

Work, Power and Energy - Work, power, energy, HP, IHP, BHP and efficiency

Work (Fig 1)

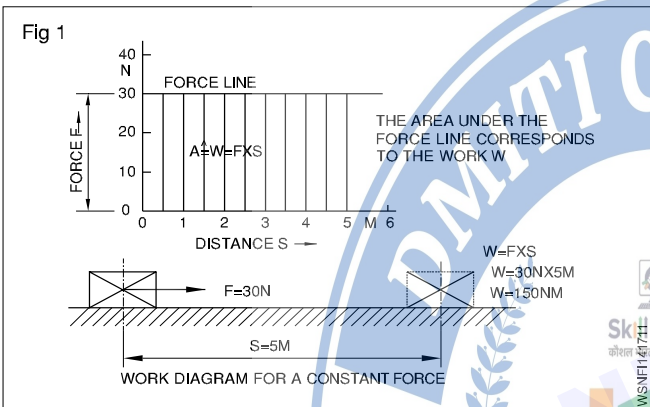
Work is said to be done by a force, when it moves, its point of application through a distance. Applied force 'F' moves a body through a distance's.

Work done  $W = F \times s$ .

The S.I. unit of work is 1 joule which is the work done by a force of moving the body through a distance of 1 metre.

Therefore joule = 1 N x 1 metre = 1 Nm

Also 1 joule = 1 Nm =  $10^5$  dynes x 100 cm =  $10^7$  dynes cm =  $10^7$  ergs.



F - force or weight force in N

s - distance the body on which force acts is moved in metres

t - time in seconds

v - speed in metre/sec

w - work done by the force in joules

P - Power in Watts

$P_{out}$  - Power output

$P_{in}$  - Power input

Force

A Force is that which changes or tends to change the state of rest or motion of a body.

Force = Mass x Acceleration

$F = Ma$

Unit

$F = M \times a$

= kg x m/sec<sup>2</sup>

= 1 Newton (SI unit)

(Newton: If 1 kg of mass accelerates at the rate of 1m/sec<sup>2</sup> then the force exerted on the mass is 1 newton)

FPS = 1 pound x 1 Feet/second<sup>2</sup>

= 1 pound

CGS = 1 gm x 1cm/second<sup>2</sup>

= Dyne

MKS = 1 kg x 1m/second<sup>2</sup>

= Newton.

1 Newton =  $10^5$  dynes

1kg wt = 9.81N

1 pound = 4.448N,

Newton = 0.225 pound.

Absolute units

In C.G.S. system unit of work = 1 erg = 1 dyne x 1 cm

In F.P.S system unit of work = 1 Foot poundal = 1 poundal x 1 foot

In M.K.S. system unit of work = 1 joule = 1 Newton x 1 metre

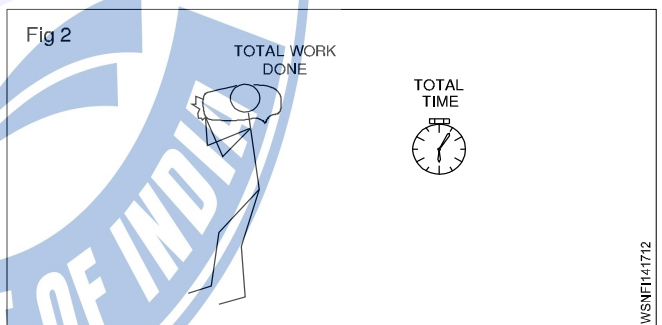
Derived units

C.G.S. system 1 Gm Wt x 1 cm = 981 ergs.

F.P.S. system 1 ft LB = 981 foot poundal

M.K.S. system 1 kgf metre = 981 joule.

