Revision- 1

Chapter 8 – Work, Energy and Mahcines

Vocabulary

work

joule

energy

work-energy theorem

kinetic energy

power

watt

Work

Work (W) is done when a force acting on an object causes a **displacement.** The unit of work is the **joule** (J), which is the same unit as **energy**. Force (F) is in newtons and displacement (d) is in meters.

When the force is constant and acts in the parallel to the displacement, work is calculated as follows,

$$W = F \times d$$

$$1\,\text{J} = 1\,\text{N} \times 1\,\text{m}$$

$$1\,\text{J} = 1\,\text{N.m}$$

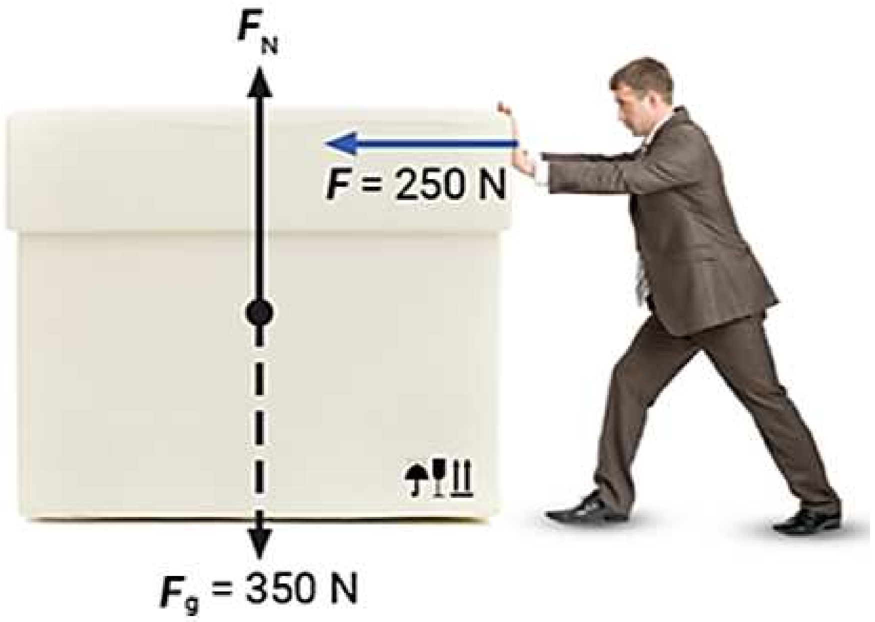
You push a shopping trolley with a constant net force of 400 N for 10 m. The work done on the trolley is

4,000 J .

W (J) = F (N) × d (m)

W (J) = 400 N × 10 m = 4,000 J

A man pushes a box with a force of 250 N and the box moves a distance of 6.5 m. The box has a weight of 350 N. Select the correct statement about the work done by the man on the box.



