"Comprehensive Support Learning Material for Students in Physics Subject Seeking to Overcome Past Setbacks."

SUBJECT:- PHYSICS (054)

Prepared by: State Council of Educational Research and Training, Maharashtra, Pune -30

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QUESTION BANK'

SUBJECT:- PHYSICS (054)

OBJECTIVES OF THE QUESTION BANK :

This **QUESTION BANK** is prepared for the help of the students who will be appearing for the Supplementary Examination to be held in July 2024 and thereafter too. It is prepared as such students could not score the minimum score to pass in the written examination or even to score marks required for eligibility in entrance examination.

This **QUESTION BANK** is designed to boost the confidence of the students. It will definitely help them to score good marks in the forthcoming examination. It will be a great support for the students who lack behind others.

It is prepared in a systematic and easiest way by the expert teachers. The students are aware of the textbook as well as the examination pattern (four different sections). Still, this **QUESTION BANK** elaborates every segment in detail. It considers the level of the students.

By preparing questions in the **QUESTION BANK**, we are quite sure that the students will be able to score good marks.

The main objectives can be summarized as under:

1) To facilitate the essential questions that will help students to understand similar questions in the examination.
2) To help every average and the below average student to achieve 100% success at the HSC Board Examination.
3) To motivate the below average students to score more than their expectation in the Biology Subject which they find as most difficult.
4) To help the teachers to reach out to students who struggle to pass in the Biology subject at the HSC Board Exam with the help of this material.
5) Sample papers based on each chapter with hints and answers are given.
6) Model question paper will definitely help students.

INTRODUCTION

Dear Students,

It does not matter if you did not score well in the regular examination held in February 2024. Remember, "every setback is a setup for a comeback." Your previous attempt must have taught you something valuable. We believe in your potential to overcome this hurdle and excel in your upcoming exams.

After a comprehensive analysis of the results, SCERT, Pune has taken an initiative for the upliftment of students who could not achieve the minimum passing score.

Use this QUESTION BANK, seek help when needed, and stay committed to your studies. Underline all answers in your textbook. This material will also prove to be extremely useful for teachers as they assist students in preparing for the supplementary examination. It will boost your confidence to appear for the exam once again. New students in the coming years can also benefit from this QUESTION BANK.

Best wishes for your journey ahead.

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Chapter wise distribution of Marks in the question Paper

** Physics **

Question Bank July 2024 (XII Sci Physics)

Answers and Hints

1. Rotational Dynamics

Answers to MCQ (One-mark questions)

1. a. Magnitude of $\vec{a}_r$ is not constant.

2. d. All $\vec{\theta}$, $\vec{\omega}$ and $\vec{\alpha}$ will be directed along the axis

3. c. Distribution of mass and angular speed

4. a. $\frac{2E}{\omega}$ Explanation $E = \frac{1}{2} I \omega^2 \therefore 2E = (I\omega)\omega \therefore \frac{2E}{\omega} = L$

5. c. $[L^1 M^2 T^1]$

6. c. 6mg

7. c. $v = \sqrt{\mu r g} = \sqrt{0.25 \times 20 \times 9.8} = 7$ m/s

8. a. Frequency of revolution $= \frac{\omega}{2\pi} = \frac{5\pi}{3} x \frac{1}{2\pi} = \frac{5}{6} Hz$

9. c. $I = \frac{1}{2} MR^2 = \frac{1}{2} x\, 10\, x\, (0.6)^2 = 1.8\, kg\, m^2$

10. c. $(K.E.)_1 = (K.E.)_2 \Rightarrow$
$\frac{1}{2} I_1 \omega_1^2 = \frac{1}{2} I_2 \omega_2^2 \Rightarrow \frac{5\, X\, 36}{2} = \frac{20\, V^2}{2} \Rightarrow 9 = V^2 \Rightarrow V = 3\, m/s$

Answers of VSA (One-mark questions)

1. Answer: $\vec{v} = \vec{\omega} \times \vec{r}$
2. Motion of a particle along the circumference of a circle with constant speed is called Uniform Circular Motion.
3. $\vec{a}_r = -\omega^2 \vec{r}$ or $a_r = -\omega^2 r$
4. Centrifugal Force
5. Pseudo force
6. Raising an Outer edge of the road with respect to the inner edge of the road is called Banking of road.
7. The angle by which the outer edge of the road is raised with reference to inner edge is called as Angle of Banking or Banking Angle
8. A point mass connected to a long, flexible, massless, inextensible string and suspended to a rigid support is called a pendulum.

9. A pendulum, when performs horizontal circular motion, so that a string moves along the right circular cone of vertical axis is called as Conical Pendulum
10. Moment of Inertia of a body about a given axis of rotation is defined as, sum of product of masses of constituent particles of body and square of their respective distances from the axis of rotation.
11. The radius of Gyration of a body about given axis of rotation is defined as, distance between the axis of rotation and the point at which the whole mass of the body is supposed to be concentrated, so as to give the same moment of inertia as the body about the same axis of rotation.
12. The Moment of Inertia of a body about any axis is, sum of its moment of inertia about parallel axis passing through centre of mass and product of mass of object and square of perpendicular / least distance between the two axes.
13. The moment of inertia of a laminar object about an axis perpendicular to its plane is the sum of its moments of inertia about two mutually perpendicular axes in its pale, all the three axes being concurrent.
14. Angular Momentum is defined as the product of Moment of Inertia of a body and angular velocity
15. $\vec{L} = \vec{r} \times \vec{P}$
16. $L = P\, r \sin sin\, \theta$
17. If no external unbalanced torque acts on the system, the angular momentum of the system is conserved or remains constant.
18. m = 2000 kg, r = 250 m, v = 25 m/s, F =? $\Rightarrow F = \frac{mv^2}{r} = \frac{2000\, x\, (25)^2}{250} = 5000\, N$
19. r = 1 m, V_{min} = ?, g = 10 m/s^2 $\Rightarrow v_{min} = \sqrt{rg} = \sqrt{1\, x 10} = \sqrt{10} = 3.16\, m/s$
20. m = 4400 kg, r = 100 m, v = 9.8 m/s, μ_{min} =? $\Rightarrow \mu_{min} = \frac{v^2}{rg} = \frac{(9.8)^2}{100x\, 9.8} = 0.098$
21. τ = 500 Nm. α = 1 rad/s^2, I =? $\Rightarrow \tau = I\alpha \Rightarrow I = \frac{\tau}{\alpha} = \frac{500}{1} = 500\, kg\, m^2$
22. D = 100 cm $\therefore$ R = 50 cm = 0.5 m, M = 25 kg, I =?

$$I = \frac{2}{5}MR^2 = \frac{2\, x\, 25\, x\, (0.5)^2}{5} = 0.625\, kg\, m^2$$

Answers to SA 1 (Two-mark question)

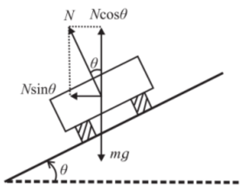
1. a. It is an accelerated motion.

   b. It is a periodic motion.

2.

Centripetal force	Centrifugal force
1. It is directed along the radius towards the centre of a circle	1. It is directed along the radius away from the centre of a circle
2. It is a real force	2. It is a pseudo force
3. It is considered in the inertial frame of reference.	3. It is considered in a non-inertial frame of reference.
4. In vector form, it is given by, $\vec{F} = -\frac{mv^2}{r}\vec{r}_0$ where symbols have their usual meanings.	4. In vector from, it is given by $\vec{F} = +\frac{mv^2}{r}\vec{r}_0$ where symbols have their usual meanings

3.



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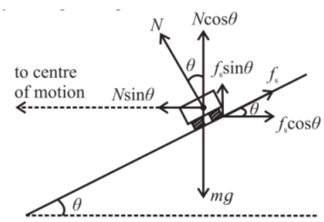

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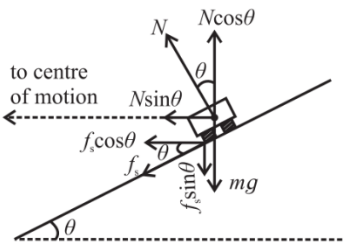

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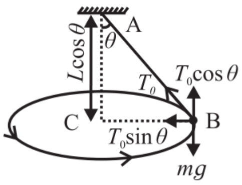

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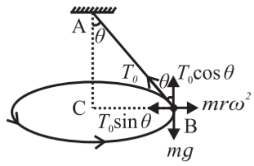
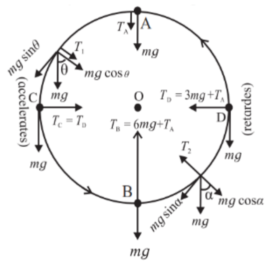


8. The maximum velocity $V_{max} = \sqrt{\mu_s rg}$. Therefore, it is
   a. Directly proportional to square root of friction between road surface and tyres of vehicle.
   b. Directly proportional to square root of radius of curvature of road.
   c. Directly proportional to square root of acceleration due to gravity at a particular place.
   d. Independent of mass of vehicle

9. The minimum velocity $V_{min} = \sqrt{\frac{\mu_s}{rg}}$. Therefore, it is
   a. Directly proportional to square root of friction between road surface and tyres of vehicle.
   b. inversely proportional to square root of radius of curvature of road.
   c. inversely proportional to square root of acceleration due to gravity at a particular place.
   d. Independent of mass of vehicle.

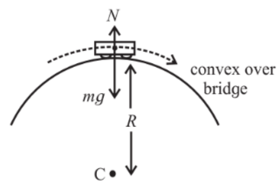
10.



1. Diagram
2. Explanation of Diagram.
3. $mg + T_A = \frac{mv_A^2}{r}$
4. For minimum velocity, $T_A = 0$
5. $\therefore (v_A)_{min} = \sqrt{rg}$

11.

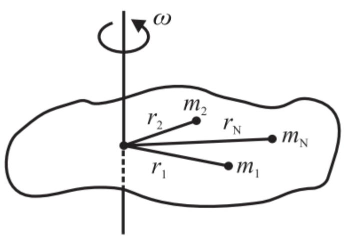
1. Diagram
2. Explanation of Diagram
3. $mg - N = \frac{mv^2}{r}$
4. $v_{max} = \sqrt{rg}$



12. Physical significances of Moment of Inertia:
    a. The moment of inertia in rotational motion is analogous to the mass of a body in translational motion.
    b. Moment of inertia increases with increase in mass.
    c. Greater the moment of inertia greater is the angular acceleration.

13. Physical Significances of Radius of gyration:
    a. The radius of gyration depends upon the shape and size of the body.
    b. It measures the distribution of mass about the axis of rotation.
    c. Small value of the radius of gyration shows the mass of the body is distributed close to the axis of rotation so that moment of inertia is small.
    d. Large value of the radius of gyration shows the mass of the body is distributed at a large distance from the axis of rotation, so that moment of inertia is large.

14. Expression for Rotational kinetic energy:
    1. Diagram
    2. Explanation



3. $v = r\omega$

$\Rightarrow v_1 = r_1\omega,\ v_2 = r_2\omega,\ v_3 = r_3\omega,\ v_n = r_n\omega$

4. $(K.E.)_1 = \frac{1}{2} m_1 v_1^2 = \frac{1}{2} m_1 r_1^2 \omega^2$

5. $Total\ Rotational\ K.E.$

$= (K.E.)_1 + (K.E.)_2 + (K.E.)_3 + \ldots\ldots\ldots + (K.E.)_n$

6. $= \frac{1}{2} m_1 r_1^2 \omega^2 + \frac{1}{2} m_2 r_2^2 \omega^2 + \frac{1}{2} m_3 r_3^2 \omega^2 + \ldots\ldots\ldots + \frac{1}{2} m_n r_n^2 \omega^2$

7. $= \frac{1}{2} (m_1 r_1^2 + m_2 r_2^2 \omega^2 + m_3 r_3^2 + \ldots\ldots\ldots\ldots\ldots + m_n r_n^2)\omega^2$

8. $\therefore\ Rotational\ Kinetic\ Energy = \frac{1}{2} I\omega^2$

$$where\ I = m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2 + \ldots\ldots\ldots\ldots + m_n r_n^2 = \sum_{i=1}^{n} m_n r_n^2$$

15. Expression for Total Kinetic Energy for a body in rolling motion.

1. For a rotating body, $\omega = \frac{v}{R}$
2. Total K.E. of rolling, E = Translational K.E. + Rotational K.E.
3. $E = \frac{1}{2} M v^2 + \frac{1}{2} I\omega^2 = \frac{1}{2} M v^2 + \frac{1}{2} M K^2 \left(\frac{v^2}{R^2}\right) = \frac{1}{2} M v^2 \left(1 + \frac{K^2}{R^2}\right)$

16. m = 1 kg, r = 0.5 m, T_L = ?, T_H = ?

a. T_L = 6 x m x g = 6 x 0.5 x 9.8 = 58.8 N, b. $T_H = 0$

17. m = 0.5 kg, r = 0.5 m, T = 5 kg-wt, v = ?, n = ?

a. $T = \frac{mv^2}{r} + mg \Rightarrow v^2 = \frac{r}{m}(T - mg) = \frac{0.5}{0.5}(5 - 0.5\,x\,9.8) = 44.1 \left(\frac{m}{s}\right)^2$

$\Rightarrow v = 6.64\ m/s$

b. $n = \frac{v}{2\pi r} = \frac{6.64}{2\,x\,3.142\,x\,0.5} = 2.113\ x\ 60\ rps = 126.8\ rps$

18. n = 5, t = 2 min = 2 x 60 = 120 s, a = π^2 m/s^2, r = ?

$$a = \frac{v^2}{r} \Rightarrow \pi^2 = \frac{(2\pi rn)^2}{t^2\,x\,r} = \frac{(10\pi r)^2}{t^2\,x\,r} = \frac{100\pi^2 r}{t^2} \Rightarrow r = \frac{(120)^2}{100} = 144\ m$$

19. K = ?, L = 3 m

$For\ a\ given\ rod,\ I = \frac{1}{3} ML^2\ \ Also\ I = MK^2$

$$\Rightarrow MK^2 = \frac{1}{3} ML^2 \Rightarrow K^2 = \frac{L^2}{3} = \frac{3^2}{3} = 3 \Rightarrow K = \sqrt{3}\ m$$

20. M = 1 kg, v = 2 m/s, K.E. = ?

$$E = \frac{1}{2} M v^2 \left(1 + \frac{K^2}{R^2}\right) = \frac{1}{2} M v^2 \left(1 + \frac{2R^2}{5}\ x\ \frac{1}{R^2}\right)$$

$$= \frac{1}{2}\,x\,\frac{7}{5}\,x\,Mv^2 = \frac{1}{2}\,x\,\frac{7}{5}\,x\,1\,x\,2^2 = 2.8\ J$$

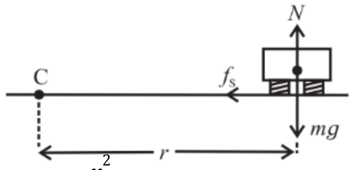
21. h = 0.4 m, K_0 = 0.5 m, K_C = ?

$$I_o = I_C + Mh^2 \Rightarrow MK_o^2 = MK_C^2 + Mh^2 \Rightarrow K_o^2 = K_C^2 + h^2$$

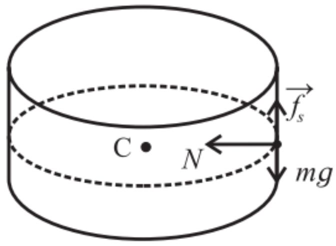
$$\Rightarrow K_C = \sqrt{K_o^2 - h^2} = \sqrt{(0.5)^2 - (0.4)^2} = 0.3\, m$$

Answers to SA 2 (Three-mark question)

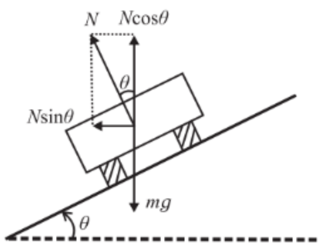
1. Expression for maximum velocity of a vehicle moving along a Horizontal Curved Road:



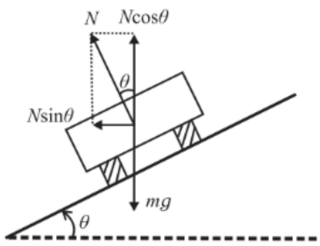
    1. Diagram
    2. Explanation
    3. $mg = N,\ f_s = mr\omega^2 = \frac{mv^2}{r} \Rightarrow f_s = \frac{v^2}{rg}$
    4. $f_{s(max)} = \mu_s N \therefore \frac{f_{s(max)}}{N} = \mu_s$
    5. For maximum velocity, $v = v_{max}$
    6. $\therefore \mu_s = \frac{v_{max}^2}{rg} \Rightarrow v_{max} = \sqrt{\mu_s rg}$
2. Expression for minimum velocity of a vehicle moving along a Well (Wall) of Death.



    1. Diagram
    2. Explanation
    3. $N = mr\omega^2 = \frac{mv^2}{r},\ f_s = mg$
    4. $f_s \leq \mu_s N \therefore mg \leq \mu_s \frac{mv^2}{r}$
    5. $v_{min} = \sqrt{\frac{rg}{\mu_s}}$
3. Expression for most safe speed of a vehicle, moving along a banked road:



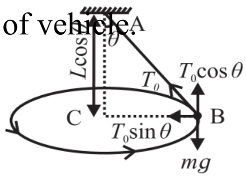
    1. Diagram
    2. Explanation
    3. $\theta = mg,\ \ \theta = \frac{mv^2}{r}$
    4. $\tan tan\,\theta = \frac{v^2}{rg}$
    5. $v^2 = \sqrt{rg \tan tan\,\theta}$
4. Expression for banking angle of a vehicle, moving along a banked road:



    1. Diagram
    2. Explanation
    3. $\theta = mg,\ \ \theta = \frac{mv^2}{r}$
    4. $\tan tan\,\theta = \frac{v^2}{rg}$
    5.
5. Most safe speed of a vehicle moving along a banked road, is independent of the mass of the vehicle. Refer Answer 3. Since, equation 5 (step 5) does not contain any mass term, the velocity is independent of mass of vehicle.

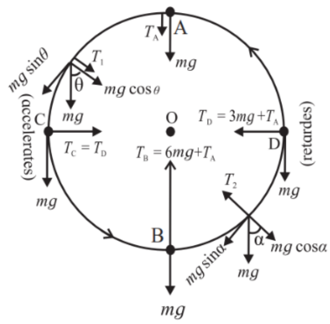
6. Banking angle / angle of banking, is independent of mass of vehicle:

   Refer to Answer 4. Since equation 5 (step 5) does not contain any mass term, the banking angle / angle of banking is independent of mass of vehicle.



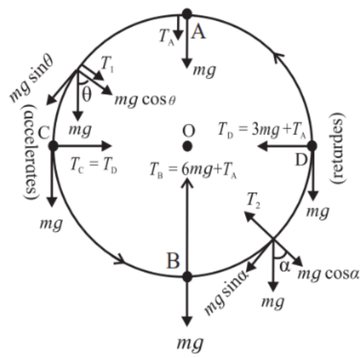
7. Expression for period of conical pendulum.
    1. Diagram
    2. Explanation
    3. $\sin T_0 sin\,\theta = mr\omega^2 \rightarrow eqn\ (1)$, $\cos T_0 cos\,\theta = mg \rightarrow eqn\ (2)$
    4. $eqn\ 1 \div eqn\ 2 \rightarrow \omega^2 = \frac{g\sin sin\,\theta}{r\cos cos\,\theta}$, $r = L\cos cos\,\theta$
    5. $\omega = \frac{2\pi}{T} = \sqrt{\frac{g}{L\cos cos\,\theta}} \Rightarrow T = 2\pi\sqrt{\frac{L\cos cos\,\theta}{g}}$
8. Expression for frequency of conical pendulum: Refer Answer 7.
    6. $n = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{g}{L\cos\theta}}$
9. Refer to Answer 7. Since the expression for the period, step 5, does not contain a mass term, the period of the conical pendulum is independent of the mass of the conical pendulum.
10. Refer to Answer 8. Since the expression, step 6, for the frequency does not contain the mass term, the frequency of the conical pendulum is independent of the mass of the conical pendulum.
11. Refer to Answer 7.
12. Refer to Answer 8.
13. Derive the expression for the minimum velocity of a body at the lowermost position, while performing Vertical Circular Motion.
    1. Diagram
    2. Explanation of Diagram
    3. $T_B - mg = \frac{mv_B^2}{r}$
    4. $\therefore mg(2r) = \frac{1}{2}mv_B^2 - \frac{1}{2}mv_A^2$

       $\therefore v_B^2 - v_A^2 = 4rg$
    5.
    6. $(v_B)_{min} = \sqrt{5rg}$



14. To Show that the difference between the tensions at uppermost and lowermost position of a body performing Vertical Circular Motion is 6mg.
    1. Diagram
    2. Explanation of Diagram
    3. $mg + T_A = \frac{mv_A^2}{r}$ □ (1)

       $T_B - mg = \frac{mv_B^2}{r}$

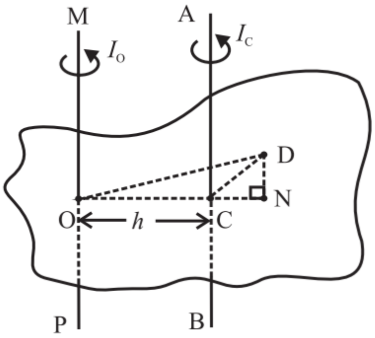


4. □ (2)

5. Subtracting eqn (2) from eqn (1)
6. $T_B - T_A - 2mg = \frac{m}{r}\left(v_B^2 - v_A^2\right)$
7. Solving we get, $T_B - T_A = 6mg$

15. Refer Answer 14.

16. Expression for Moment of Inertia in case of Parallel Axes Theorem.
1. Diagram
2. Explanation

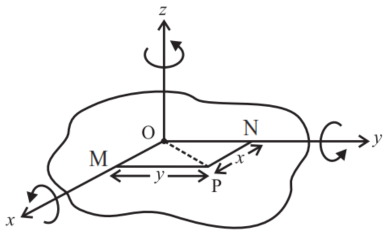


3. $I_C = \int (DC)^2 dm,\ \ I_O = \int (DO)^2 dm,$
4. $I_O = \int (DO)^2 dm = \int \left((DN)^2 + (NO)^2\right)$
5. Solving we get,
6. $I_O = \int (DC)^2 dm + 2h\int (NC) dm + h^2 \int dm$
7. But,

$\int (DC)^2 dm = I_C,\ \int (NC) dm = 0, \int dm = M$

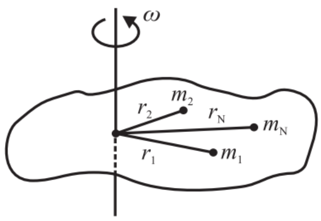
8. $\therefore I_O = I_C + Mh^2$

17. Expression for Moment of Inertia in case of Perpendicular Axes Theorem.
1. Diagram
2. Explanation



3. $I_X = \int (y)^2 dm,\ \ I_Y = \int (x)^2 dm,$
4. $I_Z = \int (y^2 + x^2)\, dm$
5. $\therefore I_Z = \int (y)^2 dm + \int (x)^2 dm$
6. $\therefore I_Z = I_X + I_Y$

18. Expression for angular momentum in terms of Moment of Inertia.
1. Diagram
2. Explanation



9. $v = r\omega$

$\Rightarrow v_1 = r_1\omega,\ v_2 = r_2\omega,\ v_3 = r_3\omega,\ v_n = r_n\omega$

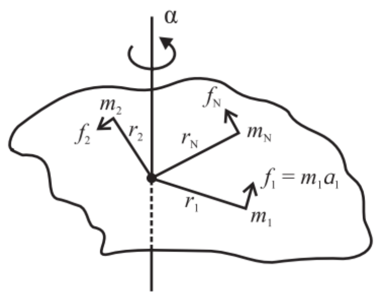
3. $p_1 = m_1 v_1 = m_1 r_1 \omega,\ \ p_2 = m_2 v_2 = m_2 r_2 \omega,$

$p_3 = m_3 v_3 = m_3 r_3 \omega, \quad p_n = m_n v_n = m_n r_n \omega$

4. $L_1 = p_1 r_1 = m_1 r_1^2 \omega, \quad L_2 = p_2 r_2 = m_2 r_2^2 \omega,$
   $L_3 = p_3 r_3 = m_3 r_3^2 \omega, \quad L_n = p_n r_n = m_n r_n^2 \omega$
5. $L = L_1 + L_2 + L_3 + \ldots\ldots\ldots\ldots + L_N$
6. $\therefore L = m_1 r_1^2 \omega + m_2 r_2^2 \omega + m_3 r_3^2 \omega + \ldots\ldots + m_n r_n^2 \omega$
7. $\therefore L = (m_1 r_1^2 + m_2 r_2^2 \omega^2 + m_3 r_3^2 + \ldots\ldots\ldots\ldots + m_n r_n^2)\, \omega$
8. $\therefore L = I\omega$
   $where\ I = m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2 + \ldots\ldots\ldots\ldots + m_n r_n^2$

19. Expression for Torque in terms of Moment of Inertia.

1. Diagram
2. Explanation
3. $a = r\alpha$



$\Rightarrow a_1 = r_1 \alpha,\ a_2 = r_2 \alpha,\ a_3 = r_3 \alpha,\ a_n = r_n \alpha$

4. $f_1 = m_1 a_1 = m_1 r_1 \alpha, \quad f_2 = m_2 a_2 = m_2 r_2$
   $f_3 = m_3 a_3 = m_3 r_3 \alpha, \quad f_n = m_n a_n = m_n r_n \alpha$
5. $\tau_1 = f_1 r_1 = m_1 r_1^2 \alpha, \quad \tau_2 = f_2 r_2 = m_2 r_2^2 \alpha,$
   $\tau_3 = f_3 r_3 = m_3 r_3^2 \alpha, \quad \tau_n = f_n r_n = m_n r_n^2 \alpha$
6. $\tau = \tau_1 + \tau_2 + \tau_3 + \ldots\ldots\ldots\ldots + \tau_N$
7. $\therefore \tau = m_1 r_1^2 \alpha + m_2 r_2^2 \alpha + m_3 r_3^2 \alpha + \ldots\ldots + m_n r_n^2 \alpha$
8. $\therefore \tau = (m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2 + \ldots\ldots\ldots\ldots + m_n r_n^2)\, \alpha$
9. $\therefore \tau = I\alpha$
   $where\ I = m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2 + \ldots\ldots\ldots\ldots + m_n r_n^2$

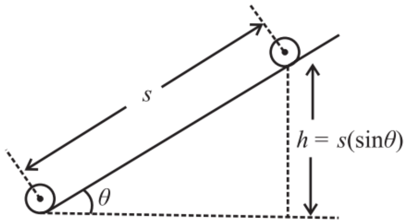
20. Conservation of Linear Momentum: (Statement and Proof)

Statement: If no external unbalanced torque act on the system, the angular momentum of the system is conserved or remains constant.

1. $\vec{L} = \vec{r}\, x\, \vec{p}$
2. $\frac{d\vec{L}}{dt} = \frac{d}{dt}(\vec{r}\, x\, \vec{p}) = \vec{r}\, x\, \frac{d\vec{p}}{dt} + \frac{d\vec{r}}{dt}\, x\, \vec{p}$
3. But, $\frac{d\vec{r}}{dt} = \vec{v}\ and\ \frac{d\vec{p}}{dt} = \vec{F}$
4. $\therefore \frac{d\vec{L}}{dt} = \vec{r}\, x\, \vec{F} + m(\vec{v}\, x\, \vec{v})$

5. But $\left(\vec{v} \times \vec{v}\right) = 0$
6. $\therefore \frac{d\vec{L}}{dt} = \vec{r} \times \vec{F}$
7. But $\frac{d\vec{L}}{dt} = \vec{\tau}$
8. $\therefore \vec{\tau} = \frac{d\vec{L}}{dt} = \vec{r} \times \vec{F}$
9. If $\vec{\tau} = 0$, then $\frac{d\vec{L}}{dt} = 0 \therefore \vec{L}$ = constant.

