Energy, power & efficiency

Key Stage 4 Revision Programme

Pupil Name	
Handbook Designed by	Dr Brooks

Timetable and Assignment Submission

Timetable – Tutorials

Tutorial	Date	Time	Location
1 (Baseline)			R305
2			R305
3			R305
4			R305
5			R305
6 (Final Assignment)			R305
7 (Feedback)			R305

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Course Rationale

Energy is the stuff that makes things happen.

The concept of energy is one of the most far-reaching and powerful ideas in all of physics. It allows us to understand and make predictions about a huge range of different phenomena - from the change in temperature of a mug of tea, to the speed of a rocket launched into space.

We can calculate all these things thanks to the *law of conservation of energy*. This law says that energy can be transferred from one form to another but can *never* be created or destroyed. Take a light bulb, for example. Some of the electrical energy used to power the bulb is transferred into useful light energy, while some of it is transferred to heat, or even to sound. However, because we can't create more energy, or make any disappear, the *total* energy (light + heat + sound) *must* be equal to the amount of electrical energy that we originally supplied.

No exceptions to this rule have ever been found. It is one of the fundamental laws that governs our universe, and as such, it forms the foundation for our understanding of it.

This course is designed to help you master the concept of energy in GCSE physics. In order to do this, we will reduce the topic into its smallest building blocks, that you will then practise and perfect. This approach is based on a simple idea; to master something, you need to break it down into its fundamentals, practise it piece by piece, and only then, put it all back together.

Sports stars and musicians are used to learning this way. For example, world-class footballers don't just improve by playing matches—they also train their footwork and ball skills through drills and set pieces. Similarly, before they take to the stage, master pianists train by practising scales and rehearsing compositions bar by bar. This method of *deliberate practice* applies to mastering concepts in physics too — and that's the approach we will take in this course. By the end of it, I hope you will feel like an energy *expert*, confident to take on any question your GCSE exam might put in your path.

Uni Pathways knowledge organiser
Energy, power & efficiency

1. Energy stores		
1	Conservation of energy [4.1.2.1]	Energy can be transferred between different energy stores, but it cannot be created or destroyed.
2	Kinetic energy [4.1.1.2]	Kinetic energy is the energy an object has due to its motion. $$E_k = \frac{1}{2}mv^2$$ Kinetic energy, E_k in joules (J) Mass, m in kilograms (kg) Velocity, v in metres per second (m/s)
3	Elastic potential energy [4.1.1.2]	Elastic potential energy is the energy stored in a stretched, or compressed, spring. $$E_e = \frac{1}{2}ke^2$$ Elastic potential energy, E_e in joules (J) Spring constant, k in newtons per metre (N/m) Extension, e in metres (m)
4	Gravitational potential energy [4.1.1.2]	Gravitational potential energy is the energy an object has due to being raised above the ground. $$E_p = mgh$$ Gravitational potential energy, E_p in joules (J) Mass, m in kilograms (kg) Gravitational field strength, g in newtons per kilogram (N/kg) Height above the ground, h in metres (m)
5	Thermal energy [4.1.1.3]	Thermal energy is the energy transferred to, or from, a system as its temperature changes. $$\Delta E = mc\Delta\Theta$$ (Change in) thermal energy, ΔE in joules (J) Mass, m in kilograms (kg) Specific heat capacity, c in joules per kilogram per degree Celsius (J/kg°C) Temperature change, $\Delta\Theta$ in degrees Celsius (°C)

1. Energy stores - continued		
6	Work done [4.5.2]	Work done is the energy transferred when a force causes an object to be displaced. $$W = Fs$$ Work done, W in joules (J) Force, F in newtons (N) Distance moved along the line of action of the force, s in metres (m)

2. Power & efficiency		
1	Power [4.1.1.4]	Power is the rate at which energy is transferred, or the rate at which work is done. $$P = \frac{E}{t} \quad \text{or,} \quad P = \frac{W}{t}$$ Power, P in watts (W) Energy transfer E, or work done, W in joules (J) Time, t in seconds (s)
2	Dissipation of energy [4.1.2.1]	During most energy transfers, some energy is 'wasted', i.e. it is transferred to a an energy store that is not useful. This energy is said to be 'dissipated'. Often energy is dissipated as thermal energy to the surroundings.
3	Efficiency [4.1.2.2]	Efficiency measures how much of the energy supplied to a device is transferred usefully: $$efficiency\ (\%) = \frac{useful\ output\ of\ energy\ transfer}{total\ input\ of\ energy\ transfer}\ x\ 100$$ Or, $efficiency\ (\%) = \frac{useful\ power\ output}{total\ power\ input} x\ 100$

References

AQA AS and A-LEVEL PHYSICS (8463) Specification (2016) available at https://www.aqa.org.uk/subjects/science/gcse/physics-8463
GCSE Physics: The complete course for AQA, CGP (2016)

Tutorial 1: Baseline Assessment

In this tutorial we will check your current understanding of energy, power and efficiency, and identify any areas for improvement.

Remember...

- Attempt every question
- Always show your working
- Check your calculations
- Give units with every numerical answer
- Look at the marks available for each question to help you plan your time.

Good luck!

Tutorial 2: Kinetic energy

Keywords: kinetic, energy, mass, velocity

Objectives

A. Define kinetic energy
B. Calculate kinetic energy
C. Calculate mass and speed from kinetic energy

Starter

Which has more kinetic energy when moving at a speed of 5 m/s; a 5 kg medicine ball, or a 10 kg medicine ball?

