in the form of loops.
2. In stationary waves, some particles of the medium vibrate with maximum amplitude are called antinodes, whereas some particles of medium do not vibrate are called nodes.
3. The distance between the two consecutive anti-nodes or nodes is half the wavelength ($\lambda/2$).
4. The distance between a node and the adjacent is quarter the wavelength ($\lambda/4$).
5. When a stationary wave is produced in a medium, then it is divided into many loops of equal length.
6. The particle in one loop vibrates in the same phase, whereas the particles in the adjacent loop vibrate in the opposite phase.
7. The amplitude of vibration of a particle in a medium varies from zero to maximum from nodes to antinodes.
8. The velocity of a stationary wave is zero, but its component is non-zero.
9. The transfer of energy through a medium cannot take place due to node points of the medium.
10. In longitudinal stationary waves, the points in the medium having maximum displacement but constant pressure are pressure node points and the points of the medium having minimum displacement and variation in pressure is maximum are pressure antinode points.
11. The wavelength and time period of a stationary wave are same as that of the component of the wave.
12. Stationary waves are periodic in space and periodic in time. It's double periodic phenomenon.

13. In stationary waves all the particle except at the nodes vibrates with the same period as that of wave.

Q.19 Derive an expression for fringe width for Bright and Dark bands. (3)

Ans:

Expression for band width of bright band:

1. Let n^{th} bright band is present at a distance x_n and $(n+1)^{th}$ bright band is present at a distance x_{n+1} from the centre of interference pattern i.e., from point P.
2. The band width, $X = x_{n+1} - x_n$
3. For n^{th} bright band, path difference is

$$\frac{x_n d}{D} = n\lambda$$

For $(n+1)^{th}$ bright band, path difference is

$$\frac{x_{n+1} d}{D} = (n+1)\lambda$$

4. On subtracting the above two equations,

$$\frac{(x_{n+1} x_n) d}{D} = n\lambda + \lambda - n\lambda$$

$$\therefore \frac{Xd}{D} = \lambda \quad [X = x_{n+1} - x_n]$$

$$\therefore X = \frac{\lambda D}{d} \text{ .... (3)}$$

This is the expression for band width of bright band.

Expression for band width of dark band:

1. Let m^{th} dark band is present at a distance x_m and $(m+1)^{th}$ dark band is present at a distance x_{m+1} from the centre of interference pattern i.e., from point P.
2. The band width, $X = x_{m+1} - x_m$

Using the relation for path difference

3. For m^{th} dark band,

$$\frac{x_n d}{D} = \left(m - \frac{1}{2}\right)\lambda$$

For $(m+1)^{th}$ dark band,

$$\frac{x_{m+1} d}{D} = \left(m + 1 - \frac{1}{2}\right)\lambda$$

4. Subtracting the relations,

$$(x_{m+1} - x_m)\frac{d}{D} = m\lambda + \lambda - \frac{\lambda}{2} - m\lambda + \frac{\lambda}{2}$$

$$\frac{Xd}{D} = \lambda$$

$$\therefore X = \frac{\lambda D}{d} \text{ .... (3)}$$

This is the expression for band width of dark band.

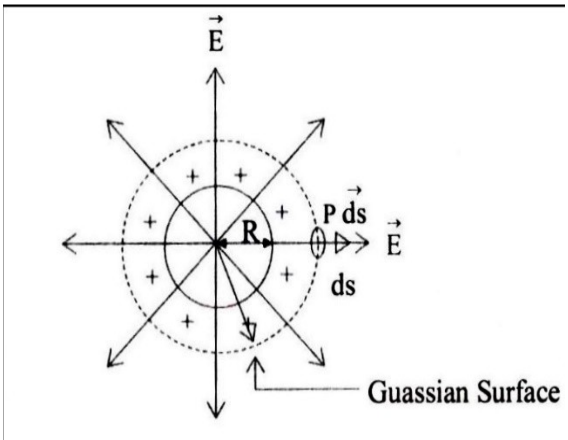
5. From the relation (3), it is clear that width of bright and dark band is same i.e., bright and dark bands are equally spaced in interference pattern.

