CBSE Class 11 Physics
Sample Paper 07 (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.

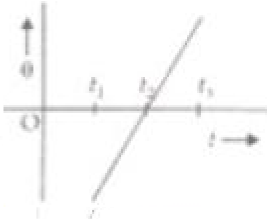
Section A

1. Can speed of an object be negative? Justify.
2. Why does a child feel more pain when she/he falls down on a hard cement floor than when she/he falls on the soft muddy ground in the garden?

OR

A car and a truck have the same momentum. Which of the two have greater speed and why?

3. The variation of angular position θ , of a point on a rotating rigid body, with time t is shown in Figure. Is the body rotating clock-wise or anti-clockwise?



4. Work done in moving a particle round a closed path under the action of gravitation force is zero. Why?

OR

When a pendulum clock is taken to a mountain, it becomes slow. But a wristwatch controlled by a spring remains unaffected. Explain.

5. Why the molecules of a liquid lying near the free surface possess extra energy?
6. What is the value of angular speed for 1 revolution?
7. State the number of significant figures in the following :
   i. $0.007\ \mathrm{m}^2$
   ii. 2.64×10^{24} kg

OR

Does AU and $\overset{\circ}{\mathrm{A}}$ represent the same unit of length?

8. Sound of maximum intensity is heard successively at an interval of 0.2 second on sounding two tuning fork together. What is the difference of frequencies of two tuning forks?

OR

Which property of the medium is responsible for propagation of Waves through it?

9. State zeroth law of thermodynamics?
10. Can there be motion in two dimensions with an acceleration only in one dimension?
11. **Assertion:** If $\vec{P} \cdot \vec{Q} = |\vec{P} \times \vec{Q}|$, then angle between $\vec{P}$ and $\vec{Q}$ is $\frac{\pi}{2}$.
    Reason: If angle between $\vec{P}$ and $\vec{Q}$ is $\frac{\pi}{2}$, then dot product is zero.
    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:** Steel is more elastic than rubber.
Reason: Under given deforming force, steel is deformed less than rubber.
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.

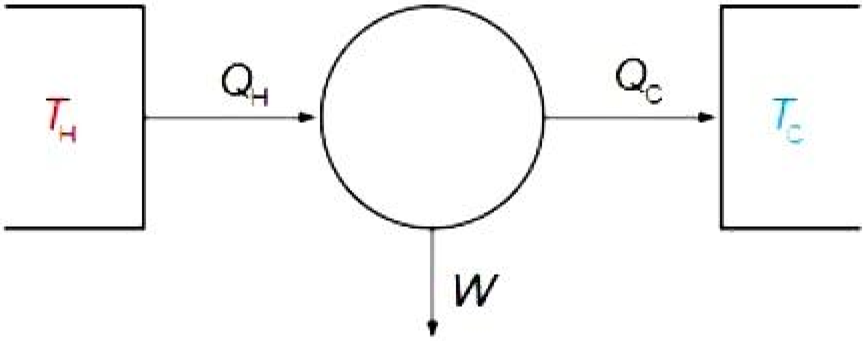
13. **Assertion:** The total translational kinetic energy of all the molecules of a given mass of an ideal gas is 1.5 times the product of its pressure and its volume.
Reason: The molecules of a gas collide with each other and the velocities of the molecules change due to the collision.
a. Assertion 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:** When a man jumps from a boat to shore, the boat slightly moves away from the shore.
Reason: The total momentum should remain conserved.
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:**

Carnot principles are only for the cyclical devices like heat engines, which state that the efficiency of an irreversible heat engine is always less than the efficiency of a reversible one operating between the same two reservoirs. The efficiencies of all reversible heat engines operating between the same two reservoirs are the same.

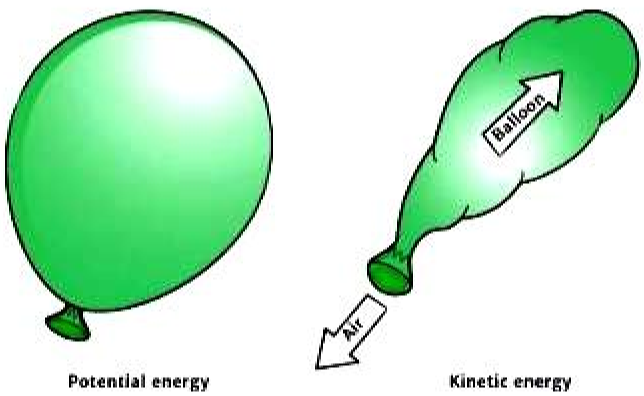


i. In a Carnot cycle, the working medium rejects heat at a _______ temperature.
   a. Higher
   b. Lower
   c. constant
   d. none of these
ii. Which of the following is NOT a state variable?
   a. work
   b. internal energy.
   c. entropy
   d. all of the above
iii. The efficiency of reversible heat engine is:
   a. $1 + (T_2/T_1)$
   b. $(T_1/T_2) + 1$
   c. $(T_1/T_2) - 1$
   d. $1 - (T_2/T_1)$
iv. Other factors remaining constant, if the temperature of the source is increased, the efficiency of the Carnot engine will:
   a. decrease
   b. increase
   c. constant
   d. increase or decrease depending upon temperature ratio
v. Over the complete Carnot cycle, entropy:

a. increase
b. decrease
c. constant
d. first increase and then decrease

16. **Read the case study given below and answer any four subparts:**
Potential energy is the energy stored within an object, due to the object's position, arrangement or state. Potential energy is one of the two main forms of energy, along with kinetic energy. Potential energy depends on the force acting on the two objects.

