SAMPLE PAPER - 5

Class 11 - Physics

Time Allowed: 3 hours **Maximum Marks: 70**

General Instructions:

1. There are 35 questions in all. All questions are compulsory.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.
3. Section A contains eighteen MCQ of 1 mark each, Section B contains seven questions of two marks each, Section C contains five questions of three marks each, section D contains three long questions of five marks each and Section E contains two case study based questions of 4 marks each.
4. There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.
5. Use of calculators is not allowed.

Section A

1. A number of particles crossing a unit area perpendicular to X-axis in unit time is given by $n = -D\frac{n_2 - n_1}{x_2 - x_1}$, where n_1 and n_2 are number of particles per unit volume for the value of x meant to x_2 and x_1. Dimensions of D (called as diffusion constant) are: **[1]**

a) M^0LT^{-3}
b) M^0LT^2
c) $M^0L^2T^{-1}$
d) $M^0L^2T^{-4}$

2. A body is allowed to fall on the ground from a height h_1. If it is to rebound to a height h_2, then the coefficient of restitution is: **[1]**

a) $\frac{h_1}{h_2}$
b) $\sqrt{\frac{h_1}{h_2}}$
c) $\sqrt{\frac{h_2}{h_1}}$
d) $\frac{h_2}{h_1}$

3. A wheel having moment of inertia 2 kg-m^2 about its vertical axis, rotates at the rate of 60 rpm about this axis. The torque which can stop the wheel's rotation in one minute would be: **[1]**

a) $\frac{\pi}{18}\mathrm{N-m}$
b) $\frac{2\pi}{15}\mathrm{N-m}$
c) $\frac{\pi}{12}\mathrm{N-m}$
d) $\frac{\pi}{15}\mathrm{N-m}$

4. Two wires A and B are of the same material. Their lengths are in the ratio 1 : 2 and the diameters are in the ratio 2 : 1. If they are pulled by the same force their increase in length will be in the ratio: **[1]**

a) 8 : 1
b) 1 : 4
c) 2 : 1
d) 1 : 8

5. In planetary motion the areal velocity of the position vector of a planet depends on angular velocity ω and the distance of the planet from Sun (r). If so, the correct relation for area velocity is: **[1]**

a) $\frac{dA}{dt} \propto \sqrt{\omega r}$
b) $\frac{dA}{dt} \propto \omega r^2$
c) $\frac{dA}{dt} \propto \omega r$
d) $\frac{dA}{dt} \propto \omega^2 r$

6. The equation of state corresponding to 8 g of O_2 is: **[1]**

a) $PV = \frac{RT}{2}$
b) PV = 8RT
c) $PV = \frac{RT}{4}$
d) PV = RT

7. One mole of oxygen is expanded from a volume 1 L to 5 L at a constant temperature T = 280 K. The change in internal energy is: **[1]**

a) 0.22 kJ
b) 11 kJ
c) 0 kJ
d) 22 kJ

8. When sound is produced in an aeroplane moving with a velocity of 200 m/s horizontally its echo is heard after $10\sqrt{5}$ seconds. If the velocity of sound in air is 300 ms^{-1}, the elevation of aircraft is: **[1]**

a) 250 $\sqrt{5}$
b) 2500 m
c) 250 m
d) 1250 m

9. The maximum average velocity of water required for streamline flow of liquid passing through a tube of radius 1.25 cm should be: (Coefficient of viscosity of water is 1×10^{-3} deca poise) **[1]**

a) 0.08 ms^{-1}
b) 0.008 ms^{-1}
c) 0.8 ms^{-1}
d) 8 ms^{-1}

10. If the earth were to suddenly contract to half the present radius (without any external torque acting on it), by how much would the day be decreased? [Assume the earth to be a perfect solid sphere of moment of inertia ($\frac{2}{5}$)MR^2]. **[1]**

a) 8 hours
b) 6 hours
c) 2 hours
d) 4 hours

11. A ballet dancer, dancing on a smooth floor is spinning about a vertical axis with her arms folded with an angular velocity of 20 rad/s. When she stretches her arms fully, the spinning speed decreases to 10 rad/sec. If I is the initial moment of inertia of the dancer, the new moment of inertia is: **[1]**

a) 2I
b) 3I
c) I/3
d) I/2

12. The average translational energy and the rms speed of molecules in a sample of oxygen gas at 300 K are 6.21×10^{-21} J and 484 m/s respectively. The corresponding values at 600 K are nearly (assuming ideal gas behaviour) **[1]**

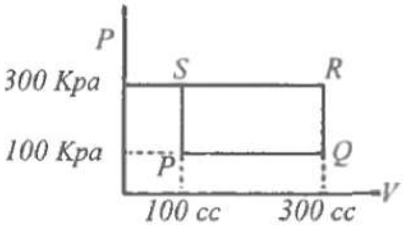
a) 6.21×10^{-21} J, 968 m/s
b) 12.42×10^{-21} J, 684 m/s
c) 8.78×10^{-21} J, 684 m/s
d) 12.42×10^{-21} J, 968 m/s

13. Two express trains X and Y are moving with speeds 25.5 m/s and 40 m/s respectively along same direction with Y ahead of X. A whistle blown from head of train X has pitch variation 600 Hz to 820 Hz. Assuming the speed **[1]**

of sound in still air as 340 m/s, the variation in frequency as heard by listener in train Y is:

a) 220 Hz
b) 184 Hz
c) 198 Hz
d) 210 Hz

14. A thermodynamic system is taken through the cycle PQRSP process. The net work done on the system is: **[1]**



a) 20 J
b) 40 J
c) -40 J
d) -20 J

15. The change in the value of the acceleration of earth towards the sun, when the moon comes from the position of the solar eclipse to the position on the other side of the earth in line with the sun is: **[1]**

(mass of the moon = 7.36×10^{22} kg, radius of the moon's orbit = 3.8×10^8 m).

a) 6.73×10^{-3} m/s^2
b) 6.73×10^{-2} m/s^2
c) 6.73×10^{-5} m/s^2
d) 6.73×10^{-4} m/s^2

16. **Assertion (A):** The magnitude of resultant of two vectors cannot be less than the magnitude of either vector. **[1]**
Reason (R): The resultant of two vectors $\vec{P}$ and $\vec{Q}$ is found out using parallelogram law.

a) Both A and R are true and R is the correct explanation of A.
b) Both A and R are true but R is not the correct explanation of A.
c) A is true but R is false.
d) A is false but R is true.

