CBSE Class 11 Physics
Sample Paper 05 (2019-20)

Maximum Marks: 70
Time Allowed: 3 hours

General Instructions:

1. All questions are compulsory. There are 37 questions in all.
2. This question paper has four sections: Section A, Section B, Section C and Section D.
3. Section A contains twenty questions of one mark each, Section B contains seven questions of two marks each, Section C contains seven questions of three marks each, and Section D contains three questions of five marks each.
4. There is no overall choice. However, internal choices have been provided in two questions of one mark each, two questions of two marks, one question of three marks and three questions of five marks weightage. You have to attempt only one of the choices in such questions.

Section A

1. Law of conservation of mass has been changed by Einstein to
   a. law of conservation of angular momentum
   b. law of conservation of momentum
   c. law of conservation of mass and energy together i.e. mass + energy is conserved
   d. law of conservation of charge
2. In a harbor, wind is blowing at the speed of 72 km/h and the flag on the mast of a boat anchored in the harbor flutters along the N-E direction. If the boat starts moving at a speed of 51 km/h to the north, what is the direction of the flag on the mast of the boat?

   a. approximately north
   b. approximately south
   c. approximately east

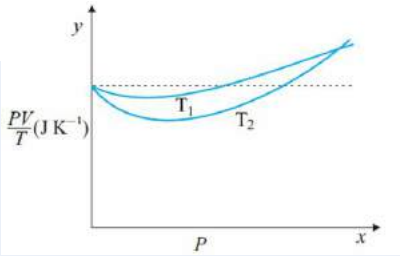
d. approximately north-east

3. The driver of a three-wheeler moving with a speed of 36 km/h sees a child standing in the middle of the road and brings his vehicle to rest in 4.0 s just in time to save the child. The mass of the three-wheeler is 400 kg and the mass of the driver is 65 kg.Find out the deceleration produced and the retarding force on a vehicle.
   a. – 2.2 m s^{-2}, 900 N
   b. – 2.5 ms^{-2} , 1162.5 N
   c. – 2.3 m s^{-2}, 1000 N
   d. – 2.4 m s^{-2}, 1100 N
4. A body is projected with a velocity of 20ms^{-1} at 50° to the horizontal. Find Time of flight.
   a. 4.2 s
   b. 3.5 s
   c. 5.1 s
   d. 3.1 s
5. In which of the following cases is the work done positive?
   a. Work done by gravitational force while a man in lifts a bucket out of a well by means of a rope tied to the bucket
   b. Work done by friction on a body sliding down an inclined plane
   c. Work done by the resistive force of air on a vibrating pendulum in bringing it to rest.
   d. work done by an applied force on a body moving on a rough horizontal plane with uniform velocity
6. The importance of the elastic behavior of materials is
   a. that it gives methods for understanding materials
   b. that it is useful in building slingshots
   c. that it is useful in making springs
   d. that it enables a safe and sound design of bridges, buildings, machinery parts.
7. In an insulated vessel, 250 g of ice at 0°C is added to 600 g of water at 18.0°C. How much ice remains when the system reaches equilibrium?
   given that latent heat of fusion of ice = 79.5 cal/gm, specific heat of water = $1 cal/gm^{\circ}C$
   a. 94 g

b. 87 g
c. 134 g
d. 114 g

8. A Carnot engine has a power output of 150 kW. The engine operates between two reservoirs at 20.0°C and 500°C. How much energy is lost per hour in its exhaust?
a. 330 MJ
b. 351 MJ
c. 320 MJ
d. 320 MJ

9. Figure shows plot of $\frac{PV}{T}$ versus P for 1.00×10^{-3} kg of oxygen gas at two different temperatures. What is the value of $\frac{PV}{T}$ where the curves meet on the y-axis?



a. 0.28 JK^{-1}
b. 0.22 JK^{-1}
c. 0.24 JK^{-1}
d. 0.26 J K^{-1}

10. A tuning fork produces 4 beats/sec. with 50 cm and 40 cm of a stretched wire, of a sonometer. The frequency of fork is
a. 90 Hz
b. 36 Hz
c. 110 Hz
d. 50 Hz

11. Fill in the blanks:

_______ describes the motion of objects without looking at the cause of the motion.

OR

Fill in the blanks:

Acceleration is 9.8 ms^{-2} (downwards) and velocity is ______ at the highest point if a ball was thrown up with velocity v.

12. Fill in the blanks:

    The set of laws that we generally deduce for macroscopic object are not always applicable to atoms, molecules, nuclei an elementary particle is known as ________.

13. Fill in the blanks:

    The minimum number of forces which are numerically equal whose vector sum can be zero is ________.

14. Fill in the blanks:

    The _________ is defined as the loss in the strength of a material caused due to repeated alternating strains to which the material is subjected.

15. Fill in the blanks:

    A special type of thermometer named ________ thermometer shows the various reading for the temperature other than the fixed points because of different expansion properties of liquids.

16. What is the angle between A and B, if A and B denote the adjacent sides of a parallelogram drawn from a point and the area of the parallelogram is 1/2AB?