Q.20 Obtain an expression for electric field intensity due to uniformly charged spherical shell or hollow sphere. (3)

Ans:

1. Consider a sphere of radius R with its centre at O, charged to a uniform charge density $\sigma\left(C/m^2\right)$ placed in a dielectric medium of permittivity $\varepsilon\left(\varepsilon = \varepsilon_0\right)k$.

2. The total charge on the sphere, $q=\sigma \times 4\pi R^2$.
3. By Gauss' theorem, the net flux through a closed surface
   $\varnothing = q/\varepsilon_0 \,(For\ air/vaccum\ k=1)$ .... (1)
   Where, q is the total charges inside the closed surface.
4. To find the electric field intensity at a point P, at a distance r from the centre of the charged sphere, imagine a concentric Gaussian sphere of radius r passing through P.
5. Let ds be a small area around the point P on the Gaussian surface.
6. Due to symmetry and spheres being concentric, electric field at each point on the Gaussian surface has the same magnitude E and it is direction radially outward. Also, angle between the direction of E and the normal to the surface of the sphere (ds) is zero i.e., $\cos\theta = 1$



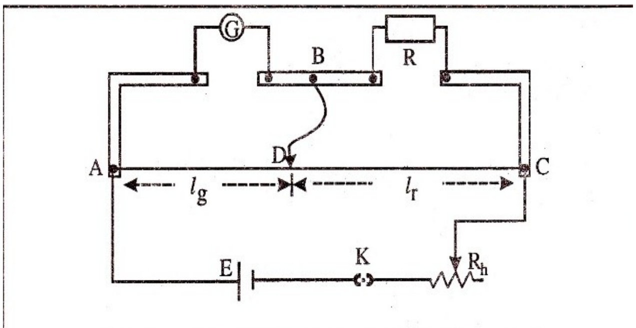
Uniformly charged spherical shell or hollow sphere

7. $\therefore \vec{E}.\vec{ds} = E\,ds\cos\theta = E\,ds$
   $\therefore$ Flux $d\varnothing$ through the area ds ¿ $E\,ds$
8. Total electric flux through the Gaussian surface $\varnothing = \oint \vec{E}.\vec{ds} = \oint Eds = E\oint ds$
   $\therefore \varnothing = E\,4\pi r^2$ .... (2)
   From equation (1) and (2),
   $q/\varepsilon_0 = E\,4\pi r^2$
   $\therefore E = q/4\pi\varepsilon_0 r^2$ .... (3)
   Since $q=\sigma \times 4\pi R^2$
9. We have $E=\sigma \times 4\pi R^2/4\pi\varepsilon_0 r^2$
   $\therefore E=\sigma R^2/\varepsilon_0 r^2$ .... (4)
   From Eq. (3) it can be seen that, the electric field at a point outside the shell is the same as that due to a point charge. Thus it can be concluded that a uniformly charged sphere is equivalent to a point charge at its center.
10. **Case-1:** If point P lies on the surface of the charged sphere: $r=R$
    $\therefore E=q/4\pi\varepsilon_0 R^2 = \sigma/\varepsilon_0$
11. **Case-2:** If point P lies inside the sphere: Since there are no charges inside $\sigma=0$,
    $\therefore E=0$.

Q.21 Describe Kelvin's method experiment to determine the resistance of a galvanometer by using a meter bridge. (3)

Ans:

1. This method is used to find out the resistance of galvanometer using Meter Bridge. If we use the meter bridge to determine the resistance of galvanometer, we require two galvanometers. Instead of using two galvanometers we can use only a single galvanometer as shown in the diagram.
2. In Kelvin's method the same galvanometer is used to find out equipotential points and to determine its resistance. This method is an equal deflection method.



Resistance of galvanometer using Kelvin's method

   Circuit diagram of meter bridge using Kelvin's method is a shown above.

Construction:

1. It consists of a wooden platform on which one meter uniform wire of conducting material is stretched between the points A and C.
2. The ends of wire are fixed using two L-shaped copper plates. The third copper plate is fixed on the board in such a way that two gaps are formed.
3. In one gap galvanometer is connected and jockey is directly connected to point B and in another gap, resistance box R is connected.
4. A source of emf 'E' plug key 'K' and variable resistance R_h are connected in series with wire.
5. A meter scale is fixed on wooden board to measure the distances between different points.

