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Chapter – 10

WORK AND ENERGY

Work

Work is done when a force produces motion.

For example, when an engine moves a train along a railway line, it is said to be doing work; a horse pulling the cart is also doing work; and a man climbing the stairs of a house is also doing work in moving himself against the force of gravity.

WORK DONE BY A CONSTANT FORCE

Let a constant force, F act on an object. Let the object be displaced through a distance, s in the direction of the force .

Let W be the work done

Work done = force × displacement

W = F s ……….…1

work done by a force acting on an object is equal to the magnitude of the force multiplied by the distance moved in the direction of the force. Work has only magnitude and no direction

In Eq. 1 if F = 1 N and s = 1 m

then the work done by the force will be 1 N m

unit of work is newton metre (N m) or joule (J).

Thus 1 J is the amount of work done on an object when a force of 1 N displaces it by 1 m along the line of action of the force.

If the force and the displacement are in the same direction:

In this situation, the work done will be equal to the product of the force and displacement. In such situations, the work done by the force is taken as positive.

If an object is moving with a uniform velocity along a particular direction. Now a retarding force, F, is applied in the opposite direction.

That is, the angle between the two directions is 180º. Let the object stop after a displacement s. In such a situation, the work done by the force, F is taken as negative and denoted by the minus sign. The work done by the force is F × (–s) or (–F × s).

Work done is negative when the force acts opposite to the direction of displacement. Work done is positive when the force is in the direction of displacement.

Energy

Energy is the ability to do work.

A body having energy can do work as follows: A body which possesses energy can exert a force on another object. During this process, some of the energy of the body is transferred to the object. By gaining energy, the object moves. And when the object moves, work is said to be done. Energy is a scalar quantity. It has only magnitude but no direction.

The units of work and energy are the same. So, the SI unit of energy is joule (which is denoted by the letter J). Whenever work is done, an equal amount of energy is consumed. Keeping this is mind, we can define 1 joule

energy as follows: The energy required to do 1 joule of work is called 1 joule energy. Joule is a small unit of energy, so sometimes a bigger unit of energy called 'kilojoule' is also used. The symbol of kilojoule is kJ. Now,

1 kilojoule = 1000 joules

or

The unit of energy called 'joule' is named after a British physicist James Prescott

KINETIC ENERGY

kinetic energy is the energy possessed by an object due to its motion. A falling coconut, a speeding car, a rolling stone, a flying aircraft, flowing water, blowing wind, a running athlete etc. possess kinetic energy.

The kinetic energy of an object increases with its speed.

the kinetic energy of a body moving with a certain velocity is equal to the work done on it to make it acquire that velocity.

Consider an object of mass, m moving with a uniform velocity, u. Let it now be displaced through a distance s when a constant force, F acts on it in the direction of its displacement.

Work = F x s

The work done on the object will cause a change in its velocity. Let its velocity change from u to v. Let a be the acceleration produced

The relation connecting the initial velocity (u) and final velocity (v) of an object moving with a uniform acceleration a, and the displacement, s is

$v^2 - u^2 = 2as$

$S = \frac{v^2 - u^2}{2a}$

work done by the force, F as

$W = m\, a \times \frac{v^2 - u^2}{2a}$

Or

$W = \frac{1}{2} m (v^2 - u^2)$

If the object is starting from its stationary position, that is, u = 0, then

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

It is clear that the work done is equal to the change in the kinetic energy of an object.

If u = 0, the work done will be $\frac{1}{2} mv^2$

Thus, the kinetic energy possessed by an object of mass, m and moving with a uniform velocity, v is

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

Potential energy

The potential energy possessed by the object is the energy present in it by virtue of its position or configuration.

POTENTIAL ENERGY OF AN OBJECT AT A HEIGHT

An object increases its energy when raised through a height. This is because work is done on it against gravity while it is being raised. The energy present in such an object is the gravitational potential energy.

The gravitational potential energy of an object at a point above the ground is defined as the work done in raising it from the ground to that point against gravity.

Consider an object of mass, m. Let it be raised through a height, h from the ground. A force is required to do this. The minimum force required to raise the object is equal to the weight of the object, mg. The object gains energy equal to the work done on it.

Let the work done on the object against gravity be W.

That is, work done, W = force × displacement

= mg × h

= mgh

Since work done on the object is equal to mgh, an energy equal to mgh units is gained by the object. This is the potential energy E_p of the object.

E_p = mgh

LAW OF CONSERVATION OF ENERGY

According to this law, energy can only be converted from one form to another; it can neither be created or destroyed. The total energy before and after the transformation remains the same.

The law of conservation of energy is valid in all situations and for all kinds of transformations.

If an object of mass, m be made to fall freely from a height, h. At the start, the potential energy is mgh and kinetic energy is zero.

The total energy of the object is thus mgh. As it falls, its potential energy will change into kinetic energy

If v is the velocity of the object at a given instant, the kinetic energy would be ½mv2 .

As the fall of the object continues, the potential energy would decrease while the kinetic energy would increase.

When the object is about to reach the ground, h = 0 and v will be the highest.

the sum of the potential energy and kinetic energy of the object would be the same at all points.

That is, potential energy + kinetic energy = constant

Or

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

The sum of kinetic energy and potential energy of an object is its total mechanical energy.

Power

Power means rate of doing work.

Power measures the speed of work done, that is, how fast or slow work is done. Power is defined as the rate of doing work or the rate of transfer of energy.

If an agent does a work W in time t,

then power is given by:

Power = work/time

P = $\frac{w}{t}$

The unit of power is watt having the symbol W.

1 watt is the power of an agent, which does work at the rate of 1 joule per second.

We can also say that power is 1 W when the rate of consumption of energy is $1 J s^{-1}$

1 watt = 1 joule/second

The power of an agent may vary with time. This means that the agent may be doing work at different rates at different intervals of time.

Therefore, the concept of average power is useful. We obtain average power by dividing the total energy consumed by the total time taken.

COMMERCIAL UNIT OF ENERGY

The unit joule is too small and hence is inconvenient to express large quantities of energy. We use a bigger unit of energy called kilowatt hour (kW h)

If this machine is used continuously for one hour, it will consume 1 kW h of energy. Thus, 1 kW h is the energy used in one hour at the rate of 1000 Js^{-1}

1 kW h = 1 kW ×1 h

= 1000 W × 3600 s

= 3600000 J

1 kW h = 3.6 × 10^6J

The energy used in households, industries and commercial establishments are usually expressed in kilowatt hour.