Power (Fig 2)



It is the work done in unit time.

$$\text{Power } P = \frac{\text{total work done}}{\text{total time}}$$

$$P = \frac{\text{Nm}}{\text{sec}}$$

The S.I units of power = 1Nm/sec =  $\frac{1 \text{ joule}}{\text{sec}}$

which is = 1 watt. power in watts =  $\frac{w}{t} = \frac{F.s}{t} = FXV$

which is equal to 1 Watt. Power in watts = w/t = F.s/t = F x V

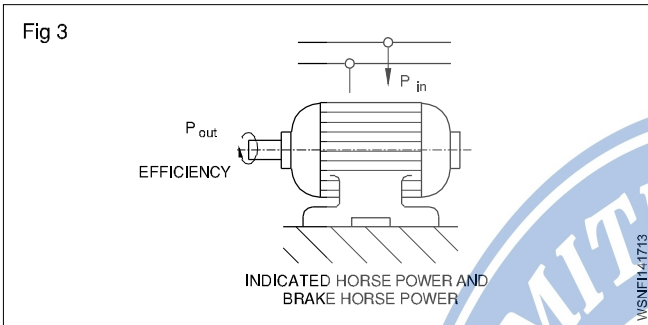
In M.K.S. system the unit is 1 kgf meter/sec. One horse power is = 75 kg metre/sec or 4500 kgf metre/min.

1HP (metric) = 735.5 Watts

1HP (British) = 746 Watts = 0.746 KW

1 KW = 1.34 HP

Power input is the power given to a machine to do work. Power output is what we get out of the machine. Power output is always less than power input due to friction in the machine. The ratio between power output to power input is efficiency of the machine and it is expressed in percentage. (Fig 3)



$$\text{efficiency} = \frac{\text{power output}}{\text{power input}} \times 100\%$$

### Indicated Horse Power and Brake Horse Power

The power actually generated by the engine or generator is the indicated horse power which is indicated on the plate.

The Brake horse power is the power available to do useful work. B.H.P is always less than I.H.P. due to losses to overcome frictional resistance.

$$\therefore \text{mechanical efficiency} = \frac{\text{B.H.P}}{\text{I.H.P}} \times 100\%$$

Work done by a force = Magnitude of the force x distance moved by the body

Power = Total work done / total time taken

$$\text{efficiency} = \frac{\text{power output}}{\text{power input}} \times 100\%$$

### Energy

The energy of a body is its capacity to do work. It is equal to power x time. Hence the unit of energy is the same as the unit of work in all systems.

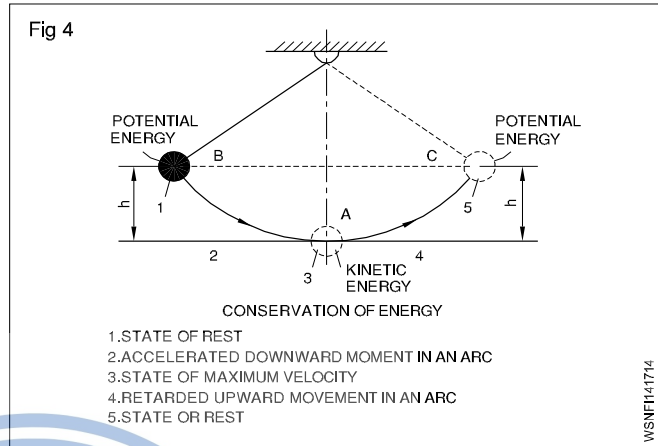
### Forms of energy

Mechanical energy, Electrical energy, Atomic energy, Heat energy, Light energy, Chemical energy, sound energy. Energy of one form can be transformed into energy of another form.

### Law of conservation of energy

- The energy can neither be created nor destroyed.
- Total energy possessed by a body remains the same. (Fig 4)

Depending upon the position of the body or body in motion, mechanical energy possessed by the body may be potential energy or kinetic energy respectively.



### Examples

- 1 A man weighting 75kg climp 200 metre high hill. Find the Work done by a man?

**Formula:** Work done (W) = F x S

**Given data:** F = 75 kg  
S = 200m

**To find:** Work done (W) = ?

**Solution:** Work done (W) = F x S  
= 75 x 200 = 15000

**Ans:** Work done (w) = 15000 kgm

- 2 Find the work required to lift a mass of 36.3 Newtons through a height of 3.7 metres?

