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Examples : Work is done when :

(i) A cyclist is pedaling the cycle.

(ii) A man is lifting load in upward or downward direction.

Work is not done when :

(i) A coolie carrying some load on his head stands stationary.

(ii) A man is applying force on a big rock.

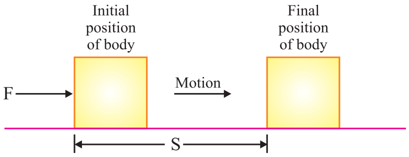
Work Done by a Fixed Force

Work done in moving a body is equal to the product of force and displacement of body in the direction of force.

$$\text{Work} = \text{Force} \times \text{Displacement}$$

$$W = F \times S$$

Work is a scalar quantity.



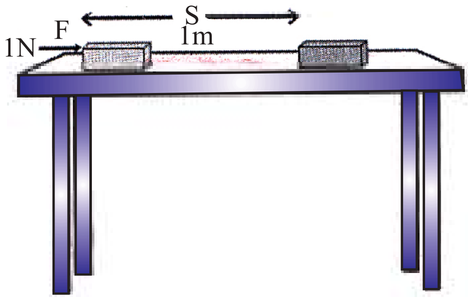
Unit of Work

Unit of work is **Newton metre or Joule.**

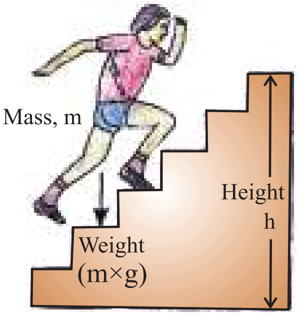
When a force of 1 Newton moves a body through a distance of 1 metre in its own direction, then the work done is 1 Joule.

$$1 \text{ Joule} = 1 \text{ Newton} \times 1 \text{ metre}$$

$$1 \text{ J} = 1 \text{ Nm}$$



1J = 1N × 1 m



During climbing work is done against gravity

The amount of work done depends on the following factors :

(i) Magnitude of force : Greater the force, greater is the amount of work & vice-versa.

(ii) Displacement : Greater the displacement, greater is the amount of work & vice-versa.

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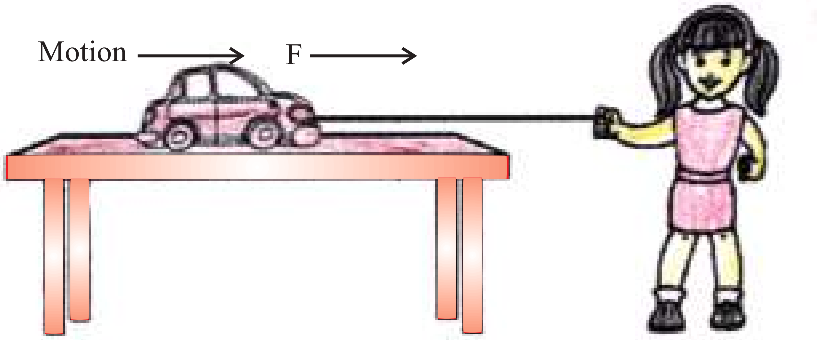
Negative, Positive and Zero Work

Work done by a force can be positive, negative or zero.

(i) Work done is **positive** when a force acts in the direction of motion of the body.[Fig. (a)] ($\theta = 0°$).

Example : A child pulls a toy car with a string horizontally on the ground. Here work done is positive.

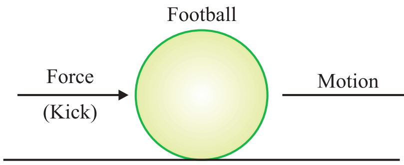
$$W = F \times S$$



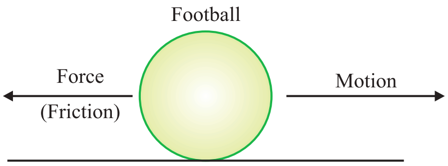
Positive work

(ii) Work done is **negative** when a force acts opposite to the direction of motion of the body.

Example : When we kick a football lying on the ground, the force of our kick moves the football. Here direction of force applied & motion of football is same so work done is positive. But when football slows due to force of friction acting in a direction opposite to direction of motion of football [Fig. (b)], work done is negative.