Under what circumstances could their kinetic energies be equal?

Objective A: Define kinetic energy

Kinetic energy is the energy an object has due to its motion.

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

Kinetic energy, E_k in joules (J)
Mass, m in kilograms (kg)
Velocity, v in metres per second (m/s)

Practice A: Define kinetic energy

1. State the equation for kinetic energy, defining the symbols you use.

2. Write a sentence describing kinetic energy in words

3. Rank the following from low to high kinetic energy: a car travelling on a motorway, a falling raindrop, a jumbo jet in flight, a racing marathon runner.

4. Explain two ways that the kinetic energy of a car could be increased.

Assessment A: Define kinetic energy

Which of the following statements are true? Which are false?

- If two objects are travelling at the same speed, the heavier object will have more kinetic energy.
- Kinetic energy is directly proportional to speed.
- Stationary objects do not have kinetic energy.
- To calculate kinetic energy, the mass must be in grams.
- There is a factor of 1/2 in the formula for kinetic energy.

Objective B: Calculate kinetic energy

Worked example 1

A 1000 kg car is travelling at 25 m/s. How much kinetic energy does the car have?

In the question we are given that the mass is 1000 kg, and the speed is 25 m/s. Using these values in the equation for kinetic energy:

Kinetic energy = 0.5 x 1000 x 25 = **12,500 J**

Worked example 2

A 20 g paper plane is thrown across a room at 2 m/s. What is its kinetic energy?

Kinetic energy = 0.5 x 0.2 x 2 = **0.2 J**

Study tip
In this question, the mass is given in grams.

We need to convert it into kilograms by dividing by 1000.

Practice B: Calculate kinetic energy

1. Mass = 0.86 kg; speed = 2.5 m/s. What is the kinetic energy?

   A: 1.1 J
   B: 5.4 J
   C: 2.7 J
   D: 2.2 J

2. An elephant of mass 1,800 kg runs at a constant speed of 3.5 m/s. How much kinetic energy does it have?

3. In 2016, Cate Campbell set the Olympic record for the women's 100 m freestyle, with a time of 52.71 s. If Cate's mass was 74 kg, how much was her kinetic energy during the race? You should assume she swims at constant speed.

4. A 4.2 g bullet travels at 1, 700 mph. How much kinetic energy does it have? 1 mile = 1.6 km.

5. A cheetah has a mass of 70 kg.
   What it its kinetic energy when running at a speed of 110 mph?
   1 mile = 1.6 km.

   A: 423,500 J
   B: 83,654 J
   C: 3, 850 J
   D: 167,309 J

6. **Challenge!** Calculate the kinetic energy of the Earth due to its rotation around the Sun.
   <u>Key data:</u>
   Mass of Earth = 6 x10^{24} kg; Distance from Earth to Sun = 150 million km

Assessment B: Calculate kinetic energy

A 3 mg snowflake falls at a terminal velocity of 3 m/s.
What is its kinetic energy?

A: 13.5 J
B: 1.35 x 10^{2} J
C: 1.35 x 10^{-5} J
D: 1.35 x 10^{-2} J

Objective C: Calculate mass and velocity.

If you already know the kinetic energy of an object, you can figure out either its mass or its speed…

Worked example 1: Finding mass

During flight, an aeroplane travels at 240 m/s. If its kinetic energy is 2.4 GJ, what is the mass of the craft?

Step 1: Rearrange the KE equation to make mass the subject…

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

Step 2: Substitute in our known values for KE and v…

$$m = \frac{2\ x\ 2.4\ x10^9}{240^2} = 83{,}333\ kg$$

Worked example 2: Finding speed

A skier has a mass of 80 kg. If his kinetic energy is 5,760 J, how fast must he be travelling?

Step 1: Rearrange the KE equation to make velocity the subject…

$$v = \sqrt{\frac{2KE}{m}}$$

Step 2: Substitute in our known values for KE and m…

$$v = \sqrt{\frac{2\ x\ 5760}{80}} = 12\ m/s$$

Study tip
Don't forget the square root!

Practice C: Calculating mass and velocity.

1. KE = 500 J, speed = 4.8 m/s. What is the mass?

2. A skateboarder of 55 kg has 248 J of kinetic energy. What speed is she travelling at?

3. A cruise ship has a mass of 100,000,000 kg. If the ship's kinetic energy is 6.7 GJ, how long will it take to cross from Miami to The Bahamas, a distance of 180 miles?

Assessment C: Calculating mass and velocity.

The mass of a cyclist and her bike is 75 kg. What speed must she be travelling at if the kinetic energy is 15 kJ?

A	400 m/s
B	40 m/s
C	20 m/s
D	0.63 m/s

Apply!

In tropical regions, mosquitos can carry malaria.

A mosquito has a mass of 5 mg. Given that its kinetic energy is 0.8 mJ, how far will it travel in one hour?

A group of mosquitos becomes infected after biting a person suffering from malaria. If the mosquitoes' average flight speed is the same as you calculated above, how large is the geographical area at risk after 12 hours?

Tutorial 3: Gravitational potential energy

Keywords: potential energy, mass, height, gravitational field strength

Objectives:

A) Define gravitational potential energy
B) Calculate gravitational potential energy, mass & height
C) Convert between gravitational potential energy and kinetic energy

Starter

Look at the picture above. Can you describe the energy transfers that occur during this rollercoaster ride?

