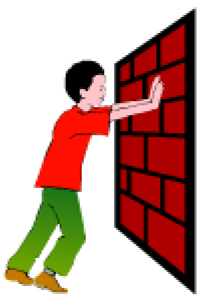
Energy

Work

Consider the following day-to-day activities: reading, speaking, singing, writing, thinking, etc. We require energy to perform these activities, which we derive from the food we eat. **Did you know that actually no work is involved in performing these activities?** Do you think that a weightlifter does work while standing with weight over his head, as shown in the given figure?



Even if you push a wall with the maximum force that you can apply, the wall will not move. It will be interesting for you to note that even in this case, you are not doing any work at all! **Do you know why?**

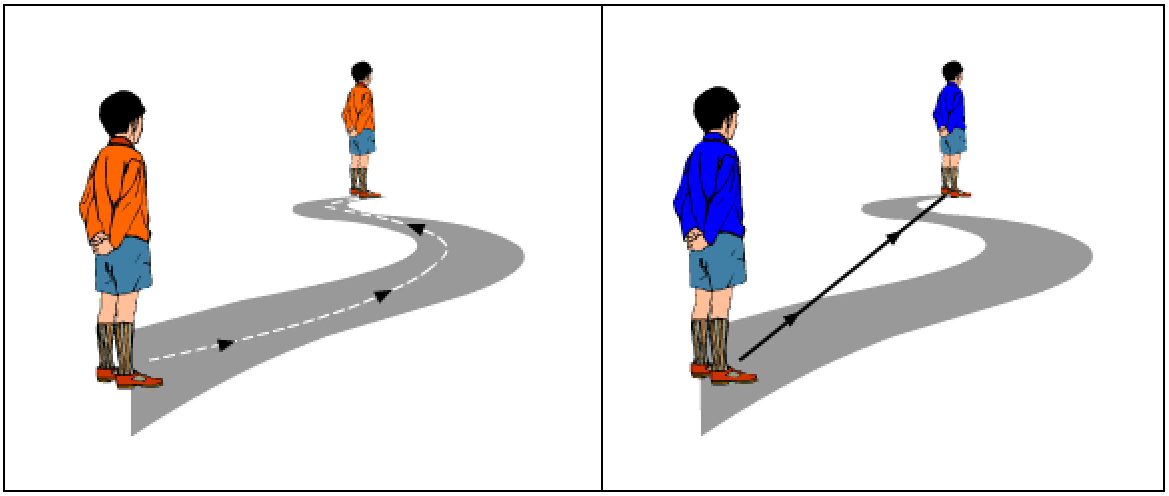
Work is not done in all the above activities because there is a basic difference between the term **work** and the term which we use for our daily activities.

Scientifically, work is defined as the work done by a force that causes a displacement in an object.

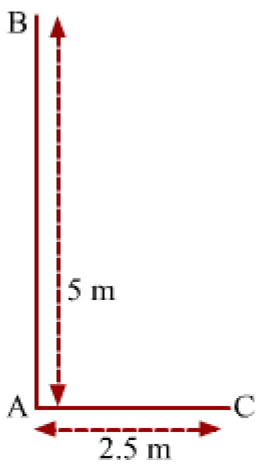
Whenever a body moves, it covers a **distance**. The straight line that joins the initial and final positions of the body is called its **displacement**.

Distance is the length of the path travelled by a body while moving from an initial position to a final position. It is a scalar quantity. Its SI unit is metre (m).

Displacement is the shortest distance between the initial and final positions of the body. It is a vector quantity. Its SI unit is also metre (m).



In displacement, the direction of motion is always directed from the initial position toward the final position.



In the science class, the teacher walks back and forth while discussing a problem in physics. He walks 5 m toward the students, turns around and then returns to his initial point. Then he walks 2.5 m toward his left and stops to answer a query from a student. What is the total distance covered by the teacher and his displacement from the point where he turns around?

The teacher walks from A to B, turns around and then walks back to A. Then, he walks from A to C.

