CBSE Class 11 Physics

Sample Paper 06 (2020-21)

Maximum Marks: 70

Time Allowed: 3 hours

General Instructions:

i. All questions are compulsory. There are 33 questions in all.

ii. This question paper has five sections: Section A, Section B, Section C, Section D and Section E.

iii. Section A contains ten very short answer questions and four assertion reasoning MCQs of 1 mark each, Section B has two case based questions of 4 marks each, Section C contains nine short answer questions of 2 marks each, Section D contains five short answer questions of 3 marks each and Section E contains three long answer questions of 5 marks each.

iv. There is no overall choice. However internal choice is provided. You have to attempt only one of the choices in such questions.

Section A

1. What are positive and negative acceleration in straight line motion?
2. A force of 1 N acts on a body of mass 1 g. Calculate the acceleration produced in the body.

OR

A person driving a car suddenly applies the brakes on seeing a child on the road ahead. If he is not wearing the seat belt, he falls forward and hits his head against the steering wheel. Why?

3. Why there are two propellers in a helicopter?
4. An artificial satellite revolving around the earth does not need any fuel. On the other hand, the aeroplane requires fuel to fly at a certain height. Why?

OR

Do the friction of force and other contact forces arise due to gravitational attraction? If not, then what is the origin of these forces?

5. Define viscosity?
6. A boat is moving with a velocity $(3\hat{i} + 4\hat{j})$ with respect to ground. The water in the river is moving with a velocity $- 3\hat{i} - 4\hat{j}$ with respect to ground. What is the relative velocity of boat with respect to water?
7. What are the dimensions of a and b in the relation: F = a + bx, where F is force and (x) is distance?

OR

The speed of sound in a solid is given by the formula $v = \sqrt{\frac{E}{\rho}}$, where E is coefficient of elasticity and ρ is density of given solid. Check the relation by the method of dimensional analysis.

8. Explosions on other planets are not heard on earth. Why?

OR

How roar of a lion can be differentiated from bucking of a mosquito?

9. Air pressure in a car tyre increases during driving. Explain.
10. What is the property of two vectors A and B such that A + B = A - B ?
11. **Assertion:** In projectile motion, the angle between the instantaneous velocity and acceleration at the highest point is 180°.

    Reason: At the highest point, velocity of projectile will be in horizontal direction only.

    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.
12. **Assertion:** Elastic restoring forces may be conservative.

    Reason: The value of strain for same stress are different while increasing the load and while decreasing the load.

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

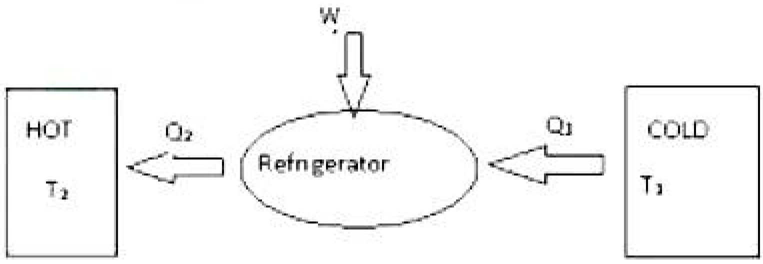
b. Assertion and reason both are correct statements but reason is not correct explanation for assertion.
c. Assertion is correct statement but reason is wrong statement.
d. Assertion is wrong statement but reason is correct statement.

13. **Assertion:** State variables (P, V and T) of any gas at low densities obey the equation PV = nRT.
Reason: Real gases are good approximation of an ideal gas at low density.
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:** No particle may have a speed as large as speed of light.
Reason: Infinite energy of any substance or system is not possible.
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.

Section B

15. **Read the case study given below and answer any four subparts:**
Refrigerator works on the principle which is reverse of a heat engine. It takes heat from the cold reservoir and then some work is done on the refrigerator and then the amount of heat is transferred to heat reservoir. Let Q_2 be the takes from the cold reservoir, W is the work done on the system and then releases Q_1 amount of heat to the hot reservoir.



i. The temperatures of inside and outside of a refrigerator are 273 K and 303 K respectively. Assuming, that the refrigerator cycle is reversible, for every joule of work done, the heat delivered to the surrounding will be nearly:

a. 10 J
b. 20 J
c. 30 J
d. 40 J

ii. What does a refrigerant do?

a. absorbs the heat leakage into the body from surroundings
b. evaporates in the evaporator
c. both a and b
d. none of these

iii. The coefficient of performance of a refrigerator working between 30 ^{0}C and 0 ^{0}C is:

a. 10
b. 9
c. 1
d. 0

iv. If the door of the refrigerator is kept open:

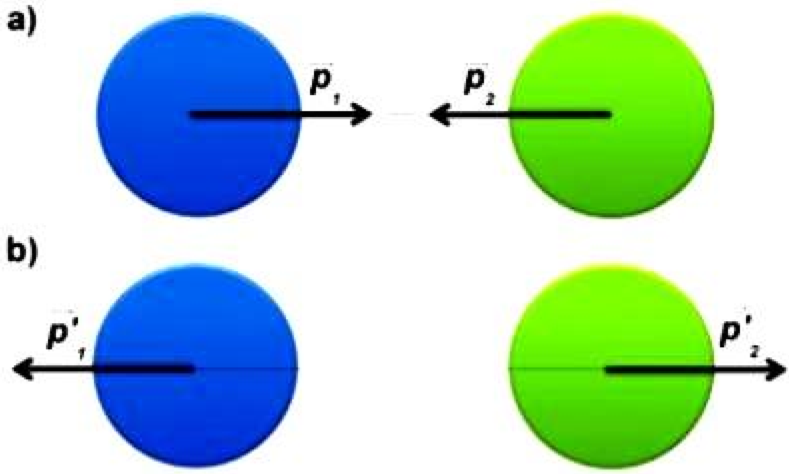
a. Room is cooled
b. Room is hot
c. Room is neither hot nor cooled
d. none of these

v. The internal energy of an ideal gas depends upon:

a. temperature only
b. volume only
c. both a and b
d. neither a and b

16. **Read the case study given below and answer any four subparts:**

The kinetic energy of an object is the energy associated with the object which is under motion. It is defined as “the energy required by a body to accelerate from rest to stated velocity.” It is a vector quantity and the momentum of an object is the virtue of its mass. It is defined as the product of mass and velocity. It is a vector quantity. The relation between them is given by E = $\frac{P^2}{2m}$. In case of the elastic collision both of these quantities remain constant.