When will the riders have the most gravitational potential energy? When will they have the least? What about their kinetic energy?

Objective A: Defining elastic potential energy

Gravitational potential energy (GPE) is the energy an object has due to being raised above the ground.

$$E_p = mgh$$

Gravitational potential energy, E_p in joules (J)
Mass, m in kilograms (kg)
Gravitational field strength, g in newtons per kilogram (N/kg)
Height above the ground, h in metres (m)

Practice A: Defining elastic potential energy

1. State the equation for gravitational potential energy, defining the symbols you use.

2. Write a sentence describing gravitational potential energy in words

3. Rank the following from low to high kinetic energy: a rhino balancing on a ball, an egg on a kitchen work top, a person in a hot air balloon.

4. Explain two ways that the gravitational potential energy of a pigeon could be increased.

Assessment A: Defining elastic potential energy

Which statements are true, and which are false?

A	Gravitational potential energy is directly proportional to mass
B	In a mechanic's garage, a motorbike and a truck are both jacked 1 m above the floor. The motorbike stores more GPE than the truck.
C	Gravitational potential energy is stored by doing work against the gravitational force.
D	During an experiment, I lift a Newton meter 1 m above the earth. If I do the same experiment on the moon, I will store less GPE in the Newton meter.

Objective B: Calculate GPE, mass & height

Worked example 1: Finding GPE

A diving platform is 10 m above the ground. When an 80 kg diver climbs to the top of the platform, how much GPE does he acquire?

Solution

In the question we are given that the mass is 80 kg, and the height is 10 m. If no value is given, we can assume that the gravitational field strength on Earth is 10 N/kg.

Using these values in the equation for GPE:

$GPE = 80\ x\ 10\ x\ 10 = 8{,}000$ J

Worked example 2: Finding mass

The record for the highest hot air balloon flight is 21,027 m. At this height, the balloon had an estimated 735 MJ of GPE. What was the mass of the balloon?

Solution

Step 1: Rearrange the GPE equation to make mass the subject:

$$m = \frac{E_p}{gh}$$

Step 2: Substitute in our known values for GPE, h and g:

$$m = \frac{735\ 000\ 000}{10\ x\ 210127} = 3{,}500\ kg$$

Worked example 3: Finding height

At what height would the same hot air balloon have 50 kJ of GPE?

Solution

Step 1: Rearrange the GPE equation to make height the subject:

$$h = \frac{E_p}{mg}$$

Step 2: Substitute in our known values for GPE, h and g:

$$h = \frac{50\ 000}{3500\ x\ 10} = 1.4\ m$$

Practise B: Calculate GPE, mass & height

1. Mass = 4.87 kg, height = 54 cm. Calculate the GPE.
2. Compare the gravitational potential energy of the motorbike and the truck in Assessment A. Take the truck's mass to be 5000 kg, and the bike's mass to be 120 kg.
3. If a 6 kg eagle in flight has 900 J of GPE, how high is it flying above the earth? A smaller bird would have to travel at twice this height to store as much GPE. What is the mass of the smaller bird?

Assessment B: Calculate GPE, mass & height

Which statements are true, and which are false?

A	A 65 kg bungee jumper stood over a 80 m drop has 52000 J of GPE
B	A 130,000 kg jet plane must reach an altitude of 1 km to gain 1.3 GJ of GPE
C	Tom Cruise hangs off the edge of a 1.2 km – high cliff face. If he has 81 000 J of GPE then he must have a mass of 75 kg.
D	A bowling ball has a mass of 7 kg. If the gravitational field strength on the moon is 1.6 N/kg, how much GPE is stored when it is lifted 0.5 m from the moon's surface?

Objective C: Convert between GPE and kinetic energy

Worked example 1:

Kris is at the top of a 5 m high slide. Assuming that all of her GPE is converted to KE, what will be her maximum speed when she reaches the bottom? Kris has a mass of 55 kg.

Solution

Step 1: Calculate Kris's GPE at the top of the slide:

$$GPE = 55 \ x \ 10 \ x \ 5 = 2750 \ J$$

Step 2: As Kris slides down, her GPE is converted to KE. At the bottom of the slide, all her GPE will have been converted to KE, i.e. her KE equals 2750 J.

Next, rearrange the KE equation to find her speed:

$$v = \sqrt{\frac{2KE}{m}}$$

Step 2: Substitute our known values for m and KE:

$$v = \sqrt{\frac{2 \ x \ 2750}{55}} = 10 \ m/s$$

Study tip
Here we assumed that **all** of the GPE was converted to KE. However, in the real world some energy would be dissipated as heat, due to friction and air resistance. This means that Kris's true speed will be **less** than we have calculated here.

Worked example 2:

Roger Federer hits a tennis ball of mass 50 g directly upwards in the air, at a velocity of 25 m/s. What is the maximum possible height the ball could reach?

Solution

Study tip
Don't forget to convert grams into kilograms to use the KE equation!

Step 1: Calculate the ball's initial kinetic energy

$$KE = \frac{1}{2}\ x\ m\ x\ v^2 = 0.5\ x\ 0.05\ x\ 25^2 = 15.6\ J$$

Step 2: The maximum possible height that the ball could reach would be if all this KE was converted to GPE, i.e the GPE becomes 15.6 J.

Next, rearrange the GPE equation for height:

$$h = \frac{E_p}{mg}$$

Step 3: Substitute in the known values for GPE, mass, and gravitational field strength:

$$h = \frac{15.6}{0.05\ x\ 10} = 31.3\ m$$

Did you know?

