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MAHARASHTRA HSC SOLVED PAPER 2018

CLASS 12

PHYSICS

Published by :
OSWAAL BOOKS
"Oswaal House" 1/11, Sahitya Kunj, M.G. Road, AGRA-282002
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LATEST SYLLABUS

1. **Circular motion**

   Angular displacement, Angular velocity and angular acceleration, Relation between linear velocity and angular velocity, Uniform circular motion, Radial acceleration, Centripetal and centrifugal forces, Banking of roads, Vertical circular motion due to earth's gravitation, Equation for velocity and energy at different positions of vertical circular motion. Kinematical equations for circular motion in analogy with linear motion.

2. **Gravitation**

   Newton's law of gravitation, Projection of satellite, Periodic time, Statement of Kepler's laws of motion, Binding energy and escape velocity of a satellite, Weightlessness condition in orbit, Variation of 'g' due to altitude, lattitude, depth and motion, Communication satellite and its uses.

3. **Rotational motion**

   Definition of M.I., K.E. of rotating body, Rolling motion, Physical significance of M.I., Radius of gyration, Torque, Principle of parallel and perpendicular axes, M.I. of some regular shaped bodies about specific axes, Angular momentum and its conservation.

4. **Oscillations**

   Explanation of periodic motion, S.H.M., Differential equation of linear S.H.M. Projection of U.C.M. on any diameter, Phase of S.H.M., K.E. and P.E. in S.H.M., Composition of two S.H.M.'s having same period and along same line, Simple pendulum, Damped S.H.M.

5. **Elasticity**

   General explanation of elastic property, Plasticity, Deformation, Definition of stress and strain, Hooke's law, Poisson's ratio, Elastic energy, Elastic constants and their relation, Determination of 'Y', Behaviour of metal wire under increasing load, Applications of elastic behaviour of materials.

6. **Surface tension**

   Surface tension on the basis of molecular theory, Surface energy, Surface tension, Angle of contact, Capillarity and capillary action, Effect of impurity and temperature on surface tension.

7. **Wave motion**

   Simple harmonic progressive waves, Reflection of transverse and longitudinal waves, Change of phase, Superposition of waves, Formation of beats, Doppler effect in sound.

8. **Stationary waves**

   Study of vibrations in a finite medium, Formation of stationary waves on string, Study of vibrations of air columns, Free and Forced vibrations, Resonance.

9. **Kinetic theory of gases and Radiation**

   Concept of an ideal gas, Assumptions of kinetic theory, Mean free path, Derivation for pressure of a gas, Degrees of freedom, Derivation of Boyle's law, Thermodynamics- Thermal equilibrium and definition of temperature, 1st law of thermodynamics, 2nd law of thermodynamics, Heat engines and refrigerators, Qualitative idea of black body radiation,Wein's displacement law, Green house effect, Stefan's law, Maxwell distribution, Law of equipartition of energy and application to Specific heat capacities of gases.

10. **Wave theory of light**

    Wave theory of light, Huygens' Principle, Construction of plane and spherical wave front, Wave front and wave normal, Reflection at plane surface, Refraction at plane surface, Polarisation, Polaroids, Plane polarised light, Brewster's law, Doppler effect in light.

11. **Interference and diffraction**

    Interference of light, Conditions for producing steady interference pattern, Young's experiment, Analytical treatment of interference bands, Measurement of wavelength by biprism experiment, Diffraction due to single slit, Rayleigh's criterion, Resolving power of a microscope and telescope, Difference between interference and diffraction.

...Contd.

12. Electrostatics

Gauss' theorem proof and applications, Mechanical force on unit area of a charged conductor, Energy density of a medium, Dielectrics and electric polarisation, Concept of condenser, Capacity of parallel plate condenser, Effect of dielectric on capacity, Energy of charged condenser, Condensers in series and parallel, van-de- Graaff generator.

13. Current electricity

Kirchhoff's law, Wheatstone's bridge, Meter bridge, Potentiometer.

14. Magnetic effects of electric current

Ampere's law and its applications, Moving coil galvanometer, Ammeter, Voltmeter, Sensitivity of moving coil galvanometer, Cyclotron.

15. Magnetism

Circular current loop as a magnetic dipole, Magnetic dipole moment of revolving electron, Magnetisation and magnetic intensity, Diamagnetism, Paramagnetism, Ferromagnetism on the basis of domain theory, Curie temperature.

16. Electromagnetic inductions

Laws of electromagnetic induction, proof of, Eddy currents, Self induction and mutual induction,

Need for displacement current, Transformer, Coil rotating in uniform magnetic induction, Alternating currents, Reactance and impedance, LC oscillations (qualitative treatment only) Power in a.c circuit with resistance, inductance and capacitance, Resonant circuit, Wattless current, AC generator.

17. Electrons and photons

Photoelectric effect, Hertz and Lenard's observations, Einstein's equation, Particle nature of light.

18. Atoms, Molecules and Nuclei

Alpha particle scattering experiment, Rutherford's model of atom. Bohr's model, Hydrogen spectrum, Composition and size of nucleus, Radioactivity, Decay law, massenergy relation, mass defect, B.E. per nucleon and its variation with mass number, Nuclear fission and fusion, de Broglie hypothesis, Matter waves – wave nature of particles, Wavelength of an electron, Davisson and Germer experiment, Continuous and characteristics X-rays.

19. Semiconductors

Energy bands in solids, Intrinsic and extrinsic semiconductors, P-type and Ntype semiconductor, P-N junction diode, I-V characteristics in forward and reverse bias, Rectifiers, Zener diode as a voltage regulator, Photodiode, Solar cell, I-V characteristics of LED, Transistor action and its characteristics, Transistor as an amplifier (CE mode), Transistor as a switch, Oscillators and Logic gates (OR, AND, NOT, NAND, NOR)

20. Communication systems

Elements of communication system, bandwidth of signals, bandwidth of transmission medium, Need for modulation, Production and detection of an amplitude modulated wave, space communication, Propagation of electromagnetic waves in atmosphere.

List of Practicals

1. To determine Young's modulus of elasticity of the material of a given wire.
2. To find the force constant and effective mass of helical spring by plotting T^2--m graph using method of oscillations.
3. To determine the surface tension of water by capillary rise method.
4. To study the relationship between the temperature of a hot body and time by plotting a cooling curve.
5. To study the relation between frequency and length of a given wire under constant tension using sonometer.
6. To study the relation between the length of a given wire and tension for constant frequency using sonometer.

...Contd.

