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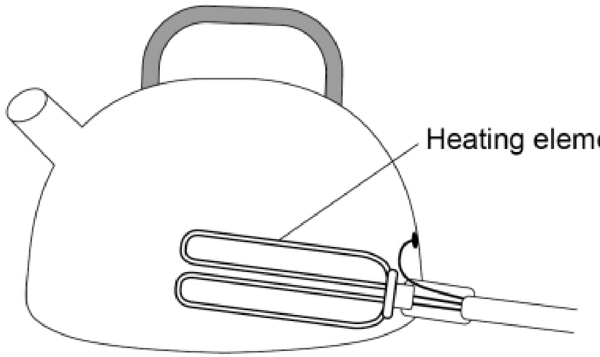
physics
aqa specification
energy
with solutions

0 5 A student investigated how the mass of water in an electric kettle affected the time taken for the water to reach boiling point.

The kettle switched off when the water reached boiling point.

Figure 4 shows the kettle.

Figure 4



0 5 . 1 The heating element of the kettle was connected to the mains supply.

Explain why the temperature of the heating element increased.

[2 marks]

electrons collide with particles in the heating element which increases the (kinetic) energy of the particles (in the heating element)

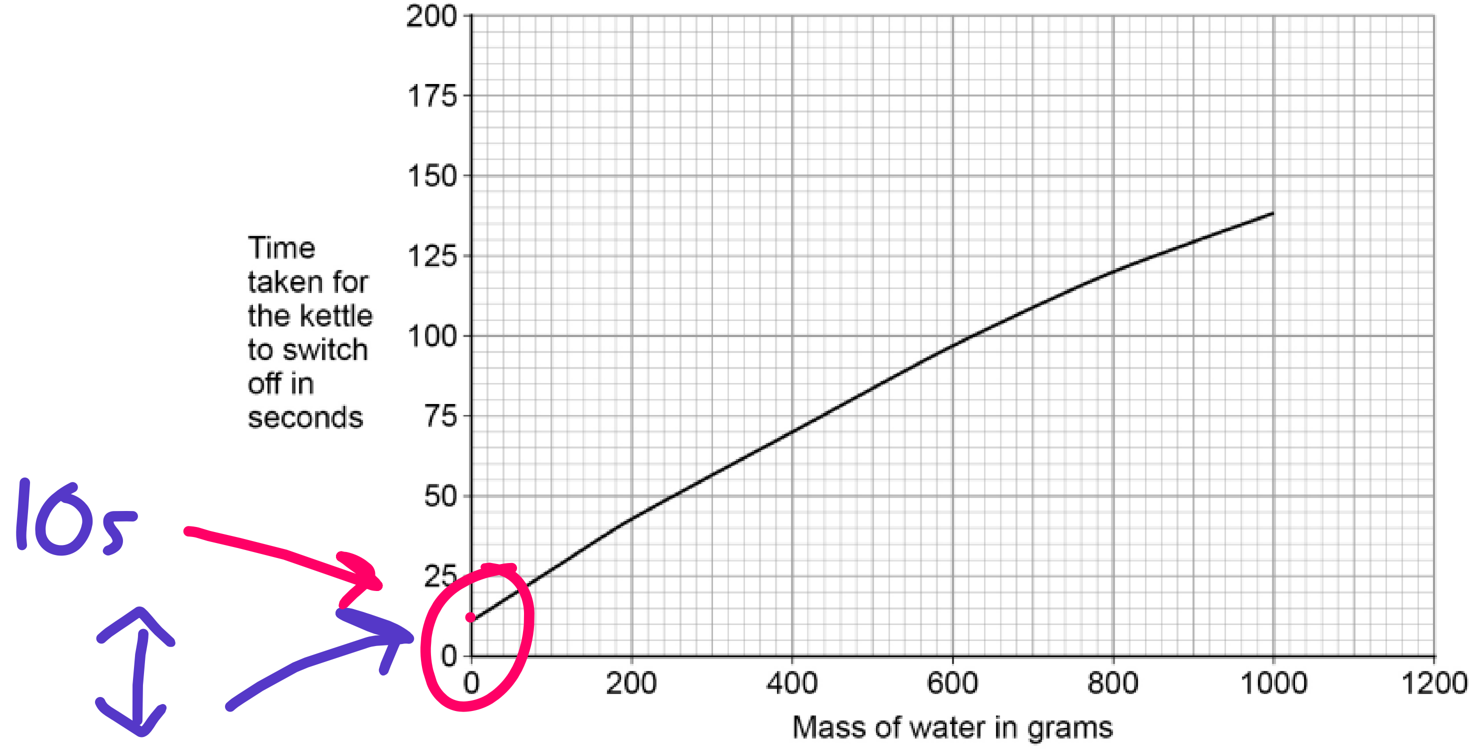
0 5 . 2 Give **one** variable that the student should have controlled.

