GIVE FEEDBACK

CONTINUE >

Although the terms work and power are used in everyday conversations, they have specific meanings in the context of engineering mechanics. It is important to understand and appropriately use the correct terminology.

Introduction to work and power

This section covers the concepts of mechanical work and power as they apply to the linear and rotational motion of moving objects and mechanical components.

Mechanical work and power may be calculated for given physical situations provided that appropriate data is available.

< BACK

GIVE FEEDBACK

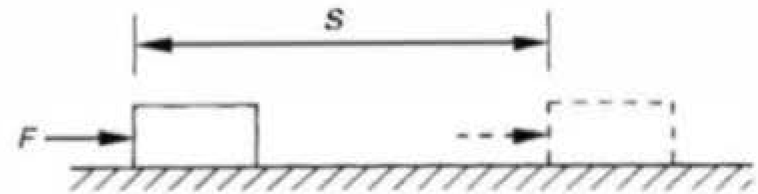
OK

Mechanical work is done when effort causes motion.

Mechanical work

Mechanical work is defined in terms of linear or rotational effort, when the result produced by the effort is the movement or rotation of a body.

For example, in the diagram below, the force F causes a linear movement with a distance of S.



GIVE FEEDBACK

OK

Select the correct definition of mechanical work.

Click the correct answer.

- Mechanical work is defined in terms of linear or rotational effort, when the result produced by the effort is the movement or rotation of a body
- Mechanical work is the result produced when the movement or rotation of a body is defined in terms of linear or rotational motion
- Mechanical work is defined in terms of linear or rotational motion, when the result produced by the motion is the movement or rotation of a body
- Mechanical work is defined in terms of maintenance and/or repair effort on a mechanical body such as an automobile

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The relationship between force and work done for linear motion

In linear motion, if a force *F* is applied to a body which moves in a straight line, a distance *S* in the direction of the force, then the work *W* done by the force on the body is said to be the product of the force and the distance.

$$W = F \times S$$

where:

W is the work done

F is the force acting on the body

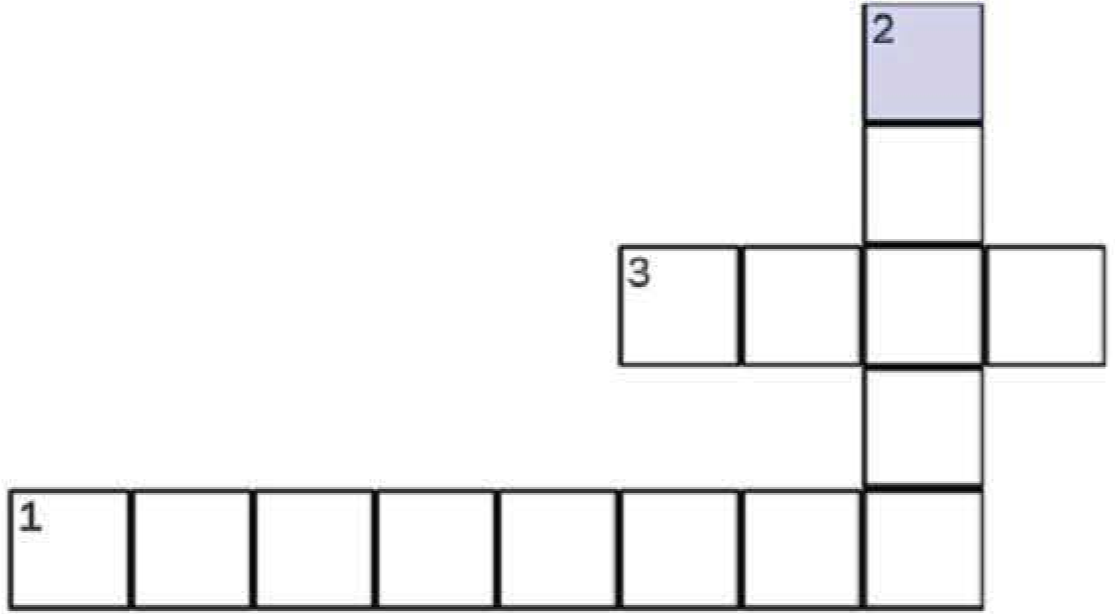
S is the distance that the body moves

GIVE FEEDBACK

OK

Work and force equation

1



1) Represented by the symbol S in the equation $W = F \times S$.

2) Represented by the symbol F in the equation $W = F \times S$.

3) Represented by the symbol W in the equation $W = F \times S$.

Done | Hint | Challenge

Match the equation symbol with the correct description for the equation $W = FS$.

Drag statements on the right to match the left.

W	The work done
F	The applied force
S	The displacement of the body

Do you know the answer?

I KNOW IT

THINK SO

UNSURE

NO IDEA

The components and SI unit for work done

The unit of work follows from the equation $W = F \times S$.

If the units of force and distance are newtons and metres respectively, then the unit of work is the newton metre.

Work is a new physical quantity different from both force and distance. It is therefore convenient to give the unit of work a special name.

The SI unit of work equal to 1 N.m is called the **joule**, denoted by J.