17. **Assertion:** Spring balances show correct readings even after they had been used for a long time interval. **[1]**
Reason: On using for long time, spring balances loose its elastic strength.

a) Assertion and reason both are correct statements and reason is correct explanation for assertion.
b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
c) Assertion is correct statement but reason is wrong statement.
d) Assertion is wrong statement but reason is correct statement.

18. **Assertion (A):** Number of significant figure in 0.005 is one and that in 0.500 is three. **[1]**
Reason (R): Zeros are not significant figure.

a) Both A and R are true and R is the correct explanation of A.
b) Both A and R are true but R is not the correct explanation of A.
c) A is true but R is false.
d) A is false but R is true.

Section B

19. A body of mass m hung at one end of the spring executes SHM. The force constant of a spring is k while its period of vibration is T. Prove that the relation $T = 2\pi m/k$ is incorrect. Also, derive the correct relation. **[2]**

20. A train has to negotiate a curve of 400 m. By how much should the outer rail be raised with respect to the inner **[2]**

rail for a speed of 48 kmh^{-1}? The distance between the rails is 1 m.

21. To what latitude does the SYNCOMS coverage extend? What is the orbital speed of a SYNCOMS? **[2]**

OR

Which planet of the solar system has the greatest gravitational field strength? What is the gravitational field strength of a planet where the weight of a 60 kg astronaut is 300 N.

22. Why are springs made of steel and not of copper? **[2]**

23. Why does evaporation cause cooling? **[2]**

OR

What is the average distance between atoms (interatomic distance) in water? The density of water is 1000 kg m^{-3}. The density of water vapour at 100 °C and 1 atm pressure is 0.6 kg m^{-3}. The volume of a molecule multiplied by the total number gives, what is called, molecular volume. Estimate the volume of a water molecule.

24. A police van moving on a highway with a speed of 30 km h^{-1} fires a bullet at a thief's car speeding away in the same direction with a speed of 192 km h^{-1}. If the muzzle speed of the bullet is 150m s^{-1}, with what speed does the bullet hit the thief's car? **[2]**

25. The motion of a particle of mass m is described by $y = ut + \frac{1}{2}gt^2$. Find the force acting on the particle. **[2]**

Section C

26. A vessel of volume 0.2 m^3 contains hydrogen gas at temperature 300 K and pressure 1 bar. Find the heat required to raise the temperature of gas to 400 K. The molar heat capacity of hydrogen at constant volume is 20.9 J mol^{-1} K^{-1}. **[3]**

27. A truck starts from rest and accelerates uniformly at 2.0 ms^{-2}. At t = 10 s, a stone is dropped by a person standing on the top of the truck (6 m high from the ground). What are the **[3]**

    i. velocity, and
    ii. acceleration of the stone at t = 11s? (Neglect air resistance.)

28. A large bottle is fitted with a siphon made of capillary glass tubing. Compare the times to empty the bottle when it is filled **[3]**

    i. with water
    ii. with petrol of density 0.8 cgs units. The viscosity of water and petrol are 0.01 and 0.02 cgs units respectively.

OR

Briefly explain Magnus effect.

29. What is the nature of sound waves in air? How is the speed of sound waves in atmosphere affected by the **[3]**

    i. temperature
    ii. and humidity

OR

A source of frequency 250Hz produces sound waves of wavelength 1.32 m in a gas at STP. Calculate the change in the wavelength, when temperature of the gas is 40°C.

30. Two vessels A and B of different materials but having identical shape, size and wall thickness are filled with ice and kept at the same place. Ice melts at the rate of 100 g min^{-1} and 150g min^{-1} in A and B, respectively. Assuming that heat enters the vessels through the walls only, calculate the ratio of thermal conductivities of their materials. **[3]**

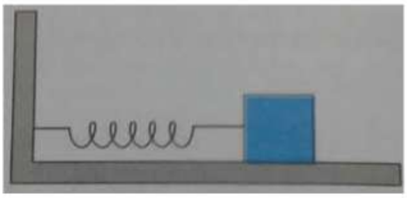
Section D

31. You are riding in an automobile of mass 3000 kg. Assuming that you are examining the oscillation characteristics of its suspension system. The suspension sags 15 cm when the entire automobile is placed on it. Also, the amplitude of oscillation decreases by 50% during one complete oscillation. Estimate the values of **[5]**

a. the spring constant *k* and
b. the damping constant b for the spring and shock absorber system of one wheel, assuming that each wheel supports 750 kg.

OR

A spring having with a spring constant 1200 N m^{-1} is mounted on a horizontal table as shown in Fig. A mass of 3 kg is attached to the free end of the spring. The mass is then pulled sideways to a distance of 2.0 cm and released.



Take the position of mass when the spring is unstreched as x = 0, and the direction from left to right as the positive direction of x-axis. Give x as a function of time t for the oscillating mass if at the moment we start the stopwatch (t = 0), the mass is

a. at the mean position,
b. at the maximum stretched position, and
c. at the maximum compressed position.

In what way do these functions for SHM differ from each other, in frequency, in amplitude or the initial phase?

32. A man can swim at the rate of 5 km /h in still water. A river 1 km wide flows at the rate of 3 km /h. A swimmer wishes to cross the river straight. **[5]**

i. Along what direction must he strike?
ii. What should be his resultant velocity?
iii. How much time he would take to cross?