17. A body is moved along a closed loop. Is the work done in moving the body necessarily zero? If not, state the condition under which work done over a closed path is always zero.

18. What makes raincoats waterproof?

19. Why is it hotter at the same distance over the top of the fire than in front of it?

20. What physical change occurs when a source of sound is stationary and the listener moves?

OR

Define non-dispersive medium.

21. A driver takes 0.20 second to apply the breaks (reaction time). If he is driving car at a speed of 54 kmh^{-1} and the breaks cause a deceleration of 6.0 ms^{-2} , find the distance travelled by car after he sees the need to put the breaks.

22. What will be the effect on horizontal range of a projectile when its initial velocity Is doubled keeping angle of projection same?

23. What are the characteristics of rotational motion?

24. At what height from the surface of the earth will the value of 'g' be reduced by 36% of its value at the surface of earth.

25. Two strips of metal are riveted together at their ends by four rivets, each of diameter 6.0 mm. What is the maximum tension that can be exerted by the riveted strip if the shearing stress on the rivet is not to exceed 6.9×10^7 Pa? Assume that each rivet is to carry one-quarter of the load.

26. Briefly explain the concept of thermal equilibrium and temperature.

OR

Calculate the heat of combustion of coil when 10 g of coal on burning raises the temperature of 2 litres of water from 20^{o} C to 55^{o} C.

27. If a certain mass of gas is heated first in a small vessel of volume V_1 and then in a large vessel of volume V_2. Draw the P - T graph for two cases?

OR

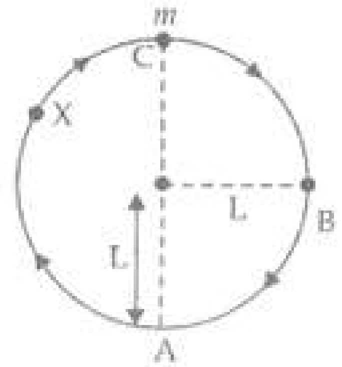
The molecules of a given mass of a gas have root mean square speeds of 100 m s^{-1} at 27°C and 1.00 atmospheric pressure. What will be the root mean square speeds of the molecules of the gas at 127°C and 2.0 atmospheric pressure?

28. A body of mass m hung at one end of the spring executes SHM. Prove that the relation T = 2πm/k is incorrect where k is the force constant of the spring. Also, derive the correct relation.

29. A car moving along a straight highway with a speed of 126km h^{-1} is brought to a stop within a distance of 200m. What is the retardation of the car (assumed uniform), and how long does it take for the car to stop?

30. A bob of mass m suspended by a light string of length L is whirled into a vertical circle as shown in figure. What will be the trajectory of the particle if the string is cut at

i. Point B?
ii. Point C?
iii. Point X?



31. Two stationary particles of masses M_1 and M_2 are a distance d part. A third particle lying on the line joining the particles experiences no resultant gravitational force. What is the distance of this particle from M_1?

32. What is the excess pressure inside a bubble of soap solution of radius 5.00 mm, given that the surface tension of soap solution at the temperature (20 °C) is $2.50 \times 10^{-2} \mathrm{Nm}^{-1}$? If an air bubble of the same dimension were formed at depth of 40.0 cm inside a container containing the soap solution (of relative density 1.20), what would be the pressure inside the bubble? (1 atmospheric pressure is $1.01 \times 10^5 \mathrm{Pa}$).

OR

A metallic sphere of radius 1×10^{-3} m and density 1×10^4 kg | m^3 enters a tank of water after a free fall through a high 'h' in earth's gravitational field. If its velocity remains unchanged after entering the water, determine the value of h.

Given :- Co-efficient of viscosity of water = 1×10^{-3} Ns | m^2; g = 10 m | s^2; density of water = 1×10^3 kg | m^3?

33. A layer of ice 10 cm thick is formed on a pond. The temperature of air is - 10^0 C. Calculate how long it will take for the thickness of ice to increase by 1mm. Density of ice = 1g|cm^3; Thermal conductivity of ice = 0.005 Cal|s|cm|^{0}C; Latent heat of ice = 80Cal|g

34. What do you mean by the terms overtones and harmonics? Briefly explain.

35. a. State Newton's second law of motion. Express it mathematically and hence obtain a relation between force and acceleration.

    b. A body of mass 400 gm moving initially with a constant speed of 36 km h^{-1} towards the north is subjected to a constant force of 8.0 N directed towards the south for half of a minute. Beyond that time the body continues its motion with uniform velocity. No other forces are acting on the body throughout its motion. Take the instant the force is applied to be at t = 0 s, the position of the body at that time to be x = 0 m. Find out its position at t = -5 s, 25 s and 100 s respectively applying Newton's equations of motion.

OR

Two masses 8 kg and 12 kg are connected at the two ends of a light, inextensible string that goes over a frictionless pulley. Find the acceleration of the masses, and the tension in the string when the masses are released. (Take g = 10 m/s^2)

36. Two particles each of mass m and speed v travel in opposite direction along parallel lines, separated by a distance d. Show that vector angular momentum of the two particles system is same whatever be the point about which angular momentum is taken.

