CBSE Board
Class XI Physics

Time: - 3 **Marks: - 70 Marks**

General Instructions

(a) All questions are compulsory.
(b) There are 29 questions in total. Questions 1 to 8 carry one mark each, questions 9 to 16 carry two marks each, questions 17 to 25 carry three marks each and questions 27 to 29 carry five marks each.
(c) Question 26 is a value based question carrying four marks.
(d) There is no overall choice. However, an internal choice has been provided in one question of two marks, one question of three marks and all three questions of five marks each. You have to attempt only one of the given choices in such questions.
(e) Use of calculator is not permitted.
(f) You may use the following physical constants wherever necessary.

$$e = 1.6 \times 10^{-19} C$$
$$c = 3 \times 10^{8} ms^{-1}$$
$$h = 6.6 \times 10^{-34} JS$$
$$\mu_o = 4\pi \times 10^{-7} NA^{-2}$$
$$k_B = 1.38 \times 10^{23} JK^{-1}$$
$$N_A = 6.023 \times 10^{23} / mole$$
$$m_n = 1.6 \times 10^{-27} kg$$

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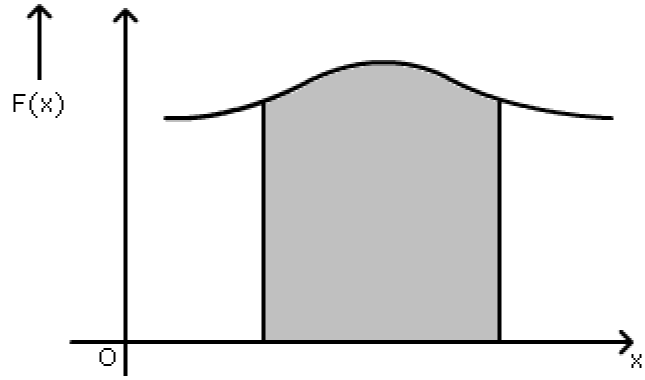
1. Can a physical quantity have units but still be dimensionless? (1)

2. Give an example to show that the direction of velocity of a body can change even when its acceleration is constant. (1)

3. Two vectors $\vec{A}$ and $\vec{B}$ are directed along y-axis and z-axis respectively. What is the direction of the vector $(\vec{B} \times \vec{A})$? (1)

4. What does the area of the shaded portion of the graph represent? (1)



5. Why do we prefer to use a wrench (spanner) of longer arm? (1)

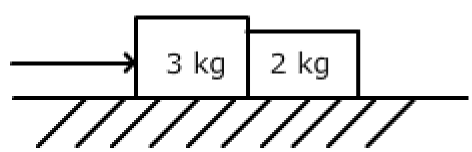
6. What is the degree of freedom of a monoatomic gas? (1)

7. For an ideal gas, show the nature of $\frac{PV}{nT}$ versus P graph, where the symbols have their usual meaning. (1)

8. State the Kelvin-Planck statement of the second law of thermodynamics. (1)

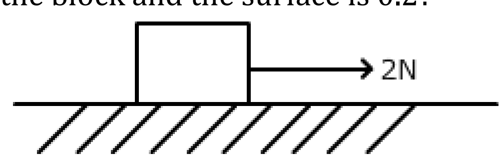
9. Differentiate between systematic errors and random errors. (2)

10. Two blocks of mass 3 kg and 2 kg are in contact with each other on a frictionless table. Find the force exerted by the smaller block on bigger block if a force of 5 N is applied on the bigger block. (2)



