WORK AND POWER

Goal:

- to understand the concepts of work and power
- to calculate the work done and power used

The definition of work in physics:

A force that causes a displacement does work.

In which of the following is work being done?

- pushing on a wall to the point of exhaustion

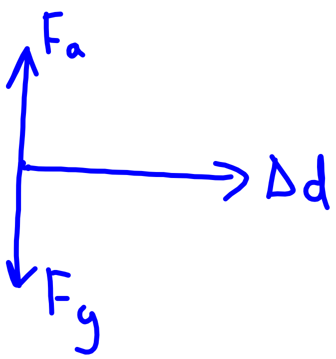
NO. No displacement

- an object falling to the ground

Yes. Gravity does work

- carrying your books across the room

NO. (But probably kind of)



To calculate work:

$$W = \vec{F} \cdot \Delta \vec{d}$$

Force **must** be in same direction as displacement.

Units of work is joules

$$1\,J = 1\,N \cdot m$$

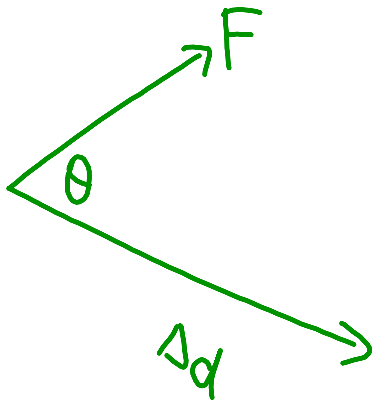
More generally:

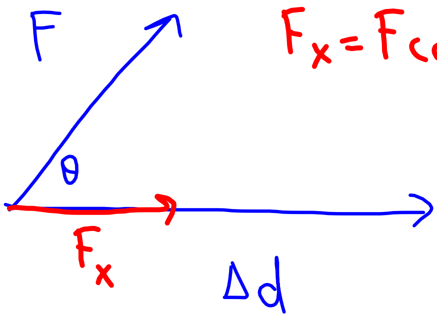
dot operator

$$W = F \cdot \Delta d$$

"dot product"

$$W = F \cdot \Delta d \cos\theta$$





$F_x = F\cos\theta$

Ex:

A worker lifts a 20 kg box from the floor and places it on a shelf 1.5 m above the ground. How much work does the worker do to accomplish this task?

$$W = F\Delta d$$
$$= mgh$$
$$= 20\,kg(9.8\,N/kg)(1.5\,m)$$
$$= 294\,J$$

A boy applies a horizontal force of 100 N (to the right) to a 40 kg box that is on the ground. Friction exerts a force of 20 N.

a) How much work does the boy do to push the box over a distance of 5.0 m?

$$W_B = F\Delta d$$
$$= 100\,N(5.0\,m)$$
$$= 500\,J$$

b) How much work is done by friction?

$$W_F = (-20\,N)(5\,m)$$
$$= -100\,J$$

Work done by friction is negative.

c) How much work is done on the box?

$$W_T = W_B + W_F$$
$$= 500\,J + (-100\,J)$$
$$= 400\,J$$

$$W_T = F_{net}\Delta d$$
$$= 80\,N(5.0\,m)$$
$$= 400\,J$$

A horizontal force of 10 N is applied to a 0.5 kg toy car so that it moves at a speed of 1.0 m/s for 2.0 s. How much work is done on the car?

$W = F\Delta d$

$= 10N(2.0m)$

$= 20 J$

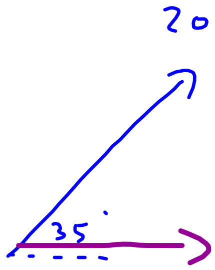
$\vec{v}_{av} = \frac{\Delta \vec{d}}{\Delta t}$

$\Delta \vec{d} = \vec{v}_{av}\Delta t$

$= 1.0 m/s(2.0s)$

$= 2.0 m$

A girl pulls a sled with a force of 200 N at an angle of 35 ° above the horizontal. She pulls the sled over a horizontal distance of 200 m. How much work does the girl do?



$F_x = 200 \cos 35°$

$= 163\text{ N}$

$W = F_x \Delta d$

$= 163\text{ N}(200\text{ m})$

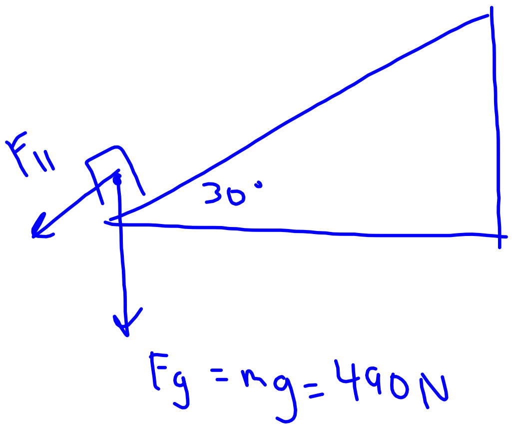
$= 32766\text{ J}$

$W = F \cdot \Delta d$

$= 200 \cdot 200 \cos 35°$

$= 32766\text{ J}$

A 50 kg box is to be brought to the top of a frictionless incline plane. The incline is set at 30° and is 4.0 m high. Find how much work is needed to get this box from the bottom to the top of the incline.



$\sin 30° = \frac{4}{h}$

$h = 8\ m$

$F_{\parallel} = 490 \cos 60°$

$= 490 \sin 30°$

$= 245\ N$

$W = F \Delta d$

$= 245\,N(8.0\,m)$

$= 1960\ J$

since there is no friction:

$W_{ramp} = W_{no\ ramp}$

$= F_g \cdot h$

$= mgh$

$= 490\,N(4\,m)$

$= 1960\ J$

The forces in the previous examples can be applied over different time intervals. This has no impact on the amount of work being done.

However, it does change the amount of power needed.

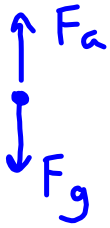
Power is the rate of work.

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

unit of power =

$1\ J/s = 1$ watt

A winch is used to raise a 50 kg box to a height of 10 m above the ground in 20 seconds at a constant velocity. What is the power of the winch?



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

$$= \frac{F\Delta d}{\Delta t} = Fv$$

$$= \frac{mg\Delta d}{\Delta t}$$

$$= \frac{490\text{ N}(10\text{ m})}{20\text{ s}} = 245\text{ W}$$