GIVE FEEDBACK

OK

Type your answer in the box.

The SI unit of work equal to 1 N.m is called the ____________.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the work done by a constant force for linear motion

Determine the work done by a force of 50 N moving a distance of 3 m in the direction of the force.

Example 1	Solution to Example 1	Example 2	Solution to Example 2	Solution to Example 2 (continued)

GIVE FEEDBACK

OK

Calculate the work done by a constant force for linear motion

Work done:

$$\begin{aligned} W &= F \times S \\ &= 50\ \mathrm{N} \times 3\ \mathrm{m} \\ &= 150\ \mathrm{J} \end{aligned}$$

Example 1	Solution to Example 1	Example 2	Solution to Example 2	Solution to Example 2 (continued)

GIVE FEEDBACK

OK

Calculate the work done by a constant force for linear motion

A hoist lifts a load of 1.5 t through a vertical distance of 20 m.

Determine the amount of work done against gravity.

Calculate the work done by a constant force for linear motion

The work is done against gravity, i.e. against the weight of the load.

The weight of the load is:

$$
\begin{aligned}
F_w &= m\,g \\
&= 1{,}500\ \text{kg} \times 9.81\ \text{N/kg} \\
&= 14{,}715\ \text{N}
\end{aligned}
$$

Example 1	Solution to Example 1	Example 2	Solution to Example 2	Solution to Example 2 (continued)

GIVE FEEDBACK

OK

Calculate the work done by a constant force for linear motion

The work done against this force is:

$$\begin{aligned} W &= F \times S \\ &= 14{,}715\ \text{N} \times 20\ \text{m} \\ &= 294{,}300\ \text{J} \\ &= 294.3\ \text{kJ} \end{aligned}$$

Example 1	Solution to Example 1	Example 2	Solution to Example 2	Solution to Example 2 (continued)

GIVE FEEDBACK

OK

A chocolate biscuit has an energy content of 490 kilojoules. What displacement will be necessary for a force of 49 N (lifting a 5 kg mass) to cover in order to perform enough work to consume the energy content of the chocolate biscuit?

+ − · ÷ Clear

Clear line

? Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Type your answer in the box.

When a person lifts a 20 kg mass from the ground to a height of 2 metres, the amount of work done is ______ J. (Answer correct to 1 decimal place.)

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The relationship between torque and work for rotational motion

In rotational terms, torque T is analogous to force, i.e. torque is a turning effort.

Similarly, angular displacement θ is analogous to linear displacement.

This analogy can be used to arrive at the expression for work done by torque on a rotating object.

$$W = T \times \theta$$

where:

W is the work done

T is the torque

θ is the angular displacement

Since torque is measured in newton metres and angular displacement in radians, which are dimensionless, it can be seen that work done by torque can also be measured in joules.

GIVE FEEDBACK

OK

Match the equation symbol with the correct description for the equation $W = T \cdot \theta$.

Drag statements on the right to match the left.

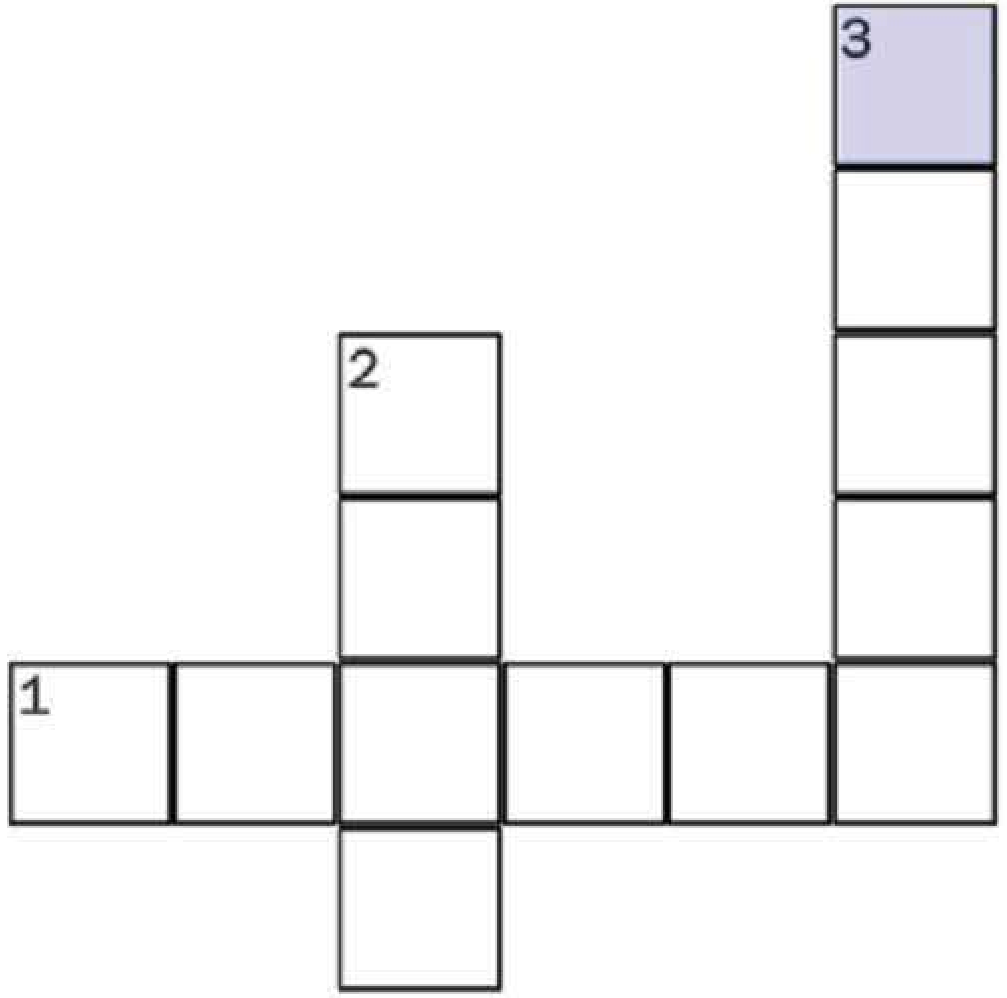
W	The work done on a rotating object
T	The torque acting on the object
θ	The angular displacement of the object in radians