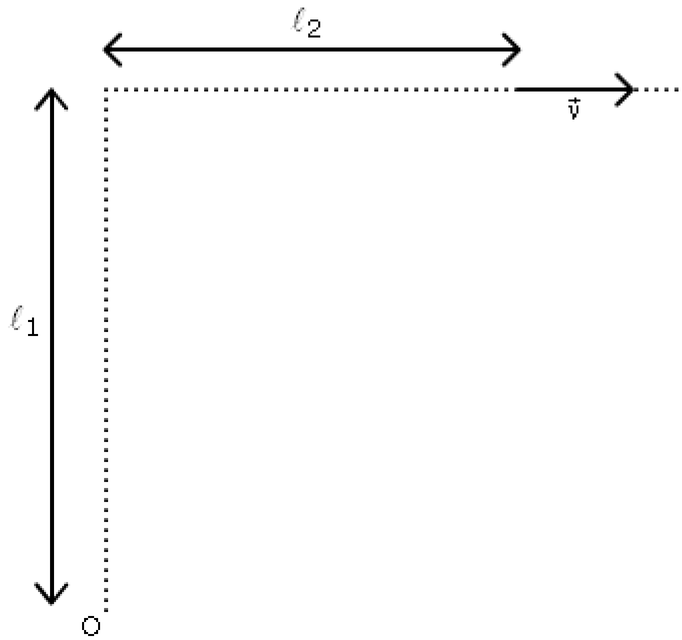
OR

Mention two ways in which static friction is a self adjusting force. How much force of static friction is acting on the block of mass 2 kg shown in figure below if the coefficient of static friction between the block and the surface is 0.2? (2)



11. The kinetic energy of a body is increased by 21%. What is the percentage increase in the linear momentum of the body? (2)

12. Find the magnitude and direction of angular momentum of the body of mass m (about point O) which is moving with velocity $\vec{v}$ as shown. (2)



13. Name the satellites which have Sun synchronous orbit. How is their orbit different from that of the satellites used for communication purpose? What is the significance of negative total energy of a satellite? (2)

14. Define breaking stress. A heavy wire is suspended from a roof and no weight is attached to its lower end. Is it under stress? (2)

15. Calculate the fall in pressure of helium initially at 1600 P_a, when it is suddenly expended to 8 times its original volume. Given $\gamma = \frac{5}{3}$. (2)

16. What is the change in internal energy of a gas during (i) isothermal expansion and (ii) adiabatic expansion? (2)

17. On a two lane road, car A is travelling with a speed of 36 km/h. Two cars B and C approach car A from opposite directions with speeds of 54 km/h each. At a certain instant, when both car B and C are at a distance of 1 km from A, B decides to overtake car A before C does. What minimum acceleration of B is required to avert an accident? (3)

18. A particle of mass m moves in a straight line with retardation proportional to its displacement. Find the expression for loss of kinetic energy for any displacement x. (3)

19. Give reasons for the following:

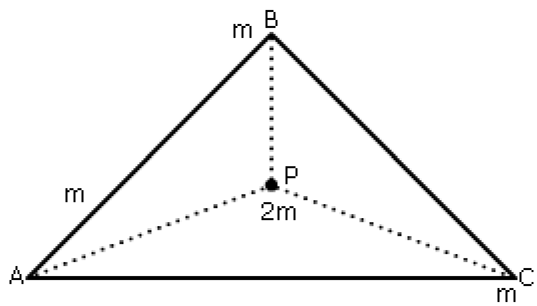
(a) A load on a thief's back does not apply any force on him when he jumps from the upper story of a house.

(b) A gun recoils on being fired.

(c) A man falling from a height receives more injury when he falls on cemented floor rather than when he falls on a heap of sand. (3)

20. A cubical ice box of thermocole has each side 30 cm long and a thickness of 5 cm. 4 kg of ice is put in the box. If outside temperature is 45°C and the coefficient of thermal conductivity is 0.01 J/S/m/°C, calculate the mass of ice left after 6 hours. Latent heat of fusion of ice = 335×10^3 J/kg. (3)

21. Three equal masses of m kg each are fixed at the vertices of an equilateral triangle ABC. What is the force acting on mass 2 m placed at the centroid P of the triangle? Take AP = BP = CP = 1 m. (3)



22. A tank of volume 0.3 m^3 contains 2 moles of helium gas at 20°C. Assuming that helium behaves like an ideal gas.

(a) Find the total thermal energy of the system.

(b) What is the average kinetic energy per molecule? (3)

OR

Nine particles of a gas have speeds of 5.00, 8.00, 12.00, 12.00, 12.00, 14.00, 14.00, 17.00 and 20.00 m/s.

(a) Find the average speed.

(b) What is the rms speed?

