CBSE Class 11 Physics
Sample Paper 03 (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 were not major technological advances during industrial revolution in England and Europe?

   a. Power loom

   b. Steam engine

   c. The cotton gin

   d. Satellite communication

2. The reason why cyclists bank when taking a sharp turn is

   a. to supply the acceleration required to move fast

   b. cyclists enjoy turning to one side and so bank

c. to decelerate at the turns as turns are dangerous

d. to supply the sidewise (centripetal) acceleration required to make the direction change

3. Friction is

a. perpendicular to contact surface and aids motion

b. perpendicular to contact surface and opposes i motion

c. parallel to contact surface and opposes the relative motion

d. parallel to contact surface and aids motion

4. A fighter plane flying horizontally at an altitude of 1.5 km with speed 720 km/h passes directly overhead an anti-aircraft gun. At what angle from the vertical should the gun be fired for the shell with muzzle speed 600 $m\ s^{-1}$ to hit the plane? At what minimum altitude should the pilot fly the plane to avoid being hit? (Take g = 10 ms^{-2}).

a. at an angle of 20.5^{o} with the vertical, 12 km

b. at an angle of 21.5^{o} with the vertical, 15 km

c. at an angle of 19.5^{o} with the vertical, 16 km

d. at an angle of 23.5^{o} with the vertical, 17 km

5. In which case is the work done zero?

a. Force and displacement are perpendicular to each other

b. Force and displacement are in the same direction

c. Force and displacement are at an angle of 45°

d. Force and displacement are at an angle of 75°

6. 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 $\times 10^7$ Pa? Assume that each rivet is to carry one quarter of the load.

a. 7.2 N

b. 7.0 N

c. 7.8 N

d. 6.5 N

7. In an experiment on the specific heat of a metal, a 0.20 kg block of the metal at 150 $^\circ$C is dropped in a copper calorimeter (of water equivalent 0.025 kg) containing 150 cm^3 of water at 27 $^\circ$C. The final temperature is 40 $^\circ$C. Compute the specific heat of the metal.

a. 0.43 J $g^{-1}K^{-1}$

b. 0.37 J $g^{-1}K^{-1}$

c. 0.40 J $g^{-1}K^{-1}$

d. 0.46 J $g^{-1}K^{-1}$

8. An ideal gas initially at 300 K undergoes an isobaric expansion at 2.50 kPa. If the volume increases from 1.00 m^3 to 3.00 m^3 and if 12.5 kJ of energy is transferred to the gas by heat, what is the change in its internal energy?

a. 7.80 kJ

b. 7.70 kJ

c. 7.60 kJ

d. 7.50 kJ

9. Two moles of an ideal gas ($\gamma = 1.4$) expands slowly and adiabatically from a pressure of 5.00 atm and a volume of 12.0 L to a final volume of 30.0 L. Find Q, W, and ΔE_{int}.

a. 100 J, 4.88 kJ, -4.88 kJ

b. 1 J, 4.22 kJ, -4.22 kJ

c. 10 J, 4.44 kJ, -4.44 kJ

d. 0, 4.66 kJ, -4.66 kJ

10. Travelling or progressive wave

    a. does not move from one point of the medium to all others

    b. does not move from one point of the medium to any other

    c. does not move from one point of the medium to another

    d. travels from one point of the medium to another

11. Fill in the blanks: ________ speed of the scooter is measured by the speedometer.

OR

Fill in the blanks: The motion in which a particle moves to and fro about a given point is known as ________.

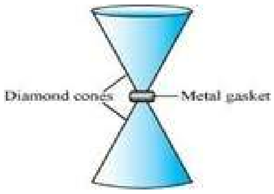
12. Fill in the blanks: ________ is the net electromagnetic force between the charged constituents of that object and our palm.
13. Fill in the blanks: _______ is defined as the time taken by a particle to complete one revolution along its circular path.
14. Fill in the blanks: If a body does not show any tendency to regain its original size and shape even after the removal of deforming force, it is said to be _______.
15. Fill in the blanks: The SI unit of latent heat is ________.
16. Plants are called as _____ because they fix carbon dioxide.
17. Two bodies of unequal mass are moving in the same direction with equal kinetic energy. The two bodies are brought to rest by applying retarding force of same magnitude. How would the distance moved by them before coming to rest compare?
18. Does Archimedes principle hold in a vessel in a free fall?
19. If gas is suddenly compressed, its temperature increases, why?
20. At what temperature will the speed of sound be double its value at 273’ K?

OR

How speed of sound waves in air varies with humidity?

21. A man runs across the roof-top of a tall building and jumps horizontally with the hope of landing on the roof of the next building which is of a lower height than the first. If his speed is 9 m/ms, the (horizontal) distance between the two building is 10 m and the height difference is 9 m, will he be able to land on the next building? (take g=10 m/s^2)
22. The greatest height to which a man can throw a stone is h. What will be the greatest distance up to which he can throw the stone?
23. Prove that the centre of mass of two particles divides the line joining the particles in the inverse ratio of their masses.
24. Calculate the escape speed of a body from the solar system from the following data:
    i. Mass of the sun = 2 $\times$ 10^{30} kg.
    ii. Separation of the earth from the sun = 1.5 $\times$ 10^{11} m.

25. Anvils made of single crystals of diamond, with the shape as shown in figure, are used to investigate behaviour of materials under very high pressures. Flat faces at the narrow end of the anvil have a diameter of 0.50 mm, and the wide ends are subjected to a compressional force of 50,000 N. What is the pressure at the tip of the anvil?



26. Two stars radiate maximum energies at wavelengths $3.6 \times 10^{-7}\ m$ and $4.8 \times 10^{-7}\ m$ respectively. What is the ratio of their temperatures?

OR

What is the value of specific heat capacity of water? Show a graph depicting variation of specific heat of water with temperature ranging from 0^{o} C to 100^{o} C.