7. To find the speed of sound in air at room temperature using a resonance tube.
8. To find resistance of given wire using metre bridge and hence determine the specific resistance of its material.
9. To verify the laws of combination (series/ parallel) of resistances using a metre bridge.
10. To compare the emf of two given cells using potentiometer.
11. To determine the internal resistance of given cell using potentiometer.
12. To determine resistance of galvanometer using metre bridge.
13. To draw the I-V characteristic curves of a p-n junction diode in forward bias and reverse bias.
14. To study the characteristics of a commonemitter npn or pnp transistor and to find out the values of current and voltage gains.
15. To draw the characteristic curve of a zener diode and to determine its reverse break down voltage.

List of Activities

1. To study dissipation of energy of a simple pendulum by plotting a graph between square of amplitude and time.
2. To study the effect of detergent on surface tension by observing capillary rise.
3. To study the factors affecting the rate of loss of heat of a liquid.
4. To study the effect of load on depression of a suitably clamped meter scale loaded
   (i) at its end (ii) in the middle.
5. To measure the resistance and impedance of an inductor with or without iron core.
6. To study the variation in potential drop with length of a wire for a steady current.
7. To draw the diagram of a given open circuit comprising at least a battery, resistor/ rheostat, key, ammeter and voltmeter. Mark the components that are not connected in proper order and correct the circuit and also the circuit diagram.
8. To study effect of intensity of light (by varying distance of the source) on an L.D.R.
9. To identify a diode, an LED, a transistor, and 1C, a resistor and a capacitor from mixed collection of such items.
10. Use of multimeter to
    (i) identify base of transistor
    (ii) distinguish between npn and pnp type transistors,
    (iii) see the unidirectional flow of current in case of a diode and an LED
    (iv) check whether a given electronic component (e.g. diode, transistor or IC) is in working order.
11. To observe polarization of light using two polaroids.
12. To assemble a household circuit comprising three bulbs, three (on/off) switches, a fuse and a power source.

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Solved Paper | Maharashtra HSC Exam February 2018 Set No. J - 236 | Physics

Time : 3 Hours **Max. Marks : 70**

Note :

(i) All questions are compulsory.
(ii) Neat diagrams must be drawn wherever necessary.
(iii) Figures to the right indicate full marks.
(iv) Use of only logarithmic tables is allowed.
(v) All symbols have their usual meaning unless otherwise stated.
(vi) Answers to both sections must be written in the same answer book.
(vii) Answer to every question must be written on a new page.

SECTION-I

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

(i) In stationary wave, the distance between a node and its adjacent antinode is ....

(a) λ (b) $\frac{\lambda}{4}$

(c) $\frac{\lambda}{2}$ (d) 2λ

(ii) If the source is moving away from the observer, then the apparent frequency ....

(a) will increase (b) will remain the same

(c) will be zero (d) will decrease

(iii) A particle of mass *m* performs vertical motion in a circle of radius r. Its potential energy at the highest point is ....

(a) 2 mgr (b) mgr

(c) 0 (d) 3 mgr

(iv) The compressibility of a substance is the reciprocal of ....

(a) Young's modulus (b) bulk modulus

(c) modulus of rigidity (d) Poisson's ratio

(v) If the particle starts its motion from mean position, the phase difference between displacement and acceleration is ....

(a) 2π rad (b) $\frac{\pi}{2}$ rad

(c) π rad (d) $\frac{\pi}{4}$ rad

(vi) The kinetic energy per molecule of a gas at temperature T is ....

(a) $\left(\frac{3}{2}\right)RT$ (b) $\left(\frac{3}{2}\right)K_BT$

(c) $\left(\frac{2}{3}\right)RT$ (d) $\frac{3}{2}\left(\frac{RT}{M}\right)$

(vii) A thin ring has mass 0.25 kg and radius 0.5 m. Its moment of inertia about an axis passing through its centre and perpendicular to its plane is ....

(a) 0.0625 kg m^2 (b) 0.625 kg m^2

(c) 6.25 kg m^2 (d) 62.5 kg m^2

2. Attempt Any SIX : **[12]**

(i) State Kepler's law of orbit and law of equal areas.

(ii) State any 'four' assumptions of kinetic theory of gases.

(iii) Define moment of inertia. State its SI unit and dimensions.

(iv) Distinguish between centripetal and centrifugal force.

(v) In Melde's experiment, when tension in the string is 10 g wt then three loops are obtained. Determine the tension in the string required to obtain four loops, if all other conditions are constant.

(vi) Calculate the work done in increasing the radius of a soap bubble in air from 1 cm to 2 cm. The surface tension of soap solution is 30 dyne/cm. ($\pi = 3.142$)

(vii) A flat curve on a highway has a radius of curvature 400 m. A car goes around a curve at a speed of 32 m/s. What is the minimum value of coefficient of friction that will prevent the car from sliding ? ($g = 9.8\ m/s^2$)

(viii) A particle performing linear S.H.M. has maximum velocity of 25 cm/s and maximum acceleration of 100 cm/s^2. Find the amplitude and period of oscillation. ($\pi = 3.142$)

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

(i) Derive Laplace's law for a spherical membrane.

(ii) State and prove principle of conservation of angular momentum.

(iii) Calculate the strain energy per unit volume in a brass wire of length 3 m and area of cross-section 0.6 mm^2 when it is stretched by 3 mm and a force of 6 kg wt is applied to its free end.

(iv) What is the decrease in weight of a body of mass 500 Kg when it is taken into a mine of depth 1000 Km ?
(Radius of earth R = 6400 km, $g = 9.8\ m/s^2$)

4. State the differential equation of linear simple harmonic motion. Hence obtain the expression for acceleration, velocity and displacement of a particle performing linear S.H.M.

A body cools from 80°C to 70°C in 5 minutes and to 62°C in the next 5 minutes. Calculate the temperature of the surroundings.

OR

What is meant by harmonics ? Show that only odd harmonics are present as overtones in the case of an air column vibrating in a pipe closed at one end.

The wavelengths of two sound waves in air are $\frac{81}{173}$ m and $\frac{81}{170}$ m. They produce 10 beats per second. Calculate the velocity of sound in air. **[7]**

SECTION-II

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

(i) The reflected waves from an ionosphere are ....

(a) ground waves (b) sky waves
(c) space wave (d) very high frequency waves

(ii) In interference pattern, using two coherent sources of light; the fringe width is ....

(a) directly proportional to wavelength. (b) inversely proportional to square of the wavelength
(c) inversely proportional to wavelength. (d) directly proportional to square of the wavelength.

(iii) Electric intensity outside a charged cylinder having the charge per unit length 'λ' at a distance r from its axis is ....