Potential and Kinetic Energy



i. A body is falling freely under the action of gravity alone in vacuum. Which of the following quantities remain constant during the fall?
   a. kinetic energy
   b. potential energy
   c. mechanical energy
   d. none of these
ii. Work done by a conservative force is positive, if
   a. potential energy decreases
   b. potential energy increases
   c. kinetic energy decreases
   d. kinetic energy increases
iii. When does the potential energy of a spring increases?
   a. only when spring is stretched
   b. only when spring is compressed
   c. both a and b
   d. none of these
iv. Dimension of k/m is, here k is force constant

a. T^2

b. T^{-2}

c. T^1

d. T^{-1}

v. A vehicle of mass 5000kg climbs up a hill of 10 m. The potential energy gained by it

a. 5 J

b. 500 J

c. 5×10^4 J

d. 5×10^5 J

Section C

17. A sphere of mass 40 kg is attracted by the second sphere of mass 60 kg with a force equal to 4 mgf. If G is 6×10^{-11} Nm^2/kg^2, then calculate the distance between them. Consider acceleration due to gravity is $10 m/s^2$.

18. An iron ring of diameter 5.231 m is to be fixed on a wooden rim of diameter 5.243 m both initially at 27°C. To what temperature should the iron ring be heated so as to fit the rim? (Coefficient of linear expansion of iron is $1.2 \times 10^{-5}\ K^{-1}$)

OR

Briefly explain the principle of a constant volume gas thermometer.

19. Calculate the energy possessed by stone of mass 200 g executing S.H.M of amplitude 1cm and time period 4s.

OR

Find the length of a second's pendulum at a place, where $g = 9.81\ ms^{-2}$.

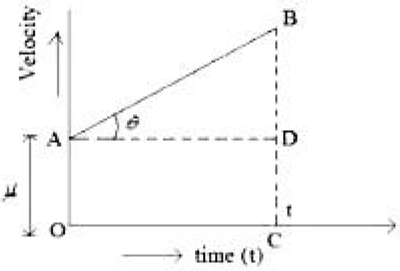
20. Give the magnitude and direction of the net force acting on a stone of mass 0.1 kg,

a. just after it is dropped from the window of a stationary train,

b. just after it is dropped from the window of a train running at a constant velocity of 36 km/h.

Neglect air resistance throughout.

21. Establish $s = ut + \frac{1}{2}at^2$ from velocity time graph for a uniform accelerated motion?



22. A wave moves with speed 300 m/s on a wire which is under tension of 400 N. Find how much tension must be changed to increase the speed to 315 m/s?

23. What is the value of linear velocity if $\overline{w} = 3\hat{i} - 4\hat{j} + \hat{x}$ and $\overline{r} = 5\hat{i} - 6\hat{j} + 6\hat{k}$?

24. Compute the following with regards to significant figures.

    i. 4.6×0.128

    ii. $\frac{0.9995 \times 1.53}{1.592}$

    iii. 876 + 0.4382

OR

The rotational kinetic energy of a body is given by E = $\frac{1}{2}I\omega^2$, where ω is the angular velocity of the body. Use the equation to obtain a dimensional formula for moment of inertia I. Also write its SI unit.

25. Points P, Q and R are in a vertical line such that PQ = QR. A ball at P is allowed to fall freely. What is the ratio of the times of descent through PQ and QR?

Section D

26. A helicopter of mass 1000 kg rises with a vertical acceleration of 15 ms^{-2}. The crew and the passengers weigh 300 kg. Give the magnitude and direction of the

    i. force on the floor by the crew and passengers,

    ii. action of the rotor of the helicopter on the surrounding air,

    iii. force on the helicopter due to the surrounding air.

27. If l_1 = (10 .0 ± 0.1) cm and l_2 = (9.0 ± 0.1) cm, find their sum, difference and percentage error in each.

OR

How can you estimate the distance of a near star by parallax method?

28. State and explain polygon law of vector addition.

OR

A cricket ball is thrown at a speed of $28ms^{-1}$ in a direction 30° above the horizontal. Calculate

i. the maximum height
ii. the time taken by the ball to return to the same level and
iii. the distance from the thrower to the point where the ball returns to the same level.

29. The blades of a windmill sweep out a circle of area A.
i. If the wind flows at a velocity v perpendicular to the circle, what is the mass of the air passing through it in time t?
ii. What is the kinetic energy of the air?
iii. Assume that the windmill converts 25% of the wind's energy into electrical energy, and that A = 30 m^2, v = 36 km/h and the density of the air is $1.2kgm^{-3}$. What is the electrical power produced?

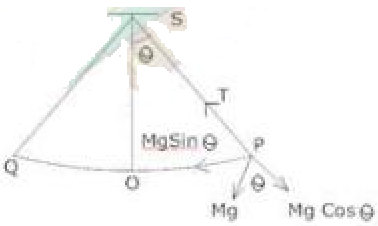
30. What will be the gravitational potential of a body of mass 67 kg at a distance of 6.6×10^{10} m from the centre of the earth?

Section E

31. Cylindrical piece of cork of density of base area A and height h floats in a liquid of density ρ_l. The cork is depressed slightly and then released. Show that the cork oscillates up and down simple harmonically with a period $T = 2\pi\sqrt{\frac{h\rho}{\rho_l g}}$ Where ρ is the density of cork. (Ignore damping due to viscosity of the liquid).

OR

What is Simple pendulum? Find an expression for the time period and frequency of a simple pendulum?



