# Work, Power and Energy

## What is Work? (काम क्या है?)

◇ Work done on an object is defined as the product of the magnitude of the force acting on the body and the displacement in the direction of the force. $W = F.s$

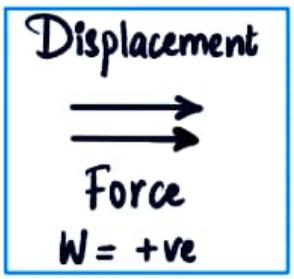
◇ If a force acting on a body causes no displacement, the work done is 0.
Example, pushing a wall.

- The unit of Work is Newton metre (Nm) or Joule (J).

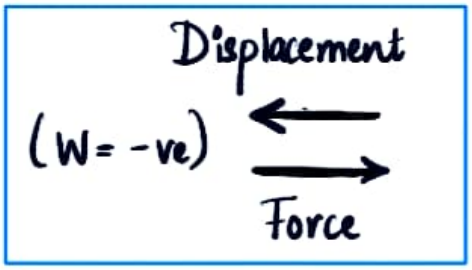
→ 1 Joule is defined as the amount of work done by force of 1N when displacement is 1 m.

→ Sign Conventions for Work Done

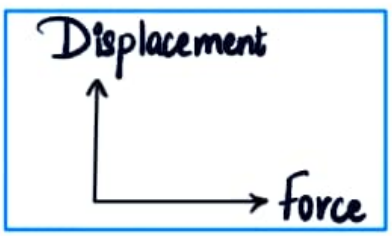
- when both the force and the displacement are in the same direction, positive work is done.
  $W = F \times s$




→ when force acts in a direction opposite to the direction of displacement, the work done is negative.
$W = -F \times s$
Angle between force and displacement is 180°




→ If force and displacent act at an angle of 90° then work done is 0.




→ If force and displacement are inclined at an angle less than 180°, then work done is given as :

→ $W = Fs \cos\theta$ (this is not very important from your class perspective, but surely you should know this!)

## Necessary Conditions for Work to be done

* Two conditions need to be satisfied for work to be done :
  - Force should act on the object.
  - Object must be displaced.

► So now whether you work hard all the day, go to school, go to market, do everything that is required and come back home, to bhi mummy bol sakti hai ki aaj aapne kuch kaam nahi kiya, kyuki aapka displacement is 0.

- Aapki initial aur final position dono ghar hi hai.
- That means your Work Done = 0.

To aisa hone par MummyOP! :(

# Energy

◊ The capacity of a body to do work is called the energy of the body.

(easy meaning : जब भी कोई इन्सान बिना थके ज़्यादा काम कर लेता है, so we say की उसकी energy ज़्यादा है, why? Because his capacity of doing work is more! Simple है)

* Unit of energy = Joules (same as work)

1KJ = 1000 J

## Forms of Energy

→ The various forms of energy are :

i) Potential energy
ii) Kinetic energy
iii) Heat energy
iv) Electrical energy
v) Light energy
vi) Chemical energy etc.

## How to remember?

S - Solar
C - Chemical
R - Radioactive
E - Electrical
A - Atomic
M - Mechanical

→ In this chapter, we are mostly discussing about mechanical energy.

Mechanical energy = Kinetic energy + Potential energy

# KINETIC ENERGY

- Energy possessed by a body due to its motion.
- Kinetic energy of an object increases with its speed.
- Kinetic energy of body moving with a certain velocity = work done on it to make it acquire that velocity.

## Derivation

∴ Work done → $W = F \times s$ ——— (i)

due to force, the velocity changes to v, and the acceleration produced is a

∴ relationship between v, u, a and s = $v^2 - u^2 = 2as$

∴ $s = \frac{v^2 - u^2}{2a}$ ——— (ii)

$F = ma$ ——— (iii)

Substitute (ii) and (iii) in (i) we get

$$W = F \times s$$

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

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

if $u = 0$, (object starts at rest)

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

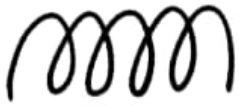
Work done = Change in kinetic energy

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

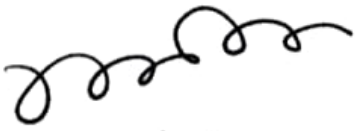
# Potential Energy

- The energy possessed by a body due to its position or shape is called its potential energy.

Shape

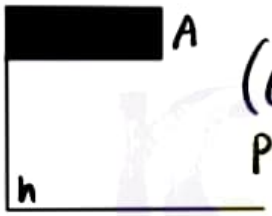


Coiled spring (Elastic potential energy)



Uncoiled spring

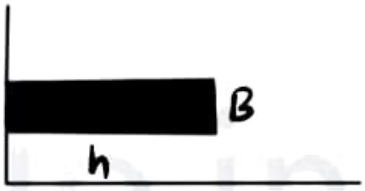
Position




(Gravitational potential energy)

at A

→ Greater energy due to compression is spring and due to greater height of the object.




at B

→ Less energy due to less compression in spring and due to less height of the object.

# Gravitational Potential Energy (GP)

◇ When an object is raised through a height, work is said to be done on it against gravity.

- The energy possessed by such an object is called the g 8/13 potential energy.
- GPE = work is done in raising a body from the ground to a point against gravity.

## Derivation


◇ Consider a body with mass m, raised through a height h, from the ground, Force required to raise the object = weight of object mg. The object gains energy to the work done on it.