Calculate work done by the man on the box

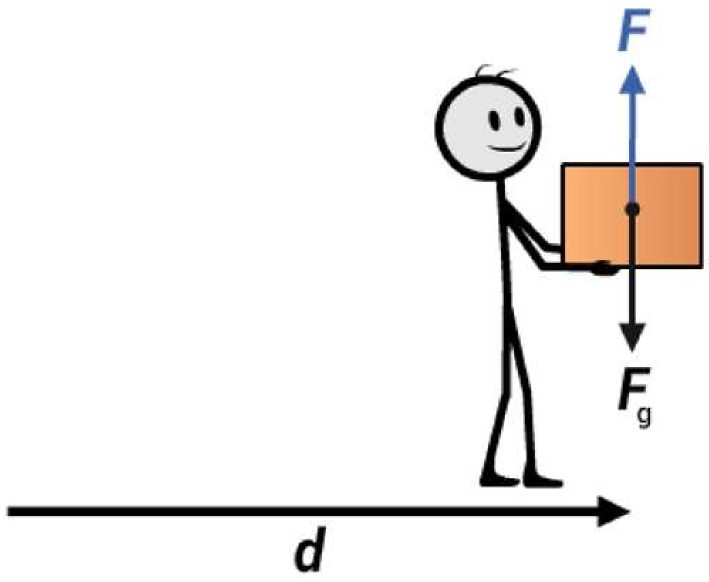
$$W = F \times d$$

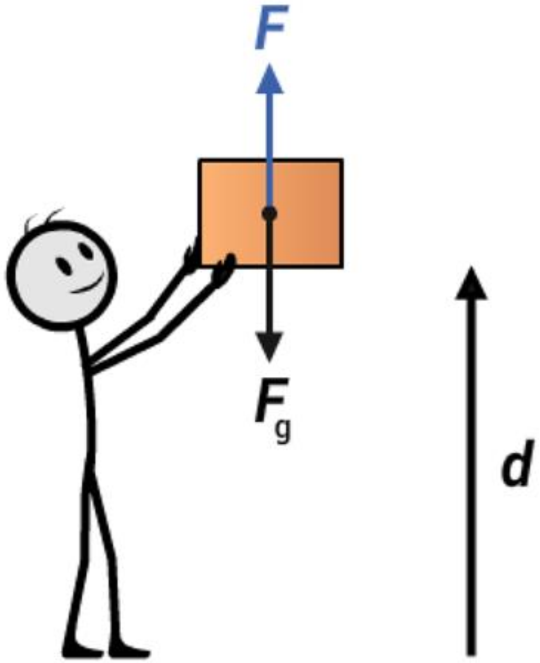
$$= 250 \times 6.5$$

$$= \underline{1625\,J}$$

W = 0

1





Work done = 0
As force and displacement are perpendicular

Work = F x d

2

An elevator has a mass of 2,000 kg. How much work is done on the elevator to move it between two successive floors, if each floor is 4 m apart? (g = 9.8 m/s^2)

$$W = F \times d$$

$$= mg \times d$$

$$= 2000 \times 9.8 \times 4$$

$$= 7.8 \times 10^4 \text{ J}$$

A weightlifter lifts a weight straight up in the air. If he exerts 350 J of work to lift the weight by 0.6 m, what is the mass being lifted?

$W = mgd$

$W = 350\,J$

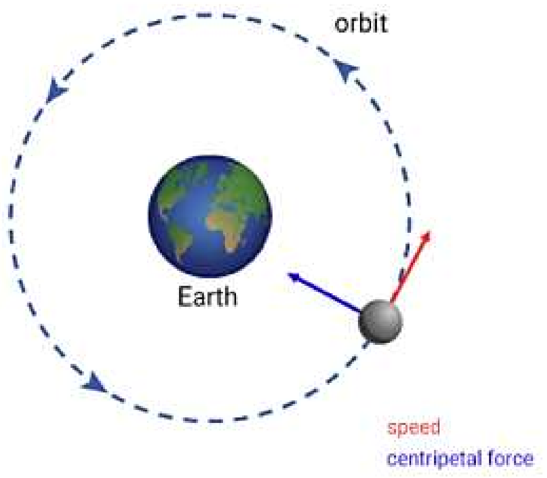
$m = ?$

$$m = \frac{W}{g \times d}$$

$$= \frac{350}{9.8 \times 0.6}$$

$= 59.52\ kg$ ✓

Additional Challenge:



Is the Earth doing work on the Moon?