OR

$\hat{i}$ and $\hat{j}$ are unit vectors along x and y-axes respectively. What is the magnitude and direction of vectors $\hat{i}$ + $\hat{j}$ and $\hat{i}$ - $\hat{j}$? What are the components of a vector A = $2\hat{\mathbf{i}}+3\hat{\mathbf{j}}$ along the direction $\hat{i}$ + $\hat{j}$ and $\hat{i}$ - $\hat{j}$?

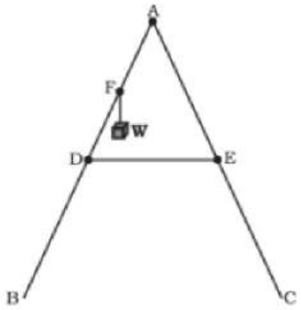
33. Prove the result that the velocity v of translation of a rolling body (like a ring, disc, cylinder or sphere) at the bottom of an inclined plane of a height h is given by $v^2=\frac{2gh}{(1+k^2/R^2)}$. **[5]**

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

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.)



Section E

34. **Read the text carefully and answer the questions:** **[4]**

Free fall is a kind of motion that everybody can observe in daily life. We drop something accidentally or purposely and see its motion. At the beginning its speed is zero and until the end it gains speed and before it reaches ground its maximum speed. It gains speed approximately 10 m/s in a second while falling because of the gravitation.

During the fall, the air resistance is neglected and the acceleration remains constant (equal to g). The object is said to be in free fall. If the height through which the object falls is small compared to the earth's radius, g can be taken to be constant and equal to 10 m/s^2 approximately.

f the object is dropped from the top of a tall building, and it takes t seconds to reach the ground hen the velocity when it reaches ground is gt. The height of the building is $\frac{1}{2}$gt^2.

(i) If an object dropped from the top of a tall building takes 2 seconds to reach ground, find the height of the building?

(ii) Which assumptions are considered when object falls freely from height?

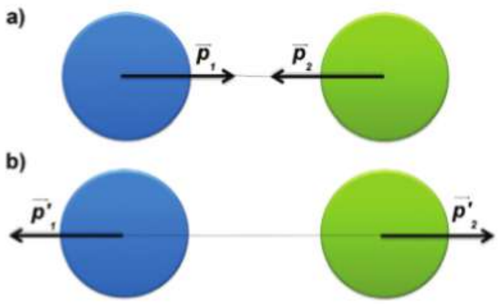
(iii) Draw velocity time graph of an object during free fall.

OR

Draw acceleration-time graph during free fall.

35. **Read the text carefully and answer the questions:** **[4]**

The kinetic energy of an object is the energy associated with the object which is under motion. It is defined as "the energy required by a body to accelerate from rest to stated velocity." It is a vector quantity and the momentum of an object is the virtue of its mass. It is defined as the product of mass and velocity. It is a vector quantity. The relation between them is given by E = $\frac{P^2}{2m}$. In case of the elastic collision both of these quantities remain constant.



(i) Two masses of 1 gm and 4gm are moving with equal linear momentum. Find the ratio of their kinetic energies.

(ii) If the linear momentum is increased by 50%, find the percentage increase in K.E of the body?

(iii) A heavy object and a light object have the same momentum. Which has the greater speed?

OR

Can kinetic energy of a body be negative. Explain.

Solution

SAMPLE PAPER - 5

Class 11 - Physics

Section A

1. **(c)** $M^0L^2T^{-1}$

   Explanation: [n] = Number of particles crossing a unit area in unit time =$[L^{-2}T^{-1}]$

   $[n_2] = [n_1]$ = number of particles per unit valume = $[L^{-3}]$

   $[x_2]=[x_1]$ = positions

   $\therefore \frac{[n][x_2-x_1]}{[n_2-n_1]} = \frac{[L^{-2}T^{-1}]\times[L]}{[L^{-3}]} = [L^2T^{-1}]$

2. **(c)** $\sqrt{\frac{h_2}{h_1}}$

   Explanation: $u_1 = \sqrt{2gh_1}$, $v_1 = \sqrt{2gh_2}$

   e = $\frac{v_1 - v_2}{u_2 - u_1}$

   Since, $u_2 = v_2 = 0$,

   $\therefore \quad e = -\frac{v_1}{u_1} = \sqrt{\frac{h_2}{h_1}}$

3. **(d)** $\frac{\pi}{15}\text{N} - \text{m}$

   Explanation: $\tau = I\alpha = \frac{I(\omega_i - \omega_f)}{t}$

   $= \frac{2\times\left(2\pi\times\frac{60}{60}-0\right)}{60} = \frac{4\pi}{60}$

   $= \frac{\pi}{15}\text{N} - \text{m}$

4. **(d)** 1 : 8

   Explanation: $Y = \frac{F}{\pi r^2} \times \frac{L}{\Delta L}$

   Since Y and F are same for both the wires, we have

   $\frac{L_1}{r_1^2\Delta L_1} = \frac{1}{r_2^2}\frac{L_2}{\Delta L_2}$

   or $\frac{\Delta L_1}{\Delta L_2} = \frac{r_2^2 L_1}{r_1^2 L_2} = \frac{(D_2/2)^2 L_1}{(D_1/2)^2 L_2}$

   or $\frac{\Delta L_1}{\Delta L_2} = \frac{D_2^2 L_1}{D_1^2 L_2} = \frac{D_2^2}{(2D_2)^2} \times \frac{L_1}{2L_1} = \frac{1}{8}$

5. **(b)** $\frac{dA}{dt} \propto \omega r^2$

   Explanation: As we know that,

   $\frac{dA}{dt} = \frac{L}{2m}$

   $\Rightarrow \frac{dA}{dt} \propto vr$

   $vr \propto \omega r^2$

6. **(c)** $PV = \frac{RT}{4}$

   Explanation: 8g of oxygen is equivalent to $(\frac{1}{4})$ mole.

