CBSE Class 11 Physics
Sample Paper 04 (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. Technology is concerned with

   a. solving a math problem

   b. making, modification, usage, and knowledge of tools, machines, techniques, crafts, systems, and methods of organization, in order to solve a problem, improve a preexisting solution to a problem, achieve a goal, handle an applied input/output relation or perform a specific function

   c. using computers for village folks

   d. solving a physics problem

2. Which of the following physical quantities a vector?

   a. density

b. number of moles

c. angular frequency

d. acceleration

3. A monkey of mass 40 kg climbs on a rope which can stand a maximum tension of 600 N. What is the tension in the rope if the monkey climbs up with a uniform speed of 5 $\mathrm{m\,s^{-1}}$

a. 400 N

b. 275 N

c. 315 N

d. 206 N

4. A cyclist is riding with a speed of 27 km/h. As he approaches a circular turn on the road of radius 80 m, he applies brakes and reduces his speed at the constant rate of 0.50 m/s every second. What is the magnitude and direction of the net acceleration of the cyclist on the circular turn?

a. $0.84\ \mathrm{m\,s^{-2}}$, 58.5^{0} with the direction of velocity

b. $0.82\ \mathrm{m\,s^{-2}}$, 59.5^{0} with the direction of velocity

c. $0.85\ \mathrm{m\,s^{-2}}$, 56.5° with the direction of velocity

d. $0.86\ \mathrm{m\,s^{-2}}$, 54.5^{0} with the direction of velocity

5. The bob of a pendulum is released from a horizontal position. If the length of the pendulum is 1.5 m, what is the speed with which the bob arrives at the lowermost point, given that it dissipated 5% of its initial energy against air resistance?

a. 5.5 m/s

b. 4.7 m/s

c. 5.3 m/s

d. 4.9 m/s

6. How much should the pressure on a litre of water be changed to compress it by 0.10 percent? Bulk modulus of water 2.2 GPa
   a. 2.4 $\times$ 10^6 N/ m^2
   b. 2.2 $\times$ 10^6 N/ m^2
   c. 2.6 $\times$ 10^6 N/ m^2
   d. 2.0 $\times$ 10^6 N/ m^2

7. if k is the thermal conductivity of the material of the bar of cross-section A whose ends are maintained at temperatures T_C and T_D, the rate of flow of heat H is :

   a. $H = kA\frac{T_C+T_D}{2L}$

   b. $H = kA\frac{T_C-T_D}{L}$

   c. $H = kA\frac{T_C-T_D}{2L}$

   d. $H = kA\frac{T_C+T_D}{L}$

8. The Carnot cycle consists of

   a. Two isobaric processes connected by two adiabatic processes

   b. Two isochoric processes connected by two adiabatic processes

   c. Two isothermal processes connected by two adiabatic processes

   d. Two isothermal processes connected by two isobaric processes

9. The number of degrees of freedom a diatomic molecule is

   a. 5.0

   b. 6

   c. 4

d. 3

10. If y(x, t) = a sin (kx + ωt + φ) represents a wave function then 'k' is

a. the period

b. the angular wavenumber

c. the frequency

d. the phase

11. Fill in the blanks:

When an object is projected upwards, its velocity at the top-most point is _______ even though the acceleration on it 9.8 m/s^2 (g).

OR

Fill in the blanks:

If the velocity of a particle is given by $v = \sqrt{180 - 16x}$ m/s, its acceleration is _______.

12. Fill in the blanks:

________ describes a process on which the system absorbs energy from its surrounding in the form of heat.

13. Fill in the blanks:

_______ is defined as the ratio of change in velocity and the corresponding time interval.

14. Fill in the blanks:

Elasticity of most of the materials ________ with increase in the temperature.

15. Fill in the blanks:

Latent heat of _________ is in latent heat for liquid-gas state change.

16. Two vectors of magnitude 3 units and 4 units are inclined at angle 60° w.r.t each other. Find the magnitude of their difference.

17. Two thermometers are constructed in the same way except that one has a spherical bulb and the other an elongated cylindrical bulb. Which one will response quickly to temperature change?

18. Why does the velocity increase when liquid flowing in a wider tube enters a narrow tube?

19. Under what condition, an ideal Carnot engine has 100% efficiency?

20. If any liquid of density higher than the density of water is used in a resonance tube, how will the frequency change?

OR

What is the nature of water waves produced by a motorboat sailing in water?

21. When an observer is standing on earth, the trees and houses appear stationary to him. However, when he is sitting in a moving train, all these objects appear to move in a backward direction. Why?

22. A man A moves towards East with velocity 6 ms^{-1} and another man B moves N - 30°E with 6 ms^{-1}. Find the velocity of B w.r.t. A.

23. Briefly discuss the motion of Earth-Moon system about their common centre of mass.

24. The mass of moon is $\frac{M}{81}$ (where M is mass of earth). Find the distance of the point where the gravitational field due to earth and moon cancel each other. Given distance of moon from earth is 60 R, where R is radius of earth.

