Work, Energy and Power

Juffrou Karen

Correct symbols and units

Work	W	J (N.m)
Energy	E	J
Power	P	$J.s^{-1}$

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Work done on an object …

Define the work done on an object by a constant force F as F Δx cosθ, where F is the **magnitude** of the force, Δx the **magnitude** of the displacement and θ the **angle between the force and the displacement**.

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Power

Define power as:

The rate at which work is done OR energy is expended.

Energy (E)

The ability to do work

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Potential energy (E_p)

The energy an object has due to its position/height above the earth

$$E_p = mgh$$

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Kinetic energy (E_k)

The energy an object has due to its motion

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

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Mechanical energy

Mechanical energy is the sum of the potential and kinetic energy at a specific point.

$$E_M = E_p + E_k$$

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Mechanical energy

Mechanical energy is conserved if only conservative forces (F_g) are doing work.

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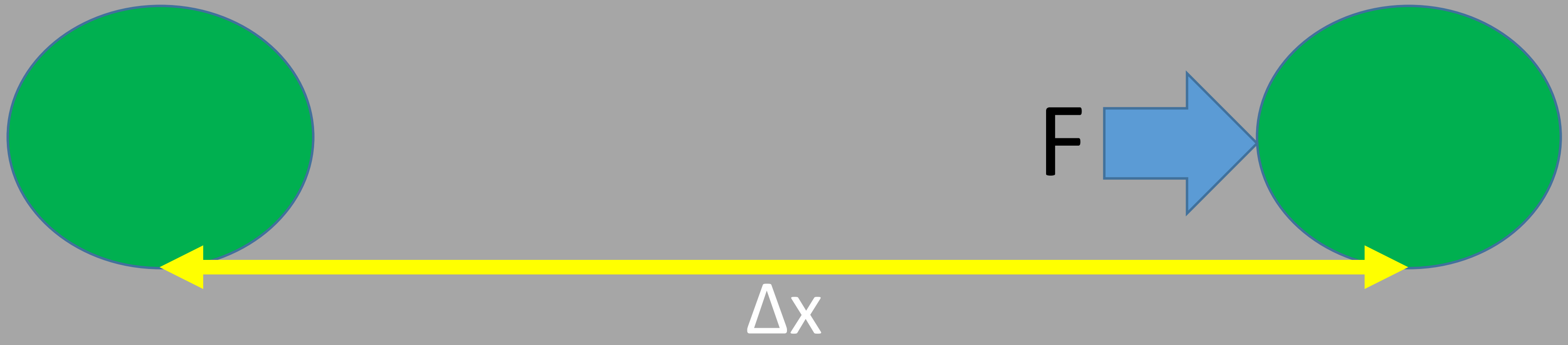
Work is the product of force and displacement, with the force and the displacement in the same straight line.

