CBSE Class 11 Physics
Sample Paper 09 (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. Which of the two - linear velocity or the linear acceleration gives the direction of motion of a body?
2. Explain why passengers are thrown forward form their seats when a speeding bus stops suddenly.

OR

If force is acting on a moving body perpendicular to the direction of motion, then what will be its effect on the speed and direction of the body?

3. What is the turning effect of force called for? On what factors does it depend?
4. Molecules in the air or atmosphere are attracted by gravitational force of the earth. Explain why all of them do not fall into the earth just like an apple falling from a tree.

OR

What is the apparent weight of a man of 60 kg who is standing in a lift which is moving up with a uniform speed?

5. Water is coming out of a hole made in the wall of tank at some depth filled with fresh water. If the size of the hole is increased, will the velocity of efflux change?
6. A stone is thrown vertically upwards and then it returns to the thrower. Is it a projectile? Explain.
7. Why length, mass and time are chosen as base quantities in mechanics?

OR

5.74 g of a substance occupies 1.2 cm^3. Express its density keeping the significant figures in view.

8. How speed of sound waves in air varies with humidity?

OR

Define non dispersive medium.

9. Two bodies at different temperatures T_1, and T_2 are brought in thermal contact does not necessarily settle down to the mean temperature of T_1 and T_2?
10. Is walking on a road be an example of resolution of vectors?
11. **Assertion:** If both the speed of a body and radius of its circular path are doubled, then centripetal force also gets doubled.

    Reason: Centripetal force is directly proportional to both speed of a body and radius of circular path.
    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:** A hollow shaft is found to be stronger than a solid shaft made of same

material.

Reason: The torque required to produce a given twist in hollow cylinder is greater than that required to twist a solid cylinder of same size and material.

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:** For an ideal gas $C_P > C_V$

Reason: Work is done in expansion of the gas at constant pressure.

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:** Graph between potential energy of a spring versus the extension or compression of the spring is a straight line.

Reason: Potential energy of a stretched or compressed spring is proportional to square of extension or compression.

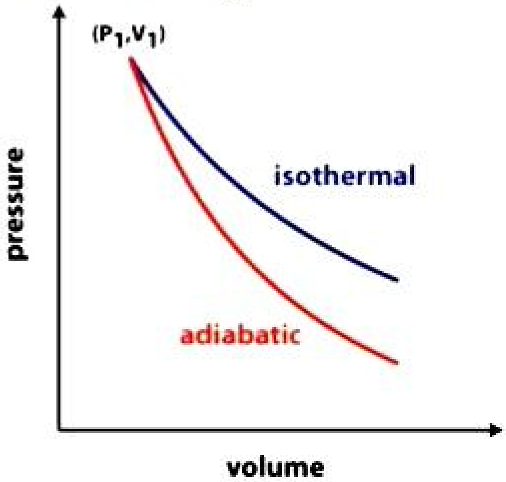
a. Assertion and reason both are correct statements and reason is correct explanation for assertion.
b. Assertion and reason both are correct statements but reason is not correct explanation for assertion.
c. Assertion is correct statement but reason is wrong statement.
d. Assertion is wrong statement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

Section B

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

A refrigerator works isothermally. A set of changes take place in the mechanism of a refrigerator but the temperature inside remains constant. Here, the heat energy is removed and transmitted to the surrounding environment.

while An adiabatic process is a process in which the system does not exchange heat with its surroundings.

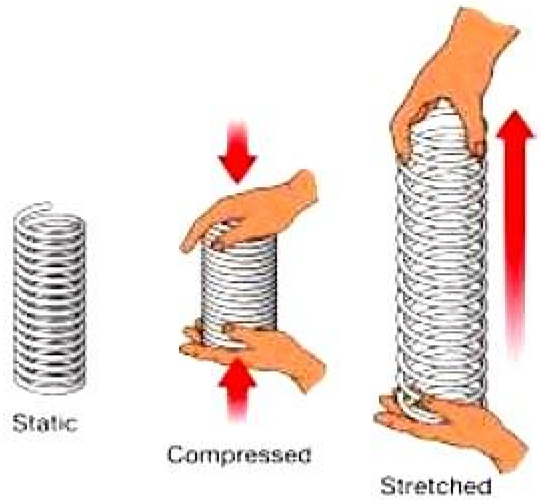


i. Specific heat of a gas during an isothermal process is-
   a. negative
   b. positive
   c. zero
   d. infinite
ii. During an adiabatic process, the square of the pressure of a gas is proportional to the fifth power of its absolute temperature. The ratio of specific heat C_p / C_v for that gas is
   a. 3/5
   b. 5/3
   c. 4/3
   d. 3/4
iii. Work done in an adiabatic change in a gas solely depends on-
   a. change in temperature
   b. change in volume
   c. change in pressure
   d. none of the above.
iv. Can two isothermals curve intersect each other-
   a. yes
   b. no
   c. yes, during critical pressure
   d. none of these
v. The internal energy of an ideal gas depends on-
   a. specific volume