i. Two masses of 1 gm and 4gm are moving with equal linear momentum. The ratio of their kinetic energy is:
   a. 4:2
   b. 4:1
   c. 1:2
   d. 1:1

ii. If the linear momentum is increased by 50%, then K.E will be increased by:
   a. 50%
   b. 100%
   c. 125%
   d. 200%

iii. A heavy object and a light object have the same momentum. Which has the greater speed?
   a. heavy object
   b. light object
   c. none of these

iv. Kinetic energy with any reference must be ________
   a. zero
   b. positive
   c. negative
   d. none of these

v. When a body moves with a constant speed along a circle then
   a. no work is done on it
   b. no acceleration is produced
   c. no force acts on it

d. none of the above

Section C

17. A satellite is moving round the earth with velocity v what should be the minimum percentage increase in its velocity so that the satellite escapes.

18. Why does a metal bar appear hotter than a wooden bar at the same temperature? Equivalently it also appears cooler than wooden bar if they are both colder than room temperature.

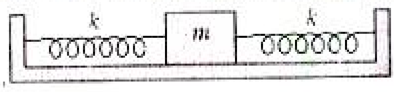
OR

Two rods of different metals of coefficient of linear expansion α_1 and α_2 and initial lengths I_1 and I_2 respectively are heated to the same temperature, Find relation in α_1, α_2, I_1 and I_2 such that difference between their lengths remains constant at any temperature.

19. An 8kg body performs S.H.M. of amplitude 30 cm. The restoring force is 60N when the displacement is 30cm. Find - a) Time period b) the acceleration c) potential and kinetic energy when the displacement is 12cm?

OR

Two identical springs of spring constant K are attached to a block of mass *m* and to fixed supports as shown in Figure. When the mass is displaced from equilibrium position by a distance x towards right, find the restoring force.



20. A block placed on a rough horizontal surface is pulled by a horizontal force F. Let f be the force applied by the rough surface on the block. Plot a graph of f versus F.

21. An object is in uniform motion along a straight line, what will be position-time graph for the motion of the object if

    i. x_0 = positive, v = negative

    ii. both x_0 and v are negative

    The letters x_0 and v represent position of object at time t = 0 and uniform velocity of the object respectively.

22. Calculate the speed of sound in dry hydrogen at NTP, assuming its density at NTP conditions as 0.089 kg m^{-3} and γ = 1.41.

23. How can you define moment of inertia of a rotating body in terms of its
    i. angular momentum
    ii. torque?

24. The unit of length convenient on the atomic scale is known as an angstrom and is denoted by $\mathring{A}$ ($1\ \mathring{A} = 10^{-10} m$). The size of a hydrogen atom is about $0.5\mathring{A}$. What is the total atomic volume in m^3 of a mole of hydrogen atoms?

OR

Convert:

i. $3.0 m/s^2$ = ... km/hr^2

ii. $6.67\ 10^{-11} Nm^2/kg^2$ = ... $g^{-1}cm^3s^{-2}$

25. A stone is dropped from the top of a cliff and is found to travel 44.1 m in the last second before it reaches the ground. What is the height of the cliff?

Section D

26. A stone of mass 0.25 kg tied to the end of a string is whirled round in a circle of radius 1.5 m with a speed of 40 rev./min in a horizontal plane. What is the tension in the string? What is the maximum speed with which the stone can be whirled around if the string can withstand a maximum tension of 200 N?

27. Using a screw gauge, the diameter of a metal rod was measured. The observation are given as follows: 0.39 mm, 0.38 mm, 0.37 mm, 0.41 mm, 0.38 mm, 0.38 mm, 0.37 mm, 0.40 mm, 0.39 mm. Calculate
    i. the most accurate value of the diameter,
    ii. the relative error, and
    iii. the percentage error in the measurement of the diameter.

OR

The length, breadth and thickness of a rectangular sheet of metal are 4.234 m, 1.005m, and 2.01 cm respectively. Give the area and volume of the sheet to correct significant figures.

28. A boy stands at 78.4 m from a building and throws a ball which just enters a window 39.2 m above the ground. Calculate the velocity of projection of the ball.

OR

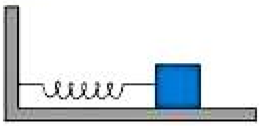
Rain is falling vertically with a speed of 30 ms^{-1}. A woman rides a bicycle with a speed of 10 ms^{-1} in the north to south direction. What is the direction in which she should hold her umbrella?

29. Consider a drop of small pebble of mass 1.00 g falling from a cliff of height 1.00 km. It hits the ground with a speed of 50.0 ms^{-1}. What is the work done by the unknown resistive force?

30. How will you weigh the sun, that is estimate its mass? The mean orbital radius of the earth around the sun is 1.5×10^8 km.

Section E

31. A spring having with a spring constant 1200 N m^{-1} is mounted on a horizontal table as shown in Fig. A mass of 3 kg is attached to the free end of the spring. The mass is then pulled sideways to a distance of 2.0 cm and released.