**Formula:** Work done (W) = F x S

**Given data:** F = 36.3 N  
S = 3.7m

**To find:** Work done (W) = ?

**Solution:** Work done (W) = F x S  
= 36.3 x 3.7 N.m  
= 134.31 Joules

**Ans:** Work done (W) = 134.31 Joules

- 3 Calculate the Work done by a man weighing 50kg in carrying a mass of 20kg over his head when he covers a distance of 15metres in vertical direction.

**Formula:** Work done (W) = F x S

**Given data:** F = 50kg + 20kg = 70kg  
S = 15 m

**To find:** Work done (W) = ?

**Solution:** Work done (W) = F x S  
= 70 x 15 = 1050

**Ans:** Work done (W) = 1050 kg.m

- 4 A man weighing 60kg lifts a weight of 40kg to the top of building 12 metres height. Find the useful Work done by him and also the efficiency?

**Formula:** Work done (W) = F x S

**Given data:** Man weight = 60kg  
Lifts a weight = 40kg  
Total weight = 60 + 40 = 100kg  
Distance (S) = 12 m

**To find:** a) Work done (W) = ?  
b) Efficiency ( $\eta$ ) = ?

**Solution:**

a) Work done (W) = F x S  
= 100 x 12 = 1200 kg.m

b) Efficiency ( $\eta$ ) =  $\frac{\text{Output}}{\text{Input}} \times 100\%$   
=  $\frac{40 \times 12}{60 \times 12} \times 100\%$   
=  $\frac{480}{720} \times 100\%$   
= 66.67%

**Ans:** a) Work done (W) = 1200 kg.m

b) Efficiency ( $\eta$ ) = 66.67%

- 5 A pump pumps 4000kg of water from 50 metres depth in 40 minutes. Find the Work done by pump in one second?

**Formula:** Work done (W) = F x S

**Given data:** F = 4000 kg  
S = 50 m

**To find:** Work done per second = ?

**Solution:**

Work done in 40 minutes,

Work done (W) = F x S  
= 4000 x 50 = 200000 kgm  
=  $\frac{200000}{40} = 5000$   
(∵ 1 min = 60 sec)

Work done in 1 second =  $\frac{5000}{60} = 83.3$

**Ans:** Work done in 1 second (W) = 83.33 kg.m

- 6 A body of 225 kg is moved by 300 metres in 90 seconds. Find the power required to lift this body?

**Formula:** Power (P) =  $\frac{F \times S}{t}$

**Given data:** F = 225 kg  
S = 300m  
t = 90 sec

**To find:** Power (P) = ?

**Solution:** Power (P) =  $\frac{F \times S}{t}$   
=  $\frac{225 \times 300}{90}$  kg.m/sec  
= 750 kg.m/sec

**Ans:** Power (P) = 750 kg.m/sec

- 7 A hydraulic press lifts a load of 5 tonnes in 5 minutes to a height of 5 metres. Calculate the power of the press?

**Formula:** Power (P) =  $\frac{F \times S}{t}$

**Given data:** F = 5 tonnes = 5000 kg  
S = 5 metres  
t = 5 minutes = 5 x 60 = 300 sec

**To find:** Power (P) = ?

**Solution:** Power (P) =  $\frac{F \times S}{t}$   
=  $\frac{5000 \times 5}{300} = 83.33$

**Ans:** Power (P) = 83.33 kg.m/sec

- 8 A man weighing 750N takes 25N material to a height of 10 metres in one minute. calculate the power of man?

**Formula:** Power (P) =  $\frac{F \times S}{t}$

**Given data:**

Man weight = 750N  
Material weight = 25N  
F = 750 + 25 = 775N  
S = 10 m  
t = 1 min = 60 sec

**To find:** Power (P) = ?

**Solution:** Power (P) =  $\frac{F \times S}{t}$   
=  $\frac{775 \times 10}{60} = 129.17$  N m/sec

**Ans:** Power (P) = 129.17N m/sec (or) watts

9 What is the power of pump which takes 15 seconds to lift 90kg of water to a tank situated at a height of 30 metres. (Take  $g = 10\text{m/sec}^2$ )?