(a) $E = \frac{2\pi \epsilon_0 \lambda}{Kr^2}$ (b) $E = \frac{\epsilon_0 \lambda}{2\pi Kr^2}$

(c) $E = \frac{\lambda}{2\pi \epsilon_0 Kr}$ (d) $E = \frac{4\pi \epsilon_0 \lambda}{Kr^2}$

(iv) SI unit of potential gradient is ....

(a) V cm (b) $\frac{V}{cm}$

(c) V m (d) $\frac{V}{m}$

(v) The momentum associate with photon is given by ....

(a) hυ (b) $\frac{h\upsilon}{c}$

(c) hE (d) $h\lambda$

(vi) A pure semiconductor is ....

(a) an extrinsic semiconductor (b) an intrinsic semiconductor
(c) p-type semiconductor (d) n-type semiconductor

(vii) Glass plate of refractive index 1.732 is to be used as a polariser, its polarising angle is ....
(a) 30° (b) 45°
(c) 60° (d) 90°

6. Attempt any SIX : **[12]**

(i) State the conditions to get constructive and destructive interference of light.

(ii) State and explain Ampere's circuital law.

(iii) Draw a neat and labelled block diagram of a receiver.

(iv) Define magnetization. Write its SI unit and dimensions.

(v) The electron in the hydrogen atom is moving with a speed of 2.3×10^6 m/s in an orbit of radius 0.53 Å. Calculate the period of revolution of electron. ($\pi = 3.142$)

(vi) A capacitor of capacitance 0.5 μF is connected to a source of alternating e.m.f. of frequency 100 Hz. What is the capacitive reactance ? ($\pi = 3.142$)

(vii) Calculate the de-Broglie wavelength of an electron moving with one fifth of the speed of light Neglect relativistic effect. ($h = 6.63 \times 10^{-32}$ J.s., $c = 3 \times 10^8$ m/s, mass of electron $= 9 \times 10^{-31}$ kg)

(viii) In a cyclotron, magnetic field of 1.4 Wb/m^2 is used. To accelerate protons, how rapidly should the electric field between the Dees be reversed ?
($\pi = 3.142$. M$p = 1.67 \times 10^{-27}$ kg, $e = 1.6 \times 10^{-19}$ C)

7. Attempt any THREE : **[9]**

(i) Explain with a neat circuit diagram how will you determine unknown resistance 'X' by using meter bridge.

(ii) What is Zener diode ? How is it used as a voltage regulator ?

(iii) In a biprism experiment, light of wavelength 5200Å is used to get an interference pattern on the screen. The fringe width changes by 1.3 mm when the screen is moved towards biprism by 50 cm. Find the distance between two virtual images of the slit.

(iv) The refractive indices of water and diamond are $\frac{4}{3}$ and 2.42 respectively. Find the speed of light in water and diamond. ($c = 3 \times 10^8$ m/s)

8. Prove theoretically the relation between e.m.f induced in a coil and rate of change of magnetic flux in electromagnetic induction. A parallel plate air condenser has a capacity of 20 μF. What will be the new capacity if :

(a) the distance between the two plates is doubled ?

(b) a marble slab of dielectric constant 8 is introduced between the two plates ?

OR

Draw a neat and labelled energy level diagram and explain Balmer series and Brackett series of spectral lines for hydrogen atom. The work function for a metal surface is 2.2eV. If light of wavelength 5000Å is incident on the surface of the metal, find the threshold frequency and incident frequency. Will there be an emission of photoelectrons or not ?
($c = 3 \times 10^8$ m/s, 1 eV$= 1.6 \times 10^{-19}$ J, $h = 6.63 \times 10^{-34}$ J.s.)

■■

Solutions

SECTION-I

1. (i) (b) $\frac{\lambda}{4}$

(ii) (d) will decrease

(iii) (a) 2mgr

(iv) (b) bulk modulus

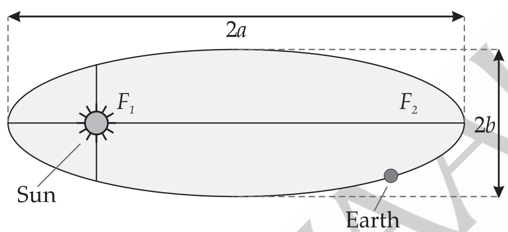
(v) (c) π radians

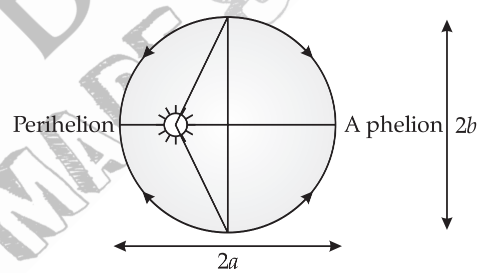
(vi) (b) $\left(\frac{3}{2}\right)K_BT$

(vii) (a) 0.0625 kg m^2

2. (i) **Kepler's Law of orbit**

Kepler's law of orbit states that all planets move in elliptical orbits with the sun situated at one of the foci of the ellipse. This law implies that the distance between the sun and the earth keeps on changing as the earth goes around its orbit.



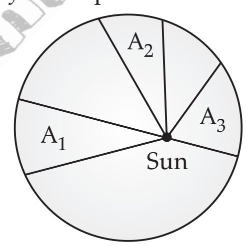


Where 'a' is the length of semi-major axis and 'b' the length of semi-minor axis.

Kepler's Law of equal areas

Kepler's Law of equal areas state that the speed of a planet varies in such a way that the radius vector drawn from the sun to a planet sweeps out equal areas in equal interval of time.

This law implies that the areal velocity of the planet around the sun remains constant.



$A_1 = A_2 = A_3$

(ii) The four assumptions of kinetic theory of gases are :

(a) A gas consists of large number of molecules which are perfectly elastic spheres and are identical in all respects for a given gas and are different for different gases.

(b) The molecules of a gas are in continuous, rapid and random motion.

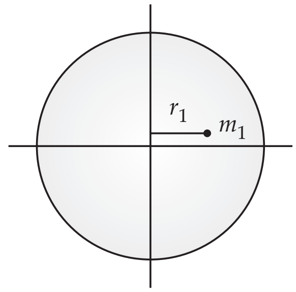
(c) The volume occupied by the molecules is negligible in comparison to the volume of the gas.

(d) The molecules do not exert any force of attraction or repulsion on each other, except during collision.