b. pressure
c. temperature
d. density

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

Elastic potential energy is Potential energy stored as a result of deformation of an elastic object, such as the stretching of a spring. It is equal to the work done to stretch the spring, which depends upon the spring constant k as well as the distance stretched



i. A spring is cut into two equal halves. How is the spring constant of each half affected?
   a. becomes 1/4th
   b. becomes half
   c. becomes double
   d. none of these

ii. What type of energy is stored in the spring of a watch?
   a. kinetic energy
   b. potential energy
   c. mechanical energy
   d. none of these

iii. When spring is compressed, its potential energy:
   a. increase
   b. decrease
   c. first increase then decrease
   d. none of these

iv. If stretch in a spring of force constant k is doubled, then the ratio of final to initial forces is:

a. 1:2
b. 2:1
c. 1:4
d. 4:1

v. A light body and a heavy body have the same kinetic energy. which one has greater linear momentum?
   a. heavy body
   b. light body
   c. both same
   d. none of these

Section C

17. A geostationary satellite orbits the earth at a height of nearly 36000 km. What is the potential due to earth's gravity at the site of this satellite (take the potential energy at a to be zero). Mass of earth is 6×10^{24} kg, radius of earth is 6400 km.

18. a. Why the brake drums of a car are heated when it moves down a hill at constant speed?
    b. Why pendulum clocks generally go faster in winter and slow in Summer?

OR

When we step barefoot into an office with a marble floor, we feel cold. Why?

19. A harmonic oscillator is oscillating with a frequency of 3 Hz. Its acceleration amplitude is $0.36\pi^2$ ms^{-2}. Determine its velocity amplitude and the amplitude of displacement.

OR

The acceleration due to gravity on the surface of moon is 1.7 m/s^2. What is the time period of simple pendulum on moon if its time period on the earth is 3.5s? (g on the surface of earth is 9.8 ms^{-2}).

20. A block of mass M is held against a rough vertical wall by pressing it with a finger. If the coefficient of friction between the block and the wall is μ and the acceleration due to gravity is g, calculate the minimum force required to be applied by the finger to hold the block against the wall?

21. A body is moving in a straight line along x-axis. Its distance from the origin is given by the equation $x = at^2 - bt^3$, where x is in metre and t is in second. Find

   i. the average speed of the body in the interval t = 0 and t = 2
   ii. its instantaneous speed at t = 2 s.

22. A person deep inside water cannot hear sound waves produces in air. Why?

23. A bullet of mass 10 g and speed 500 m/s is fired into a door and gets embedded exactly at the centre of the door. The door is 1.0 m wide and weighs 12 kg. It is hinged at one end and rotates about a vertical axis practically without friction. Find the angular speed of the door just after the bullet embeds into it.

24. If the size of nucleus($\simeq 10^{-15}$ m) is scaled upto the tip of a sharp pin($\simeq 10^{-5}$ m), what roughly is the size of the atom?

OR

Express the average distance of the earth from the sun in:

   i. a light year
   ii. par sec.

25. A police van moving on a highway with a speed of 30 km h^{-1} fires a bullet at a thief's car speeding away in the same direction with a speed of 192 km h^{-1}. If the muzzle speed of the bullet is 150m s^{-1}, with what speed does the bullet hit the thief's car?

Section D

26. A pebble of mass 0.05 kg is thrown vertically upwards. Give the direction and magnitude of the net force on the pebble,

   a. during its upward motion,
   b. during its downward motion,
   c. at the highest point where it is momentarily at rest. Do your answers change if the pebble was thrown at an angle of 45° with the horizontal direction? Ignore air resistance.

27. It is a well known fact that during a total solar eclipse the disk of the moon almost completely covers the disk of the sun. The distance of moon (r_{ME}) and sun (r_{SE}) from the earth surface is 3.84×10^8 m and 1.496×10^{11} m while the diameter of Sun is 1.390×10^9 m. Determine the approximate diameter of the moon.

OR

Which of the following is the most precise device for measuring length:

a. a vernier callipers with 20 divisions on the sliding scale
b. a screw gauge of pitch 1 mm and 100 divisions on the circular scale
c. an optical instrument that can measure length to within a wavelength of light?

28. The ceiling of a long hall is 25 m high. What is the maximum horizontal distance that a ball thrown with a speed of 40 ms^{-1} can go without hitting the ceiling of the hall?

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. A ball moving with a speed of 9 m/s strikes an identical ball at rest, such that after collision, the direction of each ball makes an angle of 30^0 with the original line of motion. Find the speed of the two balls after collision.

30. Define gravitational potential energy of a body. Derive an expression for the gravitational potential energy of body of mass 'm' located at a distance 'r' from the centre of the Earth.

Section E

31. Using the correspondence of S.H.M. and uniform circular motion, find displacement, velocity, amplitude, time period and frequency of a particle executing S.H.M?

OR

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

32. i. Define mean free path.

ii. Derive an expression for mean free path of a gas molecule.