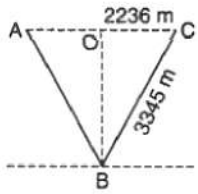
   $\therefore PV = \mu RT = \frac{RT}{4}$

7. **(c)** 0 kJ

   Explanation: In an isothermal process, the value of $\Delta T = 0$ and therefore the change in internal energy, $\Delta U = 0$.

8. **(b)** 2500 m

   Explanation:



Time for the echo = $10\sqrt{5}$ s (i.e., for sound to travel ABC). Velocity of the plane = 200 m/s.

OC = 200 × $5\sqrt{5}$ = 2236 m

BC = velocity of sound × $5\sqrt{5}$

or BC = 300 × $5\sqrt{5}$ = 3354 m

∴ OB = $\sqrt{BC^2 - OC^2}$

OB = 2500 m

The plane is 2500 m above the ground.

9. **(a)** 0.08 ms^{-1}

Explanation: As we know that,

$v_c = \frac{R_e \times \eta}{\rho \times d}$

Maximum value of R_e is 2000

∴ $v_c = \frac{2000 \times 10^{-3}}{10^3 \times 2 \times 1.25 \times 10^{-2}}$

= 0.08 ms^{-1}

10. **(b)** 6 hours

Explanation: t = $\frac{2\pi}{4\omega 1}$

$\omega_1 = \frac{2\pi}{24\text{hrs}}$

t = $\frac{2\pi \times 24hrs}{4 \times 2\pi}$

t = 6 hrs

11. **(a)** 2I

Explanation: Here, angular momentum is conserved.

Initial angular momentum = Final angular momentum

I × 20 = I' × 10

Where I' is new moment of inertia

I' = 2I

12. **(b)** 12.42 × 10^{-21} J, 684 m/s

Explanation: The average translational KE = $\frac{3}{2}$ kT which is directly proportional to T, while rms speed of molecules is given by

$v_{\text{ms}} = \sqrt{\frac{3RT}{M}}$ i.e. $v_{\text{ms}} \propto \sqrt{T}$

When temperature of gas is increased from 300 K to 600 K (i.e. 2 times), the average translational KE will increase to 2 times and rms speed to $\sqrt{2}$ or 1.414 times.

∴ Average translational KE = 2 × 6.21 × 10^{-21} J

= 12.42 × 10^{-21} J

and v_{rms} = (1.414) (484) m/s

= 684 m/s

13. **(d)** 210 Hz

Explanation: Lowest frequency heard by listener in express Y,

n' = $n\left(\frac{v-v_0}{v-v_s}\right) = 600\left(\frac{340-40}{340-25.5}\right)$ = 572.33 Hz

Highest frequency heard by listener in express Y,

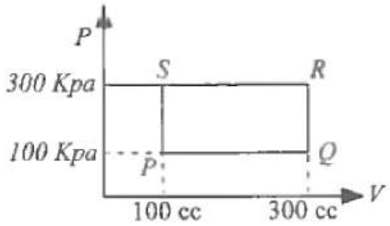
n'' = $820\left(\frac{340-40}{340-25.5}\right)$ = 782.19

Variation = n'' - n' = 209.86 Hz ≈ 210 Hz

14. **(c)** -40 J

Explanation:

Work done = Area enclosed in the diagram



$= \Delta P \Delta V$

$= (P_P - P_S)(V_Q - V_P)$

$= (1 \times 10^5 - 3 \times 10^5)(3 \times 10^{-4} - 1 \times 10^{-4})$

= -40 J

15. **(c)** 6.73×10^{-5} m/s^2

Explanation: 6.73×10^{-5} m/s^2

16. **(d)** A is false but R is true.

Explanation: When $\vec{P}$ and $\vec{Q}$ are equal, act at angle > 90^o, their resultant

$\vec{R} = \sqrt{|P|^2 + |Q|^2 + 2|P||Q|\cos\theta}$

$= \sqrt{|P|^2 + |P|^2 + 2|P|^2(-\sqrt{3}/2)}$ = 0.52 P < P

Thus magnitude of resultant is smaller than two vector.

17. **(d)** Assertion is wrong statement but reason is correct statement.

Explanation: Assertion is false but reason is true.

when a spring balance has been used for a long time, the spring in the balance gets fatigued and there is loss of strength of the spring. In such a case, the extension in the spring is more for a given load and hence the balance gives wrong readings.

18. **(c)** A is true but R is false.

Explanation: In a number less than one, zeros between the decimal point and first non zero digit are not significant. But zeros to the right of last non-zero digit are significant.

Section B

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

LHS, T = [T]

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

As the dimensions of two sides are not equal , hence the equation is incorrect.

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

$[T]^1 = [M]^a[MT^{-2}]^b = M^{a+b}T^{-2b}$

Equating dimension on both sides, we get

a + b = 0 .....(i)

-2b = 1 ......(ii)

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

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

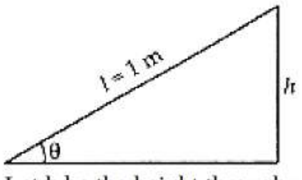
Hence, $T = \beta\sqrt{\frac{m}{k}}$

This is the correct equation.