27. Calculate the temperature of Ar atoms at which rms speed of Argon gas is equal to the rms speed of Helium gas atoms at -10°C? (Atomic mass of Ar = 39.9 u, that of He = 4 u)

OR

Calculate the mean kinetic energy of one mole of hydrogen at 273 K. Take 8.3 J mol-1 K^{-1}.

28. A book with many printing errors contains four different formulas for the displacement y of a particle undergoing a certain periodic motion:

   i. $y = \alpha \sin\left(\frac{2\pi t}{T}\right)$
   ii. $y = \left(\frac{a}{T}\right) \sin \frac{t}{a}$
   iii. $y = (a\sqrt{2})\left(\sin \frac{2\pi t}{T} + \cos \frac{2\pi t}{T}\right)$

   (a = maximum displacement of the particle, v = speed of the particle. T = time-period of motion). Rule out the wrong formulas on dimensional grounds.

29. Derive (i) v = u + at (ii) $v^2 – u^2$ = 2as by calculus method.

30. A synchronous motor is used to lift an elevator and its load of 1500 kg to a height of 20 m. The time taken for job is 20 s. What is work done? What is the rate at which work is done? If the efficiency of the motor is 75%, at which rate is the energy supplied to the motor?

31. How far away from the surface of earth does the value of g is reduced to 4% of its value on the surface of the earth? Given radius of earth = 6400km.

32. Briefly explain the cause of special cylindrical shape of bullets.

OR

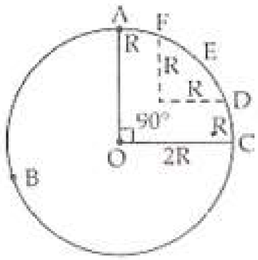
   Two capillary tubes of length 15cm and 5cm and radii 0.06cm and 0.02cm respectively are connected in series. If the pressure difference across the end faces is equal to the pressure of 15cm high water column, then find the pressure difference across the : $\rightarrow$

   i. First tube
   ii. Second tube

33. A metal rod of length 20cm and diameter 2cm is covered with a non-conducting substance. One of its end is maintained at 100^0c while the other is at 0^0c. It is found that 25g of ice melts in 5 min calculate coefficient of thermal conductivity of metal?

34. Show that the wave obtained as a result of interference of two sinusoidal waves is also a sinusoidal wave.

35. i. Obtain an expression for the centripetal force required to make a body of mass m moving with a speed v around a circular path of radius r.
    ii. A racing car travels on a track (without banking) ABCDEFA (Figure). ABC is a circular arc of radius 2R. CD and FA are straight paths of length R and DEF is a circular arc of radius R = 100 m. The coefficient of friction on the road is μ = 0.1. The maximum speed of the car is 50 ms^{-1}. Find the minimum time for completing one complete round the path.



OR

The displacement vector of a particle of mass m is given by
$\vec{r}(t) = \hat{i} A \cos \omega t + \hat{j} B \sin \omega t$

a. Show that the trajectory is an ellipse.
b. Show that $\vec{F} = -m\omega^2 \vec{r}$

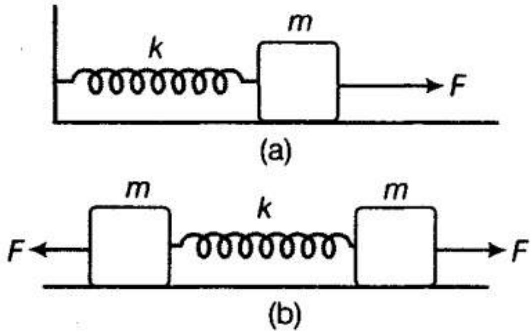
36. a. A cat is able to land on its feet after a fall. Why?
    b. If angular momentum moment of inertia is decreased, will its rotational K.E. be also conserved? Explain.

OR

A car weighs 1800 kg. The distance between its front and back axles is 1.8 m. Its centre of gravity is 1.05 m behind the front axle. Determine the force exerted by the level ground on each front wheel and each back wheel.

37. Fig. (a) shows a spring of force constant k clamped rigidly at one end and a mass m attached to its free end. A force F applied at the free end stretches the spring. Fig. (b) shows the same spring with both ends free and attached to a mass m at either end.

Each end of the spring in Fig. (b) is stretched by the same force F



i. What is the maximum extension of the spring in both the cases?
ii. If the mass in Fig. (a) and the two masses in Fig. (b) are released, then what is the period of oscillation in each case?

OR

A person normally weighing 50 kg stands on a mass less platform which oscillates up and down harmonically at a frequency of 2.0 s^{-1} and an amplitude 5.0 cm. A weighing machine on the platform gives the persons weight against time.

i. Will there be any change in weight of the body, during the oscillation? Figure In extensible string.
ii. If answer to part (a) is yes, what will be the maximum and minimum reading in the machine and at which position?

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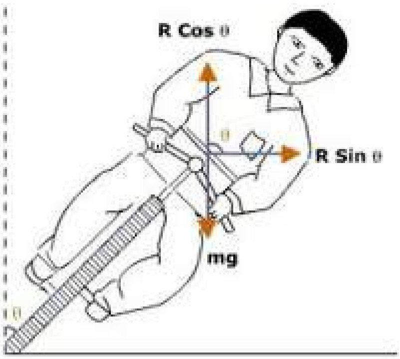
Solution
Section A

1. (d) Satellite communication
   Explanation: In 1957, the world was surprised to see the Soviets launch the first satellite into orbit, with most expecting the USA to be the first to do so. Settalite technology got wings after this year which is so far after industrial revolution in England and Europe.
2. (d) to supply the sidewise (centripetal) acceleration required to make the direction change
   Explanation: In order to take a safe turn, the cyclist has to bend a little from his vertical position. In this case, a component of the reaction provides the required centripetal force.