So, total distance covered = AB + BA + AC = 5 m + 5 m + 2.5 m = 12.5 m

The teacher turns around at B. So, we need his displacement from B to C. BC is the hypotenuse of the right triangle BAC.

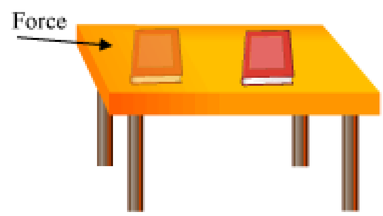
So: $BC^2 = AB^2 + AC^2$

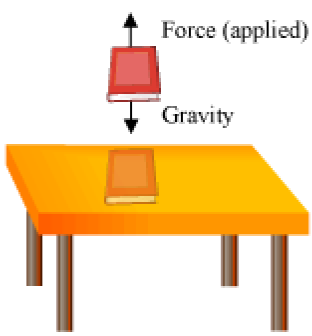
=> $BC^2 = 5^2 + 2.5^2$ => $BC^2 = 31.25$ => ∴ BC = 5.6 m

For a straight-line motion, the distance travelled and the displacement are equal in magnitude.

If you push a book placed on a table with a force, then it will move to a certain distance. Scientifically, we will say that some work has been done on the book. **Can you name the force against which work is done?**

In this case, work is done against frictional force, which exists between the book and the surface of the table.



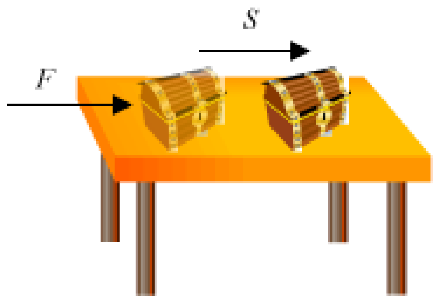


If you lift the book to a certain height, then a force is exerted against gravity, which displaces the book to a certain height. Hence, one can say that work is done on the book against the force of gravity.

If you push a trolley full of books, then it will move through a certain distance. In this case, the applied force causes a displacement in the trolley. **Do you think any work is done on the trolley?**

Work Done by a Constant Force

A wooden block is kept on a table. When a force of magnitude F acts on the block, it gets displaced through a distance S in the direction of the applied force, as shown in the given figure.



The magnitude of work done is given by the product of force (*F*) and displacement (*S*).

Let W be the work done on the block.

∴ Work = Force × Displacement

$W = F \times S$

Work has magnitude only. It has no direction.

Unit of Work

To obtain the unit of work, we substitute the SI units of force, i.e. N, and distance, i.e. m, in the equation of work.

W = N × m = N m

Hence, the unit of work is N m. In the honour of physicist James P. Joule, **the SI unit of work is written as Joule (J).**

Hence, 1 J = 1 N m

1 Joule is defined as the amount of work done by a unit force such that it displaces an object by a distance of 1 m.

Energy

Work and energy are the two terms used very often in our day-to-day lives. We often call someone very energetic, if the person is capable of doing a lot of work. In physics also, energy and work are very closely related and their meanings are not very different from the way we use them in our daily lives. What is the relation between work and energy?

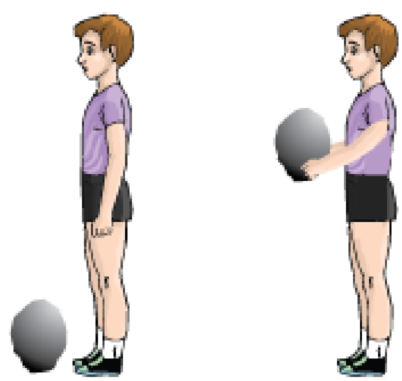
Energy is defined as the ability to do work.

You know what work is.

When a **force** displaces an object along its direction, we say the force does a work.