25. Prove that the elastic potential energy per unit volume is equal to $\frac{1}{2} \times stress \times strain.$

26. Why it is much hotter above a fire than by its side?

OR

The triple points of neon and carbon dioxide are 24.57 K and 216.55 K, respectively. Express these temperatures on the Celsius and Fahrenheit scales.

27. What will be the internal energy of 8 g of oxygen at STP?

OR

Two molecules of a gas have speeds of 9×10^6 m s^{-1} and 1×10^6 m s^{-1}, respectively. What is the root mean square speed of these molecules?

28. The volume of a liquid flowing out per second from a pipe of length l and radius r is written by a student as $V = \frac{\pi P r^4}{8\eta l}$ where P is the pressure difference between two ends of pipe and η is coefficient of viscosity of the liquid having dimensional formula $[ML^{-1}T^{-1}]$. Check whether the equation is dimensionally correct or not.

29. A food packet is released from a helicopter which is rising steadily at 2 ms^{-1}. The food packet falls on the ground after 6 s. Find the height of the helicopter when

    i. the food packet was released from it, and
    ii. when the food packet just reached the earth.

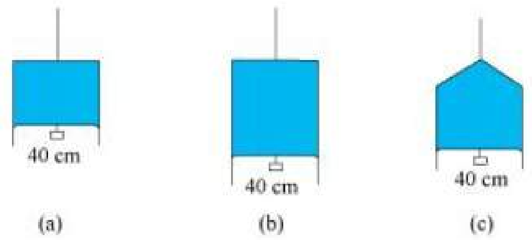
30. State work-kinetic energy theorem and prove it analytically.

31. A 400 kg satellite is in a circular orbit of radius 2R about the earth. How much energy is required to transfer it to a circular orbit of radius 4R? What are the changes in the kinetic and potential energies?

32. What is the pressure inside the drop of mercury of radius 3.00 mm at room temperature? Surface tension of mercury at that temperature (20°C) is $4.65 \times 10^{-1} Nm^{-1}$. The atmospheric pressure is 1.01×10^5 Pa. Also give the excess pressure inside the drop.

OR

In a given Figure (a) shows a thin liquid film supporting a small weight $= 4.5 \times 10^{-2}$ N. What is the weight supported by a film of the same liquid at the same temperature in Fig. (b) and (c)? Explain your answer physically.



33. Two bodies at different temperatures T_1 and T_2 are brought in contact. Under what condition, they settle to mean temperature? (after they attain equilibrium)

34. State important characteristics of the standing waves.

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

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.

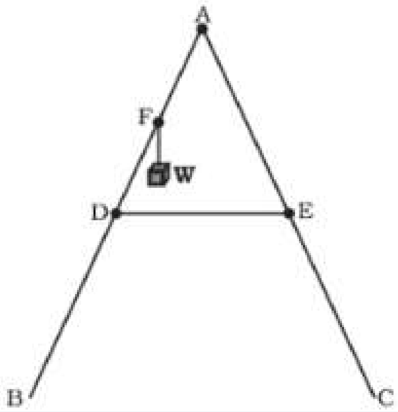
36. Derive an expression for kinetic energy of a body rotating about a given axis and find a definition for moment of inertia of the body in terms of kinetic energy of rotation.

OR

The two sides of a step ladder BA and CA are 1.6 m long and hinged at A. A rope DE, 0.5 m is tied half way up. A weight 40 kg is suspended from a point F, 1.2 m from B along the ladder BA. Assuming the floor to be frictionless and neglecting the weight of the ladder, find the tension in the rope and forces exerted by the floor on the ladder.

(Take g = 9.8 m/s^2)

(Hint: Consider the equilibrium of each side of the ladder separately.)

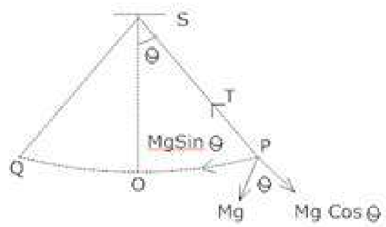


37. A body of mass *m* is attached to one end of a massless string which is suspended vertically from a fixed point. The mass is held in hand so that the spring is neither stretched nor compressed. Suddenly the support of the hand is removed. The lowest position attained by the mass during oscillation is 4cm below the point, where it was held in hand.

   i. What is the amplitude of oscillation?
   ii. Find the frequency of oscillation?

OR

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



Solution
Section A

1. (b) making, modification, usage, and knowledge of tools, machines, techniques, crafts, systems, and methods of organization, in order to solve a problem, improve a preexisting solution to a problem, achieve a goal, handle an applied input/output relation or perform a specific function
   Explanation: Technology is the making, modification, usage, and knowledge of tools, machines, techniques, crafts, systems, and methods of organization, in order to solve a problem, improve a pre-existing solution to a problem, achieve a goal, handle an applied input/output relation or perform a specific function. It can also refer to the collection of such tools, including machinery, modifications, arrangements and procedures.
2. (d) acceleration
   Explanation: Acceleration is a vector quantity because it has both magnitude and direction.