$$W = F\,\Delta x \cos\theta$$

$$W = F\Delta x\cos\theta$$

Joule (J) = N.m

Work is a scalar quantity

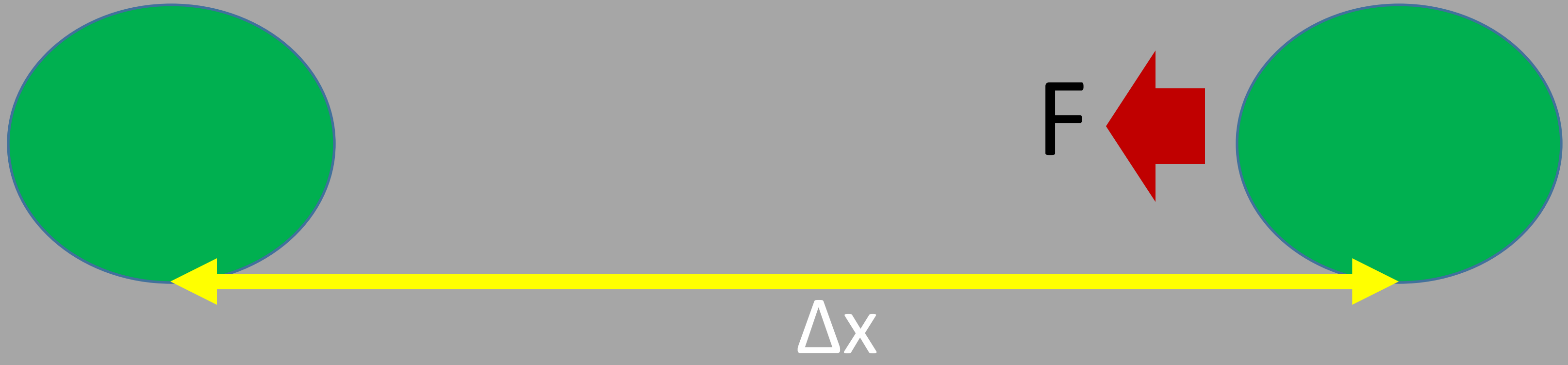


$$W_F = F\,\Delta x\,\cos\theta$$

Where $\cos(0^o) = 1$

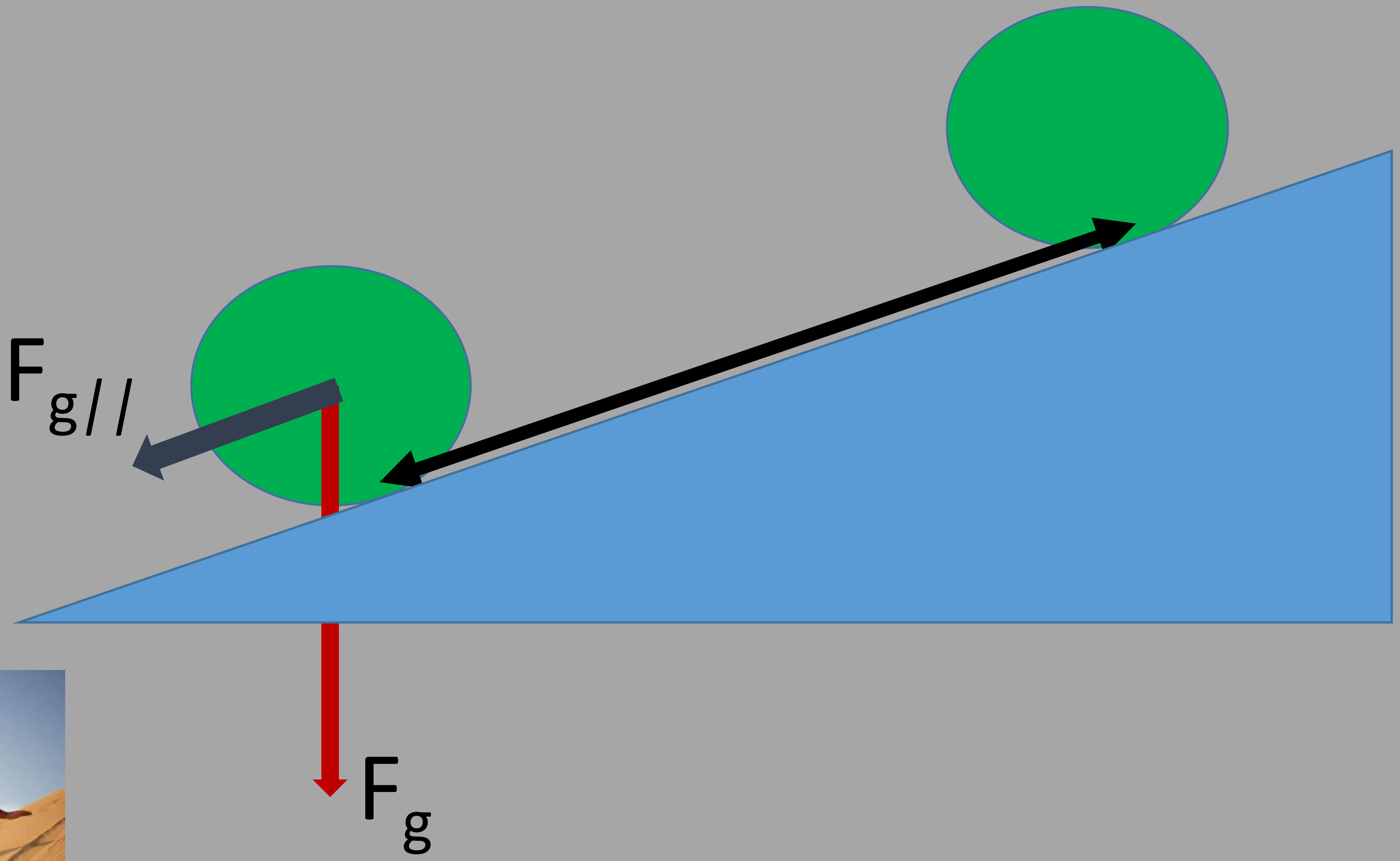
$$W_F = F\,\Delta x\cos\theta = 0\text{ J}$$

Where $\cos(90^{o}) = 0$



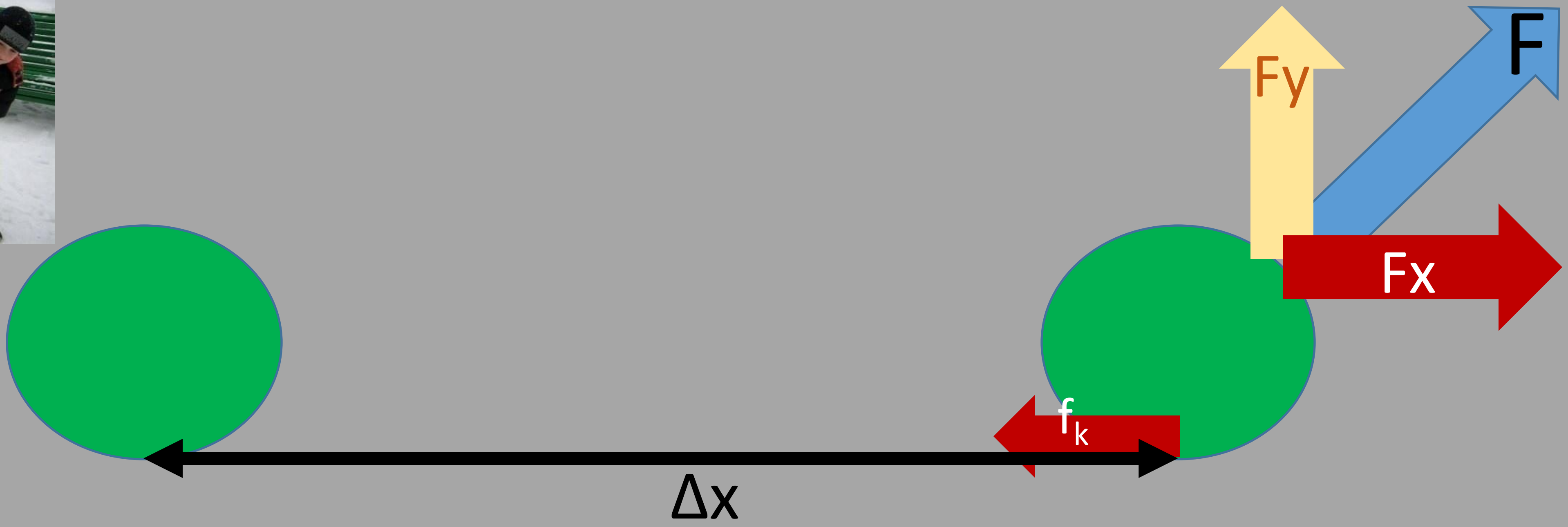
$$W_F = F\,\Delta x\cos\theta$$

Where $\cos(180^{o}) = -1$



$$W_{Fg} = F_{g||} \Delta x \cos\theta$$

Where $\cos(0^{o}) = 1$



$$W_{net} = (F_x\text{-}f_k)\ \Delta x\ \cos\theta$$

Where $\cos(0^o) = 1$

Negative work → total energy of a system decreases.
Therefore the brakes of a car will decrease the total energy of the system and negative work is performed.

Example 1

A book is pushed over a distance of 1,5m on a horizontal table top with a horizontal force of 2N. The frictional force is 0,4N.

1.1   Calculate the work done by the 2N force onto the book.

$$W_{F_{applied}} = F_{applied}\,\Delta x \cos\theta$$

$$= 2N \times 1{,}5m \times \cos(0^{o})$$

$$= 3J$$

Example 1

A Book is pushed over a distance of 1,5m on a horizontal table top with a horizontal force of 2N. The frictional force is 0,4N.

1.2 Calculate the work done by the frictional force onto the book.

$$W_f = f\,\Delta x \cos\theta$$

$$= 0{,}4N \times 1{,}5m \times \cos(180^o)$$

$$= -0{,}6J$$

Example 1

A Book is pushed over a distance of 1,5m on a horizontal table top with a horizontal force of 2N. The frictional force is 0,4N.