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Work and torque equation

1



1) Represented by the symbol *T* in the equation $W = T \times \theta$.

2) Represented by the symbol *W* in the equation $W = T \times \theta$.

3) Represented by the symbol θ in the equation $W = T \times \theta$.

Done Hint Challenge

Calculate the work done by a constant force for rotational motion

Example

A flywheel makes 200 revolutions while the torque applied to it is 35 N.m. Determine the work done.

Example | Solution

GIVE FEEDBACK

OK

Calculate the work done by a constant force for rotational motion

Solution

Angular displacement must be expressed in radians:

$$\begin{aligned} \theta &= 200 \text{ revolutions} \\ &= 200 \times 2\pi \\ &= 1{,}257 \text{ rad} \end{aligned}$$

Work done:

$$\begin{aligned} W &= T \times \theta \\ &= 35 \times 1{,}257 \\ &= 43{,}980 \text{ J} \\ &= 44 \text{ kJ} \end{aligned}$$

Example	Solution

GIVE FEEDBACK

OK

Type your answer in the box.

The work done by a torque of 87 Nm applied to a car wheel that turns through 16 revolutions is
[ ] J. (Answer to the nearest joule.)

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Determine the work done by a torque of 100 Nm applied to a car wheel that turns through 50 revolutions.

(Answer to the nearest joule).

+ − · ÷ Clear

Clear line

π $\square \times 10^{\square}$ m ? Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint Each hint will reduce the credit received for this question

Power

When work is being done continuously over a period of time, the time rate of doing work is called **power**, P.

The unit of power is equal to one joule of work per second of time, i.e. J/s.

The name given to the unit of power is the **watt**, denoted by W.

GIVE FEEDBACK

OK

Type your answer in the box.

The rate of doing work is called ______.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The relationship between power and work done

Power is the time rate of doing work.

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

where:

P is the average power

W is the work done

t is the time taken to do the work

GIVE FEEDBACK

OK

Match the correct description to the equation symbol in the equation $P = \frac{W}{t}$.

Drag statements on the right to match the left.

P	The average power
W	The work done
t	The time taken to do the work

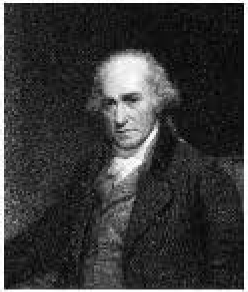
Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The components and SI unit for power

The unit of power follows from the definition and is equal to one joule of work per second of time, i.e. J/s. The name given to the unit of power is **watt**, denoted by W.

The SI unit was named after the Scottish engineer James Watt who, in the late 18th century, according to a historical anecdote, established another unit of power called **horsepower**, after actual experiments with strong dray horses. The horsepower, equal to 746 watts, is about 50 per cent more than the rate that an average horse can sustain for a working day.



GIVE FEEDBACK

OK

What is the SI unit for power?

Click the correct answer.

- watt
- what
- joule
- horsepower
- who

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Distinguish between the concepts and units of mechanical work and power

Be careful to avoid confusion between W as a symbol for work done and W as a unit symbol for power.

GIVE FEEDBACK

OK

Choose the correct statements regarding the equation $P = \frac{W}{t}$.

Check all that apply.

- [ ] The equation symbol *P* represents power which is measured in watts (symbol W)
- [ ] The equation symbol *W* represents work which is measured in joules (symbol J)
- [ ] The equation symbol *P* represents power which is measured in joules (symbol J)
- [ ] The equation symbol *W* represents work which is measured in watts (symbol W)
- [ ] The equation symbol *t* represents time which is measured in seconds (symbol s)
- [ ] The equation symbol *t* represents torque which is measured in newton metres (symbol Nm)

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate average power of a moving body

Example

If it takes 27 seconds for a hoist to perform 294.3 kJ of work, what is the average power required?