OR

An oxygen cylinder of volume 30 litres has an initial gauge pressure of 15 atm and a temperature of 27 °C. After some oxygen is withdrawn from the cylinder, the gauge pressure drops to 11 atm and its temperature drops to 17 °C. Estimate the mass of oxygen taken out of the cylinder ($R = 8.31\ J\ mol^{-1}\ K^{-1}$, molecular mass of O_2 = 32 u).

33. What is the density of water at a depth where a pressure is 80.0 atm, given that its density at the surface is $1.03 \times 10^3\ kg/m^3$, a compressibility of water is $45.8 \times 10^{-11}\ Pa^{-1}$.

OR

A rigid bar of mass 15 kg is supported symmetrically by three wires each 2.0 m long. Those at each end are of copper and the middle one is of iron. Determine the ratio of their diameters if each is to have the same tension.

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Solution

Section A

1. It is the velocity which decides the direction of motion of a body. The acceleration simply tells the rate of change of velocity. For example, when a body is thrown vertically upwards, its direction of velocity is upwards, that is why the body goes upward, whereas its acceleration is downwards.
2. This happens solely due to inertia of motion. When the speeding bus stops suddenly, lower part of the body in contact with the seat comes to rest at the very moment. But the upper part of the body of the passengers tends to maintain its uniform motion according to the inertia of motion. Hence the passengers are thrown forward.

OR

No change in speed, but there can be change in the direction of motion. Let's start with an example. When a body is in a uniform circular motion, the centripetal acceleration or centripetal force always acts perpendicular to the linear velocity of the body at any point of its trajectory. In this case the velocity of the body keeps on changing its direction time to time, but speed remains same.

3. **Torque Factors:**
   i. Magnitude of force
   ii. Perpendicular distance of force vector from axis of rotation.
4. Air molecules in the atmosphere have random motion due to the temperature. Therefore, the direction of the velocity of the air molecule is not exactly in the downward direction as an apple has due to the gravitational pull of the earth.

OR

Apparent weight = $mg = 60 \times 10N = 600N$

5. As per Torricelli's law for Newtonian fluids, velocity of efflux, $V = \sqrt{2gh}$. Since the velocity of efflux depends only on depth, not on the area of hole, so it will remain the

same.

6. A stone cannot be considered as a projectile because a projectile must have two perpendicular components of velocities but in this case a stone has velocity in one direction while going up or coming downwards.
7. In mechanics, length, mass and time are chosen as the base quantities because
   i. there is nothing simpler to length, mass and time.
   ii. all other quantites in mechanics can be expressed in terms of length, mass and time.
   iii. length, mass and time cannot be derived from one another.

OR

Density = $\frac{\text{Mass}}{\text{Volume}} = \frac{5.74\text{g}}{1.2\text{cm}^3}$ = 4.783 g cm^{-3}

= 4.8 g cm^{-3}

[according to the significant figure rule, the final result is rounded off upto 2 significant figures(minimum number of significant figures)]

8. The speed of sound waves in air increases with increase in humidity. This is because the presence of moisture decreases the density of air. And we also know that the decrease in air density increases the speed of sound.

OR

A medium in which speed of wave motion is independent of frequency of wave is called non-dispersive medium. For sound, air is non-dispersive medium.

9. Two bodies at different temperatures T_1 and T_2 when in thermal contact do not settle always at their mean temperature because the thermal capacities of two bodies may not be always equal.
10. Yes, when a man walks on the road, he presses the road obliquely, i.e. along an angle with respect to the ground. The horizontal component of the reaction helps the man to walk on the road whereas the vertical component balances man's weight.
11. (c) Assertion is correct statement but reason is wrong statement.
    Explanation: Assertion is true but reason is false.
    Centripetal force is defined by the formula

$F = \frac{mv^2}{r}$

$\therefore \frac{F_1}{F_2} = \frac{v_1^2}{r_1} \times \frac{r_2}{v_2^2} = \left(\frac{v_1}{v_2}\right)^2 \frac{r_2}{r_1} = \frac{2}{4}$

$\therefore F_2 = 2F_1$

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

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

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

    Explanation: Potential energy (U) = $\frac{1}{2} kx^2$

    i.e, $U \propto x^2$

    This is a equation of parabola. So, graph betw een U and x is a parabola, not a straight line.

Section B

15. i. d
    ii. b
    iii. a
    iv. b
    v. c
16. i. (c)
    ii. (b)
    iii. (a)
    iv. (b)
    v. (a)

Section C

17. mass of the earth (M) = 6×10^{24}

    Radius of earth (R) = 6.4×10^6

    U = potential at height $h = -\frac{GM}{R+h}$

    $U = -\frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{6.4 \times 10^6 + 36 \times 10^6} = 9.44 \times 10^6 j$

18. a. When the car moves downhill, the decrease in gravitational potential energy is converted into work against force of friction between brake shoe and drum which appears as heat.

b. Time period of pendulum $T = 2\pi\sqrt{\frac{l}{g}}$ or $T \propto \sqrt{l}$

In winter l becomes shorter so its time period reduces, i.e. the pendulum takes less time to complete an oscillation, so it goes faster. In summer l increases resulting in increase in time period, i.e. the pendulum takes more time for a complete oscillation, so the clock goes slower.