Therefore, a body has the ability to do work, if it possesses some energy. Without spending energy, a body cannot do any work. If we think about it a bit, then we will see that to apply a force, some amount of energy has to be spent. From this, we can also conclude that if work is done on a body, then some energy gets transferred to the body.

For example, if we lift a stone to a certain height, then a work is done on the stone to lift it against the force of gravity. For that, we use energy stored in our muscles. Again, the work is stored as energy in the stone by virtue of its position. Therefore, when the stone is released from the height, the stored energy gets released.



a. A stone lying on the ground   b. Stone lifted up

Thus, we can conclude that **energy is required to do some work**. On the other hand, **if some work is done on a body, then the spent energy that gets stored in the body in turn becomes capable to do some work**. This is called work−energy relation.

Different Forms of Energy and Its Transformation (Energy Chain)

You must have heard of energy drinks. What are the drinks meant for? They are supposed to provide you more energy so that you can do more work. Thus, you can easily conclude that energy and work are related to each other. **The ability to do work is called energy.**

The world requires a lot of energy. To satisfy this demand, we have natural energy sources such as the sun, wind, water at a height, tides, etc. We also have other energy sources such as petroleum, natural gas, etc.

Sun

Tide

Wind

Petrol

Energy exists in various forms such as light, sound, motion, etc.

Forms of energy

Some forms of energy are:

- Mechanical
- Light
- Heat
- Muscular
- Sound
- Magnetic
- Electrical

- Chemical
- Nuclear

In this section, we will consider only mechanical energy.

Mechanical energy

It is the form of energy possessed by an object that has the potential to do work. It is caused by the motion or the position and configuration of the object. Mechanical energy is of two types:

- Kinetic energy (caused by motion of the object)
- Potential energy (caused by position and configuration of the object)

Kinetic energy

A body possesses kinetic energy by virtue of its motion. A moving arrow can be embedded into an object. Hence, it is said that the arrow possesses kinetic energy.

The elastic string of a catapult is stretched to throw a stone. The work done is stored in the stone and the string. After its release, the stone is said to possess kinetic energy.

Kinetic energy of a body can be calculated using the expression,
K.E. = 1/2 mv^2
(where, m= mass and v^2= the square of its velocity)
Its SI unit is Joule (J).

From the above formula it is clear that kinetic energy of a body increases with its velocity. Kinetic energy of a body is directly proportional to

(i) its mass (*m*) and

(ii) the square of its velocity (v^2)

It is the kinetic energy of the wind that is used in windmills to generate electricity.

Potential Energy

Therefore, you have learned that

- potential energy possessed by a body by virtue of its **configuration** is known as **elastic potential energy**

- potential energy possessed by a body by virtue of its position with respect to the ground is known as **gravitational potential energy**

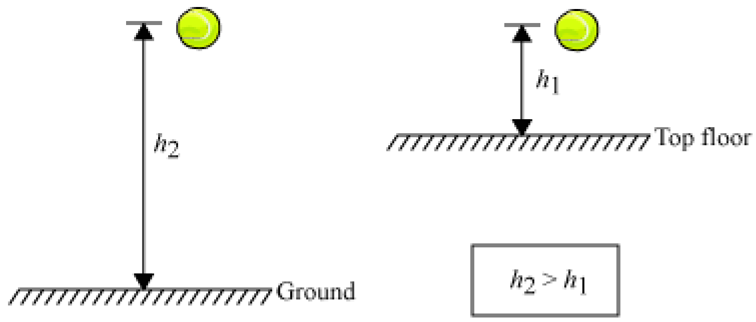
Potential energy of a body can be calculated using the expression,
P.E. = mgh
(where, m= mass, g= acceleration due to gravity, and h= height)
The SI unit of potential energy is Joule.

A body possesses potential energy by virtue of its configuration or position.

Where does a keyed toy car derive energy to move?

Take a rubber ball and go to the top floor of your house. Now, drop the ball from a height on the floor on which you are standing. The ball will be rebound to some height. Notice the height of its rebound. Now, drop the ball from the top floor on the ground and again notice the height of rebound of the ball.

