JEE Main Physics

Short Notes

Work, Energy, and Power

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Work, Energy, and Power

Work Done by a Constant and Variable Force

Work done by a Constant Force

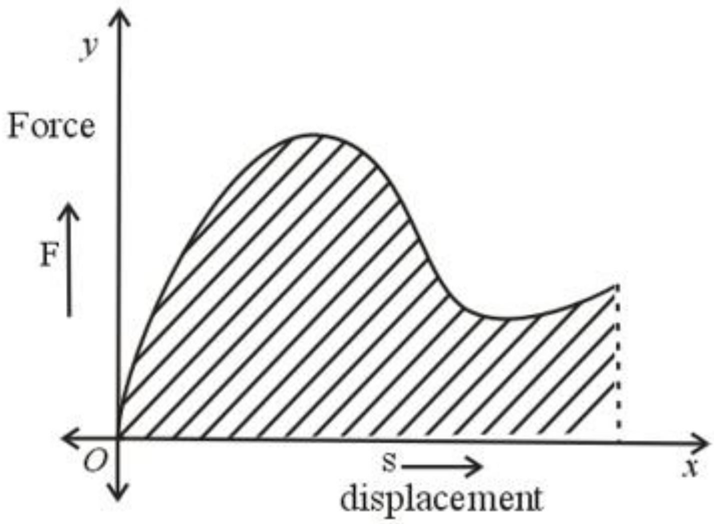
Work- The work done by a constant force is defined as the scalar product of force and the magnitude of displacement under the influence of force.

$$W = \vec{F}.\vec{d}$$
$$W = Fd\cos\theta$$

- Work is a scalar quantity.

Work done by a Variable Force

Let us assume that a variable force act on a particle and the variation of the force and the displacement due to influence of force is as shown below

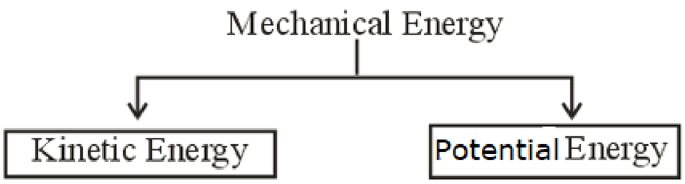


The work done by the variable force is,

W = Area under the curve

$$W=\int_0^s \vec{F}.dx$$

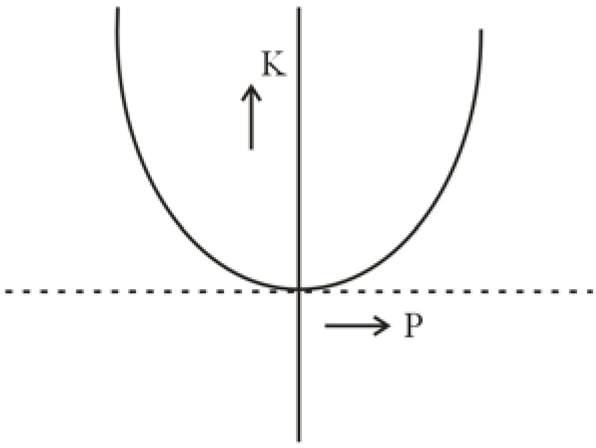
Energy – Energy is a physical quantity which enables a system to do work. There are many forms of energy in the universe but in case of mechanical energy have two forms.



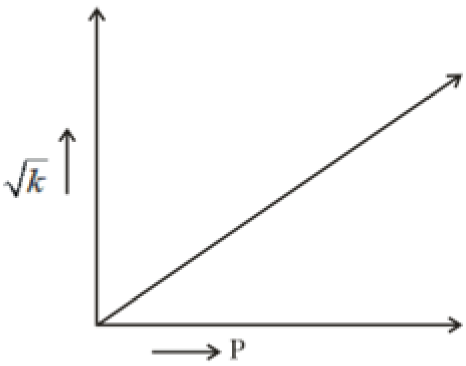
Kinetic Energy- The kinetic energy of a body is the energy possessed by the body by virtue of its motion.

Kinetic energy, $K=\frac{1}{2}mv^2$, where v is the velocity of the body

- Since both mass m and v^2 are always positive so KE is always positive and does not depend on the direction of motion of the body.
- The relation between kinetic energy and the momentum is, $K=\frac{p^2}{2m}$, where p is the momentum.
- The graph between K and p is a parabola as shown below.



- The graph between $\sqrt{K}$ and p is a straight line.



Potential Energy- The potential energy of a body is the energy possessed by the body by virtue of its position relative to other.