20. Here

$v = 48 \text{ kmh}^{-1} = \frac{48 \times 1000}{3600} = \frac{40}{3} \text{ ms}^{-1}$

r = 400 m, l = 1 m



Let h be the height through which the outer rail must be raised with respect to the inner rail, as shown in figure. If θ is the angle of banking, then

$\sin\theta = \frac{h}{l}$

For a small value of θ,

$\sin\theta \simeq \tan\theta$

or $\frac{h}{l} = \frac{v^2}{rg}$

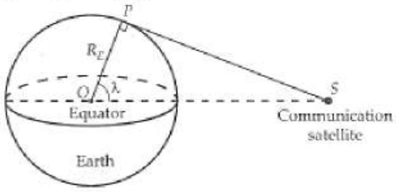
or $h = \frac{v^2 l}{rg}$

$= \frac{(40/3)^2 \times 1}{400 \times 9.8}$ = 0.0454 m

21. Clearly, the latitude of the coverage extends upto the tangent SP, as shown in Figure. From right AOPS,

$\cos\lambda = \frac{OP}{OS} = \frac{R_E}{OS} = \frac{6.37 \times 10^3 \text{ km}}{4.22 \times 10^4 \text{ km}}$ = 0.151

$\therefore \quad \lambda = 81.3^\circ$



Thus a circular arc of about 90° is left uncovered around the pole. That is why we need three satellites to cover the entire earth.

Orbital speed of the SYNCOMS

v = $\frac{2\pi r}{T} = \frac{2 \times 3.14 \times 4.22 \times 10^7 \text{ m}}{86400 \text{ s}}$ = 3067 ms^{-1}

OR

Jupiter has the maximum gravitational field strength because of its large size and mass.

As we know that gravitational field strength is the ratio of Force to mass. Therefore

$= \frac{F}{m} = \frac{300}{60}$

= 5 N kg^{-1}

22. We prefer to have a spring made of steel because Young's modulus of copper is less than that of the steel. As a result of the same shearing strain the stress i.e., the restoring force developed in the spring will be more and the spring will have more strength. In other words, we can say that in copper it does not rebound back to its original shape whereas steel comes back to its original shape.

23. The evaporation of a liquid from its surface occurs because some molecules acquire velocities sufficient enough to escape from the attractive force at the surface. Because escaping molecules have higher kinetic energy, hence the average kinetic energy of the molecules left behind decreases. As average kinetic energy is directly related to temperature, hence evaporation causes cooling.

OR

A given mass of water in vapour state has 1.67×10^3 times the volume of the same mass of water in liquid state. This is also the increase in the amount of volume available for each molecule of water. When volume increases by 10^3 times the radius increases by $V^{1/3}$ or 10 times, i.e., $10 \times 2\mathring{A} = 20\ \mathring{A}$. So the average distance is $2 \times 20 = 40\ \mathring{A}$.

24. Speed of the police van, v_p = 30 km/h = 8.33 m/s

Muzzle speed of the bullet, v_b = 150 m/s

Speed of the thief's car, v_t = 192 km/h = 53.33 m/s

Since the bullet is fired from a moving van, its resultant speed can be obtained as:

= 150 + 8.33 = 158.33 m/s

Since both the vehicles are moving in the same direction, the velocity with which the bullet hits the thief's car can be obtained as:

$v_{bt} = v_b - v_t$ = 158.33 - 53.33 = 105 m/s

25. We know

$y = ut + \frac{1}{2}gt^2$

Now,

$v = \frac{dy}{dt} = u + gt$

acceleration, $a = \frac{dv}{dt} = g$

Then the force is given by eq. $\mathbf{F} = \frac{d\mathbf{p}}{dt} = m\mathbf{a}$

F = ma = mg

Thus the given equation describes the motion of a particle under acceleration due to gravity and y is the position coordinate in the direction of g.

Section C

26. The heat required for rising in temperature is

$\Delta Q = n \cdot C_v \cdot \Delta T$

Here C_v = 20.9 $Jmol^{-1}K^{-1}$ and $\Delta T = T_2 - T_1$ = 400 - 300 = 100 K, P = 1 bar = 10^5 Pascal

From ideal gas equation, PV = nRT_1,

$n = \frac{PV}{RT_1}$

$= \frac{10^5 \times 0.2}{8.31 \times 300} = 8$ moles

$\Delta Q = 8 \times 20.9 \times 100$ = 16720 J

27. Given, the truck starts from rest

therefore, the initial velocity of the truck, u= 0

Acceleration of the truck,'a' = 2 m/s^2

Time, t = 10 s

Now from the first equation of motion,

the final velocity, 'v' is

v = u + at

$\Rightarrow$ v = 0 + 2 $m/s^2 \times$ 10 s =20 m/s

at t =10s

The velocity is 20 m/s

i. At t = 11 s,

The horizontal component of the velocity remains the same, in the absence of air resistance,

Thus, v_x = 20 m/s

According to the first equation of motion, The vertical component of velocity of the stone is given by,

$v_y = u + a_y \delta t$

where,

$\delta t = 11s - 10s = 1s$ and

since the direction is vertical the acceleration acting on it is due to the gravity.

Thus a_y= g =10 m/s^2

$\Rightarrow v_{y\,=}$ 0+ 10 $m/s^2 \times$ 1 s = 10 m/s

The final resultant velocity of the stone is given as,

$v_{res} = (v_x^2 + v_y^2)^{1/2}$

$\Rightarrow v_{res} = (20^2 + 10^2)^{1/2} = \sqrt{500} m/s$

$\Rightarrow v_{res}$ =22.36 m/s

Let us suppose that the angle made by the resultant velocity with the horizontal velocity, v_x is θ,

Thus,

$\tan \theta = \left(\frac{v_y}{v_x}\right)$

$\Rightarrow \theta = \tan^{-1}\left(\frac{10}{20}\right)$

$\Rightarrow \theta = \tan^{-1}(0.5) = 26.57^o$ mm

The velocity of the stone at t =11 s is 22.36 m/s and is at angle 26.57° with the horizontal.

ii. When the stone is dropped from the truck, the horizontal force provided by the truck acting on the stone becomes zero. The only force and thus, the acceleration, that remains is that in the vertical direction i.e. acceleration due to gravity.

Therefore, the acceleration of the stone is 10 m/s^2 and it is in the downward direction.