32. A box of $1.00m^3$ is filled with nitrogen at 1.5 atm at 300K. The box has a hole of an area

0.010 mm^2. How much time is required for the pressure to reduce by 0.10 atm, if the pressure outside is 1 atm.

OR

State equipartition law of energy. Apply it to find specific heats of a (a) monoatomic, and (b) diatmoic gas.

33. A steel wire of length 4.7 m and cross-sectional area $3.0 \times 10^{-5} \mathrm{m}^2$ stretches by the same amount as a copper wire of length 3.5 m and cross-sectional area of $4.0 \times 10^{-5} \mathrm{m}^2$ under a given load. What is the ratio of the Young's modulus of steel to that of copper?

OR

The torque required to produce unit twist in a solid shaft of radius r, length and made of material of modulus of rigidity n is given by $T = \frac{\pi \eta r^4}{2l}$ Explain why hollow shafts are preferred to solid shafts for transmitting torque?

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Solution

Section A

1. No, speed of an object can never be negative because distance is also always positive.
2. The effect of force F = ma. i.e., if the mass is constant for a system to decrease force, the 'a' should be decreased $a = \frac{v-u}{t}$ initial and final velocity of falling body on a surface are u and zero. so it cannot be changed. If time during hitting is increased, the acceleration decreased and force will decrease.

   On cemented hard floor the time to stop after fall on it is very-very small. But when she/he falls on soft ground of garden she/he sinks in ground and takes more time to stop hence smaller force or pain acts on her/him.

   OR

   As we know, Momentum, (p) = Mass (m) $\times$ Velocity (v)
   For a given momentum, $v \propto \frac{1}{m}$
   Thus, the car will have greater speed because its mass is less than the truck.

3. As the $\theta - t$ graph has +ve slope so $\frac{d\theta}{dt} = \omega$ is +ve so the rotation is clockwise.
4. Gravitational force is a conservative force which means that work done by it, is independent of a path followed.

   OR

   When a pendulum clock is taken to a mountain, it becomes slow because at the mountain, g decreases and time period of the pendulum clock increases at $T = 2\pi\sqrt{l/g}$
   On the other hand, a spring in the wrist-watch remains unaffected by the variation of g.

5. The molecules in a liquid surface have a net downward force (Cohesion) on them, so the molecules are continuously moving downwards in the liquid and other molecules are coming to the top. Those molecules that replaces the molecules in the top layer have to perform some extra work against the force of cohesion. so work done in bringing them

from within the body of liquid to the Surface increases surface energy.

6. For one complete revolution, $\theta = 2\pi$ in time period t = T.
   Therefore angular speed, $\omega = \frac{2\pi}{T}$
7. i. 1

   Explanation: Significant figure- 7. If number is less than one, then 0's before 7 are insignificant (note that there are only 0's before 7 and numbers like 0.1007 will have 0 as significant figure).

   ii. 3

   Explanation: Significant figure- 2, 6, 4. Powers of 10 are not taken in counting for significant figures.

OR

No, $\overset{o}{\mathrm{A}}$ and AU are the two different units of length.

AU = 1 astronomical unit = mean distance between the earth and the sun = 1.496×10^{11} m and 1 $\overset{o}{\mathrm{A}}$ = 1 angstrom = 10^{-10} m

8. The beat period is 0.2 second so that the beat frequency is fb = $\frac{1}{0.2}$ = 5HZ. Therefore, the difference of frequencies of the two tuning forks is 5HZ.

OR

Properties of elasticity and inertia.

9. According to this, when the thermodynamic system A and B are separately in thermal equilibrium with a third thermodynamic system C, then the system A and B are in thermal equilibrium with each other as well.
10. Yes, it can be. For example, in projectile motion, the acceleration of the particle acts vertically downwards, while the projectile follows a parabolic path(which is a 2D motion).
11. (d) Assertion is wrong statement but reason is correct statement.

    Explanation: Assertion is false but reason is true.

    If $\vec{P} \cdot \vec{Q} = |\vec{P} \times \vec{Q}|$
    or PQ cos θ = PQ sin θ

or tan θ = 1 or $\theta = \frac{\pi}{4}$
So, $\vec{P} \cdot \vec{Q} = |\vec{P} \times \vec{Q}|$, only when angle between $\vec{P}$ and $\vec{Q}$ is 45°.
Also, $\vec{P} \cdot \vec{Q} = PQ \cos \frac{\pi}{2} = 0$

12. (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.

13. (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.

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

    Explanation: Initially, the total momentum of the boat and the man is zero. When a man jumps from the boat, total momentum can be zero, only if the boat moves in a direction opposite to direction of jumping of man.

Section B

15. i. (b) lower
    ii. (a) Work
    iii. (d) 1- (T_2/T_1)
    iv. (b) increase
    v. (c) constant
16. i. c
    ii. a
    iii. c
    iv. b
    v. d

Section C

17. Given, M =40 % of m = 60 kg,

    $F = 4mgf = 4 \times 10^{-6} \times 10 = 4 \times 10^{-5} N,$
    $G = 6 \times 10^{-11} Nm^2/kg^2,$

    $g = 10 m/s^2.$

According to universal law, $F = \frac{GMm}{r^2}$

$\Rightarrow$ r = $\sqrt{\frac{GMm}{F}}$

= $\sqrt{\frac{6\times10^{-11}\times40\times60}{4\times10^{-5}}} = 0.06m = 6cm$

18. From the definition of coefficient of linear expansion, $d_2 = d_1[1 + \alpha\Delta t]$

$\Rightarrow$ 5.243 = 5.231[1 + 1.2 $\times$ 10^{-5} (T - 300)]

$\therefore \left[\frac{5243}{5231} - 1\right] = 1.2 \times 10^{-5}(T - 300)$

T = 191 + 300 = 491 K = 218°C

OR

A constant volume gas thermometer is composed of a bulb filled with a fixed amount of a dilute *gas* that is attached to a mercury manometer. It is based on the principle that under constant volume condition the pressure exerted by a given mass of an ideal gas is directly proportional to its absolute temperature i.e., $P \propto T$.