We don't really **need** to know the mass to solve this problem!

We could have started by setting the KE and GPE equations equal to each other to get:

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

Notice that we have m on both sides, so we can cancel out a factor of m to get:

$$\frac{1}{2}v^2 = gh$$

Then all we need to do is to rearrange this equation for the height...

$$h = \frac{v^2}{2g}$$

...and finally, put in our known values!

Practise C: Convert between GPE and kinetic energy

1. Dr Who chases a dangerous alien to the top of the Eiffel tower in Paris. If she were to drop her sonic screwdriver from this height, what is the maximum speed it could reach when it hits the floor? Ignore air resistance and assume that all the GPE is converted to KE. The Eiffel Tower is 300 m high, and the screwdriver has a mass of 113 grams.

2. A bullet of mass 11.3 g is fired directly up into the air with an initial KE of 3.6 kJ. What is the bullet's initial velocity? What is the maximum height the bullet could reach?

3. Felix Baumgartner was the first human being to travel faster than sound, without the aid of a vehicle! He achieved this by jumping out of a hot air balloon at a height of 39 km. His total mass, (including his special space suit) was 120 kg.

   How far did Felix fall before he broke the sound barrier? Sound travels at 343 m/s.

Assessment C: Convert between GPE and kinetic energy

An irresponsible tourist drops a penny of mass 2.5 g from the top of the Burj Khalifa in Dubai. The Burj Khalifa is 828 m high.

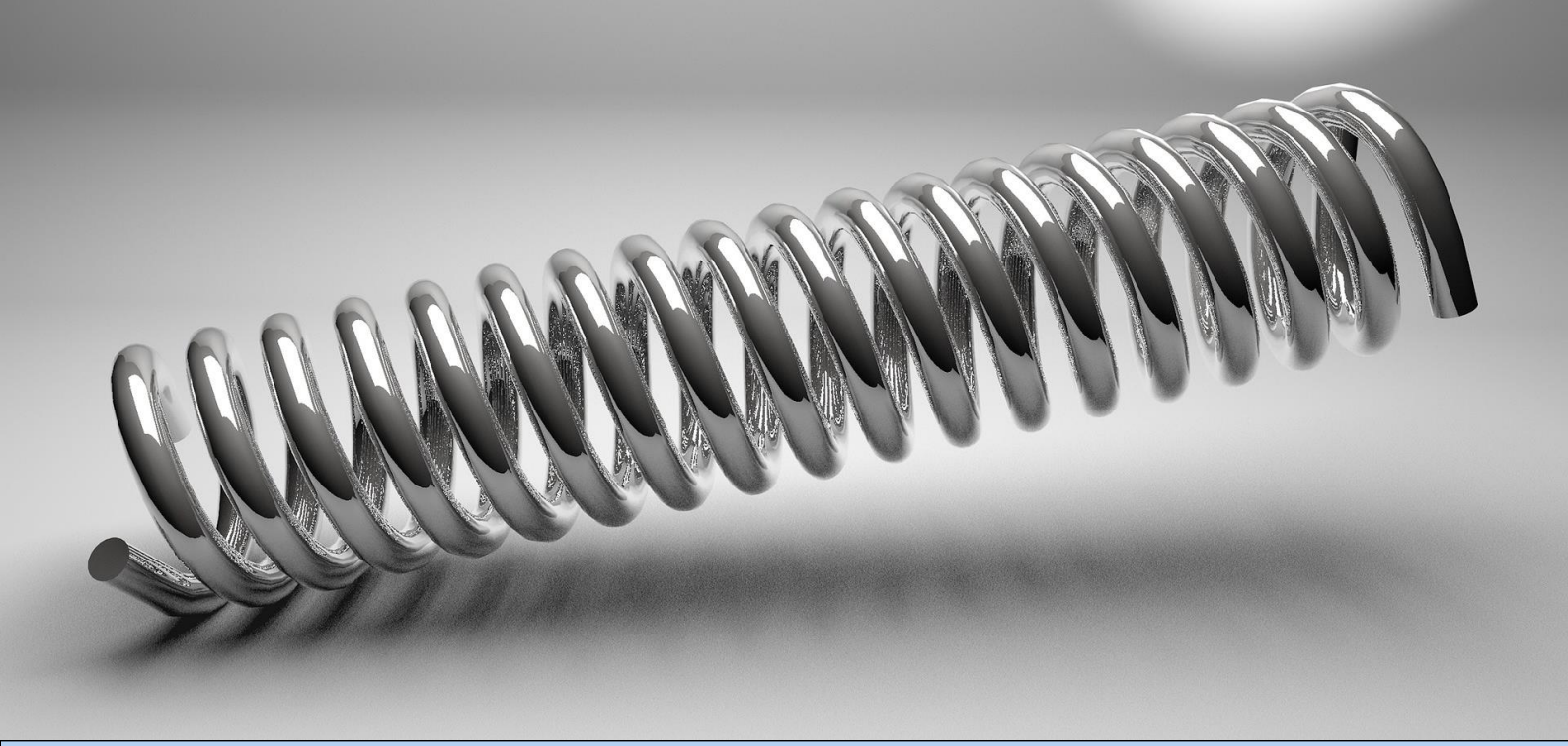
Which statements are true, and which are false?

