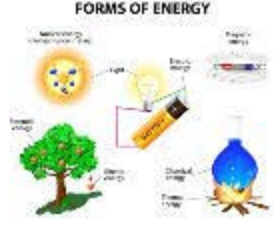
GIVE FEEDBACK

CONTINUE >

When the word 'energy' is used in everyday conversation, its meaning is very different from its precise scientific meaning.

This section considers the precise scientific meaning of mechanical energy.



While this section does not cover all forms of energy, it does discuss three forms of mechanical energy:

1. Gravitational potential
2. Kinetic
3. Strain

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Defining energy

The concept of mechanical energy is one of the most useful in engineering science. However, the colloquial meaning of the word 'energy' is very different from its precise scientific meaning. The idea of energy, by itself, is very abstract and was a matter of great confusion among many of the ablest scientific minds until well into the 19th century.

The essential unity of the concept of energy in its different forms, e.g. mechanical, thermal, electrical, chemical, was not clear until the development of the steam engine prompted men such as James Watt, James Joule and Robert Mayer to explore the relations between different forms of energy in action, such as work and heat, and to proclaim the law of conservation of energy.

This section does not consider non-mechanical forms of energy, such as heat, because they do not fit the description of mechanical systems of bodies at rest or in motion.

Therefore the definition of energy, at this stage, is restricted to mechanical energy only.

Energy is the capacity to do work.

GIVE FEEDBACK

OK

Which of the following people worked to explore the relations between different forms of energy in action, such as work and heat, and to proclaim the law of conservation of energy?

Check all that apply.

- [ ] James Watt
- [ ] James Joule
- [ ] Robert Mayer
- [ ] Isaac Newton
- [ ] Aristotle
- [ ] Albert Einstein

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following are considered to be forms of mechanical energy?

Check all that apply.

- [ ] Kinetic
- [ ] Gravitational potential
- [ ] Heat
- [ ] Strain
- [ ] Light
- [ ] Chemical

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Defining mechanical energy

Mechanical energy is usually defined as a physical quantity stored in a material body by virtue of its position, motion or strained condition, and is a measure of the capacity of the body to do work.

Doing mechanical work can alter the condition of a physical object in terms of:

- Lifting it to a higher elevation against the force of gravity
- Accelerating the object against the inertia of its mass
- Stretching or compressing a spring against the ability of its material to resist such deformation

It took many centuries of scientific thought to recognise that the work done to lift or accelerate a body, or stretch a piece of elastic material, does not disappear without a trace but is in fact stored within the body by reason of:

- Its increased elevation above some datum level
- Its higher linear or rotational velocity, or
- The amount of elastic deformation produced

Mechanical energy is, at least in theory, fully retrievable in the form of work if the process is reversed.

GIVE FEEDBACK

OK

Type your answer in the box.

_____ energy is usually defined as a physical quantity stored in a material body by virtue of its position, motion or strained condition, and is a measure of the capacity of the body to do work.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following represent an increase in the energy of a body?

Check all that apply.

- [ ] An elevator transporting passengers to a higher level in a building
- [ ] A car accelerating from rest to 50 km/h
- [ ] A horizontal moving walkway transporting passengers
- [ ] The return spring on a gate being stretched when the gate is opened
- [ ] A car travelling at 110 km/h on a level highway

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The SI unit of energy

If energy is stored work, its units must correspond to the units of work.

Therefore the SI unit of energy is joule (J).

One joule is equal to the work done by a force of one newton acting through a distance of one metre.

There are other units in which energy and work can be expressed including calories. When using equations, care should be taken to ensure that appropriate SI units are used.

Physicist, James Joule

GIVE FEEDBACK

OK

Type your answer in the box.

The SI unit for energy is the _____, which has the symbol _____.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following is the correct SI unit for energy?

Click the correct answer.

- joule
- kilojoule
- kilogram
- newton
- watt
- mayer

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

To keep things simple we will ignore friction at this stage. In later chapters friction will be included because friction causes some energy to be converted to heat.