(c) What is the most probable speed of the particles? (3)

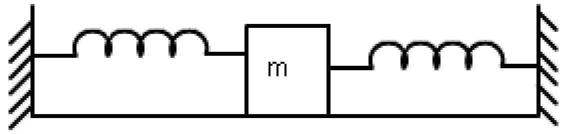
23.

(a) Which characteristic of a wave remains constant as it moves from one medium to another and why?

(b) The phase difference between two points on a progressive wave is $\frac{3\pi}{4}$. What will be the corresponding path difference?

(c) Mention one condition for production of beats. (3)

24. Two identical springs of spring constant k are attached to a block of mass m and to fixed supports as shown below.



Show that the mass executes simple harmonic motion when displaced from its rest position on either side. Also, find the period of oscillations. (3)

25.

(a) Does the first law of thermodynamics violate the law of conservation of energy?

(b) Write the limitations of the first law of thermodynamics. (3)

26. Radha found the wheel getting detached from her uncle's car. She took it to workshop and got it repaired. She informed her uncle, who is a mechanical engineer, about this matter.

(a) What according to you the values displayed by Radha?

(b) A thin wheel can stay upright on its rim for a considerable length of time when rolled with a considerable velocity, while it falls from its upright position at the slightest disturbance, when stationary. Explain. (4)

27. The displacement of a body is given to be proportional to the cube of time elapsed. What is the nature of the acceleration of the body? Justify your answer.

A car accelerates from rest at a constant rate of α for some time; after which it decelerates at constant rate of β to come to rest. If the total time elapsed is T second.

(a) Draw a velocity time graph for the motion.

(b) Calculate maximum velocity attained in terms of α, β and T. (5)

OR

(a) From the top of a building a ball is dropped while another is projected horizontally at the same time.

(i) Which ball will strike the ground first?

(ii) Which will strike the ground with more speed? Justify your answer in each case.

(b) A body is projected with speed u at an angle θ to the horizontal to have maximum range. What is the velocity at the highest point?

(c) What is the angle of projection of a projectile motion whose range R is n times the maximum height. (5)

28.

(a) Is the centrifugal force a reaction of the centripetal force? Give reason for your answer.

(b) What is the effect of reversing the sense of revolution on the centripetal force?

(c) What provides the centripetal force to a car taking a turn on level road?

(d) What is 'angle of banking'?

(e) What is the advantage of banking? (5)

OR

(a) A lawn mower is pulled with some external force. Draw a free body diagram of the system to show all the forces acting on it. Why is it easier to pull it rather than push it?

(b) Why vehicles are provided with round tyres only and not any other shape?

(c) Mention two instances when friction between two surfaces is deliberately increased. Justify the action in each case. (5)

29. Explain the Magnus effect with respect to the motion of a moving ball. What do you understand by 'viscosity'? Give its dimensions and SI unit. On what factors does the coefficient of viscosity of a liquid depend? (5)

OR

State Stoke's law for the viscous drag experienced by the spherical body falling through a viscous liquid. Why does a spherical body achieve terminal speed? On what factors does the terminal speed depend? Give one example each of motion around us with (i) Positive (ii) Negative terminal velocity. (5)

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Solution

1.
Yes. Example is angle

2.
Motion of a body thrown vertically/obliquely under constant g

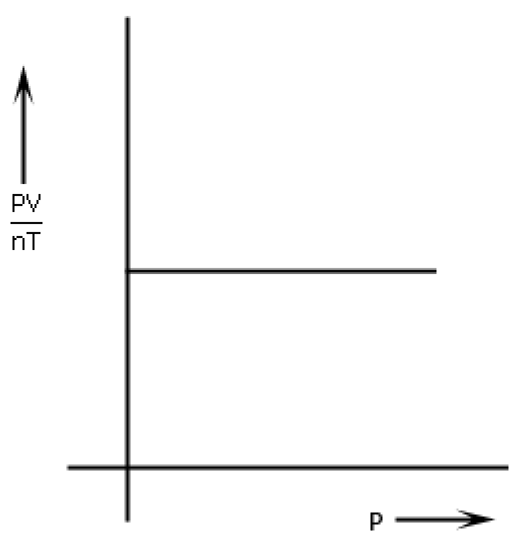
3.
- x-axis

4.
Work

5.
Since $\vec{\tau} = \vec{r} \times \vec{F}$, larger arm means larger $\vec{r}$ which requires less $\vec{F}$ for same $\vec{\tau}$.