   If q is angle made by the cyclist with the vertical then

   $Ncos\theta = mg \ldots .(1)$
   $Nsin\theta = \frac{mv^2}{r} \ldots ..(2)$
   Dividing (2) by (1), we get
   $\tan\theta = \frac{v^2}{rg}$
   $\Rightarrow \theta = tan^{-1}(\frac{v^2}{rg})$
   In actual practice, the value of q is slightly less because the force of friction also contributes towards the centripetal force.

3. (c) parallel to contact surface and opposes the relative motion
   Explanation: Whenever a body of mass m moves or tends to move over the surface of

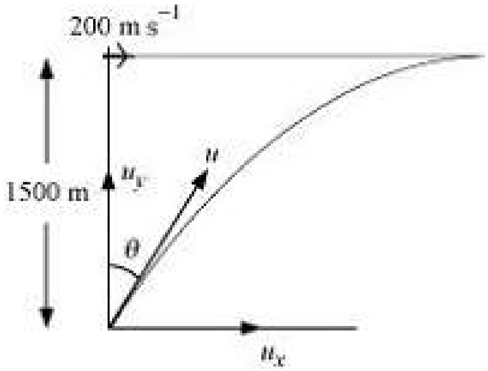
another body, then the opposite force acts parallel to the surface contact which opposes the relative motion.

4. (c) at an angle of 19.5^0 with the vertical, 16 km

Explanation: Height of the fighter plane = 1.5 km = 1500 m

Speed of the fighter plane, v = 720 km/h = 200 m/s

Let θ be the angle with the vertical so that the shell hits the plane. The situation is shown in the given figure.



Muzzle velocity of the gun, u = 600 m/s

Time taken by the shell to hit the plane = t

Horizontal distance travelled by the shell = $u_x t$

Distance travelled by the plane = vt

The shell hits the plane. Hence, these two distances must be equal.

$u_x t = vt$

u Sin θ = v

Sin θ = $\frac{v}{u} = \frac{200}{600}$ = 0.33

θ = $\sin^{-1}(0.33) = 19.5^0$

In order to avoid being hit by the shell, the pilot must fly the plane at an altitude (H) higher than the maximum height achieved by the shell.

$\therefore$ H = $\frac{u^2 \sin^2(90-\theta)}{2g} = \frac{(600)^2 \cos^2\theta}{2g}$

= $\frac{360000 \times cos^2\ (19.5)}{2 \times 10}$

= 16006.482 m

$\approx$ 16 km

5. (a) Force and displacement are perpendicular to each other

Explanation:

Work done is given as

W = Fdcosθ

Here θ is the angle between F and d if both are perpendicular then = 90 degree so cos θ = 0 and thus work done is 0.

6. (c) 7.8 N

Explanation: If the riveted strip is subjected load W, the tensile force i.e., tension in each strip (equal to W) provided the shearing force on four rivets that load is shared uniformly, thus rivet is under a shearing force equal to $\frac{W}{4}$.

Let A be the area of each rivet on which the shearing force acts.
Shearing stress on each rivet $= \frac{\text{shearing force}}{\text{area}} = \frac{W}{4A}$
Let W_{max} be the maximum permissible tension exerted by the riveted strip then
$\frac{W_{\max}}{4A} = 6.9 \times 10^7 \Rightarrow W_{\max} = 4A \times 6.9 \times 10^7 \Rightarrow (1)$
Given that diameter of each rivet d = 6.0 mm
area $A = \pi \mathrm{r}^2 = \frac{\pi \mathrm{d}^2}{4} = \frac{3.14 \times \left(6 \times 10^{-3}\right)^2}{4}$
$\mathrm{A} = 28.26 \times 10^{-9} \mathrm{m}^2$
substitute inequation 1
$\mathrm{W}_{\max} = 4 \times 28.26 \times 10^{-9} \times 6.9 \times 10^7$
$\mathrm{W}_{\max} = 7.8 \mathrm{N}$

7. (a) 0.43 J $\mathrm{g}^{-1} \mathrm{K}^{-1}$

Explanation:

Heat lost by the metal = Heat gained by the water and calorimeter system

$m_1 c_1 \Delta T_1 = (m_1 + m_2) c_2 \Delta T_2$
$200 \times c_1 \times 110 = (150 + 25) \times 4.186 \times 13$
$c_1 = \frac{175 \times 4.186 \times 13}{200 \times 110}$
$c_1 = 0.43 J g^{-1} K^{-1}$

8. (d) 7.50 kJ

Explanation:

$$W = P\Delta V = 2.5 \times 2 = 5KJ$$
$$\Delta Q = 12.5$$
$$\Delta Q = \Delta U + W$$
$$12.5 = \Delta U + 5$$
$$\Delta U = 7.5KJ$$

9. (d) 0, 4.66 kJ, -4.66 kJ

   Explanation:

   Process is adiabatic. so that Q = 0

   $$T_i = \frac{P_i V_i}{nR} = \frac{(5\times1.01\times10^5)\times(12\times10^{-3})}{2\times8.31} = 366K$$

   $$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$$
   $$P_2 = P_1\left(\frac{V_1}{V_2}\right)^{\gamma} = 5 \times \left(\frac{12}{30}\right)^{1.4} = 5 \times (0.4)^{1.4} = 1.39atm$$

   $$T_f = \frac{P_f V_f}{nR} = \frac{(1.39\times1.01\times10^5)\times(30\times10^{-3})}{2\times8.31} = 253K$$

   $$\Delta U = nC_V\Delta T = 2 \times 2.5R(253 - 366) = 2 \times 2.5 \times 8.31 \times 13 = -4.66KJ$$

   $$Q = \Delta U + W$$
   $$0 = -4.66 + W$$
   $$W = 4.66KJ$$

10. (d) travels from one point of the medium to another

    Explanation: As progressive wave means a wave propagating in some onward direction in the medium

11. Instantaneous

    OR

    oscillatory motion

12. Normal force

13. Time period

14. Perfectly plastic

15. J kg^{-1}

16. producers

17. By work-energy theorem change in KE is equal to work done by body. Hence KE = WD

$$KE_1 = KE_2 (Given)$$

$$WD_1 = WD_2$$

$$F_1 s_1 = F_2 s_2$$

$$\because F_1 = F_2 (Given)$$

$$\therefore s_1 = s_2$$

Hence, both bodies will travel equal displacement or distance (it does not depend on mass of bodies.)