OR

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

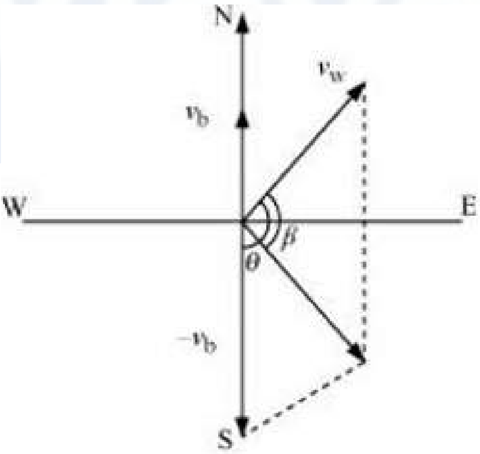
37. You are riding in an automobile of mass 3000 kg. Assuming that you are examining the oscillation characteristics of its suspension system. The suspension sags 15 cm when the entire automobile is placed on it. Also, the amplitude of oscillation decreases by 50% during one complete oscillation. Estimate the values of (a) the spring constant k and (b) the damping constant b for the spring and shock absorber system of one wheel, assuming that each wheel supports 750 kg.

OR

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).

Solution
Section A

1. (c) law of conservation of mass and energy together i.e. mass + energy is conserved
   Explanation: $E = mc^2$, equation in German-born physicist Albert Einstein's theory of special relativity that expresses the fact that mass and energy are the same physical entity and can be changed into each other.
   In the equation, the increased relativistic mass (m) of a body times the speed of light squared (c^2) is equal to the kinetic energy (E) of that body.
2. (c) approximately east
   Explanation: The flag is fluttering in the north-east direction. It shows that the wind is blowing toward the north-east direction. When the ship begins sailing toward the north, the flag will move along the direction of the relative velocity (v_{wb}) of the wind with respect to the boat.



   The angle between v_w and $(-v_b)$ = 90° + 45°
   $\tan\beta = \frac{51 Sin(90+45)}{72+51 Cos(90+45)}$
   Substituting and solving we get,
   $\tan\beta = \frac{51}{50.80} = 1.0038$
   $\therefore \beta = \tan^{-1}(1.0038) = 45.110$
   Angle with respect to the east direction = 45.11° – 45° = 0.11°

Hence, the flag will flutter approximately due east.

3. (b) – 2.5 ms^{-2} , 1162.5 N

Explanation:

V= final velocity = 0

V_0 = initial velocity = 36 km/h = 10 m/s

$$a = \frac{v - v_0}{t} = \frac{0 - 10}{4} = -2.5\frac{m}{s^2}$$

F= ma = -465 x 2.5 = -1162.5N (negative sign indicates the retarding force)

4. (d) 3.1 s

Explanation: Initial Velocity v_o = 20 ms^{-1}

$$\theta = 50^0$$

Time of flight = $\frac{2v_o sin\theta}{g}$

$$= \frac{2 \times 20 \times sin50^0}{9.8}$$

= 3.1 s

5. (d) work done by an applied force on a body moving on a rough horizontal plane with uniform velocity

Explanation: When a body is moving on a rough horizontal surface then their will be 2 forces acting on the body

i. Applied force (in the direction of motion)

ii. friction (opposite to direction of motion)

As applied force is in same direction as displacement so work done will be positive.

6. (d) that it enables a safe and sound design of bridges, buildings, machinery parts.

Explanation: More the elastic a material is , more it has the property to regain its original position which is required in construction works.

7. (d) 114 g

Explanation:

maximum heat given by water is

$Q_1 = m_w s_w \Delta T = 600 \times 1 \times (18 - 0) = 10800 cal$

Heat required to melt the complete ice = Q_2 = m_{ice} L

$Q_2 = 250 \times 79.5 = 19875 cal$

Heat given by water is not sufficient to melt complete ice. Hence temperature of mixture will be $0^\circ C$ with some ice remains unmelt.

amount of ice melt = $m = \frac{Q_1}{L} = \frac{10800}{79.5} = 136 gm$

L = latent heat of fusion of ice = 80 cal/gm

Amount of ice which remains unmelt at equilibrium = 250 - 136 =114 gm

8. (a) 330 MJ

Explanation:

$\eta = \frac{T_H - T_L}{T_L} = \frac{480}{773} = 0.62$

$\eta = \frac{\text{Work (Output)}}{\text{HeatExtracted (input)}}$

Power = Energy output per second = 150KJ

Efficiency = Energy Output / Energy Absorbed

Energy absorbed per second = Energy output / Efficiency $= \frac{150 \times 10^3}{0.62} J$

Energy loss per hour = $= \frac{150 \times 10^3}{0.62} - 150 \times 10^3 = 91935 J$

Energy loss per hour = $91935 \times 3600 = 330 MJ$

9. (d) 0.26 J K^{-1}

Explanation:

PV = nRT

$\frac{PV}{T}$ = nR = $\frac{1}{32}$ $\times$ 8.314 = 0.26 JK^{-1}

Hence the value of $\frac{PV}{T}$ where the curves meet on the y-axis is 0.26 J K^{-1}

10. (b) 36 Hz Explanation:

beat frequency is given by

$f_{beat} = f_1 - f_2$

4 = f1 - f2 ...(1)

also frequency $f \alpha \frac{1}{L}$
$\frac{f_1}{f_2} = \frac{L_2}{L_1}$
$\frac{f_1}{f_2} = \frac{40}{50}$ ...(2)
On solving equation 1 and 2

$f_1 = 16Hz$

$f_2 = -20Hz$

$|f_1 - f_2| = 36Hz$

11. Kinematics

OR

zero

12. Classical physics

13. Two

14. Elastic fatigue

15. Liquid-in-glass

16. We know that area of parallelogram is given by the cross product of vectors forming the two adjacent side of a parallelogram,

    Therefore, $|A \times B|$ = AB sinθ = $\frac{1}{2}$AB as given in the question.
    $\therefore \sin\theta = \frac{1}{2} = \sin 30^\circ$
    or $\theta = 30^\circ$

17. Work done by a body moving along closed loop can be zero if only conservative force acting on the body during motion.

    Work done by a body moving along a loop is not zero if any non-conservative force, i.e., frictional, electrostatic, magnetic force are acting on body.

18. In this case, cohesive force acting between water molecules is much more greater than the adhesive force acting between the material of raincoat and water. That's why the angle of contact between water and the material of the raincoat is obtuse. So the rainwater does not wet the raincoat.

19. At a point in front of fire, heat is received due to the process of radiation only, while at a point above the fire, heat reaches both due to radiation and convection.

20. The number of sound waves received by the listener changes.

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.

21. The car is moving at speed of 54 km/hr =15 m/sec i.e, initial speed after applying brakes is (u) = 15 m/secs
Say at point A, he sees the need to put brakes and at point B, he puts brakes and then the car starts deceleration and at point C, the car finally comes to rest.
From A to B it moves with speed of 15m/sec in 0.2 sec.
So distance covered is S_1 = v x t= 15 x 0.2 = 3 m and from B to C it moves with constant deceleration of -6 m/sec^{2}and initial speed of 15m/sec.
Here, final velocity is zero as car comes to rest finally. Using relation $v^2 - u^2 = 2(-a)s$, we have

$$S_2 = \frac{u^2}{2a} = \frac{15\times15}{2\times6} = 18.75 \text{ m}$$

Hence, the distance traveled by car after he sees need to put brakes = $S_1 + S_2$ = 3 + 18.75 = 21.75 m

22. $R = \frac{u^2 \sin 2\theta}{g} \Rightarrow R \propto u^2$

Range become four times.

23. Main characteristics of rotational motion are as given below :

    i. Rotational motion occurs when a force is applied to a rigid body capable of rotation about an axis.

ii. In rotational motion, the constituent particles of the body generate concentric circles with points on the axis of rotation as their centres.

iii. In a given time, all the constituent particles undergo same angular displacements. It means that all the particles have the same angular velocity but different linear speeds.

iv. When a torque is applied on the rotating body, its motion is accelerated. Angular acceleration of all the particles is the same but linear acceleration differs from particle to particle.

24. Given:

g be reduced by 36% of its value at the surface of earth.

$g' = 64\%$ of $g = \frac{64}{100}g$

accleration due to gravity due to height is

$g' = g\frac{R^2}{(R+h)^2} = \frac{64}{100}g$

$\therefore \frac{R}{R+h} = \frac{8}{10}$

$h = \frac{R}{4} = 1600km$

25. Diameter of the metal strip, d = 6.0 mm = 6.0×10^{-3} m

Radius, $r = \frac{d}{2} = 3.0 \times 10^{-3}m$

Maximum shearing stress $= 6.9 \times 10^7 \mathrm{Pa}$

Maximum stress $= \frac{\text{Maximum load or force}}{\text{Area}}$

Maximum force = Maximum stress $\times$ Area

$= 6.9 \times 10^7 \times \pi \times (r)^2$

$= 6.9 \times 10^7 \times \pi \times \left(3 \times 10^{-3}\right)^2$

= 1949.94 N

Each rivet carries one quarter of the load.

$\therefore$ Maximum tension on each rivet = 4 $\times$ 1949.94 = 7799.76 N

26. Two systems are in a state of thermal equilibrium if all parts of the two systems are at the same temperature. Thus, the temperature is a property which determines whether the two given systems will be in thermal equilibrium or not.