   When an object has a positive acceleration, the acceleration occurs in the same direction as the movement of the object.

   When an object has a negative acceleration (it's slowing down), the acceleration occurs in the opposite direction as the movement of the object.

3. (a) 400 N
   Explanation: When monkey climbs with uniform speed, the acceleration is zero, so

   $T = mg = 40 \times 10 = 400\,N$

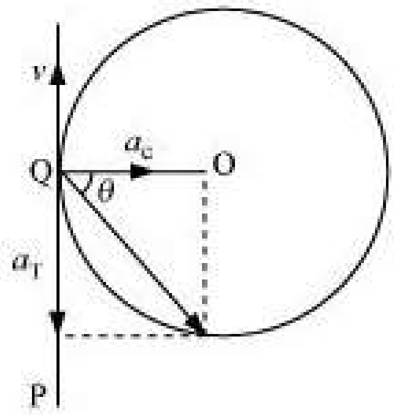
4. (d) 0.86 m s^{-2}, 54.5^{o} with the direction of velocity
   Explanation:

   Speed of the cyclist, v = 27 km/h = 7.5 m/s
   Radius of the circular turn, *r* = 80 m

Centripetal acceleration is given as:

$a_c = \frac{v^2}{r} = \frac{(7.5)^2}{80} = 0.7$ ms^{-2}

The situation is shown in the given figure:



Suppose the cyclist begins cycling from point P and moves toward point Q. At point Q, he applies the breaks and decelerates the speed of the bicycle by 0.5 m/s^2.

This acceleration is along the tangent at Q and opposite to the direction of motion of the cyclist.

Since the angle between a_c and a_T is 90^0, the resultant acceleration *a* is given by:

$a = \sqrt{(a_c)^2 + (a_T)^2} = \sqrt{(0.7)^2 + (0.5)^2}$

$= \sqrt{0.74} = 0.86$ ms^{-2}

$\tan\theta = \frac{a_c}{a_T}$

where θ is the angle of the resultant with the direction of velocity.

$\tan\theta = \frac{0.7}{0.5} = 1.4$

$\theta = \tan^{-1}(1.4) = 54.56^0$ with the direction of velocity.

5. (c) 5.3 m/s

Explanation: 95% potential energy is converted in kinetic energy.

applying conservation of mechanical energy between horizontal and lowermost points

$$mgl \times \frac{95}{100} = \frac{1}{2}mv^2$$
$$gl \times \frac{95}{100} = \frac{1}{2}v^2$$
$$v = \sqrt{\frac{2\times gl\times 95}{100}} = \sqrt{\frac{2\times 9.8\times 1.5\times 95}{100}} = 5.3\mathrm{m/s}$$

6. (b) $2.2 \times 10^6\ \mathrm{N/m^2}$ Explanation:

bulk modulus B $= \frac{\Delta P}{\frac{\Delta V}{V}}$

given V = 1 lit bulk modulus B = 2.2 Gpa = 2.2×10^9 pa

$\Delta V = 0.10\%$

$\Delta P = B \times \frac{\Delta V}{V}$

$\Delta P = 2.2 \times 10^9 \times \frac{0.10}{100 \times 1} = 2.2 \times 10^6 N/m^2$

7. (b) $H = kA\frac{T_C - T_D}{L}$ **Explanation:** rate of flow of heat H depends on

$H \propto A$

$H \propto \Delta T$

$H \propto \frac{1}{L}$

hence $H \propto \frac{A\Delta T}{L}$

$H = K\frac{A\Delta T}{L}$

K = thermal conductivity of the material

8. (c) Two isothermal processes connected by two adiabatic processes

Explanation:

The Carnot cycle consists of the following four processes:

1. A reversible isothermal gas expansion process
2. A reversible adiabatic gas expansion process
3. A reversible isothermal gas compression process
4. A reversible adiabatic gas compression process

9. (a) 5.0

Explanation: Degrees of freedom of a system refers to the possible independent motions a system can have.

the total degrees of freedom describing the motion of a diatomic molecule is 5.

3 for translation and 2 for rotation

10. (b) the angular wave number

Explanation: In the equation

y(x, t) = a sin (kx + ωt + φ)

the term with distance travelled 'x' is called angular wave number or propagation constant

Hence k is the angular wave number.

