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.

$$e = 1.6\times10^{-19} C$$
$$c = 3\times10^{8} ms^{-1}$$
$$h = 6.6\times10^{-34} JS$$
$$\mu_o = 4\pi\times10^{-7} NA^{-2}$$
$$k_B = 1.38\times10^{23} JK^{-1}$$
$$N_A = 6.023\times10^{23} / mole$$
$$m_n = 1.6\times10^{-27} kg$$

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1. Give the number of significant figures in 5.300×10^{3}. (1)

2. The dimension $ML^{-1}T^{-2}$ corresponds to which quantity? (1)

3. Why do we use a wrench of long arm to unscrew a nut tightly fitted to a bolt? (1)

4. Can kinetic energy be negative? What about potential energy? (1)

5. Does the spring constant of a spring depend on its length? (1)

6. Is the Young's modulus of rubber greater than that of steel? (1)

7. State the SI unit of angular velocity. (1)

8. Explain why a cricketer moves his hands back while holding a catch. (1)

9. Find the angle of projection for which horizontal range and maximum height are equal. (2)

OR

Is acceleration vector in uniform circular motion a constant vector? (2)

10. Differentiate between wave velocity and particle velocity for a mechanical wave in the medium. (2)

11. A light body and a heavy body have same momentum. Which one has greater kinetic energy? Support your answer with an explanation (2)

12. State the law of equipartition of energy. (2)

13. What is an adiabatic process? How is it different from an isothermal process? (2)

14. A ball of mass 5 kg strikes against a wall at an angle of 45^{o} and is reflected at the same angle. Find the change in momentum. (2)

15. Check the dimensional consistency of the following equation $\frac{1}{2}mv^2 = mgh$ where m is the mass of the body, v is its velocity, g is acceleration due to gravity and h is the height. (2)

16. The position of a particle is given by $S(t) = 5t\,\hat{i} + 6t^2\,\hat{j} - 10\hat{k}$ where t is in seconds. Find the velocity $v(t)$ and acceleration $a(t)$ of the particle at t = 1s. (2)

17. The kinetic energy of a satellite is E. Find the total energy of the satellite. (3)

18. Explain why

(i) a body with large reflectivity is a poor emitter

(ii) heating systems based on circulation of steam are more efficient in warming a building than those based on circulation of hot water. (3)

19. What is a Carnot's engine? What is its efficiency? (3)

OR

Two masses m_1 and m_2 are connected at the ends of a light inextensible string that passes over frictionless pulley. Find the acceleration, tension in the string and thrust on the pulley when the masses are released. (3)

20. A cylinder of fixed capacity 44.8 litres contains helium gas at standard temperature and pressure. What is the amount of heat needed to raise the temperature of the gas in the cylinder by 15.0 ^{0}C? Given R = 8.32J/mol/K. (3)

21. A particle executes SHM according to the equation $x = A\cos\omega t$. Draw graphs to represent the displacement, velocity and acceleration of the particle. (3)

22. A sound wave travelling along a string is described by $y = 5\times10^{-3}\sin(80x - 3t)$.

Calculate

(i) the amplitude

(ii) the wavelength

(iii) frequency of the wave. (3)

23. What is a conservative force? Prove that gravitational force is conservative and frictional force is non-conservative (3)

24. The bob A of a pendulum released from 30° to the vertical hits another bob B of the same mass at rest on a table as shown in Fig. 6.15. How high does the bob A rise after the collision? Neglect the size of the bobs and assume the collision to be elastic. (3)

25. A 400kg satellite is in a circular orbit of radius 2RE about the earth. How much energy is required to transfer it to an orbit of radius 4 RE? What are the changes in its kinetic and potential energies? (3)

26. Vineet saw his uncle planting seeds in the field. His uncle does not know methods of growing plants. Then he decided to make his uncle aware of this. He explained the importance of ploughing the land before planting the seeds. Uncle is convinced with his ideas. He planted accordingly. The plants grew successfully.