Positive work



Negative work

(iii) Work done is **zero** when a force acts at right angles to the direction of motion.

Example : The moon moves around the earth in circular path. Here force of gravitation acts on the moon at right angles to the direction of motion of the moon. So work done is zero.

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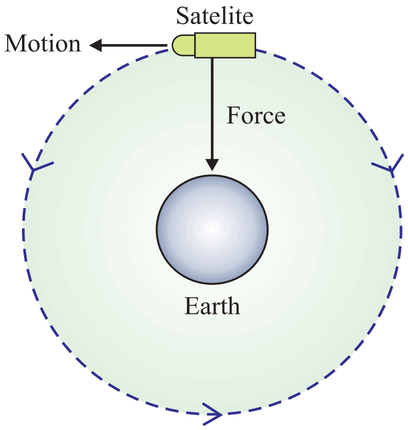

Zero work

- -ve (negative) sign indicates that work is done against gravity.

Note that if work is done against the direction of motion (gravity), then it is taken –ve.

Example. *A coolie lifts a luggage of 15 kg from the ground and put it on his head 1.5 m above the ground. Calculate the work done by him on the luggage.*

Solution : Mass of luggage (m) = 15 kg

Displacement (S) = 1.5 m

So, Work done, W = F × S

= mg × S [$f = mg$]

= 15 × 10 × 1.5 [g = 10 m/s^2]

[g = force of gravity]

= 225.0 kg m/s^2

= 225 Nm = 225 J

Hence, work done = 225 J.

Energy

(i) The sun is the biggest source of energy.

(ii) Most of the energy sources are derived from the Sun.

(iii) Some energy is received from nucleus of atoms, interior of the earth and the tides.

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Definition : The capacity of doing work is known as energy.

The amount of energy possessed by a body is equal to the amount of work it can do. Working body losses energy, body on which work is done gains energy.

Energy is a scalar quantity.

Unit : The SI unit of energy is Joule (J) and its bigger unit is kilo joule (kJ).

$$1 \text{ kJ} = 1000 \text{ J}$$

The energy required to do 1 Joule of work is called 1 Joule energy.

Forms of Energy

Main forms of energy are :

(i) Kinetic energy
(ii) Potential energy
(iii) Heat energy
(iv) Chemical energy
(v) Electrical energy
(vi) Light energy
(vii) Sound energy
(viii) Nuclear energy

- Sum of kinetic energy & potential energy of a body is called mechanical energy.

Mechanical energy

The energy possessed by a body on account of its motion or position is called mechanical energy.

Kinetic Energy

The energy of a body due to its motion is called kinetic energy.

Examples of kinetic energy :

- A moving cricket ball
- Running water
- A moving bullet
- Flowing wind
- A moving car
- A running athelete
- A rolling stone

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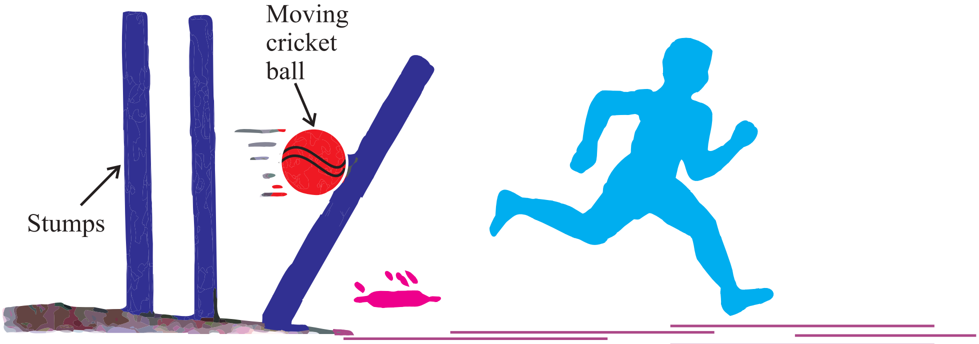
- Flying aircraft



Kinetic energy

Kinetic energy is directly proportional to mass and the square of velocity.