Example | Solution

GIVE FEEDBACK

OK

Calculate average power of a moving body

Solution

$$\text{Power} = \frac{W}{t}$$
$$= \frac{294.3\ \text{kJ}}{27\ \text{s}}$$
$$= 10.9\ \text{kJ/s}$$
$$= 10.9\ \text{kW}$$

Example | Solution

GIVE FEEDBACK

OK

Determine the power required to perform 392.4 joules of work in lifting a 20 kg mass in 2 minutes.

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Type your answer in the box.

The work done when 2 kW of power is applied to a body for 1 minute is ________ kJ. (Answer to the nearest kilojoule.)

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The relationship between force and power for linear motion

When work is done by a force moving with a constant linear velocity v, we can substitute $S = v\,t$ into the expression for power to obtain an alternate equation for power:

$$P = \frac{W}{t} = \frac{F \times S}{t} = \frac{F\,v\,t}{t} = F\,v$$

$$P = F\,v$$

where:

P is the power

F is the applied force

v is the velocity

GIVE FEEDBACK

OK

Match the equation symbol (from $P = F\,v$) with the correct description.

Drag statements on the right to match the left.

P	The power
F	The applied force
v	The velocity

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Example

A train moving at $63\ \mathrm{km/h}$ requires $40\ \mathrm{kN}$ of tractive effort at this speed.

Determine the driving power.

Example | Solution

GIVE FEEDBACK

OK

Calculate average and instantaneous power associated with linear motion

Solution

$$\begin{aligned} v &= 63 \text{ km/h} \\ &= 17.5 \text{ m/s} \end{aligned}$$

Power:

$$\begin{aligned} P &= F\,v \\ &= 40 \text{ kN} \times 17.5 \text{ m/s} \\ &= 700 \text{ kN m/s} \\ &= 700 \text{ kW} \end{aligned}$$

Example | Solution

GIVE FEEDBACK

OK

A vehicle moving at 110 km/h requires 5886 N of tractive effort at this speed. Determine the driving power. (Answer to the nearest whole number.)

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint Each hint will reduce the credit received for this question

Type your answer in the box.

A vehicle moving at 60 km/h requires 2400 N of tractive effort at this speed. The driving power required is

[ ] kW. (Answer to the nearest kW.)

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The relationship between torque and power for rotational motion

When work is done by a torque applied through a rotating member such as a shaft turning with a constant angular velocity $\omega = \frac{\theta}{t}$, substitution yields:

$$P = \frac{W}{t} = \frac{T \times \theta}{t} = \frac{T\,\omega\,t}{t} = T\,\omega$$

Therefore the power produced by a torque in rotational motion is:

$$P = T\,\omega$$

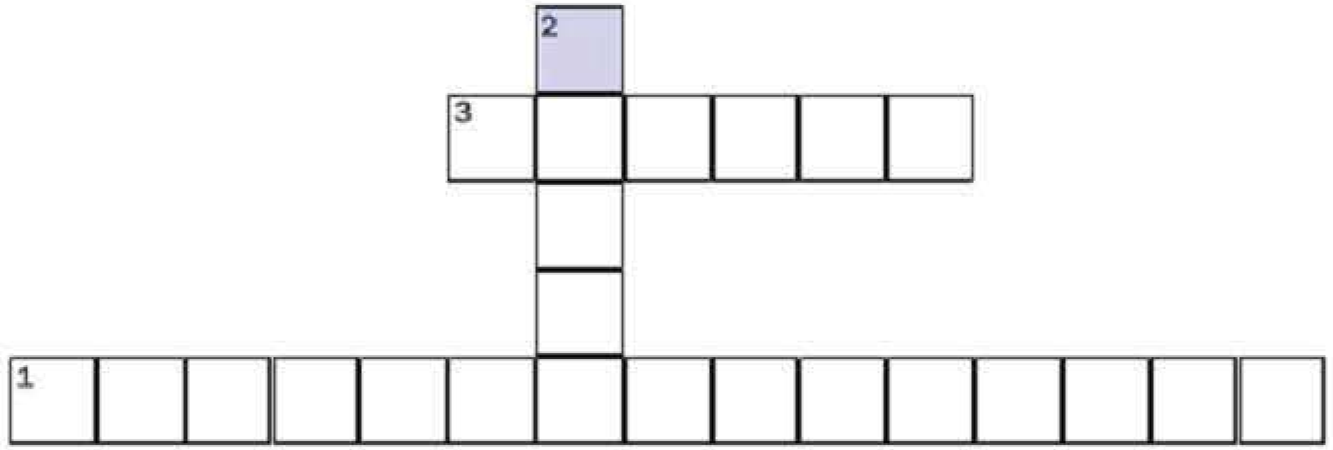
where ω is constant or average angular velocity in radians per second.

GIVE FEEDBACK

OK

Power and torque

1



1) Represented by the symbol ω in the equation $P = T\,\omega$ (two words).

2) Represented by the symbol *P* in the equation $P = T\,\omega$.

3) Represented by the symbol *T* in the equation $P = T\,\omega$.

Done Hint Challenge

Match the equation symbol with the correct description for the equation $P = T\,\omega$.

Drag statements on the right to match the left.

