PHYSICS CLASS XI

CHAPTER – 6 WORK, ENERGY AND POWER

Q.1. Calculate the power of an electric engine which can lift 20 tonne of coal per hour from a mine 180 m depth.

Ans. Power = $\frac{Work\ done}{Time\ taken} = \frac{mgh}{t}$

$= \frac{20 \times 1000 \times 9.8 \times 180}{60 \times 60}$

= 9800 W = 9.8 kW

Q.2. In what type of collision, maximum kinetic energy is transferred ?

Ans. Maximum kinetic energy is transferred when bodies of equal mass collide.

Q.3. If the momentum and total energy is conserved then define the collision is occurred?

Ans. Collision in which momentum and total energy remained conserved and total kinetic energy of the colliding particles remain constant both before and after the collision, is called elastic collision.

Q.4. Which physical terms remain conserved in an inelastic collision?

Ans. In an inelastic collision, total momentum as well as total energy remain conserved.

Q.5. What is the loss in kinetic energy after collision, if the target body is initially at rest?

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Ans. Loss in kinetic energy on collision is $\frac{1}{2}\left(\frac{m_1 m_2}{m_1+m_2}\right)u^2$, where u is the initial velocity.

Q.6. Is the total linear momentum conserved during the short time of an elastic collision of two balls ?

Ans. During the short interval of an elastic collision, total linear momentum is conserved.

Q.7. In which of the two types of collision i.e., elastic or inelastic, the momentum is conserved? What about KE?

Ans. Momentum is conserved in both the types of collisions, but KE is conserved only in elastic collision.

Q.8. Is collision between two particles possible even without any physical contact between them?

Ans. Yes, in atomic and subatomic particles collision without any physical contact between the colliding particles is taking place e.g., Rutherford's alpha particles scattering.

Q.9. A molecule in a gas container hits a horizontal wall with speed 200 ms^{-1} and angle 30° with the normal, and rebounds with the same speed. Is momentum conserved in the collision? Is the collision elastic or inelastic?

Ans. Yes, momentum remains conserved in the collision. To check whether the collision is elastic or inelastic, we consider the kinetic energy of the molecule.

We find that the initial kinetic energy $\left(\frac{1}{2}mu^2\right)$ is the same as final KE. $\left(\frac{1}{2}mv^2\right)$ of the molecule as u = v = 200 m/s i.e., thus the collision is elastic collision.

Q.10. Two ball bearing of mass m each moving in opposite directions with equal speed v collide head-on with each other. Predict the outcome of the collision, assuming it to be perfectly elastic.

Ans. Here, $M_1 = M_2 = m$, $u_1 = v$ and $u_2 = -v$

Now, $v_1 = \frac{(M_1-M_2)u_1+2M_2u_2}{M_1+M_2}$

$= \frac{(m-m)v+2m(-v)}{m+m}$

and $v_2 = \frac{(M_2-M_1)u_2+2M_1u_1}{M_1+M_2}$

$= \frac{(m-m)(-v)+2mv}{m+m} = v$

After collision, the two ball bearings will move with same speed but their directions of motion will be reversed.

Q.11. Calculate the power of a motor which is capable of raising of water in 5 min from a well 120 m deep.

Ans. Here, the volume of water raised V = 2000 L

Density of water, p = 1 kg/L

∴ Mass of water raised, m = Vp = 2000 × 1 = 2000 kg

Power, $P = \frac{W}{t} = \frac{mgh}{t} = \frac{2000\times9.8\times120}{5\times60}$ = 7840 W

= 7.840 kW [1kW = 1000 W]

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Q.12. A particle of mass 1 kg moving with a velocity $v_1 = (3\hat{\imath} - 2\hat{\imath})$ m/s experience a perfectly inelastic collision with another of mass 2 kg having velocity $v_2 = (4\hat{\jmath} - 6\hat{k})$m/s. Find the velocity and speed of the particle formed.

Ans. Given, m_1 = 1 kg, $v_1 = (3\hat{\imath} - 2\hat{\jmath})$ m/s, m_2 = 2 kg and

$v_2 = (4\hat{\imath} - 6\hat{\jmath})$ m/s

When two particles experiences a perfectly inelastic collision. They stick together and move with a common velocity v given by

$$v = \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2} = \frac{1(3\hat{\jmath} - 2\hat{\jmath}) + 2(4\hat{\jmath} - 6\hat{k})}{1+2}$$

$$= (I - 2\hat{\jmath} - 4\hat{k}) \text{ m/s}$$

Speed of combined particle

$$v = \sqrt{1^2 + (-2)^2 + (-4)^2} = \sqrt{21} \text{ m/s}$$

Q.13. A bullet of mass 0.012 kg and horizontal speed 70ms^{-1} strikes a block of wood of mass 0.4 kg and instantly comes to rest with respect to the block. The block is suspended from the ceiling by means of thin wires. Calculate the height to which the block rises. Also, estimate the amount of heat produced to the block.

