CBSE Class 11 Physics

Sample Paper 08 (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 is uniform motion? Give examples.
2. Why is it desired to hold a gun tight to one's shoulder when it is being fired?

OR

Action and reaction forces do not balance each other. Why?

3. When a labourer cuts down a tree, he makes a cut on the side facing the direction in which he wants it to fall. Why?
4. A satellite of small mass burns during its desent and not during ascent. Why?

OR

What is a parking orbit?

5. If the rate of flow of liquid through a horizontal pipe of length l and radius R is Q. What is rate of flow of liquid if length and radius of tube is doubled?
6. A football is kicked into the air vertically upwards. What is its (i) acceleration and (ii) velocity at the highest point?
7. How many parsec are there in one metre?

OR

A student measures the thickness of a human hair by looking at it through a microscope of magnification 100. He makes 20 observations and finds that the average width of the hair in the field of view of the microscope is 3.5 mm. What is the estimate on the thickness of hair?

8. Why longitudinal waves are called pressure waves?

OR

Sound waves from a point source are propagating in all directions. What will be the ratio of amplitudes at distances of x meter and y meter from the Source?

9. State zeroth law of thermodynamics?
10. State, for each of the following physical quantities, if it is a scalar or a vector: volume, mass, speed, acceleration, density, number of moles, velocity, angular frequency, displacement, angular velocity.
11. **Assertion:** The maximum horizontal range of projectile is proportional to square of velocity.
    Reason: The maximum horizontal range of projectile is equal to maximum height attained by projectile.
    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:** Stress is the internal restoring force per unit area of a body.
    Reason: Rubber is more elastic than brass.

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:** A real gas behaves as an ideal gas at high temperature and low pressure.
Reason: At low pressure and high temperature intermolecular forces vanish away and volume of gas molecules is negligible.
    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:** Power of machine gun is determined by both, the number of bullets fired per second and kinetic energy of bullets.
Reason: Power of any machine is defined as work done (by it) per unit time.
    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:**
If a person puts an ice cube into a glass of warm lemon juice and later forgets to drink it, then after a while, the person will notice that the ice has melted but the temperature of the lemonade has cooled. This is because the total amount of heat in the system has remained the same, but has just reached an equilibrium, where both the ice cube and the lemon juice are at the same temperatures. The lemon juice will eventually become warmer again when the heat from the environment is transferred to the glass itself.

i. Zeroth law leads to the concept of:-
   a. heat
   b. temperature
   c. internal energy
   d. work
ii. A thermos bottle containing coffee is vigorously shaken. If coffee is considered as a system, then the temperature of coffee will
   a. same
   b. decrease
   c. increase
   d. none of these
iii. Internal energy of the system increases by 60 J when 140 J of heat is added to the gaseous system. The amount of work done is:
   a. 80 J
   b. 100 J
   c. 120 J
   d. 240 J
iv. The First Law of Thermodynamics tell us
   a. The energy in the universe is getting larger
   b. The energy in the universe is getting smaller
   c. The energy in the universe is constant

d. none of these

v. In a thermal process, the pressure of a fixed mass of a gas is changed in such a manner that the gas molecules give out the heat of 30J and work of 10J is done on the gas. If the initial internal energy of the gas was 40 J, then the final internal energy will be?

a. 20 J
b. 30 J
c. 40 J
d. 60 J

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

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.

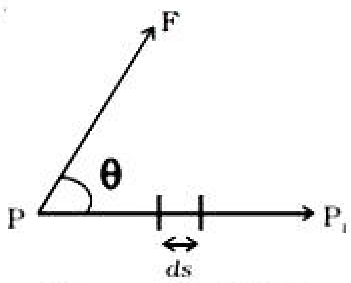


Fig. Work done by a force

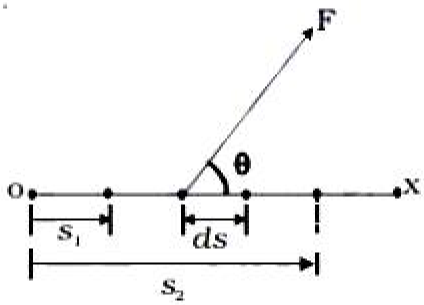


Fig. Work done by a constant force

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. 100J
b. 200 J
c. 300 J
d. 400 J

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

a. 22.5 J
b. 225 J
c. zero
d. 150 J

iii. Frictional forces are:
   a. conservative forces
   b. non- conservative forces
   c. buoyant force
   d. none of these
iv. When the body moves in circular motion, net 'work' done is:
   a. positive
   b. negative
   c. zero
   d. none of these
v. Force of 4N is applied on a body of mass 20 kg. The work done in 3rd second is:
   a. 2J
   b. 4J
   c. 6J
   d. 8J

Section C

17. Does the concentration of the earth's mass near its centre change the variation of g with height compared with a homogeneous sphere, how?

18. The coefficient of volume expansion of glycerine is 49×10^{-5} °C^{-1}. What is the fractional change in its density for a 30°C rise in Temperature?

OR

Is it possible to convert water into vapour form without increasing its temperature, if temperature and pressure of water are 30 °C and 1 atm respectively?

19. Show that the motion of a particle represented by $y = \sin \omega t - \cos s\omega t$ is simple harmonic with a period of $\frac{2\pi}{\omega}$.

OR

A simple pendulum is executing Simple harmonic motion with a time T. If the length of the pendulum is increased by 21%. Find the increase in its time period?