28. According the question, a large bottle is fitted with a siphon made of capillary glass tubing and given that

The volume of liquid flowing in time t through a capillary tube is given by

V = Qt = $\frac{\pi \rho r^4 t}{8 n l} = \frac{\pi h \rho g r^4 t}{8 \eta l}$

$\therefore$ For water, $V_1 = \frac{\pi h \rho_1 g r^4 t_1}{8\, \ln_1}$

For petrol, $V_2 = \frac{\pi h \rho_2 g r^4 t_2}{8 l \eta_2}$

But $V_1 = V_2$

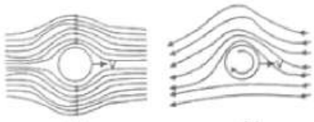
$\therefore \frac{\pi h \rho_1 g r^4 t_1}{8 l \eta_1} = \frac{\pi h \rho_2 g r^4 t_2}{8 l \eta_2}$

or $\frac{t_1}{t_2} = \frac{\eta_1}{\eta_2} \times \frac{\rho_2}{\rho_1} = \frac{0.01}{0.02} \times \frac{0.8}{1.0}$ = 0.4

OR

Magnus effect, generation of a sidewise force on a spinning cylindrical or spherical solid immersed in a fluid (liquid or gas) when there is relative motion between the spinning body and the fluid. It is responsible for the "curve" of a served tennis ball or a driven golf ball and affects the trajectory of a spinning artillery shell.

A spinning object moving through a fluid departs from its straight path because of pressure differences that develop in the fluid as a result of velocity changes induced by the spinning body. The Magnus effect is a particular manifestation of Bernoulli's theroem, fluid pressure decreases at points where the speed of the fluid increases. In the case of a ball spinning through the air, the turning ball drags some of the air around with it. Viewed from the position of the ball, the air is rushing by on all sides. The drag of the side of the ball turning into the air (into the direction the ball is traveling) retards the airflow, whereas on the other side the drag speeds up the airflow. Greater pressure on the side where the airflow is slowed down forces the ball in the direction of the low-pressure region on the opposite side, where a relative increase in airflow occurs.



29. Sound waves in air are longitudinal waves in which compressions and rarefactions take place alternately and move forward.
   i. According to the formula $v = \sqrt{\frac{\gamma P}{\rho}}$ = $\sqrt{\frac{\gamma RT}{M_0}}$

      Thus, $v \propto \sqrt{T}$

      With the increase in temperature T, the velocity v increases since it is directly proportional to the square root of absolute temperature.
   ii. According to formula $v = \sqrt{\frac{\gamma RT}{M_0}}$, where M_0 is the molar mass. Molar mass of water vapour (H_2O) $\approx$ 18 is much less than the molar mass of nitrogen (N_2) $\approx$ 28 and oxygen $\approx$ 32. The effective molar mass M_0 of air decreases with the increase in water vapour. Therefore, the speed of sound in air increases with increase in humidity.

OR

Here we have, ν_0 = 250 Hz and T_0 = 273K

Also, T_1 = 273 + 40 = 313K; λ_0 = 1.32 m

Therefore, Speed of sound = wavelength $\times$ frequency, I.e, $v_0 = \nu_0 \lambda_0$ = 250 $\times$ 1.32 = 330 m/s

Since we know that, Speed of sound, v $\propto \sqrt{T}$

Thus we have, $\frac{v_1}{v_0} = \sqrt{\frac{T_1}{T_0}}$

$v_1 = v_0 \sqrt{\frac{T_1}{T_0}}$ = 330 $\sqrt{\frac{313}{273}}$ = 353.34 m/s ....(i)

and $v_1 = v_0 \lambda_1$

$\lambda_1 = \frac{353.34}{250}$ = 1.41 m

Therfore, Change in the wavelength is given by:

$\triangle \lambda = \lambda_1 - \lambda_0$ = 1.41 - 1.32 = 0.09 m

30. Suppose m_1 and m_2 be the masses of ice melted at the same time (t = 1 min) in vessels A and B, respectively.

    The amounts of heat flowed into the two vessels will be

    $Q_1 = \frac{K_1 A (T_1 - T_2) t}{x} = m_1 L$

    $Q_2 = \frac{K_2 A (T_1 - T_2) t}{x} = m_2 L$

    where L is latent heat of ice.

    Dividing Equation (i) by Equation (ii)

    $\Rightarrow \frac{K_1}{K_2} = \frac{m_1}{m_2} = \frac{100\text{g}}{150\text{g}} = \frac{2}{3}$ = 2 : 3

Section D

31. Mass of the automobile is given by, m = 3000 kg

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

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

The equation for the restoring force for the system is given by:

F = -4kx = mg

Where, k is the spring constant of the suspension system

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

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

Spring constant, $k = 5\times10^4 N/m$

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

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

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

The amplitude of oscillation decreases by 50%.

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

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

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

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

Where,

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

$\therefore b = \frac{2\times750\times0.693}{0.7691}$

= 1351.58 kg/s

Therefore, the damping constant of the spring is given by 1351.58 kg/s.

OR

The functions have the same frequency and amplitude, but different initial phases.

Given:

Distance travelled by the mass sideways is given by, A = 2.0 cm

Force constant of the spring is given by, k = 1200 N m^{-1}

Mass, m is given by = 3 kg

Angular frequency of oscillation is given by:

$\omega = \sqrt{\frac{spring\ cons\tan t}{mass}}$

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

$= \sqrt{\frac{1200}{3}} = \sqrt{400} = 20\mathrm{rads}^{-1}$

a. When the mass is at the mean position, the initial phase is 0.

Displacement is given by,

$\Rightarrow$ x = A sin ωt = 2sin 20t

b. At the maximum stretched position, the mass is toward the extreme right. Hence, the initial phase is $\frac{\pi}{2}$.

hence, Displacement is given by,

$\Rightarrow x = A\sin\left(\omega t + \frac{\pi}{2}\right)$

$= 2\sin\left(20t + \frac{\pi}{2}\right)$ = 2cos 20t

c. At the maximum compressed position, the mass is toward the extreme left. Hence, the initial phase is $\frac{3\pi}{2}$.