Working:

1. When current flows through the circuit, without touching the jockey to any point of wire AC, note the deflection in the galvanometer. Adjust the deflection of galvanometer within scale, using variable resistance R_h.
2. By touching the jockey at different points, of wire AC, find out the equipotential point D, so that galvanometer shows same deflection, as adjusted before the point D gives same deflection in the galvanometer with or without the contact of jockey. Due to this, the method is called as equal deflection method. In the above condition, we can say that potential at points B and D are equal i.e., they are equipotential. The point D is called balance point.
3. Using Wheatstone's network principle, we can write

$$\frac{G}{R}=\frac{resistance\ of\ l_g\ length\ of\ wire}{resistance\ of\ l_r\ length\ of\ wire}$$

G is the resistance of galvanometer
If σ is resistance per unit length, then

1. Since bridge is balanced,

$$\frac{G}{R}=\frac{R_{AD}}{R_{DC}}$$

But, $\frac{R_{AD}}{R_{DC}}=\frac{\rho l_g/A}{\rho l_r/A}=\frac{l_g}{l_r}$

$$\text{.........}\left(\because R=\frac{\rho L}{A} where\ ,L\ is\ lenght\ of\ wire\right)$$

$$\therefore \frac{G}{R}=\frac{l_g}{l_r}$$

$$\therefore \frac{G}{R}=\left[\frac{l_g}{100-l_g}\right] \qquad \text{.......}(\because l_g+l_r=100\,cm)$$

$$\therefore G=\left[\frac{l_g}{100-l_g}\right]R$$

Using this formula, the unknown resistance of the galvanometer can be calculated.

Q.22 Two identical coils each of radius r and having number of turns n are lying in perpendicular planes such that they have common centre. Find the magnetic field at the centre of the coils if they carry currents equal to I and $\sqrt{3}$I respectively. (3)

Ans:

$Data: I_1=I\ ,I_2=\sqrt{3}\,I\ ,m\wedge r\ seme\ for\ both\ coils$

Let $B_1\wedge B_2$ be the magnetic fields produced by the two coils Then

$$B_1=\mu_0\ni\frac{¿}{2r}¿$$

$$B_2=\mu_0\ni\frac{¿}{2r}(\sqrt{3})¿$$

Since the planes of the coils are perpendicular to each other, $B_1 \wedge B_2$ are also perpendicular to each other. The resultant magnetic field is given by

$$B=\sqrt{B_1^2+B_2^2}=\mu_0 \ni \frac{¿}{2r} ¿¿¿$$

$$B=\mu_0 \ni \frac{¿}{r} ¿$$

Q.23 A rod of magnetic material of cross section $0.25\,cm^2$ is located in $4000\,Am^{-1}$ magnetizing field. Magnetic flux passing through the rod is $25\times10^{-6}\,Wb$. Find out (1) relative permeability (2) magnetic susceptibility and (3) magnetization of the rod.

Ans:

$A=0.25\,cm^2=0.25\times10^{-4}\,m^2$

$H=4000\,Am^{-1}, \Phi_m 25\times10^{-6}\,Wb$

$(1)\,\mu_r=?\ (2)\,X=?\ (3)\,M=?$

$$B=\left(\frac{\Phi_m}{A}\right)=\left(\frac{25\times10^{-6}}{0.25\times10^{-4}}\right)=1\,Wb/m^2$$

$$\therefore \mu=\frac{B}{H}=\left(\frac{1}{4\times10^3}\right)=2.5\times10^{-4}\,Wbm/A$$

$$\mu_r=\frac{\mu}{\mu_0}=\left(\frac{2.5\times10^{-4}}{4\times3.142\times10^{-7}}\right)=\left(\frac{2500}{12.56}\right)$$

$\therefore \mu_r=199$

$\mu_r=(1+X)$

$X=\mu_r-1$

$\therefore X=198$

$M=XH$

$¿198\times4000$

$\therefore M=7.92\times10^5\,A/m$

Q.24 A metal disc is made to spin at 20 revolutions per second about an axis passing through its centre and normal to its plane. The disc has a radius of 30 cm and spins in a uniform magnetic field of 0.20 T, which is parallel to the axis of rotation. Calculate

a) The area swept out per second by the radius of the disc.