20. A nucleus is at rest in the laboratory frame of reference. Show that if it disintegrates into two smaller nuclei the products must move in opposite directions.

21. A jet plane beginning its take-off moves down the runway at a constant acceleration of $4.00\ m/s^2$.
   i. Find the position and velocity of the plane 5.00 s after it begins to move.
   ii. If the speed of 70.0 m/s is required for the plane to leave the ground, how long a runway is required?
22. A wire of density a g/cm^3 is stretched between two clamps 1m apart while subjected to an extension of 0.05 cm. What is the lowest frequency of transverse vibration in the wire? Let young's Modulus = $y = 9 \times 10^{10} N/m^2$?
23. Define angular velocity. Give its SI unit and dimensional formula. What is its direction?
24. A SONAR (sound navigation and ranging) uses ultrasonic waves to detect and locate objects under water. In a submarine equipped with a SONAR the time delay between generation of a probe wave and the reception of its echo after reflection from an enemy submarine is found to be 77.0 s. What is the distance of the enemy submarine? (Speed of sound in water = $1450\ ms^{-1}$).

OR

If the velocity of light is taken as the unit of velocity and year as the unit of time, what must be the unit of length? What is it called?

25. A police jeep on a patrol duty on national highway was moving with a speed of 54km/hr. in the same direction. It finds a thief rushing up in a car at a rate of 126km/hr in the same direction. Police sub-inspector fired at the car of the thief with his service revolver with a muzzle speed of 100m/s. with what speed will the bullet hit the car of thief?

Section D

26. Ten one rupee coins are put on top of one another on a table. Each coin has a mass m kg. Give the magnitude and direction of
   a. The force on the 7^{th} coin (counted from the bottom) due to all coins above it.
   b. The force on the 7^{th} coin by the eighth coin (counted from the bottom) and
   c. The reaction of the sixth coin on the seventh coin (counted from the bottom).
27. The nearest star to our solar system is 4.29 light years away. How much is this distance in terms of parsec? How much parallax would this star (named Alpha Centauri) show when viewed from two locations of the earth six months apart in its orbit around the Sun?

OR

Give the definitions for SI unit of seven basic quantities.

28. An aircraft is flying at a height of 3400 m above the ground. If the angle subtended at a ground observation point by the aircraft positions 10.0 s apart is 30°, what is the speed of the aircraft?

OR

Show that vectors A = $2\hat{\mathbf{i}} - \hat{\mathbf{j}} - \hat{\mathbf{k}}$ and B = $-6\hat{\mathbf{i}} + 9\hat{\mathbf{j}} + 3\hat{\mathbf{k}}$ are parallel vectors.

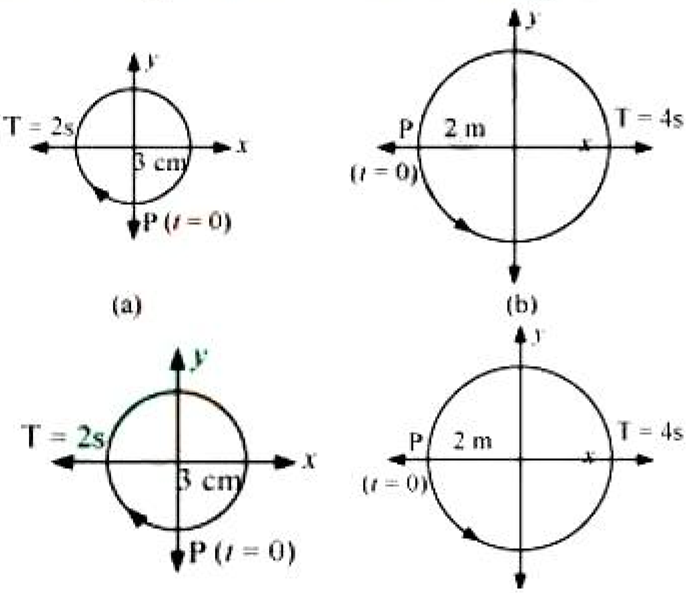
29. Develop a relation between the co-efficient of linear expansion, co-efficient superficial expansion and coefficient of cubical expansion of a solid.

30. Three equal masses of M kg each are fixed at the vertices of an equilateral triangle ABC.
   i. What is the force acting on a mass 2M placed at the centroid of the triangle?
   ii. What is the force if the mass at the centroid is doubled?

[Take AO = BO = CO = 1 m]

Section E

31. In figures correspond to two circular motions. The radius of the circle, the period of revolution, the initial position, and the sense of revolution (i.e. clockwise or anti-clockwise) are indicated on each figure.



Obtain the corresponding simple harmonic motions of the *x*-projection of the radius vector of the revolving particle P, in each case.

OR

Take the position of mass when the spring is unstreched as x = 0, and the direction from left to right as the positive direction of x-axis. Give x as a function of time t for the oscillating mass if at the moment we start the stopwatch (t = 0), the mass is

a. at the mean position,
b. at the maximum stretched position, and
c. at the maximum compressed position.

In what way do these functions for SHM differ from each other, in frequency, in amplitude or the initial phase?

32. Estimate the mean free path and collision frequency of a nitrogen molecule in a cylinder containing nitrogen at 2.0 atm and temperature 17 °C. Take the radius of a nitrogen molecule to be roughly $1.0\overset{o}{A}$. Compare the collision time with the time the molecule moves freely between two successive collisions (Molecular mass of N_2 = 28.0 u).