OR

As per question mass m of 2 litres of water = 2 kg and we know that specific heat of water

$C = 4200\ j\ kg^{-1}K^{-1}$

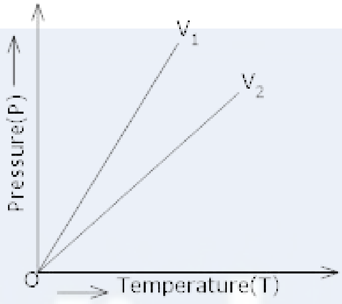
$\therefore$ The heat energy required to raise the temperature of water from 20^{o} C to 55^{o} C

$Q = mc(T_2 - T_1) = 2\ \times\ 4200 \times\ \ (55 - 20) = 2.94\ \times\ 10^5 j$

As this much heat is produced by combustion of $m_0 = 10g$ of coal, hence heat of combustion of

coal = $\frac{Q}{m_0} = \frac{2.94 \times 10^5 \text{J}}{10\text{g}} = 2.94\ \times\ 10^{-4}\ j\ g^{-1} = 2.94 \times\ 10^7\ j\ kg^{-1}$.

27. From Perfect gas equation; $P = \frac{RT}{V}$



For a given temperature, $P \propto \frac{1}{V}$ therefore when the gas is heated in a small vessel (Volume V_1), the pressure will increases more rapidly than when heated in a large vessel (Volume V_2). As a result, the slope of P - T graph will be more in case of small vessel than that of large vessel.

OR

$v_1 rms = 100m/s$

$T_1 = 27 + 273 = 300K$

$v_{2rms} = ?$

$T_2 = 127 + 273 = 400K$

$v_{rms} = \sqrt{\frac{3RT}{M}}$

M = Molar mass of gas for a gas M is constant

$\therefore v_{rms} \propto \sqrt{T}$

$\frac{v_1 rms}{v_2 rms} = \sqrt{\frac{T_1}{T_2}}$

$\frac{100}{v_{2rms}} = \sqrt{\frac{300}{400}}$

$V_{2rms} = \frac{100\times\sqrt{400}}{\sqrt{300}} = \frac{100\times2\times10}{10\sqrt{3}} \times \frac{\sqrt{3}}{\sqrt{3}}$

= $\frac{200\times\sqrt{3}}{3} = \frac{200\times1.732}{3}$

$v_{2rms} = 115.4\text{ms}^{-1}$.

28. It is given that T = $\frac{2\pi m}{k}$

LHS, T = [T]

RHS, $\frac{2\pi m}{k} = \frac{[\text{M}]}{[\text{MT}^{-2}]} = [\text{T}^2]$

$\therefore \quad \text{LHS} \neq \text{RHS}$

Hence, the relation is incorrect.

To derive the correct relation, suppose T = $\beta m^a k^b$, β is the proportionality constant, then

$[T]^1 = [M]^a[MT^{-2}]^b = M^{a+b}T^{-2b}$ so, equating dimension on both sides,

a + b = 0 ..(i)

-2b = 1..(ii)

On solving the equations. (i) and (ii), we get $b = \frac{-1}{2}, a = \frac{1}{2}$

$\therefore$ T = $\beta m^{1/2}k^{-1/2}$

Hence, T =$\beta\sqrt{\frac{m}{k}}$

29. For Car

Initial velocity (u) = 126km/h = 35m/s

Final velocity (v) = 0

Retardation of car = a m/s^2

Distance covered by the car before come to rest = 200m

Using 3rd Equation of motion,

$v^2 - u^2 = 2as$

$(0)^2 - (35)^2 = 2 \times a \times 200$

$a = -\frac{35 \times 35}{2 \times 200} = -3.06 m/s^2$

Using 1st Equation of motion,

Let time taken t sec before come to rest

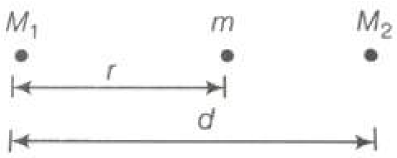
v = u + at

$t = \frac{v-u}{a} = \frac{0-35}{-3.06} = 11.44s$

30. In mechanics, circular motion is a movement of an object along the circumference of a circle or rotation along a circular path. It can be uniform, with constant angular rate of rotation and constant speed, or non-uniform with a changing rate of rotation as shown in the figure.
When the bob is whirled into circular path the required centripetal force is provided by string (towards the centre of circular path) due to tension and it balances by centrifugal force provided by tangential velocity of particle.
Hence, when string is cut off, the centripetal force become zero and bob moves with tangential velocity under gravity.

    i. When string is cut off at B, it's tangential velocity will be vertically downward, so bob will move along vertical path under gravity.
    ii. When string is cut off at C. bob has horizontal velocity, so bob will move in half parabolic path as shown in figure.
    iii. When string is cut off at X then the velocity of bob is makes some angle θ with horizontal so it moves parabolic path reaches at higher height then again parabolic.