A	The penny's GPE at the top of the Burj Khalifa is 20.7 kJ
B	The penny's GPE at the top of the Burj Khalifa is 20.7 J
C	The maximum velocity of the penny as it hits the ground is 16.5 km/s
D	The maximum velocity of the penny as it hits the ground is 0.129 km/s

Apply!

A squirrel jumps from a tree.

1. Describe the energy transfers that occur.
2. What is the minimum information that you would require to calculate the squirrel's speed as it hits the ground?
3. Explain the assumptions you would be making to complete this calculation.
4. Estimate values for the information you identified in (2) and use these to calculate the squirrel's speed as it lands.



Tutorial 4: Elastic potential energy

Keywords: spring constant, extension, joules.

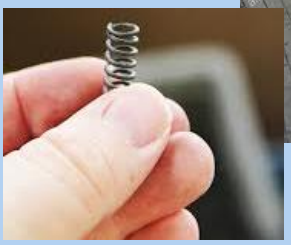
Objectives:

A) Define elastic potential energy
B) Calculate elastic potential energy
C) Convert between elastic potential and other forms of energy

Starter

Which of these springs has a larger spring constant:

a) Spring on a car's suspension.
b) Small (2 cm) spring.



Objective A: Defining elastic potential energy

Elastic potential energy is the energy stored in a stretched, or compressed, spring or elastic material:

$$E_e = \frac{1}{2}ke^2$$

Elastic potential energy, E_e in joules (J)
Spring constant, k in newtons per metre (N/m)
Extension, e in metres (m)

The spring constant is a measure of how much force is needed to stretch/compress the object.

Practice A: Defining elastic potential energy

1) State the equation for elastic potential energy, defining the terms used.

2) Write a sentence defining elastic potential energy in words.

3) You join two springs together and hang a mass off the bottom of them. How does the extension of both springs compare to the extension of one?

4) Describe the energy changes that occur when a rubber band is stretched, let go, flies straight up into the air and then falls back down to the ground.

Assessment A: Defining elastic potential energy

Which statements are true, and which are false?

A	A spring constant of 5 Nm means that it takes 5 Newtons of force to stretch the spring by 1 metre.
B	$k = E_e/(0.5 \times e^2)$.
C	Elastic potential energy is directly proportional to the extension.
D	Spring constant has units of Nm, and extension has units of metres.

Objective B: Calculating elastic potential energy

Worked example 1

How much work must be done to compress a spring by 4.0 cm if the spring constant is 55 N/m?

To compress (or stretch) a spring, work must be done on it, i.e. we must transfer some energy to it. This energy is stored in the spring as elastic potential energy (EPE). This means that if we calculate the elastic potential energy stored in the spring, we are also calculating the work

done on the spring (they are the same thing!). In the question we are given that the spring constant is 5.5 N/m, and the compression is 4.0 cm. Substituting these values into the equation for elastic potential energy, we have:

$E_e = 0.5 \times 55 \times 0.04^2$
$E_e = 0.044$ joules

> **Study tip**
> Don't forget to convert non-standard units (cm) into standard units (m)! Remember, 1 cm = 0.01 m

Worked example 2

A coil spring on a car's suspension has k = 64 kN/m. When the car strikes a bump, the spring briefly stores 80 joules of energy. How much does the spring compress?

Step 1: Rearrange the EPE equation to make compression, 'e', the subject:

$$e = \sqrt{\frac{2\,E_e}{k}}$$

Step 2: Substitute in our known values for k and E_e:

$e = \sqrt{((2 \times 80) \div 64{,}000)}$
$E_e = 0.05$ metres

> **Study tip**
> Note the unit conversion:
> 1 kN/m = 1,000 N/m

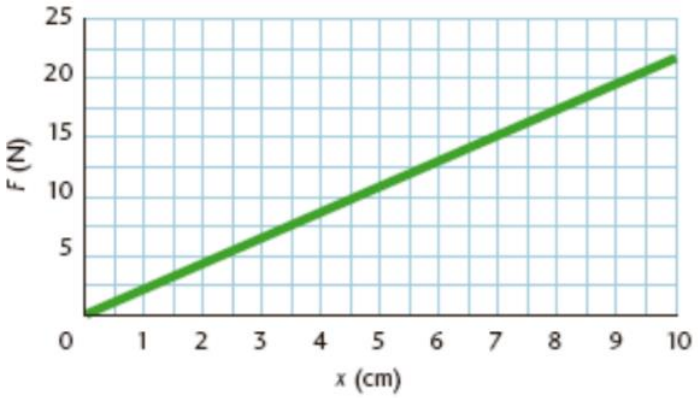
Practice B: Calculating elastic potential energy

1. Solve for each unknown:

   a) A spring with k = 45 N/m is compressed by 13 cm. How much **energy** is stored?
   b) A spring with k = 520 N/m stores 7.04 J. How far is it **extended** from the equilibrium position?
   c) A spring, when compressed 20 cm from the equilibrium position, stores 26 J. What is the value of the **spring constant?**

2. A spring attached to a ceiling has a mass of 500 g suspended from it such that the spring stretches 4.0 cm. Calculate the **spring constant**. (g = 10 N/kg)

3. Below is a graph of F versus e for an elastic spring. Determine:
   a) The spring constant.
   b) The spring's maximum amount of elastic potential energy.
   c) The change in elastic potential energy when the spring extends from 3 cm to 4 cm.



Assessment B: Calculating elastic potential energy

At maximum extension a bungee cord stores 2.0×10^6 J of energy. A 10 kg mass extends the bungee cord 1.3 m. What is the maximum extension of the bungee cord?

