Class XI Session 2023-24
Subject - Physics
Sample Question Paper - 2

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

General Instructions:

1. There are 33 questions in all. All questions are compulsory.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.
3. Section A contains sixteen questions, twelve MCQ and four Assertion Reasoning based of 1 mark each, Section B contains five questions of two marks each, Section C contains seven questions of three marks each, Section D contains two case study-based questions of four marks each and Section E contains three long answer questions of five marks each.
4. There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.
5. Use of calculators is not allowed.

Section A

1. The number of significant digits in 0.2370 is **[1]**

   a) 4 b) 3

   c) 5 d) 6

2. A point source emits sound equally in all directions in a non-absorbing medium. Two points P and Qare at distances of 2 m and 3 m respectively from the source. The ratio of the intensities of the waves at P and Q is: **[1]**

   a) 4 : 9 b) 2 : 3

   c) 3 : 2 d) 9 : 4

3. A solid sphere is rotating freely about its symmetry axis in free space. The radius of the sphere is increased keeping its mass the same. Which of the following physical quantities would remain constant for the sphere? **[1]**

   a) Angular velocity b) Angular momentum

   c) Rotational kinetic energy d) Moment of inertia

4. If a liquid does not wet glass, its angle of contact is **[1]**

   a) zero b) right angle

   c) obtuse d) acute

5. If V is the gravitational potential on the surface of the earth, then what is its value at the centre of the earth? **[1]**

   a) $\frac{2}{3}$V b) 3 V

c) $\frac{3}{2}$V

d) 2 V

6. Two waves represented by $Y_1 = a_1 \sin \omega t$ and $Y_2 = a_2 (\sin \omega t + \Delta)$ and $\Delta = \frac{\pi}{2}$ are superimposed at a point at a particular instant. The amplitude of the resultant wave is: **[1]**

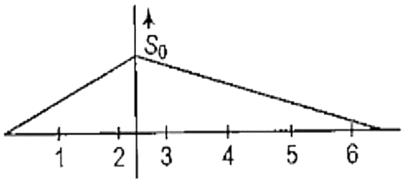
a) $a_1 + a_2$

b) $\sqrt{a_1^2 - a_2^2}$

c) $\sqrt{a_1^2 + a_2^2}$

d) $a_1 - a_2$

7. What will be ratio of speed in first two seconds to the speed in next 4 seconds? **[1]**



a) $\sqrt{2}$: 1

b) 3 : 1

c) 2 : 1

d) 1 : 2

8. A stretched string is vibrating according to equation, $y = 5\sin\left(\frac{\pi x}{2}\right)\cos 4\pi t$ where y and a are in cm and t in secs. The distance between two consecutive nodes on the string is **[1]**

a) 4 cm

b) 8 cm

c) 16 cm

d) 2 cm

9. The velocity of efflux of a liquid through an orifice in the bottom of the tank does not depend upon **[1]**

a) none of these

b) acceleration due to gravity

c) height of liquid

d) size of orifice

10. At what distance from the centre of the moon, the intensity of gravitational field will be zero? Take masses of earth and moon as 5.98×10^{24} kg and 7.35×10^{22} kg respectively and distance between moon and earth is 3.85×10^8m. **[1]**

a) Zero

b) 3.46×10^8m

c) 8×10^8m

d) 3.85×10^7 m

11. If I_1 and I_2 be the moments of inertia of two bodies of identical geometrical shape, the first is made of aluminium and the second of iron, then **[1]**

a) $l_1 > l_2$

b) $l_1 < l_2$

c) relation between l_1 and l_2 depends on the central shapes of the bodies

d) $l_1 = l_2$

12. For a black body at temperature of 727° C, its radiating power is 60 W and temperature of surroundings is 227°C. If temperature of black body is changed to 1,227°C, then its radiating power will be **[1]**

a) 304 W

b) 240 W

c) 120 W

d) 320 W

13. **Assertion:** If collision occurs between two elastic bodies their kinetic energy decreases during the time of impact. **[1]**

Reason: During impact, intermolecular distance decreases and hence elastic potential energy increases.

a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

c) Assertion is correct statement but reason is wrong statement.

d) Assertion is wrong statement but reason is correct statement.

14. **Assertion:** The specific heat of a gas in an adiabatic process is zero but it is infinite in an isothermal process. **[1]**
Reason: Specific heat of a gas is directly proportional to heat exchanged with the system and inversely proportional to change in temperature.

a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

c) Assertion is correct statement but reason is wrong statement.

d) Assertion is wrong statement but reason is correct statement.

15. **Assertion (A):** Planet is a heavenly body revolving around the sun. **[1]**
Reason (R): Star is luminous body made of gaseous material.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

16. **Assertion (A):** The cross product of a vector with itself is a null vector. **[1]**
Reason (R): The cross-product of two vectors results in a vector quantity.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

Section B

17. State few important uses of the phenomenon of beats. **[2]**

18. A large fluid star oscillates in shape under the influence of its own gravitational field. Using dimensional analysis, find the expression for period of oscillation (T) in terms of radius of star (R), mean density of fluid (ρ) and universal gravitational constant (G). **[2]**

19. The wavelength λ associated with a moving particle depends upon its mass m, its velocity v and Planck's constant h. Show dimensional relation between them. **[2]**

20. A constant retarding force of 50 N is applied to a body of mass 20 kg moving initially with a speed of 15 ms^{-1}. How long does the body take to stop? **[2]**

21. Two bodies of masses 10 kg and 1000 kg are at a distance 1 m apart. At which point on the line joining them will the gravitational field intensity be zero? **[2]**

OR

The acceleration due to gravity at the moon's surface is 1.67 ms^{-2}. If the radius of the moon is 1.74 x 10^6 m, then calculate the mass of the moon.

Section C

22. State and prove the equation of continuity for steady flow of an ideal fluid. **[3]**

23. How does the coefficient of cubical expansion of a substance vary with temperature? Draw γ versus T curve for **[3]**

copper.