11. Zero

OR

-8 m/s^2

12. Endothermic reaction
13. Acceleration
14. Decreases
15. Vaporisation
16. Let the vectors are A and B.
    Given, |A| = 3 units, |B| = 4 units and θ= 60°
    The magnitude of resultant of difference of A and B from parallelogram law of vector addition for vectors A and (-B) is given by,
    $R=|\mathbf{R}|=\sqrt{A^2+B^2-2AB\cos\theta}$
    $=\sqrt{3^2+4^2-2\times3\times4\cos60^\circ}$
    R = $\sqrt{25-12}=\sqrt{13}$= 3.61 units
17. The thermometer with cylindrical bulb will respond quickly to temperature changes because the surface area of cylindrical bulb is greater than that of spherical bulb.
18. This is due to the equation of continuity, $a_1v_1=a_2v_2$
    $\because a_1>a_2$
    $\therefore v_2>v_1$
19. As we know that efficiency of a Carnot engine is given by:

$$\eta=\left(1-\frac{T_2}{T_1}\right)$$

where, T_1 = temperature of sink source and T_2 = temperature of sink.

So for η =1 or 100%,

T_2 = 0 K

or in other words we can say that heat is rejected into a sink at 0 K temperature.

20. The frequency of vibration depends on the length of the air column and not on reflecting media, hence frequency does not change.

OR

Water waves produced by a motorboat sailing in water are both longitudinal and transverse.

21. For the stationary observer, the relative velocity of trees and houses is zero. For the observer sitting in the moving train, the relative velocity of houses and trees is negative. So these objects appear to move in backward direction. For the stationary observer, the relative velocity of trees and houses is zero. For the observer sitting in the moving train, the relative velocity of houses and trees is negative. So these objects appear to move in a backward direction.

22. Given, $v_A = 6\hat{i}$;

$v_B = 6\cos30°\hat{i} + 6\sin30°\hat{j}$; (horizontal and vertical components of the velocity vector)

$= \frac{6\sqrt{3}}{2}\hat{\mathbf{i}} + \frac{6}{2}\hat{\mathbf{j}} = 3\sqrt{3}\hat{\mathbf{i}} + 3\hat{\mathbf{j}}$

Therefore, relative velocity v_{BA} is given by

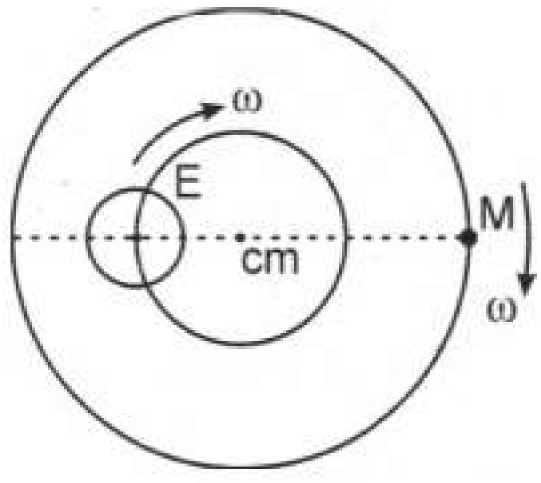
$v_{BA} = v_B - v_A = (3\sqrt{3}\hat{\mathbf{i}} + 3\hat{\mathbf{j}}) - 6\hat{\mathbf{i}}$

$v_{BA} = (3\sqrt{3} - 6)\hat{\mathbf{i}} + 3\hat{\mathbf{j}}$

$v_{BA} = \sqrt{(3\sqrt{3} - 6)^2 + (3)^2}$ = 3.11 m/s

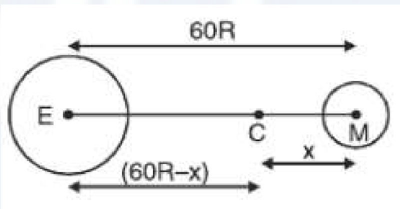
and its direction is calculated as:

$\tan\alpha = \frac{3}{3\sqrt{3}-6} = \frac{1}{\sqrt{3}-2} \Rightarrow \alpha$ = 105.13°

23. 

The moon revolves around the earth in a circular orbit and the earth goes around the sun in an elliptical orbit. Actually, the Earth-Moon system revolves about their common centre of mass in elliptical path.

As the mass of earth is very large as compared to that of the moon, the centre of mass of the Earth-Moon system lies within the earth and it appears that the moon revolves around the earth but the reality is that both revolve around their common centre of mass.

24. 

Gravitational field at C due to earth

= Gravitational field at C due to moon

$$\frac{GM}{(60R-x)^2} = \frac{Gm/81}{x^2}$$

$81x^2 = (60R - x)^2$

9x = 60R - x

X = 6 R

25. Energy Density $= \frac{\text{Energy}}{\text{Volume}} = \frac{\frac{1}{2}\frac{AY}{L}x^2}{AL}$

$= \frac{1}{2}\left(\frac{Ayx}{AL}\right) \times \frac{x}{L}$

$= \frac{1}{2} Stress \times Strain$

26. Heat carried away from a fire sideways mainly by radiation. Above the fire, heat is

carried by both radiation and convection of air but convection carries much more heat than radiation. So, it is much hotter above a fire than by its sides.

