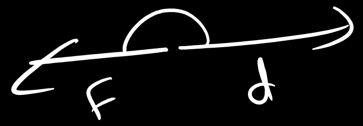
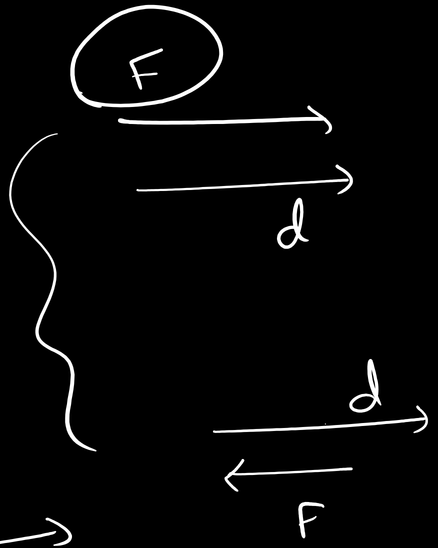
Work and Energy

Chapter 11

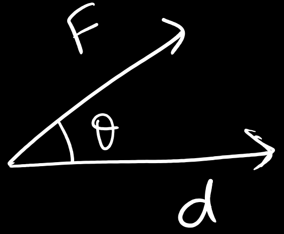


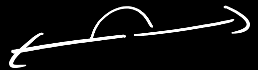


0°

+ve work

(Max. work)

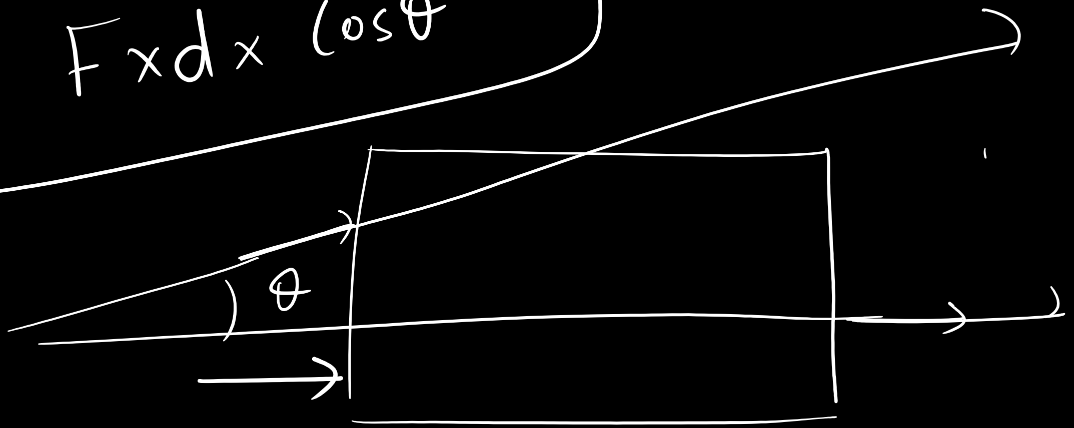


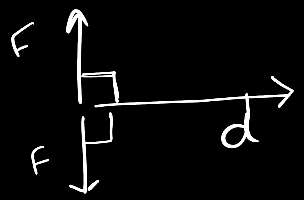


180°

−ve work

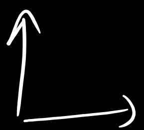
$$\boxed{W = F \times d \times \cos\theta}$$





90°

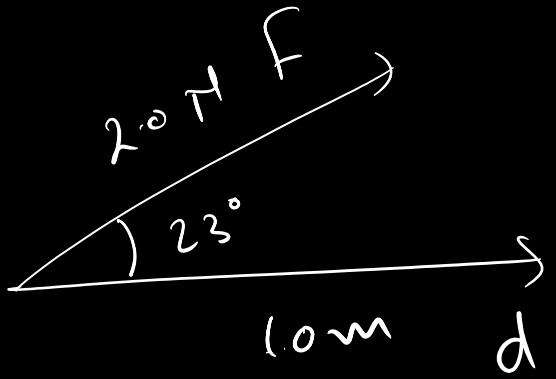
Zero work done



$\cos 180^\circ = -1$

$\cos 0^\circ = 1$

$\cos 90^\circ = 0$



$\cos 23^\circ = 0.31$

$$\boxed{W = F \times d \times \cos\theta}$$

$$W = 20 \times 10 \times \cos 23^\circ$$

$$= 20 \times 10 \times 0.31$$

$$= \underline{\qquad\qquad} \ J$$

Energy :

"Capability / Ability / capacity of any object to do work."