18. Buoyant force acting on a body which is immersed in vessel and vessel is at rest F=mg , where m is mass of body. The apparent weight of system during free fall W=m(g-g)=0. As weight of an object become zero during free fall, the buoyant force also become zero. Thus, Archimedes principle does not hold during free fall.

19. Sudden compression of a gas is an adiabatic process, Therefore
According to the first law of thermodynamics,
$\Delta Q = \Delta U + \Delta W$
$\because \Delta Q = 0$
$\therefore \Delta U = -\Delta W$
$\because \Delta W = negative \because$ work done on the gas

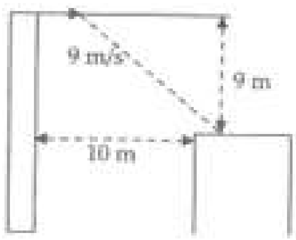
Thus, ΔU increases and gas temperature rises.

20. Say v_1 is the velocity of sound at T_1 = 273^{0}k and $v_2 = 2v_1$ at temperature T_2
Now $\frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}} \therefore \frac{2\nu_1}{v_1} = \sqrt{\frac{T_2}{273}}$
Or T_2 = 4 × 273 = 1092°K

OR

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

21. Vertical motion



When man is jumping from building he has a horizontal velocity u_x and vertical velocity u_y

let **t** be the time for man to reach from building A to building B

$u_y = 0, a = 10m/s^2$

S = 9 m

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

$9 = 0 \times \text{t} + \frac{1}{2} \times 10 \times t^2$

$t = \sqrt{\frac{9}{5}} = \frac{3}{\sqrt{5}}$ sec

Horizontal distance covered by person is

$u_x \times t = 9 \times \frac{3}{\sqrt{5}} = \frac{27}{\sqrt{5}} = \frac{27}{\sqrt{5}} \times \frac{\sqrt{5}}{\sqrt{5}}$

As 12.07 m covered during the free falling of 9 m. So he reaches on the building next farther the first edge by 12.7 - 10 = 2.07 m.

22. The greatest height to which a man can throw a stone is h.

Now, this height will be achieved when the stone is thrown vertically upwards.

$\therefore \text{v}^2 = 2\text{gh}$ ...(i)

When the stone is projected at an angle, it reaches a certain maximum distance. This is called the range of a projectile which is given as

$R = \frac{v^2 \sin 2\theta}{g}$

We know that maximum range is attained when $\theta = 45^\circ$ and $\sin 2\theta = 1$

$\therefore R = \frac{v^2}{g}$

From (1), we get

$R = \frac{2gh}{g} = 2h$

Therefore, if a man can throw a stone to maximum height h then he can throw the same stone to a maximum distance 2.

23. $\overline{r}_{\text{cm}} = \frac{m_1\bar{r}_1 + m_2\bar{r}_2}{m_1 + m_2}$

If centre of mass is at the origin

$\overline{r}_{cm} = 0$

$\Rightarrow m_1\overline{r}_1 + m_2\overline{r}_2 = 0$

$m_1\overline{r}_1 = -m_2\overline{r}_2$

In terms of magnitude $m_1|\overline{r}_1| = m_2|\overline{r}_2|$

$\Rightarrow \frac{m_1}{m_2} = \frac{r_2}{r_1}$

24. Suppose M be the mass of the sun and R be the distance of the earth from the sun, then escape velocity,

$v_e = \sqrt{\frac{2GM}{R}}$ = $\sqrt{\frac{2\times6.67\times10^{-11}\times2\times10^{30}}{1.5\times10^{11}}}$ ms^{-1}

= $\sqrt{\frac{4\times6.67}{1.5}} \times 10^4 ms^{-1} = 4.217 \times 10^4 ms^{-1}$

$v_e = 42.17\ kms^{-1}$

$\therefore$ The escape speed for the solar system is $42.17\ kms^{-1}$

25. Diameter of the cones of the narrow ends, d = 0.50 mm $= 0.5 \times 10^{-3}$m

Radius, $r = \frac{d}{2} = 0.25 \times 10^{-3} m$

Compression force, F = 50,000 N

Pressure at the tip of the anvil, $P = \frac{\text{force}}{\text{area}} = \frac{50000}{\pi(0.25\times10^{-3})^2} = 2.55 \times 10^{11} Pa$

$P = 2.55 \times 10^{11} Pa$

26. By Wien's Displacement Law

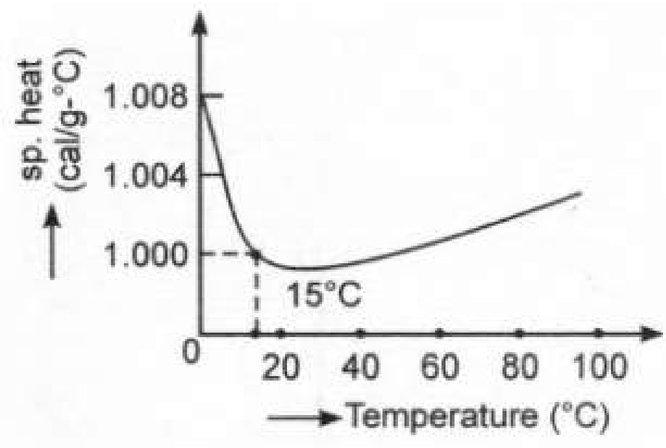
$\lambda_m T = \lambda'_m T'$ (Say, T and T' are the temperatures of two stars for their maximum radiation wavelengths λ_m and λ'_m respectively)