OR

For neon Triple point $T = 24.57K$
$\therefore T_c = T(\mathrm{K}) - 273.15$
$= 24.57 - 273.15 = -248.58^o C$
$T_F = \frac{9}{5} T_C + 32 = \frac{9}{5} \times (-248.58) + 32 = -415.44^\circ \mathrm{F}$
For carbon dioxide Triple point, $T = 216.55\ K$
$\therefore \quad T_C = T(K) - 273.15 = 216.55 - 273.15 = -56.6^\circ \mathrm{C}$
$T_F = \frac{9}{5} T_C + 32 = \frac{9}{5} \times (-56.6) + 32 = -69.88^\circ \mathrm{C}$

27. Oxygen is a diatomic gas having mass number 32.
So, number of moles of O_2 gas
$= \frac{\text{Atomic wt.}}{\text{Molecular wt.}} = \frac{8}{32}$
$= \frac{1}{4}$ = 0.25
Total energy associated with 1 mole of oxygen at STP, U = $\frac{5}{2} RT$
Hence, internal energy of 8 g of oxygen = $0.25 \times \frac{5}{2} RT$
$= 0.25 \times \frac{5}{2} \times 8.31 \times 273$
= 1417.9 J

OR

$$v_{rms=} = \sqrt{\frac{v_1^2 + v_2^2 + \ldots v_n^2}{n}} \begin{pmatrix} v_1 = 9 \times 10^6 ms^{-1} \\ v_2 = 1 \times 10^6 ms^{-1} \end{pmatrix}$$

$$\therefore v_{rms=} = \sqrt{\frac{(9 \times 10^6)^2 + (1 \times 10^6)^2}{2}}$$

$$v_{rms=} = \sqrt{\frac{81 \times 10^{12} + 1 \times 10^{12}}{2}} = \sqrt{\frac{10^{12}(81+1)}{2}}$$

$$= 10^6 \sqrt{\frac{82}{2}} = 10^6 \sqrt{41} = 10^6 \times 6.4$$

$$v_{rms=} = 6.4 \times 10^8 \mathrm{m/s}$$

28. Dimension of volume per second, V = $\frac{V}{T} = \frac{[L^3]}{[T]} = [L^3T^{-1}]$

Dimension of pressure P = $\frac{F}{A} = \frac{[MLT^{-2}]}{[L^2]} = [ML^{-1}T^{-2}]$

Dimension of radius , r = [L]

Dimension of coefficient of viscosity, η = $[ML^{-1}T^{-1}]$

Dimension of length of the pipe , l = [L]

$\therefore$ Dimension of R.H.S $= \frac{dimP \times dimr^4}{dim\eta \times diml} = \frac{[ML^{-1}T^{-2}][L^4]}{[ML^{-1}T^{-1}][L]} = [M^0L^3T^{-1}]$, π and 8 are dimensionless entities.

Dimension of L.H.S. V = $[M^0L^3T^{-1}$

clearly , dimensions R.H.S = dimensions L.H.S, therefore the given equation is dimensionally accurate as it is perfectly in accordance with the principle of Homogeniety

29. Given, helicopter is rising upwards steadily with a velocity, u = 2 ms^{-1}.

   i. When the food packet is released, its initial velocity is same as the velocity of helicopter i.e., u = 2 ms^{-1}. Time taken by the packet to reach ground, t = 6 s. Let h_1 be the height of the helicopter at the time of releasing the food packet. Using the second equation of motion, s = ut + $\frac{1}{2}at^2$ and considering downward direction as positive, we have
   h_1 = (-2) $\times$ 6 + $\frac{1}{2}$ $\times$ 9.8 $\times$ $(6)^2$ = -12 + 176.4 = 164.4 m
   ii. During time, t = 6s, the helicopter has uniform motion and risen further with a distance h' = ut = 2 $\times$ 6 = 12m. Hence, the height of the helicopter when food packet just reached the earth is,
   $h_2 = h_1$ + h' = 164.4 + 12 = 176.4 m.

30. The work-energy theorem states that the work done by a force acting on a body is equal to the change produced in its kinetic energy. If work W is being done on a body

of mass m and due to the work done, the speed of the body changes from u to v, then Work done is given by:

W = Change in its kinetic energy

Therefore, $W = \Delta K = K_2 - K_1 = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

To derive the work-kinetic energy theorem analytically consider a body of mass m moving with a velocity u. Let a force $\vec{F}$ be applied on the body and under its effect body be displaced by $\overrightarrow{ds}$, so that we can write work done as:

$$dW = \vec{F} \cdot \overrightarrow{ds}$$

But we know that, $\vec{F} = m\vec{a} = m\frac{\overrightarrow{dv}}{dt}$

Therefore, $dW = m\frac{d\vec{v}}{dt} \cdot ds = m\frac{ds}{dt}dv = mvdv$

On integrating above equation, we obtain

$\int_0^W dW = W = \int_u^v mvdv$

$= m\left[\frac{v^2 - u^2}{2}\right] = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

Obviously, $\frac{1}{2}mv^2 - \frac{1}{2}mu^2$= change in K.E. = K_f - K_i.