Formula for Kinetic Energy

If an object of mass '*m*' moving with uniform velocity '*u*', it is displaced through a distance '*s*'. Constant force '*f*' acts on it in the direction of displacement. Its velocity changes from '*u*' to '*v*'. Then acceleration is '*a*'.

Work done, $W = f \times s$ ...(i)

and $f = ma$ ...(ii)

According to third equation of motion, relationship between *u, v, s* and *a* is as follows :

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

So, $$s = \frac{v^2 - u^2}{2a}$$ ...(iii)

Now putting the value of *f* and *s* from (ii) and (iii) in equation (i),

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

$$= \frac{m}{2} \times v^2 - u^2 = \frac{1}{2} m\left(v^2 - u^2\right)$$

If $u = 0$ (when body starts moving from rest)

$$W = ½mv^2$$

Or $$E_K = ½mv^2$$

Example. *An object of mass 15 kg is moving with uniform velocity of 4 m/sec. What is the kinetic energy possessed by it ?*

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Solution : Mass of the object, $m = 15$ kg

Velocity of the object, $v = 4$ m/s

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

$= \frac{1}{2} \times 15 \text{ kg} \times 4 \text{ ms}^{-1} \times 4 \text{ ms}^{-1}$

$= 120$ J

The kinetic energy of the object is 120 J.

Potential Energy

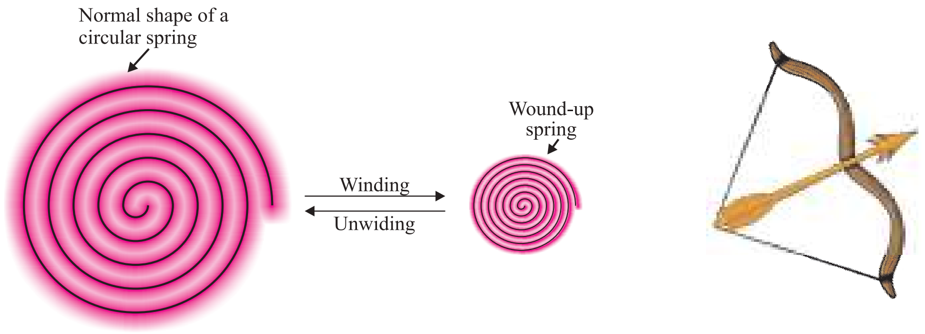
The energy of a body due to its position or change in shape is known as potential energy.

Examples :

(i) Water kept in dam : It can rotate turbine to generate electricity due to its position above the ground.

(ii) Wound up spring of a toy car : It possess potential energy which is released during unwinding of spring. So toy car moves.

(iii) Bent string of bow : Potential energy due to change of its shape (deformation) released in the form of kinetic energy while shooting an arrow.



Factors affecting Potential Energy

(i) Mass : P. E. $\propto m$

More the mass of body, greater is the potential energy and vice-versa.

(ii) Height above the ground :

P. E. $\propto h$ (Not depend on the path it follows)

Greater the height above the ground, greater is the P.E. and vice-versa.

(iii) Change in shape : Greater the stretching, twisting or bending, more is the potential energy.

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Potential Energy of an Object on a Height

If a body of mass '*m*' is raised to a height '*h*' above the surface of the earth, the gravitational pull of the earth ($m \times g$) acts in downward direction. To lift the body, we have to do work against the force of gravity.

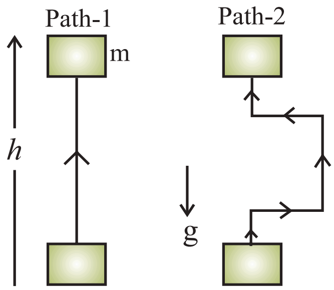
Thus, Work done, W = Force × Displacement

Or W $= m \times g \times h = mgh$

This work is stored in the body as potential energy (gravitational potential energy).

Thus, Potential energy, $E_P = m \times g \times h$

where g = acceleration due to gravity.



Ep = M×g×h = Ep = mgh

Example. *If a body of mass 10 kg is raised to a height of 6 m above the earth, calculate its potential energy.*

Solution : Potential energy of the body = *mgh*

Mass of body = 10 kg

Height above the earth = 6 m

Acceleration due to gravity = 10 m/s^2

So, $E_P = 10 \times 10 \times 6$

$= 600$ J

Thus, potential energy of the body is 600 Joules.