b) The flux cut per second by a radius of the disc.

c) The induced emf in the disc. (3)

Ans:

$f=20\,rps$

$R=30\,cm=30\times10^{-2}\,m$

$B=0.2\,T$

$(a)\ Area\ swept \in one\ revolution=\pi r^2.$

$\therefore Area\ swept \in one\ second=f\times\pi r^2$

$¿20\times3.14¿$

$¿2\times3.142\times9\times10^{-1}$

$¿56.556\times10^{-1}\,m^2.$

$\therefore A_{swept}=5.6556\,m^2$

$$(b)\ \frac{d\Phi}{dt}=\frac{1}{2}B\omega R^2=\frac{1}{2}B2\pi f R^2$$

$$¿\frac{1}{2}\times 0.2\times 20\times 2\pi ¿$$

$$¿4\pi \times 9\times 10^{-2}$$

$$\frac{d\Phi}{dt}=1.131\,Wb/s$$

$$(c)\,e=\frac{-d\Phi}{dt}\;\therefore |e|=1.131\,V$$

Q.25 Explain the theory of A.C. circuit with pure inductor. Draw the phasor diagram for voltage and current in the circuit. **(3)**

Ans:

1. Suppose an alternating source of e.m.f is applied between the terminals of a resistor of resistance R as shown in fig. (a).

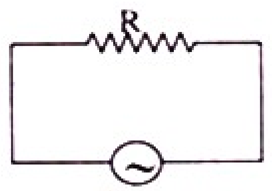


Figure (a)

The instantaneous value of e.m.f is given by,
$e=e_0\sin\omega t$ .... (1)

2. By ohm's law, the instantaneous current flowing through the circuit is given by,
$I=\frac{e}{R}$
But, $e=e_0\sin\omega t$
$\therefore I=\frac{e_{0\sin\omega t}}{R}$ .... (2)
Equation (2) represents instantaneous current in the circuit.
3. For maximum current through the circuit,
$\sin\omega t=1$.
$\therefore I_{max}=\frac{e_0}{R}¿I_0$ .... (3)
Equation (3) represents peak value of current.
4. From equation (2) and (3), we have,
$I=I_0\sin\omega t$ .... (4)
Equation (4) represents instantaneous current of a.c circuit with resistance only.
5. From equation (4) it is observed that instantaneous current varies sinusoidally with peak current.
6. Comparing $i_0=\frac{e_0}{R}$ with Ohm's law, we find that resistors behave similarly for both AC and DC voltage. Hence the behaviour of R in DC and AC circuits is the same. R can reduce DC as well as AC equally effectively.
7. From Eq (1) and Eq (4), we know that for a resistor there is zero phase difference between instantaneous alternating current and instantaneous alternating emf, i.e., they are in phase. Both e and I reach zero, minimum and maximum values at the same time.
8. A graph of current (I) or e.m.f (e) against ωt is a sine curve which is as shown in fig. (b).

$\theta = \omega t$	0	$\frac{\pi}{2}$	π	$\frac{3\pi}{2}$	2π
$e = e_0 \sin \omega t$	0	e_0	0	$-e_0$	0
$I = I_0 \sin \omega t$	0	I_0	0	$-I_0$	0

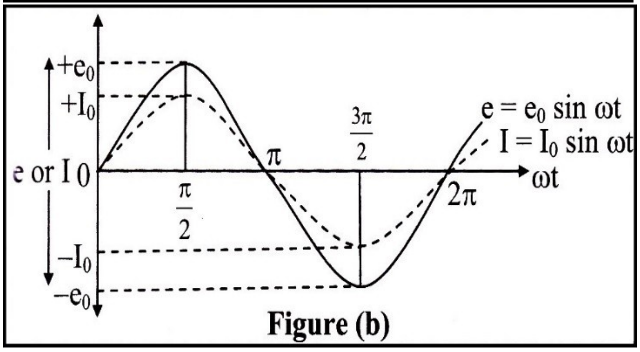
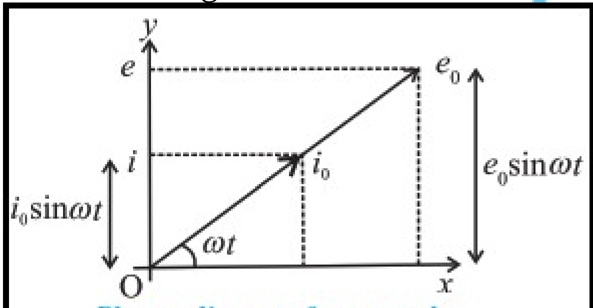


