Work and Energy

- Work is done when Produces motion.

Force → □ → □

$W = F \times S$

↑ force ↑ displacement

Force → Rock

- Work done by a force on a body depends upon two factors.
  → Magnitude of force.
  → Displacement through which the body moves.

$W = F \times S$

→ Work done in moving a body is equal to the product of force exerted on the body and the distance moved by the body in the direction of force.

→ $W = F \times S$
$= N \times m$
$W = \text{Joule}$

$1 \text{ Joule} = 1 N \times 1 M$

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.

→ work is a scalar quantity.

1st case: F → □ → 1m (1N)

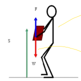
$W = F \times S$
$= 1N \times 1m$
$= 1Nm = 1J$

2nd case: −1m ← □ ← −F (−1N)

$W = F \times S$
$= -1N \times -1m$
$= 1Nm = 1J$

Positive and Negative work

When displacement of an object is in the same direction as that of force applied it is called Positive work done.

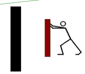


→ Work done by men = +ve.

→ work done by gravitational → −ve. force

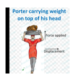
Negative work - when displacement of an object is in the opposite direction of applied force than it is negative work done.

Zero work done



$W = F \times S$
$= 0$

$\boxed{W = 0}$



Force applied, displacement

$\boxed{\text{work done} = 0}$

Example 11.1 A force of 5 N is acting on an object. The object is displaced through 2 m in the direction of the force (Fig.

2) Calculate the work done in lifting 200kg of water through a vertical height of 6 meters. (Assume g = 10 ms⁻²)

$W = F \times S$
$W = m \times a \times S$
$= m \times g \times h$
$= 200 \times 10 \times 6$
$W = 12000 \text{ J}$

3) A car weighing 1000kg & travelling at $30 ms^{-1}$ stops at a distance of 50m decelarating uniformly, What is the force exerted on it by the brakes? What is the work done by the breaks.

$F = ma$

$v^2 - u^2 = 2as$
$0 = 900 + 2 \times a \times 50$
$a = -9 ms^{-2}$

$F = -9000 N$

$W = F \times S$
$= 9000 \times 50$
$= 45 \times 10^4$

Energy

→ The ability to do work.

A ——— B Fast↑ Energy↑ work done↑

A' ——— B' Fast↓ Energy↓ work done↓

The amount of energy possessed by a body is equal to the amount of work it can do when it's energy is released.

- Energy is a scalar qty.

$WD = KE_i - KE_f$

Unit of Energy

→ Units of work and energy are the same i.e. joule.

1 kJ = 1000 Joules

Different forms of Energy

Kinetic energy, chemical energy, Potential energy.

Kinetic Energy

Energy↑ workdone↑ (wooden block)

Energy↓ work done↓

$(WD)_1 > (WD)_2$
WD → velocity
K.E → velocity

WD → mass
K.E → mass.

$W = F \uparrow d\uparrow$

work = $F \times S$

Now finding S

$v^2 - u^2 = 2as$
$S = (v^2 - u^2)/2a$

Putting value of S in above equations.

$W = F \times S$
$W = m\cancel{a} \times (v^2 - u^2)/2\cancel{a}$
$W = \frac{m(v^2 - u^2)}{2}$

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

$\boxed{K.E = \frac{1}{2}mv^2}$

The K.E. processed by an object of mass m and moving with a uniform velocity v is

$\boxed{\text{work done} = \Delta K.E}$

→ If the mass of a body is doubled/halved its KE also gets doubled / halves

→ If the velocity of a body is doubled/halved its KE becomes four times / one-fourth respectively.

1) An object of mass 15 kg is moving with a uniform velocity of $4 ms^{-1}$. What is the K.E possessed by the object?

2) what is the work to be done to increase the the velocity of a car from $30 km h^{-1}$ to $60 kmh^{-1}$ if the mass of the car is 1500 kg?

$30 \times \frac{5}{18}$ $60 \times \frac{5}{18}$

$WD = KE_i - KE_f$
$= \frac{1}{2}mv_i^2 - \frac{1}{2}mv_f^2$
$= 156250 \text{ J}$

3) How much work done on a bicycle of mass 20kg to increase its speed from $2 ms^{-1}$ to $5 ms^{-1}$. (Ignore Friction & air resistance)

→ 210 J

Ans

4) Two bodies of equal masses move with uniform velocities v and 3v respectively. Find the ratio of K.E's.