You will observe that the ball will be rebound to a greater height when dropped on the ground than when it is dropped on the top floor. This is because the energy of the ball hitting the ground is greater than that hitting the floor. **From where does the ball get a large amount of energy in the second case?**



We know the fact that an object located at a height with respect to a certain reference level is said to possess energy called gravitational potential energy. This energy depends on this reference level (sometimes also referred as ground level or zero level). When a ball is taken to the top floor from the ground floor, it acquires some gravitational potential energy.

When this ball was dropped from a height h_1 on the top floor, the zero level is the top floor itself. When the ball was dropped from a height h_2 on the ground, the zero level is the ground. Since the distance covered by the ball was greater in the second case, i.e. $h_2 > h_1$, it rebounded to a greater height from the ground than that from the top floor.

Hence, we conclude from the above discussion that **potential energy stored in a body is directly proportional to its height with respect to zero level**.

Chemical Energy

Do you know how energy is stored in energy drinks or in a food item? The energy is stored in these items in the form of **chemical energy**. This kind of energy is stored as a bonding between the molecules. When we eat or drink, the food items undergo chemical changes. As result of this, the chemical bonding in the food items breaks and energy gets released. Not only food, all the fire items such as oil, kerosene, coal, wood, gunpowder have chemical energy stored in them.

Light Energy

You must have noticed that a material becomes hot when placed under the sun for a long time. If you place a paper under bright sunlight and hold a magnifying glass over it for a long time, then you will see that the paper starts burning. Why does all this happen? What kind of energy is responsible for this? The answer is light energy. Many chemical reactions such as photosynthesis require light energy to start. Light energy also causes a reaction in the chemicals coated on a photographic film.

Heat Energy

Have you ever wondered about the process of cooking food? The food is cooked from the heat produced by burning of fuel. This energy is known as **heat energy**. The sun is

a perfect source of heat energy.
The amount of heat produced or released is measured in the unit "**Calorie**".

Nuclear Energy

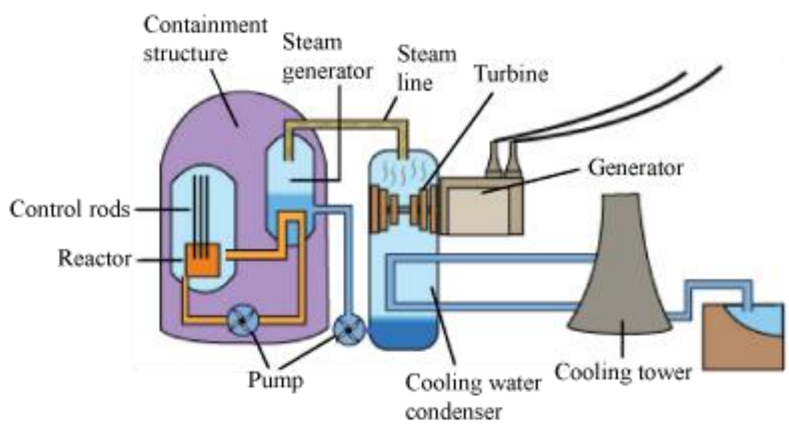
In order to understand nuclear energy, we should first understand nuclear fission reaction.

What is nuclear fission?

How is electricity produced in nuclear power plants?

Nuclear power plants consist of nuclear reactors. These reactors use uranium rods as fuel and then heat is generated by the process of nuclear fission.

Neutrons smash into the nucleus of the uranium atoms, which roughly split into half and release energy in the form of heat.



Carbon dioxide gas is pumped through the reactor to take the heat away. The hot gas then heats water to form steam. This steam drives the turbines of generators to produce electricity.

Electrical Energy

You must have seen that electric fan stops rotating as the power goes off. This is because a fan uses electric energy for its rotation. As the electric power goes off, the energy supply to the fan stops and the fan stops rotating. Therefore, electric energy is another form of energy.