(iii) Moment of Inertia is the property of a body by virtue of which it opposes the torque tending to change its state of rest or uniform relation about an axis. Moment of Inertia is also defined as the sum of the products of the masses of the particles constituting the rigid body and the square of their respective distances from the axis of rotation.

$$I = \sum_{i=1}^{n} m_i r_i^2$$

where m_i is the mass of i^{th} particle and r_i its distance from axis of rotation



Axis of Rotation

S.I. unit of Moment of Inertia – Kg m^2.

Dimensions = ML^2

(iv)

S. No.	Centripetal Force	Centrifugal force
(i)	This force is required to provide the centripetal acceleration to a particle when moving on a circular path.	This tendency of the particle in its accelerated non-inertial frame of reference, is explained by centrifugal force.
(ii)	It is directed radially towards the centre of the circular path.	It is directed radially away from the centre of the circular path.

(v) In Melde's experiment

$$\frac{p_1^2}{p_2^2} = \frac{T_1}{T_2}$$

Where T_1 and T_2 are tensions and p_1 and p_2 are number of loops formed in the string.

Given

$$p_1 = 3 \text{ (loops)}$$
$$T_1 = 10 \text{ g wt}$$
$$T_2 = ?$$
$$p_2 = 4$$
$$\frac{9}{16} = \frac{T_2}{T_1} = \frac{T_2}{10}$$

$$\Rightarrow \quad T_2 = \frac{9}{16} \times 10 = \frac{45}{8} = 5.625 \text{ gm wt}$$

(vi) Work done = (Increase in the surface area of bubble) × Surface Tension

$r_1 = 1$ cm, $r_2 = 2$ cm, S = 30 dynes/cm

$$\text{Increase in surface area} = 2 \times 4\pi (r_2^2 - r_1^2)$$
$$= 2 \times 4\pi [(2)^2 - (1)^2]$$
$$= 2 \times 4\pi \times [4 - 1]$$
$$= 2 \times 4\pi \times 3 = 24\pi \text{ cm}^2$$

$$\therefore \quad \text{Work done} = 24\pi \times 30$$
$$= 720\pi \text{ ergs.} = 720 \times 3.142 \text{ ergs.}$$
$$= 5404.2 \text{ ergs.}$$

(vii)
$$\mu N = \frac{mv^2}{R}$$

Where, R = radius of curvature of highway

v = velocity with which the car is moving

μ = coefficient of friction

N = Normal reaction of weight

$$\frac{mv^2}{R} = \mu mg$$

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$$\frac{v^2}{R} = \mu g$$

$$\Rightarrow \quad \mu = \frac{v^2}{Rg} = \frac{(32)^2}{400 \times 9.8}$$

$$= \frac{1024}{3920} = 0.261$$

(viii) In S.H.M, the velocity is given as

Velocity, $v = A\,w \cos wt$, where w is angular frequency and A is amplitude

Maximum velocity $v_m = A\,w$ $[\because \cos wt = 1]$

Acceleration $= -A\,w^2 \sin wt$

Maximum acceleration $a_m = |-A\,w^2| = Aw^2$ $(\because \sin w^2 t = 1)$

Given $a_m = 100 \text{ cm/s}^2, v_m = 25 \text{ cm/s}$

or $Aw = 25$ ...(i)

$Aw^2 = 100$ ...(ii)

Dividing (ii) by (i) $\dfrac{Aw^2}{Aw} = \dfrac{100}{25}$

$w = 4$

Time period, $T = \dfrac{2\pi}{w}$

$= \dfrac{2 \times 3.14}{4}$

$T = 1.57$ sec

3. (i) Consider a spherical liquid drop and let the outside pressure be P_o and inside pressure be P_i such that the excess pressure is $P_i - P_o$ = OP.

Let the radius of the drop increase from r to $r + \Delta r$, where Δr is very small, such that the pressure inside the drop remains constant.

Initial surface Area $A_1 = 4\pi r^2$

So Final surface Area $A_2 = 4\pi(r + \Delta r)^2$

$= 4\pi(r^2 + \Delta r^2 + 2r\,\Delta r)$

$= 4\pi r^2 + 4\pi(\Delta r)^2 + 8\pi r \Delta r$

Δr being very small, so Δr^2 is neglected

$\therefore$ Increase in surface area $dA = A_2 - A_1$

$= 4\pi r^2 + 8\pi r \Delta r - 4\pi r^2$

$= -8\pi r \Delta r$

$\therefore$ Work done due to increase in surface area dA will be the extra energy.

i.e., $dw = TA$

or $dw = T.\,8\pi r \Delta r$ ... (i)

Again $dw = dF\,\Delta r = (P_i - P_o)\,4\pi r^2.\Delta r$ ... (ii) $[\because dF = \Delta P.A = (P_i - P_o).4\pi r^2]$

or From (i) & (ii), we get $(P_i - P_o)\,4\pi r^2\,\Delta r = T.8\pi r \Delta r$

$P_i - P_o = \dfrac{2T}{r}$ which is Laplace's Law of spherical membrane

(ii) If the resultant external torque acting on a body is zero, then, the angular momentum of a body remains constant.

Proof : Torque acting on the body,

$$\vec{\tau} = \frac{d\vec{J}}{dt} \qquad (\vec{J} = \text{angular momentum})$$

If the external torque is zero *i.e.*, $\vec{\tau} = 0$

$$\Rightarrow \qquad \frac{d\vec{J}}{dt} = 0$$

$\Rightarrow$ Angular moment of a body $\vec{J}$ = constant

(iii) Strain energy per unit volume $= \frac{1}{2}$ stress $\times$ strain

$$\text{Length} = 3 \text{ m},$$
$$\text{Area of cross–section} = 0.6 \text{ mm}^2$$
$$= 0.6 \times 10^{-6} \text{ m}^2$$
$$\Delta L = 3 \text{ mm} = 3 \times 10^{-3} \text{ m}$$
$$F = 6 \text{ kg wt} = 6 \times 9.81 \text{ N} = 58.86 \text{ N}$$
$$\text{Stress} = \frac{F}{A} = \frac{58.86}{0.6\times10^{-6}} \text{ N/m}^2$$
$$= 98.1 \times 10^6 \text{ N/m}^2$$
$$\text{Strain} = \frac{\Delta L}{L} = \frac{3\times10^{-3}}{3} = 10^{-3}$$

$\therefore$
$$\text{Strain energy per unit volume} = \frac{1}{2} \times 98.1 \times 10^6 \times 10^{-3}$$
$$= 49.05 \times 10^3 \text{ N/m}^2$$

(iv) $g(d) = g\left[1-\frac{d}{R}\right]$,

Where $g(d)$ is the acceleration due to gravity at depth d.