$\therefore \frac{T}{T'} = \frac{\lambda m'}{\lambda m} = \frac{4.8\times10^{-7}}{3.6\times10^{-7}}$

= 4:3

OR

The value of specific heat of water is maximum as compared to other solids and liquids. At 15 ^{0}C, its value is 1 cal g^{-1} $^{0}C^{-1}$ or 4186 j kg^{-1} K^{-1} . However, when temperature changes the value of specific heat of water at 15 ^{0}C changes. The variation of specific heat of water with temperature is shown below:



27. As we know that, V_{rms}= $\sqrt{\frac{3RT}{M}}$

Thus, $(V_{rms})_{Ar}$ = $(V_{rms})_{He}$

$\Rightarrow \sqrt{\frac{T_{Ar}}{M_{\text{Ar}}}} = \sqrt{\frac{T_{\text{He}}}{M_{\text{He}}}}$

T_{Ar} = ?, T_{He} = 273 - 10 = 263 K

M_{Ar} = 39.9 u, M_{He}= 4 u

Thus, $\frac{T_{\text{Ar}}}{39.9} = \frac{263}{4}$

$T_{\text{Ar}} = \frac{263\times39.9}{4} = 2623.43\text{K}$, this is the required temperature of the Ar atom.

OR

Standard temperature T = 273 K.

∴ Mean kinetic energy of one mole of hydrogen at STP

$\overline{E} = \frac{3}{2}RT$

= $\frac{3}{2} \times 8.3 \times 273$

= 3403 J

= $3.4 \times 10^{3}\text{J}$

28. a. Correct

$y = \alpha \sin \frac{2\pi t}{T}$

Dimension of y = $M^0L^1T^0$

Dimension of a = $M^0L^1T^0$

Dimension of $\sin \frac{2\pi t}{T} = M^0L^0T^0$

∵Dimension of L.H.S = Dimension of R.H.S

Hence, the given formula is dimensionally correct.

b. Incorrect

$y = \left(\frac{\alpha}{T}\right)\sin\left(\frac{t}{\alpha}\right)$

Dimension of y = $M^0L^1T^0$

Dimension of $\frac{\alpha}{T} = M^0L^1T^{-1}$

Dimension of $\frac{t}{a} = M^0L^{-1}T^l$

But the argument of the trigonometric function must be dimensionless, which is not so in the given case. Hence, the formula is dimensionally incorrect.

c. Correct

$y = (\alpha\sqrt{2})\left(\sin 2\pi\frac{t}{T} + \cos 2\pi\frac{t}{T}\right)$

Dimension of y = $M^0L^1T^0$

Dimension of a = $M^0L^1T^0$

Dimension of $\frac{t}{T} = M^0I^0T^0$

Since the argument of the trigonometric function must be dimensionless (which is true in the given case), the dimensions of y and a are the same. Hence, the given formula is dimensionally correct.

29. We know

i. $a = \frac{dv}{dt}$

a dt = dv

Integrating

$\int\limits_0^t adt = \int\limits_u^v dv$

at = v - u

v = u+at

ii. We know

$a = \frac{dv}{dt}$

Multiply and Divide by dx

$a = \frac{dv}{dt} \times \frac{dx}{dx}$

$a = \frac{dv}{dx} \times v$

$adx = vdv \left(\because \frac{dx}{dt} = v\right)$

Integrating within the limits

$a\int_0^s dx = \int_u^v vdv$

$as = \frac{v^2}{2} - \frac{\nu^2}{2}$

$as = \frac{v^2 - \nu^2}{2}$

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

30. It is given that , mass (m) =1500 kg, Height (h) = 20 m, efficiency (η)=75% and time (t) = 20s

We know that, Work done, W = mgh =1500$\times$9.8$\times$20

= 2.94$\times$105 J

Now, Rate of doing work = $\frac{W}{t} = \frac{2.94 \times 10^5}{20}$

= 1.47$\times 10^4$ W

As efficiency, $\eta = \frac{\text{Output power}}{\text{Input power}}$

$\frac{75}{100} = \frac{1.47 \times 10^4}{\text{Input power}}$

Input power or the rate at which energy is supplied

$= \frac{1.47 \times 10^4 \times 100}{75} = 1.96 \times 10^4 \text{W}$

31. We know that acceleration due to gravity from the surface of Earth at height "h" is given as,

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

reduced to 4% of gravity due to earth g' = 4% of $g' = \frac{4g}{100}$

R = 6400km

$\frac{4g}{100} = g\left(\frac{R}{R+h}\right)^2$

$\frac{4}{100} = \left(\frac{R}{R+h}\right)^2$

$\frac{2}{10} = \frac{R}{R+h}$

2(R + h) = 10R

2R+2h=10R

2h =10R-2R

2h=8R

h=8R/2
h = 4R

h= 4 $\times$ 6400

h= 25,600km.

32. A special cylindrical shape is given to the bullets to ensure that when a bullet is fired form revolver/rifle/gun, it does not bend from trajectory due to Magnus effect. When we trigger of a rifle, the bullet requires a translational motion as well as spinning motion and the bullet, if spherical in shape, may deviate from its path. But in case of bullet of special cylindrical shape the axis of spinning motion is parallel to that of translational motion. Consequently, the pressure on the sides of cylindrical bullet remains uniform throughout and hence the bullet will not bend from its trajectory.

OR

From, Poiseuille's formula for flow of liquid through a tube of radius 'r' : $\rightarrow$

$$\mathrm{V} = \frac{\pi \mathrm{Pr}^4}{8\eta l}$$

V = Volume of liquid

r = Radius of tube

$\frac{P}{l} =$ Pressure Gradient

η = Co-efficient of viscosity

When two tubes are connected in series, then the volume of liquid through both the tubes is equal.