21. Expression for speed of a body rolling down on an inclined plane.
    1. Diagram
    2. Explanation
    3. For any rotating body, $\omega = \frac{v}{R}$
    4. Total K.E. of rolling, E
       = Translational K.E. + Rotational K.E.
    5. $E = \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2 =$
    6. $E = \frac{1}{2}Mv^2 + \frac{1}{2}MK^2\left(\frac{v^2}{R^2}\right) = \frac{1}{2}Mv^2\left(1 + \frac{K^2}{R^2}\right)$
    7. $E = \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2 = \frac{1}{2}Mv^2\left(1 + \frac{K^2}{R^2}\right)$
    8. $E = mgh = \frac{1}{2}Mv^2\left(1 + \frac{K^2}{R^2}\right)$
    9. $\therefore v = \sqrt{\frac{2gh}{\left(1+\frac{K^2}{R^2}\right)}}$



22. r = 500 m, $\theta = 10^0$, $\mu_s = 0.25$, v_{max} = ?, $v_{optimum}$ = ?, g = 9.8 m/s^2

$v_{max} = \sqrt{rg\left[\frac{\tan tan\,\theta + \mu_s}{1-(\mu \tan tan\,\theta)}\right]} = \sqrt{500 \times 9.8\left[\frac{\tan tan\,10 + 0.25}{1-(0.25 \times \tan tan\,10)}\right]} = \sqrt{2185} = 46.75$ m/s

$v_{optimum} = \sqrt{rg \tan tan\,\theta} = \sqrt{500 \times 9.8 \times \tan tan\,10} = \sqrt{863.9} = 29.39$ m/s

23. M = 50 kg, v = 250 m/s, r = 5 km = 5000 m, $F_{at\ top}$ =?, $F_{at\ bottom}$ = ?

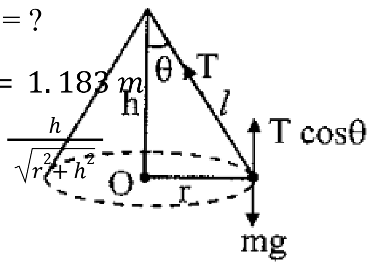
$F_{at\ top} = \frac{mv^2}{r} - mg = \frac{50 \times (250)^2}{5000} - 50 \times 9.8 = 135\ N$

$F_{at\ bottom} = \frac{mv^2}{r} + mg = \frac{50 \times (250)^2}{5000} + 50 \times 9.8 = 1115\ N$

24. L = 120 cm = 0.12 m, m = 150 g = 0.15 kg, r = 0.2 m, T = ?

From Figure, $h = \sqrt{l^2 - r^2} = \sqrt{(0.12)^2 - (0.2)^2} = 1.183\ m$

$\cos cos\,\theta = \frac{h}{l} \quad \therefore cos^2\theta = \frac{h^2}{l^2} \quad \therefore \cos cos\,\theta = \frac{h}{\sqrt{r^2+h^2}}$



$T = \frac{mg}{\cos cos\,\theta} = \frac{mg\sqrt{r^2+h^2}}{h} = mg\sqrt{1 + \left(\frac{r}{h}\right)^2}$

$= 150 \times 9.8\sqrt{1 + \left(\frac{0.2}{1.183}\right)^2}$ = 1.491 N

25. R = 2 cm = 2 x 10^{-2} m, m = 50 g = 50 x 10^{-3} kg, L = 12 cm = 12 x 10^{-2} m, I_C =?

$$I = M\left(\frac{R^2}{4} + \frac{L^2}{12}\right) = 50x\,10^{-2}\left(\frac{2^2}{4} + \frac{12^2}{12}\right)x\left(10^{-2}\right)^2 = 6.5\,x\,10^{-5}\,kg\,m^2$$

26. A solid sphere of radius 25 cm and mass 25 kg rotates about an axis through its centre. Calculate its moment of inertia. If its angular velocity changes from 2 rad/s to 12 rad/s in 5 seconds, calculate the torque applied. (target/p18/Q4)

R = 25 cm = 0.25 m, M = 25 kg, I_C =?, ω_1 = 2 rad/s, ω_2 = 12 rad/s, t = 5 s, τ = ?

$$I = \frac{2}{5}MR^2 = \frac{2}{5}\,x\,25\,x\,(0.25)^2 = 0.625\,kg\,m^2$$

$$\tau = I\alpha = I\left(\frac{\omega_2 - \omega_1}{t}\right) = 0.625\,x\left(\frac{12-2}{5}\right) = 1.25\,Nm$$

LONG ANSWER TYPE (4 marks)

1. Refer SHORT ANSWER TYPE – II, 1 AND 2

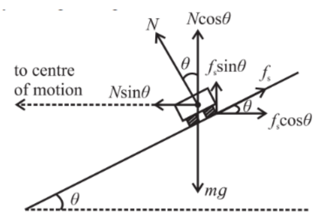
    1. FROM 1, $v_{max} = \sqrt{\mu_s rg}$ AND FROM 2 $v_{min} = \sqrt{\frac{rg}{\mu_s}}$

    2. $\frac{v_{max}}{v_{min}} = \frac{\sqrt{\mu_s rg}}{\sqrt{\frac{rg}{\mu_s}}} = \sqrt{\mu_s rg}\,x\sqrt{\frac{\mu_s}{rg}} = \mu_s$

2. Expression for the safest minimum speed of a vehicle moving along a banked road. (Consider Frictional Forces):

    1. Diagram
    2. Explanation
    3. $mg = f_s \sin sin\,\theta + N \cos cos\,\theta$

$$\frac{mv_1^2}{r} = N \sin sin\,\theta - f_s \cos cos\,\theta$$

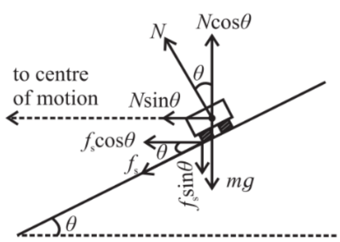


    4. Solving, the above equations, we get,
    5. $\left(v_{1_{(min)}}\right) = v_{min} = \sqrt{rg\left[\frac{\tan tan\,\theta - \mu_s}{1+\mu_s \tan tan\,\theta}\right]}$

3. Expression for the safest maximum speed of a vehicle moving along a banked road. (Consider Frictional Forces):

    1. Diagram
    2. Explanation
    3. $mg = N\cos cos\,\theta - f_s \sin sin\,\theta$

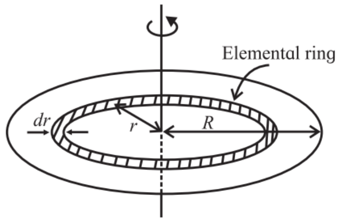
$$\frac{mv_2^2}{r} = N \sin sin\,\theta + f_s \cos cos\,\theta$$



    4. Solving, the above equations, we get,
    5. $\left(v_{2_{(max)}}\right) = v_{max} = \sqrt{rg\left[\frac{\tan tan\,\theta + \mu_s}{1-\mu_s \tan tan\,\theta}\right]}$

4. Expression for Moment of Inertia of a uniform disc:

1. Diagram
2. Explanation



3. $\sigma = \frac{m}{A} = \frac{M}{\pi R^2}$
4. Area of ring $A = 2\pi r dr$
5. $\therefore \sigma = \frac{dm}{2\pi r dr} \Rightarrow dm = 2\pi\sigma r.dr$
6. $I_r = dm.r^2$
7. $I = \int_0^R I_r = \int_0^R dm.\ r^2 = \int_0^R 2\pi\sigma r.dr.r^2 = 2\pi\sigma \int_0^R r^3 dr$
8. $I = 2\pi\sigma\left(\frac{R^4}{4}\right) = 2\pi\left(\frac{M}{\pi R^4}\right)\left(\frac{R^4}{4}\right) = \frac{1}{2}MR^2$

2. Mechanical Properties of Fluids.

Answers to MCQ (One-mark questions)

1. c. 100 Pa
2. c. Liquid helium
3. a. Bernoulli's Principle
4. d. < 1000
5. c. $f_T = 2\pi rT$
6. a. More
7. c. 5 cm
8. b. 2TL
9. a. 1 cm
10. b. 1.76×10^{-3} J

Answers of VSA (One-mark questions)

1) $[L^{-1} M^{1} T^{-2}]$
2) The difference between absolute pressure and atmospheric pressure is called the gauge pressure.
3) Atmospheric pressure
4) Hydraulic brakes are used to slow down or stop vehicles in motion.
5) An imaginary sphere with a molecule at its centre and radius equal to the molecular range is called sphere of influence of the molecule.
6) The phenomenon of rise or fall of a liquid inside a capillary tube, when it is dipped in the liquid is called capillarity.
7) $\frac{F_1}{F_2} = \frac{A_1}{A_2}$

   $F_2 = \frac{A_2}{A_1} \times F_1 = \frac{25}{30} \times 1500$

   = 1250 N/m
8) $P = \frac{2T}{R} = \frac{2 \times 0.072}{0.2 \times 10^{-3}} = 720$ N/m²
9) $\frac{P_1}{P_2} = \frac{R_2}{R_1} = 1:2$
10) $P = 2T/r \Rightarrow r = 2 \times 0.072/80 = 0.018$ m = 1.8 cm $\Rightarrow d = 3.6$ cm

Answers to SA (Two-mark questions)

1.

(i) The nature of the liquid and the solid in contact.

(ii) Impurity: Impurities present in the liquid change the angle of contact.

(iii) Temperature of the liquid: Any increase in the temperature of a liquid decreases its angle of contact.

2. (i) Oil rises up the wick of a lamp.

(ii) Cloth rag sucks water.

(iii) Sap and water rise up to the top most lives in a tree.

(iv) Blotting paper absorbs ink

3 Distinguish between streamline flow and turbulent flow

Streamline flow	Turbulent flow
In a streamline flow, velocity of a fluid at a given point is always constant.	In a turbulent flow, the velocity of a fluid at any point does not remain constant.
Two streamlines can never intersect, that is they are always parallel.	In a turbulent flow, at some points, the fluid may have rotational motion which gives rise to eddies.

4 (i) When soluble substances such as common salt is dissolved in the water, the surface tension of water increases.

(ii) When a sparingly soluble substance, such as phenol or detergent is mixed with water surface, tension of water decreases.

(iii) When insoluble impurity is added into water surface tension of water decreases.

5 Blowing off of roofs by stormy wind:

When high-speed stormy wind blows over a roof top, it causes low pressure P above the roof in accordance with Bernoulli's principle. However, the air below the roof (that is inside the room) is still at the atmospheric pressure P_0 . So due to this difference in pressure the roof is lifted up and is then blown off by the wind.

6 a) Surface tension is defined as the tangential force acting per unit length on both sides of an imaginary line drawn on the free surface of liquid. b) The extra energy of the molecules in the surface layer is called the surface energy of the liquid.

7) $P=h\rho g = 6\times1000\times9.8 = 5.88\ N/m^2$.

8) Initial radius of a soap bubble = 0

Final radius of a soap bubble = 1 cm = 0.01 m

Initial surface area of a soap bubble $= 0$

Final surface area of a soap bubble = $2\times4\pi r^2 = 8\pi r^2$

Change in area dA = $8\pi r^2 = 8\times3.142\times 10^{-4} = 0.00251 = 2.51\times 10^{-3}\ m^2$

Work Done = T×dA = $2.5 \times 10^{-2} \times 2.51\times 10^{-3} = 6.275 \times 10^{-5}$ J

9) $F = \eta A\frac{dv}{dx} \Rightarrow \eta = \frac{F}{A}\,\frac{dx}{dv} = \frac{1.5\times10^{-3}}{10^{-2}\times2\times10^{-2}} = 7.5\ \text{Ns}/m^2$

10) $\rho - \rho_0 = h\rho g$ ....(i)

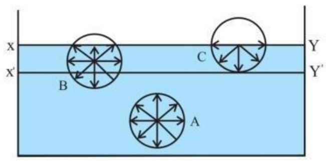
The velocity of efflux $v = \sqrt{2gh}$ ....(ii)

From equation (i) $v = \sqrt{2g(\rho - \rho_0)/\rho g)} = \sqrt{2(\rho - \rho_0)/\rho} = \sqrt{2\times4\times \frac{10^5}{10^3}}$

$v = 20\times \sqrt{2}$ m/s

Short answer type (3 marks)

1)



Consider three molecules A, B, and C such that molecule A is deep inside the liquid, molecule B within surface film and molecules on the surface of the liquid.

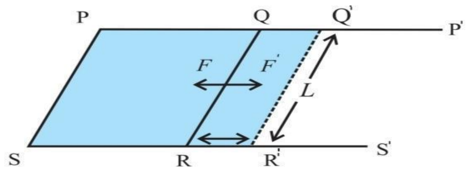
As molecule A is deep inside the liquid its sphere of influence is also completely inside the liquid. As a result, molecule A is acted upon by equal cohesive forces in all directions. Thus the net cohesive force acting on molecule A is zero.

Molecule B lies within the surface layer and below the free surface of the liquid. A larger part of its sphere of influence is inside the liquid and a smaller part is in air. Due to this a strong downward cohesive force acts on the liquid molecule. As a result, the molecule B gets attracted inside the liquid.

The same hold for molecule C which lies exactly on the free surface of the liquid. Half of the sphere of influence is in air and half in the liquid. The number of air molecules within the sphere of influence of the molecule C, above the free surface of the liquid is much less than the number of liquid molecules within the sphere of influence that lies within the liquid. As a result, the molecule C also gets attracted inside the liquid.

All molecules in the surface film are acted upon by an unbalanced net cohesive force directed into the liquid. Therefore, the molecules in the surface film are pulled inside the liquid. This minimises the total number of molecules in the surface film. As a result, the surface film remains under tension. This tension is known as surface tension.

2) Relation between the surface energy and surface tension



Consider a rectangular frame of wire P′PSS′. It is fitted with a movable arm QR as shown in Fig. This frame is dipped in a soap solution and then taken out. A film of soap solution will be formed within the boundaries PQRS of the frame.

Each arm of the frame experiences an inward force due to the film. Under the action of this force, the movable arm QR moves towards side PS to decrease the area of the film. If the length of QR is L, then this inward force F acting on it is given by

$$F = (T) \times (2L) \text{ --- (i)}$$

Since the film has two surfaces, the upper surface and the lower surface, the total length over which surface tension acts on QR is 2L. Imagine an external force F′ (equal and opposite to F) applied isothermally (gradually and at constant temperature), to the arm QR, so that it pulls the arm away and tries to increase the surface area of the film. The arm QR moves to Q′R′ through a distance dx. Therefore, the work done against F, the force due to surface tension, is given by

$$dw = F'dx$$

Using Eq. (i), $dw = T\,(2Ldx)$

But, $2Ldx = dA$, increases in area of the two surfaces of the film. Therefore, $dw = T(dA)$.

This work done in stretching the film is stored in the area dA of the film as its potential energy. This energy is called surface energy.

$$\therefore \text{Surface energy} = T\,(dA) \text{ --- (ii)}$$

Thus, surface tension is also equal to the surface energy per unit area.

3) The angle of contact is defined as the angle between the tangents drawn to the free surface of the liquid and surface of the solid at the point of contact, measured within the liquid

i) Concave meniscus - acute angle of contact:

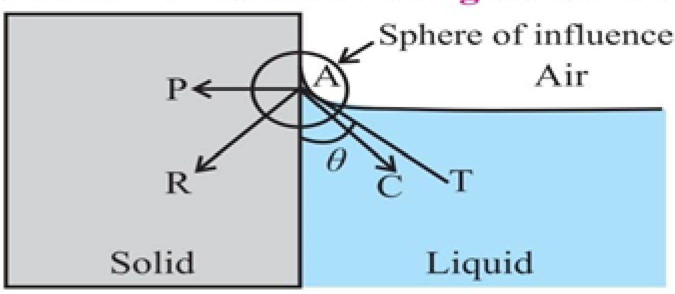


Fig. 2.19 (a): Acute angle of contact.

Figure 2.19 (a) shows the acute angle of contact between a liquid surface (e.g., kerosene in a glass bottle). Consider a molecule such as A on the surface of the liquid near the wall of the container. The molecule experiences both cohesive as well as adhesive forces. In this case, since the wall is vertical, the net adhesive force ($\overrightarrow{AP}$) acting on the molecule A is horizontal, Net cohesive force ($\overrightarrow{AC}$) acting on molecule is directed at nearly 45° to either of the surfaces. Magnitude of adhesive force is so large that the net force ($\overrightarrow{AR}$) is directed inside the solid.

For equilibrium or stability of a liquid surface, the net force ($\overrightarrow{AR}$) acting on the molecule A must be normal to the liquid surface at all points. For the resultant force $\overrightarrow{AR}$ to be normal to the tangent, the liquid near the wall should pile up against the solid boundary so that the tangent AT to the liquid surface is perpendicular to AR. Thus, this makes the meniscus concave. Obviously, such liquid wets that solid surface.

4) Expression for Capillary rise or fall by using forces.

Rise of water inside a capilary is against gravity. Hence, weight of the liquid column must be equal and opposite to the proper component of force due to surface tension at the point of contact.

The length of liquid in contact inside the

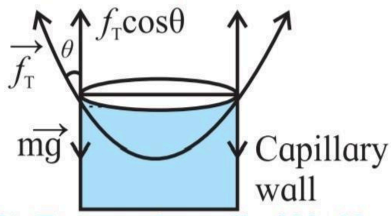


Fig 2.25 (b): Forces acting on liquid inside a capillary.

capillary is the circumference $2\pi r$. Thus, the force due to surface tension is given by,

$$f_T = \text{(surface tension)} \times \text{(length in contact)}$$
$$= T \times 2\pi r$$

Direction of this force is along the tangent, as shown in the Fig. 2.25 (b).

Vertical component of this force is

$$\left(f_T\right)_v = T \times 2\pi r \times \cos\theta \qquad \text{--- (2.29)}$$

Ignoring the liquid in the concave meniscus, the volume of the liquid in the capillary rise is $V = \pi r^2 h$.

$\therefore$ Mass of the liquid in the capillary rise,

$$m = \pi r^2 h\rho$$

$\therefore$ Weight of the liquid in the capillary (rise or fall), $w = \pi r^2 h\rho g$ --- (2.30)

This must be equal and opposite to the vertical component of the force due to surface tension. Thus, equating right sides of equations (2.29) and (2.30), we get,

$$\pi r^2 h\rho g = T \times 2\pi r \times \cos\theta$$

$$\therefore h = \frac{2T\cos\theta}{r\rho g}$$

In terms of capillary rise, the expression for surface tension is,

$$T = \frac{rh\rho g}{2\cos\theta} \quad \text{--- (2.31)}$$

6) Expression for terminal velocity

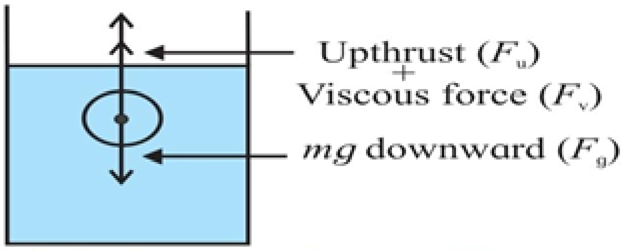


Fig. 2.32: Forces acting on object moving through a viscous medium.

Consider a spherical object falling under gravity through a viscous medium as shown in Fig. 2.32. Let the radius of the sphere be r, its mass m and density ρ. Let the density of the medium be σ and its coefficient of viscosity be η. When the sphere attains the terminal velocity, the total downward force acting on the sphere is balanced by the total upward force acting on the sphere.

Total downward force = Total upward force

weight of sphere (mg) =

viscous force + by out ant to due to the medium

$$\frac{4}{3}\pi r^3 \rho g = 6\pi\eta r v + \frac{4}{3}\pi r^3 \sigma g$$

$$6\pi\eta r v = \left(\frac{4}{3}\pi r^3 \rho g\right) - \left(\frac{4}{3}\pi r^3 \sigma g\right)$$

$$6\pi\eta r v = \left(\frac{4}{3}\right)\pi r^3 g(\rho - \sigma)$$

$$v = \left(\frac{4}{3}\right)\pi r^3 g(\rho - \sigma) \times \frac{1}{6\pi\eta r}$$

$$v = \left(\frac{2}{9}\right)\frac{r^2 g(\rho - \sigma)}{\eta} \qquad \text{--- (2.37)}$$

This is the expression for the terminal velocity of the sphere. From Eq. (2.37) we can also write,

$$\eta = \frac{2}{9}\frac{r^2(\rho - \sigma)g}{v} \qquad \text{--- (2.38)}$$

The above equation gives coefficient of viscosity of a fluid.

8) Volume of bigger drop = Volume of 8 small droplets

$$\frac{4}{3}\pi R^3 = 8 \times \frac{4}{3}\pi r^3$$

R = 2r ⟹ r= R/2 = 0.2×10^{-2}

Initial area of bigger drop $A_1 = 4\pi R^2$

Final area of 8 droplets $A_2 = 8 \times 4\pi r^2$

Change in area dA = $8 \times 4\pi r^2 - 4\pi R^2 = 8\pi R^2 - 4\pi R^2 = 4\pi R^2 = 0.16\pi$

Change in work done = T×dA = 435.5 ×0.16×3.142 = 2.18×10^{-5} J

9) $T = \frac{hr\rho g}{2cos\theta}$ $\quad \therefore$ $h = \frac{2Tcos\theta}{r\rho g} = \frac{2 \times 7 \times 10^{-2} \times 1}{1 \times 10^{-4} \times 10^{3} \times 9.8} = 0.142$ cm

10) From equation of continuity

$$A_1 V_1 = A_2 V_2$$

$$\pi r_1^2 V_1 = \pi r_2^2 V_2$$

$$r_1^2 = \frac{25 \times 10^{-4}}{2} = 12.5 \times 10^{-4}$$

$r_2 = 3.535 \times 10^{-2} \Rightarrow d_2 = 7.07X10^{-2}$

3. Kinetic Theory of Gases and Radiation

Answers of MCQ (One-mark questions)

1) c. the absolute temperature of the gas
2) a. geometric structure of the molecule
3) d. temperature
4) b. 16
5) b. $\lambda_{max} = \frac{b}{T} = \frac{2.897 \times 10^{-3}}{3000} = 0.9656 \times 10^{-6}$ = 9.656×10^{-7} = 9656 Å
6) a. $C_v = 12307.69$, $C_p/C_v = 1.65$,

   $C_p - C_v = R = 1.65C_v - C_v = C_v(1.65 - 1) = 12307.69 \times 0.65 = 7999$ J kg^{-1} K^{-1}
7) b. $Q = \sigma AtT^4 = 5.7 \times 10_{-8} \times 200 \times 10^{-4} \times 60 \times (400)^4 = 1751.04$ J
8) d. $P_1V_1=P_2V_2$, $V_2/V_1=P_1/P_2=P_1/0.9P_1=1.111$

   Therefore $(V_2-V_1)/V_1=0.1111$, i.e. 11.11%
9) b. $t = 1 - (a + r) = 1 - 0.96 = 0.04$
10) b. $E_1/E_2 = (T_1/T_2)^4 = [(1327 + 273)/(527 + 273)]^4 = (1600/800)^4 = 2^4 = 16$

Answers of VSA (one-mark questions)

1) The laws of Boyle, Charles, and Gay-Lussac are strictly valid for real gases, only if the pressure of the gas is not too high and the temperature is not close to the liquefaction temperature of the gas.
2) the wavelength of the incident radiation.
3) At room temperature also all bodies radiate as well as absorb radiation, but their rate of emission and rate of absorption are same, hence their temperature remains constant.
4) absolute zero
5) Vrms = $\sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3 \times 10^5}{1.25}} = 489.89\ m/s$
6) K.E. = $\frac{3}{2}PV = \frac{3}{2} \times 1.013 \times 10^5 \times 3 \times 10^{-3} = 455.8\ J$
7) $P = \frac{1}{3}\rho v_{rms}^2 = \frac{1}{3} \times 1.25 \times 489^2$ = 99633.75 N/m
8) A perfect blackbody is a body which absorbs all the radiant energy incident on it.
9) If the temperature of a gas increases, the mean square speed of the molecules of the gas will increase in the same portion.
10) The rate of emission of radiant energy per unit area of a perfectly blackbody is directly proportional to the fourth power of its absolute temperature.

Answers of SA 1 (two-mark questions)

1) 1. The absolute temperature of the body (T)

2. The nature of the body – the material, nature of surface – polished or not

3. Surface area of body (A)

4. Time duration for which body emits radiation (t)

2) Molar specific heat at constant volume is, $C_v = \frac{dE}{dT} = \frac{3}{2}N_A K_b T = \frac{3}{2}R$

Using above equation in Mayer's relation equation, $C_p – C_v = R$, we get $C_p = \frac{5}{2}R$

The ratio of two specific heats is $\gamma = \frac{C_p}{C_v} = \frac{5}{3}$.

3) Molar specific heat at constant volume is, $C_v = \frac{dE}{dT} = \frac{5}{2}N_A K_b T = \frac{5}{2}R$

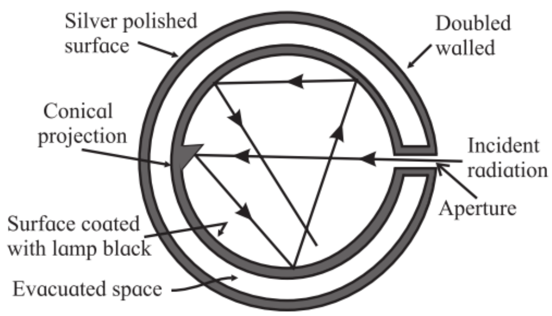
Using above equation in Mayer's relation equation, $C_p – C_v = R$, we get $C_p = \frac{7}{2}R$

The ratio of two specific heats is $\gamma = \frac{C_p}{C_v} = \frac{7}{5}$.

4) 1) Athermanous substance – Substances which are largely opaque to the thermal radiation i.e. do not transmit heat radiations incident on them, are known as athermanous substances.

2) Diathermanous substance – Substance through which heat radiations can pass is known as a diathermanous substance.

5)



Ferry's blackbody.

6) $T_1 = 727 + 273 = 1000$ K, $T_2 = 227 + 273 = 500$ K, we have $(dQ/dT) = \sigma AeT^4$

Therefore, $(dQ/dT)_1/(dQ/dT)_2 = (T_1/T_2)^4 = (1000/500)^4 = 2^4 = 16$

7) $= \frac{Q_a}{Q} = \frac{400}{1000} = 0.4$, By Kirchoff's law of radiation $a = e = 0.4$

8) $E = \frac{Q}{At} = \frac{P}{A} = \frac{10}{6 \times (4\times10^{-2})^2} = 1041.66\, J/s\, m^2$

9) (Ans. pg. no. 69, fig 3.5)

10) t = half a minute = 30 s, A = 200 cm^2 = 2 x 10^{-2} m^2, T = 273 + 127 = 400 K,

$\sigma = 5.7 \times 10^{-8}$ W/m^2 K^4, The energy radiated =

$Q = \sigma A T^4 t = 5.7 \times 10^{-8} \times 2 \times 10^{-2} \times (400)^4 \times 30 = 875.5$ J

Short Answers (3 marks each)

1) Ans pg. no. 59-60
2) Ans pg. no. 60
3) Ans pg. no. 64
4) Ans pg. no. 66
5) T_1 = 627 ºC = 627 + 273 = 900 K, T_2 = 127 ºC = 127 + 273 = 400 K,

   T_o = 27 ºC = 27 + 127 = 300 K

   $R \ \alpha \ (T_1^4 - T_o^4)$

   Therefore, $\frac{R_1}{R_2} = \frac{\left(T_1^4 - T_o^4\right)}{\left(T_2^4 - T_o^4\right)} = \frac{810000-90000}{160000-90000} = \frac{10.28}{1}$

6) $N_o = 6.03 \times 10^{26}$ molecules/kmole = 6.03×10^{23} molecules/mole

   T = 227 ºC = 227 + 273 = 500 K, R = 8.310 J/mole K, M = 28

   (i) K.E. per mole = $\frac{3}{2}RT = \frac{3}{2} \times 8.310 \times 500 = 6.232 \times 10^3$ J/mole

   (ii) K.E. per kilogram = $\frac{3RT}{2M} = \frac{6.323\times10^3}{28} = 0.225\times10^3$ J/kg

   (iii) K.E. per kmole = $\frac{3RT}{2N_o} = \frac{6.323\times10^3}{6.03\times10^{26}} = 1.048\times10^{-23}$ J

7) $V_1 = 2$ km s^{-1}, $V_2 = 4$ km s^{-1}, $V_3 = 6$ km s^{-1}

   (i) mean square velocity, $\underline{V^2} = \frac{V_1^2+V_2^2+V_3^2}{N} = \frac{4+16+36}{3} = 18.66$ km s^{-1}

   (ii) root mean square velocity, $V_{rms} = \sqrt{\underline{V^2}} = \sqrt{18.66} = 4.319$ km s^{-1}

8) Ans pg. no. 68 - 69
9) Ans pg. no. 61, 63
10) Ans pg. no. 64

Long Answers (4 marks each)

1) Ans pg. no. 69 - 70
2) Ans pg. no. 58 - 59
3) Ans pg. no. 62 - 63

4 Thermodynamic

Answers to MCQ (One-mark questions)

1. system gains energy
2. Open
3. in thermal equilibrium
4. adiabatic
5. 4 J   Q = 10J, W = F x s = 3 x 2 = 6J, therefore $\Delta U = Q - W = 10 - 6 = 4J$
6. Heat
7. isochoric
8. energy
9. isobaric
10. 5 $W/Q_c = 20\% = 0.2$,   therefore $C_{op} = Q_c/W = 1/0.2 = 5$

Answers of VSA (one-mark questions)

1. When two objects are at the same temperature.
2. Thermometry
3. Systems in thermal equilibrium are at the same temperature.
4. Internal energy
5. Thermodynamic system
6. Thermodynamic system can be classified on the basis of the possible transfer of heat and matter to environment.
7. The thermodynamic process is a process in which the thermodynamic state of a system is changed.
8. Heat is defined as the energy that is transferred between the system and its environment due to a temperature difference that exist between the two.
9. increases by the amount, $\Delta U = Q$
10. When the system does some work to increase its volume, and no heat is added to it while expanding.
11. The change in the internal energy of the system is the difference between the heat supplied to the system and the work done by the system on its surrounding.
12. $\Delta U = Q - W = 100 - 80 = 20$ kJ

Short Answers (2 marks each)

1) Draw p-V diagram of reversible process. (Ans pg. no.88, fig 4.14(a))

2) Draw a p-V diagram of the irreversible process. (Ans pg. no. 89 fig 4.13(b))

3) Draw a p-V diagram showing positive work with varying pressure. (Ans pg. no.85, fig 4.11(a))

4) Draw a p-V diagram showing negative work with varying pressure. (Ans pg. no.85, fig 4.11(b))

5) Draw a p-V diagram showing positive work at constant pressure. (Ans pg. no.85, fig 4.11(c))

6) $W = nRTln\left(\frac{V_f}{V_i}\right) = 3\times8.319\times400\times \ln ln\left(\frac{8}{4}\right) = 6919\,J = 6.919\,kJ$

7) $P_f = P_i\left(\frac{V_i}{V_f}\right)^{\gamma} = (1.01\times10^5 \times (10)^{1.4} = 25.37\times10^5\,Pa$

8) The cyclic process. (Ans pg. no.95)

9) Differentiate between reversible and irreversible processes. (Ans pg. no.88)

10) The assumptions made for thermodynamic processes. (Ans pg. no.89)

11) Pressure of one atm, p = 1.01×10^5 Pa, change in volume, $(V_f - V_i) = 0.5$

$W = p(V_f - V_i) = 1.01 \times 10^5 \times 0.5 = 5.05 \times 10^5$ J

13) The change in internal energy of a thermodynamic system (the gas) by heating it. (Ans pg. no.79)

14) Expression for work done by a gas in an isothermal process. (Ans pg. no.90)

15) $T_C = 250$ K and $T_H = 300$ K, $k = \frac{T_C}{T_H - T_C} = 5$

16) $\eta = 75\% = 0.75$ and TH = 727°C = 727 + 273 = 1000 K

$\eta = 1 - \frac{T_C}{T_H}$, TC = 250 K = (250 – 273) °C = - 23°C

K=0.3333

Short Answers (3 marks each)

1. Ans pg. no.77-78
2. Ans pg. no.79
3. Ans pg. no.79
4. Ans pg. no.83
5. Ans pg. no.85
6. Ans pg. no.95
7. $W = P(Vf - Vi) = 1.013 \times 10^5(1671 \times 10^{-6} - 1 \times 10^{-6}) = 169$ J

The heat (Q) required to convert 1 g of water into vapour state is,

Q = mL = 1 x 2256 = 2256 J.