6.
3

7.



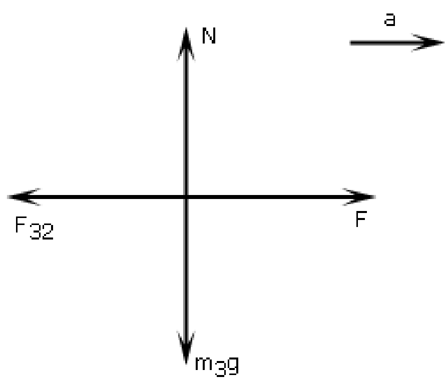
8.
No process is possible whose sole result is the absorption of heat from a reservoir and the conversion of all of this heat into work.

9.

Systematic Errors	Random Errors
1. Errors in which the deviation from true value tends to have fixed size and sign.	Deviation from true value is irregular in size as well as sign.
2. They can be attributed to a fixed cause and can be eliminated.	Irregular pattern does not allow them to be attributed to any fixed cause and hence cannot be eliminated, only minimized.

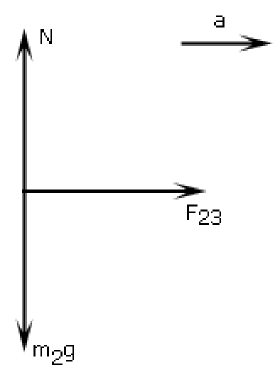
10.

For 3 kg:



$F - F_{32} = m_3a$ (i)

For 2 kg:



$F_{23} = m_2a$ (ii)

But from Newton's third law

$\Rightarrow F_{23} = F_{32}$

Therefore, from (i) and (ii), $F - m_2a = m_3a$

$F = (m_2 + m_3)a$

$\Rightarrow a = \frac{5}{5} = 1\ m/s^2$

Therefore, $F_{32} = m_2a = 2.1 = 2N$ (1/2)

OR

The two ways are:
1. Friction adjusts its **direction** to be always opposite to applied force.
2. Friction adjusts its **magnitude** up to a certain limit, to be equal to the applied force.

$$F_{ms} = \mu_s N = \mu_s mg = 0.2 \times 2 \times 10 = 4N$$

Since, applied force < F_{ms}, the static friction acting = f_s = 2 N.

11.

We know that

$$p = \sqrt{2mk}$$

$$\text{and } p' = \sqrt{2mk'} = \sqrt{2m\left(k + \frac{21}{100}k\right)} = \frac{11}{10}\sqrt{2mk} = \frac{11}{10}p$$

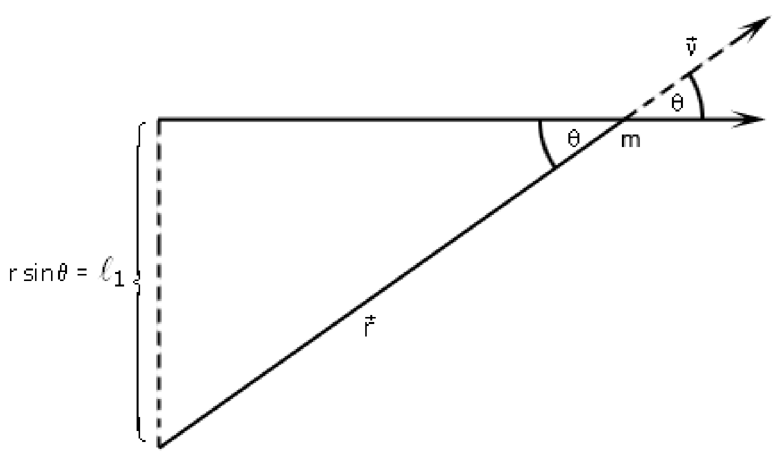
Therefore, $\frac{\Delta p}{p} = \frac{\frac{11}{10}p - p}{p} = \frac{1}{10}$

$$\frac{\Delta p}{p} \times 100 = 10\%$$

12.

$$\left|\vec{\ell}\right| = r\,p\sin\theta = \ell mv$$

Direction of $\vec{r} \times \vec{p}$ = direction of $\vec{\ell}$



13.