OR

Estimate the average thermal energy of a helium atom at

i. room temperature (27 °C),
ii. the temperature on the surface of the Sun (6000 K),
iii. the temperature of 10 million Kelvin (the typical core temperature in the case of a star).

33. A steel rod of length 2 l, cross sectional area A and mass M is set rotating in a horizontal plane about an axis passing through the centre. If Y is the Young's modulus for steel, find the extension in the length of the rod. (Assume the rod is uniform.)

OR

A steel wire and a copper wire of equal length and equal cross-sectional area are joined end to end and the combination is subjected to a tension. Find the ratio of (a) the stresses developed in the two wires, (b) the strains developed in two wires. Given that Y of steel = 2.0×10^{11} N/m^2 and Y of copper = 1.1×10^{11} N/m^2.

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Solution

Section A

1. If a body covers equal distances in equal intervals of time, howsoever small these time intervals may be, then the motion of a body is said to be uniform. For e.g, motion of the earth around its own axis, motion of the hour and minute hands of a watch are examples of uniform motion.
2. If m,M,v and V are the mass of a bullet, mass of the gun, velocity of the bullet and recoil velocity of the gun respectively, then according to the law of conservation of linear momentum $V = -mv/M$. With this velocity the gun will recoil during firing. This backward push is so hard that it can displace our shoulder and injure us. That is why the gun must be held tightly against the shoulder because gun and the shoulder constitute one system of greater mass so the back kick will be less.

   OR

   Two equal and opposite forces balance each other when they act on the same body or at the same point. Action and reaction do not balance each other because a force of action and reaction acts always on two different bodies.

3. Because the weight of tree exerts a torque about the point where the cut is made. This causes rotation of the tree about the cut, i.e. the direction in which the labourer wants the tree to fall.
4. The speed of the satellite during descent is much larger than that during its ascent. As the air resistance is directly proportional to velocity, so the heat produced during descent is very large and the satellite burns up.

   OR

   Parking orbit is that orbit in which the period of revolution of a satellite is equal to the period of rotation of the earth about its axis. It is a temporary orbit used during the launch of a satellite.

5. From Poiseuille's equation, rate of flow of liquid through a horizontal tube of radius 'R' and length 'l' is :-

$Q = \frac{\pi p R^4}{8\eta l} \rightarrow (1)$

$p \Rightarrow$ pressure difference across ends of tube

$R \Rightarrow$ radius of tube

$l \Rightarrow$ length of tube

$\eta \Rightarrow$ coefficient of viscosity

if radius and length are doubled then new radius R_1 and new length (l_1) are

$R_1 = 2R$ and $l_1 = 2l$

using equation (1) new rate of flow (Q_1) is

$$Q_1 = \frac{\pi p (R_1)^4}{8\eta(l_1)} \Rightarrow \frac{\pi p (2R)^4}{8\eta(2l)} \Rightarrow 8\ \frac{\pi p R^4}{8\eta l}$$

$Q_1 = 8\ Q$

6. i. Acceleration of the ball at the highest point = - g

   ii. Velocity of the ball at the highest point is equal to zero.

7. We know that one parsec is equal to 3.084×10^{16} m of distance,

   $\therefore \quad 1\text{m} = \frac{1}{3.084 \times 10^{16}}$ parsec$= \mathbf{3.25 \times 10^{-17}}$ **parsec**

OR

Magnification of the microscope = 100

Average width of the hair in the field of view of the microscope = 3.5 mm

$\therefore$ Actual thickness of the hair is $= \frac{3.5}{100}$ = 0.035 mm.

8. Because propagation of longitudinal waves through a medium, involves changes in pressure and volume of air when compressions and rarefactions are formed.

OR

Intensity = ampiltude$^2 \propto \frac{1}{(distance)^2}$

$\therefore$ required ratio = y/x

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. A scalar quantity is specified by its magnitude only. It does not have any direction associated with it. Hence, volume, mass, speed, density, number of moles, and angular frequency are scalar physical quantities.

    A vector quantity is specified by its magnitude as well as the direction associated with it. Hence, acceleration, velocity, displacement, and angular velocity belong to this category.

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

    Explanation: Assertion is true but reason is false.

    Horizontal range of projectile,

    $R = \frac{u^2 \sin 2\theta}{2g}$ or $R_{\max} = \frac{u^2}{g}$

    and height attained by projectile,

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

    or $H_{\max} = \frac{u^2}{2g}$

    or $R_{max.} \neq H_{max}$

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

    Explanation: Assertion is correct statement but reason is wrong statement.

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: Kinetic energy of one bullet = K

    Kinetic energy of n bullets = nK

    According to law of conservation of energy, the kinetic energy of bullets be equal to the work done by machine gun per sec.

    Power = $\frac{\text{Work}}{\text{Time}}$ = nk

Section B

15. i. b

    ii. c

iii. a

iv. a

v. d

16. i. (d)

ii. (c)

iii. (b)

iv. (c)

v. (a)

Section C

17. Any change in the distribution of the earth's mass will not affect the variation of acceleration due to gravity with height. This is because for a point outside the earth, the whole mass of the earth is effective and the earth behaves as a homogeneous sphere.