Ans. Here, mass of bullet m = 0.012 kg, initial speed of bullet u = 70 ms^{-1}, mass of wood block M = 0.4 kg.

As on collision, the bullet comes to rest w.r.t block, it means that after collision bullet and block are moving with a common speed v.

From conservation law of momentum mu = (M + m)v

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$\Rightarrow$ v = $\frac{mu}{(M+m)}$

= $\frac{0.012 \times 70}{(0.4+0.012)}$ = 2.04 ms^{-1}

If the block now rises to a maximum height of h, then using conservation law of mechanical energy, we have

$\frac{1}{2}(M+m)v^2$ - 0 = (M + m) gh

$\Rightarrow$ h = $\frac{v^2}{2g} = \frac{(2.04)^2}{2 \times 9.8}$

= 0.212 m = 21.2 cm

Q.14. A family uses 8 kW of power. (i) Direct solar energy is incident on the horizontal surface at an average rate of 200 W per square metre. If 20% of this energy can be converted to useful electrical energy, how large an area is needed to supply 8 kW? (ii) Compare this area to that of the roof of a typical house.

Ans. (i) Power used by family P = 8Kw = 8000 W

As only 20% of solar energy can be converted to useful electrical energy, hence, power to be supplied by solar energy $\frac{8000W}{20\%} = 40000$ W

As solar energy is incident at a rate of 200 Wm^{-2} , hence the area needed

A = $\frac{40000\ W}{200\ Wm^{-2}} = 200m^2$

(ii) The area needed is comparable to roof area of a large sized house.

Q.15. 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?

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If the efficiency of the motor is 75%, at which rate is the energy supplied to the motor?

Ans. Mass, m = 1500 kg, h = 20 m, η = 75%, t = 20 s

Work done W = mgh = 1500 × 9.8 × 20

$= 2.94 \times 10^5 J$

Rate of doing work = $\frac{W}{t} = \frac{2.94\times10^5}{20} = 1.47 \times 10^4$ W

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

$\frac{75}{100} = \frac{1.47\times10^4}{Input\ power}$

Input power or the rate at which energy is supplied

$= \frac{1.47\times10^4\times100}{75} = 1.96 \times 10^4$ W

Q.16. The blades of a windmill sweep out a circle of area A. (i) If the wind flows at a velocity v perpendicular to the circle, what is the mass of the air passing through it in time t? (ii) What is the kinetic energy of the air? (iii) Assume that the windmill convert 25% of the wind's energy into electrical energy, and that A = 30 m^2 , v = 36 km/h and the density of the air is 1.2 kgm^{-3}. What is the electrical power produced?

Ans. (i) Area swept by blades of windmill = A and

Wind velocity = v, which is perpendicular to the said area.

∴ Volume of air passing per unit time = Av

∴ Mass of air passing per unit time = Avρ

And mass of air passing in time t, M = Avρt

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(ii) KE of said quantity of air K = $\frac{1}{2}Mv^2 = \frac{1}{2}A\rho t v^3$

(iii) If efficiency of windmill be 25%, then

Output electrical power = 25% of input power

$$= \frac{25}{100} \times \frac{1}{2} A\rho v^3$$

As A = 30 m^2, v = 36 km/h = 36 × $\frac{5}{18} m/s$

= 10 m/s and ρ = 1.2 kgm^{-3}

∴ Output electrical power = $\frac{25}{100} \times \frac{1}{2} \times 30 \times 1.2 \times (10)^3$

= 4500 W

= 4.5 Kw [1 kW = 1000 W]

Q.17. A trolley of mass 200 kg moves with a uniform speed of 36 km/h on a frictionless track. A child of mass 20 kg runs on the trolley from one end to the other (10 m away) with a speed of 4 ms^{-1} relative to the trolley in a direction opposite to its motion, and jumps out of the trolley. What is the final speed of the trolley? How much has the trolley moved from the time the child begins to run?

Ans. Let there be an observer travelling parallel to the trolley with the same speed. He will observe the initial momentum of the trolley of mass M and child of mass m as zero. When the child jumps in opposite direction, he will observe the increase in the velocity of the trolley by Δv. Let u be the velocity of the child. He will observe child landing at velocity (u - Δv).