(a) What can you say about Vineet?

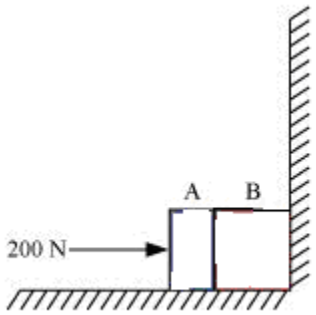
(b) What is the utility of ploughing a field? (4)

27. Draw the first three harmonics in an open organ pipe. Two piano strings A and B are playing slightly out of tune and produce beats of frequency 5Hz. The tension in string B is slightly increased and the beat frequency is found to decrease to 3Hz. What is the original frequency of B if the frequency of A is 500Hz? (5)

OR

Two identical springs each of force constant K are connected in (a) series (b) parallel, so that they support a mass m. Find the ratio of the time periods of the mass in the two systems. (5)

28. Two bodies *A* and *B* of masses 5 kg and 10 kg in contact with each other rest on a table against a rigid wall as shown in the given figure. The coefficient of friction between the bodies and the table is 0.15. A force of 200 N is applied horizontally to *A*. What are (a) the reaction of the partition (b) the action-reaction forces between *A* and *B*? (c) What happens when the wall is removed? (5)



OR

Give any three differences between progressive waves and stationary waves. A stationary wave is y = 12 sin 300 t cos 2x. What is the distance between two nearest nodes? (5)

29. What is a projectile? Write the expressions for the time of flight, and maximum height for the projectile thrown upwards at an angle θ with the horizontal direction.
The ceiling of a long hall is 25 m high. What is the maximum horizontal distance that a ball thrown with a speed of 40 m s^{-1} can go without hitting the ceiling of the hall? (5)

OR

What do you mean by the centripetal force? Derive an expression for it. (5)

CBSE Board
Class XI Physics
Solution

1.
4

2.

Pressure or energy per unit volume

3.

Greater torque will be applied if force arm is more as $\tau = rF\sin\theta$.

4.

Kinetic energy is always positive, potential energy can be negative.

5.

Yes, it is not an intrinsic property of the spring. It not only depends on the material in the spring but also the length and shape of the spring.

6.

The statement is false. This is because when steel and rubber of same length and cross-sectional area are subjected to same load, then the extension produced in steel is much less than that of rubber. So the ratio of stress to strain or Young's modulus for steel is much greater than that of rubber.

7.

rad/s.

8.

Impulse, $J = F\Delta t = P_2 - P_1$

For the same change in momentum if Δt is increased then F decreases. If the cricketer pulls back his hands, he increases Δt , and Force on his hand decreases and he does not hurt himself.

9.

Horizontal Range = Maximum height

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

$\tan\theta = 4$

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

OR

No. Even though the particle is moving with constant speed along the circle, it is accelerating as its velocity continuously changes. The acceleration vector is drawn towards the centre of the circle. So as the particle moves in uniform circular motion, the acceleration vector changes direction continuously and it is not a constant vector.

10.

Particle velocity is the velocity of the particles of the medium.

Wave velocity is the speed at which the wave disturbance travels through the medium.

11.

Let $m_1 > m_2$

$$P_1 = P_2$$

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

$$KE_1 = \frac{P_1^2}{2m_1}; KE_2 = \frac{P_2^2}{2m_2}$$

As $P_1 = P_2$ and $m_1 > m_2$

Therefore KE_2 will be greater than KE_1.

12.

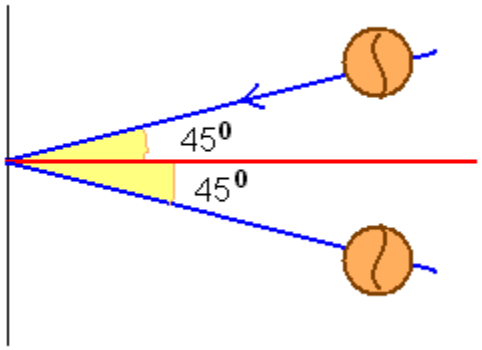
The law of equipartition of energy states that if a system is in equilibrium at absolute temperature T, the total energy is distributed equally in different energy modes of absorption, the energy in each mode being equal to $\frac{1}{2}k_BT$.