For a given mass of a permanent gas like He or H_2 under constant volume condition at a temperature of triple-point of water $T_{tr} = 273.16K$, the pressure exerted by gas be P_{tr} and at an unknown temperature T the measured value of pressure be P,

$\frac{P}{P_{tr}} = \frac{T}{T_{tr}}$

$\Rightarrow$ Unknown temperature $T = \frac{P\times T_{tr}}{P_{tr}}$ = $\frac{P}{P_{tr}} \times 273.16$K.

19. $E = 2\pi^2 mr^2 v^2 = \frac{2\pi^2 mr^2}{T^2}$

m = 0.2 kg, r = 0.01 m, t = 4s.$\therefore E = \frac{2\pi^2\times0.2\times(0.1)^2}{4^2} = 0.00246J$

OR

The time period of second's pendulum T = 2 s and g = 9.81 ms^{-2}

From the relation T = $2\pi\sqrt{\frac{l}{g}}$, we have

l = $\frac{gT^2}{4\pi^2}$

= $\frac{9.81\times(2)^2}{4\times(3.14)^2}$

= 0.995 m $\simeq$ 1 m.

20. a. When stone is dropped just after from the window of a stationary train,

Force on stone, F = Force due to gravity = mg = 0.1 kg $\times$ 10 m/s^2 = 1 N in the vertically downward direction.

b. As the train is running with constant velocity, acceleration is zero in horizontal direction i.e. direction of motion of train. Hence no force in horizontal direction. So, only force due to gravity in vertically downward direction exists. In this case too, force is same as in (a) i.e., F = 1 N downwards.

21. Displacement of the particle in time (t)

S = area under $v-t$ graph

S = area of trapezium OABC

$S=\frac{1}{2}(v+u)t$

$S=\frac{1}{2}(u+at+u)t$(v = u + at)

$S=\frac{1}{2}(2u+at)t$

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

22. We know speed, v = $\sqrt{\frac{T}{\mu}}$ ....(i), T and μ are tension and mass per unit length respectively.

Now differentiating v with respect to T,

$\Rightarrow \frac{dv}{dT}=\frac{1}{2\sqrt{\mu T}}$

$\Rightarrow \frac{dv}{v}=\frac{1}{2}\frac{dT}{T}\left[\text{putting }\sqrt{\mu}=\frac{\sqrt{T}}{V}\text{ from equation (i)}\right]$

$\Rightarrow$ dT = (2T $\times$ $\frac{dv}{v}$)

$=2\times 400\times\left(\frac{315-300}{300}\right)$

$=\frac{2\times 4}{3}\times 15$

$=2\times 4\times 5$

= 40 N

Hence, tension should be increased by 40 N.

23. $-\overline{v}=\overline{w}\times\overline{r}$

$\overline{v}=(3\hat{i}-4\hat{j}+\hat{k})\times(5\hat{i}-6\hat{j}+6\hat{k})$

$\overline{v}=-18\hat{i}-13\hat{j}+2\hat{k}$

24. i. Here, We have

4.6 $\times$ 0.128 = 0.5888 = 0.59

The obtained result has been rounded off to have two significant digits (as in 4.6)

ii. Here, we have

$\frac{0.9995\times 1.53}{1.592}$ = 0.96057 = 0.961

The above result has been rounded off to three significant digits (as in 1.53).

iii. Here, we have

876 + 0.4382 = 876.4382 = 876

Since there is no decimal point in 876, therefore, the above result of addition has been rounded off to no decimal point.

OR

It is given that the rotational kinetic energy, $E = \frac{1}{2}I\omega^2 \Rightarrow I = \frac{[E]}{[\omega^2]}$

Therefore, $I = \frac{[E]}{[\omega^2]} = \frac{[ML^2T^{-2}]}{[T^{-1}]^2}\left[\frac{ML^2T^{-2}}{T^{-2}}\right] = [ML^2]$

Its SI unit is Joule.

25. If t_1 and t_2 be the times of descent through PQ and QR, respectively.

Let PQ = QR = h (heights are equal)

Then,distance covered, PQ = h = $\frac{1}{2}gt_1^2$ .... (i)

and distance covered (PQ + QR) = 2h = $\frac{1}{2}g(t_1 + t_2)^2$ .... (ii)

By dividing (i) by (ii) we get

$\frac{1}{2} = \frac{t_1^2}{(t_1+t_2)^2}$

or $\frac{1}{\sqrt{2}} = \frac{t_1}{t_1+t_2}$

Solving it we get, $t_1 : t_2 = 1 : (\sqrt{2} - 1)$

Section D

26. Mass of the helicopter, m_h = 1000 kg, total mass of the system = 1300 kg

i. The mass of crew plus passengers m_1 = 300 kg. When the helicopter is rising up then apparent weight is

$W = m_1(g + a) = m_1(g + 15) = 300\ (10 + 15) = 7500$ N

Since the helicopter is accelerating vertically upward, the reaction force will also be directed upward. Therefore, as per the Newton's third law of motion the force acting on the floor of the helicopter is 7500 N acting downwards.

ii. The mass of the helicopter will also be included. Therefore m_2 = 1300 kg. The force acting on the surrounding air by the rotor = (1300)(10 + 15) = 32500 N acting downward.

iii. By Newton's Third Law of motion, the magnitude of the force acting on the helicopter due to the surrounding air is the same as in case (ii) above i.e., 32500 N. But the direction of the force will be opposite i.e., in the upward direction.

