CBSE Class 11 Physics
Sample Paper 06 (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. Which of these was a major scientific major advance during industrial revolution in England and Europe?

    a. mechanized cotton spinning powered by steam

    b. Development of several machine tools for cutting metal parts.

    c. Newcomen steam engine

    d. Louie Pasteur's discovery of the link between microbes and illness

2. A stone tied to the end of a string 80 cm long is whirled in a horizontal circle with a constant speed. If the stone makes 14 revolutions in 25 s, what is the magnitude and direction of acceleration of the stone?

    a. 11.9 m s^{-2} , along the radius at every point away from the center

b. 9.9 m s^{-2} , along the radius at every point away from the center

c. 10.2 m s^{-2} , along the radius at every point towards the center

d. 9.9 m s^{-2}, along the radius at every point towards the center

3. A man of mass 70 kg stands on a weighing scale in a lift which is moving upwards with a uniform speed of 10 m s^{-1}. What would be the reading if the lift mechanism failed and it hurtled down freely under gravity?

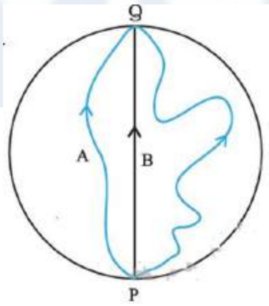
a. 105 kg

b. 70 kg

c. 0 kg

d. 35 kg

4. Three girls skating on a circular ice ground of radius 200 m start from a point P on the edge of the ground and reach a point Q diametrically opposite to P following different paths as shown in Figure. What is the magnitude of the displacement vector for each? For which girl is this equal to the actual length of path skate?



a. 200 m for each; A

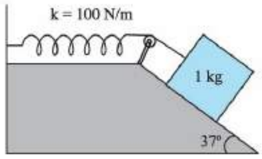
b. 300 m for each; C

c. 400 m for each; B

d. 200 m for each; B

5. A 1 kg block situated on a rough incline is connected to a spring of spring constant 100 N m^{-1} as shown in Figure. The block is released from rest with the spring in the

unstretched position. The block moves 10 cm down the incline before coming to rest. Find the coefficient of friction between the block and the incline. Assume that the spring has a negligible mass and the pulley is frictionless.



a. 0.115

b. 0.3

c. 0.07

d. 0.25

6. A lead cube measures 6.00 cm on each side. The bottom face is held in place by very strong glue to a flat horizontal surface, while a horizontal force F is applied to the upper face parallel to one of the edges. How large must F be to cause the cube to deform by 0.250 mm? (Shear modulus of lead = 0.6 $\times$ 10^{10} Pa)

a. $0.9 \times 10^5 \ N$

b. $1.4 \times 10^5 \ N$

c. $2.0 \times 10^5 \ N$

d. $1.6 \times 10^5 \ N$

7. A 1.00-kg block of copper at 20.0°C is dropped into a large vessel of liquid nitrogen at 77.3 K. How many kilograms of nitrogen boil away by the time the copper reaches 77.3 K? (The specific heat of copper is 0.092 0 cal/g. $^\circ$C. The latent heat of vaporization of nitrogen is 48.0 cal/g.)

a. 0.434 kg

b. 0.384 kg

c. 0.404 kg

d. 0.414 kg

8. First Law of Thermodynamics is

a. the general law of conservation of mass applied to any system in which the energy transfer from or to the surroundings is taken into account

b. the general law of conservation of angular momentum applied to any system in which the energy transfer from or to the surroundings is taken into account

c. the general law of conservation of energy applied to any system in which the energy transfer from or to the surroundings is taken into account

d. the general law of conservation of momentum applied to any system in which the energy transfer from or to the surroundings is taken into account

9. Molar volume is the volume occupied by 1 mol of any (ideal) gas at standard temperature and pressure (STP : 1 atmospheric pressure, 0 $^{\circ}$C). The value of Molar volume is

a. 20.4 liters

b. 24.4 liters

c. 23.7 liters

d. 22.4 liters

10. The speed of propagation of a sinusoidal wave is given by $V = \nu\lambda$ where

a. v is the angular frequency and λ is the wavelength

b. ν is the reciprocal of the time period and λ is the wavelength

c. v is the reciprocal of the period and λ is the wave number

d. v is the reciprocal of the period and λ is the dispersion

11. Fill in the blanks:

If the displacement-time graph of a particle is parallel to time-axis, then the velocity of the particle is ________.

OR

Fill in the blanks:

A flying kite in the sky comes under _______ dimensional motion.

12. Fill in the blanks:

    ________ is the scientific principle behind the technology of steam engine.

13. Fill in the blanks:

    If two or three-unit vectors are perpendicular to each other, they are known as _______ vectors.

14. Fill in the blanks:

    The Young's modulus for a perfect rigid body is ________.

15. Fill in the blanks:

    The principle of ________ states that total heat given by a hotter body equals to the total heat received by colder body.

16. What is the maximum number of components into which a vector can be resolved?

17. What is meant by positive work, negative work and zero work? Illustrate your answer with example?

18. Iceberg floats in water with part of it submerged. What is the fraction of the volume of iceberg submerged if the density of ice is ρ_i = 0.917 gm/cm^3?

19. Find the efficiency of the Carnot engine working between boiling point and freezing point of water.

20. We cannot hear echo in a room. Explain?

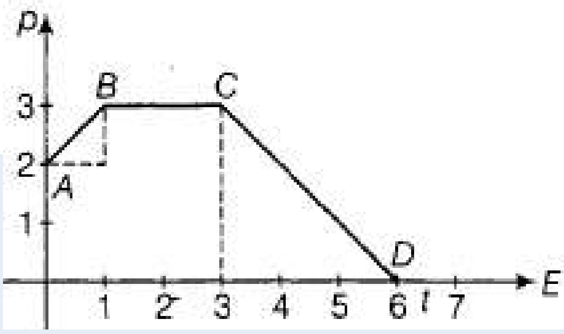
OR

Why the pitch of an organ pipe on a hot summer day is higher?

21. What causes variation in velocity of a particle?

22. Vectors A and B having equal magnitude of 5 units are inclined each other by 60°. Find the magnitude of sum and difference of these vectors.

23. The figure shows momentum versus time graph for a particle moving along x-axis. In which region force on the particle is large. Why?



24. If radius of earth is 6400km, what will be the weight of 1 quintal body if taken to the height of 1600 km above the sea level?

25. The Young's modulus of a wire of length L and radius r is Y. If the length is reduced $\frac{L}{2}$ to and radius $\frac{r}{4}$, what will be its Young's modulus? Why?