P	The power produced
T	The applied torque
ω	The angular velocity

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Example

An output shaft of an electric motor rotates at 1450 rpm and produces a torque of 81 N.m.
What is the shaft power?

Example

An output shaft of an electric motor rotates at 1450 rpm and produces a torque of 81 N.m.
What is the shaft power?

Solution

$$\begin{aligned} \omega &= \frac{2\pi \times 1{,}450}{60} \\ &= 151.8 \text{ rad/s} \\ P &= T\,\omega \\ &= 81 \text{ N.m} \times 151.8 \text{ rad/s} \\ &= 12{,}300 \text{ W} \\ &= 12.3 \text{ kW} \end{aligned}$$

Type your answer in the box.

An electric motor rotates at 900 rpm (which is equivalent to [ ] rad/s) and produces a torque of 52 N.m. (Answer correct to two decimal places.)

The shaft power is equal to [ ] kW. (Answer correct to one decimal place.)

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the power of an electric motor that produces a torque of 12.73 N.m. when it rotates at 600 rpm.

(Answer correct to the nearest watt).

+	−	·	÷	$\frac{\square}{\square}$	$1\frac{2}{3}$	$\square^2$	$\sqrt{\square}$	Clear
$(\square)$ ▾	≤ ▾	π	m ▾	$\overline{\square}$	↵		?	Undo

Clear line

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

How the work done in accelerating a body can be related to its change of velocity for linear motion

When a constant force or torque is available to accelerate a body in linear or rotational motion, the work done can be related to the acceleration produced.

This relationship can be used to determine the work necessary to change the velocity of a body in linear or rotational motion.

GIVE FEEDBACK

OK

Type your answer in the box.

When a constant force or torque is available to accelerate a body in linear or rotational motion, the ________ done can be related to the ________ produced.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

If a body of mass m is acted upon by a net accelerating force F over a distance S, the work done is $W = FS$.

At the same time:

$$S = v_{av} \times t$$
$$= \left(\frac{v + v_0}{2}\right) t$$

and:

$$F = m\,a$$
$$= m\left(\frac{v - v_0}{t}\right)$$

GIVE FEEDBACK

CONTINUE >

Substituting into the work equation:

$$
\begin{aligned}
W &= F \times S \\
&= m\left(\frac{v - v_0}{t}\right) \times \left(\frac{v + v_0}{2}\right) t \\
&= \frac{m}{2}(v - v_0) \times (v + v_0) \\
&= \frac{m}{2}(v^2 - v_0^2)
\end{aligned}
$$

< BACK GIVE FEEDBACK CONTINUE >

Therefore the work done in accelerating a mass m from an initial velocity v_0 to a final velocity v is given by:

$$W = \frac{m}{2}(v^2 - v_0^2)$$

This equation has a special significance with respect to the quantity called kinetic energy and it can be used to calculate the work required to change the velocity of a body.

< BACK GIVE FEEDBACK OK

Match the equation symbol with the correct description for the equation $W = \frac{m}{2}(v^2 - v_0^2)$.

Drag statements on the right to match the left.

W	The work done
m	The mass of the body
v	The final velocity of the body
v_0	The initial velocity of the body

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the work done and power required to accelerate a body in linear motion

Determine the force, work and average power required to accelerate a car of mass 1.2 t from rest to 72 km/h in 16 s.

Example	Determine the acceleration	Determine the force required	Determine the work required	Alternative method for calculation of work	Calculation of power	Note

GIVE FEEDBACK

OK

Calculate the work done and power required to accelerate a body in linear motion

Final velocity:

$$v = 72\ \text{km/h}$$
$$= 20\ \text{m/s}$$

Acceleration:

$$a = \frac{v - v_0}{t}$$
$$= \frac{20 - 0}{16}$$
$$= 1.25\ \text{m/s}^2$$

Example	Determine the acceleration	Determine the force required	Determine the work required	Alternative method for calculation of work	Calculation of power	Note

GIVE FEEDBACK

OK

Calculate the work done and power required to accelerate a body in linear motion

Force required:

$$
\begin{aligned}
F &= m\,a \\
&= 1{,}200\ \text{kg} \times 1.25\ \text{m/s}^2 \\
&= 1{,}500\ \text{N} \\
&= 1.5\ \text{kN}
\end{aligned}
$$

Example	Determine the acceleration	Determine the force required	Determine the work required	Alternative method for calculation of work	Calculation of power	Note

GIVE FEEDBACK

OK

Calculate the work done and power required to accelerate a body in linear motion

Work required:

$$W = \frac{m}{2}(v^2 - v_0^2)$$
$$= \frac{1{,}200}{2}(20^2 - 0)$$
$$= 240{,}000 \text{ J}$$
$$= 240 \text{ kJ}$$

Example	Determine the acceleration	Determine the force required	Determine the work required	Alternative method for calculation of work	Calculation of power	Note

GIVE FEEDBACK

OK

Calculate the work done and power required to accelerate a body in linear motion

Alternatively, distance travelled can be determined:

$$\begin{aligned} S &= \left(\frac{v + v_0}{2}\right)t \\ &= \left(\frac{20 + 0}{2}\right) \times 16 \\ &160 \text{ m} \end{aligned}$$

Hence:

$$\begin{aligned} W &= F \times S \\ &= 1.5 \text{ kN} \times 160 \text{ m} \\ &= 240 \text{ kJ} \end{aligned}$$

Example	Determine the acceleration	Determine the force required	Determine the work required	Alternative method for calculation of work	Calculation of power	Note

Calculate the work done and power required to accelerate a body in linear motion

Average power can now be calculated:

$$P = \frac{W}{t} = \frac{240\ \text{kJ}}{16\ \text{s}} = 15\ \text{kW}$$

GIVE FEEDBACK

OK

Calculate the work done and power required to accelerate a body in linear motion

It should be understood that these results refer to the force, work and power associated with the acceleration of the mass only.