31. The force on m towards M_1 is $F = G\frac{M_1 m}{r^2}$
The force on m towards M_2 is $F = G\frac{M_2 m}{(d-r)^2}$



Equating two forces,

$\Rightarrow G\ \frac{M_1 m}{r^2} = G\ \frac{M_2 m}{(d-r)^2}$

$\left(\frac{\mathrm{d - r}}{\mathrm{r}}\right)^2 = \frac{\mathrm{M_2}}{\mathrm{M_1}}$

$\Rightarrow \frac{d}{r} - 1 = \frac{\sqrt{M_2}}{\sqrt{M_1}}$

$\therefore$ distance of an particle from m,$r = d\left(\frac{\sqrt{M_1}}{\sqrt{M_1} + \sqrt{M_2}}\right)$

32. The pressure inside the air bubble$= 1.06 \times \ 10^5 Pa$

Soap bubble is of radius,$r = 5.00mm = 5 \times 10^{-3}m$

Surface tension of the soap solution,$S = 2.50 \times 10^{-2}Nm^{-1}$

The relative density of the soap solution $= 1.20$

$\therefore$ Density of the soap solution, $\rho = 1.2 \times 10^3 \text{kg/m}^3$

Air bubble formed at a depth, $h = 40cm = 0.4m$

Radius of the air bubble, $r = 5mm = 5 \times \ 10^{-3}\ m$

1 atmospheric pressure $= 1.01 \times \ 10^5\ Pa.$

Acceleration due to gravity, $g = 9.8 \quad m/s^2$

The excess pressure inside the soap bubble is given by the relation:

$p = \frac{4S}{r}$

$= \frac{4 \times 2.5 \times 10^{-2}}{5 \times 10^{-3}}$

$= 20Pa$

The excess pressure inside the air bubble is given by the relation:

$p = \frac{4S}{r}$

$= \frac{2 \times 2.5 \times 10^{-2}}{5 \times 10^{-3}}$

$= 10Pa$

At a depth of 0.4 m, the total pressure inside the air bubble

= Atmospheric pressure +$h\rho g + P$

$= 1.01 \times 10^5 + 0.4 \times 1.2 \times 10^3 \times 9.8 + 10$

= 1.057 $\times$ 10^5Pa

= 1.06 $\times$ 10^5Pa

Therefore, the pressure inside the air bubble is = 1.06 $\times$ 10^5Pa.

OR

The velocity acquired by the sphere in falling freely through a height h is $\text{V} = \sqrt{2\text{g}h}$

As per the conditions of the problem, this is the terminal velocity of sphere in water i.e.

Terminal Velocity of sphere in water is :- $V_T = \sqrt{2gh} \rightarrow 1)$

By Stoke's Law, the terminal velocity V_T of sphere in water is given by :-

$$\mathrm{VT} = \frac{2\times r^2\times(P-\sigma)_g}{9\eta}$$

r = Radius of sphere $= 1 \times 10^{-3}\mathrm{m}$

P = Density of sphere $= 1 \times 10^{+4}\mathrm{Kg}/+\mathrm{m}^3$

σ = Density of liquid $= 1 \times 10^3\mathrm{Kg}/\mathrm{m}^3$

g = Acceleration due to gravity = 10 m/s^2

η = Co-efficient of viscosity $= 1 \times 10^{-3}\mathrm{Ns}/\mathrm{m}^2$

$$\mathrm{VT} = \frac{2\times\left(1\times10^{-3}\right)^2\times\left(1\times10^4-1\times10^3\right)\times10}{9\times1\times10^{-3}}$$

V_T = 20m/s

From equation 1) $\rightarrow$

$$\mathrm{V_T} = \sqrt{\mathrm{2gh}}$$

$$V_T^2 = 2gh$$

$$h = \frac{V_T^2}{2g}$$

$$h = \frac{(20)^2}{2\times10} = \frac{400}{20} = 20\mathrm{m}$$

33. Let t be time required to increase the thickness of ice by 1 mm (=0.1 cm)
Mass of ice required to be formed is :-
M = Volume $\times$ Density $\rightarrow$ (1)
Let A be the Area of upper surface
we know that , Volume = Area $\times$ Thickness
= A $\times$ 0.1 $\rightarrow$ (2)

Substitute equation (2) in equation (1)

M = (A $\times$ 0.1) $\times$ 1

M = 0.1 A gram $\rightarrow$ (3)

Now, heat always flow from lower surface to the upper surface of ice and into atmosphere.

Let

θ be heat that flows into atmosphere.

λ be Latent heat of ice

M be Mass of ice

K = co-efficient of thermal conductivity

A = Cross-sectional Area

t be time required to increase the thickness

x be Distance between hot and cold surface

θ_1 = temperature of hot surface

θ_2 = temperature of cold surface

$\therefore \theta = ML$;

$\theta = 0.1 \times \mathrm{A} \times 80$ (Using equation 3)

θ = 8 A Cal $\rightarrow$ (4)

But $\theta = \frac{KA(\theta_1 - \theta_2)_t}{x} \rightarrow$ (5)

substitute equation (3) in equation (5)

$8A = \frac{KA(\theta_1 - \theta_2)t}{x}$

$t = \frac{8x}{K(\theta_1 - \theta_2)} \rightarrow (6)$

Now,thickness of ice layer is given as x = 10 cm,

K = 0.005 cal|cm|Δ|^{0}C

$\theta_1 - \theta_2$ = 0 - (-10) = 10^{0}C

substitute above values in equation (6), we will get,

$t = \frac{8 \times 10}{0.005 \times 10} = 1600\text{Sec}$

Hence it will take 1600 sec to increase the thickness of ice 1mm

34. When we consider a timing fork of frequency ν and gently strike its prong with a rubber pad, it starts vibrating and produces a pure note of frequency ν only.