26. Define Coefficient of thermal conductivity. Two metal slabs of the same area of cross-section, thickness d_1 and d_2 having thermal conductivities K_1 and K_2 respectively are kept in contact. Deduce an expression for equivalent thermal Conductivity.

OR

A big size balloon of mass M is held stationary in the air with the help of a small block of mass $\frac{M}{2}$ tied to it by a light string such that both float in mid-air. Describe the motion of the balloon and the block when the string is cut.

27. If a vessel contains 1 mole of O2 gas (molar mass 32) at temperature T. The pressure of the gas is P. What is the pressure if an identical vessel contains 1 mole of He at a temperature 2T?

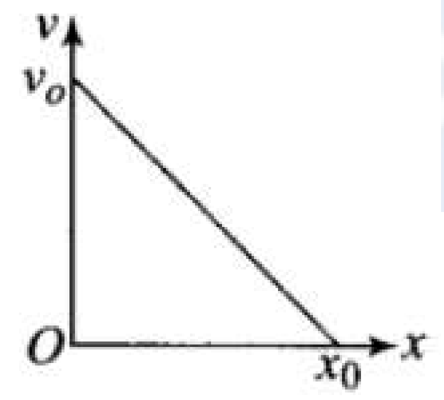
OR

Ten small planes are flying at a speed of 150 km/h in total darkness in an air space that is $20 \times 20 \times 1.5 \text{ km}^3$ in volume. You are in one of the planes, flying at random within this space with no way of knowing where the other planes are. On the average about how long a time will elapse between near collision with your plane. Assume for this rough computation that a safety region around the plane can be approximated by a sphere of radius 10 m.

28. Using a screw gauge, the diameter of a metal rod was measured. The observation are given as follows: 0.39 mm, 0.38 mm, 0.37 mm, 0.41 mm, 0.38 mm, 0.38 mm, 0.37 mm, 0.40 mm, 0.39 mm. Calculate

   i. the most accurate value of the diameter,
   ii. the relative error, and
   iii. the percentage error in the measurement of the diameter.

29. The velocity-displacement graph of a particle is shown in the figure.



   a. Write the relation between v and x.
   b. Obtain the relation between acceleration and displacement and plot it.

30. Consider a one-dimensional motion of a particle with total energy E. There are four regions A, B, C and D in which the relation between potential energy *V*, kinetic energy *(K)* and total energy *E* is as given below:
Region A : V > E
Region B : V < E
Region C : K > E

Region D : V > K

State with reason in each case whether a particle can be found in the given region or not.

31. A satellite is revolving is a circular path close to a planet of density ρ. Find an expression for its period of revolution?

32. Water is flowing with a speed of 2.0 m s^{-1} in a horizontal pipe with cross-sectional area decreasing from 2×10^{-2} m^2 to 1×10^{-2} m^2 at pressure 4×10^4 Pa. What will be the pressure at smaller cross-section?

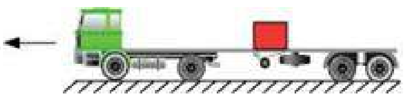
OR

A 50 kg girl wearing high heel shoes balances on a single heel. The heel is circular with a diameter 1.0 cm. What is the pressure exerted by the heel on the horizontal floor?

33. Two different adiabatic paths for the same gas intersect two thermals at T_1 and T_2 as shown in P-V diagram. How does $\frac{VA}{VD}$ Compare with $\frac{VB}{VC}$?

34. The length of a sonometer wire between two fixed ends is 110cm. Where the two bridges should be placed so as to divide the wire into three segments whose fundamental frequencies are in the ratio of 1:2:3?

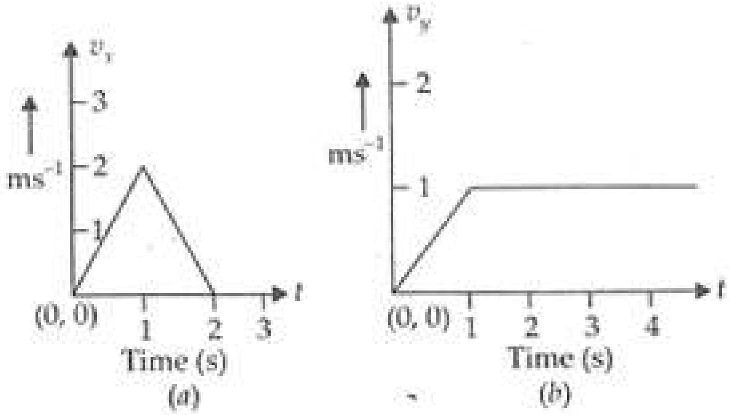
35. i. Briefly explain static friction, limiting friction and kinetic friction. How do they vary with the applied force?
    ii. The rear side of a truck is open and a box of 40 kg mass is placed 5 m away from the open end. The coefficient of static friction between the box and the surface below it is 0.15. On a straight road, the truck starts from rest and accelerates with 2 ms^{-2}. At what distance from the starting point does the box fall off the truck? (Given, g = 10 m/s^2)



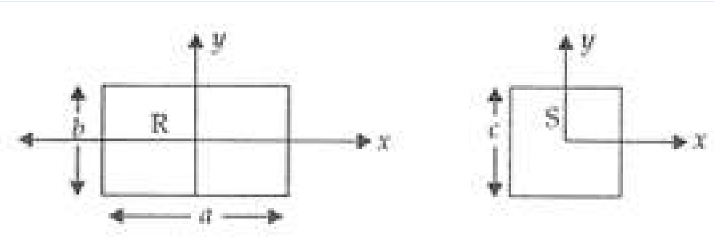
OR

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

ii. Figure (a) and (b) shows $(v_x - t)$ and $(v_y - t)$ diagrams for a body of unit mass. Find the force acting on the body, as a function of time.



36. A uniform square plate S (side c) and a uniform rectangular plate R (sides b, a) have identical areas and masses (Figure).



Show that

i. $\frac{I_{xR}}{I_{xs}} < 1$
ii. $\frac{I_{yR}}{I_{ys}} > 1$
iii. $\frac{I_{zR}}{I_{zs}} > 1$

OR

Prove the result that the velocity v of translation of a rolling body (like a ring, disc, cylinder or sphere) at the bottom of an inclined plane of a height h is given by $v^2 = \frac{2gh}{(1+k^2/R^2)}$.

Using dynamical consideration (i.e. by consideration of forces and torques). Note k is the radius of gyration of the body about its symmetry axis, and R is the radius of the body. The body starts from rest at the top of the plane.

37. Show that for a particle in linear SHM the average kinetic energy over a period of oscillation equals the average potential energy over the same period.