SI unit → joule (J)

$\boxed{1\ J\ \text{Energy}}$ ⇒ If an object has capacity to do 1 J of work, then it possesses 1 J energy.

Bigger units: . kilojoule (kJ)

$$1\ kJ = 1000\ J$$

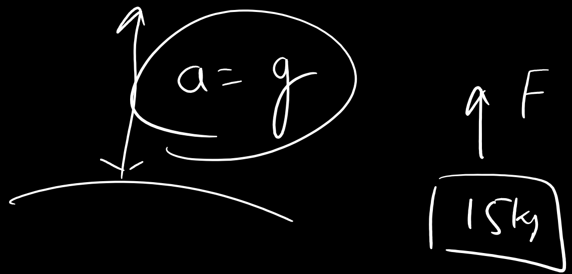
$$1\ \text{megajoule}\ (MJ) = 10^6\ J$$

Forms of Energy

- Mechanical Energy → Kinetic Energy, Potential Energy

- Electrical Energy
- Heat Energy
- Wind Energy
- Nuclear Energy
- Chemical Energy (Bond)
- Sound Energy.

Q. A porter lifts a luggage of 15 kg from the ground and puts it on his head 1.5 m above the ground. Calculate the workdone by him on the the luggage. ($g = 10$)



$$\boxed{W = F \times d}$$

$$\boxed{F = ma}$$

$$\boxed{F = mg}$$

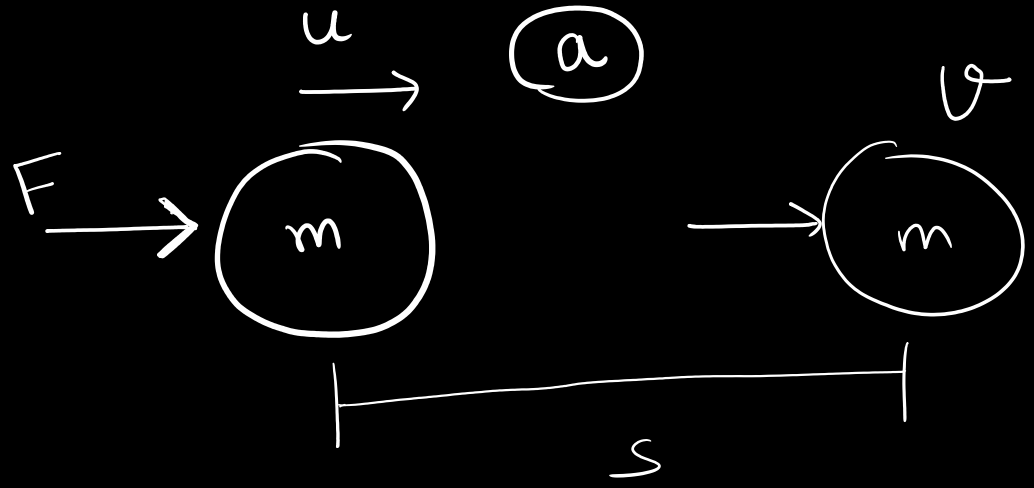
$$F = \boxed{15 \times 10}$$

$$W = 15 \times 9.8 \times 1.5$$

$$\boxed{W = 220.5\ J}$$

Kinetic Energy:

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



$$\boxed{F = ma}$$

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

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

Work done on object $= F \times S$ —— (I)
(W)