27. Given, $l_1 = (10.0 \pm 0.1)$ cm and $l_2 = (9.0 \pm 0.1)$ cm

sum = $l_1 + l_2$

Sum in terms of errors = $l_1 + l_2 = (10.0 \pm 0.1) + (9.0 \pm 0.1)$

$= (19.0 \pm 0.2)$ cm

Difference = $l_1 - l_2$

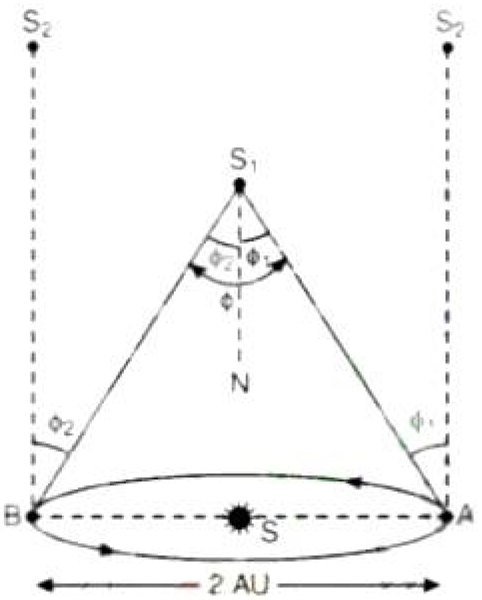
Difference = $l_1 - l_2 = (10.0 - 9.0) \pm (0.1 + 0.1)$

$= (1.0 \pm 0.2)$ cm (errors are always added up)

Now Percentage error for Sum = $\frac{0.2}{19.0} \times 100 = 1.05\%$

and percentage error for Difference = $\frac{0.2}{1.0} \times 100 = 20\%$

OR



Consider the figure. Parallax method is used to estimate the distance of a near star S_1 from Earth. Firstly consider a very distant star S_2 whose position and direction considered to remain unchanged even after six months. The parallax angle ϕ_1 subtended by a near star in one position of Earth (say A) with respect to distant star S_2 is measured. After six months, earth in its orbit around the Sun S will reach at the diametrically opposite position B. In this position again, measure the parallax angle ϕ_2 subtended by a near star S_1 on Earth with respect to distant star S_2.

∴Total parallax angle subtended by star S_1 on Earth's orbital diameter AB (where AB = 2 AU, = 2 $\times$1.496 $\times$ 10^{11} m = 3 $\times$ 10^{11} m) will be $\phi = \phi_1 + \phi_2$

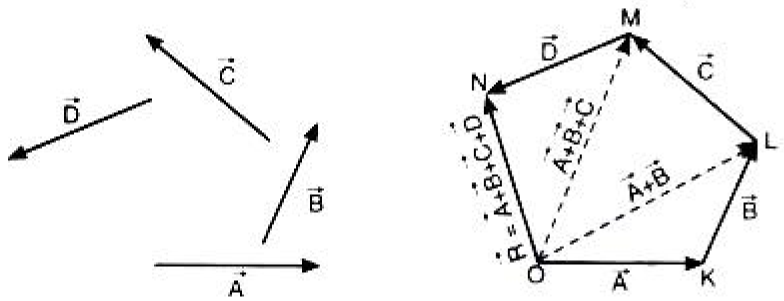
Let, $S_1A = S_1B$ = d. As, d is very large, ϕ is very small. So, AB = BS_1 and

$\phi = \frac{AB}{d} = \frac{3\times10^{11}}{d}$ rad

$\Rightarrow$ The distance of star S_1 from Earth, d = $\frac{3\times10^{11}}{\phi}$ m.

28. **Polygon law of vector addition:** It states that if a number of vectors can be represented in magnitude and direction by the sides of a polygon taken in the same order, then their resultant is represented in magnitude and direction by the closing side of the polygon taken in the opposite order.

Let us find the resultant of four vectors $\vec{A}, \vec{B}, \vec{C}$ and $\vec{D}$.



In triangle OKL, the vectors $\vec{A}$ and $\vec{B}$ are represented by the sides $\overrightarrow{OK}$ and $\overrightarrow{KL}$ taken in the same order. Therefore, from the triangle law of vector addition, the closing side $\overrightarrow{OL}$ taken in the opposite order represents the resultant of vectors $\overrightarrow{OK}$ and $\overrightarrow{KL}$.

Thus, $\overrightarrow{OK} + \overrightarrow{KL} = \overrightarrow{OL}$ .... (1)

By applying the triangle law of vector addition to the triangle OLM, it shows that the side $\overrightarrow{OM}$ is the resultant of vectors $\overrightarrow{OL}$ and $\overrightarrow{LM}$ i.e., $\overrightarrow{OL} + \overrightarrow{LM} = \overrightarrow{OM}$.