Figure (b)

9. **Phasor diagram:**
   In the AC circuit containing R only, current and voltage are in the same phase, hence both phasors for I and for e are in the same direction making an angle ωt with OX.
10. Their projections on vertical axis give their instantaneous values.
11. The phase angle between alternating current and alternating voltage through R is zero as shown in figure.

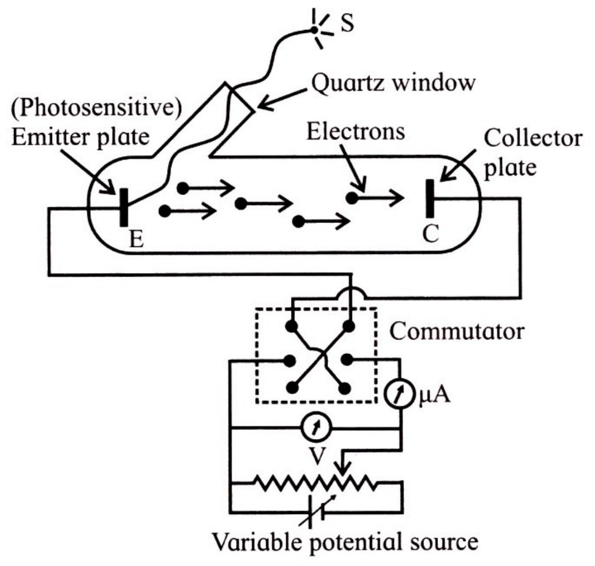


Phasor diagram for a purely resistive circuit

Q.26 With a neat labelled circuit diagram, describe the experiment to study the characteristics of photoelectric effect. **(3)**

Ans:

1. A typical laboratory experimental set-up for the photoelectric effect consists of an evacuated glass tube with a quartz window.
2. The glass tube contains photosensitive metal plates. One is the emitter E and another plate is the collector C.
3. The emitter and collector are connected to a voltage source whose voltage can be changed and to an ammeter to measure the current in the circuit.
4. A potential difference of V, as measured by the voltmeter, is maintained between the emitter E and collector C. Generally, C (the anode) is at a positive potential with respect to the emitter E (the cathode). This potential difference can be varied and C can even be at negative potential with respect to E.



Schematic of experimental set-up for photoelectric effect

5. When the anode potential (V) is positive, it accelerates the electrons. This potential is called accelerating potential. When the anode potential (V) is negative, it retards the flow of electrons. This potential is known as retarding potential.
6. A source S of monochromatic light of sufficiently high frequency (short wavelength $\leq 10^{-7}$ m) is used.

SECTION-D

Attempt any three of the following question: **[12]**

Q.27 Define period of conical pendulum and obtain an expression for its period. **(4)**

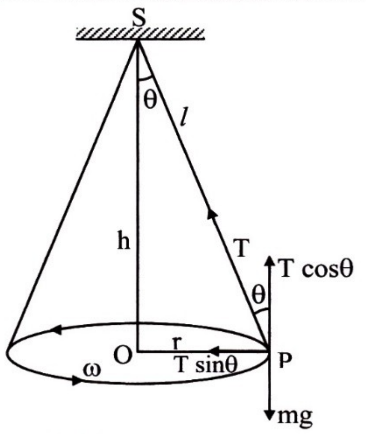
Ans:

Time taken by the bob of a conical pendulum to complete one horizontal circle is called time period of conical pendulum.