24. A particle length executes the motion described by $x(t)=x_0\left(1-e^{-rt}\right); t\geq 0, x_0>0$ **[3]**

a. where does the particle start and with what velocity?

b. find the maximum and minimum values of x(t), v(t), a(t). Show that x(t) and a(t) increases with time and v(t) decreases with time.

Main concept used: By calculating v(t) and a(t) with the help of x(t), then determining the maximum and minimum value of x(t),v(t) and a(t).

25. A railway car of mass 20 tonne moves with an initial speed of 54 kmh^{-1}. On applying brakes, a constant negative acceleration of 0.3 ms^{-2} is produced. **[3]**

a. What is the braking force acting on the railway car?

b. In what time will it stop?

c. What distance will be covered by railway car before it finally stops?

26. Find out whether these phenomena are reversible or not. **[3]**

i. Waterfall and

ii. Rusting of iron

27. a. Define impulse. State its S.I. unit. **[3]**

b. State and prove impulse-momentum theorem.

28. Calculate the total energy possessed by one kg of water at a point where the pressure is 20 $\frac{\text{gf}}{\text{mm}^2}$, velocity is 0.1 ms^{-1} and the height is 50 cm above the ground level. **[3]**

OR

A rectangular tank is 10 m long, 5 m broad and 3 m high. It is filled to the rim with water of density 10^3 kg m^{-3}. Calculate the thrust at the bottom and walls of the tank due to hydrostatic pressure. Take g = 9.8 ms^{-2}.

Section D

29. **Read the text carefully and answer the questions:** **[4]**

In everyday life, the term work is used to refer to any form of activity that requires the exertion of mental or muscular efforts. In physics, work is said to be done by a force or against the direction of the force, when the point of application of the force moves towards or against the direction of the force. If no displacement takes place, no work is said to be done.

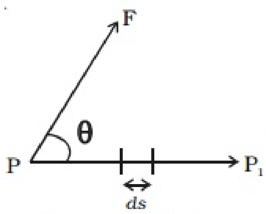


Fig. Work done by a force

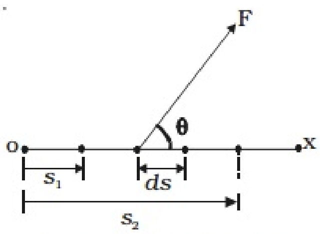


Fig. Work done by a constant force

(i) A box is pushed through 4.0 m across a floor offering 100 N resistance. How much work is done by the applied force?

a) 100 J
b) 300 J
c) 400 J
d) 200 J

(ii) What is work done in holding a 15 kg suitcase while waiting for 15 minutes?

a) 22.5 J
b) zero

c) 225 J

d) 150 J

(iii) Frictional forces are:

a) conservative forces

b) non-conservative forces

c) buoyant force

d) none of these

OR

Force of 4N is applied on a body of mass 20 kg. The work done in 3rd second is:

a) 6 J

b) 8 J

c) 4 J

d) 2 J

(iv) When the body moves in a circular motion, net 'work' done is:

a) none of these

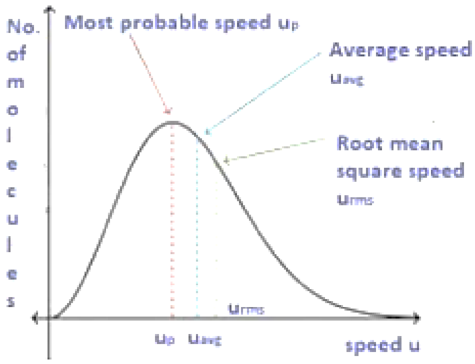
b) positive

c) negative

d) zero

30. **Read the text carefully and answer the questions:** **[4]**

Root mean square velocity (RMS value)is the square root of the mean of squares of the velocity of individual gas molecules and the Average velocity is the arithmetic mean of the velocities of different molecules of a gas at a given temperature.



(i) Moon has no atmosphere because:

a) the escape velocity of the moon's surface is more than the r.m.s velocity of all molecules

b) it is far away from the surface of the earth

c) the r.m.s. velocity of all the gas molecules is more than the escape velocity of the moon's surface

d) its surface temperature is 10^oC

(ii) For an ideal gas, $\frac{C_P}{C_V}$ is

a) ≤ 1

b) none of these

c) > 1

d) < 1

(iii) The root means square velocity of hydrogen is $\sqrt{5}$ times that of nitrogen. If T is the temperature of the gas then:

a) $T(H_2) = T(N_2)$

b) $T(H_2) < T(N_2)$

c) none of these

d) $T(H_2) > T(N_2)$

(iv) Suppose the temperature of the gas is tripled and N_2 molecules dissociate into an atom. Then what will be the rms speed of atom:

a) none of these

b) $v_0\sqrt{6}$

c) $v_0\sqrt{3}$

d) v_0

OR

The velocities of the molecules are v, 2v, 3v, 4v & 5v. The RMS speed will be:

a) 11 v

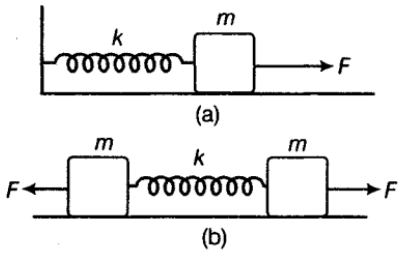
b) $v(12)^{11}$

c) v

d) $v(11)^{12}$

Section E

31. Fig. (a) shows a spring of force constant k clamped rigidly at one end and a mass m attached to its free end. A force F applied at the free end stretches the spring. Fig. (b) shows the same spring with both ends free and attached to a mass m at either end. Each end of the spring in Fig. (b) is stretched by the same force F **[5]**



i. What is the maximum extension of the spring in the two cases?
ii. If the mass in Fig. (a) and the two masses in Fig. (b) are released, then what is the period of oscillation in each case?