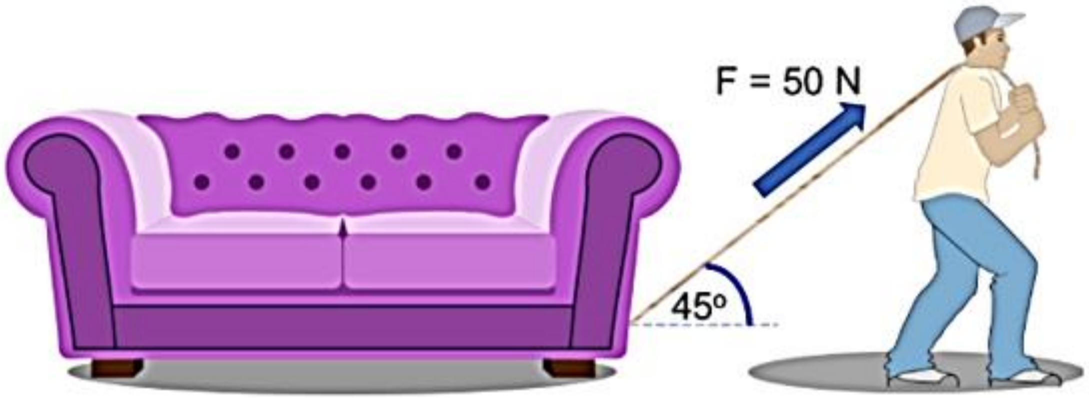
Answer: No, as force is perpendicular to displacement.

Select

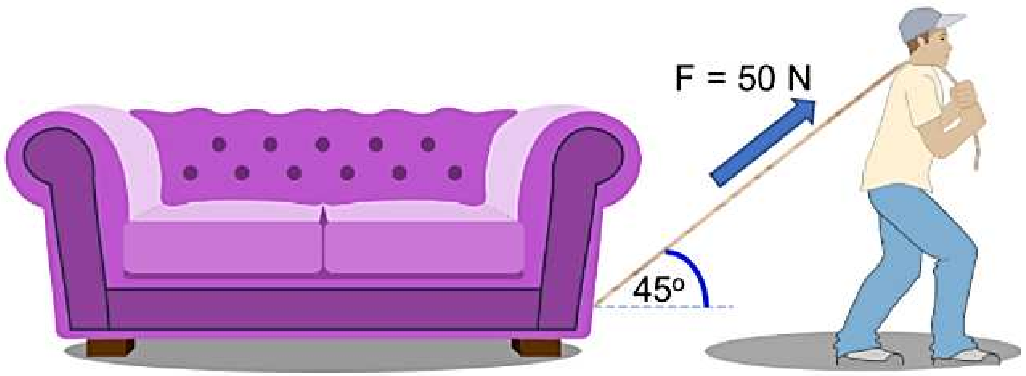
Forces Applied at an Angle to Motion

When a constant force is at an angle (θ) to displacement, work can be calculated as follows,

$W = Fd \cos \theta$



You pull on a settee using a rope with a force of 50 N, making an angle of 45° with the ground as shown. The settee moves 10 m. What work have you done on the settee?