Transformation of Energy

The change of one form of energy to another form of energy is known as transformation of energy.

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Example :

(i) A stone on a certain height has entire potential energy. But when it starts moving downward, potential energy of stone goes on decreasing as height goes on decreasing but its kinetic energy goes on increasing as velocity of stone goes on increasing. At the time stone reaches the ground, potential energy becomes zero and kinetic energy is maximum.

Thus, its entire potential energy is transformed into kinetic energy.

(ii) At hydroelectric power house, the potential energy of water is transformed into kinetic energy and then into electrical energy.

(iii) At thermal power house, chemical energy of coal is changed into heat energy, which is futher converted into kinetic energy and electrical energy.

(iv) Plants use solar energy to make chemical energy in food by the process of photosynthesis.

Law of Conservation of Energy

- Whenever energy changes from one form to another form, the total amount of energy remains constant.

- "Energy can neither be created nor be destroyed."
- Although some energy may be wasted during conversion, but the total energy of the system remains the same.

Conservation of Energy during Free Fall of a Body

- A ball of mass 'm' at a height 'h' has potential energy = mgh.
- As ball falls downwards, height 'h' decreases, so the potential energy also decreases.
- Kinetic energy at 'h' is zero but it is increasing during falling of ball.
- The sum of potential energy & kinetic energy of the ball remains the same at every point during its fall.

$$\tfrac{1}{2}mv^2 + mgh = \text{Constant}$$

Kinetic energy + Potential energy = Constant

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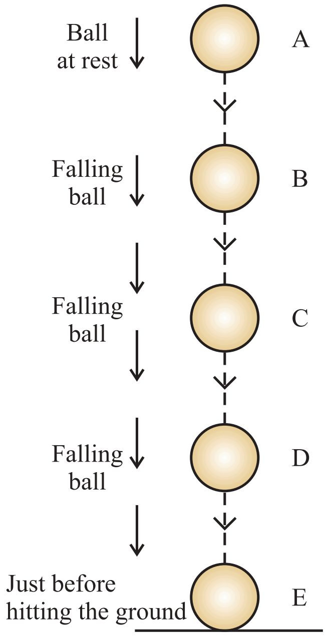

Ball	P.E. of Ball	K.E. of Ball	Total Energy of Ball (P.E. + K.E.)
A	20J	0J	20 + 0 = 20J
B	15J	5J	15 + 5 = 20J
C	10J	10J	10 + 10 = 20J
D	5J	15J	5 + 15 = 20J
E	0J	20J	0 + 20 = 20J

Rate of Doing Work – Power

"Power is defined as the rate of energy consumption."

$$\text{Power} = \frac{\text{Work done}}{\text{Time taken}} \quad \text{Or} \quad P = \frac{W}{t}$$

where P = Power

W = Work done

t = Time taken

Unit of Power

SI unit of Power is Watt (W) = 1 Joule/second.

$$1 \text{ Watt} = \frac{1 \text{ Joule}}{1 \text{ second}} \quad \text{Or} \quad 1 \text{ W} = \frac{1 \text{ J}}{1 \text{ s}}$$

Power is one Watt when one Joule work is done in one second.

$$\text{Average Power} = \frac{\text{Total work done or total energy used}}{\text{Total time taken}}$$

Power of Electrical Gadget

The power of an electrical appliance tells us the rate at which electrical energy is consumed by it.

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Bigger unit of Power : Bigger unit of power is called Kilowatt or KW.

1 Kilowatt (KW) = 1000 Watt = 1000 W or 1000 J/s

Example. *A body does 20 Joules of work in 5 seconds. What is its power ?*

Solution : $\text{Power} = \dfrac{\text{Work done}}{\text{Time taken}}$

Work done = 20 Joules

Time taken = 5 sec.

$$P = \frac{20\text{ J}}{5\text{ s}}$$

So, Power = 4 J/s = 4 W

Thus, power of the body is 4 Watts.

Commercial Unit of Energy : Joule is very small unit of energy and it is inconvenient to use it where a large quantity of energy is involved.