Potential energy, $V = mgh$, where h is the height of the of the position possessed by the body relative to the ground.

Work-Energy Theorem

The work-energy theorem by a constant force

It states that the change in the kinetic energy of a particle is equal to the work done on it by the net force.

$$W = K_f - K_i$$

$$W = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

Where K_f is the final kinetic energy and K_i is the initial kinetic energy.

The work-energy theorem by a variable force

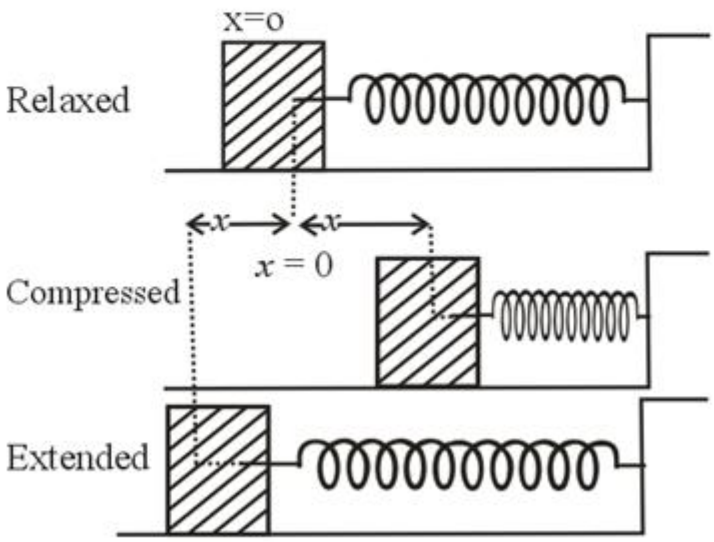
Let us assume the variable force works from position x_i to x_f then according to the work-energy theorem the change in the kinetic energy is equals to the work done on by the variable force.

$$W = K_f - K_i$$
$$\int_{x_i}^{x_f} F.dx = \int_{K_i}^{K_f} dK$$

Power- The power is defined as the work done over a time period or rate of work done is known as the power.

$$P = \frac{dW}{dt}$$
$$P = \frac{\vec{F}.d\vec{r}}{dt}$$
$$P = \vec{F}.\vec{v}$$

Potential Energy of a Spring- Let a block is attached with a spring, Initially the spring its natural relaxed condition if we compressed the spring by a constant force F. Then the work done by the force is stored in the spring as the potential energy.



The potential energy of the spring $U = \frac{1}{2}kx^2$

The conservation Law of Mechanical Energy

It states that for conservative forces the sum of kinetic and potential energy at any point remains constant throughout the motion. It doesn't depend on time.

$K_1 + U_1 = K_2 + U_2 = K_3 + U_3 = \text{Constant}$

Conservation of Other Forms of Energy

Heat Energy- The total energy of an isolated system remains constant. So, the energy can't be created and can't be destroyed.

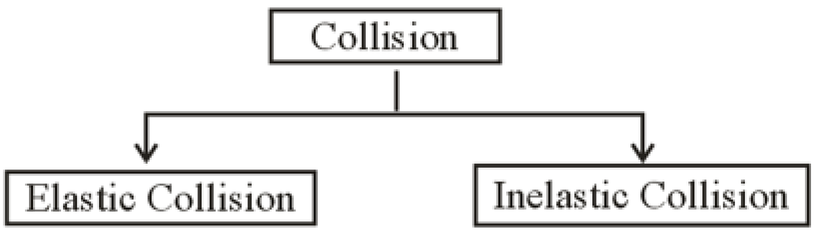
Chemical Energy- The energy may change form but total energy in a chemical reaction remains constant.

Electrical Energy – The total electric charge of a system remains constant. The charge can't be created or can't be destroyed.

Nuclear Energy- In a nuclear reaction total mass of the reactants or starting materials must be equal to the mass of the products. So, the mass can't be created nor destroyed.

Collision

The collision is the phenomenon in which two or more bodies come in physical contact with each other or it takes place when the path of one body is affected by the force exerted due to the other.