Therefore, final momentum = MΔv – m(u - Δv)

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From the law of conservation of momentum, we have

$$M\Delta v - m(u - \Delta v) = 0$$

$$\Longrightarrow \quad \Delta v = \frac{mu}{M+m}$$

Putting various values, we have

$$\Delta v = \frac{4\times20}{20+220} = 0.36 \text{ ms}^{-1}$$

∴ Final speed of trolley is 10.36 ms^{-1}

The child take 2.5 s to run on the trolley.

Therefore, the trolley moves a distance

$$= 2.5 \times 10.36 \text{ m} = 25.9 \text{ m}$$

Q.18. Rohit and suresh were going to the market when they spotted a man who left a black bag in the corner of a stall and ran away. They went near it and heard some ticking sound coming from it. They immediately called police and alerted the people nearby. By their alertness, a major tragedy was averted.

(i) What qualities of Rohit and Suresh do you appreciate?

(ii) A bomb at rest explodes into 2 fragments of mass 3.0 kg and 1.0 kg. The total KE of fragments is 6 × 10^4J. Calculate the KE of bigger fragement.

(iii) In which types of collisions, elastic or inelastic, momentum is conserved?

Ans. (i) Rohit and Suresh were very alert and courageous. They also has presence of mind.

(ii) Let v_1 = velocity of 3 kg mass (m_1)

V_2 = velocity of 1 kg mass (m_2)

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According to principle of conservation of momentum,

$m_1v_1 + m_2v_2 = 0 \Longrightarrow 3v_1 + 1v_2 = 0 \Longrightarrow \frac{v_1}{v_2} = -\frac{1}{3}$

$$\frac{E_1}{E_2} = \frac{\frac{1}{2}m_1v_1^2}{\frac{1}{2}m_2v_2^2} = \frac{3}{1}\left(-\frac{1}{3}\right)^2 = \frac{1}{3}$$

Total KE = E = $E_1 = 6 \times 10^4 J$

Using $E_1 : E_2 = 1 : 3$,

$$E_1 = \frac{6\times10^4\times1}{1+3} = 1.5 \times 10^4 J$$

(iii) Momentum is conserved in both the collisions.

Q.19. Ravi used to live in a remote village of Rajasthan which didn't have electricity. He was a good student and studied very hard to become an engineer in spite of all hardships. While studying, he came to know that solar energy can be converted to electrical energy by using speacially designed devices.

He went to his village and discussed it with villagers. He also told them that Govt. also gives subsidy for using solar devices. All the villagers agreed and they contacted the Govt. officials who obliged their request and the village became the model village which used solar energy for electricity.

(i) What can you say about Ravi?

(ii) If direct solar energy is incident on the horizontal surface at an average rate of 200 watt per square metre and 20% of this energy can be converted to use electrical energy, then how much area is needed to supply 8 kW of electrical energy?

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(iii) Why is solar energy a better source of energy?

Ans. (i) Ravi was a brilliant and hard working boy who thought about the welfare of not only himself but of all the villagers.

(ii) Let the area required be A square metre.

∴ Total power = 200 A

The electrical energy produced per sec.

$= \frac{20}{100}(200\ A)$

= 40 A

Now, 40 A = 8 k W = 8000 watt

∴ Required area A = $\frac{8000}{40}$

= 200 sq-m

(iii) (a) It is renewable source of energy.

(b) It can be used in the area where direct transmission lines cannot be laid down.

Q.20. Prove that when a particle suffers an oblique elastic collision with another particle of equal mass and initially at rest, the two particles would move in mutually perpendicular directions after collisions.

Ans. Let a particle A of mass m and having velocity u collides with particles B of equal mass at rest. Let the collision be oblique elastic collision and after collision the balls A and B move with velocities v_1 and v_2 respectively inclined at an angle θ from each other.

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Applying principle of conservation of linear momentum ,

We get

$mu = mv_1 + mv_2$

or $u = v_1 + v_2$

or $u^2 = (v_1 + v_2) \cdot (v_1 + v_2)$

$= v_1^2 + v_2^2 + 2v_1v_2cos\theta$

Again as total KE before collision = total KE after collision

$\therefore \frac{1}{2}mu^2 = \frac{1}{2}mv_1^2 + \frac{1}{2}mv_2^2 \Longrightarrow u^2 = v_1^2 + v_2^2$

Comparing Eqs. (i) and (ii), we get $2v_1v_2 \cos\theta = 0$

As in an oblique collision both v_1 and v_2 are finite, hence $\cos\theta = 0$

$\Longrightarrow \quad \theta = \cos^{-1} \quad (0) = \frac{\pi}{2}$

Thus, particles A and B are moving in mutually perpendicular directions after the collision.

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