13.

An expansion or contraction in which no heat enters or leaves the system is called an adiabatic process. In this the temperature of the system can change.

In an isothermal process, the gas expands or is compressed at constant temperature. To maintain constant temperature heat can be transferred into or out of the system.

14.



Change in momentum $2mv\cos 45^o = 2\times 5\times \cos 45^o = \frac{10}{\sqrt{2}}v$

15.

$$\frac{1}{2}mv^2 = mgh$$

Dimensions of LHS are $\left[M\right]\left[LT^{-1}\right]^2 = \left[ML^2T^{-2}\right]$

Dimension of RHS are $\left[M\right]\left[LT^{-2}\right]\left[L\right] = \left[ML^2T^{-2}\right]$

Since the dimensions of quantity on LHS is equal to the dimensions of quantity on RHS. Thus the given expression is correct.

16.

The position of a particle is given by

$$S(t) = 5t\,\hat{i} + 6t^2\,\hat{j} - 10\hat{k}$$

$$v(t) = \frac{ds(t)}{dt} = 5\hat{i} + 12t\,\hat{j}$$

$$a(t) = \frac{dv(t)}{dt} = 12\,\hat{j}$$

$$\vec{v}(t=1) = 5\hat{i} + 12\,\hat{j}$$

$$\left|\vec{v}\right| = \sqrt{5^2 + 12^2} = 13 m/s$$

$$\vec{a}(t=1) = 12\,j$$

$$\left|\vec{a}\right| = 12\,m/s^2$$

17.

Kinetic energy of a satellite $= \frac{GMm}{2r} = E$

Potential energy of a satellite $= -\frac{GMm}{r} = -2E$

Total energy $= KE + PE$

$$= E + (-2E) = -E$$

18.

(i) A body with large reflectivity is a poor absorber. Hence it is also a poor emitter.

(ii) To convert water at 100^o c to steam at 100^o c the water needs to absorb the latent heat of vaporization. So it is more efficient to use steam rather than water because when steam at 100^o c is circulated it releases latent heat in addition to heat released due to change in temperature.

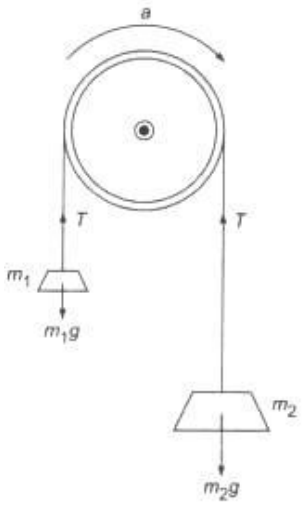
19.

It is a reversible engine in which all input heat originates from a hot reservoir at temperature T_H and all heat rejected goes into a cold reservoir at T_C, It consists of two isothermal processes and two adiabatic processes.

The efficiency of a Carnot engine is

$$\eta = 1 - \frac{T_C}{T_H}$$

OR



The pulley system with mass m1 and m2 is shown above in fig. The tension T is same throughout.

For mass m_1: $T - m_1 g = m_1 a$ (i)

For mass m_2: $m_2 g - T = m_2 a$ (ii)

Adding (i) and (ii), we have

$$(m_2 - m_1)g = (m_1 + m_1)a$$

or $$a = \left(\frac{m_2 - m_1}{m_2 + m_1}\right) g \quad \text{(iii)}$$

Putting this value in (i) we get,

$$T = m_1 g + m_1 \left(\frac{m_2 - m_1}{m_2 + m_1}\right) g$$

$$= \frac{[m_1(m_2 - m_1) + m_1(m_2 - m_1)]}{(m_2 - m_1)}$$

$$T = \frac{2m_1 m_2 g}{(m_2 + m_1)} \quad \text{(iv)}$$

∴ Thrust on the pulley is given by,

$$2T = \frac{4m_1 m_2 g}{(m_2 + m_1)}$$

20.