OR

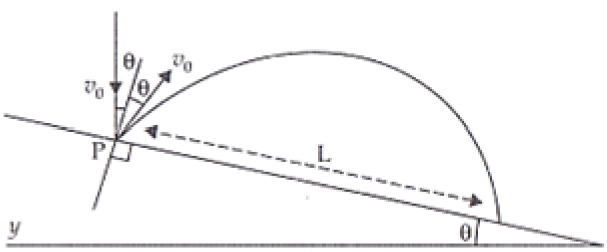
A particle executes simple harmonic motion of amplitude A.

i. At what distance from the mean position is its kinetic energy equal to its potential energy?
ii. At what points is its speed half the maximum speed?

32. On an open ground, a motorist follows a track that turns to his left by an angle of 60^o after every 500 m. Starting from a given turn, specify the displacement of the motorist at the third, sixth and eighth turn. Compare the magnitude of the displacement with the total path length covered by the motorist in each case. **[5]**

OR

A particle falling vertically from a height hits a plane surface inclined to horizontal at an angle with speed v_0 and rebounds elastically as shown in the figure. Find the distance along the plane where it will hit the second time.



Hint:

i. After rebound, particle still has speed V_0 to start.
ii. Work out angle particle speed has with horizontal after it rebounds.
iii. Rest is similar to if particle is projected up the incline.]

33. Find the components along the x, y, z axes of the angular momentum l of a particle, whose position vector is r with components x, y, z and momentum is p with components p_x, p_y and p_z. Show that if the particle moves only in the x-y plane the angular momentum has only a z-component. **[5]**

OR

A solid disc and a ring, both of radius 10 cm are placed on a horizontal table simultaneously, with initial angular speed equal to 10π rad s^{-1}. Which of the two will start to roll earlier? The co-efficient of kinetic friction is $\mu_k = 0.2$.

Solution

Section A

1. **(a)** 4

   Explanation: There are three rules on determining how many significant figures are in a number:
   - Non-zero digits are always significant.
   - Any zeros between two significant digits are significant.
   - A final zero or trailing zeros in the decimal portion ONLY are significant.

   So keeping these rules in mind, there are 4 significant digits.

2. **(d)** 9 : 4

   Explanation: Intensity = $\frac{\text{energy}}{\text{time} \times \text{area}} = \frac{\text{power}}{\text{area}}$

   From a point source, energy spreads over the surface of a sphere of radius r.

   $\therefore$ Intensity, I = $\frac{P}{A} = \frac{P}{4\pi r^2}$

   or $I \propto \frac{1}{r^2}$

   $\frac{I_1}{I_2} = \left(\frac{r_2}{r_1}\right)^2 = \left(\frac{3}{2}\right)^2 = \frac{9}{4}$

3. **(b)** Angular momentum

   Explanation: $I = \frac{2}{5}MR^2$

   $\tau_{\text{ext}} = \frac{dL}{dt} = 0 \Rightarrow$ L = constant

   $\therefore$ Angular momentum remains constant.

4. **(c)** obtuse

   Explanation: The angle of contact is obtuse for a liquid that does not wet glass.

5. **(c)** $\frac{3}{2}$V

   Explanation: V = $-\frac{GM}{R}$

   $V_{\text{centre}} = -\frac{3}{2}\frac{GM}{R^3}\left(3R^2 - r^2\right)$

   $= -\frac{3}{2}\frac{GM}{R^3}\left(3R^2 - 0\right)$

   $= -\frac{3}{2}\frac{GM}{R} = -\frac{3}{2}V$

6. **(c)** $\sqrt{a_1^2 + a_2^2}$

   Explanation: Resultant amplitude is given by

   $A^2 = a_1^2 + a_2^2 + 2a_1a_2\cos\Delta$

   where Δ is phase difference between two waves.

   here $\Delta = \frac{\pi}{2}$

   thus $A^2 = a^2{}_1 + a^2{}_2$

   A = $\sqrt{a_1^2 + a_2^2}$

7. **(c)** 2 : 1

   Explanation: Magnitude of slope of distance-time graph gives the speed of the particle.

   Slope of line AB, $m_1 = \frac{\text{BO}}{\text{AO}} = \frac{\text{x}}{2}$

   Thus speed in first two seconds, $v_1 = |m_1| = \frac{x}{2}$

   Slope of line BC, $m_2 = \frac{-BO}{CO} = \frac{-x}{4}$

Thus speed in first two seconds, $v_2 = |m_2| = \frac{x}{4}$

Thus ratio of speed $\frac{v_1}{v_2} = \frac{\frac{x}{2}}{\frac{x}{4}} = \frac{2}{1}$

8.

(d) 2 cm

Explanation: $y = 5\sin\left(\frac{\pi x}{2}\right)\cos 4\pi t$

y = a sin kx cos ωt

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

$\Rightarrow \lambda$ = 4 cm

$\therefore$ Distance between two consecutive nodes

$= \frac{\lambda}{2}$ = 2 cm

9.

(d) size of orifice

Explanation: Velocity of efflux, v = $\sqrt{2gh}$

Clearly, it does not depend on the size of the orifice.

10.

(d) 3.85×10^7 m

Explanation: Let the gravitational intensity be zero at distance x from the centre of the moon.

Then $\frac{GM_m}{x^2} = \frac{GM_e}{(r-x)^2}$

$\frac{7.35 \times 10^{22}}{x^2} = \frac{5.98 \times 10^{24}}{\left(3.85 \times 10^8 - x\right)^2}$

$\frac{3.85 \times 10^8 - x}{x} = \sqrt{\frac{5.98 \times 10^2}{7.35}}$

$\frac{3.85 \times 10^8}{x} - 1 \simeq \sqrt{81}$ = 9

x = 3.85×10^7 m

11.

(b) $l_1 < l_2$

Explanation: $\rho_{\mathrm{Al}} < \rho_{\mathrm{Fe}}$

$\Rightarrow M_{\mathrm{Al}} < M_{\mathrm{Fe}}$

$\Rightarrow I_1 < I_2$

12.