Using eq (1), we get,

$\overrightarrow{OK} + \overrightarrow{KL} + \overrightarrow{LM} = \overrightarrow{OM}$ .... (2)

Similarly, applying the triangle law of vector addition to the triangle OMN, we get,

$\overrightarrow{OM} + \overrightarrow{MN} = \overrightarrow{ON}$

Using eq (2), we get,

$\overrightarrow{OK} + \overrightarrow{KL} + \overrightarrow{LM} + \overrightarrow{MN} = \overrightarrow{ON}$ .... (3)

Now the vectors $\overrightarrow{OK} = \vec{A}$, $\overrightarrow{KL} = \vec{B}$, $\overrightarrow{LM} = \vec{C}$ and $\overrightarrow{MN} = \vec{D}$. Denoting the vector,

$\overrightarrow{ON} = \vec{R}$, the equation becomes,$\vec{A} + \vec{B} + \vec{C} + \vec{D} = \vec{R}$

OR

i. The maximum height attained by the ball is given by the equation,
$H_m = \frac{(v_0 \sin \theta_0)^2}{2g}$
$= \frac{(28 \sin 30^\circ)^2}{2(9.8)} = \frac{14 \times 14}{2 \times 9.8}$ = 10.0 m
ii. The time taken by the ball to return to the same level, i.e. time of flight is given by the equation
T =$(2v_0 \sin \theta_0) / g = (2 \times 28 \times \sin 30^\circ) / 9.8$
= 28/9.8 = 2.9 s
iii. The distance from the thrower to the point where the ball returns to the same level is the range of the projectile given by the relation
R = $\frac{(v_0^2 \sin 2\theta_0)}{g} = \frac{28 \times 28 \times \sin 60^\circ}{9.8}$ = 69.3 m

29. i. Area swept by blades of windmill = A, and velocity of wind = v
Therefore, Volume of air passing per unit time = A $\times$ v
Also, Mass of air passing per unit time = Avρ
and mass of air passing in time t, M = A $\times$ vρt
ii. Kinetic Energy of said quantity of air, K = $\frac{1}{2} Mv^2 = \frac{1}{2} A\rho t v^3$
iii. If it is assumed that the efficiency of the windmill is 25%, then we have
Output electrical power = 25% of input power $= \frac{25}{100} \times \frac{1}{2} A\rho v^3$
As A = 30 m^2, v = 36 m / h = $36 \times \frac{5}{18}$m/s = 10 m/s and ρ =1.2 kgm^{-3}
Therefore, Output electrical power $= \frac{25}{100} \times \frac{1}{2} \times 30 \times 1.2 \times (10)^3$= 4500 W= 4.5 kW
[because 1 kiloWatt = 1000 Watt]
Hence, electrical power produced = 4.5 kW

30. Mass of the earth, $M = 6.0 \times 10^{24} kg, m = 67kg$
$G = 6.67 \times 10^{-11} Nm^2 kg^{-2}$
Gravitational potential, V = - $\frac{GM}{R}$
= - $\frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{6.6 \times 10^{10}}$
$V = -6.1 \times 10^3 Jkg^{-1}$

Section E

31. This numerical can be solved using concept of Simple Harmonic Motion of floating object

in which an object is dipped into the liquid and released by pushing it down,due to increased buoyant force it will move upward due to which excess force will push it downward.This repeated up and down movement of the object is governed by the laws of Simple Harmonic Motion assuming viscous forces are absent.

so area of the cork = A

Height of the cork = h

Density of the liquid = ρ_l

Density of the cork = ω

In equilibrium:

Weight of the cork = Weight of the liquid displaced by the floating cork

Let the cork be depressed slightly by x. As a result, some extra water of a certain volume is displaced. Hence, an extra up-thrust acts upward and provides the restoring force to the cork.

Up-thrust = Restoring force, F = Weight of the extra water displaced

F = –(Volume $\times$ Density $\times$ g)

Volume = Area $\times$ Distance through which the cork is depressed

Volume = Ax

$\therefore F = -A \times \rho_l g$

According to the force law:

F = kx

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

Where, k is a constant

$k = \frac{F}{x} = -A\rho_l g$ ...(ii)

The time period of the oscillations of the cork:

$T = 2\pi\sqrt{\frac{m}{k}}$ ....(iii)

Where,

m = Mass of the cork

= Volume of the cork $\times$ Density

= Base area of the cork $\times$ Height of the cork $\times$ Density of the cork

= Ahρ

Hence, the expression for the time period will be -

$$T = 2\pi\sqrt{\frac{Ah\rho}{A\rho_l g}} = 2\pi\sqrt{\frac{h\rho}{\rho_l g}}$$

From the above expression it is proved that time period of the fork does not depend on the mass of the object rather depends on specific gravity of the cork and height of the cork and acceleration due to gravity.

OR

A simple pendulum is the most common example of the body executing S.H.M, it consists of heavy point mass body suspended by a weightless inextensible and perfectly flexible string from rigid support, which is free to oscillate. When a pendulum is displaced sideways from its resting, equilibrium position, it is subject to a restoring force due to gravity that will accelerate it back toward the equilibrium position. When released, the restoring force acting on the pendulum's mass causes it to oscillate about the equilibrium position, swinging back and forth. The time for one complete cycle, a left swing and a right swing, is called the period.

Let m = mass of bob

l = length of a pendulum

Let O is the equilibrium position, OP = X

Let θ = small angle through which the bob is displaced.

The forces acting on the bob are:-

i. The weight = Mg acting vertically downwards.
ii. The tension = T in string acting along Ps.

Resolving Mg into 2 components as Mg Cos θ and Mg Sin θ,

Now, T = Mg Cos θ

Restoring force F = - Mg Sin θ

- ve sign shows force is directed towards mean position.