The volume of 1 mol of a gas is 22.4 litres and 2 moles is 44.8 litres.

Since helium is mono atomic, its molar specific heat at constant volume $C_V = \frac{3}{2}R$ and

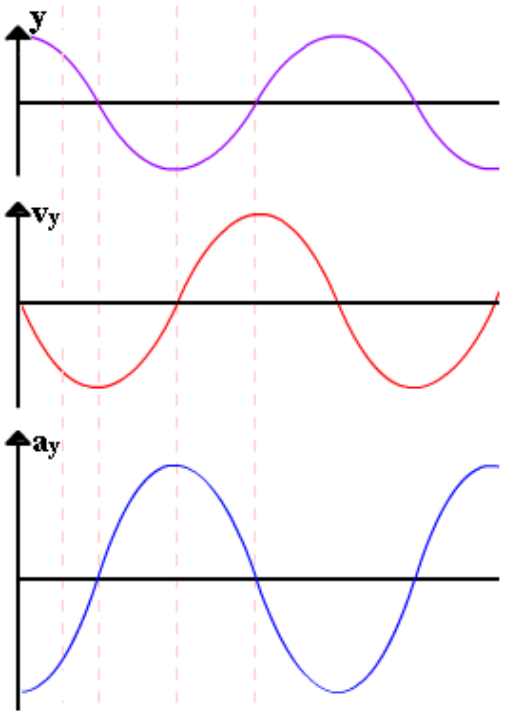
molar specific heat at constant pressure $C_P = \frac{5}{2}R$.

Here the volume is kept fixed so we will use C_V.

Heat required = no of moles x molar specific heat x rise in temperature

= 2 x 3/2R x 15=45R = 45 x 8.31 = 374J.

21.



22.

(i) Amplitude, $A = 5 \times 10^{-3} m$

$$ii) k = 80 \; ; \; k = \frac{2\pi}{\lambda} \text{ find } \lambda = \frac{\pi}{40} m$$

$$iii) \omega = 3 \; ; \; \omega = 2\pi f \text{ find } f = \frac{3}{2\pi} Hz$$

23.

Say, the work done in moving round a closed path, in a field, is zero. Then force in the field is called a conservative force.

For a ball lifted to a height and brought back to original position, work done is zero. Hence gravitational force is conservative.

For an object sliding up and down an inclined plane work done due to friction is not zero. Hence frictional force is non-conservative.

24.

Bob A will not rise at all.

In an elastic collision between two equal masses in which one is stationary, while the other is moving with some velocity, the stationary mass acquires the same velocity, while the moving mass immediately comes to rest after collision. In this case, a complete transfer of momentum takes place from the moving mass to the stationary mass.

Hence, bob A of mass *m*, after colliding with bob B of equal mass, will come to rest, while bob B will move with the velocity of bob A at the instant of collision.

25.

The change in total energy is

$$E_f - E_i$$

$$E_i = -\frac{GmM}{2(R+h)} = -\frac{GmM}{2(R+R)} = -\frac{GmM}{4R}$$

$$E_f = -\frac{GmM}{2(R+h)} = -\frac{GmM}{2(R+3R)} = -\frac{GmM}{8R}$$

$$\text{change in total energy} = \frac{GmM}{8R} = \frac{gmR}{8} = 3.13\times10^9 \text{ J}$$

The kinetic energy of the satellite reduces and it is given by -3.13×10^9 J.

The change is potential energy is twice the change in the total energy so change in potential energy is -6.26×10^9 J.

26.