1.3 Calculate the net work done onto the book by the two forces.

$$W_{net} = F_{net}\ \Delta x \cos\theta$$

$$= 1{,}6N \times 1{,}5m \times \cos(0^{o})$$

$$= 2{,}4J$$

Example 1

A Book is pushed over a distance of 1,5m on a horizontal table top with a horizontal force of 2N. The frictional force is 0,4N.

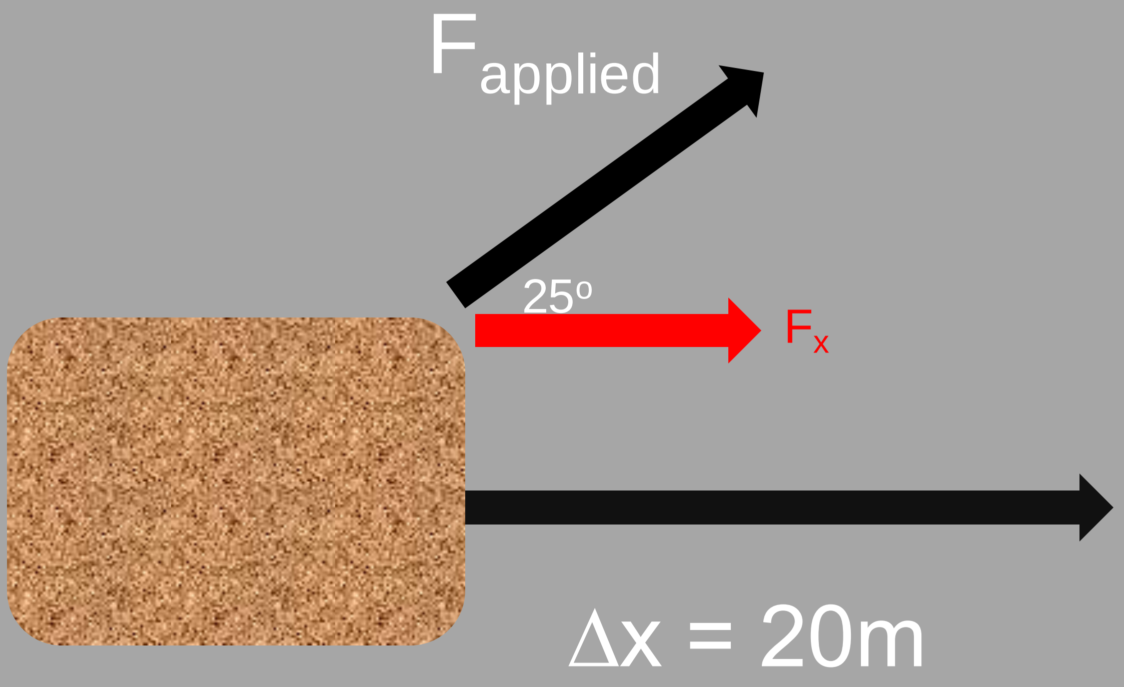
1.4 Is any work done by the normal force and the gravitational force onto the book? Explain your answer.

No. The book is not displaced in the directions of the gravitational/normal forces. These forces act perpendicular to the displacement.

Example 2

A factory worker pulls a loaded trolley across a horizontal floor. He applies a force of **750N** to the handle of the trolley, which forms an angle of 25º to the floor. The trolley experiences a frictional force of 250N when it moves 20m over the floor.

2.1 Calculate the work done by the applied force to the trolley.

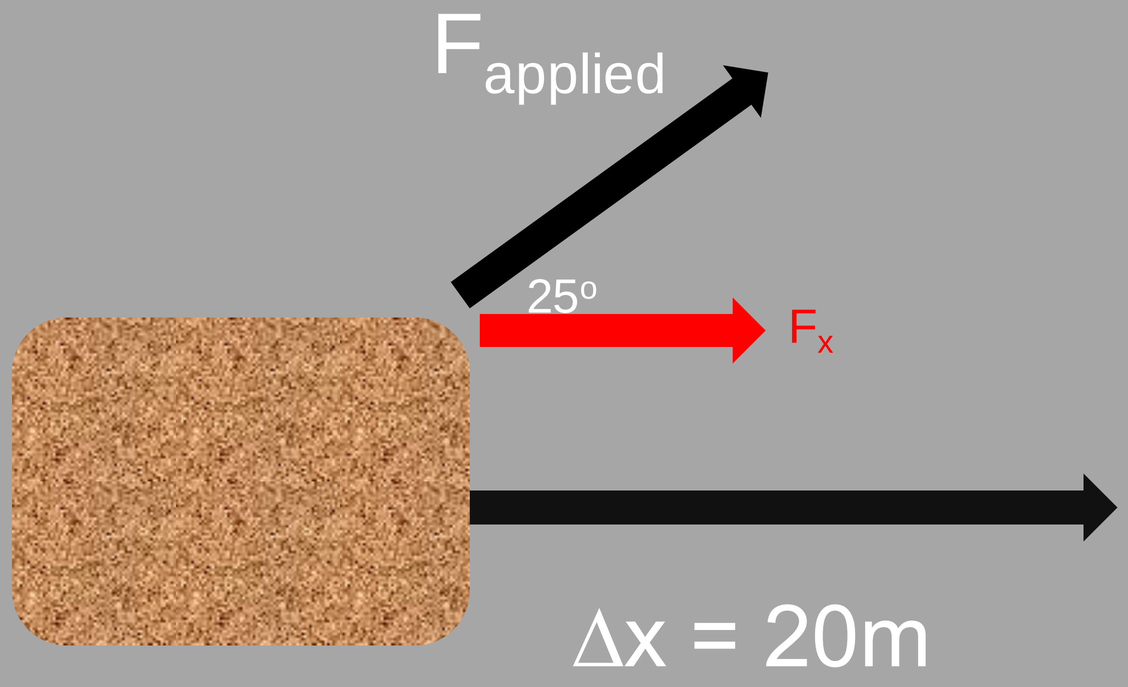


$$W_{F_{applied}} = F_x \Delta x \cos\theta$$
$$= (750\cos 25^{\circ})(20)\cos(0^{\circ})$$
$$= 13594,62J$$

Example 2

A factory worker pulls a loaded trolley across a horizontal floor. He applies a force of **750N** to the handle of the trolley, which forms an angle of 25º to the floor. The trolley experiences a frictional force of 250N when it moves 20m over the floor.