18. Suppose M be the mass of glycerine

ρ_0 = density at $0^\circ\mathrm{C}$,

ρ_t = density at $t^\circ\mathrm{C}$

$\Rightarrow \gamma = \frac{V_t - V_0}{V_0 \Delta T} = \frac{\frac{M}{\rho_t} - \frac{M}{\rho_0}}{(M/\rho_0)\Delta T}$

$\gamma = \frac{\frac{1}{\rho_t} - \frac{1}{\rho_0}}{(1/\rho_0)\Delta T} = \frac{\rho_0 - \rho_t}{\rho_0 \Delta T}$

$\therefore$ fractional change in density,

$\frac{\rho_0 - \rho_t}{\rho_0} = \gamma \Delta T$

coefficient of volume expansion of glycerine = $49 \times 10^{-5}\ {}^\circ\mathrm{C}^{-1}$ (Given)

$= 49 \times 10^{-5} \times 30 = 0.0147$

OR

Yes, water at 30°C can be converted into vapour by reducing its pressure until it equals to the vapour pressure of water at 30°C.

19. A function will represents S.H.M. if it can be written uniquely in the form of a or a sin $\left(\frac{2\pi}{T}t + \phi\right)$

Now $y = \sin\omega t - \cos\omega t$

$y = \sqrt{2}\left[\sin\omega t \frac{1}{\sqrt{2}} - \cos\omega t \frac{1}{\sqrt{2}}\right]$ (given)

$y = \sqrt{2}\left[\sin\omega t \cos\frac{\pi}{4} - \cos\omega t \sin\frac{\pi}{4}\right]$

$y=\sqrt{2}\sin\left(\omega t-\frac{\pi}{4}\right)$
Comparing with standard SHM $y=as\sin\left(\frac{2\pi}{T}t+\phi\right)$
We get $\omega=\frac{2\pi}{T}$ or $T=\frac{2\pi}{\omega}$.

OR

Time period of simple pendulum =T

l = length of simple pendulum

g = acceleration due to gravity

$T=2\pi\sqrt{\frac{1}{g}}$
If T_2 = Final time period

T_1 = Initial time period

So, $T_2=2\pi\sqrt{\frac{l_2}{g}}$
$T_1=2\pi\sqrt{\frac{l_1}{g}}$
Since 2π and g are constant, so;
$T_2=\sqrt{l_2}\rightarrow(1)$
$T_1=\sqrt{l_1}\rightarrow(2)$
Divide equation (2) by (1)
$\frac{T_2}{T_1}=\sqrt{\frac{l_2}{l_1}}$
If l_1 = l

$l_2=l_1+l_1\times\frac{21}{100}$
l_2 = 1.21l

So, $\frac{T_2}{T_1}=\sqrt{\frac{1.21l}{l}}$
$\frac{T_2}{T_1}=1.1$
T_2 = 1.1 T_1

Therefore, percentage increase in time period = $\frac{T_2-T_1}{T}\times 100\%$
$=\frac{1.1T-T}{T}\times 100\%$
$=\frac{0.1T}{T}\times 100\%$
= 10%

20. Let m, m_1, and m_2 be the respective masses of the parent nucleus and the two daughter

nuclei. The parent nucleus is at rest.

Initial momentum of the system (parent nucleus) = 0

Let v_1 and v_2 be the respective velocities of the daughter nuclei having masses m_1 and m_2.

Total linear momentum of the system after disintegration = $m_1v_1 + m_2v_2$

According to the law of conservation of momentum:

Total initial momentum = Total final momentum

$0 = m_1v_1 + m_2 + v_2$

$v_1 = \frac{-m_2v_2}{m_1}$

Here, the negative sign indicates that the fragments of the parent nucleus move in directions opposite to each other.

21. i. We take the origin of the x-axis to be the initial position of the plane so that $x_0 = 0$.

Here we have, a = 4.00 $m/s^{2,}$ v = 0 and x = 0

Since u = 0, we have v = at and $x = \frac{1}{2}at^2$

At t = 5.00

v = (4.00 m/s^2)(5.00 s) = 20.0 m/s

and $x = \frac{1}{2}\left(4.00 m/s^2\right)(5.00 s)^2$

x = 50.0 m

ii. Since u = 0, $v_x^2 = 2a_x x$

Solving for x, we obtain

$x = \frac{v^2}{2a} = \frac{(70.00 m/s)^2}{2(4.00 m/s^2)} = 612.5 \text{ m}$

22. Area = A

Density = P

The lowest frequency of transverse vibrations is given by:

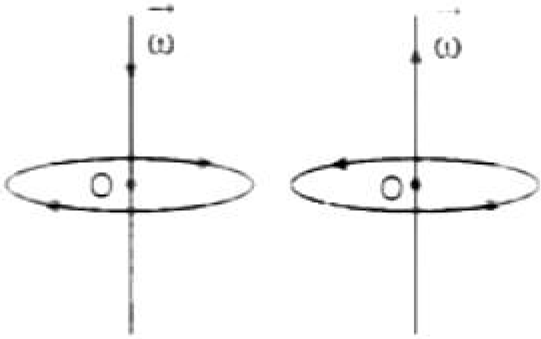
$f = \frac{1}{2l}\sqrt{\frac{T}{m}}$

Here m = mass Per unit length = area $\times$ Density

because Density $= \frac{Mass}{Volume}$

$m = A \times P$

F= 35.3 vib/sec

23. 