OR

When we walk barefooted on a marble floor, heat flows our body through the feet and we feel cold because marble is a better conductor of heat than concrete.

19. Here the frequency of oscillations ν = 3 Hz, hence, ω = $2\pi\nu$ = $2\pi \times 3$ = 6π rad s^{-1} and acceleration amplitude $a_0 = A\omega^2 = 0.36\pi^2 \text{ms}^{-2}$

$\therefore$ Velocity amplitude v_0 = $A\omega$ = $\frac{a_0}{\omega}$ = $\frac{0.36\pi^2}{6\pi}$ = 0.06π m s^{-1}

and displacement A = $\frac{v_0}{\omega}$ = $\frac{0.06\pi}{6\pi}$ = 0.01 m = 1 cm.

OR

If l = length of simple pendulum,

T = Time Period

g = Acceleration due to gravity.

Then, on earth ; $T = 2\pi\sqrt{\frac{l}{g}} \rightarrow (1)$

On Moon ; $T_1 = 2\pi\sqrt{\frac{l}{g_1}} \rightarrow 2)$

g_1 = Acceleration due to gravity on moon = 1.7 m | S^2

g = Acceleration due to gravity on earth = 9.8m | s^2

Dividing equation 2) by (1)

$\frac{T_1}{T} = \sqrt{\frac{g}{g_1}}$

$\frac{T_1}{T} = \sqrt{\frac{9.8}{1.7}}$

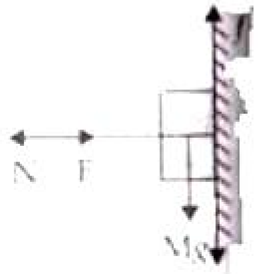
$T_1 = T \times \sqrt{\frac{9.8}{1.7}}$

$$T_1 = 3.5 \times \sqrt{\frac{9.8}{1.7}}$$

T_1 = 8.4 s

20. Let F force is applied by the finger on a body of mass M to hold rest against the wall.

Under the balanced condition



F = N

And f = Mg

$\Rightarrow \mu F = Mg$

or $F = \frac{Mg}{\mu}$ is the minimum force to hold the block against the wall at rest.

21. The given equation x = $at^2 - bt^3$

i. If time t = 0, $x_0 = 0$

If time t = 2 s, x_2 = 4a - 8b

the displacement = $x_2 - x_0$ = 4a - 8b -0 = 4a - 8b

Average speed in the given interval of time,(total displacement / total time)

$v_{\text{av}} = \frac{\Delta x}{\Delta t} = \frac{4a-8b}{2}$ = 2a - 4b

ii. Instantaneous Speed is given by differentiation of x w.r.t time

$v = \frac{dx}{dt} = \frac{d}{dt}\left(at^2 - bt^3\right)$ = $2at - 3bt^2$

At t = 2s, v = 4a - 12b m/s.

22. Because speed of sound in water is roughly four times the sound in air, hence refractiveindex

$u = \frac{\sin i}{\sin r} = \frac{Va}{Vw} = \frac{1}{4} = 0.25$

For, refraction $r_{max} = 90^0$, $i_{max}=14^0$. Since $i_{max} \neq r_{max}$ hence, sounds get reflected in air only and person deep inside the water cannot hear the sound.

23. Given parameters are :

Mass of the bullet, m = 10 g = $10 \times 10^{-3} kg$

Velocity of the bullet, v = 500 m/s

The thickness of the door, L = 1 m

The radius of the door, $r = \frac{1}{2}m$

Mass of the door, M = 12 kg

According to information provided in question bullet gets embedded exactly at centre, therefore distance from the hinged end of the door,

L/2 = r = 0.5 m

Angular momentum imparted by the bullet on the door:

α = mvr

$= \left(10 \times 10^{-3}\right) \times (500) \times \frac{1}{2} = 2.5\mathrm{kgm}^2\mathrm{s}^{-1}$ ....(i)

Moment of inertia of the door about the vertical axis at one end of its end

$I = \frac{1}{3}ML^2$

$= \frac{1}{3} \times 12 \times (1)^2 = 4\mathrm{kgm}^2$

Now Angular momentum $a = I\omega$

$\therefore \omega = \frac{a}{I}$

$= \frac{2.5}{4} = 0.625$ rad s^{-1} This is the required angular speed of the door just after the bullet embeds into it.

24. We have, magnification in size = $\frac{\text{Size of the tip of sharp pin}}{\text{Size of nucleus}} = \frac{10^{-5}}{10^{-15}} = 10^{10}$

The actual size of an atom = 1 angstrom = 10^{-10} m, which is scaled by the factor of 10^{10} ($\because$ 1 angstrom = 10^{-10} m)

Therefore, Apparent size of atom = $10^{-10} \times 10^{10}$ = 1 m

Thus, in an atom, a nucleus is as small in size as the tip of a sharp pin which is placed at the centre of a sphere having radius about 1m.