In fact, in modern civilization, it is the most widely used form of energy. Everything from a small electric bulb to a heavy machine in a factory requires electric energy. Electricity can be used for producing light, heat, sound, and even chemical energy.

Magnetic Energy

Bring a magnet near an iron nail. What do you notice? The iron nail gets attracted towards the magnet and starts moving. You already know that movement means kinetic energy. But from where does the kinetic energy come to the nail?

The attraction of the magnet causes the movement of the nail. Therefore, the magnet must possess some kind of energy that does the work on the nail. This energy is called **magnetic energy**. Magnetic energy is broadly used in industries where heavy metal pieces are shifted from one place to another. In Japan, magnetic energy is used even for running high-speed trains.

Sound Energy

Have you ever noticed that when you play music at a very high volume, the glass pane of the windows or the showcase in your room starts vibrating? Why does this happen? This happens because of the high-volume sound. We call it **sound energy**.

The interesting fact about sound energy is that it is produced because of vibration and causes vibration. When sound energy enters our ear and strikes the eardrum, it starts vibrating and thus, we can hear.

Principle of Conservation of Energy

What causes a ball dropped from a height to move? When an arrow is released from a bow, **what causes the arrow to acquire kinetic energy?**

Since a ball at a height and an arrow in the stretched string of a bow possess potential energy by virtue of their position and configuration respectively, they both acquire kinetic energy. **However, does it mean that potential energy stored inside the ball or arrow is converted into kinetic energy?**

We observe a number of examples in nature in which a form of energy is converted into another form. For example, the chemical energy of food we eat gets converted into muscular energy that can be used to do work such as cycling, walking, lifting a load, etc.

During cycling, the muscular energy of the cyclist is converted into the kinetic energy of the bicycle that moves him forward. One thing to be noted here is that the total energy of the system (cyclist + bicycle) remains unchanged i.e., muscular energy + kinetic energy remain unchanged during cycling.

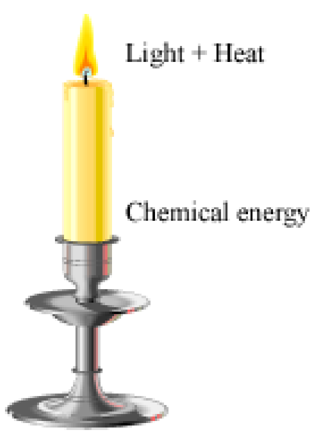
Know this: There is an energy loss in the machines when they are running for a long time due to the friction between wheel and axle. This loss of energy or friction between wheel and axle can be reduced by using some lubricating substances like grease. Therefore, to minimize the energy loss we should lubricate machines in regular interval of time.

Conservation of energy

"Energy cannot be created or destroyed. It can only be transformed from one form to another". In other words, the total amount of energy in a system always remains constant.

For example, in a burning candle, chemical energy stored in the wax is transformed into light and heat energy.

The total energy, before and after burning the candle, remains constant.

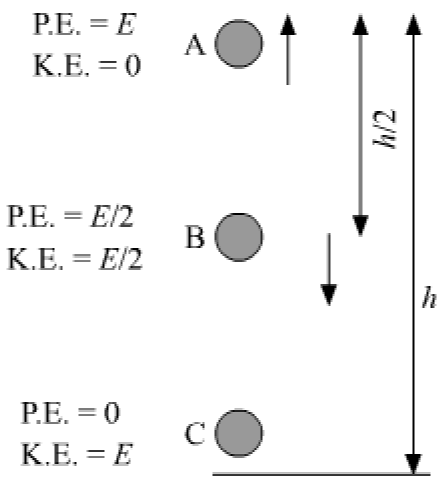


Total mechanical energy of a freely falling body always remains conserved provided friction due to air is neglected.

A body of mass *m* is falling freely under the action of gravity from the height *h* above the ground. At point A, the body posses maximum potential energy, say *E*.