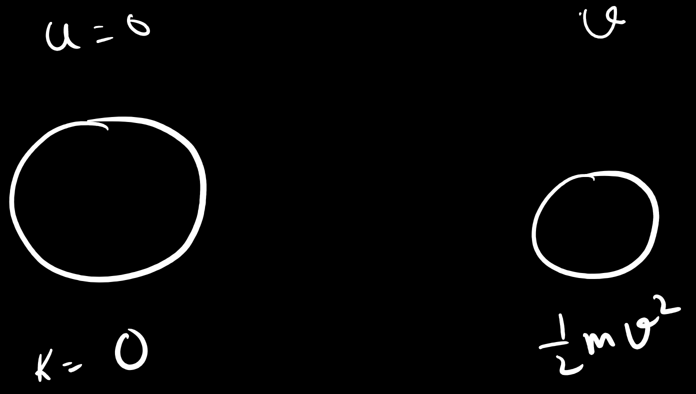
$F = ma$ —— (II) { second law of Newton }

$S = \dfrac{v^2 - u^2}{2a}$ —— (III) { From eqn. of motion

from (I), (II) & (III)

$W = m\cancel{a} \times \left(\dfrac{v^2 - u^2}{2\cancel{a}}\right)$

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



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

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

$$W = \underline{\Delta K.E} = \frac{1}{2}mv^2 - 0$$

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

Work done on any object is <u>change</u> <u>in its kinetic energy</u>.

If $u=0$, then.

$$\boxed{K.E. = \frac{1}{2}mv^2}$$ ✓

$u = 5$

$W \rightarrow 2\,kg$

$KE = \frac{1}{2} m v^2$

$= \frac{1}{2} m \times 5^2$

$= 25\,J$

$v = 10\ m/s$

$2\,kg$

$K.E. = \frac{1}{2} m v^2$

$= \frac{1}{2} \times 2 \times (10)^2$

$= 100\,J.$

$W = 100 - 0$

$\boxed{W = 100\,J}$

$W = 100 - 25$

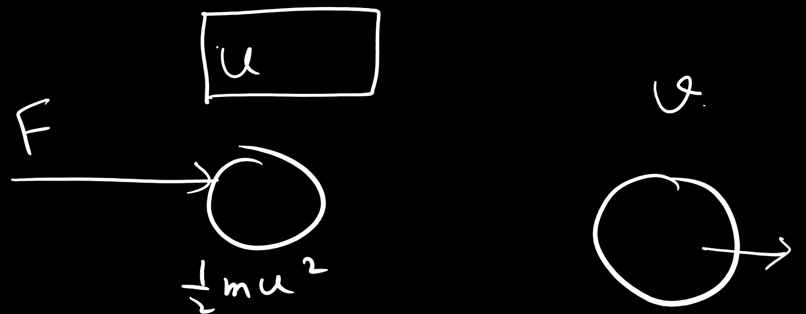
$= 75\,J$

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

Kinetic Energy

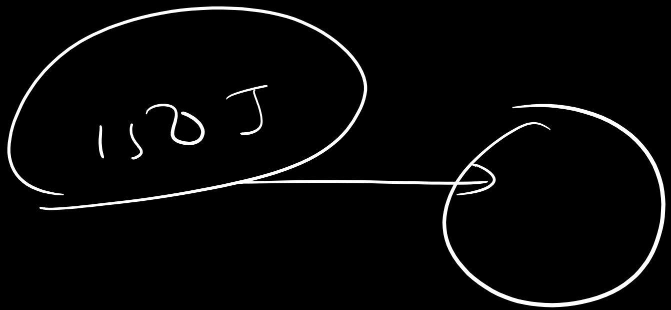
$$\boxed{E_k = \frac{1}{2} m v^2}$$

Work done : $\frac{1}{2} m v^2$



Work done. = $\frac{1}{2} m v^2$

Work done = change in K.E.

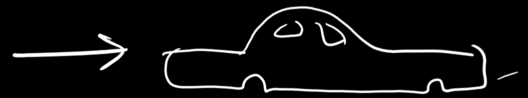


Q. An object of mass 15 kg is moving with uniform velocity of 4 m/s. What is the kinetic energy possessed by the object.

Sol.

Q. What is the work to be done to increase the velocity of a car from 30 km/h to 60 km/h if the mass of the car is 1500 kg?

Work! $u = 30$ km/h.