g is the acceleration due to gravity on Earth

R is the radius of the earth

Given : $g = 9.8 \text{ m/s}^2$

$d = 1000$ km

$R = 6400$ km

$$g(d) = 9.8\left[1-\frac{1000}{6400000}\right]$$
$$= 9.8[1 - 0.00015625]$$
$$= 9.8[0.99984375]$$
$$= 9.798 \text{ m/s}^2$$
$$\text{Decrease in weight} = mg - mg(d)$$
$$= 500\,[9.8 - 9.798] \text{ kg wt}$$
$$= [500]\,[0.002] = 1 \text{ kg wt}$$

4. (a) Differential equation of linear S.H.M

$$\frac{d^2\vec{x}}{dt^2} + \frac{k\vec{x}}{m} = 0$$

Where

m = mass of particle

$\vec{x}$ = displacement

k = force constant

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$$\frac{d^2\vec{x}}{dt^2} = \text{acceleration of the particle}$$

$$\frac{k}{m} = w^2$$

∴ Acceleration $a = \frac{d^2x}{dt^2} = -w^2x$ ... (1)

velocity $v = \frac{dx}{dt}$ (∵ For S.H.M., F = $ma = -kx$

Again, Acceleration, a $= \frac{dx^2}{dt^2} = \frac{dv}{dt} = \frac{dx}{dt} \cdot \frac{dv}{dx}$ $a = \frac{-k}{m}x = -w^2x$ where $w^2 = \frac{k}{m}$)

$$= v.\frac{dv}{dx} \quad \text{... (2)}$$

∴

$$v.\frac{dv}{dx} = -w^2x$$

$$vdv = -w^2xdx$$

Integrating $\frac{v^2}{2} = \frac{-w^2x^2}{2} + C$, where C is the constant of integration

At extreme position velocity = 0

i.e., at $x = \pm$ A, $v = 0$

∴ $0 = \frac{-w^2A^2}{2} + C \Rightarrow C = \frac{w^2A^2}{2}$

∴

$$\frac{v^2}{2} = \frac{w^2A^2}{2} - \frac{w^2x^2}{2}$$

$$v^2 = w^2(A^2 - x^2)$$

$$v = \pm w\sqrt{A^2 - x^2}$$

Again $v = \frac{dx}{dt}$

$$dx = vdt$$

$$dx = w\sqrt{A^2 - x^2}\,dt$$

$$\frac{dx}{\sqrt{A^2 - x^2}} = wdt$$

Integrating again $\sin^{-1}\frac{x}{A} = wt + \phi_1$ (ϕ is integration constant)

or $\frac{x}{A} = \sin(wt + \phi)$

or $x = A\sin(wt + \phi)$

A is the amplitude of oscillations and ϕ is the initial phase.

If $x = 0$ at $t = 0$ then $\sin\phi = 0$ or $\phi = 0$

∴ $x = A\sin wt$

(b) Average Temperature, $T_1 = \frac{80 + 70}{2} = 75°C$

Average Temperature, $T_2 = \frac{70 + 62}{2} = 66°C$

We know, that $$\frac{dT}{dt} = -k(T - T_0)$$

Where, T is average temperature

T_0 is surrounding temperature

$$\frac{10}{5} = -k(75 - T_0) \quad ...(1)$$

$$\frac{8}{5} = -k(66 - T_0) \quad ...(2)$$

Dividing (1) & (2)

$$\frac{10}{8} = \frac{75 - T_0}{66 - T_0}$$

$$T_0 = 30°C$$

OR

(a) A stretched string of a given length, fixed at both ends has many frequencies at the resonant. These frequencies of vibration are called harmonics.

The lowest possible natural frequency or the mode of vibration in which the string will vibrate in one segment is called first harmonic or fundamental mode of vibration

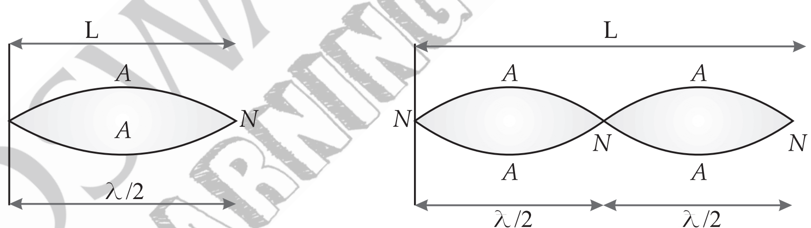
$$\lambda = \frac{2L}{n}, n = 1, 2, 3 \text{ ....} \quad \text{possible wavelengths of stationary wave}$$

Since frequency $\nu = \frac{v}{\lambda}$

$$\nu = \frac{v}{\lambda} = \frac{\lambda v}{2L}, \qquad \nu = \frac{\lambda v}{2L}, n = 1, 2$$

For First Harmonic, $n = 1$

$$\lambda_1 = 2L \text{ or } L = \frac{\lambda_1}{2}, \ \nu_1 = \frac{v}{2L}$$



The mode of vibration in which the string vibration is in two segments is called second harmonic etc.

Closed organ pipe : Let us consider the case of air column vibrating in a pipe closed at one end while open from the other.

A glass tube partially filled with water can be used as an example.

The end in contact with water is a node having maximum pressure change, while the open end is an antinode having least pressure change.

Consider the end in contact with water as $x = 0$, then the other end, $x = L$ is an antinode.

In this case, $$|\sin Kx| = 1$$

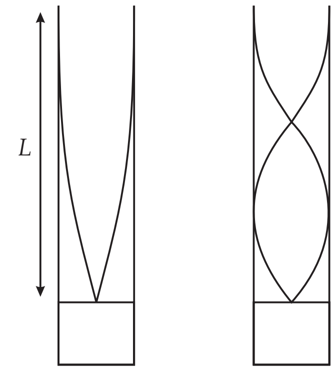
$$|\sin KL| = 1 \text{ (for antinode)}$$

$$KL = \left(n + \frac{1}{2}\right)\pi, \text{ where n} = 0, 1, 2, 3, ...$$

$$L = \left(n + \frac{1}{2}\right)\frac{\pi}{K}, \text{ But } K = \frac{2\pi}{\lambda}$$

$$\therefore \quad L = \left(n + \frac{1}{2}\right)\frac{\pi\lambda}{2\pi}$$

$$L = \frac{\lambda}{2}\left(n+\frac{1}{2}\right) = (2n+1)\frac{\lambda}{4} \text{ or } \lambda = \frac{4L}{(2n+1)}, \text{ where n} = 0, 1, 2, 3, ...$$



1^{st} harmonic $\nu = \frac{v}{\lambda} = \frac{v}{4L}$, $n = 0, 1, 2$ ....