OR

Find the time period of mass M when displaced from its equilibrium positon and then released for the system shown.

Solution
Section A

1. (d) Louie Pasteur's discovery of the link between microbes and illness
   Explanation: By the 1780s, the British Industrial Revolution, which had been developing for several decades, began to further accelerate. Manufacturing, business, and the number of wage laborers skyrocketed, starting a trend that would continue into the first half of the 19th century. This was the time when Louie Pasteur discover the link between microbes and illness.
2. (d) 9.9 $\mathrm{m\ s}^{-2}$, along the radius at every point towards the center
   Explanation: Length of the string, l = 80 cm = 0.8 m

   Number of revolutions = 14
   Time taken = 25 s
   Frequency, $\nu = \frac{Number\ of\ revolutions}{Time\ taken} = \frac{14}{25} Hz$
   Angular frequency, $\omega = 2\pi\nu$
   = $2 \times \frac{22}{7} \times \frac{14}{25} = \frac{88}{25}\ rad\ s^{-1}$
   Centripetal acceleration, $a_c = \omega^2 r$
   = $(\frac{88}{25})^2 \times 0.8$
   = 9.9 ms^{-2}
   The direction of centripetal acceleration is always directed along the string, towards the centre, at all points.

3. (c) 0 kg
   Explanation:

   When the lift falls freely under gravity, a=g

   Therefore Apparent weight,

   $$R = m(g-a) = m(g-g) = 0$$

This is the condition of weightlessness.

4. (c) 400 m for each; B

   Explanation:

   i. PQ = diameter = displacement for each girl = 2r = 2 $\times$ 200 = 400 m
   Since, displacement vector does not depend upon the actual path length and it is the shortest distance between initial and final position, so in the case of each girl the displacement is 400 m.
   ii. This is equal to the actual length of the path skated by girl B.

5. (a) 0.115

   Explanation: Weight of block can be resolved in two components.

   component parellal to incline plane $(mg\sin 37^{\circ})$ and component perpendicular to plane $(mg\cos 37^{\circ})$
   at equilibrium

   R = mg cos 37^{o}
   f = μR = μmg cos 37
   Net force acting on the block = $mg\sin 37^{\circ} - f$
   $= mg\sin 37^{\circ} - \mu mg\cos 37^{\circ}$
   At equilibrium, the work done by the block is equal to the potential energy of the spring, i.e.,
   = mg sin 37^{o} - μmg cos 37^{o} = $\frac{1}{2}$ kx^2
   $(1 \times 9.8 \times 0.6) - (\mu \times 1 \times 9.8 \times 0.8) = \frac{1}{2} \times 100 \times 0.1$
   0.602 - 0.799μ = 0.510

   $\mu = \frac{0.092}{0.799} = 0.115$

6. (a) $0.9 \times 10^{5}\quad N$ **Explanation:** shear modulus (η) is given as
   $\eta = \frac{\text{shear stress}}{\text{shear strain}} = \frac{F/A}{x/h} \rightarrow (1)$
   given for Lead $\eta = 4.4 \times 10^{10}$ pa $x = 0.250\text{mm}' h = 6.0\text{cm}$
   side of cube a = 6.0 cm

   area A = a $\times$ a = 6.0 $\times$ 6.0 = 36.0 cm^2
   from equation 1
   $F = \frac{\eta \times A \times x}{h} = \frac{0.6 \times 10^{10} \times 36 \times 10^{-4} \times 0.250 \times 10^{-3}}{6.0 \times 10^{-2}}$

$F = 0.9 \times 10^5 N$

7. (d) 0.414 kg

   Explanation: heat given by copper = heat gain by nitrogen

   $$ms\Delta T = m_{N_2} L$$
   $$1000 \times 0.092 \times 215.7 = m_{N_2} \times 48$$
   $$m_{N_2} = 414gm = 0.414Kg$$

8. (c) the general law of conservation of energy applied to any system in which the energy transfer from or to the surroundings is taken into account

   Explanation: The first law of thermodynamics is the application of the conservation of energy principle to heat and thermodynamic processes:

   $$\Delta Q = \Delta U + \Delta W$$

9. (d) 22.4 liters

   Explanation:

   $$PV = nRT$$
   $$V = \frac{nRT}{P} = \frac{1 \times 8.31 \times 273}{1.01 \times 10^5} = 0.02224m^3 = 22.4lit$$

10. (b) ν is the reciprocal of the time period and λ is the wavelength

    Explanation: v is here frequency

    we know that
    Using Speed = distance /time
    For one cycle, distance = λ , time = T
    Hence V= λ /T
    $V = \nu\lambda$

11. zero

OR

three

12. Laws of thermodynamics

13. orthogonal unit

14. ∞

15. Calorimetry

16. Infinite.

17. i. When the direction of applied force is in the direction of displacement then work done is said to be positive. e.g. When a body falls under the action of gravity, $\theta = 0^\circ$
    ii. When the direction of applied force is opposite to the direction of displacement then work done is said to be negative. e.g. When brakes are applied on a moving vehicle work done by a braking force is negative.
    iii. When the direction of applied force is perpendicular to the direction of displacement then work done is zero. e.g. A coolie carrying a load on his head moves on a horizontal platform, $\theta = 90^\circ$ work done is zero.

18. As iceberg is floating on surface of sea

    $\therefore$ Weight of ice berg = Weight of displace liquid

    $V \cdot p_{ic} g = V p_w g$

    V = Volume of ice berg

    V' = Volume of ice berg inside water or volume of displaced water by iceberg

    $\frac{\text{Volume of iceberg submerged}}{\text{Volume of iceberg}} = \frac{V'}{V} = \frac{P_{\text{ice}}}{p_w} = \frac{.917}{1}$

    Hence 0.917 part of iceberg body is submerged inside water.

19. Efficiency of Carnot engine, $\eta = 1 - \frac{T_2}{T_1}$
    $= 1 - \frac{273\text{K}}{373\text{K}} = \frac{100}{373}$
    $= 0.268 = 26.8\%$

20. We know that the basic condition for an echo to be heard is that the obstacle should be rigid and of large size. Also the obstacle should be at least at a distance of 17m

from the source. Since the length of the room is generally less than 17m, the conditions for the production of Echo are not satisfied. Hence no echo is heard in a room.