∴ Work done on the object against gravity is W.

$$W = \text{force} \times \text{displacement}$$
$$= mg \times h$$
$$W = mgh$$
$$\therefore \quad P_E = mgh$$


→ Work done in both the cases (i) and (ii) is same as a body is raised from position A to B, even if the path taken is different but the height attained is the same.

## Work-Energy Theorem

▸ The work-energy theorem states that the net work done by the forces on an object equals the change in its kinetic energy.

→ $W_{net} = KE_{final} - KE_{initial}$

$\Rightarrow W_{net} = \frac{1}{2} m[v^2 - u^2]$

- That means if I kick a moving football in a direction of its motion, to further increase its velocity, the amount of work I have done on the football = kinetic energy transferred to that ball [OR] the change in Kinetic energy (both are one and the same thing)

# Law of Conservation of Energy

◇ This law states that the Energy can neither be created nor be destroyed.

→ It can only be converted from one form to another.

→ Total Energy in the Universe remains constant.

→ This means the total energy in the Universe before 1000 years is the same as today, and will always be the same.

## Proof of Law of Conservation of Energy (very important gets usually asked in 5 marks directly

→ Let's consider an object falling from a height 'h'.

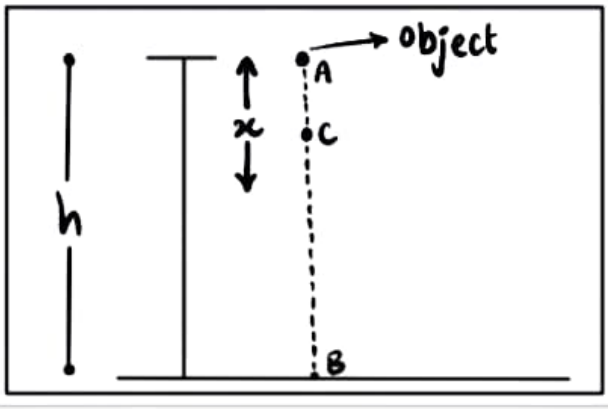
– We need to prove that its energy at every instant is same.

→ We will consider 3 points and calculate the energy at those points.

A. When the object is at the top height.

B. When object reaches the ground.

C. Any random point at a distance 'x' from the top.




Total energy = mechanical energy = potential energy + kinetic energy

**at A,**

Kinetic Energy $= \frac{1}{2} mv^2$

$\because v = 0$ at A,

$\rightarrow K.E. = 0$

$P.E. = mgh$

$T.E. = mgh + 0$

$\rightarrow$ $\boxed{\text{Total energy at A} = mgh}$ —— (1)

**at B,**

$K.E. = \frac{1}{2} mv^2$ —— (2)

from equation of motion,

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

Here, $u = 0$

$a = g$

$s = h$

$\Rightarrow v^2 - 0 = 2gh$

$\Rightarrow v^2 = 2gh$

Putting in (2),

$K.E. = \frac{1}{\cancel{2}} m (\cancel{2}gh)$

$K.E. = mgh$

$P.E. = mgh$

at B, $h = 0$

$\Rightarrow P.E. = 0$

$T.E. = K.E. + P.E.$

$\Rightarrow T.E. = mgh + 0$

$\boxed{\rightarrow \text{Total energy at B} = mgh}$ —— (3)

$\boxed{\text{at C,}}$

Kinetic Energy $= \frac{1}{2} mv^2$ ——— ④

according to equation of motion –

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

Here $u = 0$

$a = g$

$s = x$

$\Rightarrow v^2 = 2gx$

Putting in ④

$$K.E. = \frac{1}{\cancel{2}} m(\cancel{2}gx)$$

$$K.E. = mgx$$

$P.E. = mgh$

Here at C,

height from ground $= (h-x)$

$\Rightarrow P.E. = mg(h-x)$

$= mgh - mgx$

$T.E. = K.E. + P.E.$

$T.E. = \cancel{mgx} + mgh - \cancel{mgx}$

→ $\boxed{\text{Total energy at C} = mgh}$ ——— ⑤

From ①, ③ and ⑤

$\boxed{\text{Total energy at A, B and C} = mgh}$

# POWER (ताकत)

(कौन कितनी जल्दी काम खतम करता है)

→ Power is the rate of doing work.

→ More the time required to do work, less is the power.

→ Less the time required to do work, more is the power.

→ In easy words – Jab koi insaan kisi kaam ko jaldi kar leta hai, so we say he is more powerful as compared to wo jo kaam dheere dheere karta hai.

(Very important from Numericals Point of View)

$$\text{Power} = \frac{\text{Work}}{\text{Time}} \qquad \therefore P = \frac{W}{t}$$

$$\text{Watt} = \frac{\text{Joules}}{\text{Second}}$$

1 kilowatt = 1000 watts

1 kilowatt = 1000 J/s

## Commercial Unit of Energy

Commercial unit of energy = 1 kilowatt hour (kwh)

$\therefore$ 1kWh = 1 kilowatt × 1 hour

= 1000 watt × 3600 seconds

= 3600000 Joule (watt × second)

$1kWh = 3.6 \times 10^6$ J.

$\boxed{1kWh = 1 \text{ unit}}$

* The energy used in 1 hour at rate of 1kW is called 1kWh.