

# Distance, Velocity, Momentum, Force, Pressure, Work and Energy

## Distance, Speed and Acceleration

distance:  $x$  is measured in units of  $m$ , for meters.

position:  $\vec{r}$ , a vector in three dimensions described by a distance and a direction

speed:  $v = \frac{\Delta x}{\Delta t}$ , in units of  $\frac{m}{s}$

velocity:  $\vec{v}$ , a vector in three dimensions described by a speed and a direction

$x = x_o + vt$ , where  $x_o$  is the position at time  $t = 0$ .

acceleration:  $a = \frac{\Delta v}{\Delta t}$ , in units of  $\frac{m}{s^2}$

vector acceleration:  $\vec{a}$ , a vector in three dimensions described by a distance and a direction

$v = v_o + at$ , where  $v_o$  is the speed at time  $t = 0$ .

$x = x_o + v_o t + \frac{1}{2}at^2$ .

## Momentum

momentum:  $p = mv$ , where  $m$  is the mass in kg, and  $p$  is in  $kg\,m/s$

angular momentum:  $L = pr$ , where  $p$  is the linear momentum and  $r$  is the radius of the circle along which the object moves.

## Force and Pressure

The force exerted on an object is the mass of an object times the acceleration of the object:  $F = ma$ , where  $m$  is the mass in kg, and  $F$  is in  $kg\,m/s^2 = \text{Newton}$ .

force due to gravity at the surface of the earth:  $F_g = mg$  downward, where  $g = 9.8\,m/s^2$  is the acceleration due to gravity at the surface of the earth.

force exerted by a spring:  $F_s = -kx$ , where  $k$  is a constant and  $x$  is the displacement from the equilibrium position. The negative sign indicates that the force is in the direction opposite to the displacement.

Force due to friction:  $F_f = \sigma F_g$ , where  $\sigma$  is the coefficient of friction. Friction is a nonconservative force.

Pressure is force per unit area:  $P = F/A$  in  $\text{Pascal} = N/m^2$ .

## Work

Work is the force exerted on an object times the distance over which the force is exerted:  $W = Fx$ , where  $W$  is the work in  $Nm = \text{Joule}$ .

Work done to lift an object of mass  $m$  a height  $h$ :  $W = F_g h = mgh$ .

Work done against friction:  $W = F_f x$ .

## Energy

Energy is the quantity that can be used to perform work. There are two types of energy, kinetic and potential. There are many forms of energy, each involving both kinetic and potential energy.

Kinetic energy is energy associated with motion, whether in a straight line or a circle.

$KE = \frac{1}{2}mv^2$ , measured in *Joules*.

Potential energy is energy due to the position or shape of an object. Usually, it is the change in potential energy that is the important quantity, not any particular value of the potential energy.

Change in gravitational potential energy when an object of mass  $m$  is lifted a distance  $h$ :  
 $\Delta PE = mgh$ .

Potential energy of a stretched spring:  $KE = \frac{1}{2}kx^2$ , measured in *Joules*.

## Conservation of Energy and the Equivalence of Work and Energy

Energy is neither created nor destroyed, only changed from one form to another.

Work can be used to increase the potential energy of an object or a system.

The work done in lifting an object (working against the gravitational force) is equal to the change in the gravitational potential energy of the object.

When the object is lowered, the potential energy can be utilized as work.

When the object is dropped, the potential energy is converted to kinetic energy.

The work done to accelerate an object over a frictionless surface is equal to the change in kinetic energy of the object.

Kinetic energy can be used to perform work.

Work done against friction, a nonconservative force, is not converted into recoverable potential or kinetic energy but lost as heat.