Angular velocity is the rate of velocity at which an object or a particle is rotating around a center or a specific point in a given time period. It is also known as rotational velocity. Angular velocity is measured in angle per unit time or radians per second (rad/s).

Mathematically,

Angular velocity $\vec{\omega} = \lim_{\Delta t \to 0} \frac{\Delta \theta}{\Delta t} = \frac{d\vec{\theta}}{dt}$.

SI unit of angular velocity is rad s^{-1} and its dimensional formula is $[T^{-1}]$

Angular velocity is an axial vector. As shown in Figure, if a particle is rotating in x-y plane, the direction of angular velocity is said to be along the z-axis. If rotation in x-y plane is clockwise, the

direction of $\vec{\omega}$ is taken as along negative z-axis (i.e., downward/inward). If rotation is anticlockwise, $\vec{\omega}$ is along +z-axis (i.e., upward/outward). In other words, for rotation about a fixed axis, the angular velocity vector lies along the axis of rotation.

24. Let the distance between the ship and the enemy submarine be 'S'.

Speed of sound in water = 1450 m/s

Time lag between transmission and reception of Sonar waves = 77 s

In this time lag, sound waves travel a distance which is twice the distance between the ship and the submarine (2S).

Time taken for the sound to reach the submarine $= \frac{1}{2} \times 77$ = 38.5 s

$\therefore$ Distance between the ship and the submarine (S) = 1450 × 38.5 = 55825 m = 55.8 km

OR

Unit of length = Unit of velocity $\times$ Unit of time

$= 3 \times 10^8\ ms^{-1} \times 1$ year

$= 3 \times 10^8\ ms^{-1} \times 365 \times 24 \times 60 \times 60$ s

$= 9.45 \times 10^{15} ms^{-1}$

= 1 light year.

Hence, the unit of length must be 1 light year.

25. Speed of police jeep = speed of gun = 54 km/h = 15m/s

muzzle speed = relative speed of bullet wrt police jeep = 100 m/s

velocity of bullet = 100 + 15 = 115m/s

velocity of thief = 126km/h = 35m/s

relative velocity of bullet wrt thief = 115 - 35 = 80 m/s

So bullet will hit the car of thief at a velocity 80 m/s

Section D

26. a. The force on 7^{th} coin is due to weight of the three coins lying above it (i.e. the sum of weights of 8th, 9th and 10th coins).

Therefore, F = (3 m) kgf = (3 mg) N

Where g is acceleration due to gravity. This force acts vertically downwards.

b. The eighth coin is already under the weight of two coins above it and it has its own weight too. Hence force on 7^{th} coin due to 8^{th} coin is sum of the two forces i.e.

F = weight of 9^{th} and 10^{th} coin + weight of 8^{th} coin = (2m + m) kgf = (3m) kgf = (3mg) N

The force acts vertically downwards.

c. The sixth coin is under the weight of four coins (i.e. 7^{th}, 8^{th}, 9^{th} and 10^{th}) above it. Now in this case reaction force on the 6th coin will equal and opposite to the sum of weights of mentioned four coins. Hence, reaction, R = -F = -4 m (kgf) = - (4 mg) N

-ve sign indicates that reaction acts vertically upwards.

27. We know that 1 light year = speed of light $\times$1 year = $3 \times 10^8 \times 365 \times 24 \times 60 \times 60$ = 9.46×10^{15} m

$\therefore$ Distance of the star Alpha Centauri from the solar system, D = 4.29 ly = $4.29 \times 9.46 \times 10^{15}$ m

But, 1 parsec = 3.084×10^{16} m

$\therefore$ Distance of star Alpha Centauri in parsec = $\frac{4.29 \times 9.46 \times 10^{15}}{3.084 \times 10^{16}}$

= 1.316 = 1.32 parsec

Let, base distance b is the distance between two locations of the Earth six months apart. Thus,

b = Diameter of Earth's orbit = $2 \times 1.5 \times 10^{11}$ m = 3×10^{11} m

∴ Parallax angle of Alpha Centauri star is,

$\theta = \frac{b}{D} = \frac{3\times10^{11}}{4.29\times9.46\times10^{15}}$ radian = 7.39×10^{-6} radian

But, 1 sec = 4.85×10^{-6} radian, so

$\theta = \frac{7.39\times10^{-6}}{4.85\times10^{-6}} = 1.52''$

OR

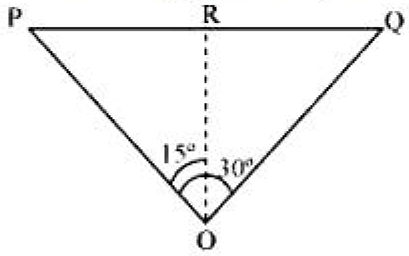
The seven basic quantities are length, mass, time, electric current, thermodynamic temperature, amount of substance and luminous intensity.