Thus, W = K_f - K_i which is the work-kinetic energy theorem.

31. The total mechanical energy of a satellite is given by,

E = $\frac{-GMm}{2r}$

Here it is given that,

Mass of satellite, $m = 400\ kg$

Thus, the initial mechanical energy is given by, $E_i = \frac{-GMm}{4R}$

Final mechanical energy is given by, $E_f = \frac{-GMm}{8R}$

$\therefore$ Energy required to increase the orbital radius from 2R to 4R is given by,

$\triangle E = E_f - E_i = \frac{-GMm}{8R}$ - $\left(\frac{-GMm}{4R}\right)$

= $\frac{GMm}{8R}$ = $\left(\frac{GM}{R^2}\right)\frac{mR}{8}$

= $\frac{gmR}{8}$ = 50 gR

The kinetic energy of the orbiting satellite is given by,

K = $\frac{GMm}{2r}$

Hence, K_i = $\frac{GMm}{2(2R)}$ = $\frac{GMm}{4R}$ = $\frac{mgR}{4}$

$K_f = \frac{GMm}{2(4R)} = \frac{GMm}{8R} = \frac{mgR}{8}$

Thus, $\Delta K = K_f - K_i = \frac{mgR}{8} - \frac{mgR}{4} = -\frac{mgR}{8} = -\frac{400}{8}$ gR = -50 gR

The potential energy of the orbiting satellite is given by,

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

Hence, $U_i = \frac{-GMm}{2R} = \frac{-mgR}{2}$

$U_f = \frac{-GMm}{4R} = \frac{-mgR}{4}$

Thus, $\Delta U = U_f - U_i = \frac{-mgR}{4} - (\frac{-mgR}{2}) = \frac{mgR}{4}$ = 100 gR

Hence, the K.E will get reduced and the P.E will become twice.

32. Radius of mercury drop r = 3.00 mm $= 3 \times 10^{-3} m$

surface tension of mercury $S = 4.65 \times 10^{-1} Nm^{-1}$

atmospheric pressure $P_{atm} = 1.01 \times 10^5 pa$

Total pressure (P_{total}) inside the mercury drop = excess pressure inside mercury + atmospheric pressure

equation for excess pressure inside mercury $P = p_i - p_o = \frac{2S}{r}$

thus $p_{\text{total}} = P + P_{\text{atm}} = \frac{2S}{r} + P_{\text{atm}}$

$p_{\text{total}} = \frac{2 \times 4.65 \times 10^{-1}}{3 \times 10^{-3}} + \left(1.01 \times 10^5\right)$

$p_{\text{total}} = 1.0131 \times 10^5 Pa$

excess pressure $P = \frac{2S}{r} = \frac{2 \times 4.65 \times 10^{-1}}{3 \times 10^{-3}}$

P = 310 Pa

OR

In case "a"-

The length of the liquid film supported by the weight, l = 40cm = 0.4cm

The weight supported by the film, $W = 4.5 \times 10^{-2} N$

A liquid film has two free surfaces thus

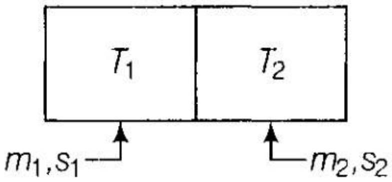
Surface tension $S = \frac{W}{2l} = \frac{4.5 \times 10^{-2}}{2 \times 0.4} = 5.625 \times 10^{-2} \mathrm{Nm}^{-1}$

In all the three figures, the liquid is same. Temperature is also same for each case.

Hence, the surface tension in figure (b) and figure (c) is the same as in figure (a) i.e.

$S = 5.625 \times 10^{-2} Nm^{-1}$

Since the length of the film in all the cases is 40 cm, the weight supported in each case is $4.5 \times 10^{-2} N$.

33. 

Let m_1 and m_2 are masses of bodies with specific heats s_1 and s_2, then if their temperature after they are in thermal equilibrium is T.
Then, if $T_1 > T > T_2$ and assuming no heat loss.
Heat lost by hot body = heat gained by cold body
$m_1 s_1 (T_1 - T) = m_2 s_2 (T - T_2)$
$\Rightarrow \frac{m_1 s_1 T_1 + m_2 s_2 T_2}{m_1 s_1 + m_2 s_2} = T$ [equilibrium temperature]
So for, bodies to settle down to mean temperature,
$m_1 = m_2$ and $s_1 = s_2$ means bodies have same specific heat and have equal masses.
Then,
$T = \frac{T_1 + T_2}{2}$ [mean temperature]