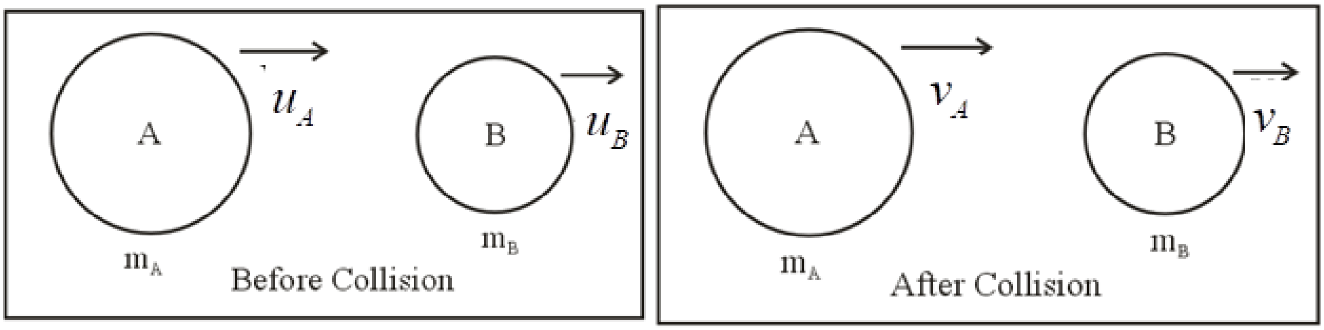
Elastic collision- A collision in which both momentum and kinetic energy of the system remains conserved. In this collision force involved in the interaction are of conservative in nature.

Inelastic collision- A collision in which only the momentum of the system is conserved but the kinetic energy is not conserved. In this collision, some or all of the forces involved are non-conservative in nature.

Collision in one dimension

Elastic Collision in one dimension

Consider two balls A and B of masses m_A and m_B are collide elastically. Let us assume that the velocity of the ball A and B before the collision is u_A and u_B and after the collision is v_A and v_B.

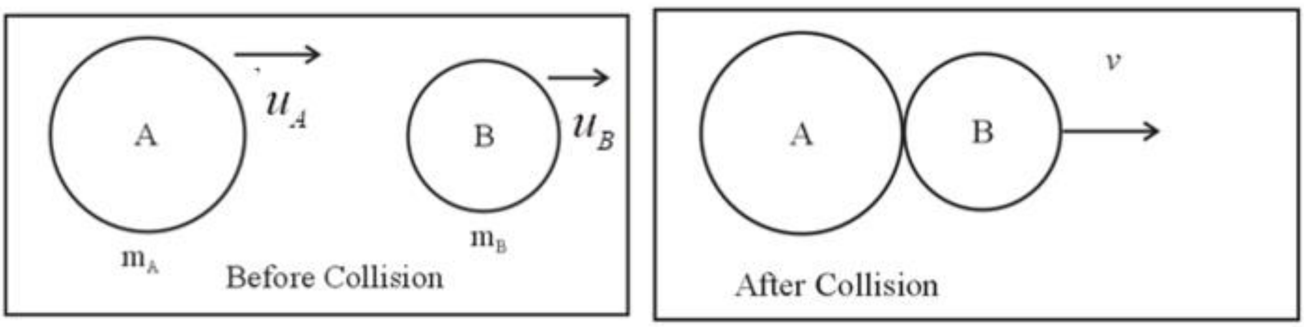


The velocity of the ball A after a collision, $v_A = \frac{(m_A - m_B)u_A}{(m_A + m_B)} + \frac{2m_B u_B}{(m_A + m_B)}$

The velocity of the ball B after a collision, $v_B = \frac{2m_A u_A}{(m_A + m_B)} + \frac{(m_A - m_B)u_B}{(m_A + m_B)}$

Inelastic Collision in one dimension

Consider two balls A and B of masses m_A and m_B are collide elastically. Let us assume that the velocity of the ball A and B before the collision is u_A and u_B ($u_B < u_A$) and after collision both the balls have same common velocity v.

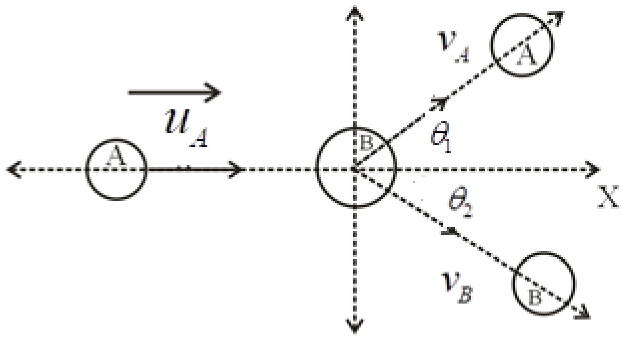


The velocity of both ball after the collision, $v = \dfrac{m_A u_A + m_B u_B}{(m_A + m_B)}$

Collisions in two dimensions

Elastic Collision in two dimensions

Consider two balls A and B of masses m_a and m_b moving along X-axis with velocities u_a and u_b respectively. When ($u_b < u_a$) the two bodies collide. After the collision, body A moves with velocity v_a at an angle θ_1 with X-axis and balls move with velocity v_b at an angle θ_b with X-axis as shown in the figure.