Radius of first tube = 0.06 cm

Radius of second tube = 0.02 cm

Length of first tube = 15 cm

Length of second tube = 5 cm

Now, Volume of liquid through first tube $V_1 = \frac{\pi P_1 r_1^4}{8\eta l_1}$

Volume of liquid through second tube, $V_2 = \frac{\pi P_2 r_2^4}{8\eta l_2}$

Equating above equations for tubes connected in Series

$V_1 = V_2$

$$\frac{\pi P_1^4}{8\eta l_1} = \frac{\pi P_2 r_2^4}{8\eta l_2}$$

Now, Pressure in first tube = P_1 = (15 - h) sg

S = Density of liquid

Pressure in Second tube = P_2 = hsg

15 cm = height of water column.

Now, $\frac{\pi(15-h)sg\times r_1^4}{8\eta l_1} = \frac{\pi hsg\times r_2^4}{8\mu l_2}$

$$\frac{(15-h)r_1^4}{l_1} = \frac{hr_2^4}{l_2}$$

$$\frac{(15-h)\times(0.06)^4}{15} = \frac{h\times(0.02)^4}{5}$$

$$\frac{(15-h)}{15} \times \left(6 \times 10^{-2}\right)^4 = \frac{h}{5} \times \left(2 \times 10^{-2}\right)^4$$

$$\frac{(15-h)}{15} \times 1296 \times 10^{-7} = \frac{h}{5} \times 16 \times 10^{-7}$$

$$\frac{(15-h)}{15} \times 1296 = \frac{h}{5}$$

h = 14.464 cm

∴ Pressure difference across first tube = 15-14.464

= 0.536 cm of water column

Pressure difference across second tube = 14.464 cm of water column.

33. Length of rod = Δx = 20cm = 2 $\times$ 10^{-3}m
Diameter = 2cm
R = 10^{-2}m
Area of cross-section = πr^2
$= \pi\left(10^{-2}\right)^2$
$= 10^{-4}\pi$ sq. m
ΔT = T_2 - T_1 = 100 - 0 = 100^0c
Mass of ice melted = m = 25g
Latent heat office = 80 cal/g
Heat conducted, ΔQ = mL
= 25 $\times$ 80
= 2000 cal
= 2000 $\times$ 4.2J
Δt = 5 min = 300s
So,
$\frac{\Delta Q}{\Delta t} = \text{KA}\frac{\Delta T}{\Delta x}$
$\frac{\Delta Q/\Delta t}{A\Delta T/\Delta x} = \frac{\Delta Q\Delta x}{\Delta t A\Delta T}$
$= \frac{2000\times4.2\times20\times10^{-2}}{300\times10^{-4}\pi\times100}$
K = 1.78J |s|m|^{0}c
K = coefficient of thermal conductivity

34. Consider two waves having same frequency, same nature travelling in same direction superimpose on each other. Let these waves be represented by
$y_1\left(x,t\right)$ = A sin(kx - ωt) ...(i)
and $y_2\left(x,t\right)$ = A sin(kx - ωt + ϕ) ...(ii)
Here the second wave has been considered to be ahead in phase as compared to the first wave by a phase angle ϕ i.e., there is a phase difference of ϕ between the superposing waves.
Applying the superposition principle, we find that the resultant wave is the algebraic

sum of two constituent waves.
Thus,
$y(x,t) = y_1(x,t) + y_2(x,t)$
$= A \sin(kx - \omega t) + A \sin(kx - \omega t + \phi)$
$= 2A\left[\cos\frac{\phi}{2}\cdot\sin\left(kx-\omega t+\frac{\phi}{2}\right)\right]$
or $y(x,t) = 2A \cdot \cos\frac{\phi}{2} . \sin(kx-\omega t+\frac{\phi}{2})$......(iii)
It shows that the resultant wave is also a sinusoidal wave of same frequency and wavelength travelling in +ve x-direction. But amplitude of resultant wave $A_r = 2A\cos\frac{\phi}{2}$ and its phase is $\frac{\phi}{2}$.
Two special cases are of particular interest here:

i. For constructive interference, $\phi=0$, then $A_r = 2A\cos 0^o = 2A$ i.e Maximum Amplitude
ii. If $\phi = \pi$, then $A_r = 2A\cos\left(\frac{\pi}{2}\right) = 0$ and the amplitude of the resultant wave is zero. It is destructive interference.

35. i. In order to maintain uniform circular motion of a particle, a force is needed because uniform circular motion is an accelerated motion. The force is known as the centripetal force. Thus, centripetal force is the force required in order to make an object move along a circular path with uniform speed. The force acts along the radius and is directed towards the centre of circular path. The centripetal force F acting on a particle moving uniformly in a circle may depend upon mass (m), velocity (v), and radius (r) of the circle.
We know that centripetal acceleration of a particle moving with a constant speed v along a circle of radius r is given by:
$a_c = \frac{v^2}{r}$ ....(1)
Hence, according to Newton's second law of motion, for a particle of mass m, we have
The centripetal force $F = ma_c = \frac{mv^2}{r}$ [by using equation (1)]
As $v = r\omega$, where ω is the angular velocity of the particle, then
$F = \frac{m}{r}(r\omega)^2 = mr\omega^2$
which is the required expression for the centripetal force.

ii. The main concept used: The centripetal force to keep the car in circular motion without skidding is provided by frictional force by the road on the wheels of the car inward to centre O.

