Kinetic energy, work and power

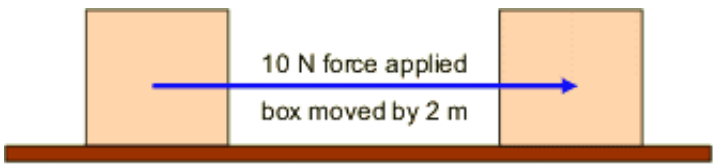
Whenever 'work' is done energy is transferred from one place to another. The amount of work done is expressed in the equation: work done = force x distance.

Power is a measure of how quickly work is being done. Power is expressed in the equation: power = work done / time taken.

Work and force

Work done

Work is done whenever a force moves something.



Everyday examples of work include walking up stairs, or lifting heavy objects. Whenever work is done **energy** is transferred from one place to another. Both energy and work are measured in **joules, J**.

Work done (joules, J) = energy transferred (joules, J)

The amount of work done depends on:

The size of the **force** on the object
The **distance** the object moves

Equation

Work done (joule, J) = force (newton, N) x distance (metre, m)

How much work is done when a man lifts a box weighing 200 N

off the floor to a shelf 2 m high?

Work done = force x distance = 200 N x 2 m = 400 J

Higher tier

Use the triangle to help you rearrange the equation to:

Force = work done / distance

Distance = work done / force

Rearranging equation activity - Higher tier

Check your understanding of this by having a go at the activity:

Work done - Higher tier

Kinetic energy and braking distance

When a car brakes, its kinetic energy is changed into **heat energy**.

Work done by brakes = loss in kinetic energy

If the speed of the car **doubles**, the kinetic energy and braking distance **quadruple**.

kinetic energy = ½ x mass x speed^2

This can be summarised as KE = ½mv^2

Example

Question

How much KE does a person of mass 50kg running at 3m/s have?

Answer

Kinetic energy = ½ x mass x speed^2

kinetic energy = ½ x 50 x 3^2
kinetic energy = ½ x 50 x 9
Kinetic energy = 225J

Power – work and time

Power is a measure of how **quickly** work is being done and so how quickly energy is being transferred.

More powerful engines in cars can do work quicker than less powerful ones. As a result they usually travel **faster** and cover the same distance in less time but also require more **fuel**.

Car comparison

	Car A (standard)	**Car B (sports)**
Power	44	240
Top speed (km/h)	160	285
Fuel consumption (litres/100km)	6	11

Question

If both fuel tanks hold 50 litres how far could each car drive without refuelling?

Answer

Car A

100 km x 50/6 = 833 km

Car B

100 km x 50/11 = 455 km (to nearest km)

Higher tier

Power is measured in Watts. One Watt is equal to one joule per second. It is calculated using the following equation.

Power (watts, W) = work done (joule, J) / time taken (seconds, s)

Question

What is the power of an engine that does 3000 J of work in 60 s?

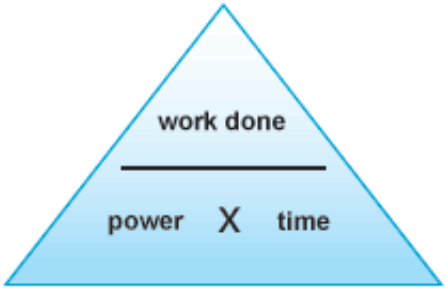
Answer

Power = work done / time taken

Power = 3000 J / 60 s = 50 W

Higher tier

Use the triangle to help you rearrange the equation to:



Work done = power x time taken

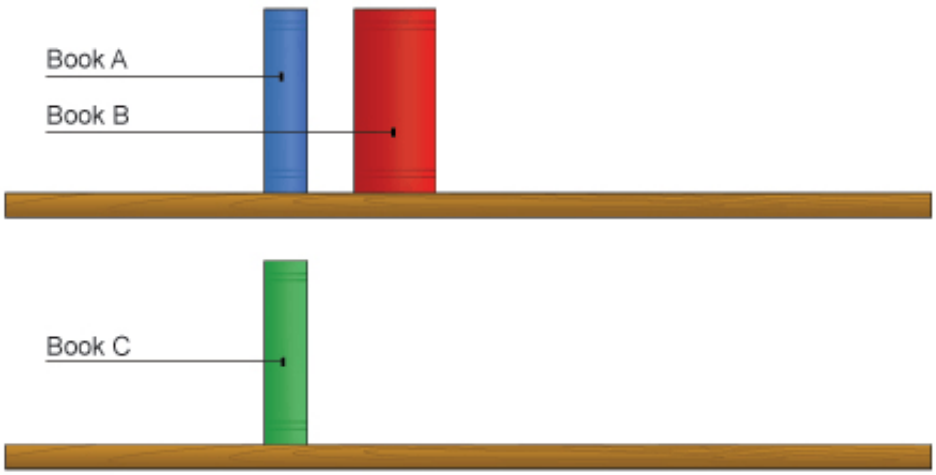
Time taken = work done / power

Gravitational potential energy (GPE)

On Earth we always have the force

of **gravity** acting on us. When we're above the Earth's surface we have **potential** (stored) energy. This is called **gravitational potential energy**. The amount of gravitational potential energy an object on Earth has depends on its:

Mass
Height above the ground



Books on a shelf have gravitational potential energy.

Book A has more than book C as it's **higher**.

Book B has more than book A because it has a greater **mass**.

The gravitational field at the Earth's surface produces a force of approximately **10 N (Newtons)** on every mass of 1 kg. Gravitational field strength is symbolised by the letter 'g'. On larger planets, like Jupiter where the gravitational field strength is greater, the gravitational potential energy would also be greater.

Gravitational field strength in different places

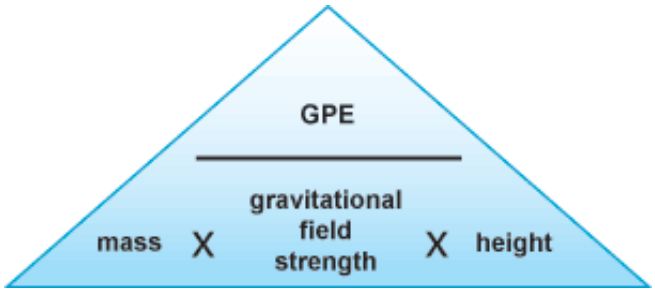
Place	Gravitational field strength
Earth	10 N/kg

Moon	1.6 N/kg
Jupiter	26 N/kg

Equation

GPE (J) = mass (kg) x gravitational field strength (or 'g') (N/kg) x height (m)

GPE = m x g x h



Use the triangle to help you rearrange the equation.

Example

Question

On Earth, a ball of mass 0.5 kg is kicked straight up. How much GPE does it have at its highest point 6 m off the ground?

Answer

GPE = 0.5 x 10 x 6 = **30 J**

Question

On the Moon, if the same ball were given the same amount of GPE, how high would it have to be above the surface?

Answer

H = GPE / (m x g) = 30 / (0.5 x 1.6) = **37.5 m**

Weight

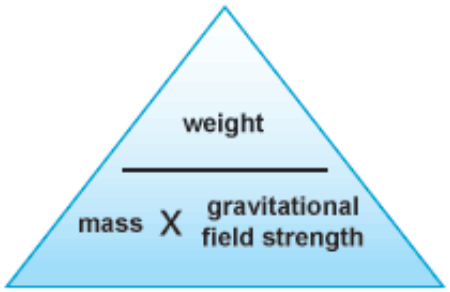
The **weight** of an object is the size of the force of **gravity** pulling the object down. An astronaut **weighs more** on Earth than on the Moon as the Earth's gravity is stronger than the Moon's.

Weight (N) = mass (kg) x gravitational field strength (N/kg)

W = m x g

Use the triangle to help you rearrange the equation.

Example:



Question

On Earth, what is the weight of a person whose mass is 45 kg?

Answer

W = m x g = 45 x 10 = **450 N**

Kinetic energy

All moving objects have **kinetic energy**. The amount of kinetic energy they have depends on:

Speed
Mass

A person has more kinetic energy when running than walking.

If a car and a lorry are driving at the same speed on the motorway the lorry has more kinetic energy than the car.

Equation

Kinetic energy = $^1/_2$ x mass x speed^2

Example

Question

How much KE does a person of mass 50 kg running at 3 m/s have?