**Formula:** Power (P) =  $\frac{F \times S}{t}$

**Given data:** F = 90 kg  
S = 30 m  
t = 15 sec

**To find:** Power (P) = ?

**Solution:** Power (P) =  $\frac{F \times S}{t}$   
=  $\frac{f \times g \times s}{t}$   
=  $\frac{90 \times 10 \times 30}{15}$   
=  $18\text{N m/sec}^2$

**Ans:** Power (P) = 180 watts

10 A hoist lifts a weight of 1000kg through a height of 33 metres in one minute. Find out the horsepower of the hoist?

**Formula:** Horsepower HP =  $\frac{F \times S}{t} \times \frac{1}{75}$

**Given data:** F = 1000 kg  
S = 33 m  
t = 1 minute = 60 sec

**To find:** Horsepower HP = ?

**Solution:** Horsepower HP =  $\frac{F \times S}{t} \times \frac{1}{75}$   
( $\because 75 \text{ kg.m/sec} = 1 \text{ HP}$ )  
=  $\frac{1000 \times 33}{60} \times \frac{1}{75}$   
= 7.33 H.P.

**Ans:** Horsepower, HP = 7.33 H.P.

11 A pump can raise 900 litres of water per minute to a height of 45 metres. Calculate the H.P of pump?

**Formula:** Horsepower HP =  $\frac{F \times S}{t} \times \frac{1}{75}$

**Given data:** F = 900 litres = 900 kg  
S = 45 m  
t = 1 minute = 60 sec

**To find:** Horsepower HP = ?

**Solution:** Horsepower HP =  $\frac{F \times S}{t} \times \frac{1}{75}$   
( $\because 1 \text{ HP} = 75 \text{ kg.m/sec}$ )

$$= \frac{900 \times 45}{60} \times \frac{1}{75} = 9 \text{ H.P}$$

**Ans:** Horsepower, HP = 9 H.P.

12 Find the horsepower of an engine to lift a weight of 2 tonnes to a height of 30 metres in two minutes?

**Formula:** Horsepower HP =  $\frac{F \times S}{t} \times \frac{1}{75}$

**Given data:** F = 2 tonnes = 2000 kg  
S = 30 m  
t = 2 minutes = 120 sec

**To find:** Horsepower HP = ?

**Solution:** Horsepower HP =  $\frac{F \times S}{t} \times \frac{1}{75}$   
( $\because 1 \text{ HP} = 75 \text{ kg.m/sec}$ )  
=  $\frac{2000 \times 30}{120} \times \frac{1}{75} = 6.67 \text{ H.P.}$

**Ans:** Horsepower, HP = 6.67 H.P.

13 Find out horsepower of a pump required to lift 10000 litres of water in 3 minutes at height of 16 metres. Assume efficiency of pump as 94%?



**Formula:** Horsepower HP =  $\frac{F \times S}{t} \times \frac{1}{75}$

$\eta = \frac{\text{Output}}{\text{Input}} \times 100\%$

**Given data:** F = 10000 litres = 10000 kg  
S = 16 metres  
t = 3 minute = 180 sec

**To find:** Horsepower HP = ?

**Solution:** Horsepower HP =  $\frac{F \times S}{t} \times \frac{1}{75}$   
( $\because 1 \text{ HP} = 75 \text{ kg.m/sec}$ )

$$= \frac{10000 \times 16}{180} \times \frac{1}{75}$$

$$= 11.85 \text{ H.P.}$$

$$\eta = \frac{\text{Output}}{\text{Input}} \times 100\%$$

$$94 = \frac{11.85}{\text{Input}} \times 100\%$$

$$\text{Input} = \frac{11.85 \times 100}{94} = \frac{1185}{94}$$

$$= 12.606 \text{ H.P.}$$

**Ans:** Input H.P of Pump = 12.606 H.P.

14 Find the horsepower of a motor which is required to lift 500 tonnes of coal per hour from a mine of 320 metre depth. Efficiency of motor is 0.75?