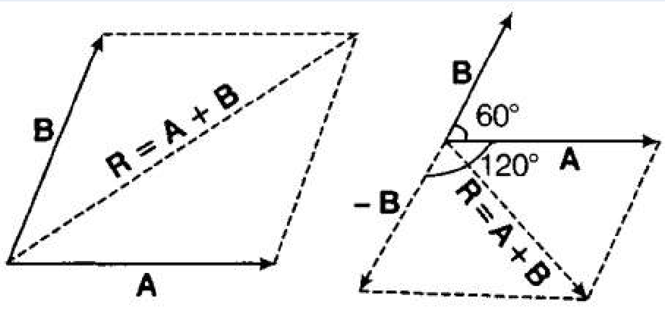
OR

On a hot day, the velocity of sound will be more since (frequency proportional to Velocity) the frequency of sound increases and hence its pitch increases.

21. Velocity of a particle changes

    i. If magnitude of velocity changes
    ii. If direction of motion changes.

22. Given, A = B = 5 units, angle between the vectors A and B, θ = 60°.
    To find: A + B = ?
    and A - B = ?



The magnitude of the resultant vectors of the sum,

$$R = \sqrt{A^2 + B^2 + 2AB\cos\theta}$$
$$= \sqrt{5^2 + 5^2 + 2 \times 5 \times 5 \times \cos 60^\circ}$$

Using cos 60^o = 0.5,

Therefore, R $= 5\sqrt{3}$

The magnitude of the resultant vectors of the difference, when vector B = - B and angle between A and B is 120° is,

R = $\sqrt{A^2 + (-B)^2 + 2AB\cos\theta}$

$$R = \sqrt{5^2 + 5^2 + 2 \times 5 \times 5\cos 120^\circ}$$

Using cos 120^o = - 0.5,

R = 5 units

23. The net force, $F_{net} = \frac{dp}{dt}$

Also, the rate of change of momentum = slope of the graph.

From the graph, $slope\ AB = slope\ CD$

And $slope(BC) = slope(DE) = 0$

Therefore, the force acting on the particle is equal in regions $AB\ and\ CD$ and in regions $BC\ and\ DE$ (which is zero).

24. R = 6400km = 6400 $\times$ 10^3m

h = 1600km

w = mg = 1 quintal = 100 kg = 100 $\times$ 9.8 N=980N

new weight of body is

weight (w') = mg'

gravity at height

$$g' = g\left(\frac{R}{R+h}\right)^2$$

$$w' = 100 \times 9.8\left(\frac{6400}{1600+6400}\right)^2$$

w' = 100 $\times$ 9.8N $\times$ 0.64= 627.2N

w'=627.2/9.8 =64kg

25. The value of Young's modulus of wire will remain unchanged at Y. On changing, length and radius values of strain and stress may change but Young's modulus depends only on the material of wire. Hence its value will remain unchanged.

26. Thermal conductivity (K) of a substance of unit length is the amount heat transferred through unit area per unit time when there is unit temperature difference between the two terminals of the substance.

In steady state the heat passing in unit time ($\frac{Q}{t}$)through the two slabs will remain same.

Now if K is the equivalent thermal conductivity

And $T_1 - T_2 = (T_1 - T) + (T - T_2)$

T_1, T_2 and T are the temperatures of left end of 1st slab, right end of 2nd slab and the junction connecting two slabs respectively.

$\frac{Q}{t} = \frac{K_1 A(T_1 - T)}{d_1} = \frac{K_2 A(T - T_2)}{d_2} \Rightarrow \frac{T_1 - T}{\frac{d_1}{K_1 A}} = \frac{T - T_2}{\frac{d_2}{K_2 A}} = \frac{T_1 - T_2}{\frac{d_1}{K_1 A} + \frac{d_2}{K_2 A}}$ ....(i)[applying the principle, $\frac{a}{b} = \frac{c}{d} = \frac{a+c}{b+d}$]

Now if K be the equivalent thermal conductivity of the combination, then -

$\frac{Q}{t} = \frac{T_1 - T_2}{\frac{d_1 + d_2}{KA}}$....(ii)

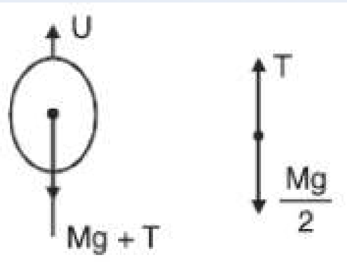
Comparing equations (i) and (ii) we get,

$\therefore \quad \frac{d_1 + d_2}{KA} = \frac{d_1}{K_1 A} + \frac{d_2}{K_2 A}$

$\therefore \quad \frac{d_1 + d_2}{K} = \frac{d_1}{K_1} + \frac{d_2}{K_2}$

$\Rightarrow K = \frac{(d_1 + d_2)}{\frac{d_1}{K_1} + \frac{d_2}{K_2}}$

OR



When the balloon is held stationary in air, the forces acting on it get balance

Up thrust = Wt. of Balloon + Tension in string

U = Mg + T

For the Small block of mass $\frac{M}{2}$ floating stationary in air

$T = \frac{M}{2} g$

$\therefore U = MG + \frac{M}{2} g = \frac{3}{2} Mg$

When the string is cut T = 0, the small block begins to fall freely, the balloon rises up with an acceleration "a such that

U - Mg = Ma

$\frac{3}{2} Mg - Mg = Ma$

$a = \frac{g}{2}$ in the upward direction.

27. By ideal gas equation :$\rightarrow$

PV = nRT

P = pressure

V = volume

n = No, of molecule per unit volume

R = Universal Gas Constant

T temperature

Now, $\frac{PV}{T} = nR$ or $\frac{PV}{T} = \text{constant}$

Hence $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ ...(i)

Now, according to question: $\rightarrow$

P_1 = P

T_1 = T

V_1 = V

T_2 = 2T

Using above equations in equation (i)

$P_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{V_2}$

$P_2 = \frac{PV}{T} \times \frac{2T}{V}$ V1 = V2 = V ($\because$ idantical vessels)

P_2 = 2P

Hence pressure gets doubled.

OR

Given, velocity of each plane(v) = 150 km/h = (150 ×5)/18 m/s ;volume of each space(V) = $20 \times 20 \times 1.5$

Number of planes, N =10, diameter (d) = 2$\times$10= 20 m

Time taken by plane, t = λ/v

and mean free path

i.e, $\lambda = \frac{1}{\sqrt{2}\pi d^2 n}$

where, d = diameter and n = number of density

So, $n = \frac{N}{V} = \frac{10}{20\times20\times1.5} = 0.0167\text{km}^{-3}$

and time elapse between collision,

$t = \frac{1}{\sqrt{2}\pi d^2 (N/V) \times v}$

$= \frac{18}{1.414\times3.14\times(20)^2\times0.0167\times10^{-9}\times150\times5}$ = 224.78 h

28. i. Mean diameter

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

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

= 0.38556 mm

$\simeq$ 0.39 mm

ii. Absolute errors,

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

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

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

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

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

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

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

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

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

Mean absolute error is given by

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

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

= 0.01111 mm = 0.01 mm

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

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

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

29. In this question, we will use the equation of the straight line graph (linear equation).

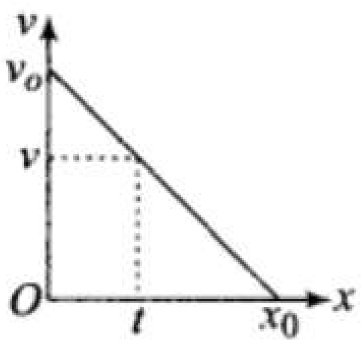
y = mx + c.