Examples of stored energy and energy in action

By its very nature, stored energy is always latent, i.e. not directly observable or measurable.

However, its quantity can be indirectly evaluated using measurements of other related physical quantities, such as mass, height, velocity and elongation.

On the other hand, the effects of energy in action are always immediately obvious, e.g. a drop hammer driving a pile into the ground or a clock mechanism driven by a spring.

The amount of work done can be taken as a measure of the amount of energy released.

GIVE FEEDBACK

OK

Which of the following are examples of stored energy?

Check all that apply.

- [ ] Energy in petroleum
- [ ] A drop hammer driving a pile into the ground
- [ ] Chemical energy in a battery
- [ ] A stationary stretched spring
- [ ] A clock mechanism driven by a spring

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Type your answer in the box.

The amount of [ ] done can be taken as a measure of the amount of [ ] released.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following are the effects of energy in action?

Check all that apply.

- [ ] A drop hammer driving a pile into the ground
- [ ] A clock mechanism driven by a spring
- [ ] Chemical energy stored in a battery
- [ ] A stationary stretched spring
- [ ] Energy stored in petroleum

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Forms of mechanical energy

Three forms of mechanical energy and their relation to the work done may be initially considered in the absence of frictional losses.

Gravitational potential energy

Kinetic energy

Elastic strain energy

GIVE FEEDBACK

OK

Which of the following are forms of mechanical energy?

Check all that apply.

- [ ] Gravitational potential energy
- [ ] Kinetic energy
- [ ] Heat energy
- [ ] Strain energy
- [ ] Sound energy
- [ ] Light energy

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Three forms of mechanical energy are:

Click the correct answer.

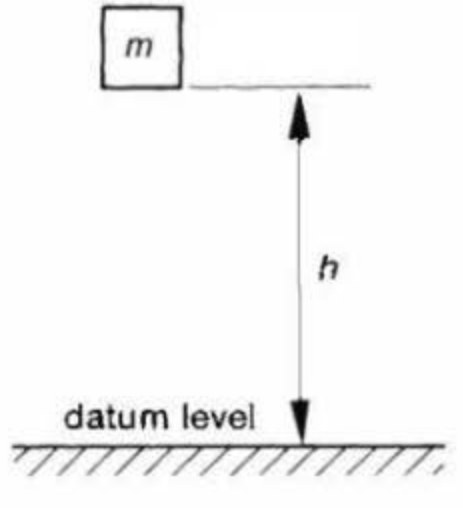
- Gravitational potential energy, kinetic energy and elastic strain energy
- Electrical energy, kinetic energy and chemical energy
- Kinetic energy, light energy and heat energy
- Heat energy, gravitational potential energy and elastic strain energy
- Elastic strain energy, kinetic energy and chemical potential energy

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Gravitational potential energy

The **gravitational potential energy** of a body is the energy that a body possesses due to its position in the gravitational field.



A raised mass has potential energy

GIVE FEEDBACK

OK

Which of the following is the correct definition of the potential energy of a body?

Click the correct answer.

- The energy that a body possesses due to its position in the gravitational field
- The energy that a body possesses due to its movement
- The energy that a body possesses due to its stretched condition
- The energy that a body possesses due to its sound output
- The energy that a body possesses due to its heat content

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following are examples of gravitational potential energy?

Check all that apply.

- [ ] A skier at the top of a mountain
- [ ] An elevator at the top floor of a building
- [ ] A stretched spring
- [ ] A car travelling on a flat highway
- [ ] A fully charged battery

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Type your answer in the box.

The potential energy of a body is the energy that a body possesses due to its _____ in the gravitational field.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The formula for potential energy

A raised mass has potential energy.

As an example of this, consider a block of mass m raised a distance h above the ground.

The force of gravity acting on the block is $F_w = m\,g$

and the work done in lifting the block is $W = F\,h = m\,g\,h$.