Determine

i. the frequency of oscillations,
ii. maximum acceleration of the mass, and
iii. the maximum speed of the mass.

OR

The motion of a particle executing simple harmonic motion is described by the displacement function, x (t) = A cos $(\omega_t + \omega)$.
If the initial (t = 0) position of the particle is 1 cm and its initial velocity is ω cm/s, what are its amplitude and initial phase angle? The angular frequency of the particle is π s^{-1}. If instead of the cosine function, we choose the sine function to describe the SHM: x = B sin $(\omega t + a)$, what are the amplitude and initial phase of the particle with the above initial conditions.

32. i. What do you understand by specific heat capacity of water?
    ii. If one mole of ideal monoatomic gas (γ = 5/3) is mixed with one mole of diatomic gas (γ = 7/ 5). What is the value of y for the mixtures?
    (here, γ represents the ratio of specific heat at constant pressure to that at constant volume)

OR

Derive an expression for the pressure due to an ideal gas.

33. Determine the volume contraction of a solid copper cube, 10 cm on an edge, when subjected to a hydraulic pressure of 7.0×10^6 Pa.

OR

Explain the following:
    i. Concrete beams used in large buildings have greater depth than breadths.
    ii. Load bearing bars are generally made in I-section.
    iii. Pillar with distributed ends is preferred over a pillar with rounded ends.

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Solution

Section A

1. If the speed of an object increases with time, its acceleration is positive (acceleration is in the direction of motion) and if speed of an object decreases with time its acceleration is negative (acceleration is opposite to the direction of motion).
2. Given, F = 1N, m = 1 g = 10^{-3} kg
   Now from Newton's second law of motion, F = ma $\Rightarrow a = \frac{F}{m} = \frac{1}{10^{-3}} = 10^3 \mathrm{m/s^2}$ = 1000 ms^{-2}.

   OR

   When a person applies brakes suddenly, the lower part of person slows rapidly with the car, but the upper part of driver continue to move with same speed in the same direction due to the inertia of motion and his head hit with car's steering.
3. Due to conservation of angular momentum
4. An artificial satellite revolving around the earth does not need any fuel but the aeroplane requires fuel to fly at a certain height because the satellite move in air-free region, while the aeroplane has to overcome air resistance.

   OR

   No, the origin of forces of friction or other contact forces arises from electromagnetic force. The origin of electromagnetic force is due to attraction/repulsion between particles.
5. Viscosity is the property of a fluid by virtue of which an internal frictional force comes into play when the fluid is in motion and opposes the relative motion of its different layers.
6. Given, Relative velocity of the boat with respect to ground, v_g = $3\hat{\mathbf{i}} + 4\hat{\mathbf{j}}$
   Relative velocity of water with respect to ground, v_w= $-3\hat{\mathbf{i}} - 4\hat{\mathbf{j}}$
   Therefore, Relative velocity of boat w.r.t. water is given by the following relation,

$v_{bw} = v_g - v_w = 3\hat{\mathbf{i}} + 4\hat{\mathbf{j}} - (-3\hat{\mathbf{i}} - 4\hat{\mathbf{j}}) = 6\hat{\mathbf{i}} + 8\hat{\mathbf{j}}$

7. Here we have, $F = a + bx$

   According to the homogeneity rule, the dimensions on both sides of the equation should be the same.

   [a] = [F] = $[MLT^{-2}]$ and $[b] = \left[\frac{F}{x}\right] = \left[\frac{MLT^{-2}}{L}\right] = [MT^{-2}]$

   OR

   In the given equation, the dimension of LHS term i.e., is $[LT^{-1}]$.

   Dimensional formula for coeficient of viscosity (E) and density of solid (ρ) are $[ML^{-1}T^{-2}]$ and $[ML^{-3}]$ respectively.

   Hence the dimensions of RHS = $\sqrt{\frac{ML^{-1}T^{-2}}{ML^{-3}}} = \sqrt{L^2T^{-2}} = [LT^{-1}]$

   Since dimensions of LHS and RHS of the equation are same, the given equation is dimensionally correct.

8. This is because no material medium is present over a long distance between earth and planets and is absence of material medium for propagation, sound waves cannot travel.

   OR

   Roaring of a lion produces a sound of low pitch and high intensity whereas buzzing of mosquitoes produces a sound of high pitch and low intensity and hence the two sounds can be differentiated.

9. During driving, reaction force due to force on tyres, temperature of gas increases so gas inside tyres expands as volume inside the tyre remains constant (Charle's law) so temperature of car tyre increases during driving $(asP \propto T)$.

10. If A + B = A - B

    Then 2B = 0

    $\Rightarrow$ B = 0

    Hence, vector B must be a zero vector.

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

    Explanation: Assertion is false but reason is true.

    At the highest point, the instantaneous velocity is acting horizontally and acceleration of projectile (acceleration due to gravity) is acting vertically downward. Therefore, angle between velocity and acceleration at the highest point is 90°.

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

    Explanation: Assertion and reason both are correct statements but reason is not correct explanation for assertion.

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

    Explanation: At sufficiently high speed (comparable to the speed of light) the law of newtonian mechanics are no longer precisely correct but must be replaced by the more general relations predicted by the special relativity. The relativistic kinetic energy K is given by:

    $$K = \frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}} - mc^2$$

    The expression becomes very large as v becomes equal to c and predicts an infinitely large energy at v = c. This suggest physically would require an infinite quantity of energy which is not possible.

Section B

15. i. c
    ii. c
    iii. b
    iv. b
    v. a
16. i. b
    ii. c
    iii. b
    iv. b
    v. a

Section C

17. The maximum orbital velocity of a satellite orbiting near its surface is given by,

$v_0 = \sqrt{gR} = \frac{v_e}{\sqrt{2}}$ where,

$v_0 =$ orbital velocity of a satellite.