A	230 m
B	0.23 m
C	0.46 m
D	460 m

Objective C: Convert between elastic potential and other forms of energy

Worked example 1

An elastic band of spring constant 5 N/m and mass 2 g is stretched by 15 cm and shot directly up in the air. Calculate the maximum height that the elastic band reaches.

To solve this problem, we need to think about the energy transfers that occur when the rubber band is stretched and then released:

- Initially, energy is stored in the band as elastic potential energy.
- When the rubber band is released, its elastic potential energy is transferred into kinetic energy, and it shoots upwards.
- As it moves upwards, its kinetic energy is converted into gravitational potential energy.
- At the band's maximum height, it has no more kinetic energy, since it has all been transferred into gravitational potential energy.

In the question we are given the spring constant and the extension, so we can find the initial elastic potential energy. We also know that at the maximum height, all the elastic potential energy has been converted into gravitational potential energy. This means that we can use the equation for gravitational potential energy to work back and find the maximum height.

Step 1: Calculate the elastic potential energy:

e = 15 cm = 0.15 m
k = 5 N/m

$E_e = 0.5 \times k \times e^2$

$E_e = 0.5 \times 5 \times 0.15^2$
$E_e = 0.056$ joules

> **Study tip**
> Don't forget to convert into standard units!

The EPE is all converted into GPE; therefore the GPE is also 2×10^{-6} Joules.

Step 2: Rearrange the GPE equation to make h the subject:

$$h = \frac{E_p}{mg}$$

h = 0.056 ÷ (0.002 x 10)
h = 2.8 metres

Practice C: Convert between elastic potential and other forms of energy

1. An arrow of mass 300g is shot directly upwards by a bow of spring constant 2000 N/m, that is extended by a distance of 20 cm. Calculate:
   a) The maximum elastic potential energy stored by the bow.
   b) The initial velocity of the arrow.
   c) The maximum height that the arrow reaches. (g = 9.8 N/kg)

2. A student stretches a 5 g elastic band by 20 cm, and aims it directly at the teacher. The student gets 10 minutes of detention for each m/s of velocity with which the band hits the teacher. The spring constant of the elastic band is 20 N/m. How long is the student's detention?

Assessment C: Convert between elastic potential and other forms of energy

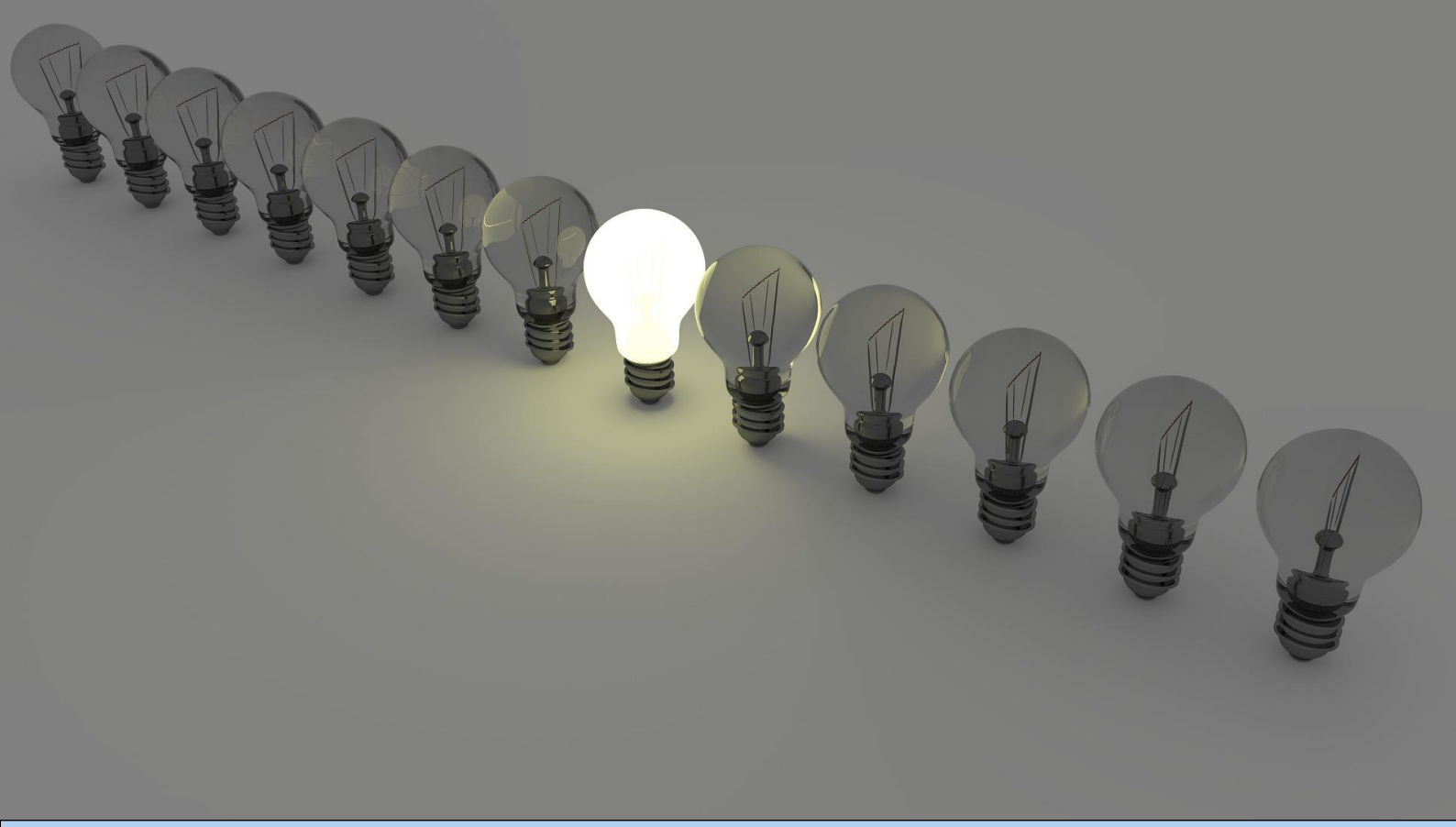
A boy bounces on a pogo stick (total mass 40 kg) of spring constant 3200 N/m. If the pogo stick is compressed by 50 cm, and all elastic potential energy is converted into gravitational potential energy; how high does the boy reach?