Answer

Kinetic energy = $^1/_2$ x mass x speed^2

Kinetic energy = $^1/_2$ x 50 x 3^2

Kinetic energy = $^1/_2$ x 50 x 9

Kinetic energy = 225 J

Kinetic energy and braking distance

When a car **brakes**, its kinetic energy is changed into **heat energy**.

Work done by brakes = loss in kinetic energy

If the speed of the car **doubles**, the kinetic energy and braking distance **quadruple**.

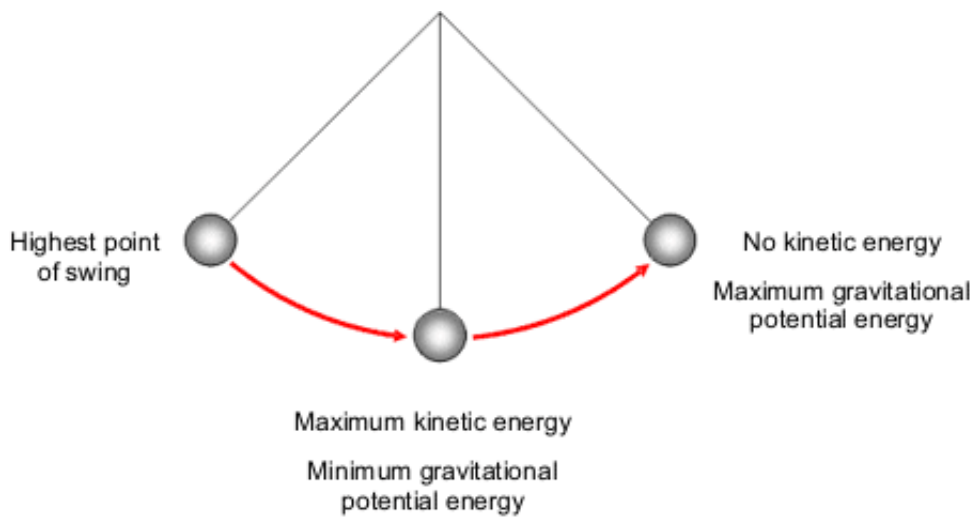
Conservation of energy

Energy is always **conserved** – the total amount of energy present stays the same before and after any changes.

The pendulum

The pendulum shows the principal of conservation of energy in action. Gravitational potential energy is converted to kinetic energy and back, over and over again, as the pendulum swings.

The diagram shows a pendulum in three positions. It shows the two ends of its swing and the position it will be in as it passes through the middle point.



How it works

When the pendulum bob is at the start of its swing it has no kinetic energy because it is not moving. If however, its *gravitational potential energy (GPE)***gravitational potential energy**: *The energy stored by an object lifted up against the force of gravity.* is at a maximum, because it is at the highest point.

As the bob swings downwards it loses height. Its gravitational potential energy (GPE) decreases. The work done on the bob by the gravitational force (weight) pulling

it downwards increases its kinetic energy. The loss of GPE = the gain in KE.
At the bottom of its swing, the bob's kinetic energy is at a maximum and its gravitational potential energy is at a minimum - because it is at its lowest point.
As the bob swings upwards it slows down. Its kinetic energy decreases as work is done against its weight. As it gains height the gravitational potential energy increases again.
At the very top of its swing it stops for a moment. It once again has no kinetic energy, but its gravitational potential energy is at a maximum.
At all points during the swing, the total (GPE + KE) is constant.

Note that in a real pendulum, the bob's swing will become slightly lower with each swing, because some energy is lost, or wasted, through heating. This is due to air resistance.

The idea of conservation of energy can be applied to a range of energy transfers, eg crash barriers or footballs being kicked. In an exam you may be expected to apply this knowledge to unfamiliar situations.

Falling objects

You should be able to calculate the kinetic energy gained when an object falls from a given height.

Question

A diver who has a mass of 50 kg dives off a diving board 3.0 metres above the water level.

What is her kinetic energy when she reaches the water?

Answer

Kinetic energy gained = gravitational potential energy lost
Kinetic energy gained = weight × height

You must calculate her weight to use in this equation

Weight = mass × gravitational field strength
Weight = 50 kg × 10 N / kg
Weight = 500 N

Kinetic energy gained = weight × height
Kinetic energy gained = 500 N × 3 m
Kinetic energy gained = 1500 J

Now try a **Test Bite**.

Now try a **Test Bite** - higher tier.

Back to Revision Bite