**Formula:**  $\eta = \frac{\text{Output}}{\text{Input}} \times 100\%$

$$\text{Output H.P} = \frac{F \times S}{t} \times \frac{1}{75}$$

**Given data:**

F = 500 tonnes = 500000 kg  
 S = 320 metres  
 t = 1 hour = 3600 sec  
 $\eta = 0.75 = 75\%$

**To find:** Pump HP = ?

**Solution:**

$$\text{Output HP} = \frac{F \times S}{t} \times \frac{1}{75}$$

( $\because$  1 HP = 75 kg.m/sec)

$$= \frac{500000 \times 320}{3600} \times \frac{1}{75}$$

$$= 592.59 \text{ H.P.}$$

$$\eta = \frac{\text{Output}}{\text{Input}} \times 100\%$$

$$75 = \frac{592.59 \times 100}{\text{Input}}$$

$$\text{Input} = \frac{59259}{75}$$

**Ans:** Input = 790.12 H.P

15 A train weighing 25 tonnes is moving at a speed of 90km/hour. Find the horsepower of the engine, if the frictional force is 5kg per tonnes?

**Formula:** Horsepower HP =  $\frac{F \times S}{t} \times \frac{1}{75}$

**Given data:** Train speed = 90 km/hour

$$= 90 \times \frac{1000}{3600} = 25 \text{ m/sec}$$

Train weight = 25 tonnes

Frictional force per tonnes = 5 kg

25 tonnes frictional force

$$(F) = 25 \times 5 = 125 \text{ kg}$$

**To find:** Horsepower of the engine = ?

**Solution:** 
$$\text{HP} = \frac{F \times S}{t} \times \frac{1}{75}$$

$$= \frac{125 \times 25}{1} \times \frac{1}{75}$$

**Ans:** HP = 41.67 H.P.

16 A pump delivers 9000 litres of water per minute to a height of 14 metres. The efficiency of the pump is 78%. The efficiency of electric motor which drives the pump is 92%. Find out the input of the motor?