Expression for time period of conical pendulum:

$\because v = \sqrt{rg\tan\theta}$

$\therefore \omega = \sqrt{\frac{g\tan\theta}{r}}$ $[\because v = r\omega]$ .... (1)



S : rigid support
T : tension in the string
l : length of string
h : height of support from bob
v : velocity of bob
r : radius of horizontal circle
θ : semi vertical angle
mg : weight of bob

1. In ΔSOP, $\tan\theta = \frac{r}{h}$

   From equation (1),

   $\omega = \sqrt{\frac{gr}{rh}}$

   $\therefore \omega = \sqrt{\frac{g}{h}}$

2. If the period of conical pendulum is T then,

   $\omega = \frac{2\pi}{T}$

   $\therefore \frac{2\pi}{T} = \sqrt{\frac{g}{h}}$

   $\therefore T = 2\pi\sqrt{\frac{h}{g}}$ .... (2)

3. Also, in ΔSOP,

   $\cos\theta = \frac{h}{l}$

   $\therefore h = l\cos\theta$

   Substituting h in equation (2), we get,

   $T = 2\pi\sqrt{\frac{l\cos\theta}{g}}$

   This is required expression for time period of conical pendulum.

Q.28 Define surface tension. State its units and dimensions. How much work is required to form a bubble of 2 cm radius from the soap solution having surface tension 0.07N/m. **(4)**

Ans:

Surface Tension: It is define as force acting per unit length on the imaginary line drawn on the free surface of a liquid in equilibrium. The force due to surface tension acts tangential to the upper surface of liquid or perpendicular to the imaginary line.

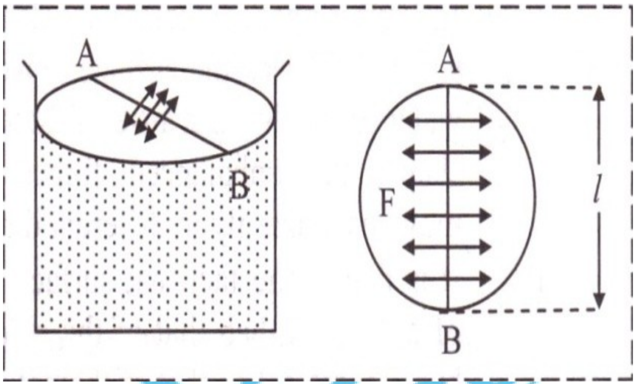
If 'F' is the force acting on the imaginary line of length '*l*' then surface tension 'T' is given by,

$T=\frac{F}{l}$

Explanation:

1. Consider a free surface of liquid in a beaker which acts like a stretched membrane. All the molecules on the surface experience a stretching force.

2. Imagine a straight-line AB drawn on the free surface of the liquid. Molecules of liquid along this line will be acted upon by a force F on each side due to surface tension. This force per unit length of the line AB measures surface tension.
3. The direction of surface tension is perpendicular to AB and tangential to liquid surface.
4. **Unit:** N/m or J/m^2 in SI system and dyne/cm or erg/cm^2 in CGS system. 1N/m ¿10^3 dyne/cm.
5. **Dimensions:** $\left[M^1L^0T^{-2}\right]$



$T=0.07\,N/m\,, r=2\,cm=2\times10^{-2}m$

$W=?$

$W=T\times(dA)$

¿$T\times\left(4\pi r^2\right)$

¿$0.07\times2\left(4\pi\times4\times10^{-4}\right)$

¿$7\times32\pi\times10^{-6}$

¿$7.038\times10^{-4}J$

Q.29 Explain on the basis of kinetic theory of gases, how the pressure of the gas changes if its volume is reduced at constant temperature.
At what temperature will nitrogen molecules have same R.M.S. speed as oxygen molecules at 400 K (molecular weight of oxygen = 32, molecular weight of nitrogen = 28) (4)

Ans:

a)

From kinetic theory of gas

$P=\frac{1}{3}\frac{N}{V}m\overline{v^2}$

$P=\frac{2}{3}\frac{N}{V}\left(\frac{1}{2}m\overline{v^2}\right)$

Where,

$\frac{1}{2}m\overline{v^2}=K.E.=$¿ Constant for all the gases at a given temperature

$N=$¿ Number of molecules which is constant for a given mass of the gas.