Polar satellites - Their orbit is perpendicular to the orbit of geostationary satellites. These are used for communication purpose. Also, the height above the Earth’s surface is lower. Negative sign of total energy indicates attractive nature of force between the satellite and the Earth.

14.

The stress required to fracture a material whether by compression, tension, or shear is called breaking stress.

Yes, the wire is under stress as its own weight acts as load.

15.

For adiabatic expression PV^{γ} = const.

Therefore, $PV^{\gamma} = P'V'^{\gamma} \Rightarrow 1600\ V^{5/3} = P'(8V)^{5/3} = 2^5 P'V^{5/3}$

Or $P' = \frac{1600}{32} = 50\,P_a$

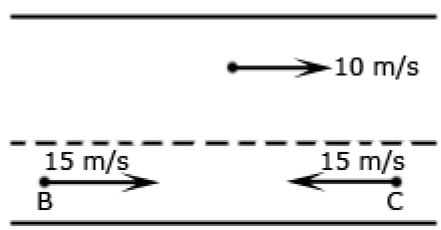
Therefore, fall in pressure = 1600 – 500 = 1550 P_a

16.

(i) For isothermal expansion $\Delta T = 0$, hence $\Delta U = 0$

(ii) For adiabatic expansion $\Delta U = \Delta Q - \Delta W = -\Delta W = -P\Delta V$ as $\Delta Q = 0$.

17.



$$v_A = 36\ km/h = \frac{36 \times 1000}{60 \times 60} = 10\ m/s$$

$$|v_A| = |v_C| = 54\ km/h = 15\ m/s$$

$$v_{BA} = v_B - v_A = 15 - 10 = 5\ m/s$$

$$v_{CA} = v_C - v_A = 15 - (-10) = 25\ m/s$$

Time taken by C to cover 1 km = $\frac{1000}{25} = 40s$

To avoid accident, B should cover 1 km is less than 40s.

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

$$\Rightarrow 1000 = 5 \times 40 + \frac{1}{2}a\,.\,(40)^2$$

$$= 200 + 800\,a$$

800a = 1000 – 200 = 800

$\Rightarrow$ a = 1 m/s^2

18.

$$a = -kx$$

$$a = v\frac{dv}{dx} = -kx$$

$$v\,dv = -kx\,dx$$

Integrating both sides, we get

$$\int_u^v v\,dv = -\int_0^x kx\,dx$$

$$\frac{1}{2}(v^2 - u^2) = -\frac{1}{2}kx^2$$

or $$\frac{1}{2}m(v^2 - u^2) = -\frac{1}{2}m\,kx^2$$

Therefore, loss in K.E. = $\frac{1}{2}m\,kx^2$

19.

(a) During free fall acceleration of thief = g = acceleration of load

So that load is unable to apply any force.

Let the force by load be N.

$$mg - N \Rightarrow N = 0 = \text{force applied by load on man}$$

(b) Along horizontal direction, $\sum \overrightarrow{F_{ext}} = 0$. Net linear momentum is conserved.

Before firing, the system is at rest.

Therefore, 0 = $m_b v_b + m_g v_g$

$$v_g = -\frac{m_b}{m_g}v_b$$

So, to conserve linear momentum, the gun recoils.

(c) The sand yields but the cemented floor doesn’t.

Hence, the time taken by man to come to rest increases in case of sand.

Since, $\frac{\Delta p}{\Delta t} = F$, force on man is less.

20.