(d) 320 W

Explanation: According to Stefan's Boltzmann's law,

$E = \sigma\left(T^4 - T_0^4\right), E' = \sigma\left(T'^4 - T_0^4\right)$

$\therefore \frac{E'}{E} = \frac{T^4 - T_0^4}{T^4 - T_0^4} = \frac{(1227+273)^4 - (227+273)^4}{(727+273)^4 - (227+273)^4}$

$E' = \frac{1500^4 - 500^4}{1000^4 - 500^4} \times 60$ [E = 60 W]

= 320 W

13. **(a)** Assertion and reason both are correct statements and reason is correct explanation for assertion.

Explanation: Assertion and reason both are correct statements and reason is correct explanation for assertion.

14. **(a)** Assertion and reason both are correct statements and reason is correct explanation for assertion.

Explanation: Assertion and reason both are correct statements and reason is correct explanation for assertion.

15.

(b) Both A and R are true but R is not the correct explanation of A.

Explanation: A heavenly body revolving round the sun is called a planet and there are nine planets in our solar system. A heavenly body made of gaseous material and luminous due to its own energy is called a star.

16.

(b) Both A and R are true but R is not the correct explanation of A.

Explanation: According to statement of reason, $\vec{A} \times \vec{B}$ = AB sin θ.

As $\vec{B} = \vec{A}$, angle between $\vec{A} \times \vec{A}$, θ = 0. Therefore,

$\vec{A} \times \vec{A}$ = A sin 0^o = $\vec{0}$ i.e. the cross product of a vector with itself is zero.

Section B

17. Some important uses of beats phenomenon are as follows:
    i. Principle of beats enables us to tune one musical instrument by sounding it against a standard frequency.
    ii. We may determine the frequency of a tuning fork by studying beats formed with another tuning fork of known frequency.
    iii. Principle of beats is made use of in heterodyne method of radio reception.
18. Let the period of oscillation T of a large fluid star depends on the radius of star, R, the mean density of fluid, ρ and universal gravitational constant, G as:

    T = k $R^a \rho^b G^c$, where k is a dimensionless constant and a, b, c are their exponents.
    Now, equating the dimensions on both the sides, we have,
    $[M^0 L^0 T^1] = [L]^a [M L^{-3}]^b [M^{-1} L^3 T^{-2}]^c = M^{b-c} L^{a-3b+3c} T^{-2c}$
    On comparing powers of M, L and T on both sides, we get,
    b - c = 0 ...(i)
    a - 3b + 3c = 0 ...(ii)
    and - 2c = 1 ...(iii)
    On simplifying these equations, we get c = $-\frac{1}{2}$, b = $-\frac{1}{2}$ and a = 0
    Thus, period of oscillation, T = $k\rho^{-\frac{1}{2}}G^{-\frac{1}{2}} = \frac{k}{\sqrt{\rho G}}$

    This is the required expression.
19. Suppose wavelength λ associated with a moving particle depends upon (i) its mass (m), (ii) its velocity (v) and (iii) Planck's constant (h), then
    $\lambda = km^a v^b h^c$ ..(1)
    where, k is a dimensionless constant.
    Representing the above equation in terms of its dimensions, we get
    $[M^0L^1T^0] = [M]^a[LT^{-1}]^b[ML^2T^{-1}]^c$
    $\Rightarrow [M^0L^1T^0] = M^{a+c}L^{b+2c}T^{-b-c}$ ..(2)
    Comparing power of M, L and T on both sides of equation (2), we get
    a + c = 0, b + 2c = 1, - b - c = 0
    we get a = -1, b = -1, c = + 1
    putting the value of a,b, and c in equation (1), we get
    $\lambda = km^{-1}v^{-1}h^1$
    $\lambda = \frac{kh}{mv}$
    Hence, the relation becomes $\lambda = \frac{kh}{mv}$ and it gives the de broglie wavelength of a moving particle.
20. Retarding force, F = -50 N
    Mass of the body, m = 20 kg
    Initial velocity of the body, u = 15 m/s
    Final velocity of the body, v = 0
    Using Newton's second law of motion, the acceleration (a) produced in the body can be calculated as:
    F = ma
    -50 = 20 $\times$ a
    $\therefore a = \frac{-50}{20} = -2.5 m/s^2$
    Using the first equation of motion, the time (t) taken by the body to come to rest can be calculated as:
    v= u + at
    $\therefore t = \frac{-u}{a} = \frac{-15}{-2.5}$
    = 6 s
21. Let the resultant gravitational intensity be zero at distance x from the mass of 10 kg on the line joining the centres of the two bodies. At this point, the gravitational intensities due to the two bodies must be equal and opposite.
    $\therefore \quad \frac{G \times 10}{x^2} = \frac{G \times 1000}{(1-x)^2}$
    or 100 $x^2 = (1 - x)^2$ or 10x = 1 - x
    or 11x = 1 or x = $\frac{1}{11}$ m

OR

g = $\frac{GM}{R^2}$ or M = $\frac{gR^2}{G}$

This relation is true not only to the earth but for any heavenly body which is assumed to be spherical.

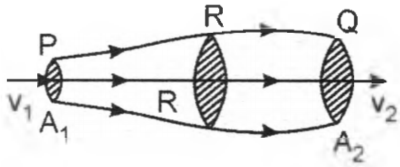
Now, $g = 1.67 ms^{-2}$, $R = 1.74 \times 10^6 m$

$G = 6.67 \times 10^{-11} Nm^{-2} kg^{-2}$

$\therefore$ Mass of the moon, M = $\frac{1.67 \times (1.74 \times 10^6)^2}{6.67 \times 10^{-11}}$ kg

$= 7.58 \times 10^{22} kg$

Section C

22. 