**Formula:**  $\eta = \frac{\text{Output}}{\text{Input}} \times 100\%$

$$\text{Output H.P} = \frac{F \times S}{t} \times \frac{1}{75}$$

$$1 \text{ H.P} = 0.7355 \text{ KW (metric)}$$

**Given data:**

F = 9000 litres = 9000 kg

S = 14 metres

t = 1 minute = 60 sec

pump  $\eta = 75\%$

motor  $\eta = 92\%$

**To find:** Electric motor (KW) = ?

**Solution:**

$$\text{Pump Output HP} = \frac{F \times S}{t} \times \frac{1}{75}$$

$$= \frac{9000 \times 14}{60} \times \frac{1}{75}$$

$$= 28 \text{ H.P.}$$

Input of the pump

$$\eta = \frac{\text{Output}}{\text{Input}} \times 100\%$$

$$78 = \frac{28}{\text{Input}} \times 100$$

$$\text{Input} = \frac{28 \times 100}{78} = 35.9 \text{ H.P}$$

Output of the motor = Input of the pump

$$\text{Output} = 35.9 \text{ H.P}$$

Input of the motor

$$\text{Motor } \eta = \frac{\text{Output}}{\text{Input}} \times 100\%$$

$$92 = \frac{35.9}{\text{Input}} \times 100$$

$$\text{Input} = \frac{35.9 \times 100}{92} = 39.02 \text{ H.P}$$

**Ans:** Motor input = 39.02 H.P

17 I.H.P of generator is 6 H.P and its efficiency is 90%.  
Find tis B.H.P.

$$\eta = \frac{\text{B.H.P}}{\text{I.H.P}} \times 100\%$$

**Formula:**  $\eta = \frac{\text{B.H.P}}{\text{I.H.P}} \times 100\%$

**Given data:**

$$\text{I.H.P} = 6 \text{ H.P}$$

$$\eta = 90\%$$

**To find:** B.H.P = ?

**Solution:**  $\eta = \frac{\text{B.H.P}}{\text{I.H.P}} \times 100\%$

$$90 = \frac{\text{B.H.P}}{6} \times 100\%$$

$$\frac{90 \times 6}{100} = \text{B.H.P}$$

$$\text{B.H.P} = 5.4 \text{ H.P}$$

**Ans:** B.H.P of generator = 5.4 H.P

18 A machine is working on 80% efficiency I.H.P of machine is 50. Calculate the power lost in friction.

**Formula:** I.H.P = B.H.P + Frictional losses

**Given data:** Efficiency  $\eta = 80\%$

$$\text{I.H.P} = 50$$

**To find:** Friction = ?

**Solution:**  $\eta = \frac{\text{B.H.P}}{\text{I.H.P}} \times 100\%$

$$80 = \frac{\text{B.H.P}}{\text{I.H.P}} \times 100\%$$

$$80 = \frac{\text{B.H.P}}{50} \times 100\%$$

$$\frac{80 \times 50}{100} = \text{B.H.P}$$

$$\text{B.H.P} = 40$$

$$\text{B.H.P} = \text{I.H.P} - \text{F.H.P}$$

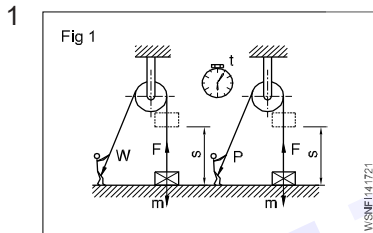
$$40 = 50 - \text{F.H.P}$$

$$40 + \text{F.H.P} = 50$$

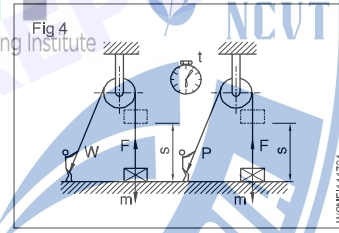
$$\text{F.H.P} = 50 - 40 = 10$$

**Ans:** Loss of friction = 10 H.P

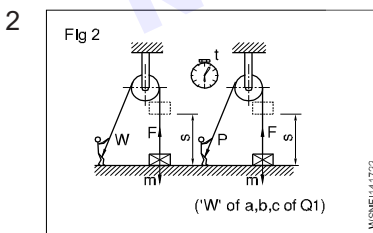
## Assignment



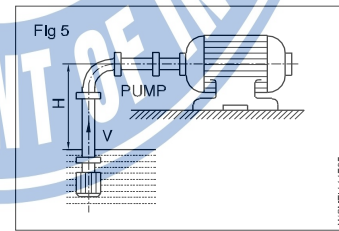
$m = 55 \text{ kg}$   
a)  $s = 1.82 \text{ metres}$   
 $W = \text{_____ joules}$   
b)  $s = 1.40 \text{ metres}$   
 $W = \text{_____ joules}$   
c)  $s = 0.85 \text{ metres}$   
 $W = \text{Joules}$



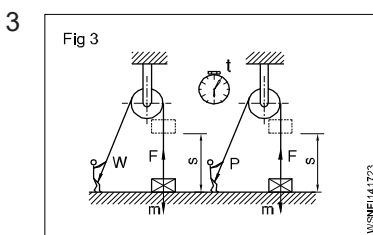
$m = 75 \text{ kg}$   
 $s = 100 \text{ metres}$   
 $t = 12 \text{ secs}$   
 $W = \text{_____ Nm}$   
 $P = \text{_____ Watts}$



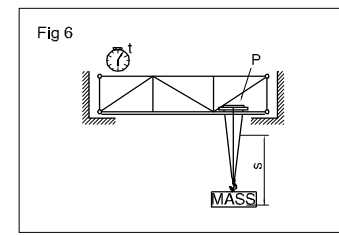
$t = 8 \text{ secs}$   
a)  $P = \text{_____ Watts}$   
b)  $P = \text{_____ Watts}$   
c)  $P = \text{_____ Watts}$



$V = 1 \text{ m}^3/\text{min}$   
 $H = 2 \text{ m}$   
 $\eta = 0.75$   
Power input = \_\_\_\_\_ kW



$W = 1312.5 \text{ Joules}$   
 $m = 350 \text{ kg}$   
 $s = \text{_____ metres}$



$P = 12 \text{ kw}$   
 $s = 4 \text{ metres}$   
 $t = 20 \text{ secs}$   
 $m = \text{_____ kg}$