Time taken from $A \rightarrow B \rightarrow C$

S_1 = length of path = $\frac{3}{4}$ th of the circumference of the bigger sphere of radius 2R

= $\frac{3}{4} \times 2\pi \times (2R) = \frac{3}{4} \times 4\pi \times 100 = 300\pi\text{m}$

v_1 = the maximum speed of car along the circular path(using the formula $\frac{mv^2}{r} = \mu mg$)

$\mu = 0.1$

$Here,\ r = R = 100\ m$ and g = 10 m/s^2

$v_1 = \sqrt{\mu rg} = \sqrt{0.1 \times 2R \times g}$

$v_1 = \sqrt{0.1 \times 2 \times 100 \times 10} = \sqrt{200} = 10 \times \sqrt{2}m/s$ =14.14 m/sec

$\therefore t_1 = \frac{s_1}{v_1} = \frac{300\pi}{14.14} = \frac{300 \times 3.14}{14.14} = 66.62s$

Time from $C \rightarrow D$ and $F \rightarrow A$

$s_2 = CD + FA = R + R = 100 + 100 = 200\text{m}$

As path CD and FA are straight path so car will travel with iti maximum speed(As, there is no function of the frictional force to provide the centripetal force here) v_2 = 50m/s

$\therefore t_2 = \frac{s_2}{v_2} = \frac{200}{50} = 4\,\text{sec}$

Time for path $D \rightarrow E \rightarrow F$ **is**

$s_3 = \frac{1}{4}$th of the circumference of the smaller sphere of radius

$R = \frac{1}{4} \times 2\pi R = \frac{1}{4} \times 2\pi \times 100 = 50\pi$

Maximum speed without skidding (centripetal force is provided by the frictional force i.e. $\frac{mv^2}{r'} = \mu mg$, r' = R)

$\therefore v_3 = \sqrt{\mu r' g} = \sqrt{0.1 \times R \times g} = \sqrt{0.1 \times 100 \times 10} = 10\text{m/s}$

$t_3 = \frac{s_3}{v_3} = \frac{50\pi}{10} = 5\pi\,\text{sec} = 5 \times 3.14 = 15.70s$

Total time taken by car $= t_1 + t_2 + t_3$

$\therefore$ t = $t_1 + t_2 + t_3$ = 66.62 + 4 + 15.70 = 86.32 sec.

OR

The Main concept used: To plot the graph (r-t) or trajectory we relate x and y coordinates.

Sol: General form of displacement vector is written as

a. $\vec{r}(t) = \hat{i}x + \hat{j}y$ Given in the question, $\vec{r}(t) = \hat{i}A\cos\omega t + \hat{j}B\sin\omega t$ Comparing the above two equations we get,
   $x = A\cos\omega t$ and $y = B\sin\omega t$
   $\frac{x}{A} = \cos\omega t \ldots (i), \frac{y}{B} = \sin\omega t \quad \ldots (ii)$
   Squaring and adding (i), (ii)
   $\frac{x^2}{A^2} + \frac{y^2}{B^2} = \cos^2\omega t + \sin^2\omega t$
   $\Rightarrow \frac{x^2}{A^2} + \frac{y^2}{B^2} = 1$ This is the equation of an ellipse. So the trajectory is an ellipse.
b. $x = A\cos\omega t$ (Given)
   $\Rightarrow \nu_x = \frac{dx}{dt} = -A\omega\sin\omega t$($v_x$ = x component of velocity)
   $\Rightarrow a_x = \frac{dv_x}{dt} = -A\omega^2\cos\omega t$ (a_x = x component of acceleration)
   and, $y = Bsin\omega t$ (Given)
   $\therefore v_y = \frac{dy}{dt} = B\omega\ Cos\omega t$($v_y$ = y component of velocity)
   $\therefore \vec{a} = a_x\hat{i} + a_y\hat{j}$
   $= -\hat{i}Aw^2\cos\omega t - \hat{j}B\omega^2\sin\omega t$
   $= -\omega^2\left[\hat{i}A\cos\omega t + \hat{j}B\sin\omega t\right]$
   $\Rightarrow \vec{a} = -\omega^2\vec{r}(t)$
   $\therefore$ Force acting on particle = $m\vec{a}$ = $-m\omega^2\vec{r}(t)$

36. a. When cat lands on the ground, it stretches its tail as a result its moment of inertia increases
   As $I\omega$ = constant (In the absence of external torque,angular momentum of the system remains constant)
   $\therefore$ Angular speed will be small due to increase in moment of inertia and the cat is able to land on its feet without any harm as it provides enough time for cat to land on the ground.
   b. Let moment of inertia of a system decrease from I to I'
   Then angular speed increase from ω to ω'
   $\Rightarrow I\omega = I'\omega'$ ($\because I\omega$ = constant because in the absence of external torque angular momentum of the system remains conserved)

$\omega' = \frac{I\omega}{I'}$

Kinetic Energy of rotation of the system

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

$KE = \frac{1}{2} I' \left(\frac{I\omega}{I'}\right)^2$

$\mathrm{K.E} = \frac{1}{2} \frac{\mathrm{I}^2 \omega^2}{\mathrm{I}'}$

As I' < I

∴ Kinetic Energy of the system has increased which means it will not remain constant.

OR

Weight of car = 1800 Kg

Distance of COG from front axle = 1.05 m

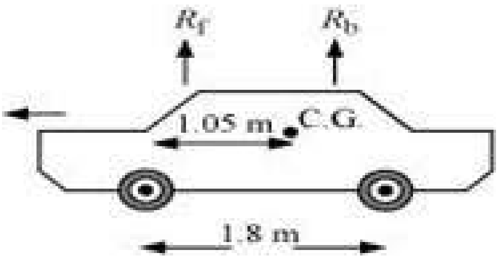
Distance of COG from back axle = 1.8 - 1.05 = 0.75 m

Vertical forces are balanced ,

So,At translational equilibrium:

$R_1 + R_2 = mg$

$R_1 + R_2 = 1800 \times 9.8 = 17640$



R_1 and R_2 are the forces exerted by the level ground on the front and back wheels respectively.