In this equation, m is the slope of the graph and c is the interception on the y-axis.

Now according to the problem, initial velocity $= v_0$

Let the distance traveled in time $t = x_0$.

For the graph $\tan\theta = \frac{v_0}{x_0} = \frac{v_0 - v}{x}$ ....(i)



Where, v is velocity and x is displacement at any instant of time t.

From Equation (i), we have

$v_0 - v = \frac{v_0}{x_0}x$

$\Rightarrow \quad v = \frac{-v_0}{x_0}x + v_0$

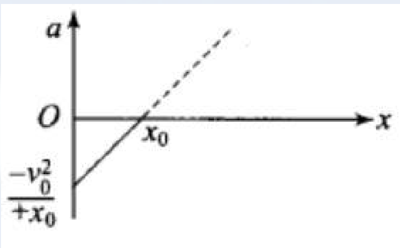
We know that,

Acceleration, $a = \frac{dv}{dt} = \frac{-v_0}{x_0}\frac{dx}{dt} + 0$

$\Rightarrow \quad a = \frac{-v_0}{x_0}(v)$

$= \frac{-v_0}{x_0}\left(\frac{-v_0}{x_0}x + v_0\right) = \frac{v_0^2}{x_0^2}x - \frac{v_0^2}{x_0}$

Graph of a versus x is given below.



30. i. For region A: V > E

E = V + K $\Rightarrow$ K = E - V

$\because$ V > E So K < 0

K.E. is negative. Which is not possible. Thus the particle cannot be in this region.

ii. In region B: V < E

$\Rightarrow$ K = E - V

$\because$ K > 0

This case is possible. Thus particle can be in this region.

iii. Region C:K > E as total energy E = K + V

$\Rightarrow$ V = E - K

$\therefore$ V < 0

P.E. is negative.

This is also possible because P.E. can be negative. Thus particle can be found in this region.

iv. Region D: V > K

K = E - V

This is also possible as P.E. for a system can be greater than KE.

Thus particle can be found in this region.

31. It is the time taken by satellite to complete one revolution around the earth is called time period

Distance travelled in one revolution is $2\pi r$

Time period =distance travelled in one revolution/orbital velocity

$T = \frac{2\pi r}{v}$.......... 1

v is orbital velocity

$v = \sqrt{\frac{Gm}{r}}$............2

put equation 2 in equation 1

$T = \frac{2\pi r}{\mathrm{v}} = \frac{2\pi r}{\sqrt{\frac{Gm}{r}}} = 2\pi\sqrt{\frac{r^3}{Gm}}$

If the earth is supposed to be a sphere of mean density ρ then the mass of the earth is

M= $\frac{4}{3}\pi R^3\rho$

$\mathrm{T} = \sqrt[2\pi]{\frac{R^3}{G\cdot\frac{4}{3}\pi R^3\rho}}$

$T = 2\pi\sqrt{\frac{3}{4\pi G\rho}}$

$T = \sqrt{\frac{3\pi}{G\rho}}$

32. Given,

$A_1 = 2\times10^{-2}m^2, v_1 = 2.0\ ms^{-1}$, $P_1 = 4\times10^4\ Pa$ and $A_2 = 1\times10^{-2}m^2$

According to the equation of continuity, $A_1v_1 = A_2v_2$

or $v_2 = \frac{A_1v_1}{A_2} = \frac{2\times10^{-2}\times2.0}{1\times10^{-2}} = 4.0\mathrm{ms}^{-1}$

According to Bernoulli's theorem, we have

$\frac{1}{2}\rho v_1^2 + P_1 = \frac{1}{2}\rho v_2^2 + P_2$

$$\Rightarrow \quad P_2 = P_1 + \frac{1}{2}\rho\left(v_1^2 - v_2^2\right)$$
$$= 4\times10^4 + \frac{1}{2}\times10^3\times\left[(2.0)^2 - (4.0)^2\right]$$
$$= 4\times10^4 - 0.6\times10^4 = 3.4\times10^4\mathrm{Pa}$$

OR

mass of girl m = 50kg

diameter of heel d = 1 cm = 0.01m

radius = heel $r = \frac{d}{2} = 0.005m$

area of heel $A = \pi r^2 = 3.14\times(0.005)^2$

$A = 7.85\times10^{-5}m^2$

force exerted by heel on floor F = mg $= 50\times9.8 = 490N$

pressure exerted by heel on floor $P = \frac{F}{A}$

$P = \frac{490}{7.85\times10^{-5}}$

$P = 6.24\times10^6 Nm^{-2}$

33. let AB and CD are isothermals at temperature T_1 and T_2 respectively

here BC and AD are adiabatic.

from the figure, points A and D lie on the same adiabatic.

for an adiabatic process of an ideal gas

$\therefore PV^\gamma = Const$

we know that, P $\propto$ T

hence $\therefore TV^\gamma = Const$

$\therefore T_A V_A^{\gamma-1} = T_D V_D^{\gamma-1}$

$T_1 V_A^{\gamma-1} = T_2 V_D^{\gamma-1}$

$\frac{T_1}{T_2} = \left(\frac{V_D}{V_A}\right)^{\gamma-1}$ ...(1)

Also from the figure, points B and C lie on the same adiabatic,

$\mathrm{T_B V_B^{\gamma-1} = T_C V_C^{\gamma-1}}$

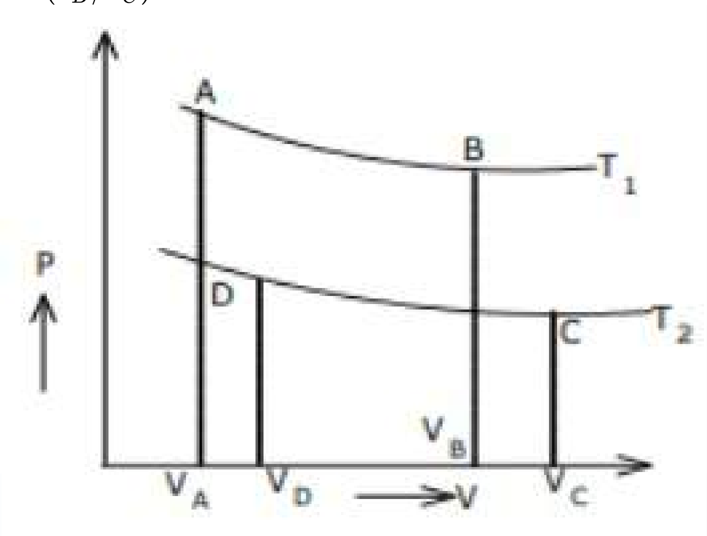
or $T_1 V_B^{\gamma-1} = T_2 V_C^{\gamma-1}$