Thus, The fundamental frequency, for $n = 0$ will be $\nu = \frac{v}{4L}$ is called fundamental mode or first harmonics

The second frequency for $n = 1$, $\nu = \frac{v}{4L}(2 \times 1 + 1) = 3\frac{v}{4L}$ is called third harmonics

So higher frequencies are only odd harmonics $\frac{v}{4L}, \frac{3v}{4L}, \frac{5v}{4L}$ etc.

(b) Given $\lambda_1 = \frac{81}{173} = 0.468$ m, $\lambda_2 = \frac{81}{170}$ m $= 0.476$ m,

$\lambda_1 = 0.468$ m, $\lambda_2 = 0.426$ m

No. of beats = 10 per second $= \nu_1 - \nu_2$

Now, $v = \nu\lambda$ or $\nu = \frac{v}{\lambda}$

Since $\lambda_1 < \lambda_2$, $\nu_1 > \nu_2$

$\therefore$

$$\nu_1 - \nu_2 = 10$$

$$\frac{v}{\lambda_1} - \frac{v}{\lambda_2} = 10$$

$$v\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right) = 10$$

$$v\left[\frac{173}{81} - \frac{170}{81}\right] = 10$$

$$v\left[\frac{3}{81}\right] = 10$$

$$v = \frac{10 \times 81}{3} \text{ m/s}$$

$$= 270 \text{ m/s}$$

SECTION-II

5. (i) (b) sky waves.

(ii) (a) directly proportional to wavelength.

(iii) (c) $E = \frac{\lambda}{2\pi \in_0 Kr}$

(iv) (d) V / m

(v) (b) $\frac{h\upsilon}{c}$

(vi) (b) intrinsic semiconductor

(vii) (c) 60°

6. (i) When two waves from coherent sources superimpose nearly equal amplitude and frequency on each other then, they interfere either constructively or destructively.

If the path difference between the waves is an integral multiple of λ then constructive interference takes place and when path difference is an odd integral multiple of $\frac{\lambda}{2}$, then destructive interference takes place.

i.e., Path difference, $\Delta d = n\lambda, n = 0, \pm 1, \pm 2$ .... for constructive interference

$\Delta d = \left(n + \frac{1}{2}\right)\lambda$ for destructive interference

(ii) The line integral of the magnetic field around a closed path is μ_0 times of total current enclosed by the path.

$\oint \vec{B}.\vec{dl} = \mu_0 I$ where $\vec{B}$ is the magnetic field and dl is the small length element

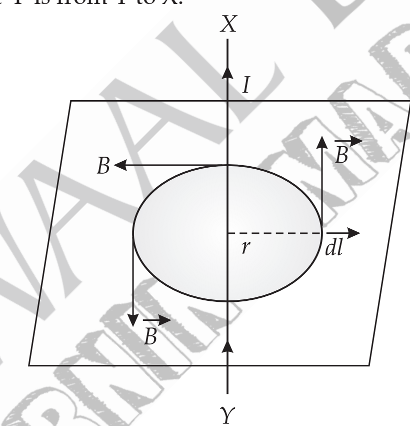
μ_0 is permeability of free space, I is current enclosed by loop.

Explanation :

It is generalised form of Biot-Savart's law which determines magnetic field at any point due to distribution of current.

Consider a long current carrying conductor XY in vacuum (straight current carrying conductor)

The direction of steady current 'I' is from Y to X.



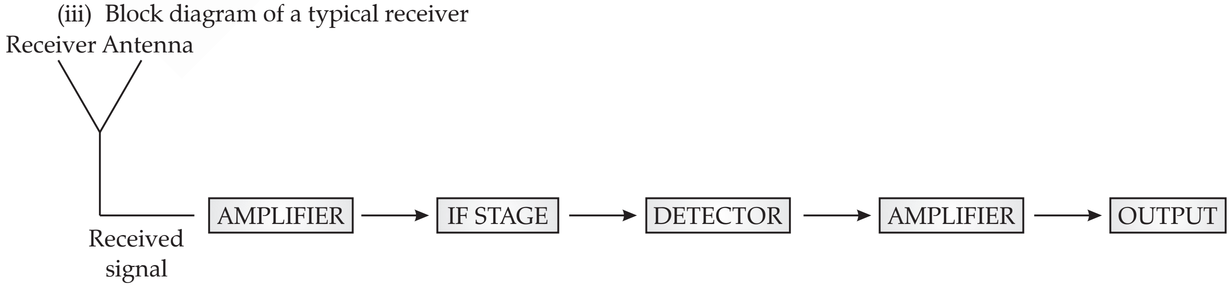
Consider a closed curve with radius r around conductor. Consider a small element of length $\vec{dl}$, which is directed along direction of traced loop.

If $\vec{B}$ be the strength of magnetic field around conductor, then, all scalar product of $\vec{B}$ and $\vec{dl}$ give the product of μ_o and I,

$\therefore$ $$\oint \vec{B}.\vec{dl} = \oint B.dl \cos\theta = \mu_0 I$$

Where θ = angle between $\vec{B}$ and $\vec{dl}$.

(iii) Block diagram of a typical receiver



IF : Intermediate Frequency

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(iv) The Magnetization, $\vec{M}$ of a sample is defined as its net magnetic moment per unit volume.

i.e.,
$$\vec{M} = \frac{\vec{m}_{net}}{V}$$

$\vec{M}$ is a vector with dimensions $L^{-1}A$.

S.I. of magnetization is Am^{-1}.