According to the equation of continuity, if there is no source or sink along the length of a pipe then for steady flow of an ideal fluid the mass of the fluid crossing any section of the pipe per unit time is always constant. Mathematically,

$A_1 v_1 p_1 = A_2 v_2 \rho_2$ = a constant

Consider steady flow of an ideal fluid through a pipe (or tube) PRQ of varying cross-section. Let us consider flow of fluid across any two transverse sections, say at P and Q, of the pipe having areas A_1 and A_2, where velocity of fluid flow is v_1 and v_2, respectively.

$\therefore$ Volume of fluid crossing the area A_1 per unit time at section P = $A_1 v_1$

Similarly, volume of fluid crossing the area A_2 per unit time at section Q = $A_2 v_2$.

If ρ_1 and ρ_2 be the densities of the given fluid at two sections, the mass of the fluid entering per unit time at section P is m_1 = $A_1 v_1 \rho_1$ and mass of the fluid leaving per unit time at section Q is m_2 = $A_2 v_2$ ρ_2

If there is no source or sink of fluid within the pipe, i.e., the flow is steady one, then from the law of conservation of matter, it follows that

$m_1 = m_2$

$\therefore A_1 v_1 \rho_1 = A_2 v_2 \rho_2$ ....(1)

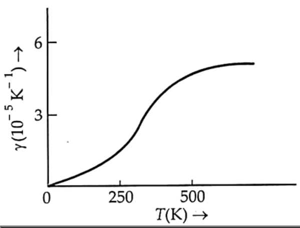
which is the general form of the equation of continuity.

For flow of an ideal incompressible liquid, the liquid density at both the cross-sections remains constant i.e., $\rho_1 = \rho_2$.

Thus, equation of continuity may be expressed as $A_1 v_1 = A_2 v_2$ ....(2)

From this equation, it is clear that at narrower portion of a pipe the velocity of flow increases and vice-versa.

23. Variation of γ with temperature. For a given substance, y varies with temperature. Figure shows the variation of the coefficient of cubical expansion of copper with temperature. The value of y first increases with temperature and then becomes constant at a high temperature (above 500 K).



Materials	**γ (K^{-1})**	**Materials**	**γ (K^{-1})**
Aluminium	7×10^{-5}	Hard rubber	2.4×10^{-4}
Brass	6×10^{-5}	Invar	2×10^{-6}
Iron	3.55×10^{-5}	Mercury	18.2×10^{-5}
Paraffin	58.8×10^{-5}	Water	20.7×10^{-5}
Ordinary Glass	2.5×10^{-5}	Ethyl alcohol	110×10^{-5}
Pyrex Glass	1×10^{-5}		

Table gives the average values of y for some common substances in the temperature range 0 - 100 °C. It can be noted that solids and liquids have small values of γ. The materials pyrex glass and invar (an alloy of iron and nickel) have still smaller values of γ. Ethyl alcohol has a higher value of y than mercury and expands more than mercury for the same rise of temperature.

24. a. When t = 0; $x(t) = x_0(1 - e^{-0}) = x_0(1 - 1) = 0$

    $x(t=0)=x_0\ \ \gamma e^{-0}=x_0\gamma(1)=\gamma x_0$

    b. x(t) is maximum when $t=\infty[x(t)]_{\max}=x_0$

    x(t) is minimum when t = 0$[x(t)]_{min}$ = 0

    v(t) is maximum when t = 0; $v(0)=x_0\gamma$

    v(t) is minimum when $t=\infty; v(\infty)=0$

    a(t) is maximum when $t=\infty; a(\infty)=0$

    a(t) is minimum when t = 0; $a(0)=-x_0\gamma^2$

25. Here it is given that mass of the railway car, m = 20 tonne = 20000 kg, initial speed u = 54 km h^{-1} = 15 m s^{-1}, acceleration a = -0.3 m s^{-2} and final velocity v = 0.

    a. The braking force on railway car F = ma = 20000 $\times$ (-0.3) = - 6000 N

    where the negative sign shows that the force is opposing the motion.

    b. From relation v - u = at, we get

    $t=\frac{v-u}{a}=\frac{0-15}{(-0.3)}$ = 50 seconds

    c. Using the relation $v^2 - u^2 = 2as$, we get

    $(0)^2 - (15)^2 = 2\times(-0.3)\times s$

    $\Rightarrow -225=-0.6s$

    $s=\frac{225}{0.6}=375\mathrm{m}$

    Thus, total distance travelled before stopping is equal to 375 m.

26. i. **Waterfall:** The falling of water cannot be reversible process. During the water fall, its potential energy convert into kinetic energy of the water. On striking the ground, some part of potential energy converts into heat and (sound not possible that heat and the sound). In nature, it automatically convert the kinetic energy and potential energy so that the water will rise back so waterfall is not a reversible process.

    ii. **Rusting of iron:** In rusting of iron, the iron become oxidised with the oxygen of the air as it is a chemical reaction, it cannot be reversed.

27. a. When a force acts on a body or on a system or on a particle for some time, then the product of the force and the time interval is called impulse.

    Impulse $\overline{I}=\overline{F}\times t$

    S.I. Unit - NS

    Impulse is a vector quantity directed along the average force $\overline{F}av$.

    b. Impulse of a force is equal to the change in momentum of the body.