2.2 Calculate the work done by the friction.

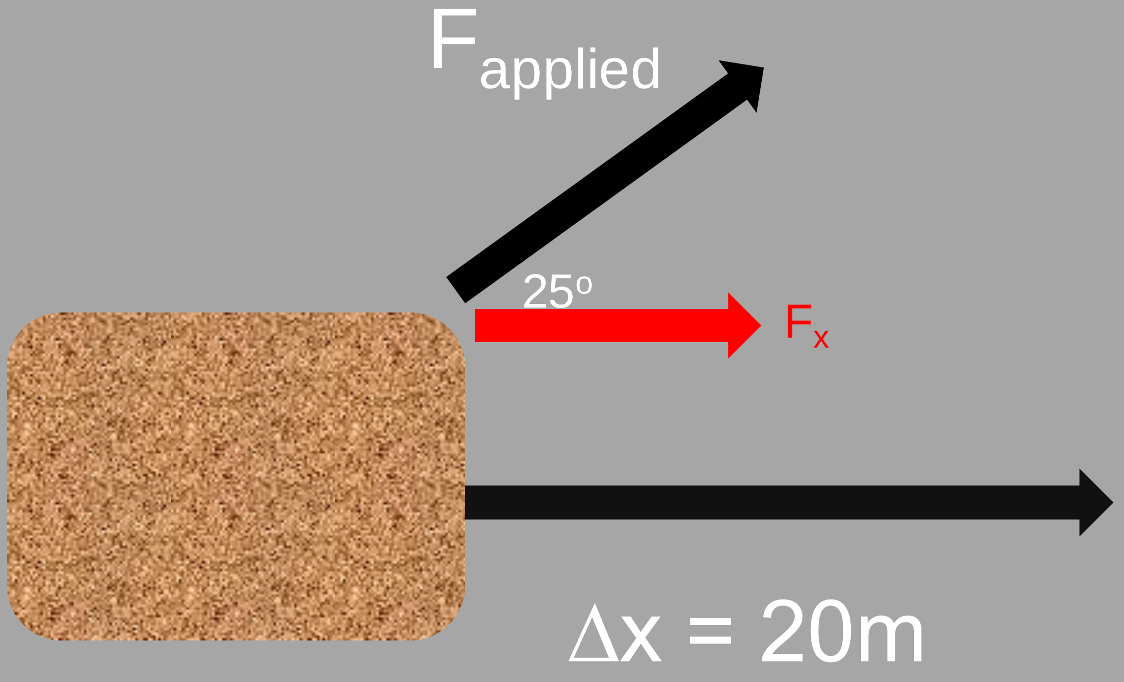


$$W_f = f\,\Delta x \cos\theta$$
$$= 250 \times 20 \times \cos(180^{\circ})$$
$$= -5000J$$

Example 2

A factory worker pulls a loaded trolley across a horizontal floor. He applies a force of **750N** to the handle of the trolley, which forms an angle of 25º to the floor. The trolley experiences a frictional force of 250N when it moves 20m over the floor.

2.3 Calculate the work done by the weight of the trolley.



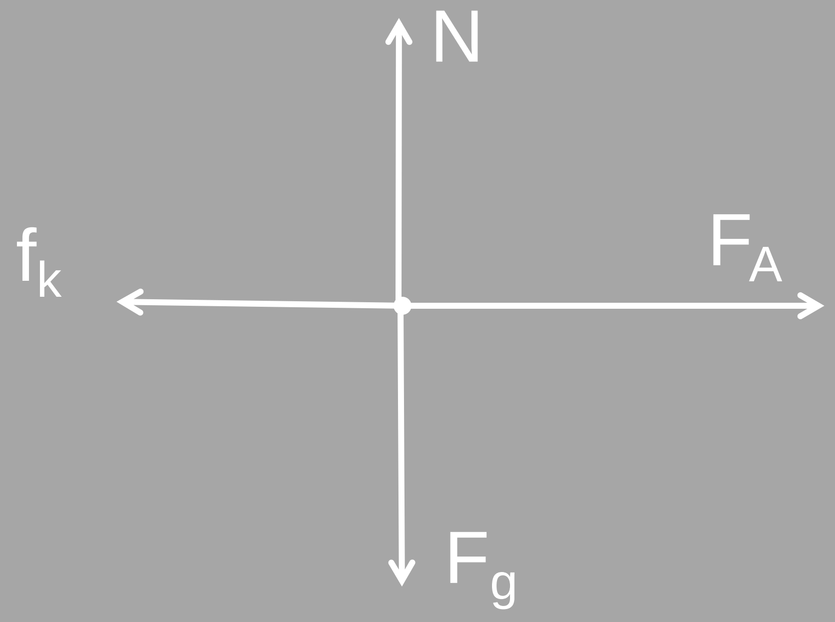
$$W_{Fg} = F_g \, \Delta x \cos\theta$$
$$= mg \times 20 \times \cos(90^o)$$
$$= 0J$$

There is no component of gravity in the same direction as the movement

Example 3

A learner tries to move a heavy cabinet, with a mass of 80kg, by applying a 50N push force parallel to the floor on it. The cabinet experiences a frictional force of 39,2N. He manages to move the cabinet for a distance of 5m.

3.1 Draw a free-body diagram and show all the forces acting on the cabinet.



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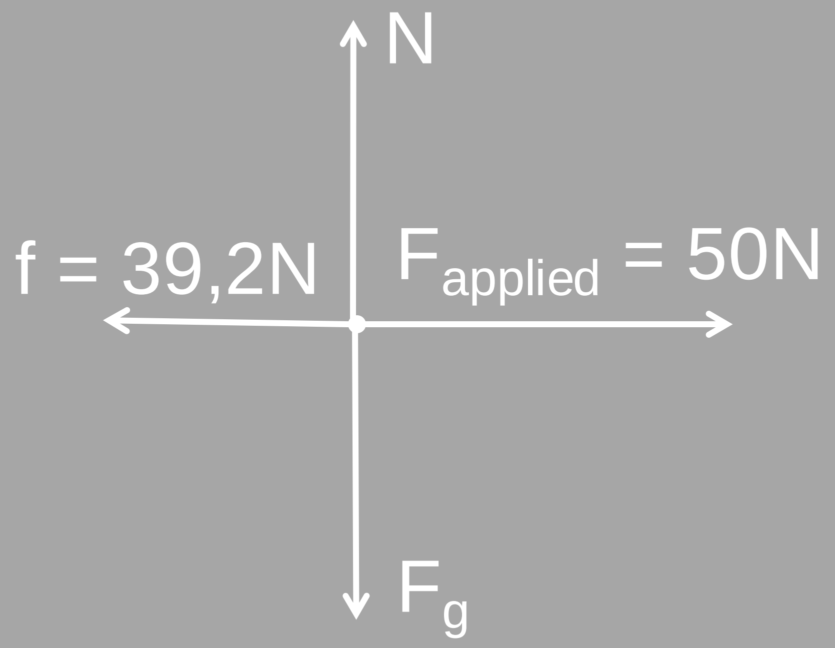
A learner tries to move a heavy cabinet, with a mass of 80kg, by applying a 50N push force parallel to the floor on it. The cabinet experiences a frictional force of 39,2N. He manages to move the cabinet for a distance of 5m.

