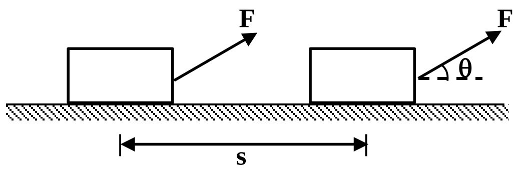
WORK, ENERGY & POWER

WORK

The work *W* done by a constant force *F* when its *point of application* undergoes a displacement *s* is defined to be

$$W = F\, s \cos\theta$$



The work *W* done by the force ***F*** when its point of application undergoes a displacement ***s*** is $W = \vec{F}.\vec{s} = Fs\cos\theta$

Where θ is the angle between $\vec{F}$ and $\vec{s}$ as indicated in figure **(1)**. Only the component of $\vec{F}$ along *s*, that is, F $cos\theta$, contributes to the work done.

Work Done by Friction

There is a misconception that the force of friction always does negative work. In reality, the work done by friction may be *zero*, *positive* or *negative* depending upon the situation.

Work Done by Gravity

If the block moves in the upward direction, then the work done by gravity is *negative* and is given by

$$W_g = -mgh$$

Work Done by a Variable Force

When the *magnitude* and *direction* of a force vary in three dimensions, it can be expressed as a function of the position vector $\vec{F}(\boldsymbol{r})$, or in terms of the coordinates $\vec{F}(x, y, z)$. The work done by such a force in an *infinitesimal* displacement ***ds*** is

$dW = \vec{F}.d\vec{s}$

Work Energy Theorem

$W = K_f - K_i = \Delta K$

The work done by a force changes the kinetic energy of the particle. This is called the

Work-Energy Theorem.

In *general*

The *net work done* by the resultant of all the force acting on the particle is equal to the change in *kinetic energy* of a particle.

$W_{net} = \Delta K$

POTENTIAL ENERGY

Potential energy is the energy associated with the relative positions of two or more interacting particles.

Gravitational Potential Energy (Near the Earth's Surface)

Potential energy is given by

$$U = mgh$$

Spring Potential Energy

The work done by the spring force when the displacement of the free end changes from x_i to x_f is given by

$$U_S = \frac{1}{2}kx^2$$

Conservation of Mechanical Energy

The quantity $E = K + U$ is called the ***total mechanical energy***.

When only conservative forces act, the change in total mechanical energy of a system is zero

POWER

Power is defined *as the rate at which work is done*. If an amount of work ΔW is done in a time interval Δt, then the average power is defined to be

$$P_{av} = \frac{\Delta W}{\Delta t}$$

The *SI* unit of power is J/s which is given the name watt (W) in the honor of *James Watt*.

Thus, 1 W = 1 J/s.

The *instantaneous* power is the limiting value of P_{av} as

$\Delta t \rightarrow 0$; that is

$$P = \frac{dW}{dt}$$

IMPULSE

Impulse is *defined as the integral of force with respect to time*.

$$\vec{\mathbf{I}} = \int_{t_i}^{t_f} \vec{\mathbf{F}} dt$$

IMPULSE - MOMENTUM THEOREM

According to *Newton's second law*, the *net* force acting on a particle is equal to the product of *mass* and *acceleration*.

$$\vec{\mathbf{F}}_{\mathbf{net}} = m\vec{\mathbf{a}}$$

$$\vec{\mathbf{I}}_{\mathbf{net}} = \Delta \vec{\mathbf{p}}$$

CONSERVATION OF LINEAR MOMENTUM

When the sum of the forces on an object is zero,

$$\vec{\mathbf{F}}_{\mathbf{net}} = \frac{d\vec{\mathbf{p}}}{dt}$$

That is, $\frac{d\vec{\mathbf{p}}}{dt} = 0$

This implies $\vec{\mathbf{p}}$ = constant

Law of Conservation of Momentum

In the absence of a net external force, the momentum of a system is conserved.

$$\vec{\mathbf{P}}_{\mathbf{initial}} = \vec{\mathbf{P}}_{\mathbf{final}}$$

$$\sum_{i=1}^{N} \vec{\mathbf{p}}_{\mathbf{i}} = \sum_{f=1}^{N} \vec{\mathbf{p}}_{\mathbf{f}}$$

COLLISION

A collision is an event in which two or more bodies exert force on each other in a relatively short period of time. The two types of collisions are either *elastic or inefficient*. In elastic, both momentum and kinetic energy are conserved and inelastic collisions occur, only linear motion is conserved.

Coefficient of Restitution (*e*)

Coefficient of restitution (*e*), $e = \frac{v_2 - v_1}{u_1 - u_2}$

For an *elastic* collision $e = 1$

For an *inelastic* collision $0 < e < 1$

For *completely inelastic* collision: $e = 0$