OR

i. Let the average distance of earth from the sun is (r), then we have

r = 1 AU = 1.496×10^{11} m

$= \frac{1.496 \times 10^{11}}{9.46 \times 10^{15}}$ = 1.58×10^{-5} light years [$\because 1\ ly = 9.46 \times 10^{15} meters$]

ii. In terms of par sec we have, r = $\frac{1.496 \times 10^{11}}{3.08 \times 10^{16}}$ par sec [$\because$ $1\ Parsec = 3.086 \times 10^{16} meters$]

= 4.86×10^{-6} par sec.

25. Speed of the police van, v_p = 30 km/h = 8.33 m/s

Muzzle speed of the bullet, v_b = 150 m/s

Speed of the thief's car, v_t = 192 km/h = 53.33 m/s

Since the bullet is fired from a moving van, its resultant speed can be obtained as:

= 150 + 8.33 = 158.33 m/s

Since both the vehicles are moving in the same direction, the velocity with which the bullet hits the thief's car can be obtained as:

$v_{bt} = v_b - v_t$ = 158.33 - 53.33 = 105 m/s

Section D

26. When an object is thrown vertically upward or it falls vertically downward under gravity then an acceleration g $= 10m/s^{-2}$ acts downward due to the earth's gravitational pull.

Mass of pebble (m) = 0.05 kg

(i) During upward motion

Net force acting on pebble (F) = ma = 0.05×10 N

= 0.50N (vertically downward)

(ii) During downward motion

Net force acting on pebble (F) = ma = 0.05×10 N

= 0.50N (vertically downward)

(iii) At the highest point

Net force acting on pebble

(F) = ma = 0.05×10N

= 0.50 N (vertically downward) If pebble was thrown at an angle of 45° with the horizontal direction then acceleration acting on it and therefore force acting on it will remain unchanged, i.e., 0.50 N (vertically downward). In case , at the highest point the vertical component of velocity will be zero but horizontal component of velocity will not be zero.

27. Given that,

Distance of the moon from the Earth (r_{ME})= 3.84×10^8 m

Distance of the sun from the Earth (r_{SE}) = 1.496×10^{11} m

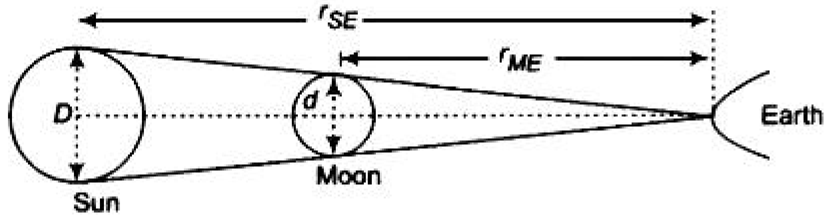
Diameter of the sun (D) = 1.390×10^9 m

During the total solar eclipse, the disk of sun is completely covered by the disk of the moon.

Which implies that,

Angular diameter of the moon = Angular diameter of the sun, that is

$\frac{d}{r_{ME}} = \frac{D}{r_{SE}}$



$\therefore \quad d = D \times \frac{r_{ME}}{r_{SE}}$

Substituting the value of the constants and solving, we get

$= 139 \times 10^9 \times \frac{3.84 \times 10^8}{1.496 \times 10^{11}}$

= 3.5679×10^6 m

= 3567.9×10^3 m

= 3567.9 km = 3.567×10^6 m

OR

The most precise device is that whose least count is minimum.

a. Least count of vernier calliper

= 1 standard division (SD) - 1 vernier division (VD)

$1SD - 19/20SD = 1/20mm = 0.005cm$

b. Least count of screw gauge = $\frac{\text{Pitch}}{\text{No of divisions}}$

$= \frac{1}{100}mm = \frac{1}{1000}cm = 0.001\text{cm}$

c. Least count of an optical device = Wavelength of light $(\lambda) \sim 10^{-5}\text{cm}$

= 0.00001 cm

Hence, it can be inferred that an optical instrument is the most suitable device to measure length.

28. Speed of the ball, u = 40 m/s

Maximum height, h = 25 m

In Projectile motion, the maximum height reached by a body projected at an angle θ, is given by the relation:

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

$25 = \frac{(40)^2}{2 \times 9.8}$

$\sin^2\theta = 0.30625$
$\sin\theta = 0.5534$
$\therefore \theta = \sin^{-1}(0.5534) = 33.60^\circ$
Horizontal range, $R = \frac{u^2 \sin 2\theta}{g}$
$R = \frac{(40)^2 \times \sin(2\times 33.60)}{9.8}$
$R = \frac{1600\times\sin(67.2)}{9.8}$
$R = \frac{1600\times 0.922}{9.8} = 150.53\text{m}$
so if ball is thrown at an angle smaller than 33.60° ball will not hit the ceiling and maximum horizontal distance the ball will cover is $\approx 150.53\ m$.