We know that

$$Q = \frac{KA(T_1 - T_2)t}{x}$$

A = area of 6 faces = $6 \times (3 \times 10^{-1})^2 = 54 \times 10^{-3}$

$$m\,L = \frac{KA(T_1 - T_2)t}{x}$$

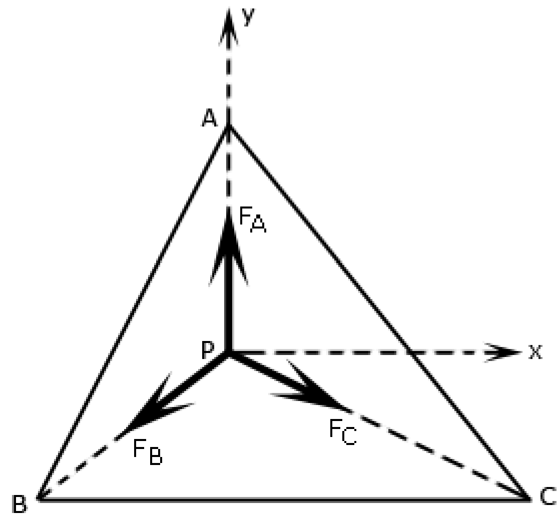
or $$m = \frac{KA(T_1 - T_2)t}{xL}$$

$$= \frac{0.01 \times 54 \times 10^{-2}(45-0) \times 6 \times 3600}{5 \times 10^{-2} \times 335 \times 10^{3}}$$

= 0.313 kg

Therefore, mass left = 4 - 0.313 = 3.687 kg

21.



$$\vec{F}_A = \frac{Gm\,.\,2m}{1}\hat{j} = 2\ Gm^2\hat{j}$$

$$\vec{F}_B = \frac{Gm\,.\,2m}{1}(-\hat{i}\cos 30^\circ - \hat{j}\sin 30^\circ) = 2Gm^2\left(-\frac{\sqrt{3}}{2}\hat{i} - \frac{1}{2}\hat{j}\right)$$

$$\vec{F}_C = \frac{Gm\,.\,2m}{1}(\hat{i}\cos 30^\circ - \hat{j}\sin 30^\circ) = 2Gm^2\left(\frac{\sqrt{3}}{2}\hat{i} - \frac{1}{2}\hat{j}\right)$$

$$\vec{F} = \vec{F}_A + \vec{F}_B + \vec{F}_C = 2Gm^2\hat{j} + 2Gm^2\left(-\frac{\sqrt{3}}{2}\hat{i} - \frac{1}{2}\hat{j} + \frac{\sqrt{3}}{2}\hat{i} - \frac{1}{2}\hat{j}\right)$$

$$= 2Gm^2\hat{j} - 2Gm^2\hat{j} = 0$$

22.

(a) $E = \frac{3}{2}NkT = \frac{3}{2}nRT$

$$= \frac{3}{2}(2)(8.31)(293)$$

$$= 7.3 \times 10^3\,J$$

(b) Average kinetic energy per molecule

$$= \frac{3}{2}(1.38 \times 10^{-23})(292)$$

$$= 6.07 \times 10^{-21}\,J$$

OR

(a) Average speed is

$$\vec{v} = \frac{5.00 + 8.00 + 12.00 + 12.00 + 14.00 + 14.00 + 17.00 + 20.00}{9}$$

$$= 12.70 \text{ m/s}$$

(b) $$v^2 = \frac{(5.0)^2 + (8.0)^2 + (12.0)^2 + (12.0)^2 + (14.0)^2 + (14.0)^2 + (17.0)^2 + (20.0)^2}{9}$$

$$= 178 \text{ m}^2/\text{s}^2$$

Therefore, $v_{rms} = \sqrt{\overline{v^2}} = \sqrt{178} = 13.3 \text{ m/s}$

(c) 3 out of 9 have speed 12 m/s, 2 have 14 m/s and the rest have different speeds. So, most probable speed is 12 m/s.

23.

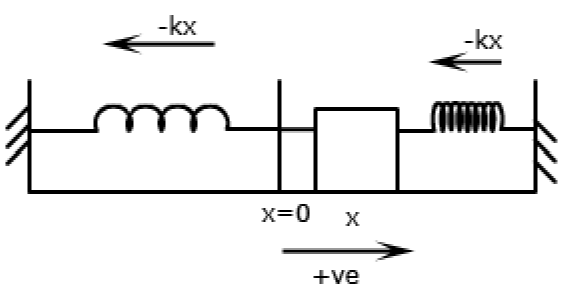
(a) Frequency remains constant as it depends on the source emitting the wave.

(b) 2π corresponds to path difference λ.

Therefore, $\frac{3\pi}{4}$ corresponds to path difference $\frac{\lambda \times \frac{3\pi}{4}}{2\pi} = \frac{3\pi}{8}$

(c) Both waves should not have frequency difference greater than 16 Hz.