As this body falls down, its potential energy changes into the kinetic energy such that at point B, half of the potential energy changes to kinetic energy and at point C the total potential energy of the body changes to kinetic energy.

Thus, at point C, the body posses only kinetic energy which will be equal to *E.* Hence the mechanical energy of the freely falling body remained conserved.



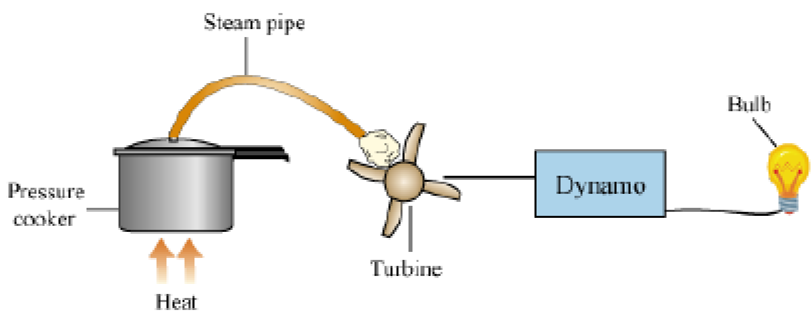
Hydel and Thermal Power Plants

Power plants generate power. You may have seen smoke coming out of the chimneys of power stations. These power stations use coal or petroleum as fuel to produce steam by heating water. The steam is then used to rotate a turbine, which drives a generator. Electric energy thus generated is known as thermal power, and such power stations are known as **thermal power plants**.

Steam is passed through the turbine and is allowed to condense in a condenser. Since a thermal power plants uses coal or petroleum as fuel, it releases huge amounts of smoke from its chimneys.

Make your own power station

You can make your own, miniature thermal power plant at home using a bicycle dynamo, pressure cooker, turbine, and bulb as illustrated in the figure.



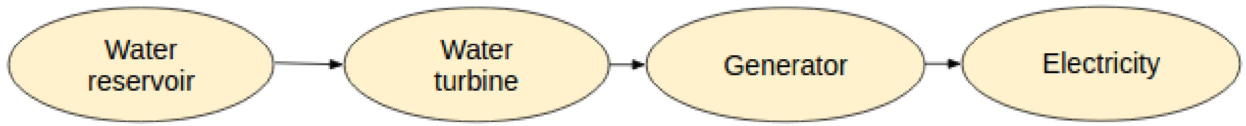
Heat is used to make steam from water in the pressure cooker. Steam spins the turbine, which in turn spins the dynamo. The dynamo generates electricity and this lights the bulb.

Since it is more convenient to transport electricity rather than fossil fuels such as coal, many thermal power plants are set up near coal or oil fields.

Hydro power plants

Instead of using steam to spin a turbine, **hydro power plants** use the potential energy of water accumulated at a height to spin a turbine.

Hydropower plants have various components, such as water reservoir, turbine and generator, all of which work together to generate electicity. This process is summarised in the following flow chart:



In India, most of the hydropower plants are associated with dams. This is because the natural flow of water in our water bodies is not such that it can spin a turbine.

Construction of dams over rivers helps to accumulate water and increase its force. A quarter of our energy requirement is met by hydroelectricity.

Major hydropower plants in India

Hydro power plant	Location
Bhakra	Punjab
Hirakud	Orissa
Matatila	Uttar Pradesh
Tehri	Uttarakhand
Salal	Jammu & Kashmir
Sardar Sarovar	Gujarat
Srisailam	Andhra Pradesh
Tungabhadra	Karnataka

Advantages of hydropower plants

- Clean and cheap
- Do not produce pollutants
- No waste by-products are produced
- They do not require transportation of fuels

- Hydro power is a renewable source of energy

Disadvantages of hydropower plants

- Limited geographic potential
- Causes a change in the course of rivers
- Sediment accumulates in a dam and eventually reduces its water storage potential
- Lot of land is submerged under water
- Fish and wildlife are affected drastically
- Large dams release methane, which is a greenhouse gas that contributes to global warming