R = radius of the earth

g = acceleration due to gravity

For the satellite to escape the gravitational pull of the earth, the velocity must become v.

But $v_t = \sqrt{2} v_0$ = 1.414 v_o = (1 + 0.414) v_o

This means that it has to increase its velocity by 0.414 in 1 or 41.4%

∴ The minimum increase required, as the velocity of the satellite is maximum When it is near the surface of the earth.

18. i. It is due to facts that conductivity of metal bar is very high as of wood. So the rate of transferring the heat in metal is very large than in wood.

ii. The specific heat of metal is very low as compared to wood, so metal requires very smaller quantities of heat than wood to change each degree of temperature. So due to larger conductivity and smaller specific heat, metals become more colder when placed in colder region as compared to wood and become more hot when placed in hot region.

OR

Say, the two rods having their initial lengths l_1 and l_2 are at same temperature t_1. And also assume that their lengths become l'_1 and l'_2 respectively at temperature t_2.

Now, from the definition of coefficient of linear expansion,

$l_1' = l_1 [1 + \alpha_1 (t_2 - t_1)]$

$And\ l_2' = l_2 [1 + \alpha_2 (t_2 - t_1)]$

Given that the difference in their length remains constant.

$\therefore \quad l_2' - l_1' = l_2 - l_1$

$\therefore l_2 [1 + \alpha_2 (t_1 - t_1)] - l_1 [1 + \alpha_1 (t_2 - t_1)] = l_2 - l_1$

Solving the above equation we get,

$\therefore \quad l_2 \alpha_2 = l_1 \alpha_1$

19. Here m = 8 kg

m = Mass, a = amplitude

a = 30cm = 0.30m

a. f = 60 N, Y = displacement = 0.30m

K = spring constant

Since, F = Ky

$K = \frac{F}{Y} = \frac{60}{0.30} = 200N|m$

As, Angular velocity $= \omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{200}{8}} = 5|s$

Time period, $T = \frac{2\pi}{\omega} = \frac{2\times 22}{7\times 5} = \frac{44}{35} = 1.256s$

b. Y = displacement = 0.12m

Acceleration, $A = \omega^2 Y$

$A = (5)^2 \times 0.12$

$A = 3.0m\ |s^2$

P.E. = Potential energy $\frac{1}{2}ky^2 = \frac{1}{2} \times 200 \times (0.12)^2$

$= \frac{1}{2} \times 200 \times 144 \times 10^{-4} = 1.44J$

Kinetic energy = $\mathrm{KE} = \frac{1}{2}k\left(a^2 - y^2\right)$

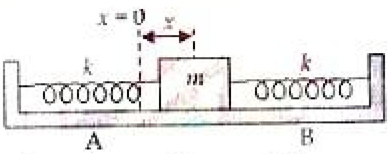
$KE = \frac{1}{2} \times 200 \times \left(0.3^2 - 0.12^2\right)$

$= \frac{1}{2} \times 200 \times (0.09 - 0.0144)$

Kinetic energy(K. E.) = 7.56J

OR

When the mass m is displaced from equilibrium position by a distance x towards right then spring B will be compressed by distance x, and apply the force (kx) on mass m towards left. But spring A will get extend by distance x apply the force (kx) on mass m towards left. But spring A will get extend by distance x and apply the force kx on mass towards left. So net force acting on block towards left side is restoring force

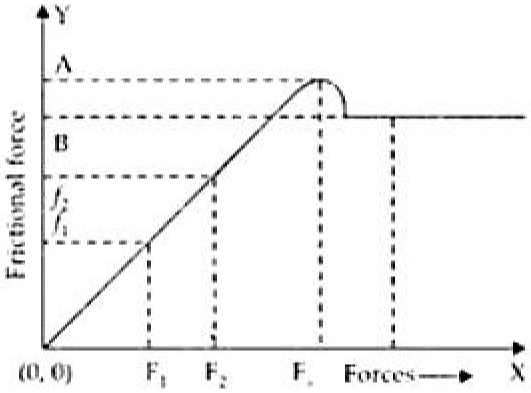


$F = kx + kx = 2kx$

$F = 2kx$ (restoring force towards left)

20. When a small force F_1 is applied on a heavier box, it does not move At this state force of friction f_1 is equal to F_1. On increasing force box does not move till $F = F_s$ the maximum

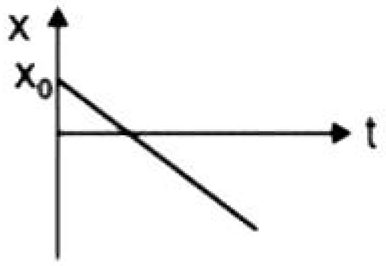
static frictional or limiting force. Its corresponding frictional force f_s on Y-axis.

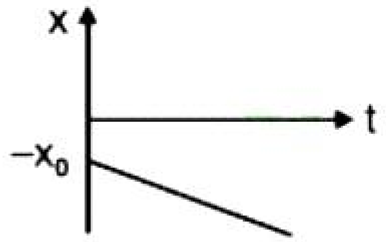


After force F_S, the frictional force decrease i.e., less force $F_K < F_S$is applied on body and it starts to move with less friction $F_K < F_S$

A = limiting frictional force and at B = kinetic frictional force.

21. The position of the object at any time (t) while moving with uniform velocity along a straight line is given by, $x = x_0 + vt$.

i. 

ii. 