Let θ = Small, so Sin $\theta \approx \theta = \frac{\text{Arc(op)}}{1} = \frac{x}{1}$

Hence F = - mg θ

$\Rightarrow$F = - mg $\frac{x}{l} \rightarrow 3)$

Now, In S.H.M, F = k x $\rightarrow$ 4)

where,k = Spring constant

Equating equation 3) & 4) for F

$\Rightarrow$- k x = - m g $\frac{x}{l}$

$\Rightarrow$Spring factor = $k = \frac{mg}{l}$

Inertia factor = Mass of bob = m

Now, Time period = T

$= 2\pi\sqrt{\frac{\text{Inertia factor}}{\text{Spring factor}}}$

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

32. Initial volume ofthe given box$= 1m^3 = V_1$

Initial pressure $= 1.5atm = P_1$

Final pressure = Initial pressure - pressure reduced by what amount = 1.5 – 0.1 =1.4 atm =P'_2

Air pressure out side the box $= P_2 = 1atm$

Initial temperature $T_1 = 300\text{K}$

Final temperature $T_2 = 300\text{K}$

A = area of hole $= 0.01\text{mm}^2 = 0.01 \times 10^{-6}\text{m}^2 = 10^{-8}\text{m}^2$

initial pressure difference between the box and the outside atmosphere,

$\Delta P = (1.5 - 1)$atm = 0.5 atm

mass of a N_2 gas molecule$= \frac{0.028\text{Kg}}{6.023\times10^{23}} = 46.5 \times 10^{-27}\text{Kg}$ (= molar mass / Avogadro's number)

Boltzmann's constant, $K_B = 1.38 \times 10^{-23}$kg $m^2s^{-2}K^{-1}$

Let ρ_{n1} is the initial number of N_2 gas molecule per unit volume per unit time. Now, in time Δt let v_{tx} is the speed of the molecules along x axis.

Number of molecules colliding in time Δt on a wall of the cube

$= \frac{1}{2}\rho_{n1}\left[(v_{tx})\,\Delta t\right]A$, A being area

$\frac{1}{2}$ is multiplied as other $\frac{1}{2}$ molecule will strike to the opposite wall of the cube.

$v_{rms}^2\,(N_2 molecule) = v_{tx}^2 + v_{ty}^2 + v_{tz}^2$

$\because |v_{tx}| = |v_{ty}| = |v_{tz}|$

Then $v_{rms}^2 = 3v_{tx}^2$

KE of the nitrogen gas molecule$= \frac{3}{2}K_BT$

$\frac{1}{2}mv_{rms}^2 = \frac{3}{2}K_BT$

$\Rightarrow m \times 3v_{tx}^2 = 3K_BT$

$\Rightarrow v_{tx} = \sqrt{\frac{K_BT}{m}}$ .....(A)

Number of N_2 gas molecules striking to a wall in Δt time $= \frac{1}{2}\rho_{n1}\sqrt{\frac{K_BT}{m}}\Delta t \times A$,outward [putting the value of v_{tx} from equation (A).]

Temperature inside the box and air are equal to T

The number of air molecule striking to hole in time Δt

inward $= \frac{1}{2}\rho_{n2}\sqrt{\frac{K_BT}{m}}\Delta t \times A$

$\rho_{n2} =$ number of air molecules per unit volume striking the wall in unit time

Net number of molecules (going outward)

$\frac{1}{2}\rho_{n1}\sqrt{\frac{K_BT}{m}}\Delta tA - \frac{1}{2}\rho_{n2}\sqrt{\frac{K_BT}{m}}\Delta tA.$

Net number of molecules going out from hole in Δt time

$= \frac{1}{2}[\rho_{n1} - \rho_{n2}]\sqrt{\frac{K_BT}{m}}.\Delta t \times A$ ......(i)

Ideal gas equation for μ moles of the gas, $P_1V = \mu RT \Rightarrow \mu = \frac{P_1V}{RT}$

As for box $\frac{\mu}{V} = \frac{P_1}{RT}$ (μ = No. of moles of gas in box)

$\rho_{n1} = \frac{N(\text{ Total number of molecules in box })}{\text{volume of box}} = \frac{\mu N_A}{V}$, N_A being Avogadro's number.

$= \frac{P_1N_A}{RT}$ .....(ii)(putting the value of $\frac{\mu}{V}$) per unit volume

Let after time T, pressure reduced by 0.1atm and becomes

$P'_2 = (1.5 - .1) = 1.4\ atm$

Then final new density of N_A molecule ρ'_{n1} (say)

Therefore, $\rho'_{n1=} = \frac{P_2N_A}{RT}$ per unit volume (iii)

Net number of molecules going out from volume V

$= (\rho_{n1} - \rho'_{n1})V = \frac{P_1N_A}{RT}V - \frac{P'_2N_A}{RT}V$

$= \frac{N_AV}{RT}[P_1 - P'_2]$ .....(iv)(using equations ii, iii)

P'_2 = final pressure of box.

From equation (i), total number of molecules going out in time τ from hole

$= \frac{1}{2}[\rho_{n1} - \rho_{n2}]\sqrt{\frac{K_BT}{m}} \times \tau \times A$.....(v)

Again, $\rho_{n1} - \rho_{n2} = \frac{P_1N_A}{RT} - \frac{P_2N_A}{RT}$

$\therefore \quad \rho_{n1} - \rho_{n2} = \frac{N_A}{RT}[P_1 - P_2]$.....(vi) ($P_2$= Pressure of air outside the box)

Net number of molecules going out in time τ from above(using equations v and vi)

$= \frac{1}{2}\frac{N_A}{RT}[P_1 - P_2]\sqrt{\frac{K_BT}{m}} \cdot \tau.A$ ......(vii)