34. Standing waves or stationary waves are waves which oscillates with time but whose peak amplitude of oscillations remains constant with time. The main characteristics of standing waves or stationary waves are as given below:

i. The period of vibration of a stationary wave is the same as that of two individual waves forming that stationary wave due to superposition
ii. They can be produced by the interference of either longitudinal or transverse waves
iii. All particles in the same loop have the same phase at a given instant.
iv. There are certain points equally spaced in the medium where medium elements are permanently at rest. At such points known as "nodes", the displacement, as well as particle velocity, is permanently zero. However, there is a set of particles called "antinodes" where the displacement amplitude and velocity amplitude are maximum.
v. The amplitude of vibration of the particles gradually increases from zero at the nodes to a maximum at antinodes.
vi. In a stationary wave, the phase does not vary regularly with space. All the particles between two consecutive nodes (i.e., lying in a segment or loop) are in

the same phase but differ in phase by n radian as compared to the particles on the opposite side of a node.

vii. The distance between two consecutive nodes or two consecutive antinodes is $\frac{\lambda}{2}$. The distance between a node and its adjacent antinodes is $\frac{\lambda}{4}$.

viii. Twice during each vibration, all the medium particles pass through their mean positions simultaneously, though with different velocities. Again two times in vibration all particles, except nodes, attain their extreme positions simultaneously.

ix. In longitudinal stationary waves, there is a maximum change of pressure and density at the nodes but at the antinodes, there is no change of pressure and density.

x. They move neither forward nor backward.

xi. In a stationary way, the energy is not transported from one point to another.

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.

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

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

$\vec{F} = \mathrm{km}\,\vec{a}$ (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

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.
$\vec{P} = m\vec{v}$
$\Rightarrow \vec{F} = \text{km}\,\frac{d\vec{v}}{dt}$
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(i) At t = -5 s
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$s = ut + \frac{1}{2}a't^2$
$= 10 \times (-5) = -50\text{m}$
(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,

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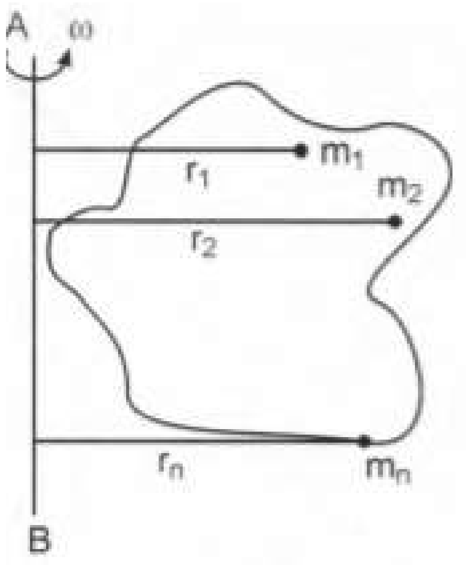
36. 

Consider a rigid body of mass M rotating about an axis AB with a constant angular velocity ω. The body may be supposed to be consisting of a large number of elementary particles of masses m_1 , m_2, m_3,.....m_n situated at normal distances r_1, r_2, r_3.......r_n. As each point is moving with a different linear velocity, we must find the kinetic energy of each point and make the sum. The linear velocity of the particle with mass m_i at distance r_i from the rotation axis is $v_i = \omega r_i$ and its kinetic energy is $\frac{1}{2} m_i v_i^2$.

Now we have, $v_1 = r_1\omega, v_2 = r_2\omega, v_3 = r_3\omega$..... (1)

Therefore, the K.E of the whole rotating body will be given by

$K_{rot} = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 + \frac{1}{2} m_3 v_3^2 + \ldots$

$= \frac{1}{2} m_1 r_1^2 \omega^2 + \frac{1}{2} m_2 r_2^2 \omega^2 + \frac{1}{2} m_3 r_3^2 \omega^2 + \ldots$ [By using equation (1)]

$= \frac{1}{2}\left[m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2 + \ldots\right]\omega^2 = \frac{1}{2}\Sigma m_i r_i^2 - \omega^2$

$= \frac{1}{2} I \omega^2$

where $I = \sum m_i r_i^2$ = moment of inertia of the body about the given axis.

The rotational kinetic energy of a body is given by:

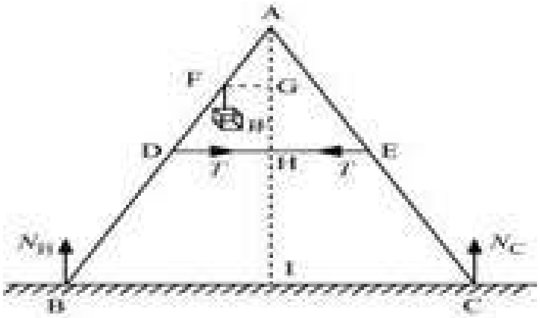
$K_{\text{rot}} = \frac{1}{2} I \omega^2$, where ω = angular velocity and I = moment of inertia of body about rotation axis.

If ω = 1, then $K_{rot} = \frac{1}{2} I \times (1)^2 = \frac{I}{2}$ or $I = 2K_{rot}$

Hence, moment of inertia of a given body about a given axis is numerically equal to twice the numerical value of its kinetic energy of rotation when rotating about the given axis with unit angular velocity.