Angular momentum about centre of gravity is zero.

So,

R1(1.05) = R2(1.8 - 1.05)

$R_1 \times 1.05 = R_2 \times 0.75$

$\frac{R_1}{R_2} = \frac{0.75}{1.05} = \frac{5}{7}$

$\frac{R_1}{R_2} = \frac{7}{5}$

$R_1 = 1.4 R_2$ .....(ii)

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

1.4 R_2 + R_2 = 17640

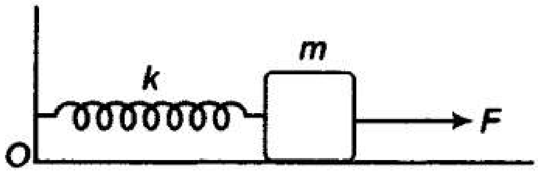
$R_2 = \frac{17640}{2.4} = 7350\text{N}$

$\therefore$ R_1 = 17640 - 7350 = 10290 N

Therefore, the force exerted on each front wheel $= \frac{R_1}{2} = \frac{7350}{2} = 3675N$, and

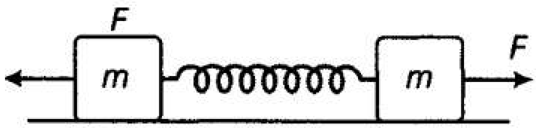
The force exerted on each back wheel $= \frac{R_2}{2} = \frac{10290}{2} = 5145N$

37. i. For Case (a), as we know that the restoring force, F = -kx $\Rightarrow$ |F| = kx

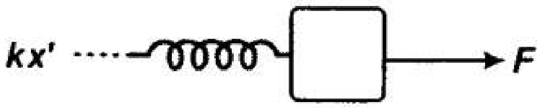


So, x = $\frac{F}{k}$

Case (b)



If x' is the extension in the spring, then drawing free body diagram of either mass (as the system under applied force is under equilibrium).



kx' = F

$\therefore x' = \frac{F}{k}$

In both the cases, extension is the same $\left(\frac{F}{k}\right)$.

ii. The period of oscillation in case(a)

As, restoring force(F) = -kx

where, x = given extension

But from Newton's 2nd law of motion we know that, F = ma

$\therefore ma = -kx \Rightarrow a = -\left(\frac{k}{m}\right)x$.......(i)

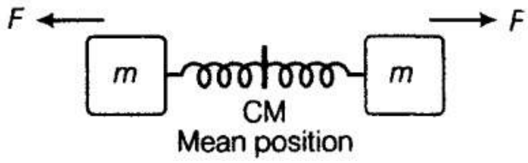
$a \propto -x$

On comparing eq.(i) with a = -ω^2x, we get

$\omega = \sqrt{\frac{k}{m}}$ (angular frequency or velocity of the motion)

Period of oscillations, $T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}}$

Case (b)



The system is divided into two similar systems with spring divided in two equal halves, forming spring constant

k' = 2k

Hence, F = - k'x

Putting k' = 2k (on cutting a spring in two halves, its k doubles)

F = -2kx

But from Newton's 2nd law of motion, F = ma

∴ma = -2kx

$\Rightarrow a=-\left(\frac{2k}{m}\right)x$.........(ii)

On comparing Eq.(ii) with a = -ω^2x, we get angular frequency or velocity,

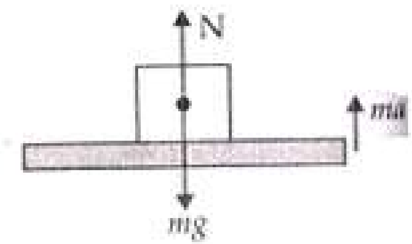
$\omega=\sqrt{\frac{2k}{m}}$

Hence the required period of oscillation of the geven question,

$T=\frac{2\pi}{\omega}=2\pi\sqrt{\frac{m}{2k}}$

OR

a. Weight in weight machine will be due to the normal reaction (N) by platform. Consider the top position of platform, two forces acting on it are due to weight of person and oscillator. They both act downward.



(mg = weight of the person with the oscillator is acting downwards, ma = force due to oscillation is acting upwards, N = normal reaction force acting upwards)

Now for the downward motion of the system with an acceleration a,

ma = mg - N .....(i)

When platform lifts form its lowest position to upward

ma = N - mg ......(ii)

$a=\omega^2 A$ is value of acceleration of oscillator

$\therefore$ From equation (i) we get,

$N = mg - m\omega^2 A$

Where A is amplitude, ω angular frequency and m mass of oscillator.

$\omega = 2\pi\nu$

$\therefore \omega = 2\pi \times 2 = 4\pi\ rad/\text{sec}$

Again using $A = 5\ cm = 5 \times 10^{-2} m$ we get

$N = 50 \times 9.8 - 50 \times 4\pi \times 4\pi \times 5 \times 10^{-2}$

$= 50\left[9.8 - 16\pi^2 \times 5 \times 10^{-2}\right]$ N

$= 50\left[9.8 - 80 \times 3.14 \times 3.14 \times 10^{-2}\right]$ N

$\Rightarrow N = 50[9.8 - 7.89] = 50 \times 1.91 = 95.50\text{N}$

So minimum weight is 95.50 N(for downward motion of the platform)

From equation (ii), N – mg = ma

For upward motion from the lowest to the highest point of oscillator,

$N = mg + ma$

$= m\left[9.81 + \omega^2 A\right] \quad \because a = \omega^2 A$

$= 50\left[9.81 + 16\pi^2 \times 5 \times 10^{-2}\right]$

$= 50[9.81 + 7.89] = 50 \times 17.70$ N = 885 N

Hence, there is a change in weight of the body during oscillation.

b. The maximum weight is 885 N, when platform moves from lowest to upward direction.

And the minimum weight is 95.5 N, when platform moves from the highest point to downward direction.