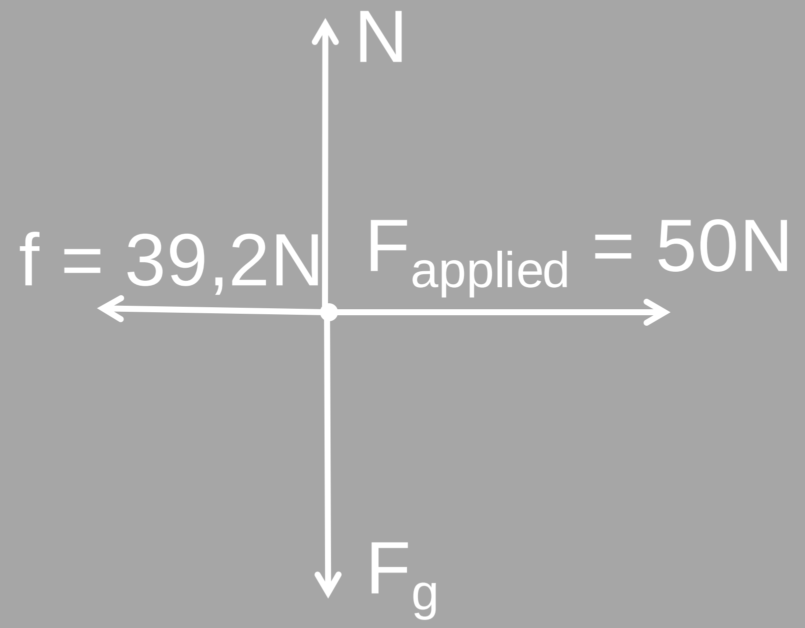
3.2 Calculate the work done on the cabinet by each of the forces.

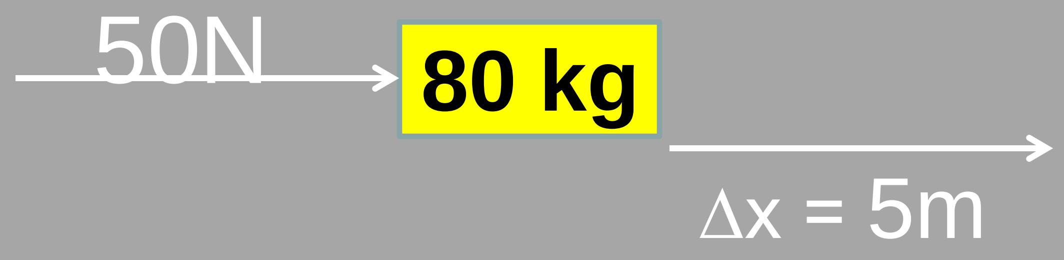


Example 3

3.2 Calculate the work done on the cabinet by each of the forces.

$$
\begin{aligned}
W_{F_g} &= F_g \Delta x \cos\theta \\
&= F_g \Delta x \cos 90^\circ \\
&= 0\,\text{J}
\end{aligned}
$$