$F = 50\,N$

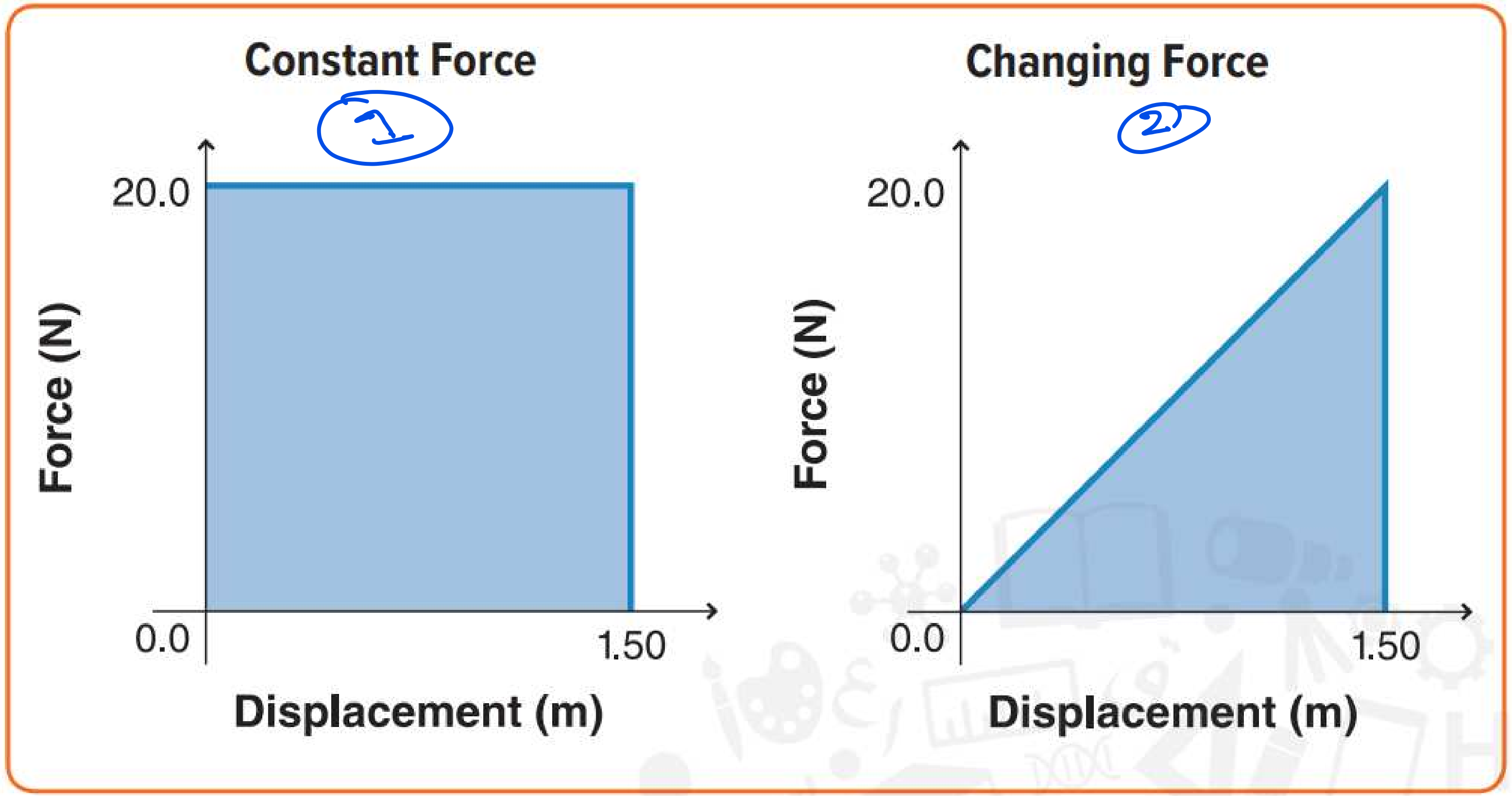
$\theta = 45^\circ$

$d = 10\,m$

$W = F \times d \times \cos\theta$

$= 50 \times 10 \times \cos 45$

$= \underline{\underline{353.6\,J}}$



Finding work done when forces change In the last example,

work done = Area under the graph

1)

$W =$ Area under the graph

$= 1.5 \times 20$

$= \underline{\underline{30\ J}}$

2) $W = \frac{1}{2} \times b \times h$

$= \frac{1}{2} \times 1.5 \times 20$

$= \underline{\underline{15\ J}}$

Work-energy theorem

The **work-energy theorem** states that the work done (W) on a system is equal to the change in energy (ΔE) of the system,

$$W = \Delta E$$

Kinetic energy (KE) is the energy generally associated with motion. **Translational kinetic energy** is the energy needed to change a system's position. It is calculated by:

$$KE_{\text{trans}} = \frac{1}{2} mv^2$$

The change in kinetic energy during the fall is the difference between the initial and final kinetic energy,

$$\Delta KE = KE_{\mathrm{f}} - KE_{\mathrm{i}}$$

$$\Delta KE = \frac{1}{2}\ mv_{\mathrm{f}}^2 - \frac{1}{2}\ mv_{\mathrm{i}}^2$$

A skier weighing 60 kg skis down a steep slope and her speed changes from 18 m/s to 22 m/s. The change in her kinetic energy is [Select...], which is equal to the work done.