24.



If the block is pulled to straight by distance x, restoring force in each spring is –kx. Therefore, for block F = ma

$$\Rightarrow -kx - kx = m\frac{d^2x}{dt^2}$$

or $$m\frac{d^2x}{dt^2} + 2kx = 0$$

or $$\frac{d^2x}{dt^2} + \frac{2k}{m}x = 0$$

which is in form $\frac{d^2x}{dt^2} + \omega^2 x = 0$

Hence, the motion is SHM.

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

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

25.

(a) No, it is in conformity with the law of conservation of energy.

(b)

(i) There is no indication available as regards the direction in which the change takes place.

(ii) It does not give any idea about the extent to which the change takes place.

26.

(a) Radha takes care of things and has concern for others. She is practical in finding the solutions to problems.

(b) When the thin wheel is rolling upright, it possesses some angular momentum in the horizontal direction along the axis of the wheel. As angular momentum is conserved in magnitude as well as direction (in the absence of external torque) the wheel cannot fall from its upright position. However, when external torque due to friction reduces angular velocity of the wheel to zero, (i.e. when the wheel becomes stationary) it falls from its upright position at the slightest disturbance, on account of moment of force due to its weight.

27.

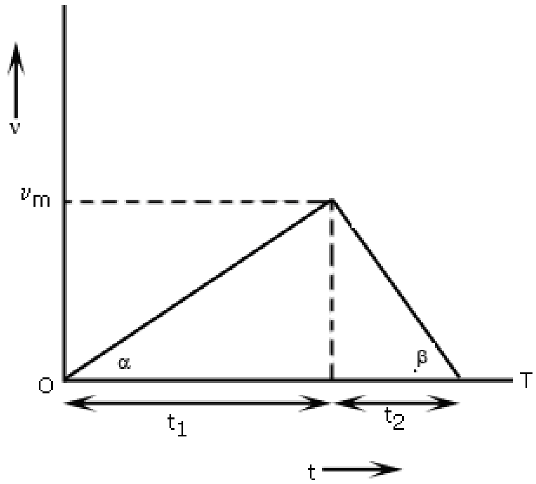
$x \alpha t^3$

$$\Rightarrow x = kt^3$$

$$\Rightarrow v = \frac{dx}{dt} = 3kt^2$$

$$\Rightarrow a = \frac{dv}{dt} = 6kt$$

Therefore, acceleration is non-uniform ($a \alpha t$)



Slope of ν– t graph = acceleration

Therefore, $\alpha = \frac{\nu_m}{t_1}$, $\beta = \frac{\nu_m}{t_2}$

$$\frac{1}{\alpha} = \frac{t_1}{\nu_m}, \frac{1}{\beta} = \frac{t_2}{\nu_m}$$

$$\frac{1}{\alpha} + \frac{1}{\beta} = \frac{t_1 + t_2}{\nu_m} = \frac{\alpha + \beta}{\alpha\beta}$$

$$\nu_m = \frac{(t_1 + t_2)\alpha\beta}{\alpha + \beta} = \frac{\alpha\beta T}{\alpha + \beta}$$

OR

(a)

(i) Both at same time since vertical motion of both are identical $\nu_y = 0$, $a_y = g$ and $S_y = H$

(ii) Second ball will strike with more speed

$$\nu_1 = \sqrt{2gH} \text{ but } \nu_2 = \sqrt{u^2 + 2gH}$$

(b) For max range $\theta = 45°$.

At highest point = $v = v_x = u\cos 45° = \frac{u}{\sqrt{2}}$

(c) $R = \frac{u^2 \sin 2\theta}{g}$

$$= n \cdot \frac{u^2 \sin^2 \theta}{2g} = nH$$

$$2 \sin\theta \cos\theta = \frac{n \sin^2 \theta}{2}$$

$$\frac{\sin\theta}{\cos\theta} = \frac{4}{n}$$

$$\theta = \tan^{-1} \frac{4}{n}$$

28.

(a) No, because action and reaction cannot act on the same body.