22. Here it is given that density of hydrogen under NTP conditions $\rho = 0.089$ kg m^{-3}, $\gamma = 1.41$ and normal pressure P = 1.013×10^5 Pa

$\therefore$ Speed of sound, $v = \sqrt{\frac{\gamma P}{\rho}}$

$= \sqrt{\frac{1.41 \times 1.013 \times 10^5}{0.089}}$

$= 1267$ ms^{-1}

23. i. We know that, $L = I\omega$ and if $\omega = 1$, then L = I. Hence, the moment of inertia (I) of a rotating body is numerically equal to its angular momentum (L) when rotating with

uniform unit angular velocity (ω about the given axis.

ii. We know that $\tau = I\alpha$ and if α = 1, then τ = I. Hence, the moment of inertia (I) of a rotating body may be numerically considered as the torque (τ) needed to produce a unit angular acceleration (α) in that body.

24. Radius of hydrogen atom, r = 0.5 $A = 0.5 \times 10^{-10} m$

Volume of hydrogen atom $= \frac{4}{3}\pi r^3$

$= \frac{4}{3} \times \frac{22}{7} \times \left(0.5 \times 10^{-10}\right)^3$

$= 0.524 \times 10^{-30} \mathrm{m}^3$

1 mole of hydrogen contains 6.023×10^{23} hydrogen atoms.

$\therefore$ Volume of 1 mole of hydrogen atoms $= 6.023 \times 10^{23} \times 0.524 \times 10^{-30}$

$= 3.16 \times 10^{-7} m^3$

OR

i. 1 hour = 3600 sec so that 1 sec = 1/3600 hour

1 km = 1000 m so that 1 m = 1/1000 km

3.0 m s^{-2} = 3.0 (1/1000 km)(1/3600 hour $)^{-2}$ = 3.9 $\times 10^4$ km/hr^2

ii. 6.67 $10^{-11} Nm^2/kg^2$ = $g^{-1} cm^3 s^{-2}$

$= 6.67 \times 10^{-11} kg^{-1} m^3 s^{-2}$

$= 6.67 \times 10^{-11} \times 10^3 \times \left(10^2\right)^3$

$= 6.67 \times 10^{-8} g^{-1} cm^3 s^{-2}$

25. Let h be the height of the cliff

Let stone fall for n second

u = 0 m/s and a = g = 9.8m/s^2

S_{nth} = u + $\frac{a}{2}$ (2n - 1)

$44.1 = 0 + \frac{9.8}{2}(2n - 1)$

$2n - 1 = \frac{44.1 \times 2}{9.8}$

$2n - 1 = 9$

$n = \frac{10}{2} = 5$ s

Height of the cliff

$h = ut + \frac{1}{2}at^2$

$h = un + \frac{1}{2}gn^2$

$h = 0 \times 5 + \frac{1}{2} \times 9.8 \times (5)^2$

$h=4.9\times 25$

$h=122.5$ m

Section D

26. Given,Mass of the stone, m = 0.25 kg , $g=10m/s^{-2}$, radius,r=1.5m and speed

$v=40rev/min$

$\nu=2\pi\times 1.5\times\frac{40}{60}=2\pi m/s$

$T=\frac{m\nu^2}{r}=\frac{0.25(2\times 3.14)^2}{1.5}=6.6N$

Tension in the string = 6.6 N

Maximum tension which can be withstand by string , T_{max} = 200 N

$T_{max}=\frac{mv_{max}^2}{r}$

$\therefore v_{max}=\sqrt{\frac{T_{max}\times r}{m}}$

$=\sqrt{\frac{200\times 1.5}{0.25}}$

$=\sqrt{1200}=34.64\mathrm{m/s}$

Therefore, the maximum speed of the stone is 34.64 m/s.

27. i. Mean diameter

$(\overline{d})=\frac{d_1+d_2+d_3+d_4+d_5+d_6+d_7+d_8+d_9}{9}$

$=\frac{0.39+0.38+0.37+0.41+0.38+0.38+0.37+0.40+0.39}{9}$

= 0.38556 mm

$\simeq$ 0.39 mm

ii. Absolute errors,

$\Delta d_1=(\overline{d})-d_1$ = 0.39 - 0.39 = 0 mm

$\Delta d_2=(\overline{d})-d_2$ = 0.39 - 0.38 = 0.01 mm

$\Delta d_3=(\overline{d})-d_3$ = 0.39 - 0.37 = 0.02 mm

$\Delta d_4=(\overline{d})-d_4$ = 0.39 - 0.41 = -0.02 mm

$\Delta d_5=(\overline{d})-d_5$ = 0.39 - 0.38 = 0.01 mm

$\Delta d_6=(\overline{d})-d_6$ = 0.39 - 0.38 = 0.01 mm

$\Delta d_7=(\overline{d})-d_7$ = 0.39 - 0.37 = 0.02 mm

$\Delta d_8=(\overline{d})-d_8$ = 0.39 - 0.40 = -0.01 mm

$\Delta d_9=(\overline{d})-d_9$ = 0.39 - 0.39 = 0 mm

Mean absolute error is given by

$\Delta \overline{d} = \frac{|\Delta d_1|+|\Delta d_2|+|\Delta d_3|+|\Delta d_4|+|\Delta d_5|+|\Delta d_7|+|\Delta d_8|+|\Delta d_9|}{9}$

$= \frac{0+0.01+0.02+0.02+0.01+0.01+0.02+0.01+0}{9}$

= 0.01111 mm = 0.01 mm

Thus, Relative error = $\frac{\Delta \overline{d}}{\overline{d}} = \frac{0.01}{0.39}$ = 0.02564

iii. Percentage Error, $\delta_d = \left(\frac{\Delta \overline{d}}{\overline{d}} \times 100\right)\%$

= 0.02564 $\times$100% = 2.564 % = 2.6%

OR

Length of sheet, l = 4.234 m

Breadth of sheet, b = 1.005 m

Thickness of sheet, h = 2.01 cm = 0.0201 m

The given table lists the respective significant figures:

Qunatity	**Number**	**Significant Figure**
l	4.234	4
b	1.005	4
h	0.0201	3

Hence, area and volume both must have at least 3 significant figures.