Change in Kinetic Energy,

$$\Delta KE = KE_f - KE_i$$

$$= \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2$$

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

$$= \frac{1}{2} \times 60 \times \left(22^2 - 18^2\right)$$

$$= \underline{\underline{4800\ J}}$$

Power

The rate of energy transfer or work done is called **power**.
Power is work done over time.

$$\text{power} \ \ (P) = \frac{\text{work}}{\text{time taken}} = \frac{W}{t}$$

It is measured in **watts** (W), named after the scientist, James Watt. A **watt** is a joule per second.

1 W = 1 J/s

Example

What is the power of an engine doing 2,000 J of work in 10 s?

$$\text{Power} = \frac{2{,}000\ \text{J}}{10\ \text{s}} = 200\ \text{W}$$

This means that the engine is transferring 200 joules of energy every second.

A supercar weighing 1,800 kg accelerates from 0 m/s to 110 m/s in 55 seconds. What is the work done and the power required for this acceleration?

$$W = \Delta KE$$

$$= \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2$$

$$= \frac{1}{2} \times 1800 \times (110^2 - 0^2)$$

$$W = 1.09 \times 10^7 \text{ J}$$

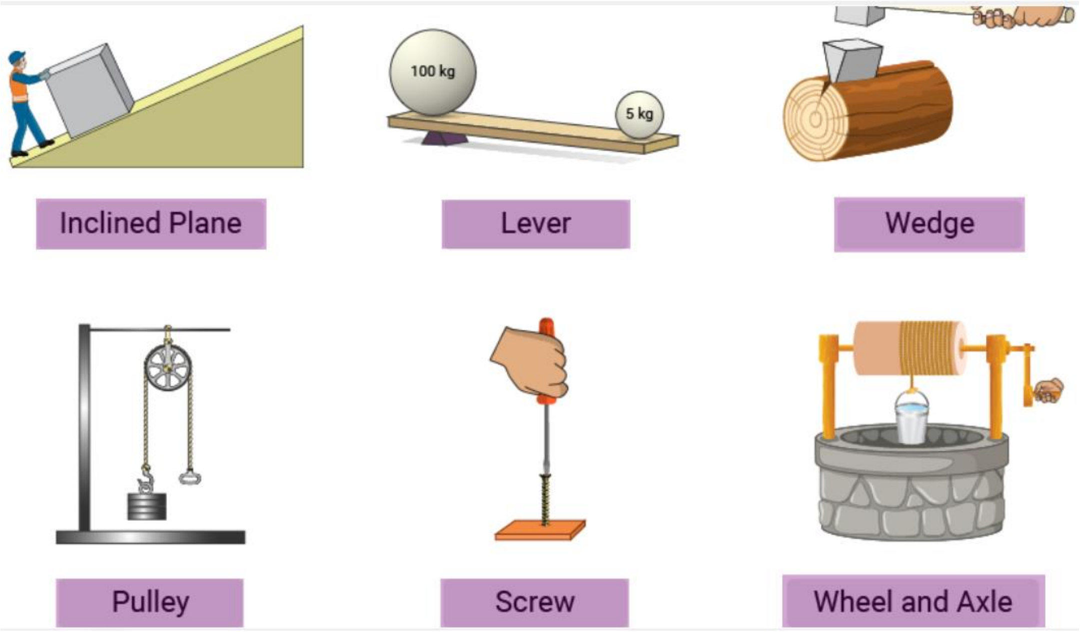
$$\text{Power} = \frac{W}{t}$$

$$= \frac{1.09 \times 10^7}{55}$$

$$= 1.98 \times 10^5 \text{ W}$$

Simple Machines

A **machine** is a device that is used to do a task with less effort, by changing the magnitude or the direction of the applied force.
Go to the next slide to find out more about machines.



To do work you need to apply a force on an object and cause it to move. The force that you apply on a machine is called the **effort force** which is represented by (F_e), and the displacement caused by the effort force is represented by (d_e). The force exerted by the machine on an object is called the **resistance force**, represented by (F_r) and it causes a displacement (d_r).

Define

Effort force is the force exerted by a user on a machine (F_e).
Resistance force is the force exerted by a machine on an object (F_r).