However, in the case of musical instruments like sitar, violin, flute, etc., besides the fundamental note of frequency ν, other notes of higher frequencies, which are integer multiples of the fundamental frequency, are also formed. These notes of higher frequencies are called harmonics/overtones. Their number and amplitude depend upon the construction of musical instruments and the method of setting vibrations in it. These are defined as follows:

Overtones of a given note are the notes of lesser intensities but higher frequencies than the fundamental note and are superimposed on the fundamental note. Frequencies of different overtones are integer multiples of the frequency of the fundamental note.

Harmonics of a given note are the waves superimposed on a fundamental wave having a frequency which is a whole multiple of the fundamental frequency. The fundamental note itself is called the first harmonic. The second harmonic has a frequency twice that of the fundamental note, the third harmonic has a frequency thrice the frequency of fundamental note and so on.

35. a. The second law states that the rate of change of momentum of a body is directly proportional to the force applied, and this change in momentum takes place in the direction of the applied force.

i.e. F $\propto$ rate of change of momentum

$\vec{F} \propto \frac{d\vec{p}}{dt}$

$\vec{F} = k\frac{d\vec{p}}{dt}$

where, k represent the proportionality constant.

$\vec{P} = m\vec{v}$

$\Rightarrow \vec{F} = \text{km}\,\frac{d\vec{v}}{dt}$

$\vec{F} = \text{km}\,\vec{a}$ (In S.I. unit K = 1)

Therefore, $\vec{F} = m\vec{a}$

b. Mass of the body, m = 400 gm = 0.40 kg

Initial speed of the body, u = 36 km/h = (36×5/18) = 10 m/s, due north

Force acting on the body, F = -8.0 N due north

Acceleration produced in the body, $a = \frac{F}{m} = \frac{-8.0}{0.40} = -20m/s^2$

(i) At t = -5 s

Acceleration, a' = 0 and initial velocity, u = 10 m/s. Both are acting in the same direction i.e. due north. Applying Newton's second equation of motion,

$s = ut + \frac{1}{2}a't^2$

$= 10 \times (-5) = -50\text{m}$

(ii) At t = 25s,

Acceleration, a'' = -20 m/s^2 and initial velocity, u = 10 m/s. Here also both are acting towards north. Applying Newton's second equation of motion,

$s' = ud' + \frac{1}{2}a''t^2$

$= 10 \times 25 + \frac{1}{2} \times (-20) \times (25)^2$

= 250 - 6250 = -6000m

At t = 100 s,

For $0 \leq t \leq 30s$:

During this time interval the body will continue its motion under the mentioned force i.e. Acceleration, a= -20 m/s^2

Initial velocity, u = 10 m/s. Both of them are acting due north. Now here also applying Newton's second equation of motion,

$s_2 = ut + \frac{1}{2}a''t^2$

$= 10 \times 30 + \frac{1}{2} \times (-20) \times (30)^2$

= 300 - 9000

= -8700 M

For $30' < t \leq 100s$:

During this time interval the action of the force will no longer present. So in this part of time there will only be the uniform velocity. The velocity gained by the body after 30 s will act here as the uniform or constant velocity. As per the Newton's first equation of motion, for t = half of a minute = 30 s, final velocity is given as:

v = u + at

= 10 + (-20) $\times$ 30 = -590 m/s, due north

Velocity of the body after 30 s = -590 m/s, acceleration = 0

For motion between 30 s to 100 s, the body will continue its journey with uniform velocity, i.e., in 70 s:

$s_2 = vt + \frac{1}{2}a''t^2$

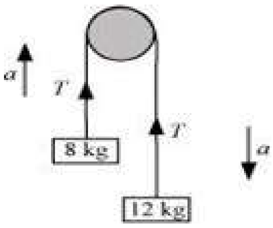
$= -590 \times 70 = -41300m$

$$= -590 \times 70 = -41300\text{m}$$

$\therefore$ Total distance, s" = $s_1 + s_2$ = - 8700 - 41300 = - 50000 m

OR

The given system of two masses 8 kg, 12 kg and a pulley can be represented as shown in the following figure. In this case weights of the two masses act downwards and tension T in the two cases act upwards:



Smaller mass, m_1 = 8 kg

Larger mass, m_2 = 12 kg

Tension in the string = T

When released, mass m_2, owing to its weight, moves downward with acceleration a, and mass m_1 moves upward with the same acceleration (as they constitute a single system).