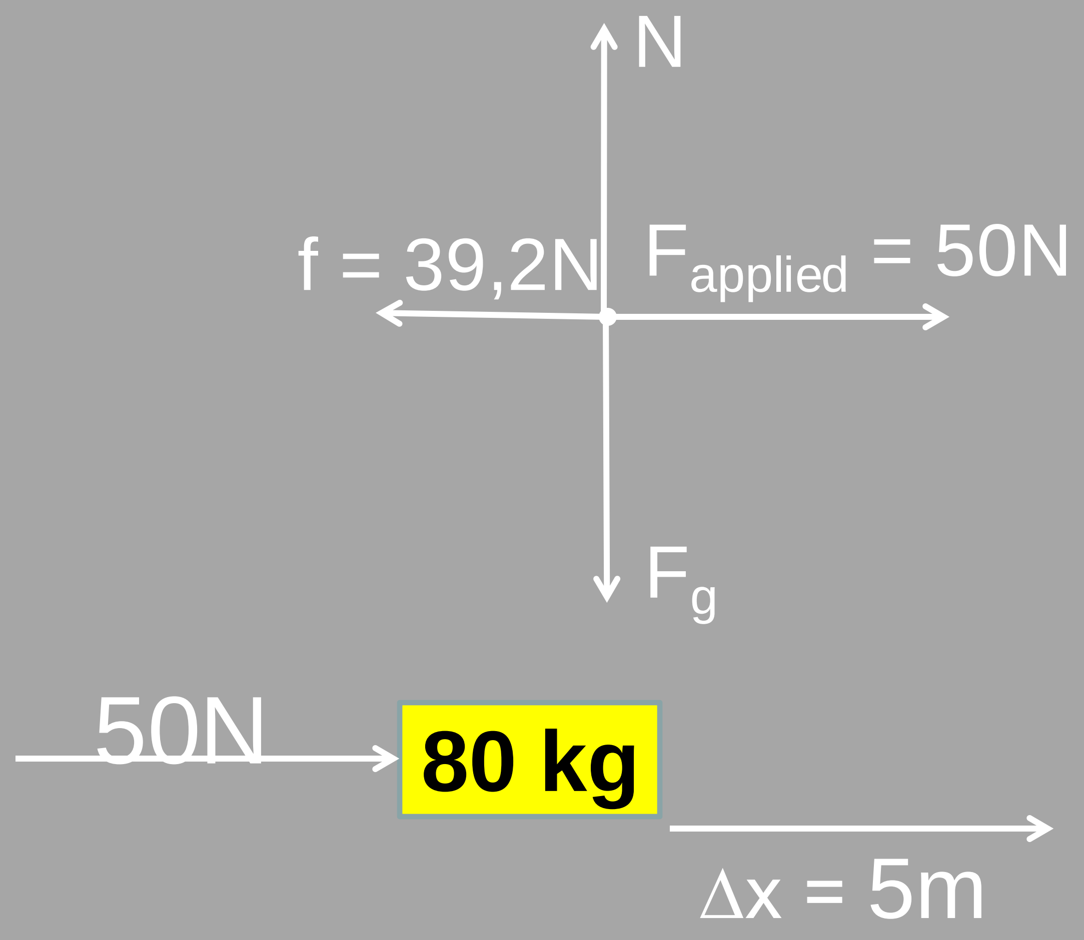




Example 3

3.2 Calculate the work done on the cabinet by each of the forces.

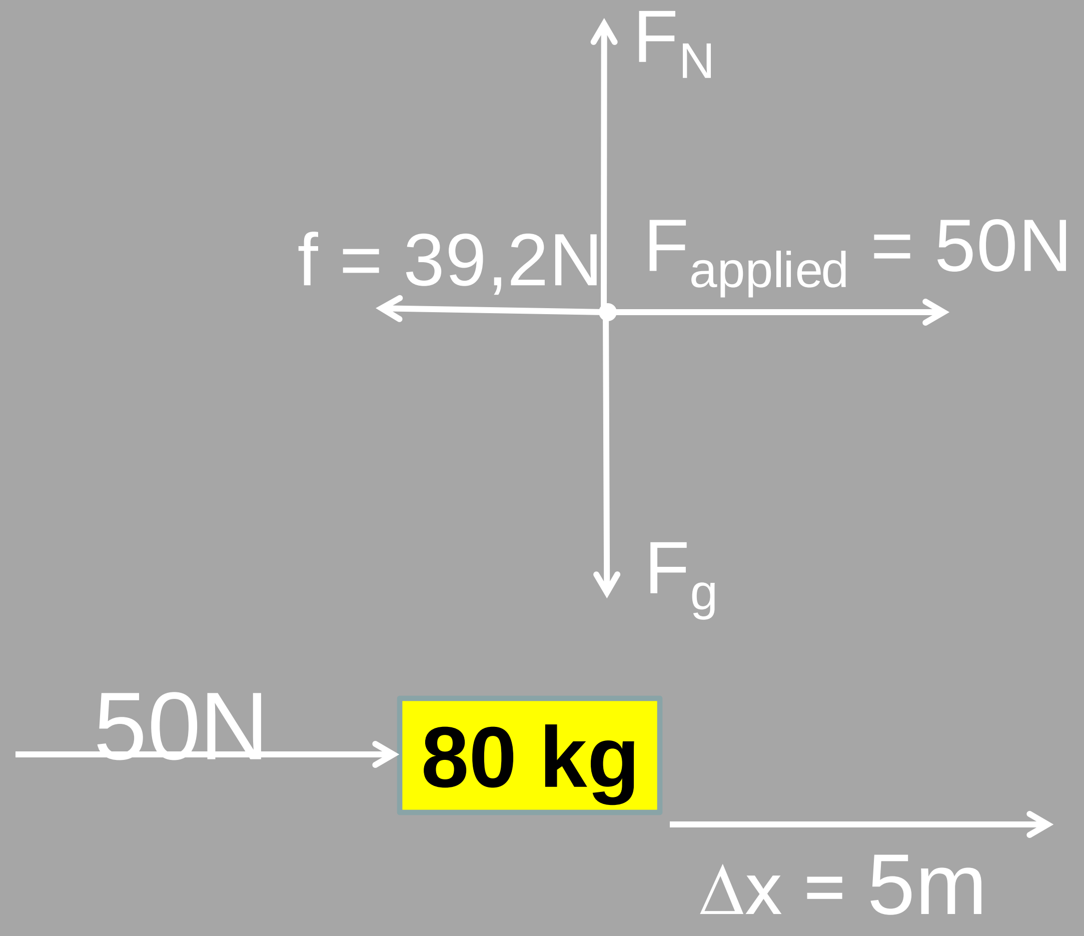
$$W_N = N\,\Delta x \cos\theta$$
$$= N\,\Delta x \cos 90^o$$
$$= 0J$$



Example 3

3.2 Calculate the work done on the cabinet by each of the forces.

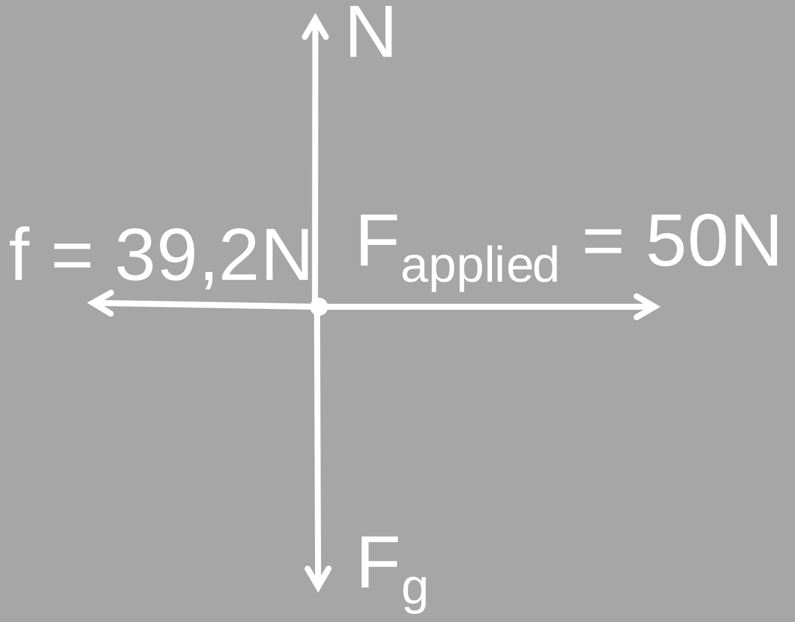
$$W_F = F\Delta x \cos\theta$$
$$= 50 \times 5 \times \cos 0°$$
$$= 250\text{J}$$



Example 3

3.2 Calculate the work done on the cabinet by each of the forces.

$$W_f = f\,\Delta x \cos\theta$$
$$= 39{,}2 \times 5 \times \cos 180^\circ$$
$$= -196\text{J}$$