According to first law of thermodynamics,

$\Delta U = Q - W = 2256 - 169 = 2087$ J

8. $T_1 = 15 + 273 = 288$ K, $V_2 = 8V_1$

As helium suddenly expands, it is adiabatic expansion.

Therefore, $T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} = 288\left(\frac{V_1}{8V_1}\right)^{\gamma-1} = 71.99\,K = -201.01$ ºC

Fall in temperature = Final temperature – Initial temperature = – 201.01 – 15 = – 216.01 ºC

9. When gas is compressed adiabatically, work done W is given by,

$$W = \frac{R}{\gamma-1}\left(T_1 - T_2\right) = \frac{8.31}{1.5-1}(300 - 370) = -11.63 \times 10^2 \text{ J}$$

Heat produced, $Q = \frac{W}{J} = \frac{11.63 \times 10^2}{4.2} = 277$ cal

10. Ans pg. no.97

Long Answers (4 marks each)

1) First law of thermodynamics and derive the relation between the change in internal energy (ΔU), work done (W) and heat (Q). (Ans pg. no.81)

2) Work done during a thermodynamic process. (Ans pg. no.86)

3) Thermodynamics of isobaric process. (Ans pg. no.91)

4)Thermodynamics of isochoric process. (Ans pg. no.92)

5) Thermodynamics of adiabatic process. (Ans pg. no.93)

5 Oscillations

Answers of MCQ (One-mark questions)

1. b. $2\pi nt + \propto$
2. a. Zero
3. a. 300
4. d. gradually decreasing
5. d. zero
6. d. $\sqrt{2}$ A $Hint : R = \sqrt{A_1^2 + A_2^2 + 2A_1A_2 \cos cos\left(\phi_1 - \phi_2\right)}$;
   $\left(\phi_1 - \phi_2\right) = 90°$
7. a. 8J [Hint : $K.E_{max} = \frac{1}{2} m\,\omega^2 A^2$; m=1kg; ω=100;A=4 x 10^{-2}m]
8. d. Remains same
9. c. g/π^2
10. a. 0.1

Answers of VSA (one-mark questions)

1. The maximum displacement of a particle performing S.H.M. on either side of its mean position is called the amplitude of S.H.M.
2. $I\frac{d^2\theta}{dt^2} + c\theta = 0$
3. Damping increases period of oscillation
4. Linear S.H.M. is defined as the linear periodic motion of a body, in which force (or acceleration) is always directed towards the mean position and its magnitude is proportional to the displacement from the mean position
5. Mean position
6. π/2 radian
7. A simple pendulum whose period is two seconds is called second's pendulum
8. 3.142 m/s [$Hint : v = \frac{dx}{dt} = \frac{6\pi}{3} cos\left[\frac{\pi}{3} \times 1\right] = \frac{6\pi}{6} = 3\cdot142\ m/s$]
9. 1/6m
10. 1 m/s^2 Hint : $|a| = \left[\frac{k}{m}\right]x = \frac{5 \times 0.04}{0.2} = 1 m/s^2$

Short Answers (2 marks each)

1. Text book pg. no 123 (answer any two laws)

   (a) The period of a simple pendulum is directly proportional to the square root of its length.

   (b) The period of a simple pendulum is inversely proportional to the square root of acceleration due to gravity.

   (c) The period of a simple pendulum does not depend on its mass.

   (d) The period of a simple pendulum does not depend on its amplitude (for small amplitude).

2. Text book pg. no 111 & 112 Art. 5.4

In a linear S.H.M., the force is directed towards the mean position and its magnitude is directly proportional to the displacement of the body from mean position. As seen in Eq. (5.1),

$$f = -kx$$

where k is force constant and x is displacement from the mean position.

According to Newton's second law of motion,

$$f = ma \quad \therefore ma = -kx \qquad \text{--- (5.3)}$$

The velocity of the particle is, $v = \frac{dx}{dt}$

and its acceleration, $a = \frac{dv}{dt} = \frac{d^2x}{dt^2}$

Substituting it in Eq. (5.3), we get

$$m\frac{d^2x}{dt^2} = -kx$$

$$\therefore \frac{d^2x}{dt^2} + \frac{k}{m}x = 0 \qquad \text{--- (5.4)}$$

Substituting $\frac{k}{m} = \omega^2$, where ω is the angular frequency,

$$\frac{d^2x}{dt^2} + \omega^2 x = 0 \qquad \text{--- (5.5)}$$

Eq. (5.5) is the differential equation of linear S.H.M.

3. Text book pg. no 125; Art. 5.13

for the angular S.H.M. of a body, the restoring torque acting upon it, for angular displacement θ, is

$$\tau \propto -\theta \text{ or } \tau = -c\theta \qquad \text{--- (5.31)}$$

The constant of proportionality c is the restoring torque per unit angular displacement. If I is the moment of inertia of the body, the torque acting on the body is given by, $\tau = I\alpha$ Where α is the angular acceleration. Using this in Eq. (5.31) we get, $I\alpha = -c\theta$

$$\therefore I\frac{d^2\theta}{dt^2} + c\theta = 0 \qquad \text{--- (5.32)}$$

4. Text book pg. no 123 Art. 5.12.1

A simple pendulum whose period is two seconds is called *second's pendulum*.

$$\text{Period } T = 2\pi\sqrt{\frac{L}{g}}$$

$$\therefore \text{For a second's pendulum, } 2 = 2\pi\sqrt{\frac{L_s}{g}}$$

where L_s is the length of second's pendulum, having period T = 2s.

$$\therefore L_s = \frac{g}{\pi^2} \qquad \text{--- (5.30)}$$

5. Text book pg. no 126 Fig. 5.13

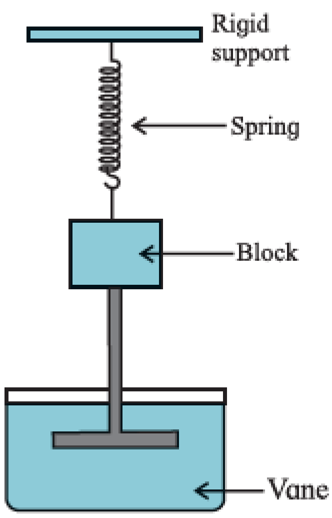


Fig. 5.13: A damped oscillator.

6. Text book pg. no 114

magnitude of velocity of the particle performing S.H.M. is $v = \pm\omega\sqrt{A^2 - x^2}$

At the mean position, $x = 0 \therefore v_{max} = \pm A\omega$.

Thus, the velocity of the particle in S.H.M. is maximum at the mean position.

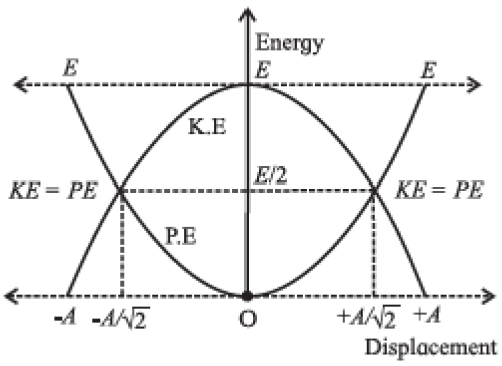
At the extreme position, $x = \pm A \;\therefore\; v_{min} = 0$.

Thus, the velocity of the particle in S.H.M. is minimum at the extreme positions.

7. Text book pg. no 124 (Write any two points of distinguish)

	Conical pendulum	Simple pendulum
1	Trajectory and the plane of the motion of the bob is a horizontal circle	Trajectory and the plane of motion of the bob is part of a vertical circle.
2	K.E. and gravitational P.E. are constant.	K.E. and gravitational P.E. are interconverted and their sum is conserved.
3	Horizontal component of the force due to tension is the necessary centripetal force (governing force).	Tangential component of the weight is the governing force for the energy conversions during the motion.
4	Period, $T = 2\pi\sqrt{\frac{L\cos\theta}{g}}$	Period, $T = 2\pi\sqrt{\frac{L}{g}}$
5	String always makes a fixed angle with the horizontal and can never be horizontal.	With large amplitude, the string can be horizontal at some instances.

8. Text book pg. no 122 (Fig. 5.9)



9. Text book pg. no 121

The total energy of a particle in S.H.M. is given as $E = 2\pi^2 mA^2/T^2$

$$E = 2\pi^2 m \frac{A^2}{T^2} \quad \text{--- (5.25)}$$

Thus, the total energy in S.H.M. is directly proportional to (a) the mass of the particle (b) the square of the amplitude (c) the square of the frequency (d) the force constant, and inversely proportional to square of the period.

(Write any two factors)

10. $v = \omega\sqrt{A^2 - x^2}$; $v_{max} = \boldsymbol{\omega}A$

$$v = \frac{vmax}{2}$$

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

$$x = \frac{\sqrt{3}}{2} A = \frac{5\sqrt{3}}{2} = 4.33\ cm$$

Distance ,x = 4.33 cm

11. compare given equation with $\frac{d^2x}{dt^2}$ = - $x\,\boldsymbol{\omega}^2$; $\boldsymbol{\omega}^2$= 100; =10 rad/s

= $2\boldsymbol{\pi}$n=10 ; n=10 /2π =1.5913 Hz

n=1.5913 Hz

T=1/n =0.6284 s

T=0.6284 s

12. $\frac{a\,max}{v\,max} = \frac{A\omega^2}{A\omega}$ = = 64/16 = 4 rad/s

$$\boldsymbol{\omega} = \frac{2\pi}{T} = 4$$

T = 1.571 s

13. K.E = 3P.E

$\frac{1}{2}$ k[A^2 - x^2] = 3 [$\frac{1}{2}$ kx^2] ; [A^2 - x^2] = 3 x^2 ; A^2 = 4 x^2

x= A/2 =16/2 = 8 cm

14. T = 1/n = π/2

$$T = 2\pi\sqrt{\frac{I}{\mu B}}$$

¼ = $\sqrt{\frac{I}{\mu B}}$ (squaring on both sides)

$$B = \frac{I\,x 16}{\mu} = \frac{3\,x\,10^{-6}\,x\,\,16}{3} = 1.6 \text{ x } 10^{-5} \text{ T}$$

Magnetic field, B = 1.6 x 10^{-5} T

15. k=f/x =10/0.05 = 200

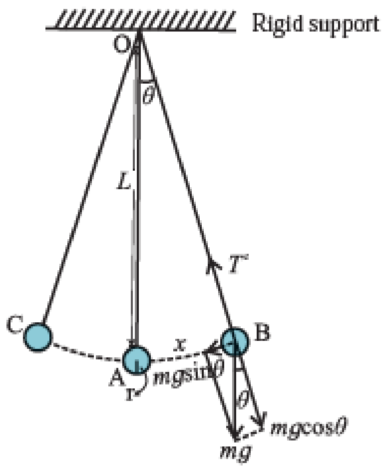
$$T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{2}{200}} = 2\pi/10 = 0.6284 \text{ s}$$

T = 0.6284 s

Short Answers (3 marks each)

1.Text book pg. no 122 and 123;5.12

*Diagram [fig 5.10]



* Explanation

★ Let m be the mass of the bob and T' be the tension in the string. The pendulum remains in equilibrium in the position OA, with the centre of gravity of the bob, vertically below the point of suspension O.

★ If now the pendulum is displaced through a small angle Θ (called angular amplitude) and released, it begins to oscillate on either side of the mean (equilibrium) position in a single vertical plane.

★ In the displaced position (extreme position), two forces are acting on the bob.

(i) Force T' due to tension in the string, directed along the string, towards the support

and

(ii) Weight mg, in the vertically downward direction.

★ At the extreme positions, there should not be any net force along the string. *The component of mg can only balance the force due to tension. Thus, weight mg is resolved into two components;

(i) The component mg cosθ along the string, which is balanced by the tension T ' and

(ii) The component mg sinθ perpendicular to the string is the restoring force acting on mass m tending to return it to the equilibrium position.

$\therefore$ Restoring force, $F = -\, mg \sin\theta$ --- (5.26)

As θ is very small ($\theta < 10°$), we can write

$\sin\theta \cong \theta^c \quad \therefore F \cong -mg\theta$

From the Fig. 5.10, the small angle $\theta, = \frac{x}{L}$

$$\therefore\ F = -mg\frac{x}{L} \qquad \text{--- (5.27)}$$

As m, g and L are constant, $F \propto -\,x$

Thus, for small displacement, the restoring force is directly proportional to the displacement and is oppositely directed.

Hence the bob of a simple pendulum performs linear S.H.M. for small amplitudes.

From Eq. (5.15), the period T of oscillation of a pendulum from can be given as,

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

$$= \frac{2\pi}{\sqrt{acceleration\ per\ unit\ displacement}}$$

Using Eq. (5.27), $F = -mg\frac{x}{L}$

$$\therefore\ ma = -mg\frac{x}{L}$$

$$\therefore\ a = -g\frac{x}{L}\ \therefore\ \frac{a}{x} = -\frac{g}{L} = \frac{g}{L}\ \text{(in magnitude)}$$

Substituting in the expression for T, we get,

$$T = 2\pi\sqrt{\frac{L}{g}} \qquad \text{--- (5.28)}$$

The Eq. (5.28) gives the expression for the time period of a simple pendulum.

2. Text book pg. no 125 and 126;5.13.1

   5.13.1 Magnet Vibrating in Uniform Magnetic Field:

   - ★ If a bar magnet is freely suspended in the plane of a uniform magnetic field, it remains in equilibrium with its axis parallel to the direction of the field.
   - ★ If it is given a small angular displacement θ (about an axis passing through its centre, perpendicular to itself and to the field) and released, it performs angular oscillations).
   - ★ Let ⌠ be the magnetic dipole moment and B the magnetic field.
   - ★ In the deflected position, a restoring torque acts on the magnet, that tends to bring it back to its equilibrium position.

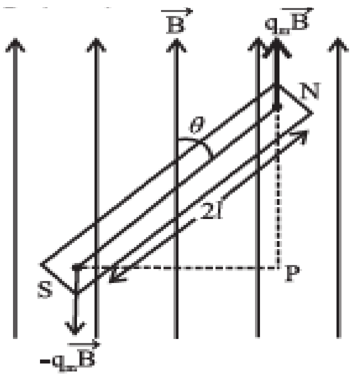


Fig. 5.12: Magnet vibrating in a uniform magnetic field.

$$\therefore \quad \tau = I\alpha = -\mu B\theta$$

where I is the moment of inertia of the bar magnet and α is its angular acceleration.

$$\therefore \alpha = -\left(\frac{\mu B}{I}\right)\theta \qquad \text{--- (5.33)}$$

Since μ, B and I are constants, Eq. (5.33) shows that angular acceleration is directly proportional to the angular displacement and directed opposite to the angular displacement. Hence the magnet performs angular S.H.M.

The magnitude of this torque is $\tau = \mu B sin\theta$

If θ is small, $\sin\theta \cong \theta^c$ $\therefore \tau = \mu B\theta$

For clockwise angular displacement θ, the restoring torque is in the anticlockwise direction.

3. Page No. 116,117 Art. 5.7

*Figure 5.4 shows the anticlockwise uniform circular motion of a particle P, with centre at the origin O. Its angular positions are decided with the reference OX.

*It means, if the particle is at E, the angular position is zero, at F it is 90° = $\pi^c/2$ at G it is 180° = π^c, and so on. If it comes to E again, it will be 360° = $2\pi^c$

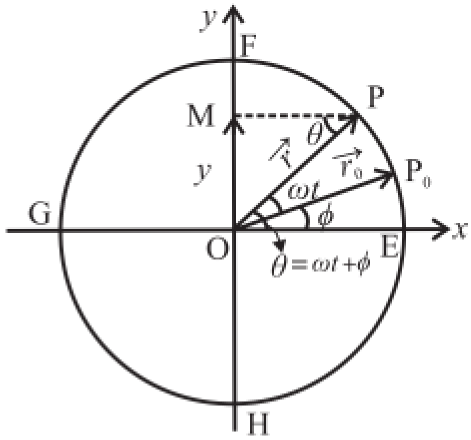


Fig 5.4: S.H.M. as projection of a U.C.M.

*r = OP be the position vector of this particle.

At t = 0, let the particle be at P_0 with reference angle ϕ. During time t, it has angular displacement ωt. Thus, the reference angle at time t is $\theta = (\omega t + \phi)$. Let us choose the diameter FH along y-axis as the reference diameter and label OM as the projection of $\vec{r}$ = OP on this.

***Projection of displacement*:** At time t, we get the projection or the position vector $\text{OM} = \text{OP}\sin\theta = y = r\sin(\omega t + \phi)$. This is the equation of linear S.H.M. of amplitude r.

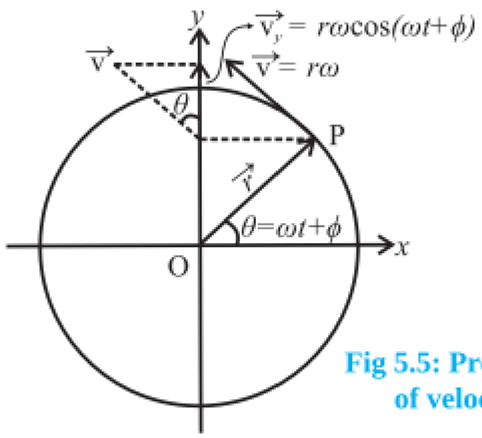


Fig 5.5: Projection of velocity.

***Projection of velocity*:** Instantaneous velocity of the particle P in the circular motion is the tangential velocity of magnitude $r\omega$ as shown in the Fig. 5.5.

Its projection on the reference diameter will be $v_y = r\omega\cos\theta = r\omega\cos(\omega t+\phi)$. This is the expression for the velocity of a particle performing a linear S.H.M.

***Projection of acceleration*:** Instantaneous acceleration of the particle P in circular motion is the radial or centripetal acceleration of magnitude $r\omega^2$, directed towards O. Its projection on the reference diameter will be

$a_y = -r\omega^2\sin\theta = -r\omega^2\sin(\omega t+\phi) = -\omega^2 y$.

Again, this is the corresponding acceleration for the linear S.H.M.

From this analogy it is clear that projection of any quantity for a uniform circular motion gives us the corresponding quantity of linear S.H.M. This analogy can be verified for any diameter as the reference diameter. Thus, the projection of a U.C.M. on any diameter is an S.H.M.

4. pg. no. 118 and 119 Art. 5.9a

5.9. Graphical Representation of S.H.M.:

(a) Particle executing S.H.M., starting from mean position, towards positive:

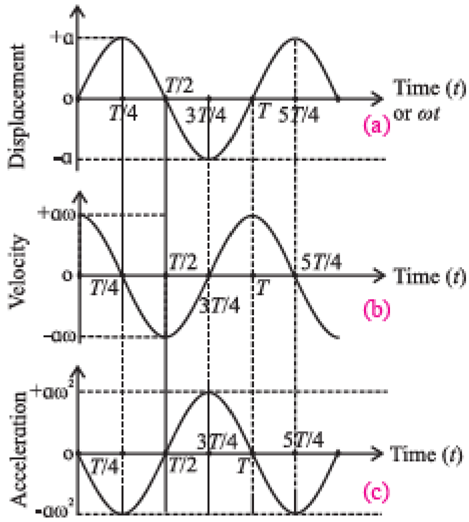
As the particle starts from the mean position Fig (5.6), towards positive, $\phi = 0$

$\therefore$ displacement $x = A\sin\omega t$

Velocity $v = A\omega\cos\omega t$

Acceleration $a = -A\omega^2\sin\omega t$

(t)	0	$T/4$	$T/2$	$3T/4$	T	$5T/4$
(θ)	0	$\frac{\pi}{2}$	π	$\frac{3\pi}{2}$	2π	$\frac{5\pi}{2}$
(x)	0	A	0	$-A$	0	A
(v)	$A\omega$	0	$-A\omega$	0	$A\omega$	0
(a)	0	$-A\omega^2$	0	$A\omega^2$	0	$-A\omega^2$



5.pg. no. 119 Art. 5.9b

(b) Particle performing S.H.M., starting from the positive extreme position.

As the particle starts from the positive extreme position Fig. (5.7), $\phi = \frac{\pi}{2}$

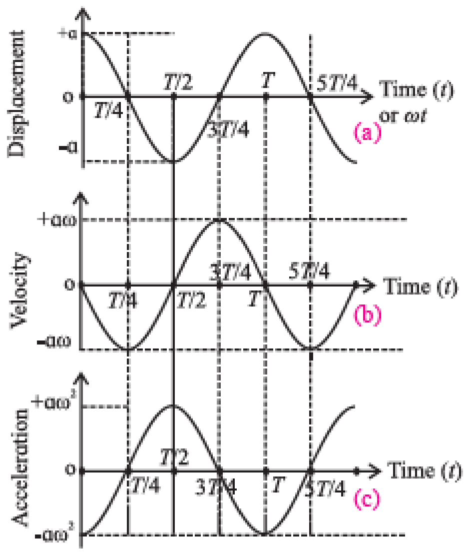
$\therefore$ displacement, $x = A\sin\left(\omega t + \pi/2\right) = A\cos\omega t$

Velocity, $v = \frac{dx}{dt} = \frac{d\left(A\cos\omega t\right)}{dt} = -A\omega\sin\left(\omega t\right)$

Acceleration,

$$a = \frac{dv}{dt} = \frac{d\left(-A\omega\sin\left(\omega t\right)\right)}{dt} = -A\omega^2\cos\left(\omega t\right)$$

(t)	0	$T/4$	$T/2$	$3T/4$	T	$5T/4$
(θ)	$\frac{\pi}{2}$	π	$\frac{3\pi}{2}$	2π	$\frac{5\pi}{2}$	3π
(x)	A	0	$-A$	0	A	0
(v)	0	$-A\omega$	0	$A\omega$	0	$-A\omega$
(a)	$-A\omega^2$	0	$A\omega^2$	0	$-A\omega^2$	0



6. Text book page no. 126 and 127 Art. 5.14

Periodic oscillations of gradually decreasing amplitude are called damped harmonic oscillations.

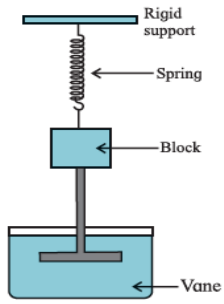


Fig. 5.13: A damped oscillator.

*Consider a block of mass m that can oscillate vertically on a spring. From the block, a rod extends to vane that is submerged on a liquid.

*As the vane moves up and down, the liquid exerts drag force on it, and thus on the complete oscillating system.

*The mechanical energy of the block-spring system decreases with time, as energy is transferred to thermal energy of the liquid and vane.

The damping force (F_d) depends on the nature of the surrounding medium and is directly proportional to the speed v of the vane and the block

$\therefore F_d = -bv$

Where b is the damping constant and negative sign indicates that F_d opposes the velocity.

For spring constant k, the force on the block from the spring is $F_s = -kx$.

Assuming that the gravitational force on the block is negligible compared to F_d and F_s, the total force acting on the mass at any time t is

$$F = F_d + F_s$$

$$\therefore ma = F_d + F_s$$

$$\therefore ma = -bv - kx$$

$$\therefore ma + bv + kx = 0$$

$$\therefore m\frac{d^2x}{dt^2} + b\frac{dx}{dt} + kx = 0 \quad \text{--- (5.35)}$$

The solution of Eq. (5.35) describes the motion of the block under the influence of a damping force which is proportional to the speed.

7. **Ans.** $T = 2\pi\sqrt{\frac{l}{g}}$

$T_1 = 2\pi\sqrt{\frac{l_1}{g}}$

$T_2 = 2\pi\sqrt{\frac{l_2}{g}}$

$\frac{T1}{T2} = \sqrt{\frac{l_1}{l_2}}$

$\frac{100}{120} = \sqrt{\frac{l_1}{l_1+0.44}}$; $l_1 = 1\,m$

Initial length = 1m

$T_1 = 2\pi\sqrt{\frac{l_1}{g}} = 2\pi\sqrt{\frac{1}{9.8}} = 2.007\,s$

Initial period = 2.007 s

1. [$v_1 = \omega\sqrt{A^2 - x_1^2}$; $v_2 = \omega\sqrt{A^2 - x_2^2}$

$$\frac{v_1}{v_2} = \frac{8}{6} = \frac{\sqrt{A^2 - 3^2}}{\sqrt{A^2 - 4^2}}$$

Amplitude (A) = 5 cm

ω = 2 rad/s [Substituting 'A' in v_1 formula]

$T = \frac{2\pi}{\omega} = 3.142$ s

Time period = 3.142 s]

8. Ans :

[$v_1 = \omega\sqrt{A^2 - x_1^2}$ **;** $v_2 = \omega\sqrt{A^2 - x_2^2}$

$$\frac{v_1}{v_2} = \frac{8}{6} = \frac{\sqrt{A^2-3^2}}{\sqrt{A^2-4^2}}$$

Amplitude (A) = 5 cm

ω = 2 rad/s [Substituting 'A' in v_1 formula]

$T = \frac{2\pi}{\omega} = 3.142$ s

Time period = 3.142 s]

9. [m= 100 gm= 0.1 kg ; **ω** =2πn =2πx10=20π rad/s ; A=20/2 =10 cm=0.1m; x =A/2]

(a) T.E $= \frac{1}{2}\, m\, \omega^2 A^2$

T.E $= \frac{1}{2}$ x 0.1 x $(20\pi)^2$x$(0.1)^2$

T.E = 1.974 J

(b) * P.E $= \frac{1}{2}\, m\, \omega^2 x^2 = \frac{1}{4}\, \{\frac{1}{2}\, m\, \omega^2 A^2\}$= 1.974/4 =0.4935J

* P.E =0.4935J
* K.E = T.E-P.E = 1.974-0.4935=1.4805 J

K.E =1.4805 J

10 [$T = 2\pi\sqrt{\frac{I}{\mu B}}$; $\pi = 2\pi\sqrt{\frac{I}{\mu B}}$

$$B = \frac{4I}{\mu}$$

$$I = M\left[\frac{l^2+b^2}{12}\right] = 0.24\left[\frac{5^2+2^2}{12}\right] \times 10^{-4}$$

$$I = 5.8 \times 10^{-5} \text{ A m}^2$$

$$B = [4 \times 5.8 \times 10^{-5}] / 5.8$$

$$B = 4 \times 10^{-5} \text{ T or Wb/ m}^2$$

Long Answers (4 marks each)

1. Textbook pg. no 112 and 113;5.5

5.5 Acceleration (*a*), Velocity (v) and Displacement (*x*) of S.H.M. :

We can obtain expressions for the acceleration, velocity and displacement of a particle performing S.H.M. by solving the differential equation of S.H.M. in terms of displacement *x* and time *t*.

From Eq. (5.5), we have $\frac{d^2x}{dt^2} + \omega^2 x = 0$

$$\therefore \frac{d^2x}{dt^2} = -\omega^2 x \qquad \text{--- (5.6)}$$

But $a = \frac{d^2x}{dt^2}$ is the acceleration of the particle performing S.H.M.

$$\therefore \; a = -\omega^2 x \qquad \text{--- (5.7)}$$

This is the expression for acceleration in terms of displacement x.

From Eq. (5.6), we have $\frac{d^2x}{dt^2} = -\omega^2 x$

$$\therefore \frac{d}{dt}\left(\frac{dx}{dt}\right) = -\omega^2 x$$

$$\therefore \frac{dv}{dt} = -\omega^2 x$$

$$\therefore \frac{dv}{dx} \; \frac{dx}{dt} = -\omega^2 x$$

$$\therefore v\frac{dv}{dx} = -\omega^2 x$$

$$\therefore v\,dv = -\omega^2 x\,dx$$

Integrating both the sides, we get

$$\int v\,dv = -\omega^2 \int x\,dx$$

$$\therefore \frac{v^2}{2} = -\frac{\omega^2 x^2}{2} + C, \qquad \text{--- (5.8)}$$

where C is the constant of integration.

Let A be the maximum displacement (amplitude) of the particle in S.H.M.

When the particle is at the extreme position, velocity (v) is zero.

Thus, at $x = \pm A$, $v = 0$

Substituting in Eq. (5.8), we get

$$0 = -\frac{\omega^2 A^2}{2} + C$$

$$\therefore C = +\frac{\omega^2 A^2}{2} \qquad \text{--- (5.9)}$$

Using C in Eq. (5.8), we get

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

$$\therefore v^2 = \omega^2\left(A^2 - x^2\right)$$

$$\therefore v = \pm\omega\sqrt{A^2 - x^2} \qquad \text{--- (5.10)}$$

This is the expression for the velocity of a particle performing linear S.H.M. in terms of displacement x.