Define

The **mechanical advantage** (*MA*) of a machine is the ratio of the resistance force (output force) to the effort force (input force) and represented by:

$$MA = \frac{\boldsymbol{F}_{\mathrm{r}}}{\boldsymbol{F}_{\mathrm{e}}}$$

A worker uses a ramp to move a barrel weighing 490 N into a truck.
What is the mechanical advantage of using the ramp if the man applies a force of 100 N to move the barrel?

$$MA = \frac{\boldsymbol{F}_r}{\boldsymbol{F}_e}$$

$$MA = \frac{490\ \mathrm{N}}{100\ \mathrm{N}}$$

$$MA = 4.9$$

Ideal mechanical advantage is the ratio of the displacement that the effort force goes through (d_e) to the displacement that the resistance force goes through (d_r).

$$IMA = \frac{d_e}{d_r}$$

A worker exerts a force of 130 N on a lever through a distance of 1.4 m as he lifts a 150 kg box, at 0.2 m from the fulcrum, as shown in the image. The ideal mechanical advantage (*IMA*) of the lever is Select 7.

$$IMA = \frac{de}{dr} = \frac{1.4}{0.2} = 7$$

Efficiency (e) is the ratio between the output work and the input work.

$$\text{efficiency } (e) = \frac{\text{output work } (W_\text{o})}{\text{input work } (W_\text{i})} \times 100\%$$

An efficient machine uses all the energy transferred into it to do the task it is designed to do.

Ideal machines have an efficiency of 1 = 100%, which means all the input work is transferred to output work with no waste of energy.

A **compound machine** is a machine made of two or more simple machines.

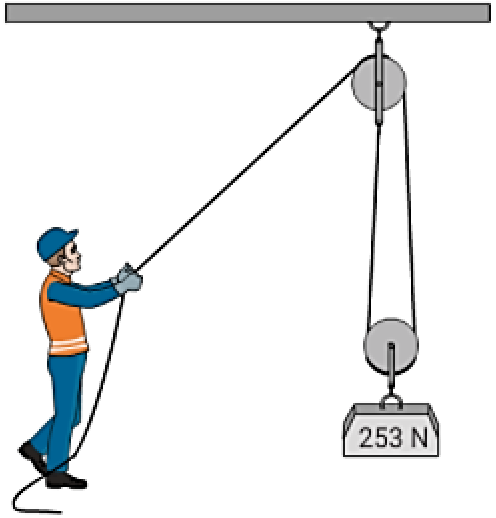
$MA_{\text{total}} = MA_1 \times MA_2$

$$MA_{\text{total}} = \left(\frac{\boldsymbol{F}_{\text{r1}}}{\boldsymbol{F}_{\text{e1}}}\right) \times \left(\frac{\boldsymbol{F}_{\text{r2}}}{\boldsymbol{F}_{\text{e2}}}\right) = \frac{\boldsymbol{F}_{\text{r2}}}{\boldsymbol{F}_{\text{e1}}}$$ (because $\boldsymbol{F}_{\text{r1}} = \boldsymbol{F}_{\text{e2}}$)

$IMA_{\text{total}} = IMA_1 \text{ x } IMA_2$

$$IMA_{\text{total}} = \left(\frac{\boldsymbol{d}_{\text{e1}}}{\boldsymbol{d}_{\text{r1}}}\right) \times \left(\frac{\boldsymbol{d}_{\text{e2}}}{\boldsymbol{d}_{\text{r2}}}\right)$$

Saeed uses a pulley to raise a 253 N box by 1.2 m. What is the efficiency of the pulley if Saeed pulls the rope a distance of 2.5 m, exerting a force of 130 N?



$$e = \frac{W_o}{W_i} \times 100\ \%$$

$$= \frac{F_r \times d_r}{F_e \times d_e} \times 100\ \%$$

$$= \frac{253 \times 1.2}{130 \times 2.5} \times 100\ \%$$

$$= 93\ \%$$