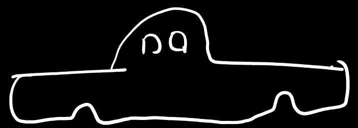


1500 kg

$\downarrow$

$\frac{1}{2}mu^2$

$v = 60$ km/h.



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

$\frac{30 \text{ km}}{1 \text{ hr.}}$

$u = 30 \times \frac{5}{18} = \frac{25}{3}$ m/s

$\frac{1}{\cancel{2}} \times \cancel{1500}^{750} \times \left(\frac{25}{3}\right)^2$

$750 \times \frac{625}{9}$

$v = \frac{50}{3}$ m/s

$\frac{1}{\cancel{2}} \times \cancel{1500}^{750} \times \left(\frac{50}{3}\right)^2$

$750 \times \frac{2500}{9}$

$$\text{Work done} = \left(750 \times \frac{2500}{9}\right) - \left(750 \times \frac{625}{9}\right)$$

$$= 750\left(\frac{2500}{9} - \frac{625}{9}\right)$$

250 625

$$= \cancel{750}\left(\frac{\cancel{1875}}{\cancel{9}}\right)$$

3

$$= \underline{250 \times 625} \quad \text{J.}$$

$$= \underline{\underline{156250}} \ \text{J}$$

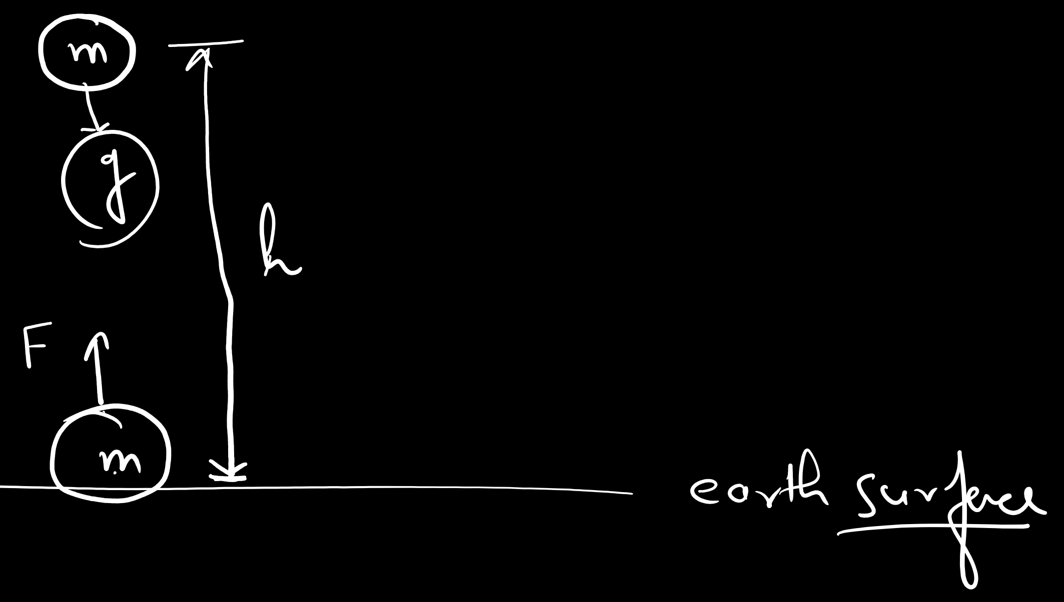
Potential Energy

Work done on mass, m $= F \times h$

$$W = mg \times h$$

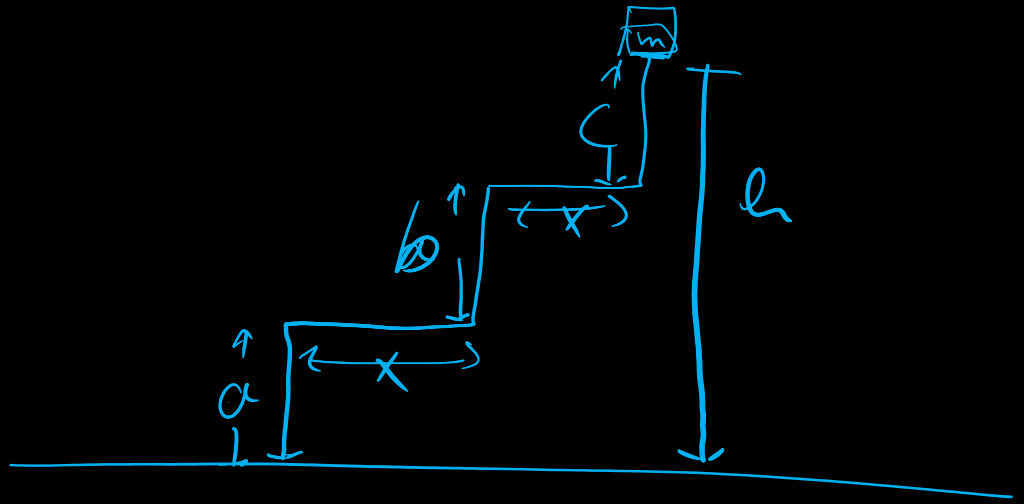
Gravitational Potential energy of object = Work done on the object