    According to Newton's second law

    $\overline{F}=\frac{d\overline{p}}{dt}$

    or $d\overline{p}=\overline{F}dt$

    Say, due to application of a force $\overline{F}$, the momentum of a body changes from $\overline{P}_1$ to $\overline{P}_2$ in the time interval 0 to t. i.e. At t = 0

    $\overline{P}=\overline{P}_1$ and at

    $t=t$, $\overline{P}=\overline{P_2}$

    $\int\limits_{\overline{P_1}}^{\overline{P_2}} d\overline{p}=\int\limits_0^t \overline{F}dt$

    $\overline{P}_2-\overline{P}_1=\overline{F}t$

    $\overline{P}_2-\overline{P}_1=\overline{I}$

    $[\because \overline{F}t=\overline{I}(\text{ Impulse })]$

28. Here Pressure(P) = 20 gf mm^{-2} = $\frac{20}{1000}\times(10^{-3})^{-2}$ kg f m^{-2} = 20 $\times$ 10^3 $\times$ 9.8 Nm^{-2} = 19.6 $\times$ 10^4 Nm^{-2}

    Velocity (v) = 0.1 ms^{-1}, h(Height from ground level) = 50 cm = 0.50 m, $\rho = 10^3$ kg m^{-3}

    Pressure energy per kg = $\frac{P}{\rho}=\frac{19.6\times10^4}{10^3}$ = 196 J

Gravitational P.E. per kg = gh = 9.8 $\times$ 0.50 = 4.90 J

K.E. per kg = $\frac{1}{2}$ v^2 = $\frac{1}{2}$ $\times$ $(0.1)^2$ = 0.005 J

Total energy possessed by per kg of water

= $\frac{P}{\rho}$ + gh + $\frac{1}{2}$ v^2 = 196 + 4.90 + 0.005 = 200.905 J.

OR

Given thath : A rectangular tank is 10 m long, 5 m broad and 3 m high.

So, Pressure on the bottom of the tank

= $h\rho g$ = 3 $\times$ 10^3 $\times$ 9.8 = 2.94 $\times$ 10^3 Nm^{-2}

Area of bottom = Length $\times$ Breadth

= 10 $\times$ 5 = 50 m^2

$\therefore$ Thrust on the bottom = Pressure $\times$ Area

= 2.94 $\times$ 10^3 $\times$ 50 = 1.47 $\times$ 10^6 N

The hydrostatic pressure on the walls of the tank increases uniformly from zero at the free surface of water to $h\rho g$ at the bottom of the tank.

$\therefore$ Average hydrostatic pressure on the walls

$= \frac{0+h\rho g}{2} = \frac{1}{2}h\rho g = \frac{1}{2}\times$ 3 $\times$ 10^3 $\times$ 9.8

= 1.47 $\times$ 10^4 Nm^{-2}

Now, area of broad walls is given by

= 2 $\times$ Length $\times$ Height

= 2 $\times$ 10 $\times$ 3 = 60 m^2

Area of narrow walls = 2 $\times$ Breadth $\times$ Height

= 2 $\times$ 5 $\times$ 3 = 30 m^2

Total area of walls = 90 m^2

$\therefore$ Thrust on the walls = Average pressure $\times$ Area

= 1.47 $\times$ 10^6 + 1.323 $\times$ 10^6

= 2.793 $\times$ 10^6 N.

Section D

29. **Read the text carefully and answer the questions:**

In everyday life, the term work is used to refer to any form of activity that requires the exertion of mental or muscular efforts. In physics, work is said to be done by a force or against the direction of the force, when the point of application of the force moves towards or against the direction of the force. If no displacement takes place, no work is said to be done.

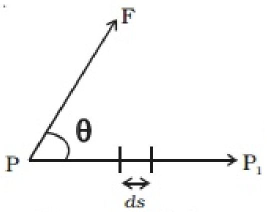


Fig. Work done by a force

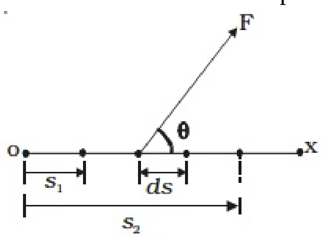


Fig. Work done by a constant force

(i) **(c)** 400 J

Explanation: 400 J

(ii) **(b)** zero

Explanation: zero

(iii) **(b)** non-conservative forces

Explanation: non-conservative forces

OR

(d) 2 J

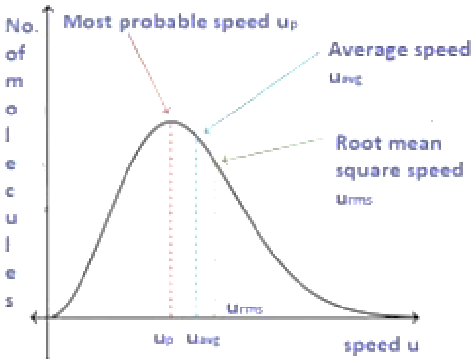
Explanation: 2 J

(iv) **(d)** zero

Explanation: zero

30. **Read the text carefully and answer the questions:**

Root mean square velocity (RMS value)is the square root of the mean of squares of the velocity of individual gas molecules and the Average velocity is the arithmetic mean of the velocities of different molecules of a gas at a given temperature.



(i) **(c)** the r.m.s. velocity of all the gas molecules is more than the escape velocity of the moon’s surface

Explanation: The r.m.s. velocity of all the gas molecules is more than the escape velocity of the moon’s surface.

(ii) **(c)** > 1

Explanation: > 1

(iii) **(b)** $T(H_2) < T(N_2)$

Explanation: $T(H_2) < T(N_2)$

(iv) **(b)** $v_0\sqrt{6}$

Explanation: $v_0\sqrt{6}$

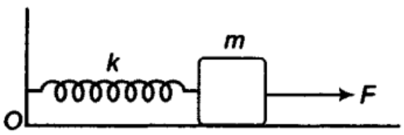
OR

(d) $v(11)^{12}$

Explanation: $v(11)^{12}$

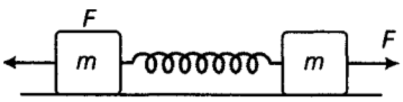
Section E

31. i. For Case (a), as we know that the restoring force is given by , F = -kx ⇒ |F| = kx

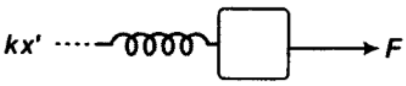


So, x = $\frac{F}{k}$

for the Case (b)



If x' is the extension in the spring, then drawing free body diagram of either mass (as the system under applied force is under equilibrium).



kx' = F

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

In both the cases, extension is the same $\left(\frac{F}{k}\right)$.

ii. The period of oscillation in case(a)