[1 mark]

the starting temperature of the water

Figure 5 shows how the mass of water in the kettle affected the time taken for the kettle to switch off.

Figure 5



0 5 . 3 Suggest why the line on **Figure 5** does **not** go through the origin.

[1 mark]

(the heating element of) the kettle took time to heat up

0 5 . 4 Suggest why the results give a non-linear pattern.

[1 mark]

the (rate of) energy transfer (per kg of water) to the surroundings decreases as the mass of water increases

0 5 . 5 The power of the kettle was 2.6 kW — P – convert = 2600 W

The kettle took 120 seconds to heat 0.80 kg of water from 18 °C to 100 °C

Calculate the specific heat capacity of water using this information.

Give your answer to 2 significant figures.

t   c   m   Δθ   82 °C

[6 marks]

$E = P \times t$

$E = 2600 \times 120$

$E = 312000\ J$

$\Delta E = mc\Delta\theta$

$312000 = 0.8 \times c \times 82$

$c = \frac{312000}{(0.8 \times 82)}$

$c = 4756.1\ J/kg\,°C$

$c = 4800\ J/kg\,°C$ (to 2sf)

Specific heat capacity = ______________________ J/kg °C

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Table 1 shows information about three different light bulbs.

Table 1

Light bulb	Total power input in watts	Useful power output in watts	Efficiency
P	6.0	5.4	0.90
Q	40	2.0	0.05
R	9.0	**X**	0.30

0 1 . 4 Write down the equation which links efficiency, total power input and useful power output.

[1 mark]

$$Eff = \frac{\text{useful output}}{\text{total input}}$$

0 1 . 5 Calculate the value of **X** in **Table 1**.

[3 marks]

$0.3 = \frac{X}{9}$

$X = 9 \times 0.3 = 2.7$

X = 2.7 W

(6)

0 1 . 6 In addition to power input, light bulbs should also be labelled with the rate at which they emit visible light.

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Suggest why.

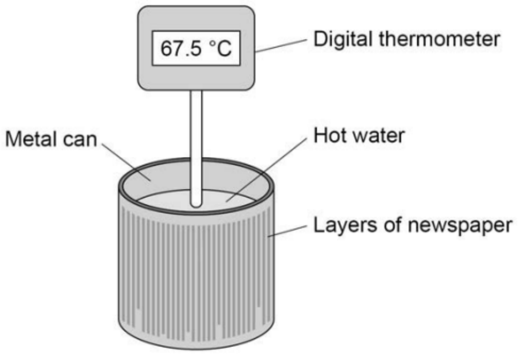
[2 marks]

bulbs also transfer thermal energy the efficiency of the light bulb also needs to be considered

0 2 A student investigated the insulating properties of newspaper.