Work and power due to other causes, such as frictional resistance, must be allowed for separately if required.

GIVE FEEDBACK OK

Calculate the work done during this action. (Answer to the nearest joule.)

+ − · ÷ □ $\square^2$ $\sqrt{\square}$ Clear

Clear line

? Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint Each hint will reduce the credit received for this question

Knowing that the work done during this action is $-240{,}000$ J calculate the power required for this action.

(Answer to the nearest watt).

+ − · ÷ Clear

Clear line

? Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Calculate the magnitude of the braking force required to achieve this result.

(Answer to the nearest newton).

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint Each hint will reduce the credit received for this question

A 1200 kg car travelling at 72 km/h is brought to rest in 4 seconds.

SMALL MEDIUM LARGE

Calculate the magnitude of the braking force required to achieve this result.

(Answer to the nearest newton).

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

A 1200 kg car travelling at 72 km/h is brought to rest in 4 seconds.

SMALL MEDIUM LARGE

Calculate the work done during this action. (Answer to the nearest joule.)

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required.
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

A 1200 kg car travelling at 72 km/h is brought to rest in 4 seconds.

SMALL MEDIUM LARGE

Knowing that the work done during this action is – 240,000 J calculate the power required for this action.

(Answer to the nearest watt).

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required.
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Type your answer in the box.

A 1300 kg car travelling at 36 km/h (10 m/s) is brought to rest in 2 seconds.

The acceleration required to achieve this result is ________ m/s^2.

The braking force required to achieve this result is ________ N.

The work done to achieve this result is ________ J.

The power required to achieve this result is ________ W.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

How the work done in accelerating a body can be related to its change of angular velocity for rotational motion 1/2

By analogy with linear motion, if a body of mass moment of inertia I is acted upon by a net accelerating torque T over an angular displacement θ, the work done is $W = T \times \theta$.

$$\begin{aligned}\theta &= \omega_{av} \times t \\ &= \left(\frac{\omega + \omega_0}{2}\right) t\end{aligned}$$

and:

$$\begin{aligned}T &= I \times \alpha \\ &= I\left(\frac{\omega - \omega_0}{t}\right)\end{aligned}$$

GIVE FEEDBACK

CONTINUE >

How the work done in accelerating a body can be related to its change of angular velocity for rotational motion 2/2

Substituting into the work equation:

$$
\begin{aligned}
W &= T \times \theta \\
&= \left(I \left(\frac{\omega - \omega_0}{t} \right) \right) \left(\frac{\omega - \omega_0}{2} \right) t \\
&= \left(\frac{I}{2} (\omega - \omega_0) \right) (\omega + \omega_0) \\
&= \frac{I}{2} (\omega^2 - \omega_0^2)
\end{aligned}
$$

< BACK GIVE FEEDBACK OK

Type your answer in the box.

The equation $W = \frac{I}{2}(\omega^2 - \omega_0^2)$ shows the relationship between the [ ] done in rotational motion and the change in [ ] velocity.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

State the formula for the work done in accelerating a mass moment of inertia (change the angular velocity of a body) for rotational motion

The work done in accelerating a body of mass moment of inertia I from initial angular velocity ω_0 to a final angular velocity ω is given by:

$$W = \frac{I}{2}(\omega^2 - \omega_0^2)$$

where:

W is the work done

I is the mass moment of inertia of the body

ω is the final angular velocity

ω_0 is the initial velocity

GIVE FEEDBACK

OK

Match the equation symbols from $W = \frac{I}{2}(\omega^2 - \omega_0^2)$ with the correct description.

Drag statements on the right to match the left.

W	The work done
I	The mass moment of inertia of the body
ω	The final angular velocity
ω_0	The initial angular velocity

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Example

Determine the torque, work and average power when a flywheel of mass moment of inertia of 53 $kg.m^2$ is accelerated from 700 rpm to 1500 rpm in 24 s.