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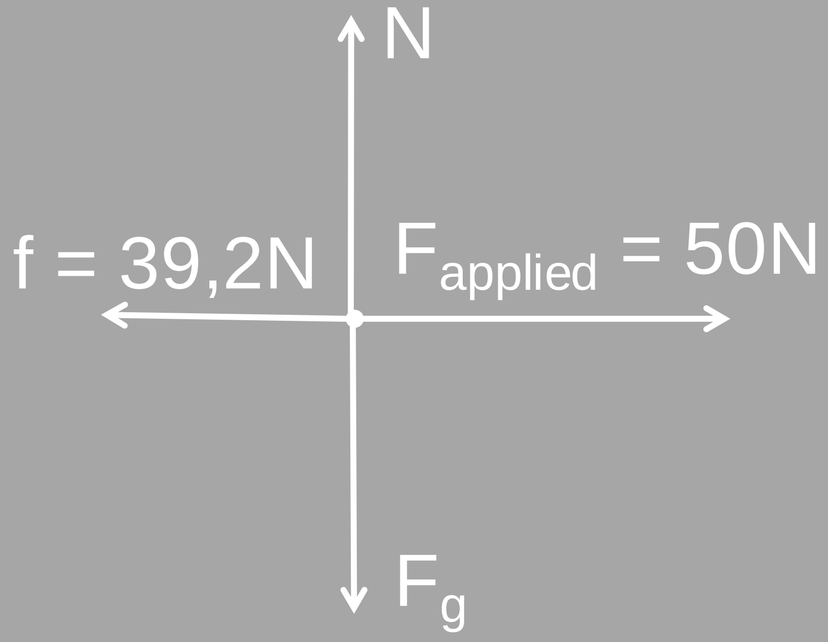
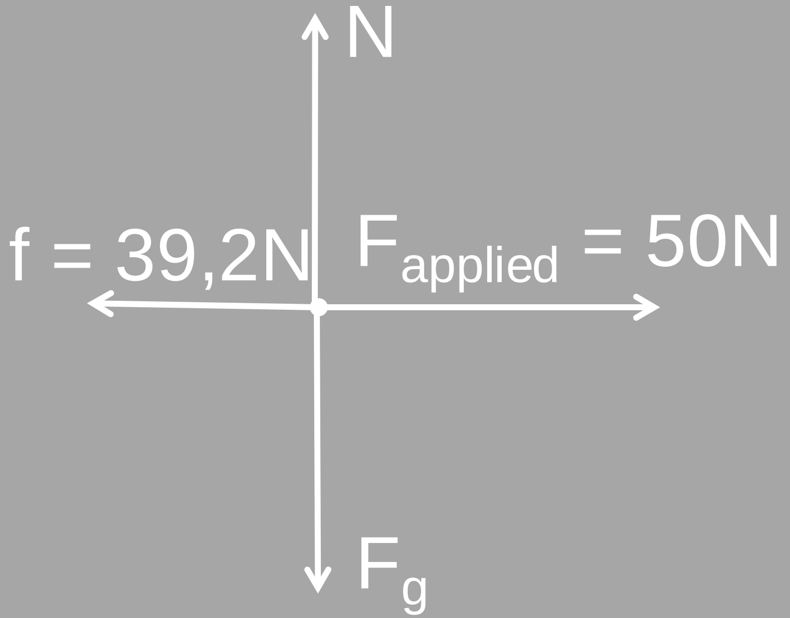


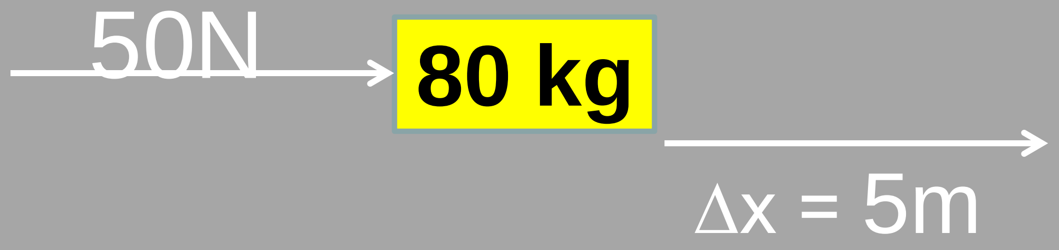
3.3 Calculate the net work done on the cabinet.

Example 3

3.3 Calculate the net work done on the cabinet.

$$W_{net} = F_{net}\Delta x\cos\theta$$
$$= (50-39{,}2)\ (5)\ (\cos 0^{o})$$
$$= 54J$$

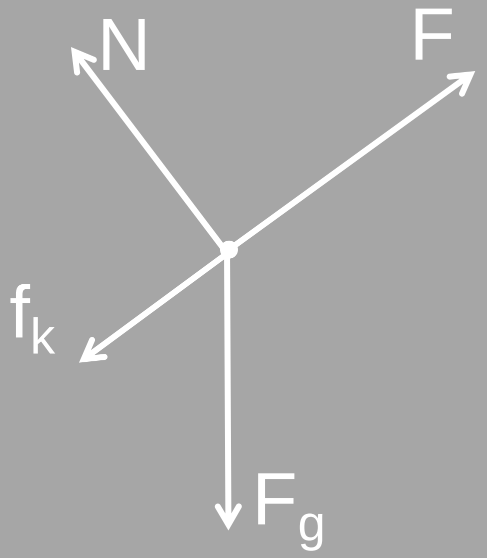




Example 4

A man pulls a cart with a load up a hill that forms an angle of 25º with the horizontal. The mass of the cart and load is 350kg and the frictional force of the road on the cart and load is 180N. He walks a distance of half a kilometre at a constant velocity (accept that the gradient remains unchanged).

4.1 Draw a free-body diagram of all the forces acting on the cart with its load.



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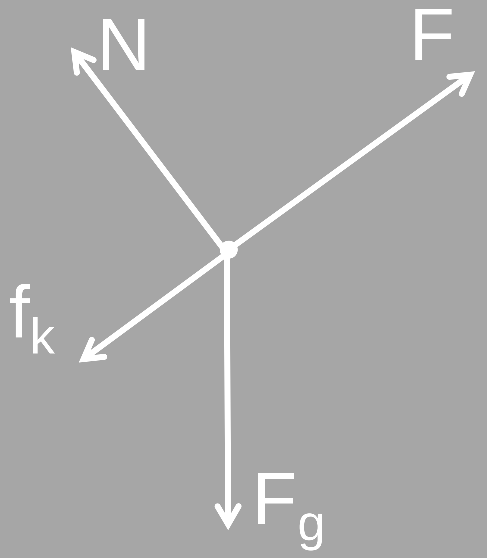
4.2 Determine the net work done on the cart and load.