Now, surface area of the sheet = 2 (l × b + b × h + h × l)

= 2(4.234 × 1.005 + 1.005 × 0.0201 + 0.0201 × 4.234)

= 2(4.25517 + 0.0202005 + 0.0851034)

= 2 × 4.36

= 8.72 m2 (three significant figures)

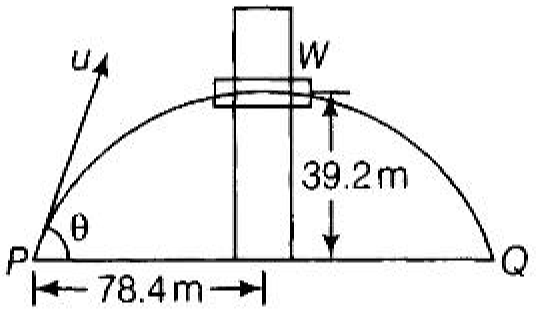
Volume of the sheet = $= l \times b \times h$

= 4.234 × 1.005 × 0.0201

= 0.0855 m^3 (three significant figures)

This number has only 3 significant figures i.e., 8, 5, and 5.

28. Consider a boy standing at position P at a horizontal distance 78.4m from the window, he throws a ball with a velocity u at an angle θ with the horizontal which just enters window W at a height 39.2 m.



For the maximum Height of projectile, we have the relation,

$H = \frac{u^2 \sin^2 \theta}{2g}$

$\Rightarrow 39.2m = \frac{u^2 \sin^2 \theta}{2g}$ ....(i)

and horizontal range, $R = \frac{u^2 \sin 2\theta}{g}$

$\Rightarrow 2 \times 78.4 = \frac{u^2 \sin 2\theta}{g}$ ....(ii)

Dividing Equations (i) and (ii), we get

$\frac{u^2 \sin^2 \theta}{2g} \times \frac{g}{u^2 2 \sin \theta \cos \theta} = \frac{39.2}{2 \times 78.4}$

$\Rightarrow \frac{1}{4} \tan \theta = \frac{1}{4} \Rightarrow \theta = 45^\circ$

Substituting θ = 45° in Eq. (ii), we get

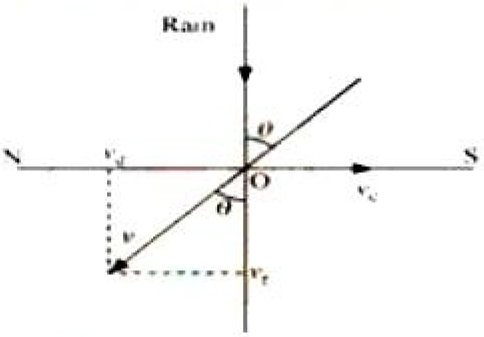
$\frac{u^2 \sin 90^\circ}{9.8} = 2 \times 78.4$

$\Rightarrow u = \sqrt{2 \times 78.4 \times 9.8}$ = 39.2 m/s

Hence, the ball should be projected at an angle of 45° with an initial speed of 39.2 m/s.

OR

The described situation is shown in the given figure.



Here,

v_c = Velocity of the cyclist

v_r = Velocity of falling rain

In order to protect herself from the rain, the woman must hold her umbrella in the direction of the relative velocity (v) of the rain with respect to the woman.

$v = v_t + (-v_c)$

$= 30 + (-10) = 20$ m/s

$\tan\theta = \frac{v_c}{v_r} = \frac{10}{30}$

$\theta = \tan^{-1}(0.333) \approx 18^\circ$

Hence, the woman must hold the umbrella toward the south, at an angle of nearly 18° with the vertical.

So these problems can be solved using relative velocity concept which requires conversion of non inertial frame into inertial frame.

29. We assume that the pebble is initially at rest on the cliff, i.e.

$u = 0$, $m = 1.00$ g $= 10^{-3}$ kg

Given that $v = 50$ ms^{-1}, $h = 1.00$ km $= 10^3$m

The change in KE of the pebble is given by the equation

$\Delta K = \frac{1}{2}mv^2 - \frac{1}{2}mu^2 = \frac{1}{2} \times 10^{-3} \times (50)^2 - 0 = 1.25\text{J}$

Assuming that acceleration due to gravity $g = 10$ ms^{-2} is constant, the work done by the gravitational force is

$W_g = mgh = 10^{-3} \times 10 \times 10^3 = 10.0$ J

If W_r is the work done by the resistive force on the pebble, then from the work-energy theorem we have, net change in kinetic energy = total work done

$\Delta K = W_g + W_r$

or $W_r = \Delta K - W_g$=1.25 - 10.0 = - 8.75 J

Hence, the work done by resistive force is 8.75 J, negative sign indicates that it is against the work done by gravitational force.

30. The orbital period is the time a given astronomical object takes to complete **one orbit** around another object, and applies in astronomy usually to planets or asteroids orbiting the Sun, moons orbiting planets, exoplanets orbiting other stars, or binary stars.

Orbital radius of the Earth around the Sun, $r = 1.5 \times 10^{11}\text{m}$

Time taken by the Earth to complete one revolution around the Sun,

T = 1 year = 365.25 days

$= 365.25 \times 24 \times 60 \times 60s$

Universal gravitational constant, $G = 6.67 \times 10^{-11}\text{Mm}^2\text{kg}^{-2}$

$M=\frac{4\pi^2r^3}{Gt^2}$
$=\frac{4\times(3.14)^2\times(1.5\times10^{11})^3}{6.67\times10^{-11}\times(365.25\times24\times60\times60)^2}$
$=\frac{133.24\times10}{6.64\times10^4}=2.0\times10^{30}kg$
Hence, the mass of the Sun is 2×10^{30}kg

Section E

31. In mechanics and physics, Simple Harmonic Motion is a special type of periodic motion or oscillation motion where the restoring force is directly proportional to the displacement and acts in the direction opposite to that of displacement.