For commercial purpose, bigger unit of energy is Kilotwatt hour (KWh).

1 KWh : 1 KWh is the amount of energy consumed when an electric appliance having a power rating of 1 Kilowatt is used for 1 hour.

Relation between Kilowatt hour and Joule

1 Kilowatt hour is the amount of energy consumed at the rate of 1 Kilowatt for 1 hour.

1 Kilowatt hour = 1 Kilowatt for 1 hour

= 1000 Watt for 1 hour

= 1000 Watt × 3600 seconds (60 × 60 seconds = 1 hour)

= 36,00,000 Joules

So, $1\text{ KWh} = 3.6 \times 10^6\text{ J} = 1\text{ unit}$

Example. *A bulb of 60 Watt is used for 6 hrs. daily. How many units (KWh) of electrical energy are consumed ?*

Solution : Power of bulb $= 60\text{ W} = \dfrac{60}{1000}\text{KW} = 0.06\text{ KW}$

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t = 6 hours

Energy = Power × Time taken = 0.06 × 6 h

t = 0.36 KWh = 0.36 units

QUESTIONS

VERY SHORT ANSWERS QUESTIONS

1. Define the term 'work'.
2. Define 1 Joule of work.
3. Give an example in which a force does positive work.
4. Give an example in which a force does negative work.
5. Define the term energy of a body.
6. Write the units of : (a) Work, (b) Energy.

SHORT ANSWERS QUESTIONS

1. Define Power.
2. Define 1 Watt energy.
3. Define 1 Kilowatt hour.
4. What do you undertstand by kinetic energy ? Write its formula.
5. On what factors does the kinetic energy of a body depends ?
6. What happens to potential energy of a body when its height is doubled ? (Ans. Doubled)
7. How many joules are there in 1 Kilowatt hour ?

LONG ANSWERS QUESTIONS

1. What is conservation of energy ? Explain with an example.
2. What are the quantities on which the amount of work done depend ? How are they related to work ?
3. A load of 100 kg is pulled up to 5 m. Calculate the work done. (g = 10 m/s2) (Ans. 5000 J)
4. A body of mass m is moving with a velocity 5 ms-1. Its kinetic energy is 25 J. If its velocity is doubled, what is its kinetic energy ? (Ans. 100 J)
5. A boy weighing 50 kg climbs up a vertical height of 100 m. Calculate the amount of work done by him. How much potential energy he gains ? (Given g = 9.8 m/s2) (Ans. 4.9 × 104 J)
6. Five electric fans of 120 watts each are used for 4 hours. Calculate the electrical energy consumed in kilowatt hours. (Ans. 2.4 KWh)
7. The power of an electric heater is 1500 Watt. How much energy it consumes in 10 hours ? [Ans. 15 KWh (units)]

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OBJECTIVE TYPE QUESTIONS

I. Objective Type Questions.

1. If Ramesh has done the same amoun of work in less time as compared to Rohan then

(a) Ramesh has more power
(b) Rohan has more power
(c) both has equal power

2. A flying kite possesses

(a) only pedantical energy
(b) Only kinetic energy
(c) both P.E. and K.E.
(d) neither P.E. nor K.E.

3. The workone on an object does not depend upon the

(a) DIs placement
(b) force applied
(c) angle between force
(d) initial velocity of the object

4. If a force F applied on a body gives its velocity V, its power will be.

(a) Fv
(b) F/v
(c) Fv^2
(d) F/v^2

5. Two particles of masses 1g and 4g have equal kinetic energies. what is the ratio between their mementa?

(a) 1:4
(b) 1:8
(c) 1:2
(d) 1:16

6. Moon revolves around the earth due to gravitational force (F) of earth on moon. The work done by the gravitational force is (r=radius of circular orbit of moon).

(a) F.2πr
(b) F.πr
(c) Zero
(d) negative work

II. Fill in the blanks :

7. A 20 Kg. mass object is being lifted through a height of __________m when 784 J of work is done on it.

8. In a heat engine, heat energy is converted into ___________

9. If the velocity of a body is tripled, then the K.E. of the body becomes _________ times that o its initial values.

10. If a proton and an electron are brought towards each other, the _________ will decrease.

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