Displacement is given by,

$\Rightarrow x = A\sin\left(\omega t + \frac{3\pi}{2}\right)$

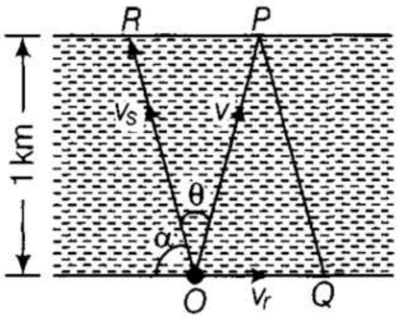
$= 2\sin\left(20t + \frac{3\pi}{2}\right)$ = –2cos 20t

d. The functions have the same frequency $\left(\frac{20}{2\pi}Hz\right)$ and amplitude (2 cm), but initial phases are different $\left(0, \frac{\pi}{2}, \frac{3\pi}{2}\right)$.

32. Given : Width of the river, d = 1 km

Velocity of swimmer, v_s = 5 km/h

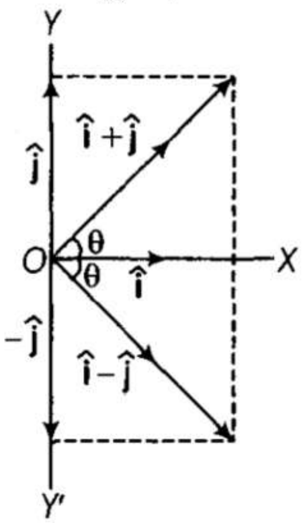
Velocity of river water, v_r = 3 km/h along OQ.



i. The swimmer wants to cross the river straight, hence the direction of swimmer's motion is perpendicular to the direction of flowing river water i.e, along OP. This is possible only if the swimmer swims at angle α with respect to the upstream as shown in the figure;
   From the geometry of the figure we have, $\alpha + \theta = 90^\circ$ or $\theta = 90^\circ - \alpha$
   From $\triangle$OPR, we have
   $\sin\theta = \sin(90^\circ - \alpha) = \cos\alpha = \frac{RP}{RO} = \frac{3}{5}$ = 0.6
   $\Rightarrow \alpha = \cos^{-1}(0.6)$
   $\Rightarrow \alpha = 53^\circ 8'$
ii. The resultant velocity along OP is given by
   $v = \sqrt{v_s^2 - v_r^2} = \sqrt{5^2 - 3^2}$ = 4 km/h
iii. Time taken by swimmer to cross the river,
   t = $\frac{d}{v} = \frac{1}{4}$ = 0.25 h = 15 min

OR

i. As we know $\hat{i}$ and $\hat{j}$ are unit vectors, Magnitude of $(\hat{i} + \hat{j}) = \sqrt{(1)^2 + (1)^2} = \sqrt{2}$ units
   If vector $(\hat{\mathbf{i}} + \hat{\mathbf{j}})$ makes an angle of θ with the x - axis, then
   $\tan\theta = \frac{A_y}{A_x} = \frac{1}{1}$ = 1 = tan 45° or θ = 45°



ii. Similarly, magnitude of
   $(\hat{\mathbf{i}} - \hat{\mathbf{j}}) = \sqrt{(1)^2 + (-1)^2} = \sqrt{2}$
   If vector $(\hat{\mathbf{i}} - \hat{\mathbf{j}})$ makes an angle θ, with x - axis, then
   $\tan\theta = \frac{A_y}{A_x} = \frac{(-1)}{1} = -1$
   $= -\tan 45^\circ \Rightarrow \theta = -45^\circ$ with $\hat{i}$
   Hence, resultant vector $(\hat{\mathbf{i}} - \hat{\mathbf{j}})$ makes an angle of 45° from x-axis in negative direction.
iii. To determine the component of A = $2\hat{\mathbf{i}} + 3\hat{\mathbf{j}}$ in the direction of $(\hat{\mathbf{i}} + \hat{\mathbf{j}})$
   Let us assume B = $(\hat{\mathbf{i}} + \hat{\mathbf{j}})$, then
   A.B = AB cosθ = (A cosθ). B
   or Acosθ = $\frac{\mathbf{A}\cdot\mathbf{B}}{B}$
   $\Rightarrow A\cos\theta = \frac{\mathbf{A}\cdot\mathbf{B}}{B} = \frac{(2\hat{\mathbf{i}}+3\hat{\mathbf{j}})\cdot(\hat{\mathbf{i}}+\hat{\mathbf{j}})}{\sqrt{(1)^2+(1)^2}}$

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

$= \frac{2+3}{\sqrt{2}} = \frac{5}{\sqrt{2}}$. This is the component of vector A in the direction of $(\hat{\mathbf{i}}+\hat{\mathbf{j}})$

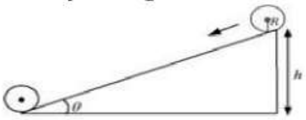
iv. Unit vector along $(\hat{\mathbf{i}}+\hat{\mathbf{j}}), \hat{\mathbf{n}} = \frac{(\hat{\mathbf{i}}+\hat{\mathbf{j}})}{|\hat{\mathbf{i}}+\hat{\mathbf{j}}|} = \frac{(\hat{\mathbf{i}}+\hat{\mathbf{j}})}{\sqrt{2}}$

Component of A along $(\hat{\mathbf{i}}-\hat{\mathbf{j}})$

The magnitude of the component of A in the direction of

$(\hat{\mathbf{i}}-\hat{\mathbf{j}}) = \frac{(2\hat{\mathbf{i}}+3\hat{\mathbf{j}})\cdot(\hat{\mathbf{i}}-\hat{\mathbf{j}})}{|\hat{\mathbf{i}}-\hat{\mathbf{j}}|} = \frac{2\hat{\mathbf{i}}\cdot\hat{\mathbf{i}}-3\hat{\mathbf{j}}\hat{\mathbf{j}}}{\sqrt{(1)^2+(-1)^2}} = \frac{2-3}{\sqrt{2}} = \frac{-1}{\sqrt{2}}$. This is the component of vector A in the direction of $(\hat{\mathbf{i}}-\hat{\mathbf{j}})$.