Substituting $v = \frac{dx}{dt}$ in Eq. (5.10), we get

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

$$\therefore \frac{dx}{\sqrt{A^2 - x^2}} = \omega\, dt$$

Integrating both the sides, we get

$$\int \frac{dx}{\sqrt{A^2 - x^2}} = \omega \int dt$$

$$\sin^{-1}\left(\frac{x}{A}\right) = \omega t + \phi \qquad \text{— (5.11)}$$

Here ϕ is the constant of integration. To know ϕ, we need to know the value of x at any instance of time t, most convenient being $t = 0$.

$$\therefore x = A \sin(\omega t + \phi) \qquad \text{— (5.12)}$$

This is the general expression for the displacement (x) of a particle performing linear S.H.M. at time t.

2. Textbook pg. no 119 and 120; Art. 5.10

5.10 Composition of two S.H.M.s having same period and along the same path:

Consider a particle subjected simultaneously to two S.H.M.s having the same period and along same path (let it be along the x-axis), but of different amplitudes and initial phases. The resultant displacement at any instant is equal to the vector sum of its displacements due to both the S.H.M.s at that instant.

Equations of displacement of the two S.H.M.s along same straight line (x-axis) are

$x_1 = A_1 \sin(\omega t + \phi_1)$ and $x_2 = A_2 \sin(\omega t + \phi_2)$

The resultant displacement (x) at any instant (t) is given by $x = x_1 + x_2$

$$x = A_1 \sin(\omega t + \phi_1) + A_2 \sin(\omega t + \phi_2)$$

$$\therefore x = A_1 \sin\omega t \cos\phi_1 + A_1 \cos\omega t \sin\phi_1 + A_2 \sin\omega t \cos\phi_2 + A_2 \cos\omega t \sin\phi_2$$

A_1, A_2, ϕ_1 and ϕ_2 are constants and ωt is variable. Thus, collecting the constants together,

$$x = (A_1 \cos\phi_1 + A_2 \cos\phi_2)\sin\omega t + (A_1 \sin\phi_1 + A_2 \sin\phi_2)\cos\omega t$$

As A_1, A_2, ϕ_1 and ϕ_2 are constants, we can combine them in terms of another convenient constants R and δ as

$$R\cos\delta = A_1\cos\phi_1 + A_2\cos\phi_2 \quad \text{--- (5.17)}$$

and $\quad R\sin\delta = A_1\sin\phi_1 + A_2\sin\phi_2 \quad$ --- (5.18)

$\therefore x = R(\sin\omega t\cos\delta + \cos\omega t\sin\delta)$

$\therefore \; x = R\sin(\omega t + \delta)$

This is the equation of an S.H.M. of the same angular frequency (hence, the same period) but of amplitude R and initial phase δ. It shows that the combination (superposition) of two linear S.H.M.s of the same period and occurring a long the same path is also an S.H.M.

Resultant amplitude,

$$R = \sqrt{(R\sin\delta)^2 + (R\cos\delta)^2}$$

Substituting from Eq. (5.17) and Eq. (5.18), we get

$R^2 = A_1^2 + A_2^2 + 2A_1A_2\cos(\phi_1 - \phi_2)$

$\therefore R = \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos(\phi_1 - \phi_2)}$ - (5.19)

Initial phase (δ) of the resultant motion: Dividing Eq. (5.18) by Eq. (5.17), we get

$$\frac{R\sin\delta}{R\cos\delta} = \frac{A_1\sin\phi_1 + A_2\sin\phi_2}{A_1\cos\phi_1 + A_2\cos\phi_2}$$

$$\therefore \tan\delta = \frac{A_1\sin\phi_1 + A_2\sin\phi_2}{A_1\cos\phi_1 + A_2\cos\phi_2}$$

$$\therefore \delta = \tan^{-1}\left(\frac{A_1\sin\phi_1 + A_2\sin\phi_2}{A_1\cos\phi_1 + A_2\cos\phi_2}\right) \quad \text{--- (5.20)}$$

Special cases: (i) If the two S.H.M.s are in phase, $(\phi_1 - \phi_2) = 0^\circ$, $\therefore \cos(\phi_1 - \phi_2) = 1$.

$\therefore R = \sqrt{A_1^2 + A_2^2 + 2A_1A_2} = \pm(A_1 + A_2)$. Further, if $A_1 = A_2 = A$, we get $R = 2A$

(ii) If the two S.H.M.s are 90° out of phase, $(\phi_1 - \phi_2) = 90^\circ$ $\therefore \cos(\phi_1 - \phi_2) = 0$.

$\therefore \; R = \sqrt{A_1^2 + A_2^2}$ Further, if $A_1 = A_2 = A$, we get, $R = \sqrt{2}A$

3. Text book pg. no 120 and 121, Art. 5.11

Consider a particle of mass m, performing a linear S.H.M. along the path MN about the mean position O. At a given instant, let the particle be at P, at a distance x from O.

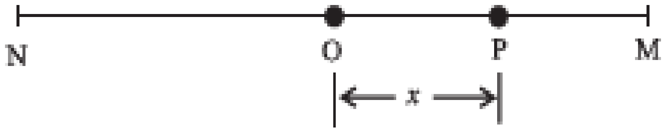


Fig. 5.8: Energy in an S.H.M.

Velocity of the particle in S.H.M. is given as $v = \omega\sqrt{A^2 - x^2} = A\omega\cos(\omega t + \phi)$,

where x is the displacement of the particle performing S.H.M. and A is the amplitude of S.H.M.

Thus, the kinetic energy,

$$E_k = \frac{1}{2}m\omega^2\left(A^2 - x^2\right) = \frac{1}{2}k\left(A^2 - x^2\right) \text{---} (5.21)$$

This is the kinetic energy at displacement x.

The restoring force acting on the particle at point P is given by $f = -kx$ where k is the force constant. Suppose that the particle is displaced further by an infinitesimal displacement dx against the restoring force f. The external work done (dW) during this displacement is

$$dW = f(-dx) = -kx(-dx) = kx\,dx$$

The total work done on the particle to displace it from O to P is given by

$$W = \int_0^x dW = \int_0^x kx\,dx = \frac{1}{2}kx^2$$

This should be the potential energy (P.E.) E_p of the particle at displacement x.

$$\therefore E_p = \frac{1}{2}kx^2 = \frac{1}{2}m\omega^2x^2 \qquad \text{--- (5.23)}$$

At time t, it is

$$E_p = \frac{1}{2}kx^2 = \frac{1}{2}kA^2\sin^2(\omega t + \phi)$$

$$= \frac{1}{2}mA^2\omega^2\cos^2(\omega t + \phi)$$

Thus, with time, it varies as $\sin^2\theta$.

The total energy of the particle is the sum of its kinetic energy and potential energy.

$$\therefore E = E_k + E_p$$

Using Eq. (5.21) and Eq. (5.23), we get

$$E = \frac{1}{2}m\omega^2(A^2 - x^2) + \frac{1}{2}m\omega^2x^2$$

$$E = \frac{1}{2}m\omega^2A^2 = \frac{1}{2}kA^2 = \frac{1}{2}m(\mathrm{v}_{max})^2 \qquad \text{---(5.24)}$$

This expression gives the total energy of the particle at point P

6 Superposition of waves

Answers to MCQ (One-mark questions)

1. c. $\frac{1}{2(n1-n2)}$
2. b. Frequency
3. c. ⌊/4
4. d. 5
5. a. $\sqrt{T}$
6. c. 0.6
7. d. 200
8. a. 2:3
9. d. 357 m/s
10. b. 128

Answers of VSA (one-mark questions)

1. In a stationary wave, the point at which the amplitude of the particle of the media is maximum are called antinodes
2. ***π*** radian
3. The wave is moving in the negative direction of X-axis
4. Loudness is the human perception of intensity of sound. (text book pg. no 153)
5. ⌊/2
6. When two identical waves travelling along the same path in opposite directions interfere with each other, the resultant wave is called a stationary wave.
7. 1000 Hz Hint:[second overtone of pipe closed at one end = 5 x fundamental]
8. 0.25 m Hint: (⌊=v/n=48/96= 0.5 m ; distance between two nodes=⌊/2 = 0.25 m)
9. 400 Hz [third overtone of pipe open at both ends = 4 x fundamental]
10. 66 cm Hint [$l = \frac{3}{2}\lambda$; ⌊= 2 x 99/3 = 66 cm]

Answers of SHORT ANSWER TYPE - I - 2 MARKS EACH

1. Text book pg. no 131 and 132 ; Art. 6.2.1

   Write any four characteristics of progressive waves

   6.2.1 Properties of progressive waves:

1) Each particle in a medium executes the same type of vibration. Particles vibrate about their mean positions performing simple harmonic motion.
2) All vibrating particles of the medium have the same amplitude, period and frequency.
3) The phase, (i.e., state of vibration of a particle), changes from one particle to another.
4) No particle remains permanently at rest. Each particle comes to rest momentarily while at the extreme positions of vibration.
5) The particles attain maximum velocity when they pass through their mean positions.
6) During the propagation of the wave, energy is transferred along the wave. There is no transfer of matter.
7) The wave propagates through the medium with a certain velocity. This velocity depends upon properties of the medium.
8) Progressive waves are of two types - transverse waves and longitudinal waves.
9) In a transverse wave, vibrations of particles are perpendicular to the direction of propagation of waves and produce crests and troughs in their medium of travel.

   In a longitudinal wave, vibrations of particles produce compressions and rarefactions along the direction of propagation of the wave.
10) Both, the transverse as well as the longitudinal, mechanical waves can propagate through solids but only longitudinal waves can propagate through fluids.

2. Text book pg. no 141 ; 6.7

   Harmonics:

   The term Harmonics is used when the frequency of a particular overtone is an integral multiple of the fundamental frequency.

   Overtone:

   The tones whose frequencies are greater than the fundamental frequency are called Overtones.

3. Text book pg. no 139 and 140 ; 6.5.3

   Write any four properties of stationary waves

   6.5.3 Properties of Stationary Waves:

1) Stationary waves are produced due to superposition of two identical waves (either transverse or longitudinal waves) travelling through a medium along the same path in opposite directions.
2) If two identical transverse progressive waves superimpose or interfere, the resultant wave is a transverse stationary wave as shown in Fig. 6.8 (a).
   - When a transverse stationary wave is produced on a string, some points on the string are motionless. The points which do not move are called nodes.
   - There are some points on the string which oscillate with greatest amplitude (say A). They are called antinodes.
   - Points between the nodes and antinodes vibrate with values of amplitudes between 0 and A.
3) If two identical longitudinal progressive waves superimpose or interfere, the resultant wave is a longitudinal stationary wave. Figure 6.8 (b) shows a stationary sound wave produced in a pipe closed at one end.
   - The points, at which the amplitude of the particles of the medium is minimum (zero), are called nodes.
   - The points, at which the amplitude of the particles of the medium is maximum (say A), are called antinodes.
   - Points between the nodes and antinodes vibrate with values of amplitudes between 0 and A
4) The distance between two consecutive nodes is ⌊/2 and the distance between

   two successive antinodes is ⌊/2
5) Nodes and antinodes are produced alternately. The distance between a node consecutive antinodes is $\lambda/4$
6) The amplitude of vibration varies periodically in space. All points vibrate with the same frequency.
7) Though all the particles (except those at the nodes) possess energy, there is no propagation of energy. The wave is localized and its velocity is zero. Therefore, we call it a stationary wave.
8) All the particles between adjacent nodes (i.e., in one loop) vibrate in phase. There is no progressive change of phase from one particle to another particle.

All the particles in the same loop are in the same phase of oscillation, which reverses for the adjacent loop.

4. Text book pg. no 140 and 141 ; 6.6 (Write any two distinguish points)

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 when an external periodic force of any frequency
2.	To start free vibrations, the force is required initially only.	Continuous external periodic force is required. If external periodic force is stopped, then forced vibrations are stopped.
3.	The frequency of free vibration depends upon the natural frequency	The frequency of forced vibration depends upon the frequency of the external periodic force.
4.	Amplitude of vibrations decreases with time.	Amplitude is small but remains constant as long as external periodic forces act on it.

5. When there is a superposition of two sound waves, having the same amplitude but slightly different frequencies, travelling in the same direction, the intensity of sound varies periodically with time. This phenomenon is known as the production of beats.
   Applications of beats (Write any two)
   1. The phenomenon of beats is used for matching the frequencies of different musical instruments by artists.
   2. The speed of an aeroplane can be determined by using Doppler RADAR.
   3. The unknown frequency of a sound note can be determined by using the phenomenon beats.
6. Text book pg. no 134 ; 6.3.2
   - ★ Consider a longitudinal wave travelling from a rarer medium to a denser medium.

★ In a longitudinal wave compression is a high pressure region while rarefaction is a low pressure region.

★ When compression reaches the denser medium, it tries to push the particles of that medium.

★ According to Newton's third law of motion, an equal and opposite reaction comes into play. As a result, the particles of the rarer medium get compressed.

★ Thus, when the longitudinal wave travels from a rarer medium to a denser medium, a compression is reflected as a compression and a rarefaction is reflected as a rarefaction.

★ There is no change of phase during this reflection

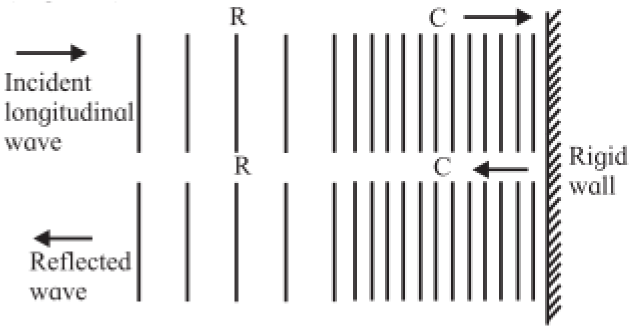


Fig. 6.4: Reflection of a longitudinal wave from a denser medium.

7. Text book pg. no 132 and 133 ; 6.3.1

6.3.1 Reflection of a Transverse Wave:

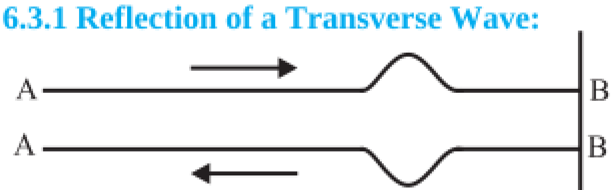


Fig. 6.1: Reflection of a wave pulse sent as a crest from a rarer medium to a denser medium.

★ Consider a long light string AB whose one end B is fixed to a rigid support and the other end A is free, where a jerk is given, so a crest is generated in the string.

★ When the crest moves along the string towards B, it pulls the particles of string in upward direction.

★ Similarly when the crest reaches B at rigid support, it tries to pull the point B upwards.

★ But being a rigid support, B remains at rest and an equal and opposite reaction is produced on the string according to Newton's third law of motion.

- ★ The string is pulled downwards. Thus a crest gets reflected as a trough or a trough gets reflected as a crest.
- ★ So we can conclude that when a transverse wave is reflected from a denser medium, a crest is reflected as a trough and a trough is reflected as a crest.
- ★ There is a phase difference of π radian between the particles at a crest and at a trough. Therefore there is a phase change of π radian on reflection from a denser medium.

8. Text book pg. no 144 ; Art. 6.7.4

For a pipe closed at one end:

$$v = 4n_1L_1 = 4n_2L_2$$

$$\therefore n_1L_1 = n_2L_2$$

$$\therefore n_1(l_1 + e) = n_2(l_2 + e)$$

$$e = \frac{n_1l_1 - n_2l_2}{(n_2 - n_1)}$$

9. Text book pg. no 144 ; 6.7.4

For a pipe open at both ends:

$$v = 2n_1L_1 = 2n_2L_2 \quad \text{using Eq. (6.23)}$$

$$\therefore n_1L_1 = n_2L_2$$

$$\therefore n_1(l_1 + 2e) = n_2(l_2 + 2e)$$

$$\therefore \; e = \frac{n_1l_1 - n_2l_2}{2(n_2 - n_1)} \text{ or } \frac{n_2l_2 - n_1l_1}{2(n_1 - n_2)} \quad \text{--- (6.29)}$$

10. [$n_c = \frac{v}{4L_c}$

$n_o = \frac{v}{2L_o}$

Third overtone of open pipe $(n_o)' = 4\,n_o = \frac{2v}{L_o}$

$n_c = (n_o)'$

$$\frac{v}{4L_c} = \frac{2v}{Lo}$$

$\frac{Lc}{L_o}$ = 1/8 = 1:8

The ratio of lengths of air column of the closed and open pipe is **1:8**

11. $n = \frac{1}{2l}\sqrt{\frac{T}{m}}$

$100 = \frac{1}{2\,x\,0.5}\sqrt{\frac{5\,x\,9.8}{m}}$ (squaring both sides)

$m = 4.9 \times 10^{-3}$ kg/m

12 Distance between two successive nodes = $\lambda/2 = 3.5 \times 10^{-2}$ m

$\lambda = 7 \times 10^{-2}$ m

$n = v/\lambda = 1400/(7 \times 10^{-2})$

$n = 200 \times 10^{2}$

n =20 kHz

13 $n = \frac{v}{4(l+e)}$; $e = 0.3\, d = 0.3 \times 2 = 0.6$ cm

$$n = \frac{350}{4(34.4+0.6)10^{-2}} \quad \frac{35000}{4 \times 35} = 250\ Hz$$

14 The moving end is an antinode and four complete loops are formed.

(Therefore 4& ½ loops is formed)

$\frac{9}{4}\lambda = L$ [L=1m]

$\lambda = \frac{4}{9}$

n =18Hz

$v = n\lambda = 18 \times \frac{4}{9} = 8$ m/s.

v = 8 m/s]

15 $\lambda = \frac{v}{n} = \frac{330}{550} = \frac{3}{5}$

$$\Delta\phi = \frac{2\pi}{\quad} * \Delta x$$

$$\Delta\phi = \frac{2\pi}{3/5} * (3.6 - 3) = \frac{10\pi}{3} * (0.6)$$

$\Delta\phi$ **= 2$\boldsymbol{\pi}$**

The phase difference between the wave is **2 $\boldsymbol{\pi}$**

Answers of VSA (three-mark questions)

1. Text book pg. no.146 and 147; Art. 6.7.5)

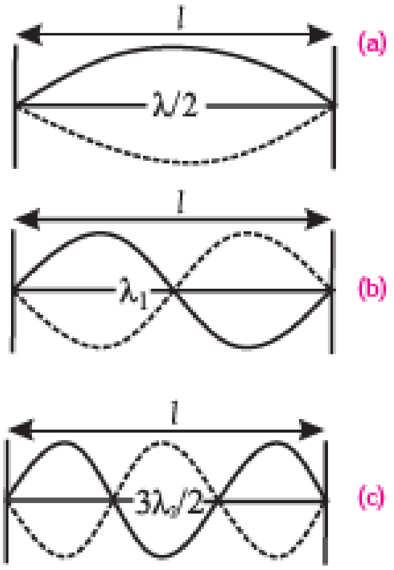


Fig. 6.11: Different modes of vibrations of a stretched string.

Consider a string of length l stretched between two rigid supports. The linear density (mass per unit length of string) is m and the tension T acts on the string due to stretching. If it is made to vibrate by plucking or by using a vibrator like a tuning fork, a transverse wave can be produced along the string.

If a string is stretched between two rigid supports and is plucked at its centre, the string vibrates as shown in Fig 6.11 (a). It consists of an antinode formed at the centre and nodes at the two ends with one loop formed along its length. If λ is the wavelength and l is the length of the string, we get

$$\text{Length of loop} = \frac{\lambda}{2} = l$$

$$\therefore \lambda = 2l$$

The frequency of vibrations of the string,

$$n = \frac{v}{\lambda} = \frac{1}{2l}\sqrt{\frac{T}{m}} \qquad \left(\because v = \sqrt{\frac{T}{m}}\right)$$

This is the lowest frequency with which the string can vibrate. It is the fundamental frequency of vibrations or the first harmonic.

If the centre of the string is prevented from vibrating by touching it with a light object and string is plucked at a point midway between one of the segments, the string vibrates as shown in Fig. 6.11 (b).

Two loops are formed in this mode of vibrations. There is a node at the centre of the string and at its both ends. If λ_1 is wavelength of vibrations, the length of one loop = $\frac{\lambda_1}{2} = \frac{l}{2}$

$\therefore \lambda_1 = l$

Thus, the frequency of vibrations is given as

$$n_1 = \frac{1}{\lambda_1}\sqrt{\frac{T}{m}}$$

$$n_1 = \frac{1}{l}\sqrt{\frac{T}{m}}$$

Comparing with fundamental frequency we get that $n_1 = 2n$.

Thus the frequency of the first overtone or second harmonic is equal to twice the fundamental frequency.

The string is made to vibrate in such a way that three loops are formed along the string as shown in Fig. 6.11 (c). If λ_2 is the wavelength here, the length of one loop is $\frac{\lambda_2}{2} = \frac{l}{3}$

$\therefore \lambda_2 = \frac{2l}{3}$

Therefore the frequency of vibrations is

$$n_2 = \frac{1}{\lambda_2}\sqrt{\frac{T}{m}}$$

$$n_2 = \frac{3}{2l}\sqrt{\frac{T}{m}}$$

Comparing with fundamental frequency, we get that $n_2 = 3n$.

Thus frequency of second overtone or third harmonic is equal to thrice the fundamental frequency. Similarly for higher modes of vibrations of the string, the frequencies of vibrations are as $4n$, $5n$, $6n$...etc. Thus all harmonics are present in case of a stretched string and the frequencies are given by

$$n_p = pn \qquad \text{— (6.25)}$$

2 Text book pg. no 143 and 144 ; Art. 6.7.3)

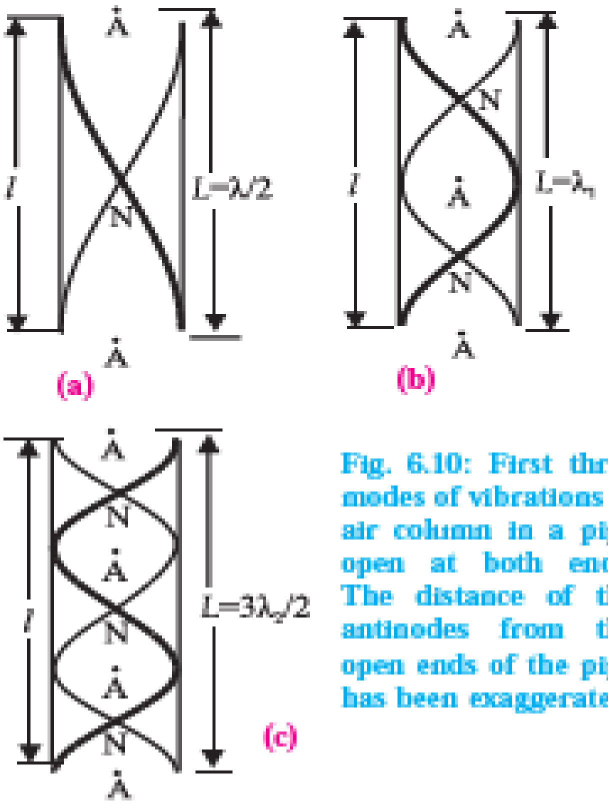


Fig. 6.10: First three modes of vibrations of air column in a pipe open at both ends. The distance of the antinodes from the open ends of the pipe has been exaggerated.

The different modes of vibrations of air column in pipe open at both ends are shown in Fig. 6.10 (a), (b) and (c). The fundamental tone or mode of vibrations of air column open at both ends is as shown in Fig. 6.10 (a). There are two antinodes at two open ends and one node between them.

$\therefore$ Length of air column $= L = \frac{\lambda}{2}$ or, $\lambda = 2L$

$$\therefore n = \frac{v}{\lambda} = \frac{v}{2L} = \frac{v}{2(l+2e)} \quad \text{---(6.22)}$$

$$\text{and } v = 2\,nL \quad \text{---(6.23)}$$

This is the fundamental frequency or the first harmonic. It is the lowest frequency of vibration.

The next possible mode of vibrations of air column open at both ends is as shown in Fig. 6.10 (b). Three antinodes and two nodes are formed.

$\therefore$ Length of air column $= L = \lambda_1$

$$\text{i.e., } \lambda_1 = L = (l + 2e) \quad \text{---(6.24)}$$

If n_1 and λ_1 are frequency and wavelength of this mode of vibration of air column respectively, then

$$v = n_1\lambda_1$$

$$n_1 = \frac{v}{\lambda_1} = \frac{v}{L} = \frac{v}{(l+2e)}$$

$$\therefore n_1 = 2n \quad \text{--- (6.25)}$$

This is the frequency of second harmonic or first overtone.

In the next of vibrations of air column open at both ends (as shown in Fig. 6.10 (c)), four antinodes and three nodes are formed.

$\therefore$ Length of air column $= L = \frac{3\lambda_2}{2}$

$$\therefore \lambda_2 = \frac{2L}{3} = \frac{2(l+2e)}{3} \quad \text{--- (6.26)}$$

If n_2 and λ_2 are the frequency and wavelength of this mode of vibration of air column respectively, then $v = n_2\lambda_2$

$$\therefore n_2 = \frac{v}{\lambda_2} = \frac{3v}{2L} = \frac{3v}{2(l+2e)}$$

$$\therefore n_2 = 3n \quad \text{--- (6.27)}$$

This is the frequency of third harmonic or second overtone.

Thus all harmonics are present as overtones in the modes of vibration of air column open at both ends.

3 Text book pg. no 142 and 143 ; Art. 6.7.2)

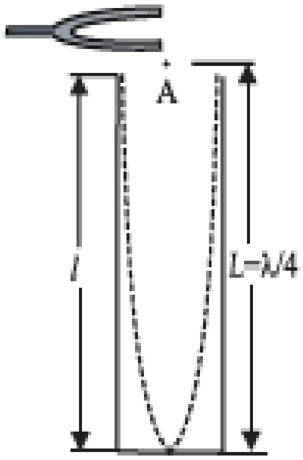
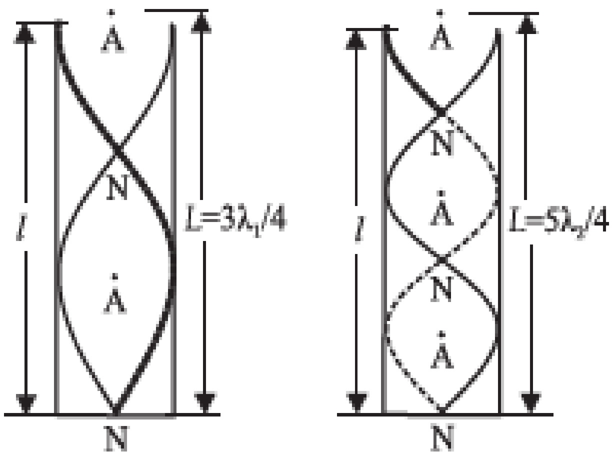


Fig. 6.9 (a): Set-up for generating vibrations of air column in a pipe closed at one end. The distance of the antinode from the open end of the pipe has been exaggerated.



(b) (c)

The first mode of vibrations of air column closed at one end is as shown in Fig. 6.9 (a).

This is the simplest mode of vibration of air column closed at one end, known as the fundamental mode.

$\therefore$ Length of air column

$L = \frac{\lambda}{4}$ and $\lambda = 4L$

where λ is the wavelength of fundamental mode of vibrations in air column. If n is the fundamental frequency, we have

$$v = n\lambda \qquad \text{--- (6.15)}$$

$$\therefore n = \frac{v}{\lambda}$$

$$\therefore n = \frac{v}{4L} = \frac{v}{4(l+e)} \qquad \text{--- (6.16)}$$

The fundamental frequency is also known as the first harmonic. It is the lowest frequency of vibration in air column in a pipe closed at one end.

The next mode of vibrations of air column closed at one end is as shown in Fig. 6.9 (b). Here the air column is made to vibrate in such a way (as shown in Fig. 6.9 (b)) that it contains a node at the closed end, an antinode at the open end with one more node and antinode in between. If n_1 is the frequency and λ_1 is the wavelength of wave in this mode of vibrations in air column, we have, the length of the air column $L = \frac{3\lambda_1}{4}$

$$\therefore \lambda_1 = \frac{4L}{3} = \frac{4(l+e)}{3} \qquad \text{--- (6.17)}$$

The velocity in the second mode is given as $v = n_1\lambda_1$

$$\therefore n_1 = \frac{v}{\lambda_1} = \frac{3V}{4L} = \frac{3V}{4(l+e)}$$

$$\therefore n_1 = 3n \qquad \text{--- (6.18)}$$

This frequency is the third harmonic. It is the first overtone.

The next higher mode of vibrations of air column closed at one end is as shown in Fig. 6.10 (c). Here the same air column is made to vibrate in such a way that it contains a node at the closed end, an antinode at the open end with two more nodes and antinodes in between. If n_2 is the frequency and λ_2 is the wavelength of the wave in this mode of vibrations in air column, we have

Length of air column $L = \frac{5\lambda_2}{4}$

$$\therefore \lambda_2 = \frac{4L}{5} = \frac{4(l+e)}{5} \quad \text{--- (6.19)}$$

The velocity this mode is given as

$v = n_2\lambda_2$

$$\therefore n_2 = \frac{v}{\lambda_2} = \frac{5V}{4L} = \frac{5V}{4(l+e)} \quad \therefore n_2 = 5n \quad \text{-- (6.20)}$$

This frequency is the fifth harmonic. It is the second overtone.