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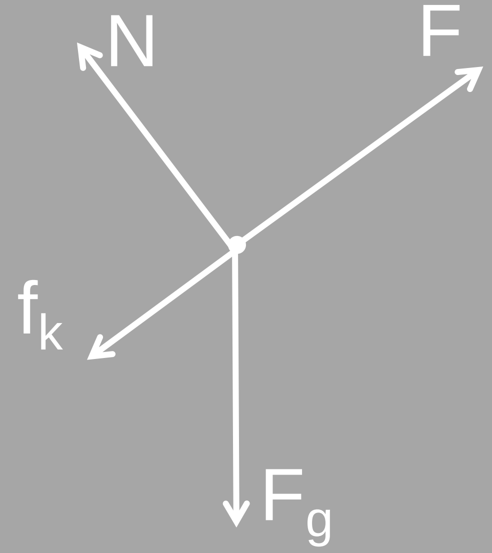

$$W_{net} = F_{net}\,\Delta x \cos\theta$$
$$= 0\text{J}$$

Example 4

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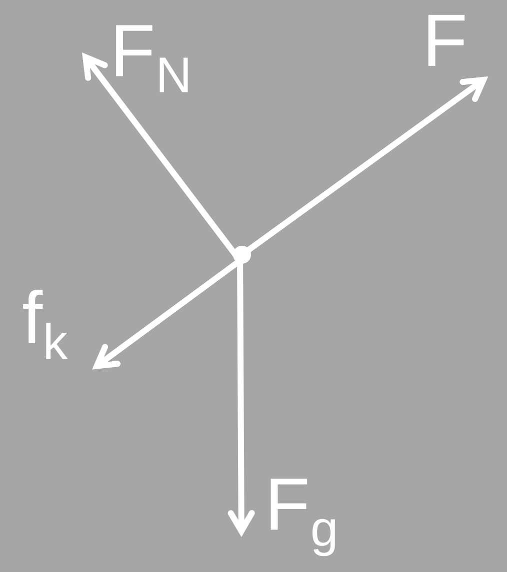
4.3 Calculate the work that the man does on the cart and the load.

$$F_{net} = F + F_{g//} + f = 0$$

$$F + (-350 \times 9{,}8 \times \sin 25^{o}) + (-180) = 0$$

$$F = 1629{,}58\text{N}$$



$$W_F = F\,\Delta x \cos\theta$$

$$= (1629{,}58)(500)(\cos 0^{o})$$

$$= 814790{,}32\text{J}$$

Work-energy theorem

The net/ total work done on an object is equal to the CHANGE in the object's kinetic energy

OR

The work done on an object by a resultant/ net force is equal to the change in the object's kinetic energy

Work-energy theorem

$$W_{net} = \Delta E_k$$

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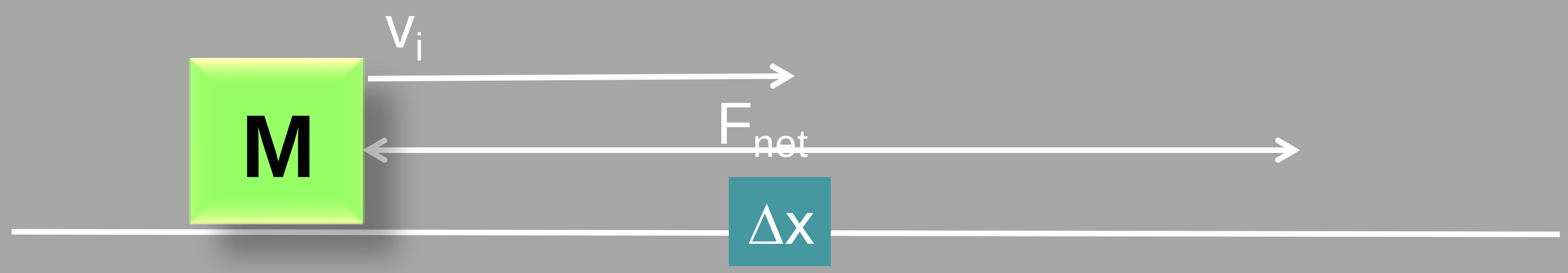
Work-energy theorem



$$v_f^2 = v_i^2 + 2a\Delta x$$

$$a = (\tfrac{1}{2} v_f^2 - \tfrac{1}{2} v_i^2)/\Delta x$$

$$\begin{aligned} W_{net} &= F_{net}\Delta x \cos\theta \\ &= (ma)\,\Delta x \cos 0 \\ &= \tfrac{1}{2} m v_f^2 - \tfrac{1}{2} m v_i^2 \\ &= \Delta E_k \end{aligned}$$

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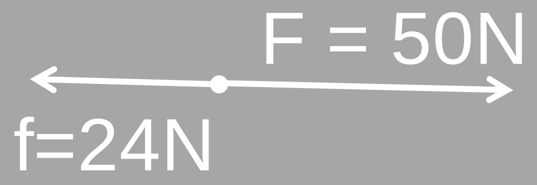
Example 5

A father pushes his son on a tricycle, by applying a horizontal force of 50N. The mass of the son and the tricycle is 35kg.

Calculate the velocity the son reaches on the tricycle after the father has pushed him a distance of 20m from a stationary position. The road exerts a frictional force of 8N **on each wheel**.



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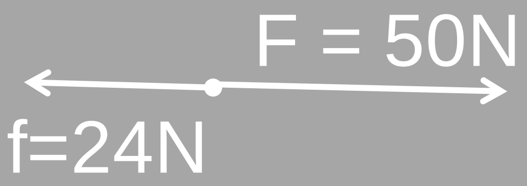

$$
\begin{aligned}
W_{net} &= \Delta E_k \\
(50 + (-24)) \times 20 \times \cos 0^{o} &= \tfrac{1}{2} m v_f^2 - \tfrac{1}{2} m v_i^2 \\
520 &= \tfrac{1}{2} (35) v_f^2 - 0 \\
\therefore v_f &= 5{,}45 \text{ m.s}^{-1}\text{; in the direction of motion}
\end{aligned}
$$

Conservative forces

A force for which the work done in moving an object between two points is independent of the path taken.

Example:
Gravitational force

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Non-conservative forces

A force for which the work done in moving an object between two points depends on the path taken.

Example:
Frictional force

The principle of conservation of mechanical energy

The total mechanical energy in an isolated system remains constant.

NOTE: A system is isolated when the net external force (**excluding the gravitational force**) acting on the system is zero.

$$E_{M(A)} = E_{M(B)}$$

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As you continue on your WEP journey, you will be introduced to the formulae below:

WORK, ENERGY AND POWER

$W = F\Delta x \cos\theta$	$U = mgh$ OR $E_P = mgh$
$K = \frac{1}{2}mv^2$ OR $E_k = \frac{1}{2}mv^2$	$W_{net} = \Delta K$ OR $W_{net} = \Delta E_k$ $\Delta K = K_f - K_i$ OR $\Delta E_k = E_{kf} - E_{ki}$
$W_{nc} = \Delta K + \Delta U$ OR $W_{nc} = \Delta E_k + \Delta E_p$	$P = \frac{W}{\Delta t}$
$P_{ave} = Fv_{ave}$	

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