Spring constant, k = 1200 N m^{-1}

Mass, m = 3 kg

Displacement, A = 2.0 cm = 0.02 cm

i. Frequency of oscillation v, is given by the relation:
$v=\frac{1}{T}=\frac{1}{2\pi}\sqrt{\frac{k}{m}}$
Where T is the time period
$\therefore v=\frac{1}{2\times3.14}\sqrt{\frac{1200}{3}}=3.18\mathrm{m/s}$
Hence, the frequency of oscillations is 3.18 cycles per second.

ii. Maximum acceleration (a) is given by the relation:
$a=\omega^2A$
Where,
ω = Angular frequency = $\sqrt{\frac{k}{m}}$
A = Maximum displacement
$\therefore a=\frac{k}{m}A=\frac{1200\times0.02}{3}=8ms^{-2}$
Hence, the maximum acceleration of the mass is 8.0 m/s^2.

iii. Maximum velocity, $v_{\max}=A\omega$
$=A\sqrt{\frac{k}{m}}=0.02\times\sqrt{\frac{1200}{3}}=0.4\mathrm{m/s}$
Hence, the maximum velocity of the object is 0.4 m/s at its mean position i.e at x = 0.

OR

Consider a simple harmonic progressive wave travelling along the positive direction of x-axis. At any instance t,the displacement of the particles of medium situated at the origin is given by -

y = a sin wt

here a is the amplitude of oscillation and $2\pi/w$ is the period of oscillation and w is the angular frequency of the wave.

Initially, at t = 0:

Displacement, x = 1 cm

Initial velocity, v = ω cm/sec.

Angular frequency, ω = π rad/s^{-1}

It is given that:

$x(x) = A\cos(\omega t + \phi)$

$1 = A\cos(\omega \times 0 + \phi) = A\cos\phi$

$A\cos\phi = 1$ ...(i)

Velocity, $v = \frac{dx}{dt}$

$\omega = -A\omega\sin(\omega t + \phi)$

$1 = A\sin(\omega \times 0 + \phi) = A\sin\phi$

$A\sin\phi = -1$ ....(ii)

Squaring and adding equations (i) and (ii), we get:

$A^2\left(\sin^2\phi + \cos^2\phi\right) = 1 + 1$

$A^2 = 2$

$\therefore A = \sqrt{2}\mathrm{cm}$

Dividing equation (ii) by equation (i), we get:

$\tan\phi = -1$

$\therefore \phi = \frac{3\pi}{4}, \frac{7\pi}{4}, \ldots\ldots$

SHM is given as:

$x = B\sin(\omega t + a)$

Putting the given values in this equation, we get:

$1 = B\sin[\omega \times 0 + a]$

B sin a = 1 ....(iii)

Velocity, $v = \omega B\cos(\omega t + a)$

Substituting the given values, we get:

$\pi = \pi B\sin a$

B sin a = 1 ...(iv)

Squaring and adding equations (iii) and (iv), we get:

$B^2\left[\sin^2 a+\cos^2 a\right]=1+1$

$B^2 = 2$

$\therefore B=\sqrt{2}\text{cm}$

Dividing equation (iii) by equation (iv), we get:

$\frac{B\sin a}{B\cos a}=\frac{1}{1}$

$\tan a=1=\tan\frac{\pi}{4}$

$a\frac{\pi}{4},\frac{5\pi}{4},\ldots\ldots$

32. i. We know that water molecule is made up of 3 atoms (2 hydrogen and 1 oxygen).

By using law of equipartition of energy, average energy associated with one atom of water molecule

$=2\times\left(\frac{1}{2}k_BT\right)=k_BT$

In three dimension, the average energy per atom of water molecule = $3k_BT$

Total energy of one molecule of water is

$=3\times(3k_BT)=9k_BT$

Now, total energy of 1 mole of water is

$U=3\times 3k_BT\times N_A=9RT$

Molar specific heat of water,

$C=\frac{\Delta Q}{\Delta T}=\frac{\Delta U}{\Delta T}=9R$

Specific heat capacity of water, C = 9 R

$\Rightarrow$ C = 74.79 J $mol^{-1}K^{-1}$(putting the value of R = 8.314 J mol^{-1} K^{-1})

ii. For monoatomic gas, $C_V=\frac{3}{2}R$

For diatomic gas, $C_V'=\frac{5}{2}R$

Let μ and μ' be the number of moles of mono-atomic and diatomic gases, then

C_V(mixture) = $\frac{\mu C_V+\mu' C_V'}{\mu+\mu'}$

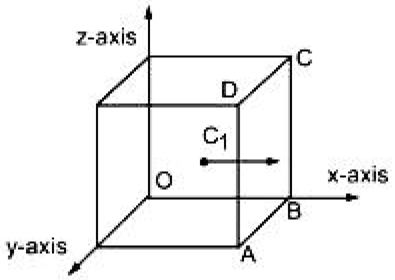
$\Rightarrow C_V=\frac{1\times\frac{3}{2}R+1\times\frac{5}{2}R}{1+1}=2R$

$\therefore\gamma(\text{ mixture })=1+\frac{R}{C_{V(\text{ mixture })}}$, using the relation $C_P - C_V = R$

$=1+\frac{R}{2R}$

= 1.5

OR



Consider an ideal gas contained in a cubical container shown in figure above, having each of side a and having volume V. Now, V = a^3 [∵$(Side)^3$ = volume of cube]

Let n = number of molecules of the gas contained in the container

m = Mass of each molecule

M = mn = Total mass of the gas contained

Consider one molecule is moving with velocity C_1 such that, $\vec{C_1} = v_{1x}\hat{i} + v_{1y}\hat{j} + v_{1z}\hat{k}$

X-component of change in momentum of the molecule along +X axis = mv_{1x} - (- v_{1x}) = $2mv_{1x}$ in time t = $2a/v_{1x}$

Now rate of change of momentum (X component) = $(2mv_{1x})/t$ = $\frac{mv_{1x}{}^2}{a}$, this is the X component of the force, F_{1x} by the molecule.