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. Given, m_1 = m2 = m, u_1 = 9 m/s, u2 = 0

$\theta_1 = \theta_2 = 30^0$, v_1 = ?, v_2 = ?

According to principle of conservation of linear momentum, we have

$m_1u_1 + m_2u_2 = m_1v_1\cos\theta_1 + m_2v_2\cos\theta_2$

Along the direction of motion in x-axis, we have

$m\times 9 + 0 = mv_1\cos 30^0 + mv_2\cos 30^0$

$9 = v_1\frac{\sqrt{3}}{2} + v_2\frac{\sqrt{3}}{2} = \frac{(v_1+v_2)\sqrt{3}}{2}$
$v_1 + v_2 = \frac{18}{\sqrt{3}}$ .... (i)
Along a direction of motion in y-axis

$0+0=m_1v_1\sin\theta_1-m_2v_2\sin\theta_2$

$\Rightarrow mv_1 \sin 30^0 = mv_2 \sin 30^0 \Rightarrow v_1 = v_2$ .... (ii)

Substitute the value from Eq. (ii) in Eq. (i), and find out values of v_1 and v_2 i.e.,

$2v_1=\frac{18}{\sqrt{3}}\Rightarrow v_1=\frac{9}{\sqrt{3}}\times\frac{\sqrt{3}}{\sqrt{3}}=\frac{9\sqrt{3}}{3}=3\sqrt{3}\text{m/s}$

Hence, the two balls move with same velocity = $3\sqrt{3}$ m/s after collision.

30. **<u>Gravitational potential energy</u>**: The gravitational potential energy of a body at a point is defined as the amount of work done is bringing the body from infinity to that point in the gravitational field of Earth.

Let us find the gravitational potential energy of a body of mass m situated at a point A at a distance r from centre of Earth of mass M and radius R.

Let at any instant the body be at point P situated at a distance x from centre of Earth, then gravitational force acting on the body is given as:

$F = \frac{GMm}{x^2}$

If the body be moved through an infinitesimally small distance dx from point P to Q, then work done can be written as:

$dW = F\,dx = \frac{GMm}{x^2}dx$ ....(i)

Therefore, Total work done in bringing the body from ∞ to point A (i,e., x = r) is

$W=\int dW=\int_{x=\infty}^{x=r}\frac{GMm}{x^2}dx=\left[-\frac{GMm}{x}\right]_{\infty}^{r}=-\frac{GMm}{r}$ [by integrating equation (i)]

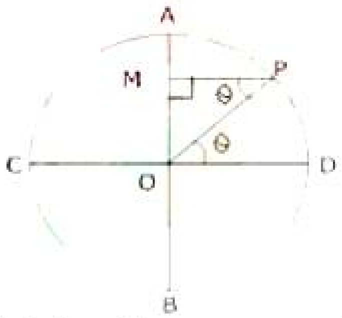
$\therefore$ gravitational potential energy of the given body is given by:

$U = -\frac{GMm}{r}$.

Section E

31. If initially at t = 0 particle was at D

Then at time t Particle is at point P



i. Then draw a perpendicular From P on AB,

If the displacement OM = Y

Ratios of circle of reference = Amplitude = a then In ΔOMP, $\angle$POD = $\angle$OPM = θ ($\because$ Alternate Angles)

$sin\theta = \frac{OM}{OP}$

$\Rightarrow \sin\theta = \frac{y}{a}$, 'a' being radius of the above circle.

$\Rightarrow y = a\sin\theta$

Again $\theta = \omega t$

So, $y = a\sin\omega t$

ii. Velocity, $v = \frac{dy}{dt}$

$\Rightarrow v = \frac{d}{dt}(\mathrm{a}\sin\omega \mathrm{t})$

$\Rightarrow v = a\omega\cos\omega t$

again $\cos\theta = \sqrt{1-\sin^2\theta}$

So, $v = a\omega\times\sqrt{1-\sin^2\omega t}$

From equation of displacement : $\sin\omega t = \frac{y}{a}$

So, $v = a\omega\times\sqrt{1-\frac{y^2}{a^2}}$

$\Rightarrow v = aw\sqrt{\frac{a^2-y^2}{a^2}}$

$v = \omega\sqrt{a^2-y^2}$

iii. Acceleration : $f = \frac{dv}{dt}$

$\Rightarrow f = a\omega\times\omega(-\sin\omega t)$

$\Rightarrow f = -\omega^2 a\sin\omega t \Rightarrow f = -\omega^2 y$

iv. $\text{Time Period}, T = \frac{2\pi}{\omega}$

v. $freuency = \frac{1}{\mathrm{T}} = \frac{\omega}{2\pi}$

OR

Given, displacement equation x(t) = Acos($\omega t + \phi$) ...(i)