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



m = Mass of the body

R = Radius of the body

K = Radius of gyration of the body

At highest point,

energy of body (E_i)= PE = mgh

At lowest point,

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

= $\frac{1}{2} \times$ mv² + $\frac{1}{2} \times I\omega^2$

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

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

$= \frac{1}{2}mv^2\frac{k^2}{R^2} + \frac{1}{2}mv^2$

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

From the law of conservation of energy, we have:

$E_i = E_f$

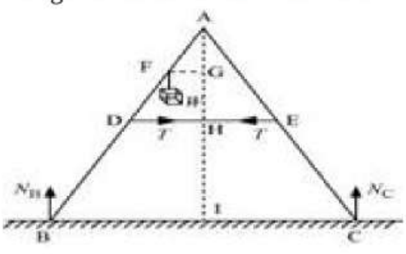
$mgh = \frac{1}{2}mv^2\left(1+\frac{k^2}{R^2}\right)$

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

Hence, the given result is proved.

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 × 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

∴ T = 96.7 N

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

Section E

34. **Read the text carefully and answer the questions:**

Free fall is a kind of motion that everybody can observe in daily life. We drop something accidentally or purposely and see its motion. At the beginning its speed is zero and until the end it gains speed and before it reaches ground its maximum speed. It gains speed approximately 10 m/s in a second while falling because of the gravitation.

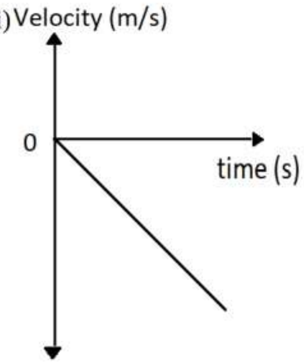
During the fall, the air resistance is neglected and the acceleration remains constant (equal to g). The object is said to be in free fall. If the height through which the object falls is small compared to the earth's radius, g can be taken to be constant and equal to 10 m/s^2 approximately.

f the object is dropped from the top of a tall building, and it takes t seconds to reach the ground hen the velocity when it reaches ground is gt. The height of the building is $\frac{1}{2}gt^2$.

(i) Height of building is given as
H = $\frac{1}{2}gt^2 = \frac{1}{2} \times 10 \times 2^2$ = 20 m

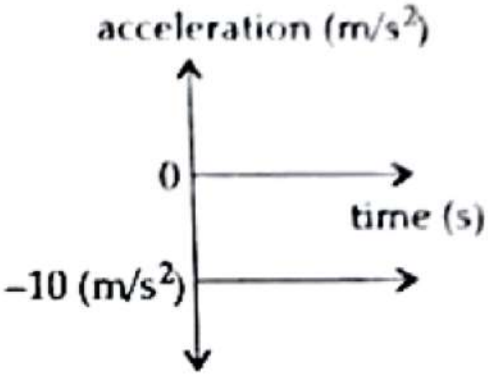
(ii) It is assumed that there is no air resistance and height through which the object falls is small compared to the earth's radius.

(iii)



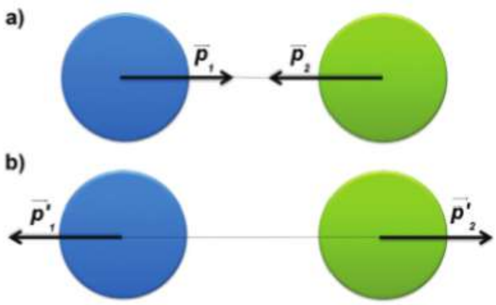
OR

The acceleration is constant during the free fall, acceleration time graph is given as



35. **Read the text carefully and answer the questions:**

The kinetic energy of an object is the energy associated with the object which is under motion. It is defined as "the energy required by a body to accelerate from rest to stated velocity." It is a vector quantity and the momentum of an object is the virtue of its mass. It is defined as the product of mass and velocity. It is a vector quantity. The relation between them is given by E = $\frac{P^2}{2m}$. In case of the elastic collision both of these quantities remain constant.



(i) Energy and momentum are related as

as $E = \frac{P^2}{2m}$

so $E\alpha\frac{1}{m}$

therefore $\frac{E_1}{E_2} = \frac{m_2}{m_1} = \frac{4}{1}$

so energy ratio will be 4 : 1.

(ii) Linear momentum and kinetic energy are related as

$E_1 = \frac{P^2}{2m}$

on increa sin g the momentum by 50%, new momentum is

$P' = \frac{150}{100}$

P = 1.5 P

the new kinetic energy

$E_2 = \frac{\mathbf{P'^2}}{2\,\mathrm{m}} = \frac{(\mathbf{1.5P})^2}{2\,\mathrm{m}}$

$\frac{E_2}{E_1}$ = $(1.5)^2$ = 2.25 ...(i)

Percentage change in kinetic energy of body is

$\frac{E_2 - E_1}{E_1} \times 100 = \left(\frac{E_2}{E_1} - 1\right) \times 100$ ...(ii)

from (i) and (ii) we get

$\frac{E_2 - E_1}{E_1} \times 100$ = (2.25 - 1) $\times$ 100 = 125

so percentage change in kinetic energy will be 125 percent.

(iii)As speed of body is given by

speed = $\frac{momentum}{mass}$

as momentum is constant

so speed $\alpha \frac{1}{mass}$

so for lighter body speed will be more.

OR

as kinetic - energy $= \frac{1}{2}mv^2$

as velocity square is always positive and mass is a positive quantity, there fore kinetic energy is a positive quantity.