The symbols and definitions of SI units of seven basic quantities are:

i. **Length -** Its SI unit is metre (m). A metre is defined as the length of the path travelled by light in a vacuum during a time interval of $\frac{1}{299792458}$ of a second.
ii. **Mass -** Its SI unit is kilogram (kg). It is equal to the mass of the international prototype of kilogram (a platinum-iridium alloy cylinder) kept at International Bureau of Weights and Measures at Sevres, near Paris, France.
iii. **Time-** Its SI unit is second (s). A second is defined as the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom.
iv. **Electric current-** Its SI unit is ampere (A). The ampere is defined as that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 m apart in a vacuum, would produce a force between these conductors equal to 2×10^{-7} N per metre of length.
v. **Thermodynamic temperature-** Its SI unit is kelvin (K). The Kelvin is defined as the fraction $\frac{1}{273.16}$ of the thermodynamic temperature of the triple point of water.
vi. **Amount of substance-** Its SI unit is mole (mol). The mole is defined as the amount of substance of a system, which contains as many elementary entities as there are atoms in 0.012 kg of carbon-12.
vii. **Luminous intensity-** Its SI unit is candela (cd). The candela is defined as the luminous intensity, in a given direction of a source that emits monochromatic radiation of frequency 540×10^{12} Hz and that has a radiant intensity in that direction of $\frac{1}{683}$ watt per steradian.

28. The positions of the observer and the aircraft are shown in the given figure. The aircraft

is following path PRQ and observer is at 'O'.



Height of the aircraft from ground, OR = 3400 m

Angle subtended between the position, $\angle POQ = 30^\circ$

Time interval, t = 10 s

In ΔPRO

$\tan 15^\circ = \frac{PR}{OR}$

PR = OR tan 15°

$PR = 3400 \times \tan 15^\circ$

ΔPRO is similar to ΔRQO

$\therefore PR = RQ$

P Q = PR + RQ

$PQ = 2PR = 2 \times 3400 \tan 15^\circ$

$PQ = 6800 \times 0.268 = 1822.4\text{m}$

$\therefore$ Speed of the aircraft $= \frac{distance}{time\ interval} = \frac{1822.4}{10} = 182.24 \text{ m/s}$

OR

The given vectors are

A = $2\hat{\mathbf{i}} - \hat{\mathbf{j}} - \hat{\mathbf{k}}$

and B = $-6\hat{\mathbf{i}} + 9\hat{\mathbf{j}} + 3\hat{\mathbf{k}}$

We know that, the vectors are parallel, if their cross product is zero, i.e. θ = 0,

$\mathbf{A} \times \mathbf{B} = 0.$

$$\therefore \quad \mathbf{A} \times \mathbf{B} = \begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ 2 & -3 & -1 \\ -6 & 9 & 3 \end{vmatrix}$$

$= \hat{\mathbf{i}}(-9+9) - \hat{\mathbf{j}}(6-6) + \hat{\mathbf{k}}(18-18) = 0$

Now, $|\mathbf{A} \times \mathbf{B}| = 0$, but we know that vector A and B are non zero vectors. Therefore,

$\therefore \sin\theta = 0$ or $\theta = 0$

Hence, the vectors A and B are parallel.

29. Since, co-efficient of linear expansion , $\alpha = \frac{\Delta L}{L\Delta T}$

ΔL = change in length

L = length

ΔT = change in temperature , for an infinitesimally small change in temperature

$\alpha = \frac{dL}{LdT}$

Similarly, co-efficient of superficial expansion , $\beta = \frac{dS}{SdT}$

dS = infinitesimal change in area

S = original area

dT = infintesimaly change in temperature

$S = L^2$

$\beta = \frac{1}{L^2}\frac{dL^2}{dT} = 2L\frac{dL}{dT}$

$\beta = 2\alpha$

similarly , Co-efficient of cubical expansion, $\gamma = \frac{dV}{VdT}$

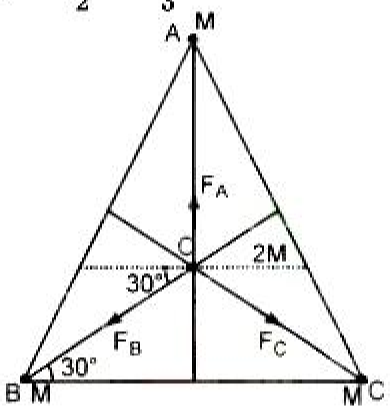
dV = infinitesimal change in volume

V = original volume

dT = infinitesimal change in temperature

$\gamma = \frac{1}{L^3}\frac{dL^3}{dT} = 3\frac{1}{L}\frac{dL}{dT} = 3\alpha$

$\alpha = \frac{\beta}{2} = \frac{\gamma}{3}$

30. 

i. As AO = BO = CO = 1 m, hence we have

$$\left|\overrightarrow{F_A}\right| = \left|\overrightarrow{F_B}\right| = \left|\overrightarrow{F_C}\right| = \frac{GM \cdot 2M}{(1)^2} = 2GM^2$$

If we consider direction parallel to BC as x-axis and perpendicular direction as y-axis, then as shown in figure, we have

$$\vec{F}_A = 2GM^2\hat{j}$$

$$\vec{F}_B = \left(-2GM^2\cos 30^\circ\hat{i} - 2GM^2\sin 30^\circ\hat{j}\right)$$

and $\overrightarrow{F_C} = \left(2GM^2 \cos 30^\circ \hat{i} - 2GM^2 \sin 30^\circ \hat{j}\right)$

Therefore, the net force on mass 2M placed at the centroid O is given by,

$\vec{F} = \vec{F}_A + \vec{F}_B + \vec{F}_C$

$= 2GM^2 \left[j + \left(-\frac{\sqrt{3}}{2}\hat{i} - \frac{1}{2}\hat{i}\right) + \left(\frac{\sqrt{3}}{2}\hat{i} - \frac{1}{2}\hat{j}\right)\right]$

$= 0$

ii. If mass at the centroid of the triangle gets doubled, even then the net force on it will be zero.