Continuing in a similar way, for the p^{th} overtone we get the frequency n_p as

$$n_p = (2p+1)n. \quad \text{-- (6.21)}$$

Thus for a pipe closed at one end only odd harmonics are present and even harmonics are absent.

4 Text book pg. no 136; Art. 6.4.3)

6.4.3 Amplitude of the Resultant Wave Produced due to Superposition of Two Waves:

Consider two waves having the same frequency but different amplitudes A_1 and A_2. Let these waves differ in phase by φ. The displacement of each wave at $x = 0$ is given as

$$y_1 = A_1 \sin \omega t$$

$$y_2 = A_2 \sin(\omega t + \varphi)$$

According to the principle of superposition of waves, the resultant displacement at $x = 0$ is

$$y = y_1 + y_2$$

or, $y = A_1 \sin\omega t + A_2 \sin(\omega t + \varphi)$

$$y = A_1 \sin\omega t + A_2 \sin\omega t \cos\varphi + A_2 \cos\omega t \sin\varphi$$

$$y = (A_1 + A_2 \cos\varphi) \sin\omega t + A_2 \sin\varphi \cos\omega t$$

If we write

$$A_1 + A_2 \cos\varphi = A \cos\theta \qquad \text{--- (6.4)}$$

and $A_2 \sin\varphi = A \sin\theta$ --- (6.5)

we get

$$y = A\cos\theta \sin\omega t + A \sin\theta \cos\omega t$$

$$\therefore \quad y = A \sin(\omega t + \theta) \qquad \text{--- (6.6)}$$

This is the equation of the resultant wave. It has the same frequency as that of the interfering waves. The resultant amplitude A is given by squaring and adding Eqs. (6.4) and (6.5).

$$A^2\cos^2\theta + A^2\sin^2\theta = (A_1 + A_2\cos\varphi)^2 + A_2^2 \sin^2\varphi$$

$$A^2 = A_1^2 + 2A_1A_2\cos\varphi + A_2^2\cos^2\varphi + A_2^2\sin^2\varphi$$

$$\therefore \quad A = \sqrt{A_1^2 + 2A_1A_2\cos\varphi + A_2^2} \qquad \text{--- (6.7)}$$

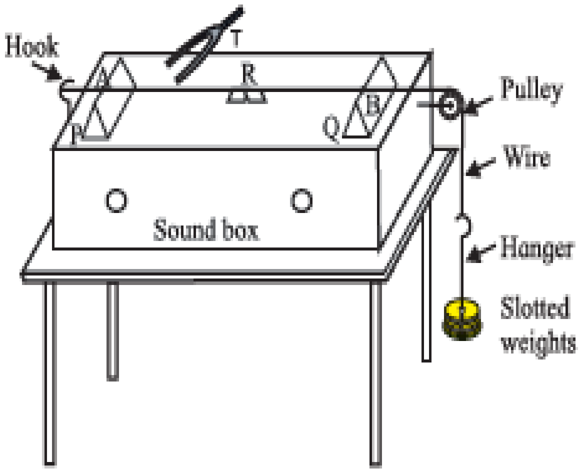
5 Textbook pg. no 147; Art. 6.7.6)

1) Law of length: The fundamental frequency of vibrations of a string is inversely proportional to the length of the vibrating string, if tension and mass per unit length are constant.

2) Law of tension: The fundamental frequency of vibrations of a string is directly proportional to the square root of tension, if vibrating length and mass per unit length are constant.

3) Law of linear density: The fundamental frequency of vibrations of a string is inversely proportional to the square root of mass per unit length (linear density), if the tension and vibrating length of the string are constant.

6 Text book pg. no 148; Art. 6.8(1)



1) Verification of first law of a vibrating string:

★ By measuring length of wire and its mass, the mass per unit length (m) of wire is determined. Then the wire is stretched on the sonometer and the hanger is suspended from its free end.

★ A suitable tension (T) is applied to the wire by placing slotted weights on the hanger.

★ The length of wire (l1) vibrating with the same frequency (n1) as that of the tuning

The fork is determined as follows.

★ A light paper rider is placed on the wire midway between the bridges. The tuning fork is set into vibrations by striking on a rubber pad.

★ The stem of the tuning fork is held in contact with the sonometer box. By changing distance between the bridges without disturbing the paper rider, frequency of vibrations of wire is changed.

★ When the frequency of vibrations of wire becomes exactly equal to the frequency of tuning fork, the wire vibrates with maximum amplitude and the paper rider is thrown off.

In this way a set of tuning forks having different frequencies n_1, n_2, n_3, ...are used and corresponding vibrating lengths of wire are noted as $l1, l2, l3$.........by keeping the tension constant (T) . We will observe that $n_1 l_1 = n_2 l_2 = n_3 l_3 =$.......= constant, for constant value of tension (T) and mass per unit length (m).

$\therefore nl$ = constant

i.e., $n \propto \frac{1}{l}$, if T and m are constant.

Thus, the first law of a vibrating string is verified by using a sonometer.

7 $\lambda_1 = 83/170$; $\lambda_2 = 83/172$; $\lambda_1 > \lambda_2$; $n_2 > n_1$;

$n_2 - n_1 = 8$

$n_1 = \frac{v}{\lambda 1}$; $n_2 = \frac{v}{\lambda 2}$

$n_2 - n_1 = v\left[\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right]$

$8 = v\left[\frac{172}{83} - \frac{170}{83}\right]$

V = 332 m/s

$n_1 = 332\, x \frac{170}{83}$ = 680 Hz

$n_1 =$ 680 Hz

$n_2 = 332\, x \frac{172}{83}$ = 688 Hz

n_2 =688 Hz

8 * <u>for a pipe open at both the ends</u>

frequency of first overtone of, $n_1 = 2 \text{ x } n_o = 2 \text{ x } 680 = 1360$ Hz

$n_1 = 2 \text{ x } \frac{v}{2L} = 1360$; L = 340/1360 =0.25 m

L = 0.25 m

[* <u>for a pipe closed at one end</u>

frequency of first overtone of, $n_1' = \frac{3v}{4L'}$

$n'_1 = n_1$ [as per given condition]

$\frac{3v}{4L'} = 1360$

$L' = \frac{3x\,340}{4x1360} = 0.1875$ m

L’ = 0.1875 m

9 Given equation can be written as y=4 sin 2π (t/0.02 – x/40)

Comparing with y=A sin 2π (t/T – x/λ)

(a) A = 4 cm
(b) T = 0.02 s
(c) n = 1/T =50 Hz

(d) l = 40 cm

(e) V = n l = 50 x 40 = 2000 cm/s = 20 m/s

10 $n_1 = \frac{1}{2l_1}\sqrt{\frac{T_1}{m}}$; $n_2 = \frac{1}{2l_2}\sqrt{\frac{T_2}{m}}$

$n_1 = n_2$

$\frac{1}{2l_1}\sqrt{\frac{T_1}{m}} = \frac{1}{2l_2}\sqrt{\frac{T_2}{m}}$

$l_2 = \sqrt{l_1^2 x \frac{T_2}{T_1}}$

$l_2 = \sqrt{0.5^2 * \frac{8}{2}}$

$l_2 = 0.5\, x\, 2 = 1\, m$

Long Answers (4 marks each)

1 Text book pg. no 138 and 139 ; Art. 6.5.2)

6.5.2 Equation of Stationary Wave on a Stretched String:

Consider two simple harmonic progressive waves of equal amplitudes (a) and wavelength (λ) propagating on a long uniform string in opposite directions (remember $2\pi/\lambda = k$ and $2\pi n = \omega$).

The equation of wave travelling along the x-axis in the positive direction is

$$y_1 = a \sin \left\{2\pi\left(nt - \frac{x}{\lambda}\right)\right\} \quad \text{--- (6.10)}$$

The equation of wave travelling along the x-axis in the negative direction is

$$y_2 = a \sin \left\{2\pi\left(nt + \frac{x}{\lambda}\right)\right\} \quad \text{--- (6.11)}$$

When these waves interfere, the resultant displacement of particles of string is given by the principle of superposition of waves as

$$y = y_1 + y_2$$

$$y = a \sin\left\{2\pi\left(nt - \frac{x}{\lambda}\right)\right\} + a \sin\left\{2\pi\left(nt + \frac{x}{\lambda}\right)\right\}$$

By using,

$\sin C + \sin D = 2\sin\left(\frac{C+D}{2}\right)\cos\left(\frac{C-D}{2}\right)$, we get

$$y = 2a \sin(2\pi nt)\cos\frac{2\pi x}{\lambda}$$

$$y = 2\, a \cos\frac{2\pi x}{\lambda}\sin(2\pi nt) \quad \text{or,} \quad \text{--- (6.12)}$$

Using $2a\cos\frac{2\pi x}{\lambda} = A$ in Eq. (6.12), we get

$$y = A\sin(2\pi nt)$$

As $\omega = 2\pi n$, we get, $y = A\sin\omega t$.

This is the equation of a stationary wave which gives resultant displacement due to two simple harmonic progressive waves. It may be noted that the terms in position x and time t appear separately and not as a combination $2\pi\,(nt \pm x/\lambda)$.

Hence, the wave is not a progressive wave. x is present only in the expression for the amplitude. The amplitude of the resultant wave is given as $A = 2a\cos\frac{2\pi x}{\lambda}$.

Condition for node:

Nodes are the points of minimum displacement. This is possible if the amplitude is minimum (zero), i.e.,

$$2a\cos\frac{2\pi x}{\lambda} = 0$$

or, $\cos\frac{2\pi x}{\lambda} = 0,$

or, $\frac{2\pi x}{\lambda} = \frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2}, \ldots\ldots\ldots$

$\therefore x = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}, \ldots\ldots\ldots$

i.e., $x = (2p-1)\frac{\lambda}{4}$ where $p = 1, 2, 3, \ldots\ldots\ldots$

The distance between two successive nodes is $\frac{\lambda}{2}$.

Condition for antinode:

Antinodes are the points of maximum displacement,

i.e., $A = \pm 2a$

$\therefore 2a\cos\frac{2\pi x}{\lambda} = \pm 2a$

or, $\cos\frac{2\pi x}{\lambda} = \pm 1$

$\therefore \frac{2\pi x}{\lambda} = 0, \pi, 2\pi, 3\pi \ldots$

or, $x = 0, \frac{\lambda}{2}, \lambda, \frac{3\lambda}{2}, \ldots\ldots$

i.e., $x = \frac{\lambda p}{2}$ where $p = 0, 1, 2, 3\ldots.$

The distance between two successive antinodes is $\frac{\lambda}{2}$. Nodes and antinodes are formed alternately. Therefore, the distance between a node and an adjacent antinode is $\frac{\lambda}{4}$.

2 Text book pg. no 150 and 151 ; Art. 6.9

When there is superposition of two sound waves, having same amplitude but slightly different frequencies, travelling in the same direction, the intensity of sound varies periodically with time. This phenomenon is known as production of beats.

The occurrences of maximum intensity are called waxing and those of minimum intensity are called waning. One waxing and successive waning together constitute one beat. The number of beats heard per second is called beat frequency.

6.9.1 Analytical method to determine beat frequency:

Consider two sound waves, having same amplitude and slightly different frequencies n_1 and n_2. Let as some that they arrive in phase at some point x of the medium. The displacement due to each wave at any instant of time at that point is given as

$$y_1 = a\sin\left\{2\pi\left(n_1 t - \frac{x}{\lambda_1}\right)\right\}$$

$$y_2 = a\sin\left\{2\pi\left(n_2 t - \frac{x}{\lambda_2}\right)\right\}$$

Let us assume for simplicity that the listener is at $x = 0$.

$$\therefore \quad y_1 = a\sin(2\pi n_1 t)$$

and $y_2 = a\sin(2\pi n_2 t)$

According to the principle of superposition of waves,

$$y = y_1 + y_2$$

$$\therefore\ y = a\sin(2\pi n_1 t) + a\sin(2\pi n_2 t)$$

or,

$$y = 2a\sin\left[2\pi\left(\frac{n_1+n_2}{2}\right)t\right]\cos\left[2\pi\left(\frac{n_1-n_2}{2}\right)t\right]$$

--- (6.31)

[By using formula,

$\sin C + \sin D = 2\sin\left(\frac{C+D}{2}\right)cos\left(\frac{C-D}{2}\right)$]

Rearranging the above equation, we get

$$y = 2a\cos\left[\frac{2\pi(n_1-n_2)}{2}t\right]\sin\left[\frac{2\pi(n_1+n_2)}{2}t\right]$$

Substituting $2a\cos\left[\frac{2\pi(n_1-n_2)}{2}t\right] = A$

and $\frac{n_1+n_2}{2} = n$, we get

$$y = A\sin(2\pi nt) \qquad \text{--- (6.37)}$$

This is the equation of a progressive wave having frequency n and amplitude A. The frequency n is the mean of the frequencies n_1 and n_2 of arriving waves while the amplitude A varies periodically with time.

The intensity of sound is proportional to the square of the amplitude. Hence the resultant intensity will be maximum when the amplitude is maximum.

For maximum amplitude (waxing),

$$A = \pm 2a$$

$$\therefore\ 2a\cos\left[\frac{2\pi(n_1-n_2)}{2}\right]t = \pm 2a$$

or, $\cos\left[\frac{2\pi(n_1-n_2)}{2}\right]t = \pm 1$

i.e. $\left[2\pi\left(\frac{n_1-n_2}{2}\right)t\right] = 0, \pi, 2\pi, 3\pi, \cdots\cdots$

$$\therefore\ t = 0, \frac{1}{n_1 - n_2}, \frac{2}{n_1-n_2}, \frac{3}{n_1-n_2}, \ldots$$

Thus, the time interval between two successive maxima of sound is always $\frac{1}{n_1-n_2}$.

The intensity of sound will be minimum when amplitude is zero (waning):

For minimum amplitude, $A = 0$,

$$\therefore\ 2a\cos\left[2\pi\left(\frac{n_1-n_2}{2}\right)t\right]=0$$

or,

$$\cos\left[2\pi\left(\frac{n_1-n_2}{2}\right)t\right]=0$$

$$\therefore\left[2\pi\left(\frac{n_1-n_2}{2}\right)t\right]=\frac{\pi}{2},\frac{3\pi}{2},\frac{5\pi}{2}\ldots\ldots$$

$$\therefore t=\frac{1}{2(n_1-n_2)},\frac{3}{2(n_1-n_2)},\frac{5}{2(n_1-n_2)},$$

Therefore time interval between two successive minima is also $\frac{1}{(n_1-n_2)}$,

Hence the period of beats is $T=\frac{1}{n_1-n_2}$.

7. Wave Optics

Answers to MCQ (One-mark questions)

1. d. Frequency
2. b. wavenormal
3. b. decreases
4. a. 2:1
5. b. 2 x 10^8 m/s
6. c. 5° < ib <90°
7. b. 1 mm
8. b. 0, 2 π, 4 π
9. b. decreases
10. a. 5:1

VERY SHORT ANSWER TYPE (1 mark)

1. Two sources which emit waves of the same frequency having a constant phase difference, independent of time are called coherent.
2. Polaroid is a synthetic plastic sheet which produces plane polarised light.
3. path difference = nλ

   $167.5\lambda = \left(168 - \frac{1}{2}\right)n$ ⇛ Point P is 168th dark band
4. The locus of all points having same phase at a given instant of time is called wavefront
5. Sun and stars are the primary sources of light.
6. Plane wavefront
7. The phenomenon of restriction of the vibration of light waves, perpendicular to the direction of wave motion in a particular plane is called polarisation of light.
8. The tangent of the polarising angle is equal to the refractive index of the refractive medium at which partial reflection takes place. $\mu = \tan\Theta_B$
9. The condition for constructive interference in terms of phase difference is given by $\Delta\varphi\eta = \eta\, 2\pi$, $\eta = 0, 1, 2,$
10. The bending of light near the edges of an obstacle or slit and spreading into the region of geometrical shadow is known as diffraction of light.

VERY SHORT ANSWER TYPE – 2 marks

1. page no- 162
2. page no- 162
3. Ans: page no- 165

Unpolarised light	Polarised light
1. Intensity is greater. 2. Intensity is not zero even in crossed position. 3. Intensity remains the same when analysed by an analyzer. 4. It contains electromagnetic waves with both electric and magnetic vectors.	1. Intensity is smaller 2. Intensity is zero when analysed by a polaroid in crossed position. 3. Intensity varies from maximum to zero. 4. It contains either electric or magnetic vectors.

4. The multiple colours observed over a thin film of oil floating on a water is due to the interference of light waves reflected from the upper and lower water surface of the film. The two rays have a path difference. (Diagram- page number-173)
5. Text book page no-175

   Path length is the total distance travelled regardless of where it travelled.

   A path length of Δx in a medium of refractive index (n) is equivalent to a path length of n Δx in a vacuum.

   n Δx is the optical path travelled by a wave. Thus, the optical path through a medium is the effective path travelled by light in a vacuum to generate the same phase difference.
6. Text book page no-182
7. $$u = \frac{C}{v}$$

   $$\therefore v_g = \frac{C}{\mu_g}$$

   $$v_w = \frac{C}{\mu_w}$$

   $$\therefore v_w - v_g = \frac{C}{\mu_w} - \frac{C}{\mu_g}$$

   $$2.7 \times 10^7 = C\left(\frac{3}{4} - \frac{2}{3}\right)$$

   $$2.7 \times 10^7 = C\left(\frac{9-8}{12}\right)$$

   $C = 2.7x12x10^7$

   $=3.24x10^8 m/ s$

\

8. $n = \frac{4}{3}$, i = 90° - 40° = 50°

$n = \frac{\sin i}{\sin r}$

$\sin r = \frac{\sin i}{n}$

$= \frac{\sin 50^\circ}{\frac{4}{3}}$

$= \frac{0.7660}{\frac{4}{3}}$

$= 0.5745$

The angle of refraction,

$r = \sin^{-1}(0.5745) = 35°4'$

9. Plane of Vibration: The plane of vibration of an electromagnetic wave is the plane of vibration of the electric field vector containing the direction of propagation.

   Plane of polarisation: The plane perpendicular to the plane of vibration where there are no vibrations of polarised light is called plane of polarisation.

10. **Given:** $\lambda = 5000\ \text{Å} = 5 \times 10^{-7}$ m

    D = 200 × 2.54 cm = 5.08 m

    $\theta = \frac{1.22\lambda}{D}$

    $= \frac{1.22 \times 5 \times 10^{-7}}{5.08}$

    $= 1.2 \times 10^{-7}$ rad

11. **T**he minimum distance is given by $d$min = 0.61λ /tan b

    $d$min = 0.61 x 5.0 x 10^{-7}/tan 30° = 5.28 x 10^{-7} m.

12. The reflected light will be completely polarized when the angle of incidence is equal to the Brewster's angle which is given by

    $$\Theta_{B} = \tan^{-1}\frac{n_2}{n_1},$$

    where n_1 and n_2 are refractive indices of the first and the second medium respectively. In this case, $n_1 = 1$ and $n_2 = 1.5$. Thus, the required angle of incidence = Brewster's angle = $\tan^{-1}$ 1.51 = 56.31°

SHORT ANSWER TYPE – II – 3 marks

1. Text book page no-162
2. Text book page no-180

3. Text book page no-162
4.

Data: λ = 546 nm = 546×10^{-9} m,

a = 0.4 mm = 4×10^{-4} m

D = 40 cm = 40×10^{-2} m

$$y_{md} = m\frac{\lambda D}{a}$$

$$\therefore y_{1d} = 1\frac{\lambda D}{a} \text{ and}$$

$$2y_{1d} = \frac{2\lambda D}{a}$$

$$= \frac{2 \times 546 \times 10^{-9} \times 40 \times 10^{-2}}{4 \times 10^{-4}} \text{m}$$

= $2 \times 546 \times 10^{-6} = 1092 \times 10^{-6}$

= 1.092×10^{-3} m = **1.092 mm**

5. Text book page no-166
6. Text book page no-163
7. **Data:** D = 2 m, y_{1d} = 5 mm = 5×10^{-3} m,

a = 0.2 mm = 0.2×10^{-3} m = 2×10^{-4} m

$$y_{md} = m\frac{\lambda D}{a}$$

$$\therefore \lambda = \frac{y_{1d}\, a}{D} \quad ....(\because m = 1)$$

$$\lambda = \frac{5 \times 10^{-3} \times 2 \times 10^{-4}}{2}$$

λ = 5×10^{-7} m = $5 \times 10^{-7} \times 10^{-10}$ Å = **5000 Å**

8. Text book page no-182
9. Text book page no-162
10.

Given that $\frac{I_1}{I_2} = 2$

$$I_{max} = I_1 + I_2 + 2\sqrt{I_1 . I_2}$$

$$I_{min} = I_1 + I_2 - 2\sqrt{I_1 . I_2}$$

$$\therefore \frac{I_{max}}{I_{min}} = \frac{I_1 + I_2 + 2\sqrt{I_1 . I_2}}{I_1 + I_2 - 2\sqrt{I_1 . I_2}}$$

$$= \frac{I_2(I_1/I_2 + 1 + 2\sqrt{I_1/I_2})}{I_2(I_1/I_2 + 1 - 2\sqrt{I_1/I_2})}$$

$$= \frac{2 + 1 + 2\sqrt{2}}{2 + 1 - 2\sqrt{2}}$$

≈ 34

11. Text book page no-181
12. Text book page no-175

Given λ = 5400 Å, the refractive index of the material of the film = 1.1 and the shift of the central bright fringe = 5 mm.

Let *t* be the thickness of the film and P be the point on the screen where the central fringe has shifted. Due to the film kept in front of slit S1 say, the optical path travelled by the light passing through it increases by *t* (1.1-1)= 0.1*t*.

The difference in distances S2P – S1P = *yλ/d,* optical paths introduced by the film.

Thus, 0.1*t* = 0.005 x 5400 x 10-10/0.0005. ∴ *t* = 5.4 x 10 -5m = 0.054 mm

13. Text book page no-173

LONG ANSWER TYPE – 4 marks

1. Page number 170-171
2. Page number 162
3. Page number 166
4. Page number 173-174
5. Page number 177
6. Page number 180-182
7. 2W = 6mm ∴ W= 3 mm = 3×10^{-3} m, y = 2.5 m,

   (a) λ_1 = 500 nm = 5×10^{-7} m

   (b) λ_2 = 50 μm = 5×10^{-5} m

   (c) λ_3 = 0.500 nm = 5×10^{-10} m

(a) $W = \frac{y\lambda_1}{a}$

$$\therefore\ a = \frac{y\lambda_1}{W} = \frac{(2.5)(5 \times 10^{-7})}{3 \times 10^{-3}}$$

$$= \mathbf{4.167 \times 10^{-4}\ m}$$

$$= \mathbf{0.4167\ mm}$$

(b) $W = \frac{y\lambda_2}{a}$

$$\therefore\ a = \frac{y\lambda_2}{W} = \frac{(2.5)(5 \times 10^{-5})}{3 \times 10^{-3}}$$

$$= 4.167 \times 10^{-2}\ m$$

$$= \mathbf{41.67\ mm}$$

(c) $W = \frac{y\lambda_3}{a}$

$$\therefore\ a = \frac{y\lambda_3}{W} = \frac{(2.5)(5 \times 10^{-10})}{3 \times 10^{-3}}$$

$$= \mathbf{4.167 \times 10^{-7}\ m}$$

$$= \mathbf{4.167 \times 10^{-4}\ mm}$$

8. Path difference at a point P on the screen at a distance y from the centre is given by $\Delta l = y\frac{d}{D}$ where d and D are the distances between the slits and between the wall containing the slits and the screen respectively. Thus, we are given,

$\Delta l_A = y_A d/D = 0.0075$ mm and $\Delta l_B = y_B\, d/D == 0.0015$ mm, giving

$y_A = 0.0075\, D/d$ and $y_B = 0.0015\, D/d$ mm

Here, y_A and y_B are the distances of points A and B from the centre of the screen.

Thus, the distance between the points A and B is $y_{A+}\, y_B + = 0.009\, D/d$ mm.

The width of a bright or dark fringe (i.e., the distance between two bright or two dark fringes) is given by W = $\lambda\, D/d$. Thus, there will be (0.009 $D/d)$/W = 0.009/ $\lambda = 0.009/(6000 \times 10^{-7}) = 15$ bright fringes between A and B (including the central one) and 14 dark fringes in between the bright fringes.

8 Electrostatics

Answers to MCQ (One-mark questions)

1. c. zero
2. b. increase in dielectric constant
3. b. $W = pE(1 - cos)$
4. d. n^2
5. b. $[M^{-1}L^{-2}T^4A^2]$
6. a. the increase of capacity
7. a. 1 J
8. c. 1.6×10^{-12} F
9. b. 3 ∫J
10. b. 0.8 μf

Answers of VSA (one-mark questions)

1. Concentric spherical surfaces centred at the charge
2. When the area increases, capacitance increases
3. E = - dV/dx
4. $E = \frac{\lambda}{2\Pi\varepsilon_0 r}$
5. zero
6. zero
7. ⌊= q/l = 3 x 10^{-6}/2 =1.5 x 10^{-6} C/m = 1.5 ∫C/m
8. Q = CV = 5 x 10^{-6} x 200 = 10^{-3} C
9. $1/C_p = 1/C_1 + 1/C_2 + 1/C_3 + 1/C_4 = 4/4$ ∴ $C_p = 1\mu$ F
10. Energy acquired = $\frac{1}{2}$ QV = $\frac{1}{2}$ x 2 x 2 = 2J

Answers to VSA (two-mark questions)

1. For the answer refer textbook page no. 204
    - ★ Consider a metal plate P_1 having area A. Let some positive charge +Q be given to this plate.
    - ★ Let its potential be V. Its capacity is given by $C_1 = Q/V$
    - ★ Now consider another insulated metal plate P_2 held near the plate P_1. By induction a negative charge is produced on the nearer face and an equal positive charge develops on the farther face of P_2 (Fig. 8.24 (a)).
    - ★ The induced negative charge lowers the potential of plate P_1, while the induced positive charge raises its potential.
    - ★ As the induced negative charge is closer to P_1 it is more effective, and thus there is a net reduction in potential of plate P_1 .
    - ★ If the outer surface of P_2 is connected to earth, the induced positive charges on P_2 are free flow to earth. The induced negative charge on P_2 stays on it, as it is bound to the positive charge of P_1. This greatly reduces the potential of P_2 , (Fig 8.24 (b)).
    - ★ If V_1 is the potential on plate P_2 due to charge (- Q) then the net potential of the system will now be $+V-V_1$.

      Hence the capacity $C_2 = Q/V-V_1$

      $\therefore C_2 > C_1$
    - ★ Thus capacity of metal plate P_1 increased by placing an identical, earth connected metal plate P_2 near it.

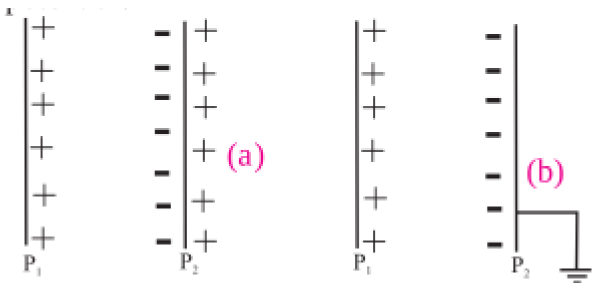


Fig. 8.24: (a) and (b) Parallel plate capacitor.

2. For answer refer text book page no. 204
    1. Capacitors in series:

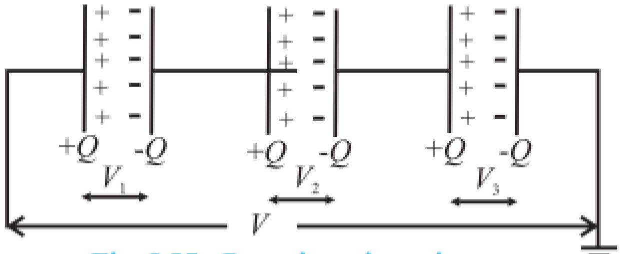


Fig. 8.25: Capacitors in series.

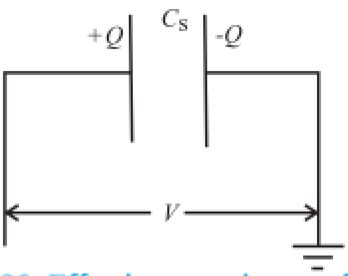


Fig. 8.26: Effective capacitance of three capacitors in series.

★ Capacitors are said to be connected in series, if they are connected end to end in the form of a chain.

★ Let C_1, C_2, C_3 be connected in series and V_1, V_2, V_3 be the corresponding potential difference in the capacitors.

★ In series combination, charges on the plates (± Q) are the same on each capacitor. Potential difference across the combination of capacitor is V volt,

where $V = V_1 + V_2 + V_3$

$$\therefore V = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

Let C_s represent the equivalent capacitance shown in Fig. 8.26, then $V = \frac{Q}{C_s}$

$$\therefore \frac{Q}{C_s} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$\therefore \frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

3. $C_p = 25$ μF, $C_s = 6$ μF

$C_p = C_1 + C_2$; $C_s = C_1C_2/ (C_1 + C_2)$

$6 = C_1C_2/25$; $C_2 = 150/C_1$ therefore $25 = C_1 + 150/C_1$

$C_1^2 – 25\ C_1 +150 = $ $C_1 = 15$ μF, $C_2 = 10$ μF or $C_2 = 15$ μF, $C_1 = 10$ μF

4. For the answer refer textbook page no.191

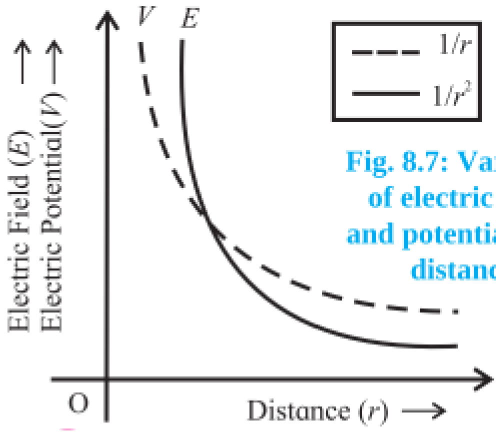


Fig. 8.7: Variation of electric field and potential with distance

5. Ans : Refer (Text book pg. no 200 ; Art 8.8)

Polar Molecule

A molecule in which the centre of mass of positive charges (protons) does not coincide with the centre of mass of negative charges (electrons), because of the asymmetric shape of the molecules is called polar molecule.