This work is stored in the body as potential energy with respect to the ground as the datum.

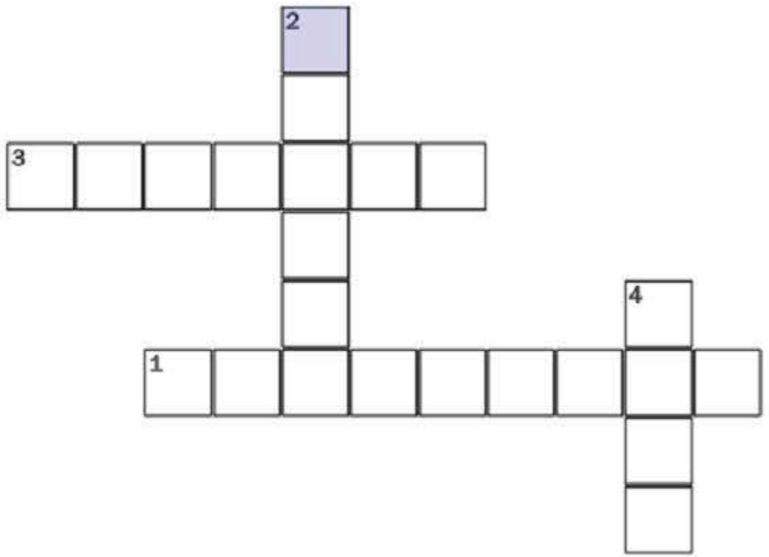
Equation

GIVE FEEDBACK

OK

Equation for gravitational potential energy

1



1) In the equation GPE=mgh, the symbol GPE represents gravitational _____ energy.

2) In the equation GPE=mgh, the symbol h represents _____ above a datum.

3) In the equation GPE=mgh, the symbol g represents acceleration due to _____.

4) In the equation GPE=mgh, the symbol m represents _____.

Done | Hint | Challenge

Match the symbol from the equation $GPE = m\,g\,h$ with the correct description.

Drag statements on the right to match the left.

GPE	Gravitational potential energy
m	Mass
g	Acceleration due to gravity
h	Height above the datum

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate gravitational potential energy

Example

Calculate the potential energy of a drop hammer which has a mass of 1 t and is raised 1.5 m above the pile head before being allowed to drop freely in order to drive it into the ground.

Example	Solution	Discussion

GIVE FEEDBACK

OK

Solution

The gravitational potential energy of the hammer relative to the pile is:

$$GPE = m\,g\,h$$

$$= 1{,}000 \times 9.81 \times 1.5$$

$$= 14{,}715\ \text{J}$$

Example | Solution | Discussion

Calculate gravitational potential energy

Discussion

It is interesting to note that a rudimentary idea of potential energy goes back to Galileo, who recognised that when a load is lifted with a pulley system, the force applied multiplied by the distance through which that force must be applied, i.e. the work done, remains constant even though the force and distance may vary.

Example | Solution | Discussion

Calculate the gravitational potential energy of an 1800 kg elevator car that is suspended 30 metres above ground level. (Answer in joules.)

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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 gravitational potential energy of a 100 kg skier who is positioned at an elevation of 102 metres up a ski slope. (Answer in joules.)

Clear

Clear line

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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.
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Hint

Each hint will reduce the credit received for this question

Type your answer in the box.

The gravitational potential energy of a 1,200 kg car at the top of a hill that is 50 metres above the reference point is _____ joules.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Kinetic energy

In order to accelerate a body in linear motion, work must be done on that body. As a result of doing W units of work, the velocity changes, so that:

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

The quantity $\frac{m\,v^2}{2}$ was first recognised in the 17th century and was then called *vis viva*, or 'living force'. In the 19th century, it was finally accepted that *vis viva* was not a force but a form of mechanical energy now called 'kinetic energy'.

The **kinetic energy** of a body is the energy which it possesses due to its velocity. Kinetic energy is proportional to the mass and the square of the velocity.