$\because \frac{\mathrm{T_1}}{\mathrm{T_2}} = \left(\frac{\mathrm{V_C}}{\mathrm{V_B}}\right)^{\gamma-1}$ ...(2)

From equation (1) & (2)

$$\left(\frac{\mathrm{V_D}}{\mathrm{V_A}}\right)^{\gamma-1} = \left(\frac{\mathrm{V_C}}{\mathrm{V_B}}\right)^{\gamma-1}$$

$$\frac{V_D}{V_A} = \frac{V_C}{V_B}$$
$$\frac{V_A}{V_D} = \frac{V_B}{V_C}$$
$$\therefore \frac{(V_A/V_D)}{(V_B/V_C)} = 1$$



34. Let l_1, l_2 and l_3 be the length of the three parts of the wire and f_1, f_2 and f_3 be their respective frequencies.

Since T and m are fixed quantities, and 2 is constant

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

$\Rightarrow f = \alpha \frac{1}{l}$

or r_1 = constant

So, f_1 l_1 = Constant $\rightarrow$ (1)

f_2 l_2 = Constant $\rightarrow$ (2)

f_3 l_3 = Constant $\rightarrow$ (3)

Equating equation 1), 2) & 3)

$f_1 l_1 = f_2 l_2 = f_3 l_3$

Now, $l2 = \frac{f_1}{f_2} l|$1l

$\Rightarrow l_2 = \frac{1}{2} l_1 \rightarrow (4) \left(\frac{f_1}{f_2} = \frac{1}{2}\right)$ Given

Also, $l_3 = \frac{f_1}{f_3} l_1$

$\Rightarrow l_3 = \frac{1}{3} l_1 \left(\frac{f_1}{f_3} = \frac{1}{3} (\text{given}) \right)$

Now, Given Total length = 110cm

i.e $l_1 + l_2 + l_3 = 110cm$

$l_1 + \frac{1}{2} l_1 + \frac{1}{3} l_1 = 110$

$\Rightarrow \frac{11 l_1}{6} = 110$

$\Rightarrow l_1 = \frac{110 \times 6}{11} = 60cm$

i. e

$\Rightarrow. l_1 = 60cm$

$\Rightarrow l_2 = 30cm$

Now,

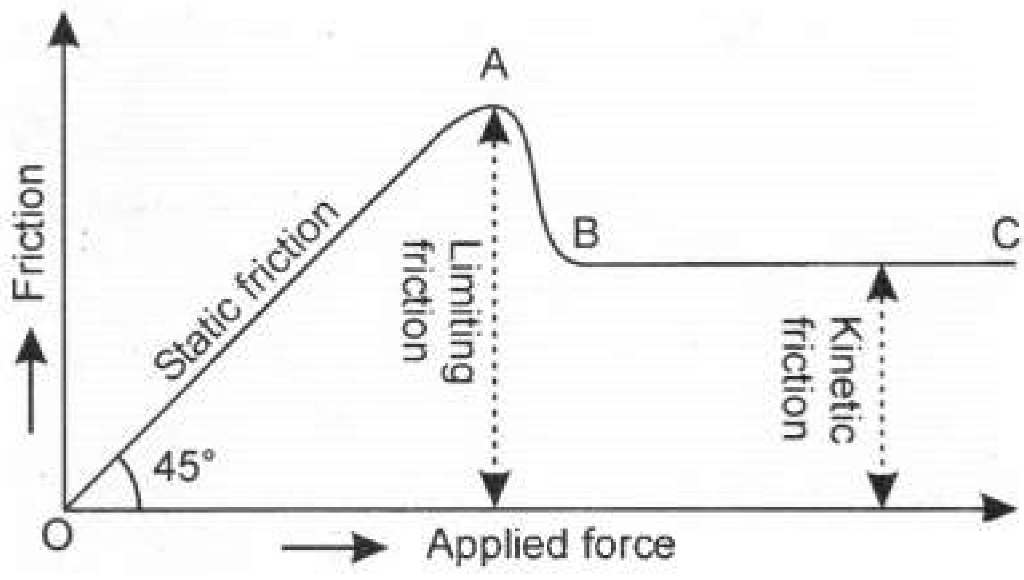
$\Rightarrow l_3 = \frac{l_1}{3}$

$\Rightarrow l_3 = \frac{60}{3}$

$\Rightarrow l_3 = 20$ cm

So length of three parts are 60cm, 30cm, 20cm.

35. i. We know that when the applied force on a body is small enough, it does not move. It means that force of friction is just balancing the applied force. However, as the applied force is increased beyond a limit, the body starts moving. Force of friction is present when the given body is in motion.



From these considerations we classify friction in case of sliding motion in following three categories:

Static friction: Static friction is a self-adjusting force because it comes into play when the body is lying over the surface of another body without any motion. If we have not applied any force on a body to move the body, the frictional force also becomes zero. In Figure, the region OA of the graph is the region of static friction.

Limiting friction: It is the maximum value of static friction. Thus, limiting friction is the force of friction at the moment when a body just tends to slide over the surface of another body i.e, when that body overcomes the force of static friction, the maximum value of static friction is reached which is known as limiting friction. In the figure, frictional force corresponding to point A represents the limiting friction.

Kinetic friction: Kinetic friction is that opposing (or retarding) force which comes into play when a body actually slides over the surface of another body. The value of kinetic friction for a given pair of surfaces is less than the corresponding value of limiting friction. Moreover, the force of kinetic friction throughout remains constant for a given body and does not depend upon the speed of motion of the body. In the figure, the region BC of the graph is representing kinetic friction.

ii. In this problem the backward reaction force produced in the box by the movement of the truck exceeds the static frictional force offered by the floor of the truck on the box in the direction of motion of the truck and the box falls off the truck after a certain time.

