আন্তর্জাতিক ইসলামী বিশ্ববিদ্যালয় চট্টগ্রাম

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L8

Work

We use the term 'work' in various manners in our daily life. A gatekeeper guarding a house all day long, sitting on a tool, may claim to have done a lot of work, but in the words of physics that is not any work. In terms of physics the word 'work' is well defined. If a force F is applied on any object and the object traverses a distance s during the application of force (that is displacement occurs) then, the amount of work W done by the force is:

$$W=Fs$$

> Unit of work: J (Joule)
>
> Dimension of work $[W] = ML^2T^{-2}$

Force is a vector quantity and the distance traversed or displacement is also a vector quantity but in case of work the product of those two vectors is a scalar quantity.
As individual vectors there is no such condition that the direction of force and distance travelled has to be same but in these book, we will only discuss the force and distance travelled in the same direction.

Have you noticed, while discussing work, we said that the 'force' has done the work. A person or a machine may push any object to some distance by applying a force. In terms of daily life we say that the person or the machine has done the work. But in physics, neither the person nor the machine does the work, always the force applied does the work. This force may be applied by a person or a machine.

Let us assume that, you have pushed an object to a distance s by applying a force F and left it after setting it in motion. The object has travelled an additional distance d and at last it has stopped. How much work is done?

The amount of work done is $W=Fs$, as no force was applied while traversing the distance d, so no work is done.

Example

Question: Your mass is 50 kg. You have climbed up a 10 storied building, how much work have you done? (Height of each floor is 3 m)

Answer: If your mass is 50 kg, weight is $50 \times 9.8 = 490$ N. This weight is a force, that is acting downwards. If you want to climb up, you have to exert an equal force upwards to draw yourself up.
So, upward applied force: 490 N
Distance travelled upwards: 10×3 m $= 30$ m
So the amount of work done, 490 N $\times$30 m =14700 J=14.7 kJ

Suppose, a moving object is coming towards you, you try to stop the object by applying force F, the object pushes you backwards by a distance s. How much work was done by the force applied by you? Certainly you have noticed that, this time the distance traversed is not along the direction of force, rather opposite to it. So the amount of work done

$$W=F\,(-s)=-Fs$$

That is, the work done is negative. In our daily lives, we talk about work and useless work, but what is meant by positive and negative work in terms of physics? If the work is positive, then it can be said that work is done by the force. If it is negative, then it is said that the work is done 'on' the force or against the force. We must have a clear conception about energy before understanding what has just been written.

Energy

Ability to do work is energy! Not only that, when a positive work is done by applying a force on an object, the force creates an energy in that object. The amount of work done on the object is the amount of energy created in it, and the person who is applying the force has to give exactly the same amount of energy.

So now you have understood the meaning of negative work. If any force does a negative work on an object, then it is to be understood that a certain amount of energy is taken away from the energy contained in the object. The amount of negative work done is equal to the amount of energy taken away, and he who has applied the force gets this energy anyway. So, on any object

Doing positive work $\rightarrow$ giving energy to the object.
Doing negative work $\rightarrow$ taking away energy from the object.

You can clearly understand that energy has no direction and it is a scalar quantity. As we produce energy by doing work or do work spending energy, these two have the same unit and the same dimension.

Unit of energy: J (Joule)

Dimension of energy $[W] = ML^2T^{-2}$

We use different kinds of energy for different purposes. For example, heat energy is needed for water to be heated, we need light energy to see anything, we hear by using sound energy. We run machines by using electrical energy, and we create electricity from electric cells by using chemical energy. We generate electric energy too from the nuclear energy we get by dividing a heavy nucleus or by addition of light nucleuses. Energy is developed in our body taking nutrition from food, we perform our activities.
The history of our civilization itself is the history of utilization of energy by generating energy. We see different forms of that energy around us, for example-mechanical energy, heat energy, sound energy, light energy, magnetic energy, electrical energy, chemical energy, nuclear energy and solar energy.
The most general form of energy is the mechanical energy, the energy that is obtained due to position, shape and motion of the object is called mechanical energy. There are two forms of mechanical energy; these are kinetic energy and potential energy.

4.3.1 Kinetic Energy

We have discussed earlier that the ability to do work is energy. Everyone of us knows that when an object is in motion, it can push another object and set it into motion resulting in the object moving a certain distance due to the pushing. Making another object move means, definitely a force has been applied there and traversing a distance due to this force means work is done there!

Therefore we can say firmly that the energy that develops due to motion in a body is certainly one kind of energy or kinetic energy. In the previous chapter we said that the terrible road accidents that happen and the losses that occur are mainly due to kinetic energy. When a bus-truck or a car moves at high speed then it has a huge amount of kinetic energy.

We can easily calculate how much kinetic energy is acquired by an object when work is done by a force on that object.

So, Kinetic Energy = $\frac{1}{2}\mathbf{m}v^2$

Where, m is mass
V is velocity

Example

Question: Motion is created in a body of mass 10 kg by applying a force, if its kinetic energy becomes 80 J, what is its velocity?
Answer: Kinetic energy is,

$$\frac{1}{2}mv^2 = 80\ \text{J}$$

$$v^2 = \frac{2 \times 80\ \text{J}}{\text{m}} = \frac{160\ \text{m}^2}{10\ \text{s}^2}$$
$$v = 4\ \text{m/s}$$

Potential Energy

Potential energy is the energy stored in an object due to its position, configuration, or condition. It has the potential to do work in the future. For example, a rock at the top of a hill has stored energy because of its height.

Potential Energy = mgh

Where**,** m = Mass of the object (in kilograms, kg)

g = Gravitational acceleration (9.8 m/s on Earth)

h = Height of the object above a reference point (in meters, m)

Example

A 10 kg object is lifted to a height of 5 meters above the ground. What is potential energy ?

Power

The term 'power' is used a lot of times in our daily lives, not that the term is always used for good purposes! But it has a definite meaning in physics; power is the rate of doing work. That is, if work W is done in time t, then power P is:

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

We have seen before that work is nothing but transformation of energy. As energy can't be destroyed, so it is only being transformed by doing work. So we can say, if we desire, power is the rate of transformation of energy. As work or energy is a scalar quantity, then power is also a scalar quantity.

We have known about different quantities, their units, and tried to know their dimensions in every case while learning physics. Unit and dimension of power are:

Unit of power: W (Watt)
Dimension of power: $[P] = ML^2T^{-3}$

Example

If a machine does 500 J of work in 10 s, its power output is?