Solution

Initial angular velocity:

$$\omega_0 = 700\ \text{rpm}$$
$$= 73.3\ \text{rad/s}$$

Final angular velocity:

$$\omega = 1{,}500\ \text{rpm}$$
$$= 157.1\ \text{rad/s}$$

Angular acceleration:

$$\alpha = \frac{\omega - \omega_0}{t}$$
$$= \frac{157.1 - 73.3}{24}$$
$$= 3.49\ \text{rad/s}^2$$

< BACK GIVE FEEDBACK CONTINUE >

Torque required:

$$\begin{aligned} T &= I\,\alpha \\ &= 53\,\text{kg.m}^2 \times 3.49\,\text{rad/s}^2 \\ &= 185\,\text{N.m} \end{aligned}$$

Work done:

$$\begin{aligned} W &= \frac{I}{2}(\omega^2 - \omega_0^2) \\ &= \frac{53}{2}(157.1^2 - 73.3^2) \\ &= 511{,}465\,\text{J} \\ &= 511.5\,\text{kJ} \end{aligned}$$

< BACK GIVE FEEDBACK CONTINUE >

Alternatively, angular displacement can be determined:

$$\begin{aligned}\theta &= \left(\frac{\omega + \omega_0}{2}\right)t \\ &= \left(\frac{157.1 + 73.3}{2}\right)\times 24 \\ &= 2{,}764 \text{ rad}\end{aligned}$$

Hence:

$$\begin{aligned}W &= T \times \theta \\ &= 185 \text{ N.m} \times 2{,}764 \text{ rad} \\ &= 511{,}465 \text{ J} \\ &= 511.5 \text{ kJ}\end{aligned}$$

< BACK
GIVE FEEDBACK
CONTINUE >

Average power can now be calculated:

$$
\begin{aligned}
P &= \frac{W}{t} \\
&= \frac{511.5\ \text{kJ}}{24\ \text{s}} \\
&= 21.3\ \text{kW}
\end{aligned}
$$

< BACK GIVE FEEDBACK OK

Type your answer in the box.

A flywheel of mass moment of inertia of 10.8 $kg.m^2$ is accelerated from rest to 955 rpm (100 rad/s) in 5 s.

The angular acceleration required to achieve this change in angular velocity is ______ rad/s^2.

The torque required to produce this angular acceleration is ______ Nm.

The work done in this case is ______ joules.

The average power to achieve this result is ______ watts.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

In many practical situations mechanical work is done by a changing force such as deforming a coil spring.

Free length of a coil spring

It is possible to consider the relatively simple but useful case of work done in deforming a coil spring.

This case involves a variable force changing at a uniform rate.

This treatment requires consideration of the undeformed length of a coil spring, usually referred to as its **free length**.

GIVE FEEDBACK

OK

Type your answer in the box.

The undefomed length of a coil spring is referred to as its ________ ________. (Type one word in each box.)

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Hooke's law for a linear spring

It is found that within the normal operating limits of the material, the force required to produce axial compression or elongation of the spring is directly proportional to the amount of deformation from the free length.

We can express this as a formula:

$$F = k\,x$$

where:

x is the amount of elongation or compression

F is the force corresponding to the amount of deformation

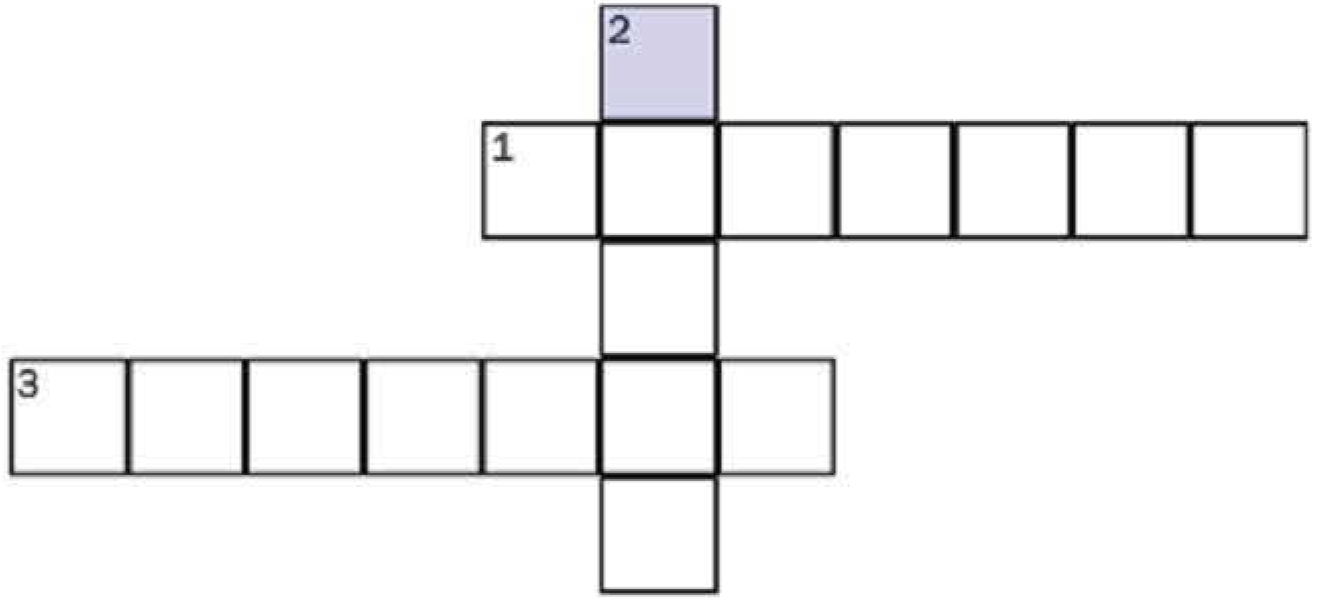
k is the constant of proportionality

GIVE FEEDBACK

OK

Work done deforming a coil spring

1



1) In the equation $F = kx$, the symbol k refers to the spring ____________.