5) 1st body mass is twice the mass of 2nd and 2nd body's velocity is thrice of 1st. Find the ratio of K.E's.

1st body: $m_1 = 2m$, $V_1 = V$
2nd body: $m_2 = m$, $V_2 = 3V$

$\frac{KE_1}{KE_2} = \frac{\cancel{\frac{1}{2}} \times 2\cancel{m} \times V^2}{\frac{1}{2} \times \cancel{m} \times (3V)^2}$

$= \frac{2V^2}{9V^2} = \frac{2}{9}$

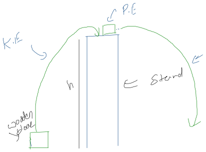
Potential Energy

Mechanical Energy → K.E, P.E

→ Strech → K.E

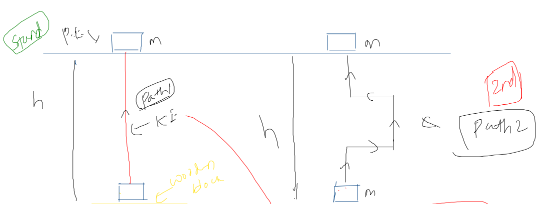
→ regained back it's original shape → P.E

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



To lift the body above surface of the earth we have to do work against the gravity.

Work done = Force × distance
$= mg \times h$
$P.E = m \times g \times h$
$= mgh$



Potential Energy (E_P) = mgh

K.E $= \frac{1}{2}mv^2 = \frac{1}{2} \times m \times 2gh$

$v^2 - u^2 = 2gh$

$v^2 = u^2 + 2gh$

$v^2 = 2 \times 10 \times h$

h = 1500, 3h = 4500, P.E = 1500 J

1) An object with 100N weight is raised to height of 1500 cm. Find the PE possessed by the object of that ht. Also find the new PE if the same object is raised to three times of the original ht. (given g = 10 ms⁻¹)

Sol: P.E = mgh = 100 × 15 = 1500 J

P.E = 3 × 1500 J = 4500 J

2) Find the energy possessed by an object of mass 10 kg when it is at a height of 6 m above the ground. Given, $g = 9.8 ms^{-2}$.

P.E = mgh = 10 × 9.8 × 6 = 588 J

3) An object of mass 12 kg is at a certain height above the ground, if the potential energy of the object is 480 J, find the height at which the object is with respect to the ground. Given, $g = 10 ms^{-1}$

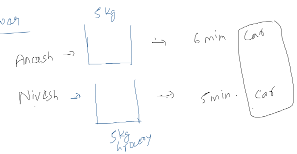
Ans — 4m

4) A bag of wheat weighs 200 kg. To what height should it be raised so that its potential energy may be 9800 joules? (Take $g = 9.8 ms^{-2}$) ans = 5m

5) If acc^n due to gravity is $10 ms^{-2}$, what will be the potential energy of a body of mass 1 kg at a height of 5 m?

ans = 50 J

Power



→ Power is defined as rate of doing work.

→ Work done (W = F×S) in both cases are same.

→ Time taken for doing the work is different.

→ Time taken by Nivesh < Time taken by Ancesh.

→ Nivesh has more power than Ancesh.

→ Power = $\frac{\text{work done}}{\text{Time taken}}$

$= J s^{-1} = \text{watt}$

F = ma
$= kg\, ms^{-2}$ Newton

→ 1 watt = 1 joule per second.

Electrical system

✓ 40 watt reading means bulb consumes 40 joules energy in 1 second.

✓ 15 watt " " " " 15 " "

✓ Power : how much energy is consumed in a second.

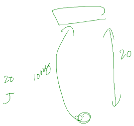
✓ Different electrical appliances have different power rating.

✓ Greater the power of an appliances and the longer is switched on → more electrical energy it consume.

1) A body does 30 joules of work in 5 seconds. What is its power?