Mass of the box, m = 40 kg

Coefficient of static friction, μ_s = 0.15

Initial velocity, u = 0

Acceleration, a = 2 m/s^2

Distance of the box from the end of the truck, s' = 5 m

As per Newton's second law of motion, the force on the box caused by the accelerated motion of the truck is given by:

F = ma

= 40 $\times$ 2 = 80 N

As per Newton's third law of motion, an equal and opposite reaction force of 80 N is acting on the box in the backward direction. A portion of this backward reaction force on the box is opposed by the force of static friction f_s, acting between the box and the floor of the truck in the direction of motion of the truck. This force is given by:

$f_s = \mu_s mg$

$= 0.15 \times 40 \times 10 = 60N$

$\therefore$ Net force acting on the block:

F_{net} = 80 - 60 = 20 N, directed backward, which is responsible for the falling of the box from the truck.

The backward acceleration produced in the box is given by:

$a_{back} = \frac{F_{net}}{mass\ of\ the\ box(m)} = \frac{20}{40} = 0.5\mathrm{m/s}^2$

Using Newton's second equation of motion, time t can be calculated as:

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

$\Rightarrow 5 = 0 + \frac{1}{2} \times 0.5 \times t^2$

$\therefore t = \sqrt{20}\, s$

Hence, the box will fall from the truck after $\sqrt{20}\, s$ from the starting point.

The distance s, travelled by the truck in $\sqrt{20}\, s$ is given by Newton's 2nd law of motion :

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

$= 0 + \frac{1}{2} \times 2 \times (\sqrt{20})^2$

= 20m

i.e. when the truck covers a distance of 20m from the starting point, the box falls off the truck.

OR

i. 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, $\vec{F} = m\vec{a}$

ii. Consider Figure (a)
   $v_x = 2t\ m/s$ For $0 < t < 1s$
   Initial velocity in this time interval $v_{x_1} = 0\ m/s$ and final velocity $v_{x_2} = 2\ m/s$
   $\therefore a_x = \frac{v_{x_2} - v_{x_1}}{t} = \frac{2}{1} = 2\ m/s^2$ For $0 < t < 1s$
   $v_x = 2(2-t)$for $1 < t < 2s$
   Initial and final velocities in this time interval are $v'_{x_1} = 2\ m/s$ and
   $v'_{x_2} = 0\ m/s$ respectively.
   $\therefore a'_x = \frac{v'_{x_2} - v'_{x_1}}{t} = \frac{0-2}{1} = -2\ m/s^2$ for $1 < t < 2s$
   $\therefore F_x = ma$ and m = 1 unit (Given)
   $\therefore F_x = 1 \times 2 = 2$ units for $0 < t < 1s$
   and $F'_x = 1 \times (-2) = -2$ units For $2 > t > 1\ s$
   Similarly, from figure (b)
   $a_y = \frac{1}{1} = 1\ ms^{-2}$ 0 < t < 1s
   $F_y = ma = 1.1 = 1$ unit for 0 < t < 1s
   $a'_y = 0$ for $t > 1s$

$F'_y = 1 \times 0 = 0$ unit for $t > 1\ s$

$\vec{F} = \vec{F}_x\,\hat{i} + F_y\,\hat{j}$

Now in vector form, $\vec{F} = F_x\hat{i} + F_y\hat{j} = 2\hat{i} + 1\hat{j}$ units for 0 < t < 1s

$\vec{F}' = F'_x\hat{i} + F'_y\hat{j} = -2\hat{i} + 0\hat{j}\ units$ for $1 < t < 2s$

$\therefore \vec{F} = -2\hat{i}\ units$ for 1 < t < 2 s

For more than 2 sec $\left.\begin{array}{l} a_y = 0 \\ a_x = 0 \\ a'_x = 0\ and \\ a'_y = 0 \end{array}\right\} \quad \therefore \vec{F} = 0\ unit$

$a_x = 0$

$a_z = 0$

$a'_x = 0$

$a'_y = 0$ and

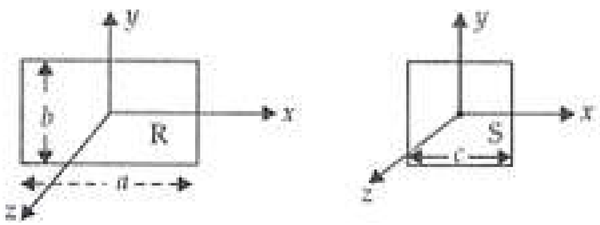
$\therefore \vec{F}$ = 0 unit

36. Moment of inertia, in physics, quantitative measure of the rotational inertia of a body- i.e., the opposition that the body exhibits to having its speed of rotation about an axis altered by the application of a torque (turning force). The axis may be internal or external and may or may not be fixed. The moment of inertia (*I*), however, is always specified with respect to that axis and is defined as the sum of the products obtained by multiplying the mass of each particle of matter in a given body by the square of its distance from the axis. The unit of moment of inertia is a composite unit of measure. In the International System (SI), m is expressed in kilograms and *r* in metres, with I (moment of inertia) having the dimension kilogram-metre square.

$m_R = m_S = m$

Area of square = Area of rectangle

$c^2 = ab$ ...(i)



a. $\because I = mr^2$

$$\frac{I_{xR}}{I_{xz}} = \frac{m\cdot\left(\frac{b}{2}\right)^2}{m\left(\frac{c}{2}\right)^2} = \frac{b^2}{4}\frac{4}{c^2} = \frac{b^2}{c^2}$$

$\because c > b$ [from (i)]

Or $c^2 > b^2$

$1 > \frac{b^2}{c^2} : \frac{I_{xR}}{I_{xs}} < 1$

Hence proved.

b. $\frac{I_{yR}}{I_{ys}} = \frac{m\left(\frac{a}{2}\right)^2}{m\left(\frac{c}{2}\right)^2} = \frac{a^2}{4} \cdot \frac{4}{c^2} = \frac{a^2}{c^2}$

$\because a > c \Rightarrow \frac{a^2}{c^2} > 1$

$\frac{I_{yR}}{I_{ys}} > 1$

c. $I_{\text{zR}} - L_{zs} = m\left(\frac{d_R}{2}\right)^2 - m\left(\frac{ds}{2}\right)^2$

$I_{zR} - I_{zS} = \frac{m}{4}\left[d_R^2 - d_S^2\right] = \frac{m}{4}\left[a^2 + b^2 - 2c^2\right]$

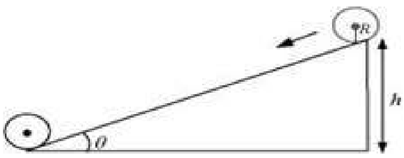
$\therefore I_{zR} - I_{zS} = \frac{m}{4}\left(a^2 + b^2 - 2ab\right) = \frac{m}{4}(a-b)^2\ (c_2 = ab)$

$\therefore I_{zR} - I_{zS} > 0 \because \frac{m}{4}(a-b)^2 > 0$

$\Rightarrow \frac{I_{\text{zR}}}{I_{zS}} > 1$ Hence proved.