Eg. HCl, Water, Alcohol, NH_3 (Write any one example)

Non-Polar molecule

A molecule in which the centre of mass of positive charges coincides with the centre of mass of negative charges, because of the symmetrical shape of the molecule, is called a nonpolar molecule.

Eg. Hydrogen, Nitrogen, Oxygen, Co_2, Benzene, Methane (Write any one)

6. Ans : Refer (Text book pg. no 203 ; Art 8.9)

*The ability of a conductor to store electric charge is called the capacity of a capacitor.
*Mathematical equation
C = Q / V (C = capacitance, Q = charge stored, V = Potential difference)

*S.I. unit [farad (F) or coulomb/volt (C/V)]

7. Ans : Refer (Text book pg. no 211 Fig 8.33)

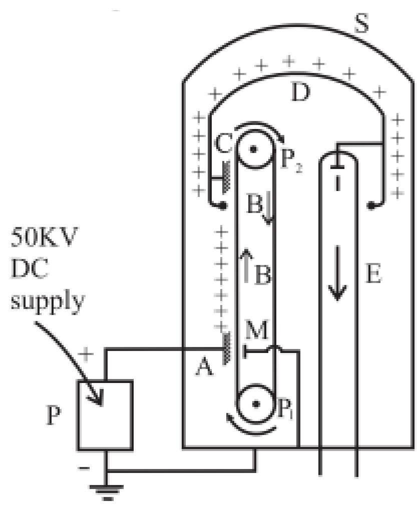


Fig. 8.33: Diagram of van de Graff generator.

P_1 P_2 = Pulleys

BB = Conveyer belt

A = Spray brush

C = Collector brush

D = Dome shaped hollow conductor

E = Evacuated accelerating tube

I = Ion source

P = DC power supply

S = Steel vessel filled with nitrogen

M = Earthed metal plate

8. C = $\frac{A\epsilon_0 K}{d}$ = (8.85 X 10^{-12} X 9 X10^{-3}) / 3 X 10^{-3} = 2.655 x 10^{-11} F

9. E = $\frac{1}{4\pi\epsilon_0 K}\frac{q}{r^2}$ = 0.02823 x 10^6 N/C

10. Electric Flux = φ =Eds cos θ = 4.5 x 10^6 x 2 x 10^{-6} x cos 60° = 4.5 x 10^6 x 2 x 10^{-6} x ½

= 4.5 N m^2/C

SHORT ANSWER TYPE - II – (3 MARKS EACH)

Ans : Refer (Text book pg. no 201)

- ★ In the presence of an external electric field E_o, the centres of the positive charge in each molecule of a non-polar dielectric is pulled in the direction of E_o, while the centres of the negative charges are displaced in the opposite direction. Therefore, the two centres are separated and the molecule gets distorted.
- ★ The displacement of the charges stops when the force exerted on them by the external field is balanced by the restoring force between the charges in the molecule.
- ★ Each molecule becomes a tiny dipole having a dipole moment.
- ★ The induced dipole moments of different molecules add up giving a net dipole moment to the dielectric in the presence of the external field.

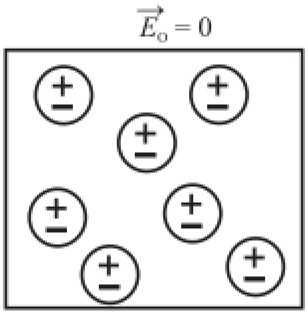


Fig. 8.20 (a) Shows the non polar dielectric in absence of electric field while.

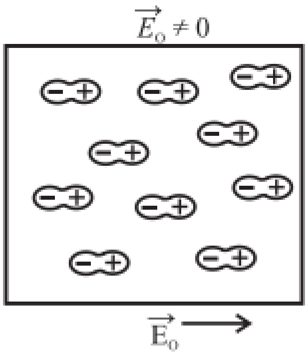


Fig. 8.20 (b) shows it in presence of an external field.

*The dipole moment per unit volume is called polarisation

★ Ans : Refer (Text book pg. no 209 and 210 ; Art 8.12)

8.12 Energy Stored in a Capacitor:

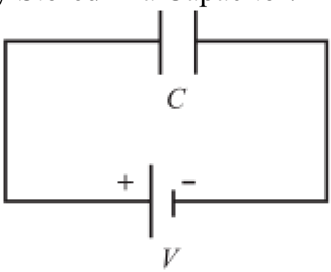


Fig. 8.32: Capacitor charged by a DC source.

*Consider a capacitor of capacitance C being charged by a DC source of V volts as shown in Fig.
*During the process of charging, let q' be the charge on the capacitor and V be the potential difference between the plates. Hence

$$C = \frac{q'}{V}$$

A small amount of work is done if a small charge dq is further transferred between the plates.

$$\therefore dW = V\,dq = \frac{q'}{C}\,dq$$

Total work done in transferring the charge

$$W = \int dw = \int_{O}^{Q} \frac{q'}{C}\,dq = \frac{1}{C}\int_{O}^{Q} q'\,dq$$

$$= \frac{1}{C}\left[\frac{(q')^2}{2}\right]_0^Q = \frac{1}{2}\frac{Q^2}{C}$$

This work done is stored as electrical potential energy U of the capacitor. This work done can be expressed in different forms as follows.

$$\therefore U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2 = \frac{1}{2}QV \quad (\because Q = CV)$$

★ Ans : Refer (Text book pg. no 206 ; Art 8.10a)
*A parallel plate capacitor consists of two thin conducting plates each of area A, held parallel to each other, at a suitable distance d apart.
*The plates are separated by an insulating medium. One of the plates is insulated and the other is earthed as shown in Fig.

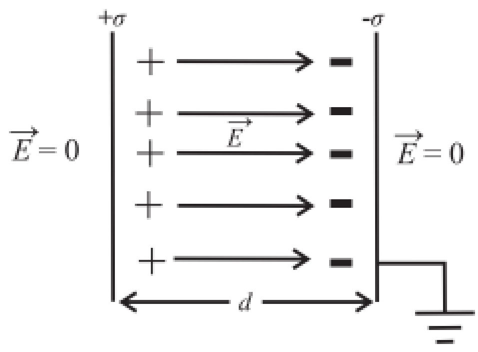


Fig. 8.28: Capacitor with dielectric.

*When a charge +Q is given to the insulated plate, then a charge -Q is induced on the inner face of earthed plate and +Q is induced on
its farther face. But as this face is earthed the charge +Q being free, flows to earth.
*In the outer regions the electric fields due to the two charged plates cancel out. The net field is zero.

$$E = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$

In the inner regions between the two capacitor plates the electric fields due to the two charged plates add up. The net field is thus

$$E = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0} \quad \text{--- (8.20)}$$

The direction of E is from positive to negative plate.
Let V be the potential difference between the 2 plates. Then electric field between the plates is given by

$$E = \frac{V}{d} \text{ or } V = Ed \quad \text{--- (8.21)}$$

Substituting Eq. (8.20) in Eq. (8.21) we get $V = \frac{Q}{A\varepsilon_0} d$

Capacitance of the parallel plate capacitor is given by

$$C = \frac{Q}{V} = \frac{Q}{\left(\frac{Qd}{A\varepsilon_0}\right)} = \frac{A\varepsilon_0}{d} \quad \text{--- (8.22)}$$

★ Ans : Refer (Text book pg. no 198 ; Art 8.6e)

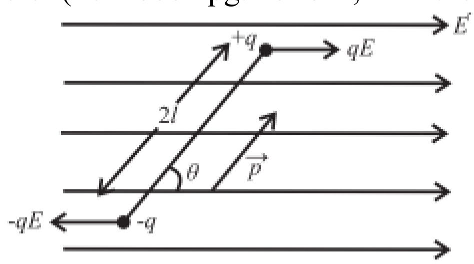


Fig. 8.17 : Couple acting on a dipole.

*Consider a dipole with charges -q and +q separated by a finite distance 2l, placed in a uniform electric field E.
*It experiences a torque τ which tends to rotate it.

$$\vec{\tau} = \vec{p} \times \vec{E} \text{ or } \tau = pE\sin\theta$$

*To neutralize this torque, let us assume an external torque τ_{ext} is applied, which rotates it in the plane of the paper from angle θ^0 to angle θ, without angular acceleration and at an infinitesimal angular
speed.
*Work done by the external torque

$$W = \int_{\theta_0}^{\theta} \tau_{ext}(\theta)\, d\theta = \int_{\theta_0}^{\theta} pE\sin\theta\, d\theta$$

$$= pE\left[-\cos\theta\right]_{\theta_0}^{\theta}$$

$$= pE\left[-\cos\theta - \left(-\cos\theta_0\right)\right]$$

$$= pE\left[-\cos\theta + \cos\theta_0\right]$$

$$= pE\left[\cos\theta_0 - \cos\theta\right]$$

*This work done is stored as the potential energy of the system in the position when the dipole makes an angle θ with the electric field. The zero potential energy can be chosen as per convenience. We can choose U (θ_0) = 0, giving

$$\therefore U(\theta) - U(\theta_0) = pE\left(\cos\theta_0 - \cos\theta\right)$$

★ Ans : Refer (Text book pg. no 191 ; Art 8.4a)
*Consider a point charge +q,
located at point O. We need to determine its potential at a point A, at a distance r from it.

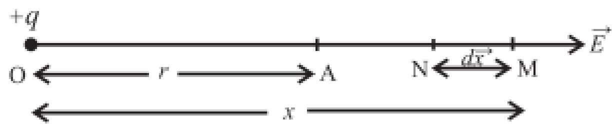


Fig. 8.6: Electric potential due to a point charge.

*Let M be an intermediate point on this path where OM = x. The electrostatic force on a unit positive charge at M is of magnitude

$$F = \frac{1}{4\pi\epsilon_0} \times \frac{q}{x^2} \qquad \text{--- (8.10)}$$

It is directed away from O, along OM. For infinitesimal displacement *dx* from M to N, the amount of work done is given by

$$\therefore dW = -Fdx \qquad \text{--- (8.11)}$$

The negative sign appears as the displacement is directed opposite to that of the force.

∴ Total work done in displacing the unit positive charge from ∞ to point A is given by

$$W = \int_{\infty}^{r} -Fdx \quad = \int_{\infty}^{r} -\frac{1}{4\pi\varepsilon_0}\frac{q}{x^2}\,dx$$

$$= \frac{-q}{4\pi\varepsilon_0} \int_{\infty}^{r} x^{-2}\, dx$$

$$= \frac{-q}{4\pi\varepsilon_0} \left[\frac{-1}{x}\right]_{\infty}^{r} \quad \left(\because \int x^{-2}\, dx = \frac{-1}{x}\right)$$

$$= \frac{q}{4\pi\varepsilon_0} \left[\frac{1}{r} - \frac{1}{\infty}\right] \quad \left(\because \frac{1}{\infty} = 0\right)$$

$$W = \frac{q}{4\pi\varepsilon_0 r} \qquad \text{--- (8.12)}$$

By definition this is the electrostatic potential at A due to charge q.

$$\therefore V = W = \frac{q}{4\pi\varepsilon_0 r} \qquad \text{--- (8.13)}$$

★ Ans : Refer (Text book pg. no 187 ; Art 8.2.2)

*Consider a uniformly charged wire of infinite length having a constant linear charge density λ (charge per unit length), kept in a medium of permittivity ε ($\varepsilon = \varepsilon_0 k$) .

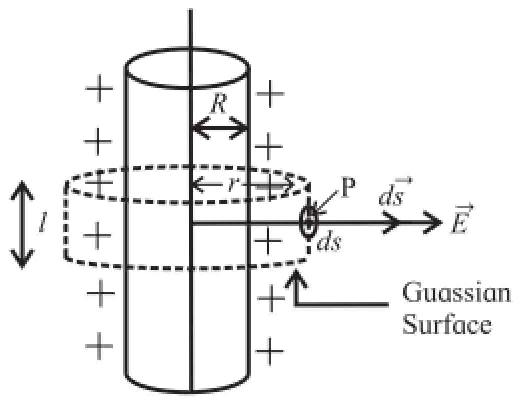


Fig. 8.2: Infinitely long straight charged wire (cylinder).

*To find the electric field intensity at P, at a distance r from the charged wire, imagine a coaxial Gaussian cylinder of length l and radius r (closed at each end by plane caps normal to the axis) passing through the point P. Consider a very small area ds at the point P on the Gaussian surface.

*By Gauss Theorem, the net flux through a closed surface,

$$\phi = q/\epsilon_0$$

*By symmetry, the magnitude of the electric field will be the same at all the points on the curved surface of the cylinder and will be directed radially outward. The angle between the direction of E and the normal to the surface of the cylinder (ds) is zero i.e.,

$\cos\theta = 1$

$\therefore \vec{E}.\vec{ds} = Eds\cos\theta = Eds$

Flux $d\phi$ through the area $ds = E\,ds$.

Total electric flux through the Gaussian surface $\phi = \oint \vec{E}\cdot\vec{ds} = \oint Eds = E\oint ds$

$\therefore \phi = E.\,2\pi rl$ --- (8.5)

From equations (8.1) and (8.5)

$q/\varepsilon_0 = E\,2\pi\,rl$

Since $\lambda = q/l$, $q = \lambda\, l$

$\therefore \lambda\, l/\varepsilon_0 = E\,2\pi\,rl$

$E = \lambda\ /\ 2\pi\varepsilon_0 r$ --- (8.6)

7 (i) Max. Torque = pE sinθ = $q(2l)$ x E=$10^{-6} \times 2 \times 10^{-2} \times 10^5 = 2 \times 10^{-3}$ Nm

(ii) Work done W = pE (cos θ_1-cos θ_2) = 2 x 10^{-8} x 10^5(cos0-cos180)

= 2 x 10^{-3}(1 +1) = 4 x 10^{-3}J (Refer Pg. 199 Eg. 8.14)

8. E = - $\frac{dV}{dX} = \frac{-2000}{5\,x\,10^{-2}}$ = -4x10^4V/m,

F = mg = qE

m = $\frac{qE}{g} = \frac{(-1.6\,x\,10^{-19})(-4\,x\,10^{4})}{9.8}$ = 6.531 x 10^{-16} kg (Refer Eg. 8.9 pg. 195 & 196)

9. Refer Text book pg 210, solved example 8.19

Solution : Energy stored in the capacitor with air

$$E_a = \frac{1}{2} CV^2 = \frac{1}{2} \times 3 \times 10^{-9} \times (400)^2$$
$$= 24 \times 10^{-5} \text{ J}$$

when the slab of dielectric constant 3 is introduced between the plates of the capacitor, the capacitance of the capacitor increases to

$$C' = kC$$
$$C' = 3 \times 3 \times 10^{-9} = 9 \times 10^{-9} \text{ F}$$

Energy stored in the capacitor with the dielectric (E_d)

$$E_d = \frac{1}{2} C' V^2$$
$$E_d = \frac{1}{2} \times 9 \times 10^{-9} \times (400)^2$$
$$= 72 \times 10^{-5} \text{ J}$$

Change in energy $= E_d - E_a = (72 - 24) \times 10^{-5}$
$= 48 \times 10^{-5}$ J

There is, therefore, an increase in the energy on introducing the slab of dielectric material.

1. Refer pg. 196 Eg. 8.10

Solution : Given

$q_1 = 5$ nC $= 5 \times 10^{-9}$ C

$q_2 = -2$ nC $= -2 \times 10^{-9}$ C

$r = (20 - 2)$ cm $= 18$ cm $= 18 \times 10^{-2}$ m

$$U = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r}$$

$$= \frac{9 \times 10^9 \times 5 \times 10^{-9} \times -2 \times 10^{-9}}{18 \times 10^{-2}}$$

$= -5 \times 10^{-7}$ J $= -0.5 \times 10^{-6}$ J $= -0.5$ µJ

Long Answers (4 marks each)

Ans: Refer (Text book pg. no 210 and 211; Art. 8.13)

*Neat Labelled Diagram:

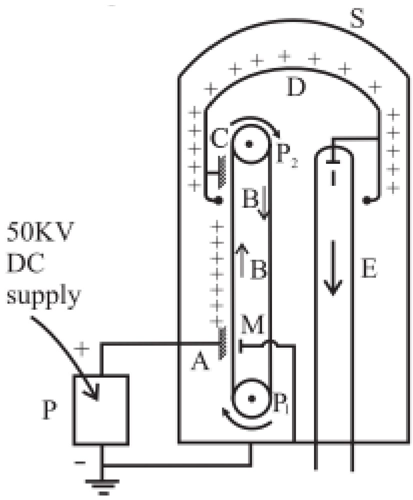


Fig. 8.33: Diagram of van de Graff generator.

P_1 P_2 = Pulleys

BB = Conveyer belt

A = Spray brush

C = Collector brush

D = Dome shaped hollow conductor

E = Evacuated accelerating tube

I = Ion source

P = DC power supply

S = Steel vessel filled with nitrogen

M = Earthed metal plate

*Construction:

* An endless conveyor belt BB made of an insulating material such as reinforced rubber or silk, can move over two pulleys P_1 and P_2. The belt is kept continuously moving by a motor (not shown in the figure) driving the lower pulley (P_1).

*The spray brush A, consisting of a large number of pointed wires, is connected to the positive terminal of a high voltage DC power supply. From this brush positive charge can be sprayed on the belt which can be collected by another similar brush C.

*This brush is connected to a large, dome-shaped, hollow metallic conductor D, which is mounted on insulating pillars (not shown in the figure). E is an evacuated accelerating tube having an electrode I at its upper end, connected to the dome-shaped conductor.

*To prevent the leakage of charge from the dome, the pulley and belt arrangement, the dome and a part of the evacuated tube are enclosed inside a large steel vessel S, filled with nitrogen at high pressure. A small quantity of Freon gas is mixed with nitrogen to ensure better insulation between the vessel S and its contents.

*A metal plate M held opposite to the brush A on the other side of the belt is connected to the vessel S, which is earthed.

Working:

*The electric motor connected to the pulley P_1 is switched on, which begins to rotate

setting the conveyor belt into motion. The DC supply is then switched on.

- ★ From the pointed ends of the spray brush A, positive charge is continuously sprayed on the belt B.
- ★ The belt carries this charge in the upward direction, which is collected by the collector brush C and sent to the dome shaped conductor.
- ★ As the dome is hollow, the charge is distributed over the outer surface of the dome.

Its potential rises to a very high value due to the continuous accumulation of charges on it. The potential of the electrode I also rises to this high value.

- ★ The positive ions such as protons or deuterons from a small vessel (not shown in the figure) containing ionised hydrogen or deuterium are then introduced in the upper part of the evacuated accelerator tube.
- ★ These ions, repelled by the electrode I, are accelerated in the downward direction due to the very high fall of potential along the tube; these ions acquire very high energy.
- ★ These high energy charged particles are then directed so as to strike a desired target.

2. Ans: Refer (Text book pg. no 192 and 193; Art. 8.4b)

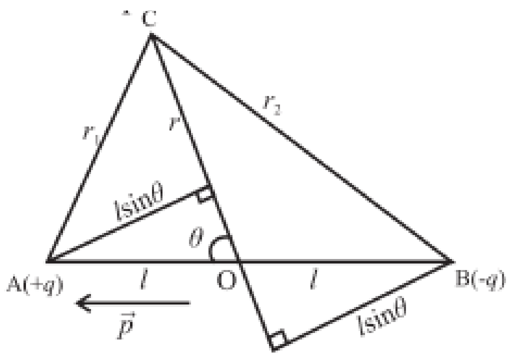


Fig. 8.8: Electric potential due to an electric dipole.

- Figure 8.8 shows an electric dipole AB consisting of two charges +q and -q separated by a finite distance 2ℓ.

★ Its dipole moment is p, of magnitude p = q × 2l, directed from -q to +q.

★ Let the origin be at the centre (O) of the dipole.

★ Let C be any point near the electric dipole at a distance r from the centre O inclined at an

★ angle θ with the axis of the dipole. r_1 and r_2 are the distances of point C from charges +q and -q, respectively.

*Potential at C due to charge +q at A is, $$V_1 = \frac{+q}{4\pi\varepsilon_0 r_1}$$

Potential at C due to charge -q at B is,

$$V_2 = \frac{-q}{4\pi\varepsilon_0 r_2}$$

The electrostatic potential is the work done by the electric field per unit charge, $\left(V = \frac{W}{Q}\right)$.

The potential at C due to the dipole is,

$$V_C = V_1 + V_2 = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$

By geometry,

$$r_1^2 = r^2 + \ell^2 - 2r\ell\cos\theta$$

$$r_2^2 = r^2 + \ell^2 + 2r\ell\cos\theta$$

$$r_1^2 = r^2\left(1 + \frac{\ell^2}{r^2} - 2\frac{\ell}{r}\cos\theta\right)$$

$$r_2^2 = r^2\left(1 + \frac{\ell^2}{r^2} + 2\frac{\ell}{r}\cos\theta\right)$$

For a short dipole, $2\ell << r$ and

If $r >> \ell$ ℓ/r is small $\therefore \frac{\ell^2}{r^2}$ can be neglected

$$\therefore r_1^2 = r^2\left(1 - 2\frac{\ell}{r}\cos\theta\right)$$

$$r_2^2 = r^2\left(1 + \frac{2\ell}{r}\cos\theta\right)$$

$$\therefore r_1 = r\left(1 - \frac{2\ell}{r}\cos\theta\right)^{1/2}$$

$$r_2 = r\left(1 + \frac{2\ell}{r}\cos\theta\right)^{1/2}$$

$$\therefore \frac{1}{r_1} = \frac{1}{r}\left(1 - \frac{2\ell}{r}\cos\theta\right)^{-1/2} \text{ and}$$

$$\frac{1}{r_2} = \frac{1}{r}\left(1 + \frac{2\ell}{r}\cos\theta\right)^{-1/2}$$

$$\therefore V_C = V_1 + V_2 = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r}\left(1 - \frac{2\,\ell\cos\theta}{r}\right)^{-1/2}\right.$$

Using binomial expansion, $(1 + x)^n = 1 + nx$, $x << l$ and retaining terms up to the first order of r only, we get

$$V_C = \frac{q}{4\pi\varepsilon_0}\frac{1}{r}\left[\left(1 + \frac{\ell}{r}\cos\theta\right) - \left(1 - \frac{\ell}{r}\cos\theta\right)\right]$$

$$= \frac{q}{4\pi\varepsilon_o r}\left[1 + \frac{\ell}{r}\cos\theta - 1 + \frac{\ell}{r}\cos\theta\right]$$

$$= \frac{q}{4\pi\varepsilon_o r}\left[\frac{2\ell}{r}\cos\theta\right]$$

$$\therefore V_C = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2} \quad (\because p = q \times 2\ell)$$

Electric potential at C, can also be expressed as,

$$V_C = \frac{1}{4\pi\varepsilon_0}\frac{\vec{p}\cdot\vec{r}}{r^3}$$

$$V_C = \frac{1}{4\pi\varepsilon_0}\frac{\vec{p}\cdot\hat{r}}{r^2}, \left(\hat{r} = \frac{\vec{r}}{r}\right)$$

where $\hat{r}$ is a unit vector along the position vector, $\overrightarrow{OC} = \hat{r}$

3.Ans: Refer (Text book pg. no 207 and 208; Art. 8.10b)

*Consider a parallel plate capacitor with the two plates each of area A separated by a distance d. The capacitance of the capacitor is given by

$$C_0 = \frac{A\varepsilon_0}{d}$$

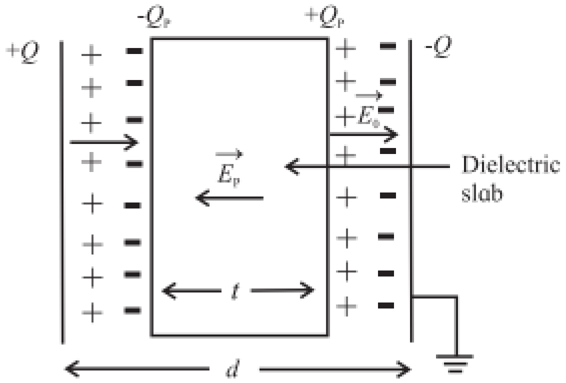


Fig. 8.29: Dielectric slab in the capacitor.

*Let E_0 be the electric field intensity between the plates before the introduction of the dielectric slab. Then the potential difference between the plates is given by $V_0 =$

$$\text{where } E_o = \frac{\sigma}{\varepsilon_o} = \frac{Q}{A\varepsilon_o}\text{, and}$$

E_0d,

σ is the surface charge density on the plates.

*Let a dielectric slab of thickness t (t < d) be introduced between the plates of the capacitor.

*The field E_0 polarizes the dielectric, inducing charge - Q_p on the left side and $+Q_p$ on the right side of the dielectric as shown in Figure.

*These induced charges set up a field E_p inside the dielectric in the opposite direction of E_0

*The induced field is given by

$$E_p = \frac{\sigma_p}{\varepsilon_o} = \frac{Q_p}{A\varepsilon_o}\left[\sigma_p = \frac{Q_p}{A}\right]$$

*The net field (E) inside the dielectric reduces to E_0 Hence,

$$E = E_o - E_p = \frac{E_o}{k}\left[\because \frac{E_o}{E_o - E_p} = k\right],$$

where k is a constant called the dielectric constant.

$$E = \frac{Q}{A\varepsilon_0 K} \text{ or } Q = AK\varepsilon_0 E \text{ --- (8.23)}$$

*The field E_p exists over a distance t and E0 over the remaining distance (d - t) between the capacitor plates. Hence the potential difference between the capacitor plates is

$$
\begin{aligned}
V &= E_o\left(d - t\right) + E\left(t\right) \\
&= E_o\left(d - t\right) + \frac{E_o}{k}\left(t\right) \qquad \left(\because E = \frac{E_0}{k}\right) \\
&= E_o\left[\left(d - t\right) + \frac{t}{k}\right] \\
&= \frac{Q}{A\varepsilon_o}\left[d - t + \frac{t}{k}\right]
\end{aligned}
$$

*The capacitance of the capacitor on the introduction of dielectric slab becomes

$$
C = \frac{Q}{V} = \frac{Q}{\frac{Q}{A\varepsilon_0}\left(d - t + \frac{d}{k}\right)} = \frac{A\varepsilon_0}{\left(d - t + \frac{t}{k}\right)}
$$

9 Current Electricity

Answers to MCQ (One-mark questions)

1. b. conventional current
2. a. charge
3. d. 30 ohm
4. b. Potential
5. a. Electric current
6. d. Meter bridge
7. c. 2/8 Ω
8. a. Potentiometer
9. a. 1.2 m
10. a. 0.5 Ω

Answers of VSA (one-mark questions)

1. The algebraic sum of the currents at a junction is zero in an electrical network.

2. The algebraic sum of the potential differences and electromotive forces in a closed loop is zero.

3. Potential gradient can be defined as potential difference per unit length of wire.

4.

$$r = R\left(\frac{l_1}{l_2} - 1\right)$$

5. Potentiometer is not portable and direct measurement of potential difference or EMF is not possible.

6. A galvanometer is a device used to detect weak electric currents in a circuit.

7. 3 Ω, 6 Ω.

8. 4 Ω

9. 7/13

10. 0.3 Ω

Answers to VSA (two-mark questions)

1. Junction: Any point in an electric circuit where two or more conductors are joined together is a junction.
   Loop: Any closed conducting path in an electric network is called a loop or mesh.
2. i) A potentiometer is more sensitive than a voltmeter.
   ii) A potentiometer can be used to measure a potential difference as well as an emf of a cell. A voltmeter always measures terminal potential difference, and as it draws some current, it cannot be used to measure an emf of a cell.

3.

AMMETER	VOLTMETER
It measures current.	It measures potential difference.
It is connected in series	It is connected in parallel
It is an MCG with low resistance. (Ideally zero)	It is an MCG with high resistance. (Ideally infinite)

4. : i) Potentiometer is used as a voltage divider.

   ii) Potentiometer is used as an audio control.

   iii) Potentiometer is used as a sensor.

5. Source of errors.

   i) The cross section of the wire may not be uniform.

   ii)The measurements of x and R may not be accurate and contact resistance introduced.

6. To minimise the errors

   (i) The value of R is so adjusted that the null point is obtained to the middle one third of the wire (between 34 cm and 66 cm) so that percentage error in the measurement of x and R are minimum and nearly the same.

   (ii) The experiment is repeated by interchanging the positions of unknown resistance X and known resistance R.

7. To minimise the errors

   (i) The value of R is so adjusted that the null point is obtained to the middle one third of the wire (between 34 cm and 66 cm) so that percentage error in the measurement of X and R are minimum and nearly the same.

   (ii) The experiment is repeated by interchanging the positions of unknown resistance X and known resistance R.