GIVE FEEDBACK

OK

Type your answer in the box.

The kinetic energy of a body is the energy which it possesses due to its _____.

Kinetic energy is proportional to the _____ and the square of the _____.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following are examples of kinetic energy?

Check all that apply.

- [ ] A car travelling on a flat highway
- [ ] An elevator car moving upwards in a building
- [ ] An elevator car moving downwards in a building
- [ ] A stationary stretched spring
- [ ] A fully charged battery
- [ ] An elevator car stationary at its highest point in a building

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The formula for kinetic energy for linear motion

Kinetic energy is proportional to the mass and the square of the velocity:

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

where:

KE is the kinetic energy in J

m is the mass of the body in kg

v is the velocity of the body in m/s

GIVE FEEDBACK

OK

Which of the following is the correct equation for the calculation of kinetic energy?

Click the correct answer.

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

$KE = m g h$

$KE = \frac{1}{2} k x^2$

$KE = \frac{1}{2} a t^2$

$KE = v i^n$

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Match the symbol from the equation $KE = \frac{1}{2} m v^2$ with the correct description.

Drag statements on the right to match the left.

KE	The kinetic energy
m	The mass of the body
v	The velocity of the body

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the kinetic energy of linear motion

Example

Calculate the kinetic energy of a vehicle of mass 1720 kg, moving with a velocity of 80 km/h.

Example	Convert velocity to m/s	Solution

GIVE FEEDBACK

OK

Calculate the kinetic energy of linear motion

Velocity:

$$v = 80\ \mathrm{km/h}$$
$$= 22.2\ \mathrm{m/s}$$

Example | Convert velocity to m/s | Solution

GIVE FEEDBACK

OK

Calculate the kinetic energy of linear motion

Solution

Kinetic energy:

$$KE = \frac{1}{2} m v^2$$
$$= \frac{1}{2} 1{,}720 (22.2)^2$$
$$= 424{,}700 \text{ J}$$
$$= 424.7 \text{ kJ}$$

Example	Convert velocity to m/s	Solution

GIVE FEEDBACK

OK

Type your answer in the box.

The kinetic energy of a football with mass 800 g when travelling at 12 m/s is _____ J. (Answer correct to one decimal place).

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the kinetic energy of a 90 kg person who is running at 10 metres per second. (Answer correct to the nearest joule.)

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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 kinetic energy of a 1400 kg car that is travelling at 110 km/h on a freeway. (Answer correct to the nearest joule.)

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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

The formula for kinetic energy for rotation

Kinetic energy of rotating bodies can also be calculated using rotational analogues of the linear terms mass and velocity, namely mass moment of inertia I and angular velocity ω.

Therefore for a rotating body:

$$KE = \frac{I\,\omega^2}{2}$$

where:

KE is the kinetic energy in J

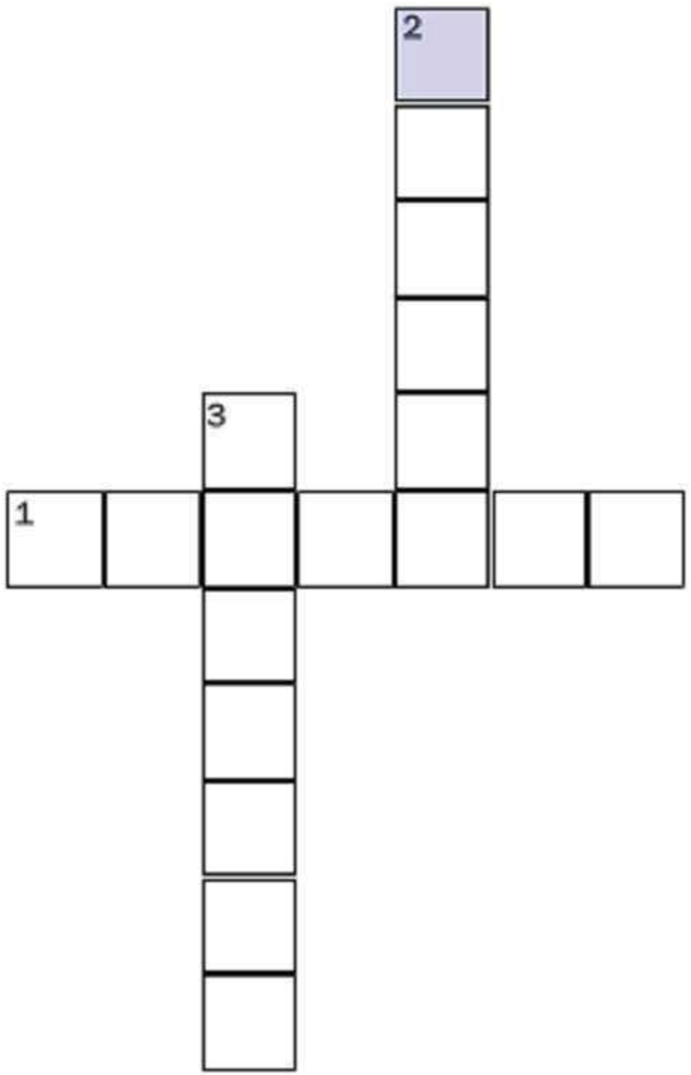
I is the mass moment of inertia in $kg.m^2$

ω is the angular velocity in rad/s

GIVE FEEDBACK

OK

Kinetic energy of rotation



Identify what is represented by each of the symbols in the equation $KE = \frac{1}{2}\omega^2$.

1) The _____ energy, represented by the symbol *KE*.

2) The mass _____ of inertia, represented by the symbol *I*.

3) The _____ velocity, represented by the symbol ω.

Done | Hint | Challenge

Match the symbol from the equation $KE = \frac{1}{2} I \omega^2$ with the correct description.

Drag statements on the right to match the left.

KE	The kinetic energy of the rotating body
I	The mass moment of inertia of the rotating body
ω	The angular velocity of the rotating body

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following is the correct equation for calculation of the kinetic energy of a body in rotational motion?

Click the correct answer.

$KE = \frac{1}{2} I \omega^2$

$KE = m g h$

$KE = \frac{1}{2} k x^2$

$KE = \frac{1}{2} a t^2$

$KE = v i^n$

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the kinetic energy of rotational motion

Example

Calculate the kinetic energy of a flywheel with mass moment of inertia 61 kg.m^2 rotating at 250 rpm.

Example	Convert the angular velocity to radians per second	Solution

GIVE FEEDBACK

OK

Calculate the kinetic energy of rotational motion

Angular velocity:

$$\omega = 250 \text{ rpm}$$
$$= 26.18 \text{ rad/s}$$

Example	Convert the angular velocity to radians per second	Solution

GIVE FEEDBACK

OK

Solution

Hence kinetic energy stored in the flywheel at this speed is given by:

$$\begin{aligned} KE &= \frac{1}{2} I \omega^2 \\ &= \frac{1}{2} 61 \{26.18\}^2 \\ &= 20{,}900 \text{ J} \\ &= 20.9 \text{ kJ} \end{aligned}$$

Example	Convert the angular velocity to radians per second	Solution

Type your answer in the box.

The kinetic energy of a wheel with a mass moment of inertia of 10 kgm^2 when it is rotating at 50 radians per second is _____ joules.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the kinetic energy of a flywheel with mass moment of inertia $53\ \mathrm{kg\,m^2}$ when it is rotating at 360 rpm. (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

Calculate the kinetic energy of a motorcycle wheel with mass moment of inertia $12\ \mathrm{kg\,m^2}$ when it is rotating at 700 rpm. (Answer correct to the nearest joule.)

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

Strain energy

A form of mechanical energy is the energy of elastic deformation, such as that stored in a stretched or compressed coil spring. This form of energy is called **strain energy**.