Applying Newton's second law of motion to the system of masses:

For mass m_1:

The equation of motion can be written as:

$T - m_1g = ma$ ...(i) (as the tension T exceeding the weight m_1g causes the motion of mass m_1)

For mass m_2:

The equation of motion can be written as:

$m_2g - T = m_2a$ ...(ii)(here weight m_2g exceeding the tension T causes motion of mass m_2)

Adding equations (i) and (ii), we get:

$(m_2 - m_1)g = (m_1 + m_2)a$

$\therefore a = \left(\frac{m_2 - m_1}{m_1 + m_2}\right) g$ ...(iii)

$= \left(\frac{12-8}{12+8}\right) \times 10 = \frac{4}{20} \times 10 = 2m/s^2$

Therefore, the acceleration of both the masses is 2 m/s^2.

Substituting the value of 'a' in equation (ii), we get:

$$m_2 g - T = m_2\left(\frac{m_2 - m_1}{m_1 + m_2}\right) g$$

$$T = \left(m_2 - \frac{m_2^2 - m_1 m_2}{m_1 + m_2}\right) g$$

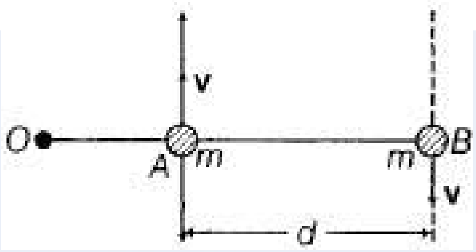
$$= \left(\frac{2m_1 m_2}{m_1 + m_2}\right) g$$

$$= \left(\frac{2 \times 12 \times 8}{12 + 8}\right) \times 10$$

$$= \frac{2 \times 12 \times 8}{20} \times 10 = 96N$$

Therefore, the tension in the string is 96 N.

36. Suppose, O be the origin chosen.



Then, angular momentum of particle at A is

$$I_1 = OA \times p = OA \times mv$$

$$= m(OA \times v)$$

and angular momentum of particle at B is

$$I_2 = OB \times p = OB \times (-mv)$$

$$= -m(OB \times v)$$

so, total angular momentum of the system of particles is

$$L = I_1 + I_2$$

$$= m(OA \times v) - m(OB \times v)$$

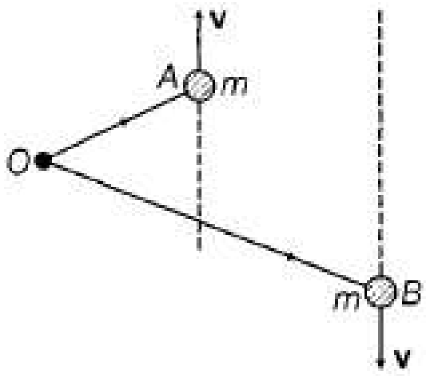
$$= m(OA - OB) \times v$$

$$= m(BA) \times v$$

$$= m(BA) \times v$$

{As, $BA =$ position vector of A - position vector of B}

Above expression is independent of choice of origin.



This is true even when particles are not in a straight line.

$L_i(I_1 \ + I_2 \ = m(OA \times \ v - OB \times \ v)$

$= m(BA) \ \times \ v$

Which is the same as a previous result. So, the angular momentum of the system is independent of the choice of origin.

OR

$l_x = yp_z - zp_y$

$l_y = zp_x - xp_z$

$l_z = xp_y - yp_x$

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

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

As we know the angular momentum of a moving particle about a point is given as,

$\vec{l} = \vec{r} \times \vec{p}$ where p and r are linear momentum and position vector respectively,

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

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

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

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

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

$l_x = yp_z - zp_y$

$l_y = xp_z - zp_x$ .....(i)

$l_z = xp_y - yp_x$

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

$z = p_z = 0$

Thus, equation (i) reduces to:

$l_x = 0$

$l_y = 0$

$l_z = xp_y - yp_x$

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

37. Mass of the automobile, m = 3000 kg

Displacement in the suspension system, x = 15 cm = 0.15 m

There are 4 springs in parallel to the support of the mass of the automobile.

The equation for the restoring force for the system:

F = -4kx = mg

Where, k is the spring constant of the suspension system

Time period, $T = 2\pi\sqrt{\frac{m}{4k}}$

And $k = \frac{mg}{4x} = \frac{3000\times10}{4\times0.15} = 5000 = 5 \times 10^4 N/\text{m}$

Spring constant, $k = 5 \times 10^4 N/m$

a. Each wheel supports a mass, M = $\frac{3000}{7}$ = 750 kg

For damping factor b, the equation for displacement is written as:

$x = x_o e^{-bt/2M}$

The amplitude of oscillation decreases by 50%.

$\therefore\ x = \frac{x_0}{2}$

$\frac{x_0}{2} = x_0 e^{-bt/2M}$

$\log_e 2 = \frac{bt}{2M}$

$\therefore b = \frac{2M \log_e 2}{t}$

Where,

Time period, $t = 2\pi\sqrt{\frac{m}{4k}} = 2\pi\sqrt{\frac{3000}{4\times5\times10^4}}$ = 0.7691 s

$\therefore b = \frac{2 \times 750 \times 0.693}{0.7691}$
= 1351.58 kg/s
Therefore, the damping constant of the spring is 1351.58 kg/s.

OR

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.