8. The voltmeter reading, V = IR

$$= \left(\frac{E}{R+r}\right)R$$

$$= \left(\frac{2}{30+10}\right)30$$

$$= \left(\frac{2}{40}\right)30$$

= 1.5 V

9 **Data:** $K = 5 \times 10^{-3}\ \frac{V}{m}$, L = 216 cm = 216×10^{-2} m

E = KL

$\therefore E = 5 \times 10^{-3} \times 216 \times 10^{-2}$

$= 1080 \times 10^{-5}$

= 0.01080 V

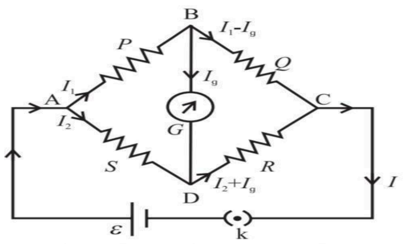
10 Ig = 25 μA. , Maximum voltage to be measured is V =10 V., G = 25Ω.

The resistance to be added in series,

$$X = \frac{V}{Ig} - G = \frac{10}{25 \times 10^{-6}} - 25 = 399.975 \times 10^{3}\ \Omega.$$

Answers of VSA (three-mark questions)

1 Expression for balancing condition for Wheatstone network



Four resistances P, Q, R and S are connected to form a quadrilateral ABCD as shown in the Fig. A battery of emf 'ε' along with a key 'k' is connected between the points A and C such that point A is at higher potential with respect to the point C. A galvanometer of internal resistance G is connected between points B and D.

When the key is closed, current 'I' flows through the circuit. It divides into I_1 and I_2 at point A.

I_1 is the current through P and I_2 is the current through S. The current I_1 gets divided at point B. Let I_g be the current flowing through the galvanometer. The currents flowing through Q and R are respectively

$(I_1 - I_g)$ and $(I_1 + I_g)$,

From the Fig. $I = I_1 + I_2$ --- (i)

Consider the loop ABDA. Applying Kirchhoff's voltage law in the clockwise sense

shown in the loop we get,

$-I_1 P - I_g G + I_2 S = 0$ --- (ii)

Now consider loop BCDB, applying Kirchhoff's voltage law in the clockwise sense

shown in the loop we get,

$-(I_1 - I_g)Q + (I_2 + I_g)R + I_g G = 0$ ------(iii)

From these three equations (i), (ii) and (iii) we can find the current flowing through any branch of the circuit.

A special case occurs when the current passing through the galvanometer is zero. In this case, the bridge is said to be balanced.

Condition for the balance is $I_g = 0$. This condition can be obtained by adjusting the values of P, Q, R and S. Substituting Ig = 0 in Eq. (ii) and Eq.(iii) we get,

$-I_1P + I_2S = 0 \therefore I_1P = I_2S$ --- (iv)

$-I_1Q + I_2R = 0 \therefore I_1Q = I_2R$ --- (v)

Dividing Eq. (iv) by Eq. (v), we get

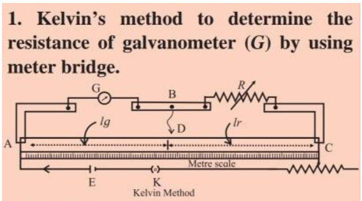
$\frac{P}{Q} = \frac{S}{R}$--- (vi)

This is the condition for balancing the Wheatstone bridge.

If any three resistances in the bridge are known, the fourth resistance can be determined by using Eq. (vi).

2. Kelvin's method to determine the resistance of a galvanometer by using a metre bridge.

Ans:



The galvanometer whose resistance (G) is to be determined is connected in one gap and a known resistance (R) in the other gap.

Working :

(i). A suitable resistance is taken in the resistance box. The current is sent round the circuit by closing the key. Without touching the jockey at any point of the wire, the deflection in the galvanometer is observed.

(ii). The rheostat is adjusted to get a suitable deflection Around (2/3)rd of range.

(iii). Now, the jockey is tapped at different points of the wire and a point of contact D for which, the galvanometer shows no change in the deflection, is found.

(iv). As the galvanometer shows the same deflection with or without contact between the point B and D, these two points must be equipotential points.

(v). The length of the bridge wire between the point D and the left end of the wire is measured. Let lg be the length of the segment of wire opposite to the galvanometer and lr be the length of the segment opposite to the resistance box.

Calculation :

Let R_{AD} and R_{DC} be the resistance of the two parts of the wire AD and DC respectively. Since bridge is balanced

G/R = $R_{AD}/R_{DC} = l_g/l_r$

$G/R = l_g/l_r = (\frac{l_g}{100 - l_r})$

$G = (\frac{l_g}{100 - l_r}) \times R$

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

3. Potentiometer is used to compare the emfs of two cells by connecting the cells individually.

Ans:

A) To Compare emf. of Cells

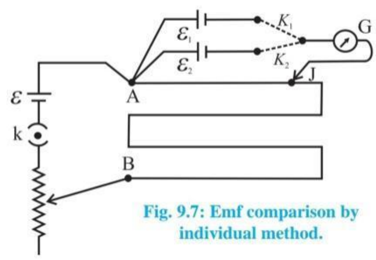


Fig. 9.7: Emf comparison by individual method.

A potentiometer circuit is set up by connecting a battery of emf ε , with a key K and a rheostat such that point A is at higher potential than point B. The cells whose emfs are to be compared are connected with their positive terminals at point A and negative terminals to the extreme terminals of a two-way key K_1K_2 . The central terminal of the two way key is connected to a galvanometer. The other end of the galvanometer is connected to a jockey (J). (Fig. 9.7) Key (K) is closed and then, key K_1 is closed and key K_2 is kept open.

Therefore, the cell of emf ε_1 comes into the circuit. The null point is obtained by touching the jockey at various points on the potentiometer wire AB. Let l_1 be the length of the wire between the null point and the point A. l_1 corresponds to emf ε_1 of the cell. Therefore,

$\varepsilon_1 = k\, l_1$ where k is the potential gradient along the potentiometer wire. Now key K_1 is kept open and key K_2 is closed. The cell of emf ε_2 now comes in the circuit. Again, the null point is obtained with the help of the Jockey. Let l_2 be the length of the wire between the null point and the point A. This length corresponds to the emf ε_2 of the cell.

$\therefore \varepsilon_2 = kl_2$

From the above two equations we get $\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$

Thus, we can compare the emfs of the two cells. If any one of the emfs is known, the other can be determined.

4. The internal resistance of a cell by using potentiometer with the necessary formula.

Ans:

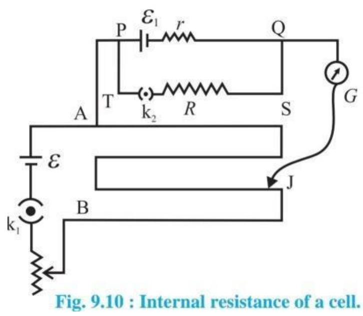


Fig. 9.10 : Internal resistance of a cell.

To Find Internal Resistance (r) of a Cell:

The experimental set up for this method consists of a potentiometer wire AB connected in series with a cell of emf ε , the key K_1 , and rheostat as shown in Fig. 9.10. The terminal A is at higher potential than terminal B. A cell of emf ϵ_1 whose internal resistance r_1 is to be determined is connected to the potentiometer wire through a galvanometer G and the jockey J. A resistance box R is connected across the cell ϵ_1 through the key K_2.The key K_1 is closed and K_2 is open. The circuit now consists of the cell ε , cell ϵ_1 , and the potentiometer wire. The null point is then obtained. Let l_1 be the length of the potentiometer wire between the null point and the point A. This length corresponds to emf ϵ_1

$\therefore \epsilon_1 = kl_1$ where k is the potential gradient of the potentiometer wire which is constant.

Now both the keys K_1 and K_2 are closed so that the circuit consists of the cell ε , the cell ϵ_1, the resistance box, the galvanometer and the jockey. Some resistance R is selected from the resistance box and null point is obtained.

The length of the wire l_2 between the null point and point A is measured. This corresponds to the voltage between the null point and point A.

$$\therefore V = ll_2$$

$$\therefore \epsilon_1 / V = kl_1 / kl_2 = l_1 / l_2$$

Consider the loop PQSTP.

$\epsilon_1 = IR + Ir$ and $V = IR$

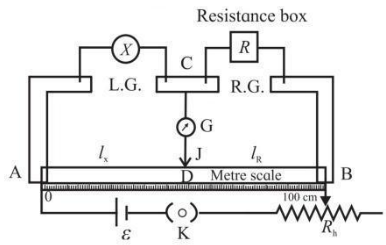
$$\therefore \frac{\varepsilon_1}{V} = \frac{IR + Ir}{IR} = \frac{R + r}{R} = \frac{l_1}{l_2}$$

$$\therefore r = R\left[\frac{l_1}{l_2} - 1\right]$$

This equation gives the internal resistance of the cell.

5. Expression for the unknown resistance by using metre bridge.

Ans:



Metre bridge (Fig.) consists of a wire of uniform cross section and one metre in length, stretched on a metre scale which is fixed on a wooden table. The ends of the wire are fixed below two L shaped metallic strips.

A single metallic strip separates the two L shaped strips leaving two gaps, left gap and right gap. Usually, an unknown resistance X is connected in the left gap and a resistance box is connected in the other gap. One terminal of a galvanometer is connected to terminal C on the central strip, while the other terminal of the galvanometer is connected to the jockey (J).

Temporary contact with the wire AB can be established with the help of the jockey. A cell of emf ε along with a key and a rheostat are connected between the points A and B.

A suitable resistance R is selected from the resistance box. The jockey is brought in contact with AB at various points on the wire AB and the balance point (null point), D, is obtained. The galvanometer shows no deflection when the jockey is at the balance point.

Let the respective lengths of the wire between A and D, and that between D and C be x and R . Then using the conditions for the balance, we get

$$\frac{X}{R} = \frac{R_{AD}}{R_{DB}}$$

where R_{AD} and R_{DB} are resistance of the parts AD and DB of the wire resistance of the wire. If l is length of the wire, ρ its specific resistance,

and A its area of cross section then

$R_{AD} = \rho l_{AD} / A$

$R_{DB} = \rho l_{DB} / A$

$$\frac{X}{R} = \frac{R_{AD}}{R_{DC}} = \frac{\rho l_{AD} / A}{\rho l_{DB} / A}$$

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

Therefore, $X = \frac{l_X}{l_R} \times R$

Knowing R, l_X and l_R , the value of the unknown resistance can be determined.

6. Conversion of a moving coil galvanometer into a voltmeter.

Ans: Galvanometer as a Voltmeter:

A voltmeter is an instrument used to measure potential difference between two points in an electrical circuit. It is always connected in parallel with the component across which voltage drop is to be measured. A galvanometer can be used for this purpose.

To Convert a Moving Coil Galvanometer into a Voltmeter.

To convert an MCG into a Voltmeter the modifications necessary are:

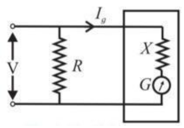
i). Its voltage measuring capacity must be increased to the desired higher value.

ii). Its effective resistance must be increased, and

iii). It must be protected from the possible damages, which are likely due to excess applied potential difference.

All these requirements can be fulfilled, if we connect a resistance of suitable high value (X) in series with the given MCG.

A voltmeter is connected across the points where potential difference is to be measured. If a galvanometer is used to measure voltage, it draws some current (due to its low resistance), therefore, actual potential difference to be measured decreases. To avoid this, a voltmeter should have very high resistance. Ideally, it should have infinite resistance.



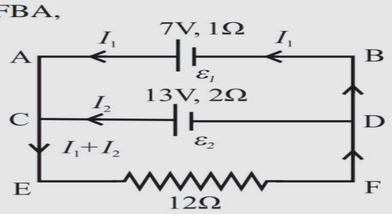
(Fig. Voltmeter)

A very high resistance X is connected in series with the galvanometer for this purpose as shown in fig.

7. Ans:

Solutions: Let the currents passing through the two batteries be I_1 and I_2.

Applying Kirchhoff second law to the loop AEFBA,



$$-12(I_1+I_2)-1I_1+7=0$$

$$12(I_1+I_2)+1I_1=7 \qquad \text{--- (1)}$$

For the loop CEFDC

$$-12(I_1+I_2)-2I_2+13=0$$

$$12(I_1+I_2)+2I_2=13 \qquad \text{--- (2)}$$

From (1) and (2) $2I_2-I_1=13-7=6$

$$I_1=2I_2-6$$

Substituting I_1 value in (2)

$$I_2=\frac{85}{38}=2.237\,A$$

$$I_1=2I_2-6$$

$$I_1=2\times\frac{85}{38}-6=-1.526\,A$$

$$I=I_1+I_2=-1.526\,A+2.237\,A=0.711\,A$$

Potential difference across 12 Ω resistance

$V=IR=0.711\times12=8.53V$

8. Ans:

Solution: Given G = 40 Ω and $I_G = 4\ mA$

(a) To convert the galvanometer into an ammeter of range 0.4 A,

$$(I-I_G)S=I_GG$$

$$(0.4-0.004)S=0.004\times40$$

$$S=\frac{0.004\times40}{0.396}=\frac{0.16}{0.396}=0.4040\ \Omega$$

(b)To convert the galvanometer into a voltmeter of range of 0.5 V

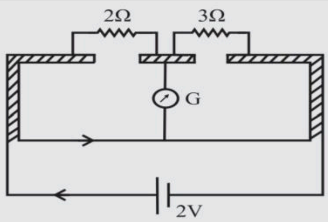
$$V=I_G(G+X)$$

$$0.5=0.004(40+X)$$

$$X=\frac{0.5}{0.004}-40=85\,\Omega$$

9. Ans: When the bridge is balanced the resistance is 2 and 3 ohm are in series and the total resistance is 5 ohm. When the bridge is balanced the resistance is 2 and 3 ohm are in series and the total resistance is 5 ohm.

Let R_1 be the resistance of the wire = 1.49 ohm and R_2 be the total resistance (2+3) = 5 ohm.



$$R_p = \frac{R_1 R_2}{R_1 + R_2} = \frac{1.49 \times 5}{1.49 + 5} = 1.15\Omega$$

The current through the cell

$$= \frac{\varepsilon}{R_p} = \frac{2}{1.15} = 1.74\,A$$

Specific resistance of the wire $= \rho = \frac{R\pi r^2}{l}$

$$l = 1m,\ r = \frac{0.12}{2} = 0.06\text{cm},\ \ R = 1.49\,\Omega$$

$$\rho = \frac{R\pi r^2}{l} = \frac{1.49 \times 3.14 \times \left(0.06 \times 10^{-2}\right)^2}{1}$$

$$= 1.68 \times 10^{-6}\,\Omega\,\text{m}$$

10. Ans: The resistances 10 ohm, 12 ohm, 15 ohm are connected in parallel. Their equivalent resistance Rp is given by

$$\frac{1}{R_p} = \frac{1}{10} + \frac{1}{12} + \frac{1}{15}$$

$$= \frac{6+5+4}{60}$$

$$= \frac{15}{60} = \frac{1}{4}$$

$\therefore R_p = 4\ \Omega$

For resistance R_p , 10 Ω, 12 Ω and 15 Ω connected in series, the equivalent resistance,

$R_S = 4 + 10 + 12 + 15 = 41\ \Omega$

Thus, the total resistance = R_S = 41 Ω

Now, $V = IR_S$

$\therefore 4.1 = I \times 41$

$\therefore I = 0.1$ A

The total resistance and current through the circuit are 41 Ω and 0.1 A respectively.

10 Magnetic Fields due to electric current

Answers to MCQ (One-mark questions)

1. c. Gauss' law in electrostatics
2. d. $\frac{q^2B^2R^2}{2m}$
3. c. in the direction perpendicular to both field and its length
4. c. concave pole pieces of magnet
5. b. $I \propto \theta$
6. a. 90^O
7. a. 0
8. c. 0.24 mA
9. d. 5.6×10^{-5} T
10. d. 0.51×10^{-5} T

Answers of VSA (one-mark questions)

1. Zero
2. $\underline{F}_m = I\ \underline{L} \times \underline{B}$
3. Zero $\quad (\underline{F} = q\,(\underline{v} \times \underline{B}) = qvB \sin\theta \quad \theta = 0 \ \therefore F = q \times 0 = 0)$
4. Tm / A
5. $d\underline{B} = \frac{\mu_0}{4\pi}\frac{I\,\underline{dl} \times \underline{r}}{r^3}$
6. 1 Tesla = 10^4 Gauss
7. $\oint \underline{Bdl} = \mu_0 I$
8. $\mu = NIA = 6.3 \times 10^{-6}$ Am^2
9. $B = \frac{\mu_0 NI}{2R} = 3.142 \times 10^{-3}$T
10. $B = \mu_0 NI = 2 \times 10^{-3}$ T

Answers of VSA (two-mark questions)

1. Statement and explanation of Ampere's law – Textbook page 245
2. Cyclotron equation – Textbook page 232, Article 10.3
3. Diagram of suspended MCG- Textbook page 238, fig. 10.13
4. Diagram of cyclotron- Textbook page 233, fig. 10.6
5. Magnetic dipole moment-Textbook page 238, Article 10.8
6. Equation of Lorentz force-Text book page 231, Article 10.2

7. $t = T/2 = \frac{\pi m}{qB} = \frac{3.142 x 1.67 x 10^{-27}}{1.6 x 10^{-19} x 1.4} = 2.384 \text{ x} 10^{-8}$s

8. $B = \mu_0 NI/d \quad \therefore\ d = \frac{4\pi\times10^{-7}\times5\times10}{0.5\times10^{-4}} = 1.257$m

9. $I = \left(\frac{C}{nAB}\right)\theta \quad \therefore \theta = \frac{nABI}{C} = \frac{3\times10^{-4}\times0.05\times0.01}{5\times10^{-9}} = 30°$

10. Magnetic potential energy $U_m = -\mu B\cos\theta$

Case 1: when $\theta = 180°$ $\cos\theta = -1$ $\therefore U_{max} = \mu B$

It corresponds to most unstable position

Case 2: when $\theta = 0°$ $\cos\theta = +1$ $\therefore U_{min} = -\mu B$

It corresponds to the most stable position.

Answers of VSA (three-mark questions)

1. Magnetic field produced by a current in a circular arc of wire: Text book pg 242
2. Moving coil galvanometer: Textbook pg 238
3. Force acting on a current carrying straight wire: Textbook pg 234 & 235
4. $F/l = \frac{\mu_0 I_1 I_2}{2\pi a}$ $\therefore F/l = \frac{\mu_0 I^2}{2\pi a}$ $\therefore I^2 = 3213$ $\therefore I = 56.68$A
5. Torque on a current loop Textbook pg 236 - 237
6. Biot -Savart Law- Textbook pg 239 and 240
7. Time period of a cyclotron Textbook pg 233
8. $KE_{max} = \frac{q^2 B^2 r_{max}^2}{2m}$ after substitution we get, $KE_{max} = 5.5 \text{ x } 10^{-12}$J $= 34 \text{ x } 10^6$eV
9. $B = \frac{\mu_0 I}{2r}$ $\therefore I = \frac{2Br}{\mu_0} = 1.253$A

   $\mu = NIA = NI\pi r^2 = 5.956 \text{ x } 10^{-2}$ Am^2
10. $\theta = \frac{nABI}{C}$ $\therefore$ $I = c\theta/nAB = 1.2\text{x}10^{-5}$A

Long Answers (4 marks each)

1. Ampere's circuital law : Textbook pg 245 and 246
2. Axial magnetic field produced by current in a circular loop: Textbook pg 243

   (Figure and explanation, derivation)
3. Magnetic field produced by a current carrying solenoid: Textbook pg 246 and 247
4. Magnetic induction at a point along the axis of toroid: Textbook pg 247 and 248

(Figure and explanation with derivation)

5. Construction theory and working of a moving coil galvanometer: Textbook pg 238 (Construction and working)
6. Magnetic field due to an infinitely long straight wire carrying current I: Text book pg 240 (Figure and explanation)
7. Force acting per unit length of the wire in case of two long parallel wires carrying currents in the same direction: Text book pg 241 (Figure & explanation with equation)

11 Magnetic Materials

Answers to MCQ (One-mark questions)

1. b. Negative
2. c. Inversely proportional to temperature
3. a. Low coercivity and low retentivity
4. b. Ferromagnetic rod
5. b. 1/2
6. c. 1/600
7. d. $\mu_r = 1 + \chi$
8. a. 12×10^{-8}, $M = \chi H$
9. c. 5499

a. c. $L = \frac{2m_e m_0}{e}$

10. Answers of VSA (one-mark questions)

1. Soft iron having large permeability and small amount of retaining magnetization is useful for preparing electromagnet.
2. The ratio of magnetic moment to the volume of the material is called magnetisation.
3. The process of taking magnetic material through the hysteresis loop once is called a hysteresis cycle.
4. The hysteresis loop represents behaviour of ferromagnetic materials in terms of flux density when placed in an external magnetic field.
5. Magnetic susceptibility.
6. -0.925, hint: $\chi = \mu_r - 1$
7. $\vec{T} = \vec{M} \, x \, \vec{B}$
8. Lead, silicon, glass and water
9. Electric bells, loud speakers, circuit breakers, research laboratories.
10. $M = 4 \times 10^4 \ Am^{-1}$
11. Gyromagnetic ratio = $M_{orbital}/t = e/2me$

Answers of VSA (two-mark questions)

1 Soft iron having large permeability and small amount of retaining magnetisation. Hard magnetic materials are those having a property to retain the magnetisation to a larger extent.

2 Magnetization in paramagnetic material is directly proportional to the applied magnetic field and inversely proportional to the temperature of the material.

3 The quantity $\frac{eh}{4\pi m_e}$, the magnetic moment of an atom is stated in terms of Bohr magneton. Its value is 9.274 x 10^{-24} A/m^2

4 Page no. 258

5 2.495×10^5 Am^{-1}, H = NI, $\chi = \mu_r - 1$, M= XH = (μr − 1) H

6 Page no. 254

7 The quantity $\frac{eh}{4\pi m_e}$, the magnetic moment of an atom is stated in terms of Bohr magneton. Its value is 9.274 x 10^{-24} A/m^2

8 I= 500 g cm^2, T=6 sec B_H = 0.36 gauss

$$m = \frac{4\pi^2}{T^2}\frac{I}{B} = \qquad m = 1.524 \text{ A m}^2$$

9 initial susceptibility- Initial temperature= T1=27° C,27+ 273 K= 300 K

Final susceptibility- $\chi/3$ $\chi_1/\chi_2 = T_1/T_2$ T2= 900-273=627 °C

$$\chi_m H = C\frac{\mu_0 H}{T} \quad \therefore\ \chi_m = C\frac{\mu_0}{T}$$

$$\therefore\ \chi_m \propto \frac{1}{T} \quad \therefore\ \frac{\chi_{m1}}{\chi_{m2}} = \frac{T_2}{T_1}$$

$$\therefore\ T_2 = \frac{\chi_{m1}}{\chi_{m2}} \times T_1 = 3\frac{\chi}{\chi} \times 300 = 900 \text{ K} = \mathbf{627\,°C}$$

10 $\theta_0 = 0°$, $\theta_1 = 90°$, $\theta_2 = 60°$, $W_1 = nW_2$

The work done by an external agent to rotate the magnet from θ_0 to θ is

$$W = MB(\cos\theta_0 - \cos\theta)$$

$\therefore W_1 = MB(\cos\theta_0 - \cos\theta_1) = MB(\cos 0° - \cos 90°) = MB(1 - 0) = MB$

$\therefore W_2 = MB(\cos 0° - \cos 60°) = MB(1 - 1/2) = 0.5MB$

$\therefore W_1 = 2W_2 = MB$

Given $W_1 = nW_2$. Therefore N = 2.

Answers of VSA (three-mark questions)

1 Ans, see textbook page no. 254

2 Magnetisation = magnetic moment /volume; $M_Z = 3*10^5$Am

3 Bohr magneton = h/2π * gyromagnetic ratio

4 l = 10 cm, b = 0.5 cm, h = 0.2 cm, H = 0.5×10^4 Am^{-1}, M = 5 A·m^2

The volume of the plate, V = 10 × 0.5 × 0.2 = 1 cm^2 = 10^{-6} m^2

$B = \mu_0 (H + M_z) = \mu_0 (H + MV)$

The magnetic induction in the plate,

$\therefore B = 4\pi \times 10^{-7} (0.5 \times 10^{4} + 510-6) = 6.290$ T

5 The magnetization of a given sample material M can be defined as the net magnetic moment for that material per unit volume. $M_Z = m_{net}$ / volume. The ratio of the magnetizing field to the permeability of free space is called magnetic intensity. The strength of a magnetic field at a pont can be given in terms of a vector quantity called magnetic intensity (H). $H_o = B_o / u_o$. Unit of magnetic intensity is Am^{-1}

6 Page no 257 textbook

The magnetic field inside the solenoid without Aluminium, $B_0 = \mu_0 H$

The magnetic field inside the solenoid with Aluminium $B = \mu H$

$$\frac{B-B_0}{B_0} = \frac{\mu-\mu_0}{\mu_0}, \quad \mu = \mu_0 (1 + \chi)$$

$$\frac{\mu-\mu_0}{\mu_0} = \chi,$$

$$\frac{B-B_0}{B_0} = \frac{\mu-\mu_0}{\mu_0} = \chi$$

Ans- 0.0023 %

7

Formulae:

i. $m_{orb} = \frac{evr}{2}$

ii. $L = mvr$

Calculation:

From formula (i),

$$m_{orb} = \frac{1.6 \times 10^{-19} \times 2 \times 10^{6} \times 5.3 \times 10^{-11}}{2}$$

$= 1.6 \times 5.3 \times 10^{-24}$

$= 8.48 \times 10^{-24}$ Am^2

From formula (ii),

$L = 9.1 \times 10^{-31} \times 2 \times 10^{6} \times 5.3 \times 10^{-11}$

$= 96.46 \times 10^{-36}$

8. According to Curie's Law, the magnetization in a paramagnetic material is directly proportional to the applied magnetic field and inversely proportional to the temperature.

Curie's Law Formula

Curie's Law can be framed into an equation. M = C x (B/T)

Wherein, M = Magnetism, B = Magnetic field (in Tesla)

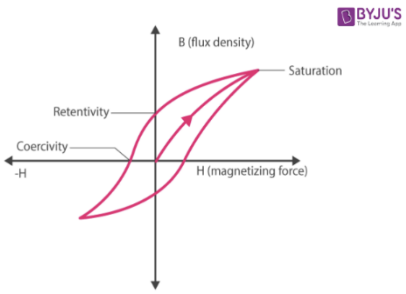
T = absolute temperature (in Kelvins), C = Curie constant

Curie's law holds good for high temperatures and not so strong magnetic fields.

9. Ferromagnetic materials are those materials which exhibit a spontaneous net magnetisation at the atomic level, even in the absence of an external magnetic field. When placed in an external magnetic field, ferromagnetic materials are strongly magnetised in the direction of the field. Ferromagnetic materials are strongly attracted to a magnet. These materials will retain their magnetisation for some time, even after the external magnetising field is removed. This property is called hysteresis.

On removing the external magnetic field, a ferromagnetic material doesn't get demagnetised fully. To bring the material back to zero magnetisation, a magnetic field in the opposite direction has to be applied. The property of ferromagnetic materials retaining magnetisation after the external field is removed. This is called hysteresis.

The magnetisation of the material measured in terms of magnetic flux density (B) when plotted against the external applied magnetic field intensity (H) will trace out a loop. This is called the hysteresis loop.



Retentivity is the magnetic flux density that remains when the magnetising force is reduced to zero. Coercivity is the strength of the reverse magnetising field that must be applied to completely demagnetise the material.

10. Ans: page no.258

For a rod of diamagnetic material suspended freely in a magnetic field, a torque acts on the induced dipole. When the dipole is in a direction opposite to the direction of the magnetic field, it has a large magnetic potential energy and is unstable.

The dipole then tries to attain a position where the magnetic potential energy is least, which is when the rod is perpendicular to the direction of the magnetic field.

Hence, the rod of a diamagnetic material when suspended freely aligns itself in the direction perpendicular to the direction of external magnetic field.

Long Answers (4 marks each)

1.

i. **Relation between magnetic field intensity(H) and magnetization(M):**

a. Consider a magnetic material (rod) placed in a magnetizing field (solenoid with n turns per unit length and carrying current I).

b. The magnetic field inside the solenoid is given by,

$B_0 = \mu_0 nI$ ....(1)

Where μ_0 = permeability of free space.

c. The magnetic field inside the rod is given as,

$B_m = \mu_0 M$ ....(2)

Where M = magnetization of the material

d. The net magnetic field inside the rod is expressed as,

$B = B_0 + B_m$ ....(3)

$\therefore B = \mu_0 nI + \mu_0 M$

$\therefore B = \mu_0 H + \mu_0 M$

$\therefore B = \mu_0 nI + \mu_0 M$

$\therefore B = \mu_0 H + \mu_0 M$

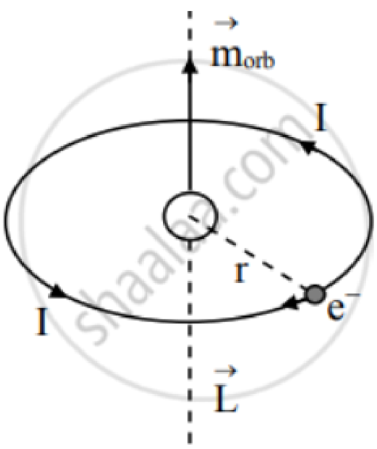
Where H = nI = Magnetic field intensity

$\therefore B = \mu_0 (H + M)$

$\therefore H = \dfrac{B}{\mu_0} - M$ ....(4)

e. Equation (4) shows that the magnetic field (B) induced in the material depends on magnetic field intensity (H) and magnetization (M).