(b) No effect

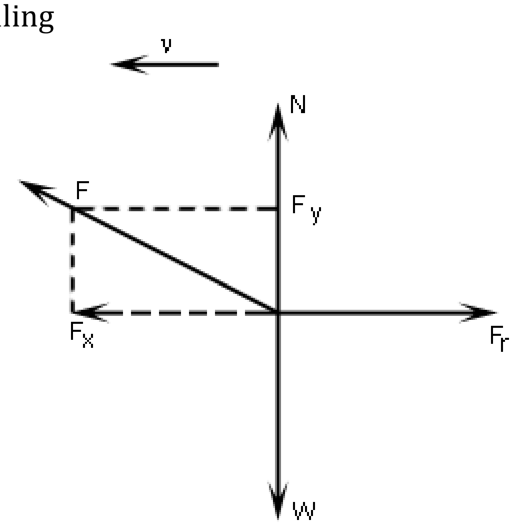
(c) The sideways friction between the road and car tyres.

(d) The angle by which the outer edge of a curved road is raised over the inner edge.

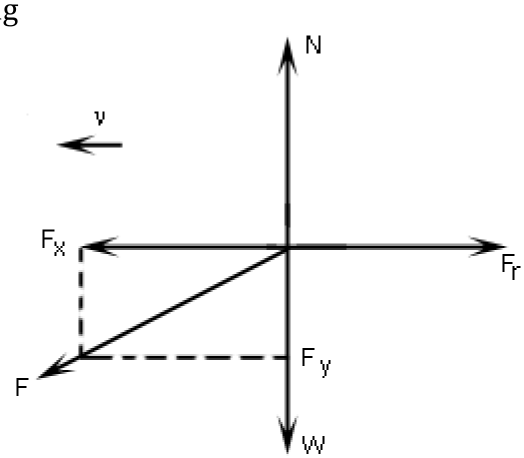
(e) Banking results in additional contribution to centripetal force by a component of normal reaction. So, the vehicles can negotiate a turn at a higher speed without skidding.

OR

(a) Pulling



Pushing



In case of pushing, vertical component of applied force F adds to the weight, thus increasing the friction $F_r = \mu N = \mu\ (F_y + W)$

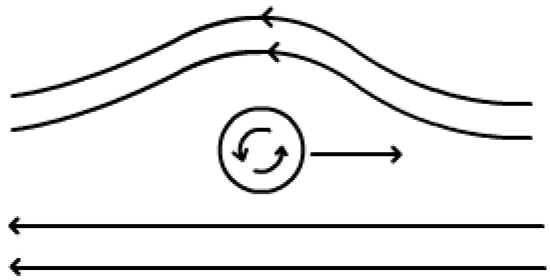
But in case of pulling, vertical component of applied force reduces the downward force, thus decreasing the friction $F = \mu N = \mu(W - F_y)$

(b) Because it changes sliding friction to rolling friction which is smaller.

(c) (i) Car tyres have grooves to increase the friction and hence their grip on the road for perfect rolling.

(ii) To enable walking on slippery ice, sand is sprinkled to increase friction.

29.



Magnus effect: If a moving ball is given a spin, the air layers at the top acquire higher velocity than those at the bottom. So, as per Bernoulli's theorem, pressure below the ball becomes greater than that at the top. Due to net upward force, the ball follows a curved path.

Viscosity is a measure of the resistance of a fluid which is being deformed by either shear stress or extensional stress.

Dimension: $[ML^{-1}T^{-1}]$
SI unit: Poiseulli/decapoise

Depends on: 1. Temperature
2. Nature of liquid

OR

Stokes' Law is written as

$$F_d = 6\pi\mu\ Vd$$

Where F_d is the drag force of the fluid on a sphere, m is the fluid viscosity, V is the velocity of the sphere relative to the fluid, and d is the diameter of the sphere.

Reason: The viscous drag $F_v \alpha\ v$, hence it increases as the body falls. At a certain instant the weight gets neutralized by the buoyant force and the viscous drag. Hence, in absence of any net force, the speed becomes constant.

Terminal speed depends on:
1. Radius of the body
2. Coefficient of viscosity of the fluid
3. Density of body
4. Density of fluid.

Positive terminal velocity ($+v_t$): motion of parachute.
Negative terminal velocity ($-v_t$): motion of air bubbles in water.