$$\boxed{E_p = mgh}$$



$$E_p = mg(a+b+c)$$

$$\boxed{E_p = mgh}$$



An object of mass 12 kg is at certain height above the ground. If the potential energy of the object is 480 J, find the height at which the object is w.r.t. the ground.

Given $g = 10 ms^{-2}$.

Energy of universe is conserved

Law of Conservation of Energy ✓

$v = 0 \quad K_E = 0 + P = 100$

$\boxed{TE = 100\,J}$

$\boxed{\text{Mechanical } E = K.E + P.E}$

Total 100 J $\Rightarrow$ $\boxed{PE_{\uparrow}^{=30} + KE^{=70}}$ $v\uparrow$

$v\uparrow$

Total 100 J $\Rightarrow$ $K.E.\uparrow = 100$, $G.PE = 0$

$\boxed{KE\uparrow = 100}$ $PE = 0$

$$\boxed{PE + K.E. = \text{constant}}$$

$$\boxed{mgh + \frac{1}{2}mv^2 = \underline{\text{constant}}}$$

Mechanical energy = P.E. ↑ + K.E. ↓

PE = 100 KE = 0

= 25 J

50 J K.E ↓ P.E ↑

50.

KE ↑ v ↑ ↑

PE = 0

KE = 1

Heat

20

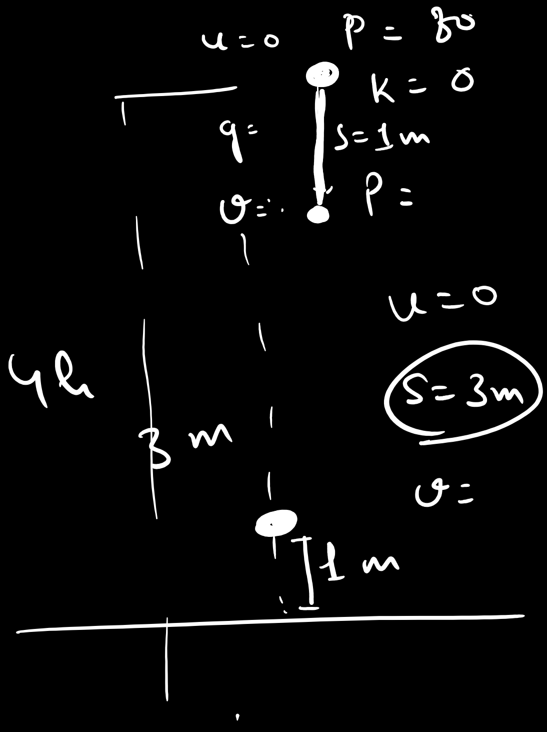
5 J S

- Mechanical Engy K P
- Thermal.
- Nuclear Eng
- Electrical.
- Magnetism
- Sound | Light
- Chemical engy.
- Ionisation engy.