2.



i. **Origin of magnetism in material:**

a. Magnetism has its origin in the circulating charges in an atom.

b. Circulating electron is equivalent to a current loop and has a magnetic dipole moment.

c. An atom of any substance consists of a small massive positively charged nucleus surrounded by negatively charged electrons revolving in a circular orbit around the nucleus.

d. The magnetic moment is associated with the motion of an electron in its orbit and is termed an orbital magnetic moment.

ii. **Expression for magnetic dipole moment:**

a. Consider an electron of mass me and charge e revolving in a circular orbit of radius r around the positive nucleus in the clockwise direction, leading to an anticlockwise current.

U.C.M of an electron around the nucleus

b. If the electron travels a distance 2πr in time T then, its orbital speed v = 2πr/T

c. The magnitude of circulating current is given by,

$I = e\left(\frac{1}{T}\right)$

But, $T = \frac{2\pi r}{v}$

$\therefore I = e\left(\frac{1}{2\pi r/v}\right) = \frac{ev}{2\pi r}$

d. The orbital magnetic moment associated with the orbital current loop is given by,

$m_{orb} = IA = \frac{ev}{2\pi r} \times \pi r^2$ [∵ Area of current loop, $A = \pi r^2$]

$\therefore m_{orb} = \frac{evr}{2}$ ....(1)

e. The angular momentum of an electron due to its orbital motion is given by, $L = m_e vr$

f. Multiplying and dividing the R.H.S of equation (1) by m_e,

$m_{orb} = \frac{e}{2m_e} \times m_e vr$

$\therefore m_{orb} = \frac{eL}{2m_e}$

g. This equation shows that orbital magnetic moment is proportional to the angular momentum. But as the electron bears negative charge, the orbital magnetic moment and orbital angular momentum are in opposite directions and perpendicular to the plane of the orbit.

Using vector notation, $\vec{m}_{orb} = -\left(\frac{e}{2m_e}\right)\vec{L}$

3. See textbook. Page no. 258, 259
4. Page no 262. Applications of an electromagnet:

Electromagnets are used in electric bells, loud speakers and circuit breakers.

1. Large electromagnets are used in junkyard cranes and industrial cranes to lift iron scraps.
2. Superconducting electromagnets are used in MRI and NMR machines, as well as in particle accelerators of the cyclotron family.
3. Electromagnets are used in data storage devices such as computer hard disks and magnetic tapes.

5 Data: $M = 2 \times 10^{-2}$ A·m^2, $I = 7.2 \times 10^{-7}$ kg·m^2,

$T = 6/10 = 0.6$ S

$T = 2\pi\sqrt{\frac{I}{MB}}$

The magnitude of the magnetic field is

$B = 4\pi^2 IMT^2$

$= (4)(3.14)^2(7.2\times10-7)(2\times10-2)(0.6)^2$

$= 3.943 \times 10^{-3}$ T = 3.943 mT

12 Electromagnetic Induction

Answers to MCQ (One-mark questions)

1. c. Lenz's law
2. b. magnetic flux
3. c. energy
4. a. Eddy currents
5. c. 100%
6. a. Weber/s
7. d. 1.25J
8. c. 8 mH
9. c. 240
10. b. Self-inductance
11. a. 1/RC
12. a. 0.1 V
13. c. South pole
14. b. Mutual inductance
15. b. Motor

Answers of VSA (one-mark questions)

1. First law- whenever there is a change in the magnetic flux associated with a coil, an emf is induced in the coil.
   Second law- The magnitude of induced emf is directly proportional to the rate of change of magnetic flux.
2. Lenz's law- The direction of the induced emf is such as to oppose the change in magnetic flux which produces it.
3. A change in the magnetic flux linked with the coil produces an emf in the coil, which causes an electric current to flow through it.
4. Field generated due to changing magnetic flux with time.
5. Voltage produced by the movement of conducting wire or a conductor in a magnetic field.
6. The emf generated by a running motor due to coil that turns in a magnetic field which opposes the voltage that powers the motor.
7. Blv
8. $E=1/2* Bwl^2$

9. volt
10. scalar
11. henry or H
12. If an emf of 1 volt is induced in a coil, when the current in the coil is changing at the rate of 1 ampere per second then induced emf is 1 henry.
13. The coefficient of coupling (K) for radio coils lies between 0.001 to 0.05
14. K= 1, indicates that two coils are perfectly coupled and M = $\sqrt{L_1 L_2}$
15. If K > 0.5 the coils are tightly coupled and if K< 0.5 then coils are loosely coupled.
16. Mutual inductance is the principle of the transformer.
17. The ratio of the number of turns of secondary to the number of turns of primary is called the turn ratio.
18. For an ideal transformer input power is equal to output power.
19. AC output voltage across the secondary is greater than the AC input voltage applied to the primary. It is called a step up transformer.
20. AC output voltage across the secondary is less than the AC input voltage applied to the primary. It is called a step down transformer.
21. To minimize eddy currents.
22. By parallel arrangement, 1H
23. $W=1/2*LI^2$ =10H
24. Induced emf = 1/60 volt = 0.0166V

Answers of VSA (two-mark questions)

1. First law- whenever there is a change in the magnetic flux associated with a coil, an emf is induced in the coil.

Second law- The magnitude of induced emf is directly proportional to the rate of change of magnetic flux.

Lenz's law- The direction of the induced emf is such as to oppose the change in magnetic flux which produces it. All these together are called as laws of electromagnetic induction.

2. The two coils kept close are perfectly coupled, when the coefficient of coupling is K = 1,
3. The circulating currents induced in a metal block, when it is moving in a magnetic field or placed in a changing magnetic field are called eddy currents.
4. Eddy currents are minimised by laminating the core of the transformer.

5 Unit of self-inductance is henry or H. If an emf of 1 volt is induced in a coil, when the current in the coil is changing at the rate of 1 ampere per second then induced emf is 1 henry.

6 Magnetic permeability.

7 Inductance per unit length near the middle of the solenoid is $B= \mu_0 n^2 A$

8 Magnetic field inside the toroid $B= \mu_0 NI$

9 Series arrangement of inductance is used to increase the effective inductance of the circuit.

10 Series arrangement of inductance is used to decrease the effective inductance if the circuit.

11

Sr.no	Self-inductance	Mutual inductance
1	Induced emf in a coil when changing current passes through it.	Induced emf in one coil due to change of current in the neighbouring coil
2	It depends upon shape, size, and number of turns of the coil	It depends upon the number of turns of both the coils and their geometrical shape.

12 Magnetic flux linked with each turn of the coil =Flux/no. of turns

Ǿ =NLI =400 x 20 x 10^{-3} x 8 x 10^{-3} =64 x 10^{-3}Wb

Ǿ /N = 1.6 x 10^{-4} Wb

13 L = Ǿ/I = 20 x 10^{-3}/4 = 5 x 10^{-3} H

14 Magnetic flux [M L^2 T^{-2} I^{-1}]

15 If a coil of metal wire is held stationary in a non-uniform magnetic field the emf will not be induced in it.

16 Induced emf = e = d Ǿ/dt = 0.2 x 10^{-2} / 0.12 = .0167 volt

17 The back emf induced in the coil is the measure of the inertia of the coil against the change of current through it. Emf is a measure of inertia of the coil against the change of current through it.

18 Speedometer and electric brakes, induction furnace eddy currents are used.

19 Fleming's right-hand rule-Stretch the thumb and the first two fingers of the right hand in such a way that they are mutually perpendicular to each other. If the forefinger points in the direction of the magnetic field and the thumb in the direction of motion of the conductor, the middle finger indicates the direction of induced emf.

20

Sr.no	Step up	Step down transformer
1	Output voltage is more than input voltage	Output voltage is less than input voltage
2	Output current is less than input current	Output current is more than input current
3	Primary coil is thicker than secondary coil	Secondary coil is thicker than primary coil

21 Unit for self and mutual inductance is henry or H. Its dimension $[M^1L^2T^{-2}A^{-2}]$.

22 The rate of change of magnetic flux is directly proportional to induced current.

23 The mathematical form of electromagnetic induction is $e = -N \times d\phi/dt$

Answers of VSA (three-mark questions)

1. Ans text book page no 270 (Figure, explanation, and derivation)
2. Ans text book page no 273 and 274, (Figure, explanation, and derivation)
3. Ans text book page no 277, (Figure, explanation, and derivation)
4. Ans text book page no 284, (Figure, explanation, and derivation)
5. $\Phi = (2t^3+3t^2+8t+5) \times 10^{-3}$ Wb ,N = 1, t =3

   $e = d/dt\ (2t^3+3t^2+8t+5) \times 10^{-3} = (6t^2+6t+8) \times 10^{-3}$ volt

   At t =3 s, $e = 80 \times 10^{-3}$ volt = 80mV
6. $N_p = 460$, $N_s = 40000$, Vp=230 volt,

   $V_s = V_p \times N_s/N_p = 230*40000/460 = 20000$ volt

   Secondary voltage per turn = $V_s/ N_s = 20000/40000 = 0.5$ volt
7. The coefficient of coupling $K = M / \sqrt{L_1L_2} = 0.334$

13 AC circuits

Answers to MCQ (One-mark questions)

1. b. Direct current
2. a. Alternating current
3. d. Zero
4. d. Average value of AC over complete cycle is zero
5. a. 325 volt
6. c. Phasor diagram
7. c. Emf and current both are in the same phase
8. a. Current leads emf by 90 degrees
9. b. Emf leads current by 90 degrees
10. c. Frequency.

Answers of VSA (one-mark questions)

1. In alternating current the polarity of the voltage keeps changing periodically.
   $E = E_o$ sinwt
2. Zero
3. $I_{rms} = I_0/\sqrt{2} = 0.707\ I_0$
4. A rotating vector that represents a quantity varying sinusoidally with time is called a phasor.
5. The phase difference between current and emf for resistive circuits is zero.
6. The phase difference between current and emf is 90 degrees for capacitive circuits.
7. The phase difference between current and emf for an inductive circuit is 90 degrees. In an inductive circuit emf leads current by 90 degrees.
8. Inductive reactance $X_L = 2\pi fL$
9. Capacitive reactance $X_C = 2\pi fC$
10. The resistance offered by a capacitor or inductor in an AC circuit is called reactance.
11. The total effective resistance of an LCR circuit is called impedance.
12. The reciprocal of impedance of an AC circuit is called admittance.
13. Unit for admittance is mho.
14. Unit of reactance is ohm.
15. Unit of impedance is ohm.
16. The phase difference between current and emf in LCR series circuit is Φ
    where $\cos \Phi = R/Z$
17. Average power associated with resistance is called as apparent power

18. Average power associated with an LCR circuit is called true power.
19. Average power dissipated in LCR circuit is = e_{rms} x i_{rms} cos Φ
20. Average power dissipated in resistive circuit is = e_{rms} x i_{rms}
21. Average power associated with a pure inductor is zero.
22. Average power associated with a pure inductor is zero.
23. Series resonance condition for LCR circuit is $X_L = X_C$
24. Parallel resonance condition for LCR circuit is $X_L = X_C$
25. Resonant frequency $f_r = \frac{1}{2\pi\sqrt{LC}}$
26. Q- factor = resonant frequency / bandwidth
27. The maximum value of power factor is e_{rms} x i_{rms} and minimum value is zero.
28. Peak value of AC voltage = 1.414 x e_{rms} = 311 volt
29. $e_{rms} = e_0\, x\, 0.707$
30. Current through a pure inductor or ideal capacitor which consumes no power for its maintenance is called true power.
31. The sharpness of resonance is measured by a coefficient called the Q- factor
32. The quality factor depends upon inductance, capacitance, and resistance of the circuit.
33. [M^0 L^0 T^1]
34. [M^0 L^0 $T^{1/2}$]
35. 18.4 degrees
36. Power factor = cos 45=0.707
37. Power factor = cos Φ= R/Z =0.666

Answers of VSA (two-mark questions)

1. True power = power factor x apparent power
2. When average power consumed in a pure inductor or ideal capacitor is zero then current is wattless.
3. The average value of AC over a cycle is zero. Because it has one positive peak and one negative peak over a cycle.
4. Because it measures the average value which is zero over a cycle.
5. DC voltmeter and ammeter measures average value of ac which is zero over a complete cycle.
6. Heating effect is used in an ammeter which is independent of direction of current.
7. Average value is measured.

8. Same voltage = 110 volt
9. AC has a peak value of 311 volt but DC has a fixed value of 220 volt.
10. The reactance of an inductor in a dc circuit is zero.
11. In series LCR circuits at resonance, the current reaches its maximum value because impedance is minimum.
12. The maximum value of power factor one when current and emf are in the same phase.
13. The minimum value of power factor zero when current and emf are not in the same phase.
14. Yes, we can use it.
15. Admittance = 1/cos 60 =1.04 mho
16. L/R = T = time, $[M^0 L^0 T^1]$
17. Natural frequency of LC circuit = $\frac{1}{2\pi\sqrt{LC}}$
18. The resonance value of the power factor is one.
19. A parallel resonant circuit is called a rejector circuit.
20. A series resonance circuit is also called an acceptor circuit.
21. Peak value of current = 1.414 x 5 =7.07A
22. Resistance = $V^2/ P = (220)^2/100 = 484$ ohm.
23. $F_r = \frac{1}{2\pi\sqrt{LC}}$, So capacitor =249.7pF
24. Current = P/V = 60/240 =0.25A
25. $X_L = 1/2\pi fL = 31.4$ ohm

Answers to VSA (three-mark questions)

1. For Ans refer to textbook page 297 – 13.6-b (see the derivation)
2. For Ans refer to textbook page 294 – Table 13.1 (Distinguishing points)
3. For Ans refer to textbook page 301 and 302
4. For Ans refer to textbook page 291 – Fig 13.4 (see the graph)
5. For Ans refer to textbook page 295 (Figure & derivation)
6. For Ans refer to textbook page 301 and 302
7. For Ans refer to textbook page 301 (figure, explanation & derivation)
8. For Ans refer to textbook page 302 (figure, explanation & derivation)
9. For Ans refer to textbook page 303 (figure and explanation)
10. $\mathbf{X_L} = 1/2\pi fL$ =31.4 ohm
$\mathbf{X_C} = 1/2\pi fC = 63.7$ ohm

$Z = \sqrt{R^2 + (X_L - X_C)^2}$ = 33.81 ohm

I= E/Z =2.96A

Power factor = cos Φ= R/Z = 0.296

Power = EI cos Φ = 87.62 W

11. E_{rms} = E_O/1.414 =300/1.414 = 212.16 V

I_{rms} = E_{rms}/ R = 212.16/100 = 2.121 A

12. The impedance = $Z = \sqrt{R^2 + (X_L - X_C)^2}$ = 50 ohm

Tan Φ = $(X_L - X_C)$/R = 1.33

Φ = 53.1 degrees

13. Resonant frequency = $F_r = \frac{1}{2\pi\sqrt{LC}}$ = 2500 Hz

Q-factor = $2\pi f_r L/R$ = 12.5

14 Dual nature of radiation and matter

Answers to MCQ (One-mark questions)

1. (a) Planck
2. (a) UV
3. (c) 6.626 x 10^{-34}
4. (c) $K.E._{max} = h\nu - \phi_0$
5. (a) electrical, light
6. (d) 0.1 nm
7. (d) Photoelectric effect
8. (d) 36.46 x 10^{-3} eV
9. (b) 19.8 x 10^{29} J
10. (a) 6.626 x 10^{-33} m

Answers to VSA (one-mark questions)

1. No, it is not necessary to use red light in the photoelectric effect.
2. 'ν' is the frequency of incident light.
3. Every particle of matter of mass 'm' moving with velocity 'v' is associated with a wave whose wavelength is given by '$\lambda = h/p$'.
4. The surface that emits electrons when illuminated by electromagnetic radiation of appropriate frequency is called a photosensitive surface.
5. The photoelectric effect refers to the emission of electrons from the surface of a metal in response to the incident light.
6. As the wavelength of incident light is greater than the threshold wavelength, the frequency of incident light is smaller than the threshold frequency and hence electrons will not emit.
7. $\lambda = h / p = 6.63 \times 10^{-34} / 10^{-26} = 6.63 \times 10^{-34}$ x $10^{26} = 6.63 \times 10^{-8}$ m
8.

Data: λ = 0.5 Å = 5×10^{-11} m, h = 6.63×10^{-34} J.s

The momentum of the electron,

$$p = \frac{h}{\lambda}$$

$$= \frac{6.63 \times 10^{-34}}{5 \times 10^{-11}}$$

= 1.326×10^{-23} kg.m/s

Answers to VSA (two-mark questions)

1. Pg. 316 - Diagram (1M) , Construction (1M)
2. Pg. 307, Fig. 14.2, Neat labelled circuit diagram (2M)
3. Pg. 309, Correct definition (1 mark each)
4. Pg. 316 – 317, Explanation/Definition ($\frac{1}{2}$ M)

$E = h\nu$ ($\frac{1}{2}$ M)

$mc^2 = h\nu$

$hc/\lambda = mc^2$ ($\frac{1}{2}$ M)

$\lambda = h/mc$

or

$\lambda = h/p$ ($\frac{1}{2}$ M)

5. Pg. 309, Two points. (1 Mark each)
6. Formula & Substitution (1 Mark)

$$E = \frac{hc}{\lambda}$$

$$\therefore \lambda = \frac{hc}{E} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{2.072 \times 1.6 \times 10^{-19}} = 6 \times 10^{-7} m$$

$$\text{Wave number } \bar{v} = \frac{1}{\lambda}$$

$$\Rightarrow \frac{1}{6 \times 10^{-7}} = 1.67 \times 10^{6} m^{-1}$$

Calculation & Correct answer (1 Mark)

7. Formula & Substitution (1 Mark)

To calculate kinetic energy, K.E. = $h\nu - h\nu_o$

$$K.E. = hc\left[\frac{1}{\lambda} - \frac{1}{\lambda_o}\right]$$

$$K.E. = 19.89 \times 10^{-19}\left[\frac{1}{2.6} - \frac{1}{3.8}\right]$$

$$K.E. = \frac{2.416 \times 10^{-19}}{1.6 \times 10^{-19}}$$

K.E. = 1.51 eV

Calculation & Correct answer (1 Mark)

8. Formula & Substitution (1 Mark each)

Formula: $n = \frac{E}{h\nu}$

Calculation:

Using formula,

$$n = \frac{6.63}{6.63 \times 10^{-34} \times 10^{14}}$$

$\therefore$ **n = 10^{20}**

Calculation & Correct answer (1 Mark)

9. Formula & Substitution (1 Mark each)

$$\lambda_0 = \frac{hc}{W_0}$$

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{4.8 \times 10^{-19}}$$

$$\lambda_0 = 4.14 \times 10^{-7} m$$

Calculation & Correct answer (1 Mark)

10. Formula & Substitution (1 Mark each)

The Energy of the incident radiation is

$$E = \frac{hc}{\lambda}$$

$$\Rightarrow \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{5 \times 10^{-7}}$$

$$E = 3.972 \times 10^{-19} J$$

$$\therefore E > \phi$$

As E is greater than ϕ. So, photoelectric emmission will occur.

Calculation & Correct answer (1 Mark)

11. $W_0 = h\nu_0$

$\nu_0 = W_0/h = \frac{5 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}} = 1.2 \times 10^{15}$ Hz

Answers to VSA (three-mark questions)

1. Photoelectric equation $h\gamma = \frac{1}{2}(mv^2) + W_0$

Characteristics textbook page 312-313

2. Textbook page no. 316
3. Textbook page no. 313
4. Textbook page no. 313-314
5. Textbook page no. 313-314
6. Textbook page no. 317
7. $\lambda_0 = hc/\phi = (6.63 \times 10^{-34})\ 3 \times 10^8 / 6.72 \times 10^{-19} = 2960\ A^0$

   $KE_{max} = ev_o = 4.8 \times 10^{-19}$ J

8. $1/2mv^2_{max} = hc\ (1/\lambda - 1/\lambda_0) = 2.402 \times 10^{-19}$ J = 1.51 ev

9. $\gamma_o = \phi_0 / h = 5.550 \times 10^{14}$ Hz

   $C = \gamma\lambda$, $\gamma = C/\lambda = 4.412 \times 10^{14}$ Hz

   There will be no emission of photoelectrons.

10 $KE_{max} = hc/\lambda - \phi_{0 = =} 2.95 \times 10^{-19}$ J

   $V_{max} = 8.054 \times 10^5$ m/s

11. $E = hc/\lambda$

   For $\lambda_1 = 5650A^0$, $E_1 = hc/\lambda_1 = 3.52 \times 10^{-19}$ J

   $E_2 = hc/\lambda_2 = 3.84 \times 10^{-19}$ J

   Photoelectric effect will occur in both the cases.

12 $\gamma_0 = \phi_0 /h = 5.309 \times 10^{14}$ Hz

   $\gamma = c/\lambda = 6.0 \times 10^{14}$ Hz

   As $\lambda > \lambda_0$, there will be emission of photoelectrons.

Long Answers (4 marks each)

1. Textbook page no. 318
2. Textbook page no. 316.
3. Textbook page no. 315
4. $½\ mv^2_{max} = hc/\lambda - \phi_0 = 1.22 \times 10^{-19}$ J

   $V_{max} = 5.178 \times 10^5$ m/s

   $B = 1.472 \times 10^{-5}$ T

15 Structure of atoms and nuclei

Answers of MCQ (One-mark questions)

1. c. 486-656 nm
2. c. h/2π
3. d. $\frac{h^2\varepsilon_0}{\pi m_e e^2}$
4. b. -13.6
5. d. +13.6ev
6. c. Angular momentum
7. b. Neutrons
8. c. Atomic number
9. c. Photons
10. c. Damping factor

Answers to VSA (one-mark questions)

1. Minimum angular momentum = nh/ 2π
2. Balmer series
3. Bohr magneton
4. $E = E_n – E_p$
5. 10.2ev
6. λ = 0.693/ T = 0.5 per year
7. $r_2/r_1 = 2.126A^0$

Answers to VSA (two-mark questions)

1. M = ver/2 textbook page no. 327
2. Textbook page 327
3. Textbook page 330
4. Textbook page 327
5. First postulate and second postulate
6. E_n = -13.6 ev = - me^4 / ($8€_0^2\ n^2h^2$)

   $E_n\ \alpha\ 1/n^2$, So, $E_3 = E_1$ /9 = -1.511 ev
7. f = v/(2πr) = 2.2 x 10^{-6} /(2 x 3.142 x 0.53 x 10^{-10}) = 6.6 x 10^{15} Hz
8. E_5 = -0.544ev
9. $T_{1/2}$ = 0.693/ λ = 0.693/ 4.33x 10^{-4} = 1600 years
10. f = v/(2πr) = 8.105x 10^{14}Hz

11. 8 alpha particles and 8 beta particles are emitted.
12. $1/\lambda = R\,(1/p^2 - 1/n^2)$ so , $\lambda_l = 144/7R$ and $\lambda_s = R/4$, $\lambda_l/\lambda_s = 5.131$
13. $T = 2\pi r/v = 1.44\times10^{-16}$ sec; $f = 1/T = 6.9\times10^{15}$ Hz
14. Angular momentum = $nh/2\pi = 4.22\times 1o^{-34}$ kgm^2/s
15. $E_1 = -16.6$ ev
16. $T_{1/2} = 0.693/\lambda$; $\lambda = 0.2166$ per day.
17. $\lambda_{Lmax} / \lambda_{Bmax} = 5/27$
18. decay constant $= \lambda = 0.0693$

Answers to VSA (two-mark questions)

1. For answer see textbook page no. 336
2. For answer see textbook page no. 329
3. For answer see textbook page no. 329
4. Three postulates textbook page no. 327; $r_2 = 2.127\ A^0$
5. For answer see textbook page no. 329
6. Angular momentum = $L_o = 0.1443 \times 10^{-33}$ kgm^2/s
7. $1/\lambda_{H\alpha} = 6563A^0$; $1/\lambda_{H\beta} = 4862A^0$
8. For answer see textbook page no. 329

Long Answers (4 marks each)

1. Refer Bohr's formula. $\lambda_{p\alpha} / \lambda_{B\alpha} = 81/175$

   Period of revolution = $T = 1.366 \times 10^{-16}$ sec
2. For answer see textbook page no. 339
3. For answer see textbook page no. 325
4. Centripetal force = electrostatic force between proton and electron = 8.2×10^{-8} N
5. For answer see textbook page no. 326
6. For answer see textbook page no. 327-328

16 Semiconductor devices

Answers of MCQ (One-mark questions)

1. a. Rectification
2. b. NOR gate
3. d. $\frac{1}{9}$ mA
4. c. 100 Hz
5. c. an optocoupler
6. c. the short circuit current
7. b. 0.99
8. d. 1 mA
9. c. from emitter to base
10. b. Ga As

Answers of VSA (one-mark questions)

1. Dark resistance of a photodiode is defined as the ratio of maximum reverse voltage and its dark current $R_d = \frac{Maximum\ reverse\ voltage}{Dark\ current}$
2. The Boolean expression for X-OR gate is $Y = A \oplus B = \vec{A} . B + A . \vec{B}$
3. 180^{0O} *or* π^C
4. 1) Counters & Switches 2) Burglar alarm system
5. $\alpha = \frac{I_C}{I_E} = \frac{6.20}{6.28} = 0.987$
6. $\beta = \frac{\alpha}{1-\alpha} = \frac{0.96}{1-0.96} = 24$
7. $A_v = \frac{V_o}{V_i} \therefore V_o = A_v \cdot V_i = 150 \text{ x } 10 \text{ x } 10^{-3} = 1.5$ V
8. A power supply whose output changes when a load is connected across it is called Unregulated power supply.
9. $I_c = 0.98 I_E$ $\beta = \frac{I_C}{I_B} = \frac{0.98\, I_E}{I_E - 0.98 I_E} = \frac{0.98\, I_E}{0.02\, I_E} = 49$
10. Anti reflective coating allows visible light to pass through it and reflects the IR (heat) radiation, thus protecting the solar cell from heat.

Answers of VSA (two-mark questions)

1. Explanation of LED - Textbook Page 354
   Circuit symbol - Textbook Fig. 16.15 (a)
2. Filter circuit - Textbook Page 346
3. Schematic symbols - Textbook Page 362
4. Ripple factor - Textbook Page 346
5. a) Photothermal devices b) Photovoltaic devices
6. GaAsP – red or yellow light, ZnSe – blue light
7. $I_c = \alpha \times I_E = 6.84$ mA, $I_B = I_E - I_c = 7.2 - 6.84 = 0.36$ mA
8. Given: $\frac{80}{100} \times I_E = I_c \therefore \frac{80}{100} \times I_E = 24$ mA $\therefore I_E = 30$ mA, $I_B = 30 - 24 = 6$ mA
9. $A_v = \beta \cdot \frac{R_o}{R_i} = 50 \times \frac{2000}{200} = 500$
10. Textbook page 346, solved e.g. 16.1

Answers of VSA (three-mark questions)

1. Working of n-p-n transistor - Textbook Page 357
2. Definition of α_{dc} = In common emitter mode α_{dc} is defined as the ratio of the collector current (I_c) to the emitter current (I_E) $\alpha_{dc} = \frac{I_c}{I_E}$

   Definition of β_{dc} = In common emitter mode β_{dc} is defined as the ratio of the collector current (I_c) to the base current (I_B) $\beta_{dc} = \frac{I_c}{I_B}$

   Relation between them: Textbook page 359.
3. LED is a diode which emits light when large forward current passes through it (Textbook page 354) working - Textbook page 355
4. Circuit diagram of Half wave rectifier - Textbook page 345,
   working - Textbook page 345
5.

LED	Photodiode
1. It is a forward biased pn junction diode.	1. It is a special purpose reverse biased p-n junction diode

2. It emits light due to direct radiative recombination of excess electron-hole pairs.	2. It generates charge carriers in response to photons and high energy particles.
3.The intensity of the emitted light is directly proportional to the diode forward current.	3. The photocurrent in the external circuit is proportional to the intensity of the incident radiation.

6. Diagram and working of an amplifier - Textbook page 360 and 361

7. $I_L = \frac{V_Z}{R_L} = \frac{5}{1000} = 5$ mA, $I_S = \frac{V_s - V_z}{R_s} = \frac{10-5}{500} = 10$ mA, $I_z = I_s - I_L = (10-5) = 5$ mA

8. a) Maximum current $Iz = \frac{P_z}{V_0} = \frac{4}{8} = 500$ mA

   a) $R_s = \frac{V_s - V_z}{I_z} = \frac{15-8}{0.5} = 14\ \Omega$

   b) $I_L = \frac{V_z}{R_L} = \frac{8}{400} = 20$ mA

   c) $I_z = I_s - I_L = 500 - 20 = 480$ mA

9. Logic gate - Textbook page 361

   Boolean expression & truth table of AND gate - Textbook page 362

10. Band gap energy of the given photodiode $E_g = 2.8$ eV

    Wavelength $\lambda = 6000 \times 10^{-9}$ m

    Energy of the signal = $E = \frac{hC}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{6000 \times 10^{-9}} = 3.313 \times 10^{-20}$ J

    $$= \frac{3.313 \times 10^{20}}{1.6 \times 10^{-19}} = 0.207 \text{ eV}$$

    The energy of the signal of wavelength 6000 nm is 0.207 eV is less than the energy band gap of the photodiode which is 2.8 eV. Hence the photodiode cannot detect the signal.

Long Answers (4 marks each)

1. Zener Diode -Text book page 348 and 349
2. Rectifier: It is an electronic device that converts an AC into DC by using one or more p-n junction diodes

   Full wave rectifier: circuit diagram, explanation/working, input and output waveform - Textbook page 345 & 346
3. Solar cell – structure Textbook page 352, working -Text book page 353

4. Transistor amplifier – circuit diagram and working of amplifier- Textbook page 360
5. Photodiode – What is a photodiode- Textbook page 350, working principle -Text book page 351
6. a) LED- Textbook page 355 & 356, b) Photodiode - Textbook page 352
7. Analog and digital circuit - Textbook page 361, X-OR gate -Text book page 363

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