OR

The given situation can be shown as:



N_B = Force exerted on the ladder by the floor point B

N_C = Force exerted on the ladder by the floor point C

T = Tension in the rope

BA = CA = 1.6 m

DE = 0. 5 m

BF = 1.2 m

Mass of the weight, m = 40 kg

Draw a perpendicular from A on the floor BC. This intersects DE at mid-point H.

ΔABI and ΔAIC are similar

$\therefore$ BI = IC

Hence, I is the mid-point of BC.

DE || BC

BC = 2 $\times$ DE = 1 m

AF = BA - BF = 0.4 m ...(i)

D is the mid-point of AB.

Hence, we can write:

$AD = \frac{1}{2} \times BA = 0.8\text{m}$ ....(ii)

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

FE = 0.4 m

Hence, F is the mid-point of AD.

FG || DH and F is the mid-point of AD. Hence, G will also be the mid-point of AH.

ΔAFG and ΔADH are similar

$\therefore \frac{FG}{DH} = \frac{AF}{AD}$

$\frac{FG}{DH} = \frac{0.4}{0.8} = \frac{1}{2}$

$FG = \frac{1}{2} DH$

$= \frac{1}{2} \times 0.25 = 0.125$

In ΔADH:

$AH = \sqrt{AD^2 - DH^2}$

$= \sqrt{(0.8)^2 - (0.25)^2} = 0.76m$

For translational equilibrium of the ladder, the upward force should be equal to the downward force.

$N_C + N_B$ = mg = 392 ...(iii)

For rotational equilibrium of the ladder, the net moment about A is:

$-N_B \times BI + mg \times FG + N_c \times CI + T \times AG - T \times AG = 0$

$-N_B \times 0.5 + 40 \times 9.8 \times 0.125 + N_c \times (0.5) = 0$

$(N_c - N_B) \times 0.5 = 49$

N_c - N_B = 98

Adding equations (iii) and (iv), we get:

N_C = 245 N

N_B = 147 N

For rotational equilibrium of the side AB, consider the moment about A.

$-N_B \times BI + mg \times FG + T \times AG = 0$

$-245 \times 0.5 + 40 + 9.8 \times 0.125 + T \times 0.76 = 0$

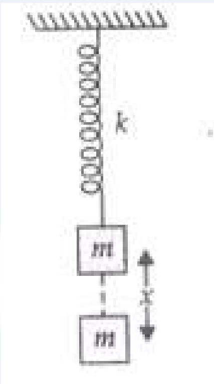
0.76 T = 122.5 - 49

$\therefore$ T = 96.7 N

Hence, tension in the given question will be 96.7 N from the above calculation.

37. a. Let the mass reaches at its new position x unit displacement from previous.

Then P.E. of spring or mass = gravitational P.E. lost by man



$PE = mgx$

But P.E. due to spring is $\frac{1}{2}kx^2, k = \omega^2 A$

$\therefore \frac{1}{2}kx^2 = mgx$

$x = \frac{2mg}{k}$

Mean position of spring by block will be when let extension is x_0 then

$F = +kx_0$

$F = mg \therefore mg = +kx_0$ or $x_0 = \frac{mg}{k}$ ....(ii)

From (i) and (ii)

$x = 2\left(\frac{mg}{k}\right) = 2x_0$

$x = 4\text{cm} \quad \therefore 4 = 2x_0$

$x_0 = 2\text{cm}$

The amplitude of oscillator is the maximum distance from mean position i.e.,

$x - x_0 = 4 - 2 = 2\text{cm}$

b. Time Period $T = 2\pi\sqrt{\frac{m}{k}}$ which does not depend on amplitude

$\frac{2mg}{k} = x$ from (i)

$\frac{m}{k} = \frac{x}{2g} = \frac{4\times10^{-2}}{2\times9.8}$ or $\frac{k}{m} = \frac{2\times9.8}{4\times10^{-2}}$

$v = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\times3.144}\sqrt{\frac{2\times9.8}{4\times10^{-2}}} = \sqrt{\frac{4.9\times10^{2}}{6.28}}$

$v = \frac{10\times2.21}{6.28} = 3.52\text{Hz}$

Oscillator will not rise above the positive from where it was released because total extension in spring is 4 cm when released and amplitude is 2 cm. So it oscillates below the released position.

OR

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

Let m = mass of bob

l = length of a pendulum

Let O is the equilibrium position, OP = X

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

The forces acting on the bob are:-

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

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

Now, T = Mg Cos θ

Restoring force F = - Mg Sin θ

- ve sign shows force is directed towards mean position.

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

Hence F = - mg θ

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

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

where,k = Spring constant

Equating equation 3) & 4) for F

⇒- k x = - m g $\frac{x}{l}$

⇒Spring factor = $k = \frac{mg}{l}$

Inertia factor = Mass of bob = m

Now, Time period = T

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

⇒$T = 2\pi\sqrt{\frac{l}{g}}$