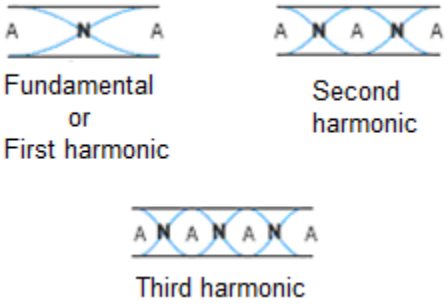
(a) Vineet has good knowledge of agriculture. He is very much interested in putting his ideas into practice, uses his knowledge to convince his uncle.

(b) When the field is ploughed, the capillaries are broken. So water cannot rise to the surface and the soil is able to retain its moisture.

27.

Draw the different modes of vibration.

As the ends are open antinodes are formed here.



Increase in tension increases the frequency.

Let us look at two possibilities:

Say originally $f_A > f_B$, then on increasing the frequency of B the difference between frequencies of A and B would further increase.

However on increasing the frequency of B the difference between A and B is decreasing. So this means that originally $f_A < f_B$.

$$f_A - f_B = 5Hz$$
$$f_B = 500Hz$$
$$f_A = 505Hz$$

OR

For each spring, spring constant is k

In series spring constant is $\frac{k}{2}$

In parallel spring constant is 2k.

$$T_{\text{series}} = 2\pi\sqrt{\frac{m}{k/2}} = 2\pi\sqrt{\frac{2m}{k}}$$

$$T_{\text{Parallel}} = 2\pi\sqrt{\frac{m}{2k}} = 2\pi\sqrt{\frac{m}{2k}}$$

$$T_{\text{series}} = 2T_{Parallel}$$

28.

(a) Mass of body A, m_A = 5 kg

Mass of body B, m_B = 10 kg

Applied force, F = 200 N

Coefficient of friction, μ_s = 0.15

The force of friction is given by the relation:

$f_s = \mu\ (m_A + m_B)g$

$= 0.15\ (5 + 10) \times 10$

$= 1.5 \times 15 = 22.5$ N leftward

Net force acting on the partition = 200 – 22.5 = 177.5 N rightward

As per Newton's third law of motion, the reaction force of the partition will be in the direction opposite to the net applied force.

Hence, the reaction of the partition will be 177.5 N, in the leftward direction.

(b) Force of friction on mass A:

$f_A = \mu m_A g$

$= 0.15 \times 5 \times 10 = 7.5$ N leftward

Net force exerted by mass A on mass B = 200 – 7.5 = 192.5 N rightward.

As per Newton's third law of motion, an equal amount of reaction force will be exerted by mass B on mass A, i.e., 192.5 N acting leftward.

When the wall is removed, the two bodies will move in the direction of the applied force.

OR

Progressive Wave	**Stationary wave**
(i) All particles have same phase and amplitude. (ii) Speed of motion is same. (iii) Energy is transported.	(i) Amplitude varies with position. (ii) Speed varies with position. (iii) Energy is not transported.

$y = 12 \sin 300t \cos 2x$

Comparing with equation of stationary wave, $y=2A \sin\omega t \cos Kx$

$K=2$

Distance between two consecutive nodes$=\frac{\lambda}{2}$

where, λ is wavelength

$K=\frac{2\pi}{\lambda}$

$\Rightarrow \frac{\pi}{\lambda/2} = 2$

$\frac{\lambda}{2} = \frac{\pi}{2}$

So, the distance between two nearest nodes is $\frac{\pi}{2}$.

29.

A body thrown up in space and allowed to fall under the effect of gravity alone is called a projectile.