(v) $r = 0.53$ Å, $v = 2.3 \times 10^6$ m/s

$$\text{Frequency of electron } \nu = \frac{v}{2\pi r}$$

$$\therefore \quad \text{Period of revolution, } T = \frac{1}{\nu} = \frac{2\pi r}{v}$$

$$= \frac{2 \times 3.142 \times 5.3 \times 10^{-11}}{2.3 \times 10^{6}} \text{s}$$

$$= \frac{33.3052}{2.3} \times 10^{-17} \text{s} = 14.48 \times 10^{-17} \text{ s.}$$

(vi)
$$\text{Capacity reactance } X_C = \frac{1}{2\pi fc}$$

$$f = 100 \text{ Hz}$$
$$C = 0.5\ \mu F = 0.5 \times 10^{-6} \text{ F}$$
$$X_C = \frac{1}{2 \times 3.142 \times 100 \times 0.5 \times 10^{-6}}$$
$$= \frac{1}{2 \times 3.142 \times 0.5 \times 10^{-4}}$$
$$= \frac{10^4}{3.142} = 3182.686\ \Omega$$

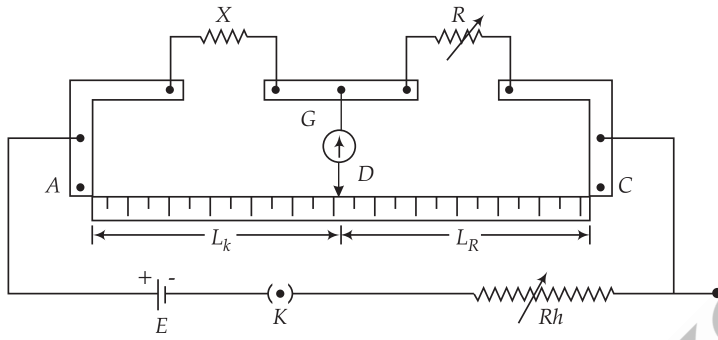
(vii) deBroglie wavelength is given by $\lambda = \frac{h}{p}$, p – momentum, λ – wavelength

$$h = 6.63 \times 10^{-34} \text{ JS.}$$
$$p = mv = 9 \times 10^{-31} \times v$$
$$v = \frac{1}{5} \times 3 \times 10^6 \text{ m/s} = \frac{3}{5} \times 10^8 \text{ m/s}$$
$$\therefore \quad p = 9 \times 10^{-31} \times \frac{3}{5} \times 10^8 \text{ kg m/s}$$
$$= \frac{27}{5} \times 10^{-23} \text{ kg m/s}$$
$$\therefore \text{ Again,} \quad \lambda = \frac{h}{p}, \ \lambda = \frac{6.63 \times 10^{-34}}{27 \times 10^{-23}} \times 5 = \frac{33.15 \times 10^{-11}}{27} = 1.227 \times 10^{-11} \text{ m}$$
$$= 12.27 \text{ Å}$$

(viii) $B = 1.4$ wb/m^2, $m_p = 1.67 \times 10^{-27}$ kg, $e = 1.6 \times 10^{-19}$ C

$$t = \frac{\pi m_p}{Bq_p} = \frac{3.142 \times 1.67 \times 10^{-27}}{1.4 \times 1.6 \times 10^{-19}}$$
$$= \frac{5.24714 \times 10^{-8}}{2.24} = 2.34 \times 10^{-8} \text{ s}$$

7. (i)



X - Unknown Resistance,
R = Resistance box, G = Galvanometer
AC = Uniform resistance wire, Rh = Rheostat
D = Null point, E = Cell, K = Plug key

The key is closed to pass current by choosing suitable resistance R in resistance box. The jockey is tapped on the wire till a point D is located such that the galvanometer deflection is zero. The bridge is then said to be balanced.

From Wheatstone Bridge Principle,

$$\frac{X}{R} = \frac{l_x}{l_R}$$

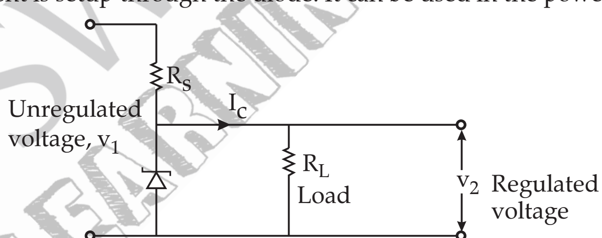
But $$l_R = 100 - l_x$$

$\therefore$ $$\frac{X}{R} = \frac{l_x}{(100 - l_x)} \text{ or } X = R\left[\frac{l_x}{100 - l_x}\right]$$

As l_x, R are known values, so the unknown resistance X can be calculated.

(ii) A Zener diode is a heavily doped p-n junction diode which is not damaged by high reverse current during the breakdown.

By suitably varying the doping level, the breakdown voltage is made very sharp. In the forward bias, Zener diode acts as an ordinary diode. At reverse breakdown, the resistance of Zener diode becomes almost zero and so, a large current is setup through the diode. It can be used in the power supplies as voltage regulator.



Any increase/decrease in the input voltage results in increase/decrease of voltage drop across R_L, without any change in the voltage across Zener diode. This is because in the breakdown region, Zener voltage remains constant even though the current through the Zener diode changes.

(iii) $\beta_1 = \frac{\lambda D_1}{d}$, $\beta_2 = \frac{\lambda D_2}{d}$, λ = 5200 A°, D = Distance between screen and biprism

$$\beta_1 - \beta_2 = 1.3 \text{ mm} = 1.3 \times 10^{-3} \text{ m}$$

$$d = \text{distance between two virtual images of the slit}$$

$$D_1 - D_2 = 50 \text{ cm} = 0.5 \text{ m}$$

$\therefore$ $$\beta_1 - \beta_2 = \frac{\lambda}{d}(D_1 - D_2) = 1.3 \times 10^{-3} \text{ m}$$

or $$\frac{5200 \times 10^{-10}}{d}(0.5) = 1.3 \times 10^{-3} \text{ m.}$$

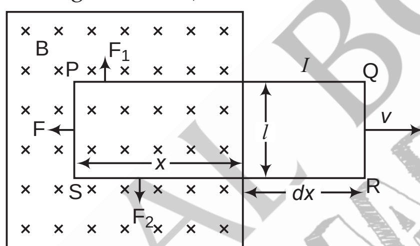
$\Rightarrow$ $$d = \frac{5200 \times 10^{-10} \times 0.5}{1.3 \times 10^{-3}} = 2 \times 10^{-4} \text{ m}$$

(iv)
$$\mu_w = \frac{c}{v_w}$$
$$v_w = \frac{c}{\mu_w} = \frac{3\times10^8}{\frac{4}{3}} \text{ m/s}$$
$$= \frac{9}{4} \times 10^8 \text{ m/s}$$
$$v_w = 2.25 \times 10^8 \text{ m/s}$$
$$\mu_d = \frac{c}{v_d}$$
$$v_d = \frac{3\times10^8}{2.42} \text{ m/s} = 1.34 \times 10^8 \text{ m/s}$$

8. (i) Suppose 'l' be length of side PS and 'x' be length of loop within the field.