As, restoring force(F) is given by = -kx

where, x = is the given extension

But from Newton's 2nd law of motion we know that, F = ma

$\therefore ma = -kx \Rightarrow a = -\left(\frac{k}{m}\right)x$ ....(i)

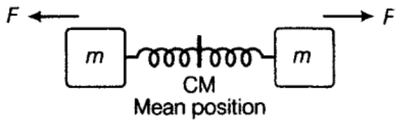
$a \propto -x$

On comparing eq.(i) with a = $-\omega^2$x, we get

$\omega = \sqrt{\frac{k}{m}}$ (angular frequency or velocity of the motion)

Period of oscillations is given by, $T=\frac{2\pi}{\omega}=2\pi\sqrt{\frac{m}{k}}$

Case **(**b)



The system is divided into two similar systems with spring divided in two equal halves, forming spring constant hence, k' = 2k

Hence, force is , F = - k'x

Putting k' = 2k (on cutting a spring in two halves, its k doubles)

F = -2kx

But from Newton's law of motion, force is given by F = ma

$\therefore$ma = -2kx

$\Rightarrow a=-\left(\frac{2k}{m}\right)x$ . . . . . (ii)

On comparing Eq.(ii) with a = -ω^2x, we get angular frequency or velocity is,

$\omega=\sqrt{\frac{2k}{m}}$

Hence the required period of oscillation of the given question,

$T=\frac{2\pi}{\omega}=2\pi\sqrt{\frac{m}{2k}}$

OR

The potential energy and kinetic energy of a particle at a displacement y are given

$E_p = \frac{1}{2}ky^2$

and $E_k = \frac{1}{2}k\left(A^2-y^2\right)$ ...(i)

where A is the amplitude and k is the force constant.

i. As $E_k = E_p$

$\therefore \frac{1}{2}k\left(A^2-y^2\right)=\frac{1}{2}ky^2$ or $2y^2 = A^2$

or y = $\pm\frac{A}{\sqrt{2}}=\pm$ 0.71 A

= 0.71 times the amplitude on either side of the mean position.

ii. Here, v = $\frac{1}{2}v_{\max}$

In general, kinetic energy

$=\frac{1}{2}mv^2=\frac{1}{2}m\left(\frac{1}{2}v_{\max}\right)^2=\frac{1}{4}\cdot\frac{1}{2}mv_{\max}^2$

= $\frac{1}{4}\times$ Maximum kinetic energy

or $E_k = \frac{1}{4}\times(E_k)_{\max}$ ...(ii)

From equation (i),

$E_k = \frac{1}{2}k\left(A^2-y^2\right)$

$\therefore (E_k)_{\max} = \frac{1}{2}kA^2$ [Put y = 0]

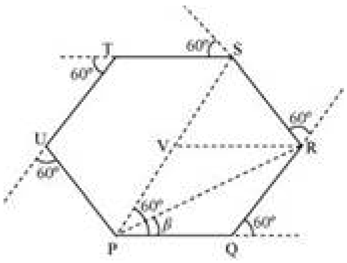
Putting these values in equation (ii), we get

$\frac{1}{2}k\left(A^2-y^2\right)=\frac{1}{4}\times\frac{1}{2}kA^2$

or $4y^2 = 3A^2$

or y = $\pm\frac{\sqrt{3}}{2}A=\pm$ 0.86 A

= 0.86 times the amplitude on either side of the mean position.

32. 

The path followed by the motorist is a regular hexagon with side 500 m, as shown in the given figure.

Let the motorist start from point P. The motorist takes the third turn at S.

Magnitude of displacement = PS = PV + VS = 500 + 500 = 1000 m ($\because PV=QR, VS=SR$)

Total path length, d_1 = PQ + QR + RS = 500 + 500 + 500 = 1500 m

The motorist take the sixth turn at point P, which is the starting point

∴ Magnitude of displacement = 0

Total path length, d_2 = PQ + QR + RS + ST + TU + UP

d_2 = 500 + 500 + 500 + 500 + 500 = 3000 m

The motorist takes the eight turn at point R

∴ Magnitude of displacement = PR

$PR = \sqrt{PQ^2 + QR^2 + 2(PQ)\cdot(QR)\cos 60^\circ}$

$PR = \sqrt{500^2 + 500^2 + (2 \times 500 \times 500 \times \cos 60^\circ)}$

$PR = \sqrt{250000 + 25000 + \left(500000 \times \frac{1}{2}\right)}$

$PR = \ 866.03\ m$

$\beta = \tan^{-1}\left(\frac{500 \sin 60^\circ}{500 + 500 \cos 60^\circ}\right) = 30^\circ$

Therefore, the magnitude of displacement is 866.03 m at an angle of 30^o with PR.

Total path length = Circumference of the hexagon + PQ + QR

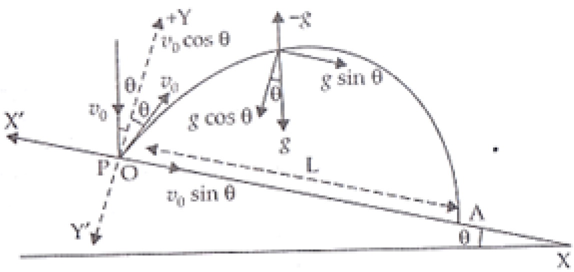
Total path length= 6 × 500 + 500 + 500 = 4000 m

The magnitude of displacement and the total path length corresponding to the required turns is shown in the given table

Turn	**Magnitude of displacement (m)**	**Total path length (m)**
Third	1000	1500
Sixth	0	3000
Eighth	866.03; 30^o	4000

OR

From the figure resolving the components of v_0 and g, we get



$v_x = v_0 \sin \theta$ and $v_y = v_0 \cos \theta$

$g_x = gcos\theta$,$g_y = gsin\theta$ acting vertically downwards

Consider the motion of particle from O to A in new YOY' axis.