Section E

31. a. ⇒ Time period, T = 2 s

⇒ Amplitude, A = 3 cm

⇒ At time, t = 0, the radius vector OP makes an angle $\frac{\pi}{2}$ with the positive x-axis, i.e., phase angle

$\Rightarrow \phi = \frac{\pi}{2}$

⇒ Therefore, the equation of simple harmonic motion for the x-projection of OP, at time t, is given by the displacement equation:

$\Rightarrow x = A\cos\left[\frac{2\pi t}{T} + \phi\right]$

$= 3\cos\left(\frac{2\pi t}{2} + \frac{\pi}{2}\right) = -3\sin\left(\frac{2\pi t}{2}\right)$

$\therefore x = -3\sin \pi t \text{cm}$

b. ⇒ Time period, T = 4 s

⇒ Amplitude, a = 2 m

⇒ At time t = 0, OP makes an angle π with the x-axis, in the anticlockwise direction. Hence, phase angle, $\boldsymbol{\Phi} = +\pi$

⇒ Therefore, the equation of simple harmonic motion for the x-projection of OP, at time t, is given as:

$\Rightarrow x = a\cos\left(\frac{2\pi t}{T} + \phi\right) = 2\cos\left(\frac{2\pi t}{4} + \pi\right)$

$\therefore x = -2\cos\left(\frac{\pi}{2}t\right)m$

OR

→ The functions have the same frequency and amplitude, but different initial phases.

Given:

Distance travelled by the mass sideways, A = 2.0 cm

Force constant of the spring, k = 1200 N m^{-1}

Mass, m = 3 kg

Angular frequency of oscillation is given by:

$\omega = \sqrt{\frac{spring\ cons\tan t}{mass}}$

$\rightarrow \omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{1200}{3}} = \sqrt{400} = 20\text{rads}^{-1}$

a. When the mass is at the mean position, initial phase is 0.

   Displacement,→ x = Asin ωt = 2sin 20t

b. At the maximum stretched position, the mass is toward the extreme right. Hence, the initial phase is $\frac{\pi}{2}$.

   Displacement,→ $x = A\sin\left(\omega t + \frac{\pi}{2}\right)$

   $= 2\sin\left(20t + \frac{\pi}{2}\right)$ = 2cos 20t

c. At the maximum compressed position, the mass is toward the extreme left. Hence, the initial phase is $\frac{3\pi}{2}$.

   Displacement→, $x = A\sin\left(\omega t + \frac{3\pi}{2}\right)$

   $= 2\sin\left(20t + \frac{3\pi}{2}\right)$ = –2cos 20t

d. The functions have the same frequency $\left(\frac{20}{2\pi}Hz\right)$ and amplitude (2 cm), but initial phases are different $\left(0, \frac{\pi}{2}, \frac{3\pi}{2}\right)$.

32. The answers of the above question are,

Mean free path, l = $1.11 \times 10^{-7}\text{m}$

Collision frequency, $\frac{v_{rms}}{l}$ = $4.58 \times 10^{9}s^{-1}$

Successive collision time, T' $\approx$ $500\times$ Single collision time(T)

Derivation of the solution:

Pressure inside the cylinder containing nitrogen, P = 2.0 atm(given) = $2.026 \times 10^{5}\text{Pa}$ [1 atm = 1.013 × 10^5 Pa]

Temperature inside the cylinder, T = 17°C(given) = (273+17)K =290 K

Radius of a nitrogen molecule, r = 1.0 $\overset{0}{A}$ (given)= $1 \times 10^{-10}\text{m}$ [since, 1$\overset{0}{A}$ = 10^{-10} m]

Diameter, d = 2r = $2 \times 1 \times 10^{-10} = 2 \times 10^{-10}\text{m}$

Molecular mass of nitrogen, M= 28.0 g(given) = $28 \times 10^{-3}kg$

The root mean square speed of nitrogen gas molecules is given by the relation:

$v_{rms} = \sqrt{\frac{3RT}{M}}$, M = molar mass of nitrogen and T = absolute temperature of nitrogen gas and

R is the universal gas constant = 8.314 J mole^{-1} K^{-1}

$\therefore v_{rmv} = \sqrt{\frac{3\times8.314\times290}{28\times10^{-3}}}$ = 508.26 m/s

The mean free path (l) is given by the relation:

$l = \frac{kT}{\sqrt{2}\times\pi d^2\times P}$, d = diameter of nitrogen gas molecule, and

K is the Boltzmann constant = $1.38\times10^{-23}\mathrm{kgm^2s^{-2}K^{-1}}$, putting all these values in the above equation we get,

$\therefore l = \frac{1.38\times10^{-23}\times290}{\sqrt{2}\times3.14\times(2\times10^{-10})^2\times2.026\times10^5}$

$= 1.11\times10^{-7}\mathrm{m}$

Collision frequency = rms velocity of gas molecules/mean free path $= \frac{v_{rms}}{l}$

$= \frac{508.26}{1.11\times10^{-7}} = 4.58\times109s^{-1}$

Collision time is given as:

$T = \frac{d}{v_{rms}}$,(d = diameter of nitrogen gas molecule, v_{rms} = root mean square velocity of the gas)

$= \frac{2\times10^{-10}}{508.26} = 3.93\times10^{-13}s$

Time taken by the gas molecules between successive collisions with each other:

$T' = \frac{l}{v_{rms}}$

$= \frac{1.11\times10^{-7}m}{508.26\mathrm{m/s}} = 2.18\times10^{-10}\mathrm{s}$

$\therefore \frac{T'}{T} = \frac{2.18\times10^{-10}}{3.93\times10^{-13}} \simeq 500$ (ratio of time between two successive collisions to the single collision time)

Hence, the time taken between two successive collisions is 500 times the time taken for a single collision.