A	1.00 m
B	1000 m
C	2.00 m
D	0.100 m

Apply!

Your engineering team has been asked to design safety features for a lift. The 2,000 kg lift is suspended using steel cables, however, if these were to break, the lift could fall up to 15 m down the shaft.

You decide to install a large spring at the bottom of the shaft, to cushion the fall of the lift. When the lift falls onto the spring, the spring should compress by 2 m. What will you need the spring constant of your safety spring to be?



Tutorial 5: Power & efficiency

Keywords: power, efficiency, useful, input, output.

Objectives:

A) Define power
B) Define efficiency
C) Calculate power & efficiency

Starter
What makes an energy-efficient LED light bulb better than an incandescent filament bulb?

Why do scientists and engineers strive to make technology more efficient? What challenges do you think they might face?

Objective A: Defining power

Power is the rate at which energy is transferred, or the rate at which work is done.

$$P = \frac{E}{t} \quad \text{or,} \quad P = \frac{W}{t}$$

Power, P in watts (W)
Energy transfer E, or work done, W in joules (J)
Time, t in seconds (s)

Practice A: Defining power

1) State the equation for power, defining the terms used.

2) Write a sentence defining power in words.

3) Kettle A and Kettle B both transfer the same amount of energy to boil a cup of water. Kettle A takes 75 s to do this, while Kettle B takes 8 s. Which kettle is more powerful?

4) A woman is working out at the gym. She burns 7 calories per minute on the rowing machine, and 3 calories per minute weightlifting. During which exercise is she being more powerful?

Assessment A: Defining power

Which of the statements are true, and which are false?

A	If a microwave oven has a power rating of 700 W, this means it can transfer 700 J of energy each second
B	A hare and a tortoise race 100 m without stopping. The hare is more powerful than a tortoise.
C	A 100 W bulb is not as bright as a 60 W bulb.
D	Power can be defined in terms of work done, or in terms of energy transferred.

Objective B: Define efficiency

Efficiency measures how much of the energy supplied to a device is transferred usefully:

$$efficiency\ (\%) = \frac{useful\ energy\ output}{total\ energy\ input}\ x\ 100$$

It can also be calculated using the ratio of the power output to the total power input:

$$efficiency\ (\%) = \frac{useful\ power\ output}{total\ power\ input}\ x\ 100$$

Practice B: Define efficiency

1) State the equation for efficiency, defining the terms used.

2) Write a sentence defining efficiency in words.

3) Car A does 20 mpg (miles per gallon of fuel), while car B does 22 mpg. Which is more efficient?

4) When I cycle on a flat road, I am more efficient than when I cycle uphill. Suggest why this is the case.

Assessment B: Define efficiency

Which of the statements are true, and which are false?

A	Applying oil to the chain of a bike can improve its efficiency
B	Devices that are more powerful are always more efficient
C	Devices that are more powerful are always less efficient
D	Reducing the amount of energy that a device 'wastes' will make it less efficient.

Objective C: Calculate power & efficiency

Worked example 1

A light bulb is on for one hour, emitting 25 kJ of light energy. During this time, it transfers 216 kJ of electrical energy. What is the power rating of the bulb? How efficient is it?

Solution

Step 1: Calculate the power
We are told that the bulb is on for one hour, and transfers 216 kJ of electrical energy.

Substituting these values into the power equation gives:

$$P = \frac{E}{t} = \frac{216,000}{60 \times 60} = 60\ W$$

Study tip
Don't forget to convert hours into seconds!

Step 2: Calculate the efficiency

We are told that total (electrical) input energy is 216 kJ, and the useful (light) energy output is 25 kJ

Substituting these values into the efficiency equation gives:

$$efficiency\ (\%) = \frac{useful\ energy\ output}{total\ energy\ input}\ x\ 100 = \frac{25,000}{216,000} \times 100 = 11.6\ \%$$

Practice C: Calculate power & efficiency

1) A toaster transfers 110 kJ of energy in 2.5 mins. What is its power rating?
2) If the toaster in question 1 is 30% efficient, how much energy is usefully transferred?
3) A crane lifts a boulder of mass 500 kg through a height of 5 m. If this takes 30 seconds, what is the power of the crane?
4) The crane in question 3 'wastes' 5 kJ of energy while lifting the boulder. What is the efficiency of the crane?