Now X component of pressure exerted by the molecule $P_{1x} = F_{1x}/a^2 = mv_{1x}{}^2/a^3$

Now taking all the molecules, net X component of pressure, P_x =

$\frac{m}{a^3} \times (v_{1x}^2 + v_{2x}^2 + \ldots + v_{nx}^2)$(for n number of molecules)

Similarly P_y = $\frac{m}{a^3}\left(v_{1y}^2 + v_{2y}^2 + \ldots . + v_{ny}^2\right)$ and

$P_z = \frac{m}{a^3}\left(v_{1z}^2 + v_{2z}^2 + \ldots . + v_{nz}^2\right)$

All three component of pressures are equal for all the gas molecules.

P = Total pressure of a single molecule = $\frac{P_x + P_y + P_z}{3}$

$= \frac{1}{3}[\frac{m}{a^3}(v_{1x}^2 + v_{2x}^2 + \ldots + v_{nx}^2) + \frac{m}{a^3}\left(v_{1y}^2 + v_{2y}^2 + \ldots + v_{nz}^2\right) + \frac{m}{a^3}(v_{1z}^2 + v_{2z}^2 + \ldots + v_{nz}^2)]$

$\therefore P = \frac{m}{3V}\left[C_1^2 + C_2^2 + \ldots . + C_n^2\right]$ where $C_1{}^2 = v_{1x}{}^2 + v_{1y}{}^2 + v_{1z}{}^2$, $C_2{}^2 = v_{2x}{}^2 + v_{2y}{}^2 + v_{2z}{}^2$,......, $C_n{}^2 = v_{nx}{}^2 + v_{ny}{}^2 + v_{nz}{}^2$

multiplying and dividing by n (total no of molecules of gas)

$\therefore P = \frac{m \times n}{3V}\left[\frac{C_1^2 + C_2^2 + \ldots . + C_n^2}{n}\right]$

$\Rightarrow P = \frac{M}{3V}C^2 = \frac{1}{3}\rho C^2$

$where\ C^2 = \frac{C_1^2+C_2^2+....+C_n^2}{n}$ or $C = \sqrt{\frac{C_1^2+C_2^2+....+C_n^2}{n}}$

C = r. m s. velocity of gas and ρ being the mass density of the gas.

33. Given:

Length of an edge of the solid copper cube, l = 10 cm = 0.1 m

Hydraulic pressure, P = 7.0×10^6 Pa

Bulk modulus of copper, B = 140×10^9 Pa

Bulk modulus, B = $\frac{P}{(\Delta V/V)}$

Where,

$\frac{\Delta V}{V}$ = Volumetric strain

ΔV = change in volume = $\frac{PV}{B}$

V = original volume

Original volume of the cube, V = $length^3 = l^3$

$\therefore \Delta V = \frac{Pl^3}{B}$

$\triangle V = \frac{7\times10^6\times(0.1)^3}{140\times10^9}$

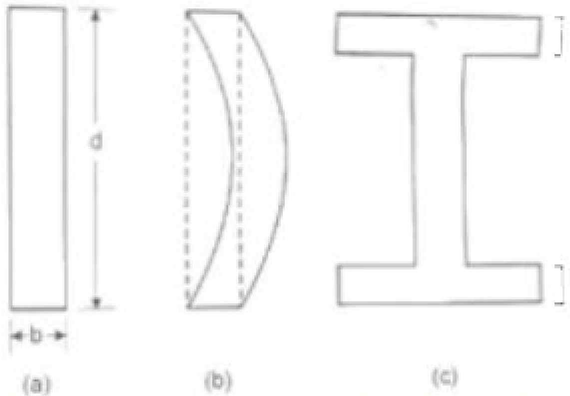
$\triangle V = 5 \times 10^{-8} m^3$ = 5×10^{-2} cm^{-3}

Therefore, the volume contraction of the solid copper cube is 5×10^{-2} cm^{-3}.

OR

i. The major function of beam is to resist moment generated by applied load or to resist the deflection which generates again high Moment on beam. So this applied Moment is resisted through the special property of beam "EI" which includes type of material (Modulus of Elasticity) and dimensions of beam (width & depth). Concrete beams are commonly used in large buildings to support the weight of roof. It is found that depression of a beam of length l, breadth b and depth d when loaded at the centre by a load W and supported at the ends on walls in the middle is given by
$\delta = \frac{Wl^3}{4bd^3\gamma}$
Thus, to have less depression we prefer a beam of greater depth (because $\delta \propto \frac{1}{d^3}$).

ii. A bar of rectangular section with large depth may buckle as shown in Fig. (b), when the load W is not at the right place. To avoid this, we use a I-section beam. It provides a large load bearing surface, enough depth to prevent bending. The shape reduces the weight of the beam without sacrificing the strength and hence reduces the cost.



iii. A pillar with distributed ends, as shown in Fig. (b) is preferred over a pillar with rounded ends because it supports much more load than a pillar with rounded ends.