OR

i. According to law of equipartition of energy we know that the energy of a gas molecule per degree of freedom = $\frac{1}{2}kT$. For helium atom in the given question, there are 3 degrees of freedom with total thermal energy = $3\times\frac{1}{2}kT = \frac{3}{2}kT$. Now at room temperature, T= 27°C = (273+27)K=300 K

We know that, the average thermal energy per molecule $= \frac{3}{2}kT$

Where k is the Boltzmann constant $= 1.38\times10^{-23}\mathrm{m^2kg}s^{-2}\mathrm{K}^{-1}$

$\therefore \frac{3}{2}kT = \frac{3}{2}\times1.38\times10^{-23}\times300$ (k = 1.38 × 10^{-23}kg m^{2}s^{-2}K^{-1}, T = 300 K)

$= 6.21\times10^{-21}J$

Hence, the average thermal energy of a helium atom at room temperature (27°C) is
$6.21 \times 10^{-21} J$.

ii. On the surface of the sun, T= 6000 K

Average thermal energy $= \frac{3}{2} kT$ with k = 1.38×10^{-23} kg $m^2 s^{-2} K^{-1}$
$= \frac{3}{2} \times 1.38 \times 10^{-23} \times 6000$
$= 1.241 \times 10^{-19} J$

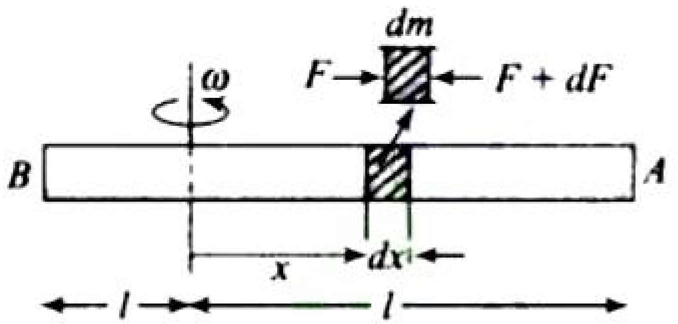
Hence, the average thermal energy of a helium atom on the surface of the sun having temperature 6000 K is $1.241 \times 10^{-19} J$.

iii. At temperature, T= 10 million K = 100 lakhs K = $10^5 \times 10^2$ K = 10^7K

Average thermal energy $= \frac{3}{2} kT$ with k = 1.38×10^{-23}kg $m^2 s^{-2} K^{-1}$
$= \frac{3}{2} \times 1.38 \times 10^{-23} \times 10^7$
$= 2.07 \times 10^{-16} J$

Hence, the average thermal energy of a helium atom at the core of a star is
$2.07 \times 10^{-16} J$.

33. Consider an element of width dx at a distance x from the given axis of rotation as shown in the figure:



As rod is uniform, so mass per unit length, $\mu = \frac{M}{2l}$

Mass of small element dm = $\left(\frac{M}{2l}\right) dx$

Centripetal force acting on this element,

dF = dm.xω^2

$\Rightarrow \quad dF = \left(\frac{M}{2l}\right) dx \cdot x\omega^2$

Let tension in the rod be F at a distance x from the axis of rotation. F is due to centripetal force acting on all the elements from x to l, i.e.

$F = \frac{M\omega^2}{2l} \int_x^l x dx = \frac{M\omega^2}{4l} \left(l^2 - x^2\right)$

If d(r) is the extension in the element of length dx at position x, then,

$d(r) = \frac{F dx}{YA} \left[\because Y = \frac{F/A}{d(r)/dx}\right]$ where Y is Young's Modulus.

Hence, extension in the half on the rod (from axis to point A) is given by

$$\Delta r = \int_0^l d(r) = \int_0^l \frac{Fdx}{YA}$$

$$= \frac{M\omega^2}{4YAl}\left[l^2(x) - \frac{x^3}{3}\right]_0^l = \frac{M\omega^2}{4YAl}\left[l^3 - \frac{l^3}{3}\right] = \frac{M\omega^2 l^2}{6YA} = \frac{\mu\omega^2 l^3}{3YA}$$ (putting M = 2μl)

Hence, total extension in whole rod of length 2l = $2\triangle$r = $\frac{2}{3YA}\mu\omega^2 l^3$

OR

Given, $L_1 = L_2$, $A_1 = A_2$ and F is same.

a. Stress $\sigma = \frac{F}{A}$

$\therefore$ stress in steel wire and in copper wire are equal.

b. Strain $\varepsilon = \frac{\Delta L}{L} = \frac{\text{stress}}{Y}$ and stress is equal.

$$\frac{\varepsilon_{\text{steel}}}{\varepsilon_{\text{copper}}} = \frac{Y_{\text{copper}}}{Y_{\text{steel}}} = \frac{1.1\times 10^{11}}{2.0\times 10^{11}} = \frac{11}{20} = 0.55 : 1$$