$P = \frac{W}{T} = \frac{30}{5} = 6$ watt

2) What is the power of a pump which takes 10 seconds to lift 100 000 gm of water tank situated at a height of 20 00 cm? ($g = 10 ms^{-2}$)



Sol: $P = \frac{\text{Work}}{T} = \frac{Nm}{} = \text{Joule}$
$= kg\,ms^{-2}\,m$

work done = m × g × h = 100 kg × 10 × 20
= 20 000 J

Time, t = 10s

$P = \frac{W}{T} = \frac{20\,000}{10} = 2000$ watts

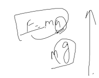
1 KW = 1000 watt

2 KW = 2000 watt

3) An electric bulb consumes 7.2 KJ of electricity in 2 mins. Power of electric bulb?

→ $P = \frac{W}{T} = \frac{7.2\,KJ}{2\,min} = \frac{7200\,J}{2 \times 60\,sec} = \frac{7200}{120} = 60\,Js^{-1}$
= 60 watt

Example 11.7 Two girls, each of weight 400 N climb up a rope through a height of 8 m. We name one of the girls A and the other B. Girl A takes 20 s while B takes 50 s to accomplish this task. What is the power expended by each girl?



(i) Power expended by girl A:

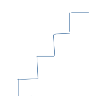
Weight of the girl (mg) : 400 N
Displacement (h) : 8m.
Time taken (t) : 20 s

Power = $\frac{\text{Work done}}{\text{Time taken}} = \frac{mgh}{t} = \frac{400 \times 8}{20} = 160$ W

(ii) Power expended by girl B → 64 W

Example 11.8 A boy of mass 50 kg runs up a staircase of 45 steps in 9 s. If the height of each step is 15 cm, find his power. Take $g = 10$ m s^{-2}.

m = 50 kg
t = 9 sec
height of staircase = $45 \times \frac{15}{100}$ m
= 6.75 m



$P = \frac{W}{T} = \frac{mgh}{t} = \frac{(50 \times 10 \times 6.75)}{9} = 375$ W

11.3.1 Commercial unit of energy

Energy unit → Joule

Power = 60 watt.

i.e. it consumes 60 joules per second.

→ How much energy in 1 minute?
1 sec = 60 J
60 sec = 60 × 60
1 min = 3600 J

→ How much energy in 1 hour?
1 min = 3600 J
60 min = 3600 × 60
1 hour = 216000 J

→ How much energy in 10 hours?
10 hour = 216000 × 10 J

→ What about a day?
1 hour = 216000 J
24 hr = 216000 × 24
1 day = 5184000 J

→ Commercial unit of Energy is Kilowatt hour.

→ The unit of joule is too small and hence is inconvenient to express large quantities of energy.

→ we use a bigger unit of energy called Kilowatt hour, kWh.

1 kWh = ?

1 kWh = 1000 Wh

1 kWh = 1000 W × 60 × 60 s

$= 36 \times 10^5$ W s → power unit W (watt) = Joule / second.

$= 36 \times 10^5 \frac{J}{s} \times s$

$= 36 \times 10^5$ J

$$\boxed{1\ kWh = 3.6 \times 10^6\ J}$$

→ Electricity energy used during a month is expressed in term of 'units'.

→ 1 unit = 1 kilowatt hour

Law of Conserving of energy

Energy can neither be created nor destroyed.

Steps in turning on bulb

Switch on → Electricity supply → Bulb → light energy, heat energy

Energy → transformed.

$PE = mgh$
$KE_O = \frac{1}{2}mv^2 = 0$
$ME_O = KE + PE = mgh$

$KE_B = \frac{1}{2}mv^2$
$= \frac{1}{2} \times m \times 2gh$
$= mgh$

$v^2 - u^2 = 2gh$
$v^2 = 2gh$

$PE_B = mgh$
$= m \times g \times 0$
$= 0$

$ME_B = KE_B + PE_B$
$= mgh + 0 = mgh$

$KE_A = \frac{1}{2}mv^2$
$= \frac{1}{2} \times m \times 2gx = mgx$
$v^2 - u^2 = 2gx$
$v^2 = 2gx$

$PE_A = mgh$
$= mg(h-x)$
$= mgh - mgx$

$ME_A = KE_A + PE_A$
$= mgx + mgh - mgx$
$= mgh$