OR

A body rolling on an inclined plane of height h, is shown in the following figure:



m = Mass of the body

R = Radius of the body

K = Radius of gyration of the body

At highest point,

energy of body (E_i)= PE = mgh

At lowest point,

Energy of body(E_f) = linear kinetic energy + rotation kinetic energy

= $\frac{1}{2} \times mv^2 + \frac{1}{2} \times I\omega^2$

But I = mk^2 and $\omega = \frac{v}{R}$

$$\therefore E_f = \frac{1}{2}\left(mk^2\right)\left(\frac{v^2}{R^2}\right) + \frac{1}{2}mv^2$$
$$= \frac{1}{2}mv^2\frac{k^2}{R^2} + \frac{1}{2}mv^2$$
$$= \frac{1}{2}mv^2\left(1 + \frac{k^2}{R^2}\right)$$

From the law of conservation of energy, we have:

$E_i = E_f$

$$mgh = \frac{1}{2}mv^2\left(1 + \frac{k^2}{R^2}\right)$$
$$\therefore v = \frac{2gh}{\left(1+k^2/R^2\right)}$$

Hence, the given result is proved.

37. We know that,

$\Rightarrow$The equation of displacement of a particle executing SHM at an instant t is given as:

$$\Rightarrow x = A\sin\omega t$$

Where,

$\Rightarrow$A = Amplitude of oscillation

$\Rightarrow \omega$ = Angular frequency $= \sqrt{\frac{spring\ consant}{mass}}$

$$\Rightarrow \omega = \sqrt{\frac{k}{M}}$$

$\Rightarrow$The velocity of the particle is given by :

$$\Rightarrow v = \frac{dr}{dt} = A\omega\cos\omega t$$

$\Rightarrow$The kinetic energy of the particle is given as:

$$\Rightarrow E_k = \frac{1}{2}Mv^2$$

$$\Rightarrow E_k = \frac{1}{2}M\omega^2A^2\cos^2\omega t$$

$\Rightarrow$The potential energy of the particle is given as:

$$\Rightarrow E_p = \frac{1}{2}kx^2$$

$\Rightarrow E_k = \frac{1}{2} M\omega^2 A^2 \sin^2 \omega t$

$\Rightarrow$For time period T, the average kinetic energy over a single cycle is given as:

$\Rightarrow (E_k)_{Avg} = \frac{1}{T} \int_0^T E_k dt$

$= \frac{1}{T} \int_0^T \frac{1}{2} MA^2 \omega^2 \cos^2 \omega t dt$

$= \frac{1}{2T} MA^2 \omega^2 \int_0^T \frac{(1+\cos 2\omega t)}{2} dt$

$= \frac{1}{4T} MA^2 \omega^2 \left[t + \frac{\sin 2\omega t}{2\omega}\right]$

$= \frac{1}{4T} MA^2 \omega^2 (T)$

$= \frac{1}{4} MA^2 \omega^2$ ....(i)

$\Rightarrow$And, average potential energy over one cycle is given as:

$\Rightarrow (E_p)_{Avg} = \frac{1}{T} \int_0^T E_p dt$

$= \frac{1}{T} \int_0^T M\omega^2 A^2 \sin^2 \omega t dt$

$= \frac{1}{2T} M\omega^2 A^2 \int_0^T \frac{(1-\cos 2\omega)}{2} dt$

$= \frac{1}{4T} M\omega^2 A^2 \left[t - \frac{\sin 2\omega t}{2\omega}\right]_0^T$

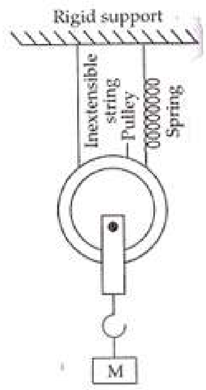
$= \frac{1}{4T} M\omega^2 A^2 (T)$ ....(ii)

$\Rightarrow$So,from equations (i) and (ii) we can infer that the average kinetic energy for a given time period is equal to the average potential energy for the same time period.

OR

When mass M is pulled and released then mass M oscillates up and down along with pulley

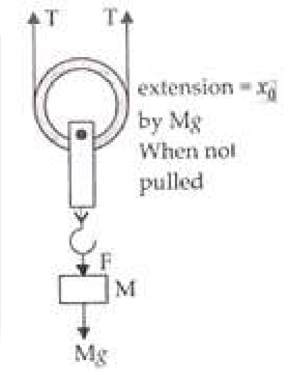
Let the spring extends by x_0 when loaded by mass M. The extension and compression of spring from initial position is larger and smaller respectively due to acceleration due to gravity by same amount of forces always. So effect of gravitational force can be neglected.



Now let the mass 'M' is pulled by force 'F' downward by displacement x. Then extension in spring will be $2x$ as string can not be extended.

So, total extension in spring $= (x_0 + 2x)$

$T' = k(x_0 + 2x)$ (when pulled downward by x)



$T = kx_0$ (when no pulling)

$F = 2T$

$F = 2kx_0$

And,

$F' = 2T'$

$\rightarrow F' = 2k(x_0 + 2x)$

Restoring force

$\rightarrow F_{rest} = -(F' - F)$

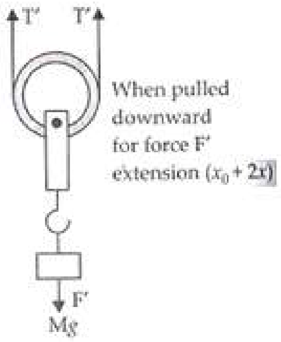
$\rightarrow f_{rest} = -[2k(x_0 + 2x) - 2kx_0)]$

$\rightarrow F_{rest} = -2k.2x$

$\rightarrow Ma = -4kx$

$a \propto -x$

$\rightarrow$ Hence, the motion is simple harmonic motion(SHM).



$\rightarrow a = -\omega^2 x$

$\therefore \omega^2 = \frac{-a}{x} = \frac{+4k}{M}$

$\omega = 2\sqrt{\frac{k}{M}}$

$\Rightarrow \frac{2\pi}{T} = 2\sqrt{\frac{k}{M}}$

$T = \pi\sqrt{\frac{M}{k}}$.

$\rightarrow$Therefore, Time period is given by relation $\rightarrow T = \pi\sqrt{\frac{\mathrm{M}}{\mathrm{k}}}$