At t = 0; x(0) = 1 cm, velocity of the particle v = ω cm/s

Angular frequency $\omega = \pi$ s^{-1}

$\Rightarrow 1 = A\cos(\omega t + \phi)$

For t = 0, 1 = A cosϕ..........(i)

Now, $v(t) = \frac{dx(t)}{dt} = \frac{d}{dt}A\cos(\omega t + \phi)$

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

Again at t = 0, $v = \omega$ cm/s

$\Rightarrow \omega = -A\omega\sin\phi$

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

Squaring and adding eqs.(i) and (ii),

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

$A^2 = 2 \Rightarrow A = \pm\sqrt{2}\text{cm}$

Hence, the amplitude of the SHM = $\sqrt{2}$ cm

Dividing Eq. (ii) by (i), we get

$\frac{A\sin\phi}{A\cos\phi} = \frac{-1}{1}$ or $\tan\phi = -1$

$\Rightarrow \phi = -\frac{\pi}{4}$ or $\frac{7\pi}{4}$

Now, if instead of cosine, we choose the sine function in the displacement equation, then

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

At t = 0, x = 1 cm, $\Rightarrow 1 = B\sin(0 + \alpha)$

or $B\sin\alpha = 1$............(iii)

Velocity v(t) = $\frac{dx(t)}{dt} = \frac{d}{dt}[B\sin(\omega t + \alpha)]$

$= +B\omega\cos(\omega t + \alpha)$

Again at t = 0, v(t) = ω cm/s

B cosα = + 1..............(iv)

Squaring and adding Eqs.(iii) and (iv),

$B^2\sin^2\alpha + B^2\cos^2\alpha = (1)^2 + (+1)^2$

$\Rightarrow B^2\sin^2\alpha + B^2\cos^2\alpha = 2$

$B^2\left(\sin^2\alpha + \cos^2\alpha\right) = 2$

$B^2 1 = 2 \Rightarrow B = \pm\sqrt{2}\text{cm}$

Hence, amplitude of the simple harmonic motion in both types of trigonometric wave equation expression = $\sqrt{2}$ cm

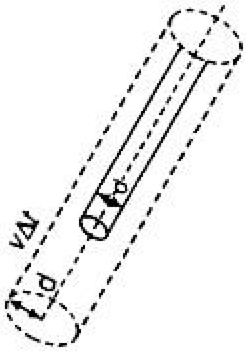
Dividing Eq. (iii) by (iv), we get

$\frac{B\sin\alpha}{B\cos\alpha} = \frac{1}{1}$ or $\tan\alpha = 1$

$\therefore \alpha = \frac{\pi}{4}$, only the phase angle differs for sine and cosine wave equation.

32. i. The mean free path of a gas molecule is defined as the average distance travelled by a molecule between two successive collisions.

    ii. Let d be the diameter of each molecule of the gas, then a particular molecule will suffer a collision with any molecule that comes within a distance d between centres of two molecules.



Volume swept by a molecule in time Δt

If $\vec{v}$ is the average speed of a molecule, then from the figure, the volume swept by the molecule in small time Δt in which any molecule will collide with it

$= \pi d^2 \langle v \rangle \Delta t$ [$\langle v \rangle$ is the magnitude of the velocity of the molecule]

If n is number of molecules per unit volume of the gas, then a number of collisions suffered by the molecule in time Δt.

$= \pi d^2 \langle v \rangle \Delta t \times n$

So, number of collisions per second

$= \frac{\pi d^2 \langle v \rangle \Delta t \times n}{\Delta t} = n\pi d^2 \langle v \rangle$

The average time between two successive collisions, $\tau = \frac{1}{n\pi d^2 \langle v \rangle}$

Mean free path(λ)= average distance between two successive collision

$\Rightarrow \lambda = \tau \times$ mean velocity

$= \frac{1}{n\pi d^2 \langle \nu \rangle} \times \bar{v} = \frac{1}{n\pi d^2}$ [since $\langle v \rangle = \bar{v}$]

Hence the required expression for the mean free path is $\lambda = \frac{1}{n\pi d^2}$

OR

Initial volume of oxygen, V_1 = 30 litres = $30 \times 10^{-3} m^3$ (putting1 litre = 10^{-3} m^3)

Initial gauge pressure, P_1 = 15 atm = $15 \times 1.013 \times 10^5 Pa$ = 15.195 × 10^5 Pa(putting 1 atm = 1.013 × 10^5 Pa)

Initial temperature, T_1 = 27°C = (273 + 27)K = 300 K

Universal gas constant, R = 8.314 J mol^{-1} K^{-1}

Let the initial number of moles of oxygen gas in the cylinder be n_1.

The n_1 mole ideal gas equation is given as:

$P_1V_1 = n_1RT_1$

$\therefore n_1 = \frac{P_1 V_1}{RT_1}$

$= \frac{15.195 \times 10^5 \times 30 \times 10^{-3}}{(8.314) \times 300} = \frac{151.95}{8.314}$ = 18.276

But, $n_1 = \frac{m_1}{M}$ (as, number of moles = total given mass of the gas ÷ molar mass of the gas)

Where,

m_1 = Initial mass of oxygen

M = Molecular mass of oxygen = 32 g

∴ m_1 = number of moles × molar mass of oxygen = n_1 M = 18.276 × 32 = 584.84 g

After some oxygen is withdrawn from the cylinder, the pressure and temperature reduces.