$y = u_y t + \frac{1}{2} a_y t^2$

Where, $z = 0, \quad v_y = v_0 \cos \theta, \quad a_y = -g \sin \theta$

$\therefore t = T \quad$ (time of flight) , y = 0

$\Rightarrow 0 = v_0 \cos \theta T - \frac{1}{2} g \sin \theta T^2$

$\Rightarrow T = \frac{2v_0 \cos \theta}{g \cos \theta}$

$T = \frac{2v_0}{g}$

Now consider the motion along OX axis.

$x = L, u_x = v_0 \sin \theta, a_x = g \sin \theta, t = T = \frac{2v_0}{g}$

$x = u_x t + \frac{1}{2} a_x t^2$

$L = \left[\frac{2v_5}{g}\right] v_0 \sin \theta + \frac{1}{2} g \sin \theta \left[\frac{2v_0}{g}\right]^2$

$L = \frac{2v_0^2}{g} \sin \theta + \frac{1}{2} g \sin \theta \cdot \frac{4v_0^2}{g^2}$

$= \frac{2v_0^2}{g} [\sin \theta + \sin \theta] = \frac{4v_0^2}{g} sin\theta$

$\Rightarrow L = \frac{4v_0^2}{g}\sin\theta$.

Hence the value of L is $\frac{4v_0^2}{g}\sin\theta$.

33. $l_x = yp_z - zp_y$

$l_y = zp_x - xp_z$

$l_z = xp_y - yp_x$

The linear momentum of the particle in cartesian coordinate, $\vec{p} = p_x\hat{i} + p_y\hat{j} + p_z\hat{k}$

Position vector of the particle in cartesian coordiantes , $\vec{r} = x\hat{i} + \hat{y} + z\hat{k}$

As we know the angular momentum of a moving particle about a point is given as, $\vec{l} = \vec{r} \times \vec{p}$ where p and r are linear momentum and position vector respectively,

$= \left(x\hat{i} + \hat{y}' + z\hat{k}\right) \times \left(p_x\hat{i} + p_y\hat{j} + p_z\hat{k}\right)$

$= \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ x & y & z \\ p_x & p_y & p_z \end{vmatrix}$

$l_x\hat{i} + l_y\hat{j} + l_z\hat{k} = \hat{i}\left(yp_z - zp_y\right) - \hat{j}\left(xp_z - zp_x\right) + \hat{k}\left(xp_y - yp_x\right)$

$= = \hat{i}\left(yp_z - zp_y\right) + \hat{j}\left(-xp_z + zp_x\right) + \hat{k}\left(xp_y - yp_x\right)$

Comparing the coefficients of $\hat{i}, \hat{j}$, and $\hat{k}$ we get the components of angular momentum as :

$l_x = yp_z - zp_y$

$l_y = xp_z - zp_x$ …..(i)

$l_z = xp_y - yp_x$

b) If the particle moves in the x-y plane only. Hence, the z-component of the position vector and z component of linear momentum vector become zero, i.e.,

$z = p_z = 0$

Thus, equation (i) reduces to:

$l_x = 0$

$l_y = 0$

$l_z = xp_y - yp_x$

Therefore, when the particle is confined to move in the x-y plane, the x and y components of linear momentum are zero and hence the direction of angular momentum is along the z-direction.

OR

Radii of the ring and the disc, *r* = 10 cm = 0.1 m

Initial angular speed, ω_z =10 π rad s^{-1}

Coefficient of kinetic friction, μ_k= 0.2

Initial velocity of both the objects, u = 0

Motion of the two objects is caused by frictional force. As per Newton's second law of motion, we have frictional force, *f* = *ma*

μ_k mg = ma

Where,

a = Acceleration produced in the objects

m = Mass

$\therefore a = \mu_k$ g … (*i*)

As per the first equation of motion, the final velocity of the objects can be obtained as:

v = *u* + *at*

$= 0 + \mu_\mathrm{k}\mathrm{gt}$

$= \mu_\mathrm{k}\mathrm{gt}$… (*ii*)

The torque applied by the frictional force will act in a perpendicularly outward direction and cause a reduction in the initial angular speed.

Torque, T= - Iα

α = Angular acceleration

u_z mgr = -Iα

$\therefore a = \frac{-\mu_k mgr}{I}$ …….(iii)

Using the first equation of rotational motion to obtain the final angular speed:

$\omega = \omega_e + at$

$= \omega_x + \frac{-\mu_k mgr}{I}t$ ……(iv)

Rolling starts when linear velocity, *v* = *ru*

$\therefore v = r\left(\omega_0 - \frac{\mu_k gmrt}{I}\right)$ …..*.(v)*

Equating equations (*ii*) and (*v*), we get:

$\mu_k gt = r\left(\omega_0 - \frac{\mu_k gmrt}{I}\right)$

$= r\omega_0 - \frac{\mu_i gmr^2 t}{I}$ …….(vi)

For the ring $I = mr^2$

$\therefore \mu_k gt = r\omega_0 - \frac{\mu_k gmr^2 t}{mr^2}$

$= r\omega_0 = u_k - \frac{u_k gmr^2 t}{mr^2}$

$2\mu_{\dot{k}} gt = r\omega_0$

$\therefore t_r = \frac{r\omega_0}{2\mu_k g}$

$= \frac{0.1 \times 10 \times 3.14}{2 \times 0.2 \times 9.8} = 0.80s$ ……(vii)

For the ring $I = \frac{1}{2}mr^2$

$\therefore \mu_k gt_d = r\omega_0 - \frac{\mu_k gmr^2 t}{\frac{1}{2}mr^2}$

$= r\omega_0 - 2\mu_k gt$

$3\mu_k gt_d = r\omega_0$

$\therefore t_d = \frac{r\omega_0}{3\mu_k g}$

$= \frac{0.1 \times 10 \times 3.14}{3 \times 0.2 \times 9.8} = 0.53s$ ……(viii)

Since$t_d > t_r$, the disc will start rolling before the ring.