Height at which object is located (m)	Potential Energy ($E_p = mgh$)	KE $E_K = \frac{1}{2}mv^2$	Mechanical Energy $T_M = E_p + E_K$
4	800 J.	0 J	800 J
3	600 J	200 J	800 J
2	400 J	400 J	800 J
1	200 J	600 J	800 J
Just above ground.	0 J	800 J	800 J

$v^2 =$

KE.



object of mass 20kg is dropped from height of 4 m.

$$g = 10 \text{ m/s}^2$$

$v^2 - u^2 = 2gs$

$KE = \frac{1}{2} \times 20 \times 80$

$=$

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

$= \frac{1}{2} \times 20 \times 20$

$v^2 = 2 \times 10 \times 1$

$v^2 = 20$

$v = \sqrt{20}$

$$\boxed{v^2 - u^2 = 2aH}$$

$v^2 = 2 \times 10 \times 1$

$= 20$

$v = \sqrt{20}$ m/s.

Power : Rate of doing work

$$\boxed{P = \frac{W}{t}}$$

TJ

4 S-presso

400 km

Fortuner ✓

Power

$$\boxed{1\,W = 1\,J\,s^{-1}}$$

SI unit = $\frac{J}{s}$ $\boxed{J\,s^{-1}}$

Preffered SI unit is W (watt)

James Watt

Define 1 W power

$1000\,W = \frac{1000\,J}{1\,s}$

$$P = \frac{1\ \text{J Work done}}{1\,s\ \ t} = \frac{\text{Energy consumed}}{t}$$

1 W

⇒ { Power of an agent/machine/motor is 1 W when it does 1 J work in 1 second. }

⇒ { Power of an agent/machine/motor is 1 W when it consumes 1 J energy in one second. }

1min

10,000 W

50 W

$$P = \frac{W}{t}$$

$J\,s^{-1}$

watt (W)

$P = 100\,W$ $\quad 100\,J\,s^{-1}$

$P = 5W$ $\quad 5\,J\,s^{-1}$

$$P = \frac{W}{t} = \frac{E}{t}$$

1000 - 2000W

1kW - 2kW

1kW = 1000 W

$\boxed{\text{Unit} \Rightarrow \text{watt}}$

$$\boxed{1\,W = 1\,J s^{-1}}$$

Higher units :

- Kilowatt (kW)
- Megawatt (MW)

$$\boxed{\begin{aligned} 1\,kW &= 1000\,W = 10^3\,W \\ 1\,MW &= 10^6\,W \end{aligned}}$$

Q. 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. $\boxed{g = 10\ m s^{-2}}$

Potential Energy of boy $= 50 \times 10 \times 6.75$

$= 3375\ J$

Power $= \dfrac{W}{t} = \dfrac{3375}{9} = 375\ W$

Commercial unit of Energy

Power unit = kW

Time = hour.

$\boxed{\text{SI unit of Energy : J}}$

$\boxed{P = \frac{E}{t}}$

$\boxed{P = \frac{W}{t}}$

$\boxed{W = P \times t}$

$kW = \frac{E}{hour}$

$\boxed{2\,kW}$

2 h

W

Ws

kW

$\boxed{E = P \times t}$

$= 2\,kW \times 2\,h.$

$= 4\,kWh.$

$1\ kWh = 1000\ W \times 3600\ s$

$= 1000\ \frac{J}{\cancel{s}} \times 3600\ \cancel{s}$

$= 3600 \times 1000\ J$

$3.6\ 00\ 000.0$

$\boxed{3.6 \times 10^6\ J}$

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

$\boxed{1 \text{ unit energy}} \rightarrow \boxed{Rs.\ 6.5}$

$\boxed{300 \text{ unit}}$

$\boxed{300\ kWh}$

$\Leftarrow \boxed{300 \times 6.5}$

fixed Rate + $\boxed{Rs.\ 1950}$

Rs 300

$1\ kWh = 1000\ W \times 1\ hr$

$1\ kWh$

$1hr$

$1000\ \frac{J}{s}$

$E = \_$

$\frac{1000\ J}{\text{energy } 1\ s}$

$\boxed{1\ kWh}$

$\boxed{E = P \times t}$

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

$\boxed{1\ kWh}$ = An object of power 1 kW, when runs for 1 hour, consumes 1 kWh energy.