$\therefore$ Area of loop, $A = lx$

Magnetic flux $\phi = BA = Blx$



Rate of change of magnetic flux
$$\frac{d\phi}{dt} = \frac{d}{dt}(Blx) = Bl\frac{dx}{dt}$$
But
$$\frac{dx}{dt} = v$$
$\therefore$
$$\frac{d\phi}{dt} = Blv \qquad \text{...(i)}$$
Work done in time 'dt' during small displacement 'dx'
$$dW = -Fdx \qquad \text{(–ve sign indicates their opposite direction)}$$
$\therefore$
$$dW = -BIl\,dx, \text{ Since } F = BIl \qquad \text{... (ii)}$$
Mechanical power,
$$P = \frac{dW}{dt} = BIl\frac{dx}{dt}$$
$$P = BIl\,v$$
If 'e' is induced e.m.f.,
$$\text{Electric power} = \frac{dW}{dt} = eI$$
$\therefore$
$$dW = eIdt \qquad \text{...(iii)}$$
From (ii) and (iii)
$$eIdt = BIl\,dx$$
$\therefore$
$$e = -Bl\left(\frac{dx}{dt}\right) = -Blv \qquad \text{...(iv)}$$
Using (i) and (iv)
$$e = \frac{-d\phi}{dt}$$

(ii) $$C = 20\mu F = 20 \times 10^{-6} F$$

Let 'd' be the distance between the plate of condenser, then $C = \dfrac{\epsilon_0 A}{d}$

(a) If distance is doubled *i.e.* $d' = 2d$

$$C = \frac{A\epsilon_0}{d} \text{ and } C' = \frac{A\epsilon_0}{2d}$$

$$\frac{C'}{C} = \frac{A\epsilon_0}{2d} \cdot \frac{\epsilon_0 A}{d} = \frac{1}{2}$$

$$C' = \frac{C}{2} = \frac{20\times10^{-6}}{2} F = 10^{-5} F \text{ or } 10\mu F$$

It d is doubled, 'C' becomes half

(b) Dielectric constant = 8, C = 20 μF

When initially air is filled between parallel plates, it has dielectric constant K = 1

$$\therefore \quad C = \frac{A\epsilon_0}{d}$$

Now marble slab is introduced with $k' = 8$

$$C' = \frac{K'\epsilon_0 A}{d}$$

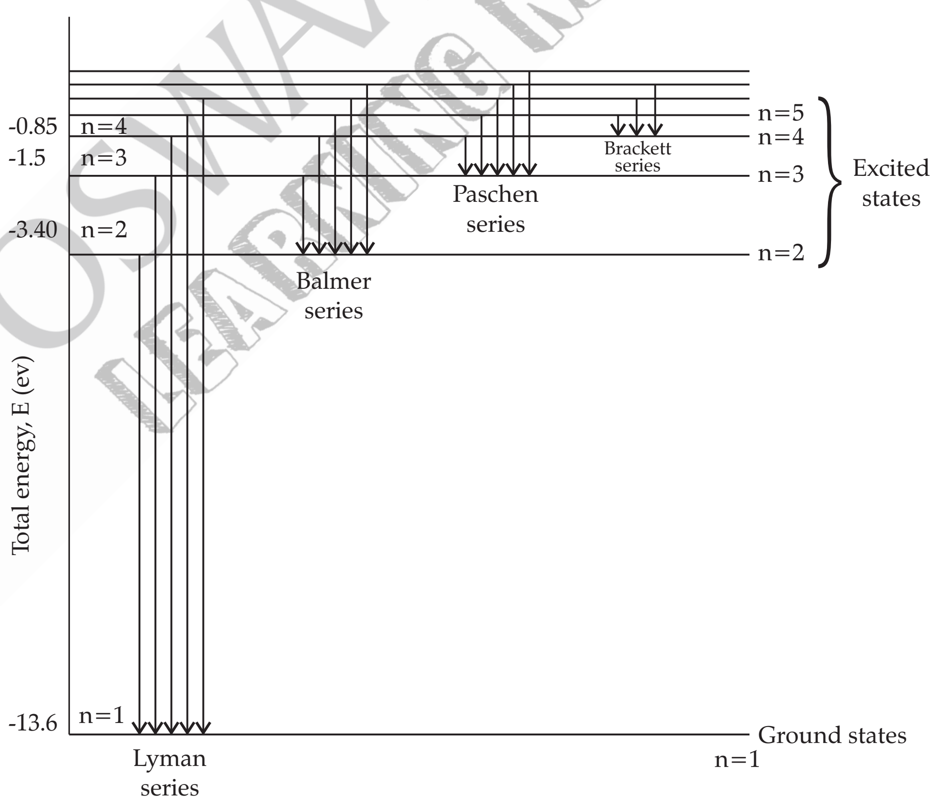
$$\therefore \quad C' = \frac{8A\epsilon_0}{d} = 8C$$

$$C' = 8C$$

$$\therefore \quad C' = 8 \times 20\ \mu F = 160\ \mu F.$$

OR

(i)



The **Balmer series** of the radiation corresponds to $n_i = 2$ and $n_0 = 3, 4, 5$ .... The wavelength is given by

$$\frac{1}{\lambda} = R_H\left[\frac{1}{2^2} - \frac{1}{n_0^2}\right], R_H = \text{Rydberg's constant}$$

They lie in the visible region.

The **Brackett series** of the radiation corresponds to $n_i = 4$ and $n_0 = 5, 6, 7$ ....

The wavelength of radiations is given by

$$\frac{1}{\lambda} = R_H\left[\frac{1}{4^2} - \frac{1}{n_0^2}\right]$$

They lie in the far infrared region.

(ii) Given work function $\phi_0 = 2.2$ eV

$$= 2.2 \times 1.6 \times 10^{-19}\text{ J}$$

$$= 3.52 \times 10^{-19}$$

$\lambda = 5000$ Å $= 5000 \times 10^{-10}$ m, $c = 3 \times 10^8$ m/s, $h = 6.63 \times 10^{-34}$ JS

$$\text{Incident frequency } \nu = \frac{c}{\lambda} = \frac{3\times10^8}{5000\times10^{-10}}$$

$$= \frac{3\times10^8}{5\times10^{-7}} = \frac{3}{5}\times10^{15}\text{Hz}$$

$$= \frac{30}{5}\times10^{14}\text{Hz} = 6 \times 10^{14}\text{ Hz}$$

$$\text{Threshold frequency } \nu_0 = \frac{\phi_0}{h} = \frac{3.52\times10^{-19}\text{ J}}{6.63\times10^{-34}\text{ Js}}$$

$$= 0.53 \times 10^{15}\text{ Hz} = 5.3 \times 10^{14}\text{ Hz}$$

Emission of photoelectron takes place only if incident frequency is greater than the threshold frequency.

But, in this case $n > n_0$, therefore, photoelectric emission takes place.

■■