$P=\frac{Constant}{V}$

$P\propto\frac{1}{V}$

b)

$Data: Molecular\ weigh\,of\ O_2=M_0=32\,, Molecular\ weight\ of\ N_2=M_N=28\,,$

$Temp.\,of\ O_2 molecules\left(T_1\right)=400\,K\,, Temprature\ of\ nitrogen\left(T_2\right)=?$

$\overline{V}_{Rms} = \sqrt{\frac{3RT}{T}}$

$\therefore R.M.S. \, speed \, for \, O_2 = \overline{V}_0 = \sqrt{\frac{3RT}{M_{\circ}}}$

$\therefore R.M.S. \, speed \, for \, N_2 = V_N = \sqrt{\frac{3RT_2}{M_N}}$

But it is given that, $\overline{V}_0 = \overline{V}_N$

$\sqrt{\frac{3RT_1}{M_0} = ¿\sqrt{\frac{3RT_2}{M_N}} ¿}$

$\therefore \frac{T_1}{M_0} = \frac{T_2}{M_N}$

$\therefore T_2 = \frac{M_N}{M_O} \times T_1$

$\therefore T_2 = \frac{28}{32} \times 400$

$\therefore T_2 = 350\,K$

Q.30 What do you mean by energy level diagram for hydrogen atom? Determine the series limit of Balmer given the series limit for Lyman series is 912 $\dot{A}$. (4)

Ans:

a) The origin of spectral lines in hydrogen spectrum can be represented by energy level diagram. The energy level come closer as *n*(principal quantum number) increases and their energy reaches a limiting value of zero as *n* goes to infinity.

b) $\lambda_{SL} = 912\,Å = 0.912 \times 10^{-7}\,m$

Condition for series limit for Lyman series is

$n = 1, m = \infty$

$\frac{1}{\lambda_{SL}} = R_H \left(\frac{1}{4} - \frac{1}{\infty^2} \right)$

$\therefore \frac{1}{\lambda_{SL}} = R_H$

Condition for series limit for Balmer series

$n = 2, m = \infty$

$\frac{1}{\lambda_{SB}} = R_H \left(\frac{1}{4} - \frac{1}{\infty^2} \right) = \frac{R_H}{4}$

Dividing (1) by (2)

$\therefore \frac{\lambda_{SB}}{\lambda_{SL}} = 4$

$\therefore \lambda_{SB} = 4\,\lambda_{SL}$

$¿ 4 \times 0.912 \times 10^{-7} = 3.648 \times 10^{-7}\,m$

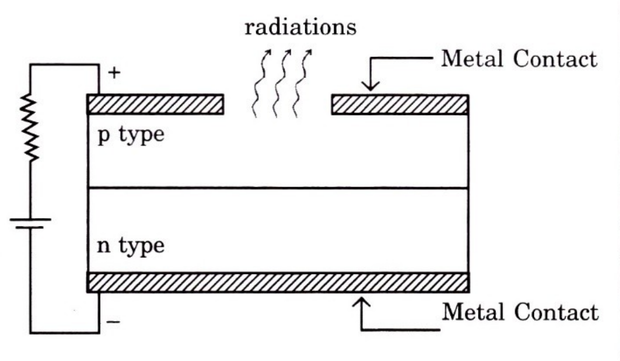
$¿ 3648\,Å$

$\therefore \lambda_{SB} = 3648\,Å$

Q.31 What is LED? With neat diagram, explain the construction of a LED. State any four applications of LED. (4)

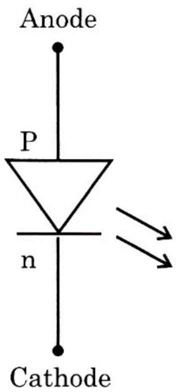
Ans:

a)
Principle: *In any p – n junction diode when electrons are combined with holes, energy in form of light is released.*
Construction:



LED

In LED the upper layer is p type semiconductor and deposited on lower n type layer by diffusion.
The metal electrodes are fixed at the outer edges of p type such that to provide more central area for light to escape.
Metal electrode is also fixed to n type.



Schematic symbol of LED

b)
1. LEDs are used as status indicators on various instruments.
2. Used in advertising boards, rolling displays, in offices, banks, railway station and airports.
3. Used in traffic control light system.
4. They are used in burglar alarm.
5. They are used in optical fiber communication.
6. They are used in FAX machines.
7. They are used in visual displays by arranging LEDs in seven segments.
8. Used in optical mousses in computers.
9. Infrared LEDs are used for remote control in T.V sets.

"All the Best"

"You don't get,

what you wish for.
You get what you work for."