Strain energy is the result of work having been done in stretching or compressing the spring against the stiffness of its material to reach its 'strained' condition.

Like other kinds of mechanical energy, strain energy is potentially recoverable when the spring is allowed to return to its original free length.

GIVE FEEDBACK

OK

Type your answer in the box.

_____ energy is the energy of elastic deformation, such as that stored in a stretched or compressed coil spring.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following defines strain energy?

Click the correct answer.

- The energy of elastic deformation
- The energy of motion
- The energy of relative position
- The energy of sound
- The energy of chemical potential

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The formula for strain energy stored in a coil spring

We know that the amount of work required to stretch or compress a simple coil spring from its free length is given by:

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

This amount of work is then stored within the material of the spring and becomes its strain energy:

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

where:
SE is the strain energy in J of a coil spring
k is the spring modulus in N/m
x is the amount of elongation or compression in m

GIVE FEEDBACK

OK

Which of the following is the correct equation for the calculation of strain energy?

Click the correct answer.

$SE = \frac{1}{2} k x^2$

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

$SE = m g h$

$SE = \frac{1}{2} I \omega^2$

$SE = v e^n$

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Match the symbol from the equation $SE = \frac{1}{2} k x^2$ with the correct description.

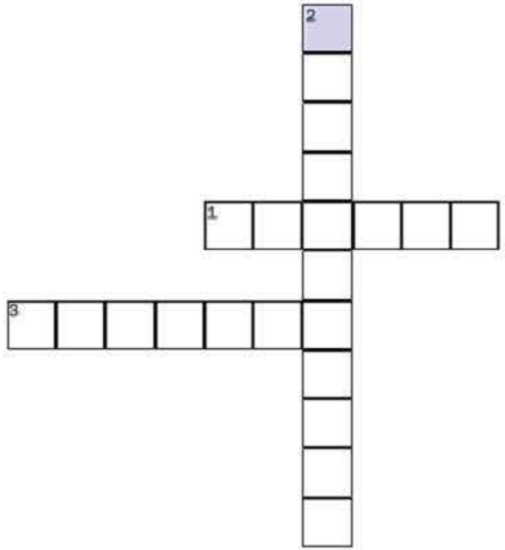
Drag statements on the right to match the left.

SE	The strain energy
k	The spring modulus
x	The elongation or compression of the spring

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Strain energy equation



1) _____ energy, represented by the symbol *SE* in the equation $SE = \frac{1}{2} k x^2$.

2) Elongation or _____ of the spring, represented by the symbol *x* in the equation $SE = \frac{1}{2} k x^2$.

3) Spring _____, represented by the symbol *k* in the equation $SE = \frac{1}{2} k x^2$.

Done Hint Challenge

Calculate strain energy stored in a coil spring

Example

Given that a bumper spring of stiffness 20 N/mm is compressed by 150 mm from its free state, what is the strain energy at the end of compression?

Example | Solution

GIVE FEEDBACK

OK

Calculate strain energy stored in a coil spring

Solution

Note that in order to obtain correct units for energy, it is necessary to use base units when using the formula for strain energy stored in the spring at the end of compression:

$$\begin{aligned} SE &= \frac{1}{2} k x^2 \\ &= \frac{1}{2} (20{,}000 \text{ N/m}) (0.15 \text{ m})^2 \\ &= 225 \text{ J} \end{aligned}$$

Example | Solution

GIVE FEEDBACK

OK

Type your answer in the box.

When a slinky spring with a spring modulus of 20 N/m is stretched a distance of 2.6 m, the strain energy is _____ J? (Answer correct to one decimal place.)

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the strain energy at the end of compression given that a spring of stiffness $15\ \mathrm{N/mm}$ is compressed by $70\ \mathrm{mm}$ from its free state. (Answer in joules correct to two decimal places.)

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 strain energy at the end of elongation given that a spring of stiffness 28 N/mm is stretched by 20 cm from its free state. (Answer correct to the nearest joule.)

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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.
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