2) In the equation $F = kx$, the symbol F refers to the ____________.

3) In the equation $F = kx$, the symbol x refers to the ____________.

Done

Hint

Challenge

Match the symbols from the equation $F = k\,x$ with the correct description.

Drag statements on the right to match the left.

x	The amount of elongation or compression
F	The force corresponding to the amount of deformation
k	The constant of proportionality

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Spring modulus or spring constant

The constant of proportionality k is known as the **spring modulus**, or simply **spring constant**, and represents the force required to deform the spring a unit distance.

GIVE FEEDBACK

OK

Type your answer in the box.

The constant of proportionality k in the equation $F = k\,x$ is known as the spring ________ or spring ________.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The components and SI unit for spring constant

The most common practical unit for expressing spring constants is the newton per millimetre (N/mm).

However, it is sometimes necessary to convert from this practical unit into the more fundamental newton per metre (N/m) to ensure dimensional homogeneity of calculations performed.

GIVE FEEDBACK

OK

What is the SI unit for the spring modulus?

Click the correct answer.

- N/m
- N.m
- N
- m
- kg

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the force in deforming a coil spring from its free length

Example

Determine the initial, final and average force when a coil spring is stretched 12 mm from its free length. The spring constant is 200 N/mm.

Example | Solution

GIVE FEEDBACK

OK

Calculate the force in deforming a coil spring from its free length

Solution

The initial force is zero, as the term 'free length' implies. Therefore $F_0 = 0$. The final force, i.e. at the end of stretching, is:

$$
\begin{aligned}
F &= k\,x \\
&= 200\ \text{N/mm} \times 12\ \text{mm} \\
&= 2{,}400\ \text{N}
\end{aligned}
$$

The average force is:

$$
\begin{aligned}
F_{av} &= \frac{F_0 + F}{2} \\
&= \frac{0 + 2{,}400}{2} \\
&= 1{,}200\ \text{N}
\end{aligned}
$$

Example | Solution

GIVE FEEDBACK

OK

Type your answer in the box.

A coil spring is stretched 22 mm from its free length. The spring constant is 168 N/mm.

The initial force is ____ N.

The final force is ____ N.

The average force is ____ N.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Work done in deforming a spring can be calculated using:

$$W = F_{av} x$$

When $F_0 = 0$ and $F = k x$, the average force is:

$$F_{av} = \frac{F_0 + F}{2}$$

Substitution yields:

$$W = F_{av} x = \frac{k x}{2} x = \frac{k x^2}{2}$$

GIVE FEEDBACK

CONTINUE >

Therefore work done in deforming a coil spring from its free length is:

$$W = \frac{k x^2}{2}$$

where:

k is the spring constant in N/m

x is the amount of elongation or compression in m

< BACK GIVE FEEDBACK OK

Match the symbols from the equation $W = \frac{k x^2}{2}$ with the correct description.

Drag statements on the right to match the left.

W	The work done in deforming the spring in J
k	The spring constant in N/m
x	The amount of elongation or compression in m

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Example 1

Determine the amount of work done by the variable force when stretching a spring 12 mm from its free length if the spring constant is 200 N/mm.

Example 1 | Solution to Example 1 | Example 2 | Solution to Example 2

GIVE FEEDBACK

OK

Calculate the work done in deforming a coil spring from its free length

Solution 1

Work done:

$$\begin{aligned} W &= F_{av}\, x \\ &= 1{,}200\ \text{N} \times 0.012\ \text{m} \\ &= 14.4\ \text{J} \end{aligned}$$

Example 1	Solution to Example 1	Example 2	Solution to Example 2

GIVE FEEDBACK

OK

Calculate the work done in deforming a coil spring from its free length

Example 2

Use the equation $W = \frac{k\,x^2}{2}$ to check the answer obtained in Example 1.

Example 1	Solution to Example 1	Example 2	Solution to Example 2

GIVE FEEDBACK

OK

Calculate the work done in deforming a coil spring from its free length

Solution 2

Using base units, $k = 200{,}000\ \mathrm{N/m}$ and $x = 0.012\ \mathrm{m}$

Substitute:

$$\begin{aligned} W &= \frac{k x^2}{2} \\ &= \frac{200{,}000 \times 0.012^2}{2} \\ &= 14.4\ \mathrm{J} \end{aligned}$$

Example 1	Solution to Example 1	Example 2	Solution to Example 2

GIVE FEEDBACK

OK

Type your answer in the box.

The work done in stretching a spring 22 mm if it has a spring constant of 168 N/mm is

[   ] joules. (Answer correct to three decimal places.)

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the work done in stretching a spring 200 mm if it has a spring modulus of 53 N/mm.

(Answer correct to the nearest joule).

Clear

Clear line

?

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question