$\boxed{3.6 \times 10^6\ J}$

$\boxed{1\ W} = \frac{1\ J}{1\ s}$

$\boxed{1 \text{ unit Energy}}$

$P = \frac{W}{t} = 1000\ W$

$1\ kW = 1000\ W =$

Electric heater

An object of power 1 kW runs for 1 hr. Find the energy consumed by this object in joule.

$$E = P \times t$$
$$= 1\,kW \times 1\,hr = \boxed{1\,kWh}$$
$$= \frac{1\,J}{1\,\cancel{s}} \times 3600\,\cancel{s}$$
$$= 3600\,J = 3.6 \times 10^3\,J.$$

$$= 1000\,W \times 3600\,s$$
$$= \frac{1000\,J}{1\,\cancel{s}} \times 3600\,\cancel{s}$$
$$= 3.6 \times 10^6\,J$$

$\boxed{1\ kW} = \underline{\underline{1000 W}} = \frac{1000 J}{1 s}$

$P = \frac{J}{s} = 1 W$

Q. An electric bulb of 60 W is used for 6 h per day. Calculate the unit of energy consumed in one day by the bulb.

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

$$1 \text{ kW} = 1000 \text{ W}$$

$$P = 60 \text{ W} = 0.06 \text{ kW}$$

W h

$$E = P \times t$$

$$E = P \times t$$

$$= 0.06 \times 6 \text{ hr}$$

$$\boxed{E = 0.36 \text{ kWh}}$$

0.36 unit of energy

Ekademy

A lamp consumes 1000 J of electrical energy in 10s. What is its power?

$P = \frac{E}{t} =$

$= \frac{1000}{10} = 100 \; \boxed{J\,s^{-1}} \; \boxed{W}$

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

Q. An electric heater is rated $\boxed{1500\text{ W}}$. How much energy does it use in 10 hours. (commercial unit)

$E = P \times t = 1500 \times 10 \times 60 \times 60$ J

$=$

$\boxed{1.5 \times 10}$ $\boxed{\text{kWh}}$

$\boxed{15\text{ kWh}}$ ✓

$\boxed{15\text{ unit}}$

Q. Find the energy in kWh consumed in 10 hours by four devices of power 500 W each.

2000×36000

$4 \leftarrow$ 500, 500, 500, 500

$2000\ W \Rightarrow 2\ kW$

$E = P \times t$

$= 2\ kW \times 10\ h.$

$$\boxed{E = 20\ kWh.}$$

$= 20 \times 3.6 \times 10^6\ J$

$= 7.2 \times 10^7\ J$

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

Q. Calculate the work required to be done on a car of 1500 kg moving at velocity of 60 km/h. to make its speed 36 km/h.

$1\ kW = 1000\ W$

$1000\ W = 1\ kW$

$1\ W = \frac{1}{1000}\ kW$

$60\ W = \frac{1}{1000} \times 60\ kW$

Work done $= \frac{1}{2}mu^2 - \frac{1}{2}mu^2$

$W = -\frac{1}{2}mu^2$

$= -\frac{1}{2} \times 1500 \times$

$= -\frac{1}{2} \times 1500 \times \frac{50}{3} \times \frac{50}{3}$

$\frac{-250 \times 2500}{3 \times 3}$

$= \frac{-625000}{3}$

$\cancel{60} \times \frac{5}{18}$ $\frac{50}{3}$

208333.3 J

$\frac{625000}{3}$

$W = \boxed{-208333.3\ J}$

, –ve sign means force is applied in opposite

$u = 60$ km/h. $v = 36$ km/h.

$\frac{1}{2}mu^2$ $\frac{1}{2}mv^2$

$\frac{\cancel{36}^{2} \times 5}{\cancel{18}}$

$= 10$ m/s.

$= \frac{1}{2} \times 1500 \times 100$

$= 1500 \times 50$

$= 75000$ J.

$\boxed{\text{Work done = change in kinetic energy.}}$

$\boxed{133333.3}$ J

$$\begin{array}{r} 208333.3 \\ -\ 75000.0 \\ \hline 133333.3 \end{array}$$