From equations (iv) and (vii),

$\frac{N_AV}{RT}(P_1 - P'_2) = \frac{1}{2}\frac{N_A}{RT}(P_1 - P_2)\sqrt{\frac{K_BT}{m}} \cdot \tau.A$

$\therefore \tau = \frac{N_AV}{RT}(P_1 - P'_2) \times \frac{2RT}{N_A}\frac{1}{(P_1 - P_2)}\sqrt{\frac{m}{K_BT}} \cdot \frac{1}{A}$

$\therefore \tau = \frac{2(P_1 - P_2')}{(P_1 - P_2)} \cdot \frac{V}{A}\sqrt{\frac{m}{K_B T}}$

$= \frac{2[1.5-1.4]}{(1.5-1)}\frac{1}{10^{-8}}\sqrt{\frac{46.5\times10^{-27}}{1.38\times10^{-23}\times300}}$ (As P_2 = atmospheric pressure = 1 atm)

$= \frac{2\times0.1}{0.5\times10^{-8}}\sqrt{\frac{4650\times10^{-27+23-2}}{138\times3}}$

$= 0.4\times10^{-8}\sqrt{\frac{775\times10^{-5}}{69}}$

$= 0.4\times10^{8}\times10^{-3}\times\sqrt{11.23} = 0.4\times10^{5}\times3.35$

$\therefore \tau = 1.34\times10^{5}$ seconds.

This is the required time in the question.

OR

The law of equipartition of energy states that if a system is in thermal equilibrium at absolute temperature T, the total energy of the system is distributed equally in different energy modes of absorption and the energy in each mode is equal to $\frac{1}{2}k_BT$. Each translational and rotational degree of freedom corresponds to one energy mode of absorption and has energy $\frac{1}{2}k_BT$. Each vibrational frequency has two modes of energy (kinetic and potential) absorption with corresponding energy equal to $2\times\frac{1}{2}k_BT = k_BT$.

Expression for principal specific heats:

a. **Monoatomic gas:** Each molecule of a monatomic gas possesses only three degrees of freedom and
   As per equipartition law mean energy per degree of freedom per molecule = $3\times\frac{1}{2}$ kBT
   $\therefore$ Mean energy of 1 molecule of a monatomic gas = $\frac{1}{2}k_BT$
   and internal energy of 1 mole of a monoatomic gas $U = N_A\times\frac{3}{2}$ kBT = $\frac{3}{2}$ RT
   As under constant volume $\Delta W = 0$, hence
   $C_v = \frac{\Delta Q}{\Delta T} = \frac{\Delta U}{\Delta T} = \frac{dU}{dT} = \frac{3}{2}R$
   and molar specific heat under constant pressure $C_p = C_v + R = \frac{3}{2}R + R = \frac{5}{2}R$
   and for a monatomic gas, $\gamma = \frac{C_p}{C_v} = \frac{\frac{5}{2}R}{\frac{3}{2}R} = \frac{5}{3}$.

b. **Diatomic gas:** As each molecule of a diatomic gas normally possesses 5 degrees of freedom (neglecting vibrational motion, if any), Hence mean energy per molecule = $5 \times \frac{1}{2} k_B T = \frac{5}{2} k_B T$.

and total internal energy of 1 mole of a diatomic gas U = $N_A \times \frac{5}{2} k_B T = \frac{5}{2} RT$

$\therefore C_v = \frac{dU}{dT} = \frac{5}{2} R$

and $C_p = C_v + R = \frac{5}{2} R + R = \frac{7}{2} R$

and for a diatomic gas, $\gamma = \frac{C_p}{C_v} = \frac{\frac{7}{2}R}{\frac{5}{2}R} = \frac{7}{5}$.

33. Length of the steel wire, L_1 = 4.7 m

Area of cross-section of the steel wire, $A_1 = 3.0 \times 10^{-5} m^2$

Length of the copper wire, L_2 = 3.5 m

Area of cross-section of the copper wire, $A_2 = 4.0 \times 10^{-5} m^2$

Change in length in both wires is same. Thus

$\triangle L_1 = \triangle L_2 = \triangle L$

Force applied in both the cases $\Rightarrow$ F

Young's modulus of the steel wire: $Y_1 = \frac{FL_1}{A_1 \triangle L} = \frac{F \times 4.7}{3.0 \times 10^{-5} \times \triangle L}$ .... (i)

Young's modulus of the copper wire: $Y_2 = \frac{FL_2}{A_2 \triangle L} = \frac{F \times 3.5}{4.0 \times 10^{-5} \times \triangle L}$ .... (ii)

Dividing (i) by (ii), we get: $\frac{Y_1}{Y_2} = \frac{4.7 \times 4.0 \times 10^{-5}}{3.0 \times 10^{-5} \times 3.5} \frac{Y_1}{Y_2} = 1.79 : 1$

OR

Torque required to produce unit twist in a solid shaft of radius r, $\tau = \frac{\pi \eta r^4}{2L}$.

Torque required to produce unit twist in a hollow shaft of internal radius r_1 and external radius r_2,

$$\tau' = \frac{\pi (r_2^4 - r_1^4)}{2L}$$

$$\therefore \quad \frac{\tau'}{\tau} = \frac{r_2^4 - r_1^4}{r^4} = \frac{(r_2^2 + r_1^2)(r_2^2 - r_1^2)}{r^4}$$

If the shafts are made of material of equal volume,

$\pi r^2 I = \pi (r_2^2 - r_1^2) I$ or $r_2^2 - r_1^2 = r^2$

$\frac{\tau'}{\tau} = \frac{r_2^2 + r_1^2}{r^2} \Rightarrow \tau' > \tau$