But as the cylinder of volume 30 litres is not changed, so the final volume of the gas will remain same.

∴Final volume, V_2 = 30 litres = $30 \times 10^{-3} m^3$

Final gauge pressure, P_2 = 11 atm = $11 \times 1.013 \times 10^3 \text{Pa}$ (given)

Final temperature, T_2 = 17°C = (273 + 17)K = 290 K(given)

Let n_2 be the number of moles of oxygen left in the cylinder.

Again the ideal gas equation for n_2 moles of Oxygen is given as:

$P_2V_2 = n_2RT_2$

$\therefore n_2 = \frac{P_2 V_2}{RT_2}$

$= \frac{11.143 \times 10^5 \times 30 \times 10^{-3}}{8.314 \times 290} = \frac{11.143 \times 3}{8.314 \times 0.29}$= 13.86

But, $n_2 = \frac{m_2}{M}$ (again using the formula, number of moles = total supplied mass of the gas ÷ molar mass of the gas)

Where,

m_2 is the mass of oxygen remaining in the cylinder

∴ m_2 = number of moles remaining × molar mass of Oxygen = n_2 × M = 13.86 × 32 = 453.1 g

The mass of oxygen taken out of the cylinder is given by the relation:

Change in mass, $\Delta m =$ Initial mass of oxygen in the cylinder - Final mass of oxygen in the cylinder

= $m_1 - m_2$

= 584.84 g - 453.1 g

= 131.74 g

= 0.131 kg

Therefore, 0.131 kg of oxygen is taken out of the cylinder.

33. Density of water at the surface (ρ) = 1.03×10^3 kg/m^3

Pressure ($\triangle$p) = 80 atm = $80 \times 1.013 \times 10^5$ Pa

[$\because 1\ atm = 1.013 \times 10^5 pa$]

Compressibility of water $\left(\frac{1}{B}\right)$ = 45.8×10^{-11} Pa^{-1}

Let V and V' be the volumes of a certain mass of water at the surface and at a given depth.

The density of water at the given depth be ρ'.

Volume of water at the surface, V = $\frac{m}{\rho}$

At the given depth, volume $V' = \frac{m}{\rho'}$

$\therefore$ Change in volume, $\Delta V = V - V' = m\left(\frac{1}{\rho} - \frac{1}{\rho'}\right)$

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

= m $\left(\frac{1}{\rho} - \frac{1}{\rho'}\right) \times \frac{\rho}{m}$

= $\left(1 - \frac{\rho}{\rho'}\right)$

Compressibility = $\frac{1}{\text{Bulk modulus } (B)}$

= $\frac{1}{\frac{\Delta p}{(\Delta V/V)}}$ = $\frac{\Delta V}{\Delta p V}$

$45.8 \times 10^{-11} = \left(1 - \frac{\rho}{\rho'}\right) \times \frac{1}{80 \times 1.013 \times 10^5}$

$45.8 \times 10^{-11} \times 80 \times 1.013 \times 10^5 = 1 - \frac{1.03 \times 10^3}{\rho'}$

$3.712 \times 10^{-3} = 1 - \frac{1.03 \times 10^3}{\rho'}$

$\frac{1.03 \times 10^3}{\rho'} = 1 - 3.712 \times 10^{-3}$

or ρ' = $\frac{1.03 \times 10^3}{1 - 0.003712} = 1.034 \times 10^3 kg/m^3$

Thus, density of water at depth $= 1.034 \times 10^3 kg/m^3$

OR

As The tension force acting on each wire is the same. Thus, the extension in each case is the same.

Since the wires are of the same length, the strain will also be the same.

The relation for Young's modulus is given as : $Y = \frac{\text{longitudinal stress}}{\text{longitudinal strain}}$

$$= \frac{\frac{F}{A}}{strain} = \frac{\frac{F}{\pi r^2}}{strain} = \frac{\frac{4F}{\pi d^2}}{strain} \text{ ... (1)}$$

Where, F $\Rightarrow$ Tension force

A $\Rightarrow$ Area of cross - section

d $\Rightarrow$ Diameter of the wire

from equation (1) $Y \propto \frac{1}{d^2}$

Young's modulus for iron, $Y_1 = 190 \times 10^9 Pa$

Diameter of the iron wire = d_1

Young's modulus for copper, $Y_2 = 120 \times 10^9 Pa$

Diameter of the copper wire = d_2

Therefore, the ratio of their diameters is given as:

$$\frac{d_1}{d_2} = \sqrt{\frac{Y_1}{Y_2}} = \sqrt{\frac{19\times10^{10}}{12\times10^{10}}} = 1.25 : 1$$