The expressions for maximum height and time of flight are:

$$H = \frac{u^2 \sin^2 \theta}{2g}$$

$$T = \frac{2u \sin \theta}{g}$$

Given that speed of the ball, u = 40 m/s

Maximum height, H = 25 m

In projectile motion, the maximum height reached by a body projected at an angle θ, is given by the relation:

$$H = \frac{u^2 \sin^2 \theta}{2g}$$

$$25 = \frac{(40)^2 \sin^2 \theta}{2 \times 9.8}$$

$\sin^2 \theta = 0.30625$

$\sin \theta = 0.5534$

$\therefore \quad \theta = \sin^{-1}(0.5534) = 33.60°$

Horizontal range, R

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

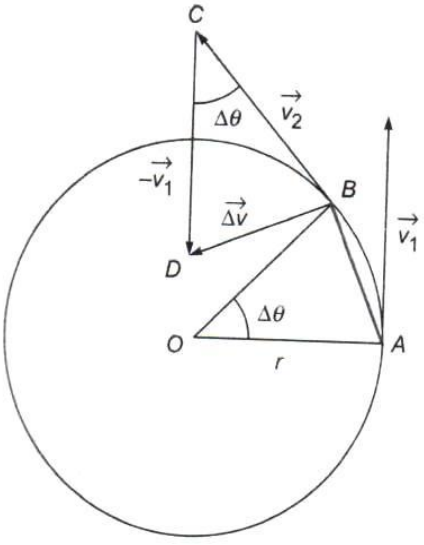
$$= \frac{(40)^2 \times \sin 2 \times 33.60}{9.8}$$

$$= \frac{1600 \times \sin 67.2}{9.8}$$

$$= \frac{1600 \times 0.922}{9.8} = 150.53 \text{ m}$$

OR

Centripetal force is that force which is required to move a body in circular path with uniform speed. This force acts on the body along the radius and towards the centre.



Consider a body of mass m moving along a circular path of radius r. A and B denotes the position of the body at times t and t + Δt respectively and the angular displacement is $\Delta\theta$ in time Δt.

The velocities at A and B are represented by $\overrightarrow{v_1}$ and $\overrightarrow{v_2}$ respectively.

As the speed is uniform,

$$\left|\overrightarrow{v_1}\right| = \left|\overrightarrow{v_2}\right| = v$$

Change in velocity in going from A to B $= \Delta\vec{v} = \overrightarrow{v_2} - \overrightarrow{v_1}$

where $\overrightarrow{CD} = -\overrightarrow{v_1}$

From ΔBCD, $\overrightarrow{BD} = \overrightarrow{BC} + \overrightarrow{CD}$

or $\overrightarrow{\Delta v} = \overrightarrow{v_2} - \overrightarrow{V_1}$

Thus, when the body moves from A to B the change in velocity is represented by $\overrightarrow{BD}$

From similar ΔAOB and ΔBCD, $\frac{BD}{AB} = \frac{BC}{OA}$

or $\left|\overrightarrow{\Delta v}\right| = \frac{AB \times BC}{OA} = \frac{r\Delta\theta \times v}{r}$ $\left[\because \Delta\theta = \frac{\overset{\frown}{AB}}{r} \simeq \frac{AB}{r} \text{ and } \left|\overrightarrow{BC}\right| = BC = \left|\overrightarrow{v_2}\right| = v\right]$

or $\Delta v = v\,\Delta\theta$

Dividing by Δt on both sides we get,

$$\frac{\Delta v}{\Delta t} = v\frac{\Delta\theta}{\Delta t}$$

or $\lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = v\left[\lim_{\Delta t \to 0} \frac{\Delta\theta}{\Delta t}\right]$

or $\frac{dv}{dt} = v\omega$

Or $a_c = v\omega$

where a_c is called the centripetal acceleration.

But, $v = r\omega$

$\therefore a_c = r\omega^2 = \frac{v^2}{r}$

If F is the magnitude of the centripetal force,

$$F = ma_c = \frac{mv^2}{r} = mr\omega^2$$

Since $\vec{F} = m\overrightarrow{a_c} = m\left[\lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t}\right]$

The direction of the centipetal force is same as $\Delta\vec{v}$, when $\Delta t \to 0$.

When $\Delta t \to 0, \Delta\theta \to 0$ and $B \to A$

In such a case, $\Delta\vec{v}$ points along $\overrightarrow{BO}$, i.e. the radius of the circle.

Hence, $\vec{F}$ points along the radius and towards the centre of the circle.