Assessment C: Calculate power & efficiency

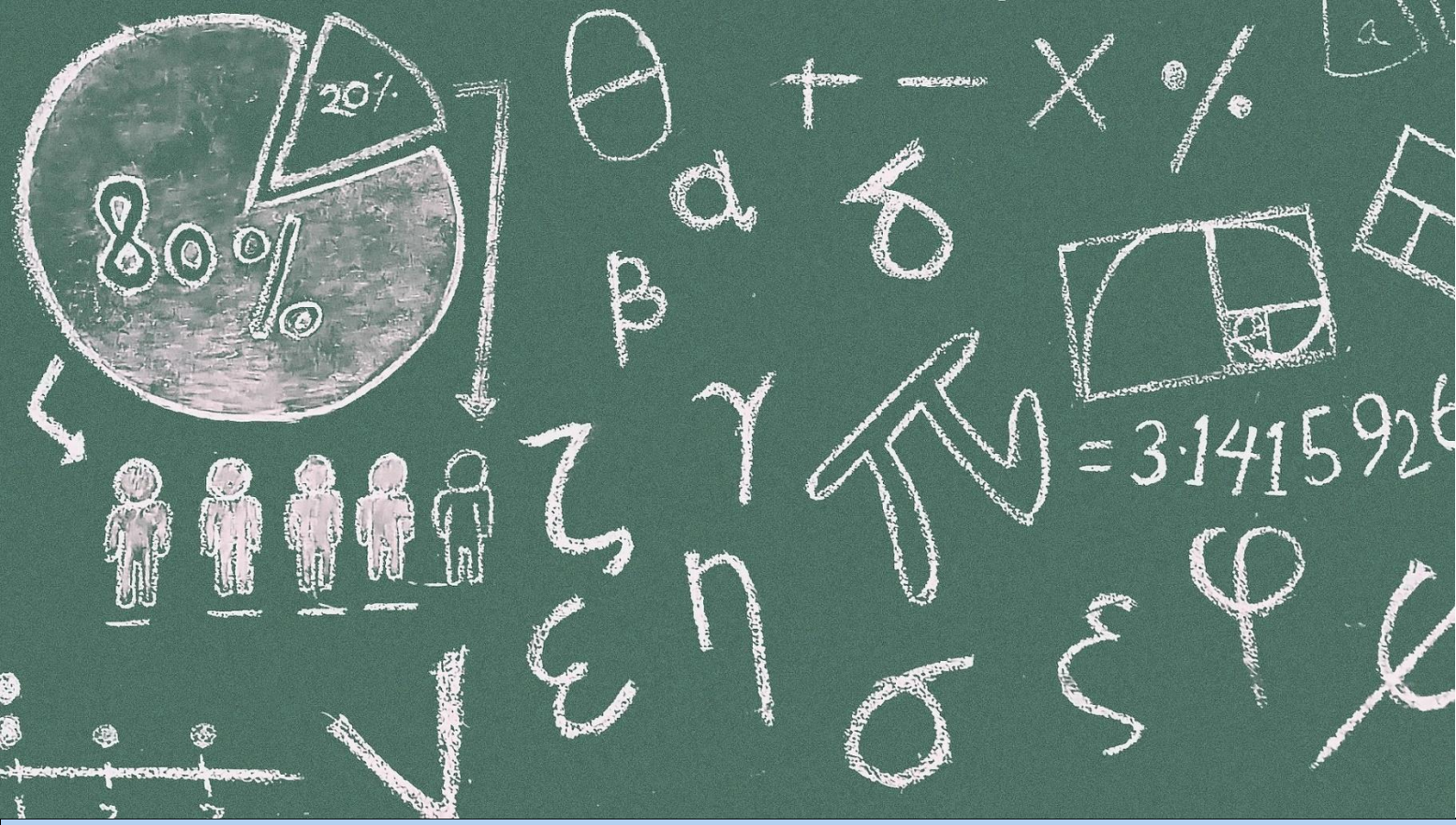
A toy car has a mass of 450 g. The toy is placed at the top of a ramp, such that it is raised 35 cm above the floor. The car takes 20 s to reach the bottom of the ramp, where it has a speed of 2.5 m/s. Calculate the power and the efficiency.

A	P = 70 W; efficiency = 8.9%
B	P = 70 mW; efficiency = 89%
C	P = 0.70 W; efficiency = 0.89%
D	P = 7.0 W; efficiency = 8.9%

Apply!

If the annual electrical energy consumption of the United States is 1.0×10^{19} J, what is the average rate of energy consumption in watts? If the population is around 300 million people, what is average rate of electrical energy consumption per person?

If the average efficiency of an electronic device is around 70 %, how much energy does each person waste, each day?



Tutorial 6: Final Assignment

Congratulations, you've now completed the whole revision course!

Now it's time to put it all together and see how your understanding has progressed.

<u>As with any test, don't forget to…</u>

- Read the question carefully
- Highlight the information given
- Attempt every question
- Always show your working
- Check your calculations
- Give units with every numerical answer
- Look at the marks available for each question to help you plan your time.

Good luck!

Tutorial 7 - Feedback

What is the Purpose of Tutorial 7?

- To receive feedback on final assignments.
- To share examples of best practice with the other pupils in your group.
- To write targets for improvement in school lessons.
- To reflect on the programme including what was enjoyed and what was challenging.

Final assignment feedback

What I did well...	What I could have improved on...
•	•
•	•
•	•

My target for future work is...

Reflecting on Uni Pathways

What did you most enjoy about Uni Pathways?

What did you find challenging about the programme?	How did you overcome these challenges?

Notes

Notes

Notes

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