Since the collision is elastic, kinetic energy is conserved.

$$\frac{1}{2} m_A u_A^2 + \frac{1}{2} m_B u_B^2 = \frac{1}{2} m_A v_A^2 + \frac{1}{2} m_B v_B^2$$

According to the conservation of momentum

Initial momentum along X-axis before collision = Final momentum along X-axis after the collision

$$m_A u_A + m_B u_B = m_A v_A \cos\theta_1 + m_B u_B \cos\theta_2$$

Initial momentum along Y-axis before collision = Final momentum along Y-axis after the collision

$$0 = m_A v_A \sin\theta_1 - m_B v_B \sin\theta_2$$
$$m_A v_A \sin\theta_1 = m_B v_B \sin\theta_2$$

The coefficient of restitution - The ratio of the relative velocity of separation (after collision) to the relative velocity of collision (before collision). $e = \dfrac{v_B - v_A}{u_A - u_B}$

For perfectly elastic collision, e = 1

For perfectly inelastic collision, e = 0

- A ball dropped from a height h and attaining height h_n after n rebounds. Then $h_n = e^{2n}h$
- A ball dropped from height h and travelling a total distance S before coming to rest. Then, $S = h\left[\dfrac{1+e^2}{1-e^2}\right]$. where e is the coefficient of restitution.

All the best!

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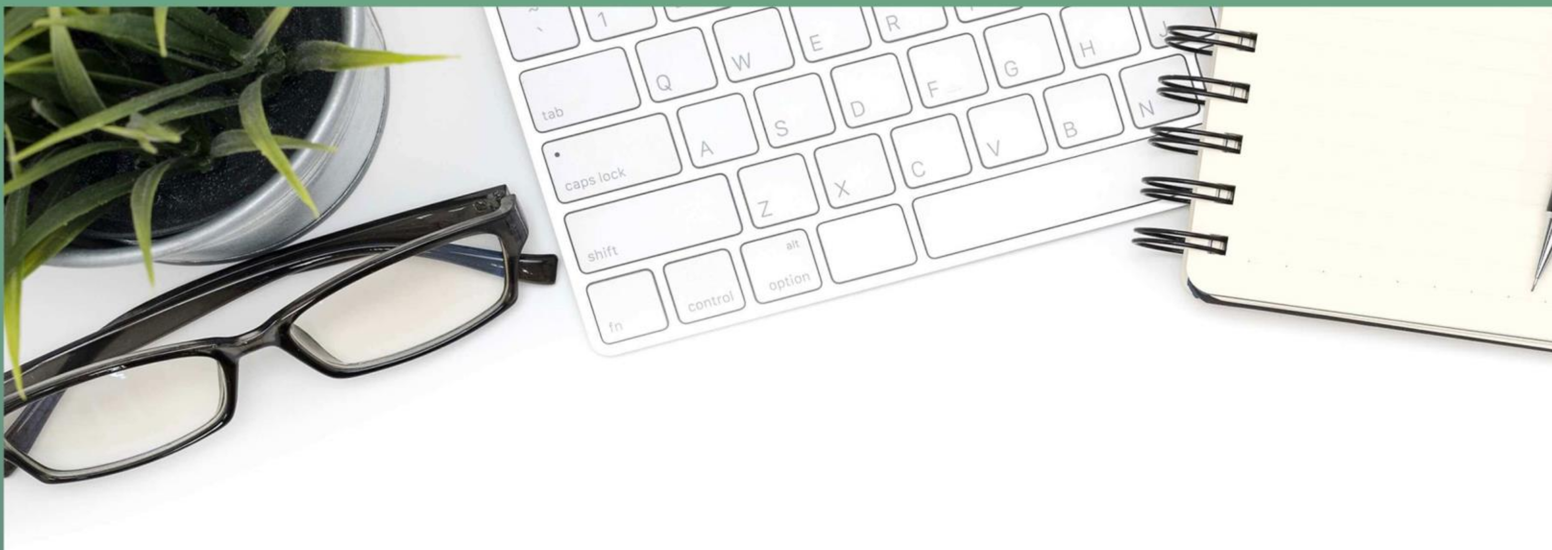

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