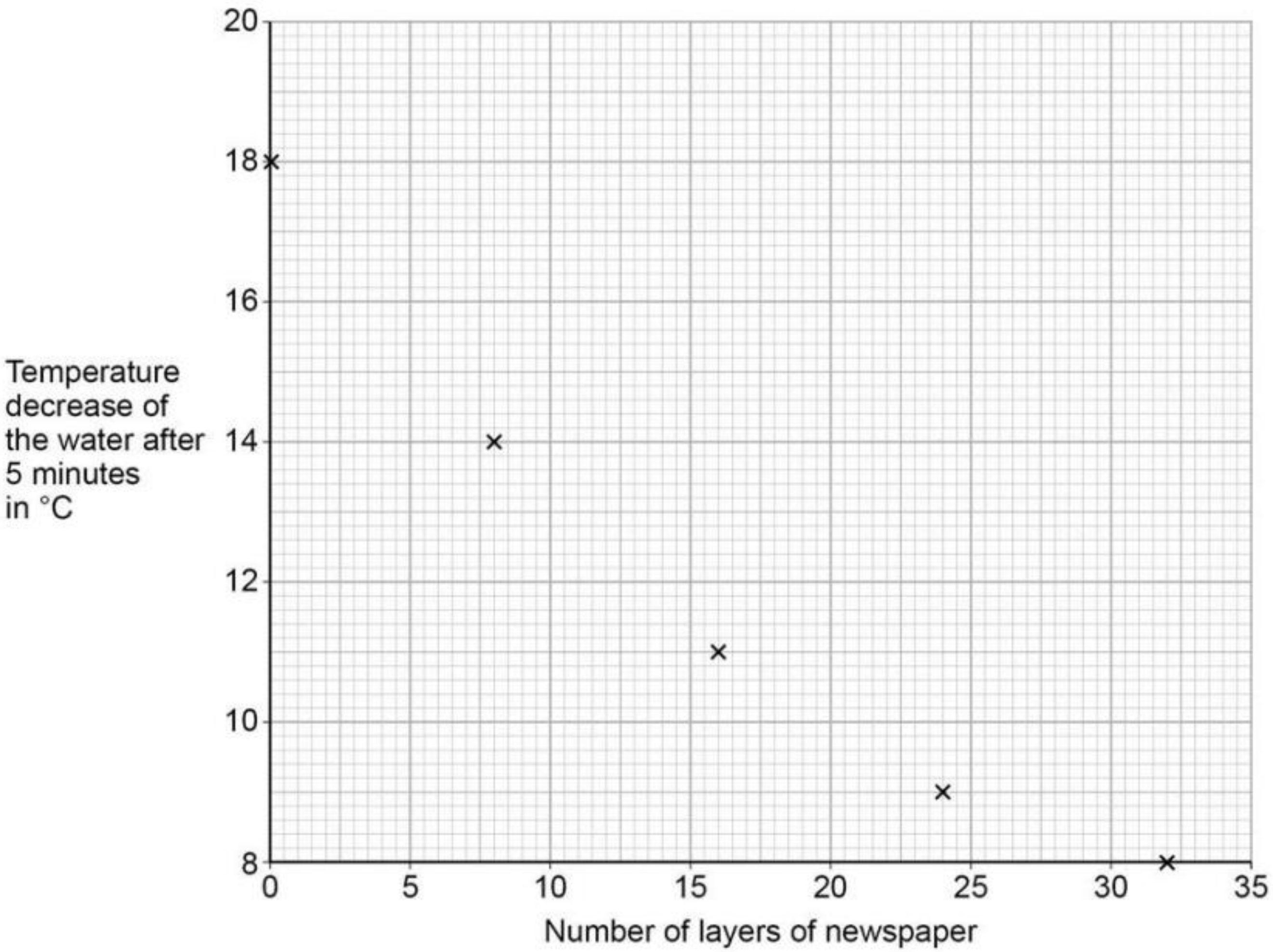
Figure 1 shows the apparatus the student used.

Figure 1



The student's results are shown in **Figure 2**.

Figure 2



0 2 . 1 Describe a method the student could have used to obtain the results shown in **Figure 2**.

[6 marks]

- Wrap N layers of newspaper around the metal can
- Heated water in a kettle

or

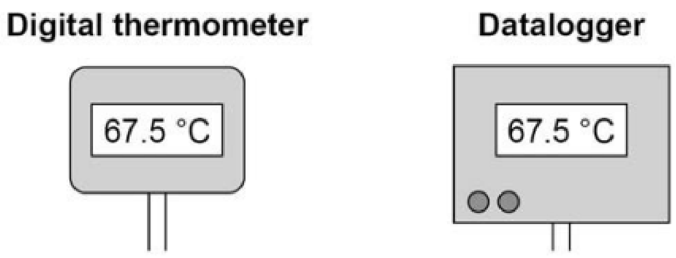
Using a Bunsen burner

- Put hot water in the metal can
- Use a measuring cylinder to measure the volume of water
- Measure initial and final temperature with the digital thermometer
- Use a stopclock / stopwatch to measure a time of 5 minutes
- Calculate temperature decrease
- Repeat with different number of layers of newspaper
- Repeat with no layers of newspaper
- Use same initial temperature of hot water
- Use same volume of water each time

0 2 . 2 The student could have used a datalogger with a temperature probe instead of the digital thermometer.

Figure 3 shows the readings on the digital thermometer and the datalogger.

Figure 3



The datalogger records 10 readings every second.

The student considered using a temperature probe and datalogger.

Explain why it was **not** necessary to use a temperature probe and datalogger for this investigation.

[2 marks]

the digital thermometer and the datalogger have the same resolution only need to measure the start and end temperature **or** only need 2 readings **or** only need to calculate the temperature change

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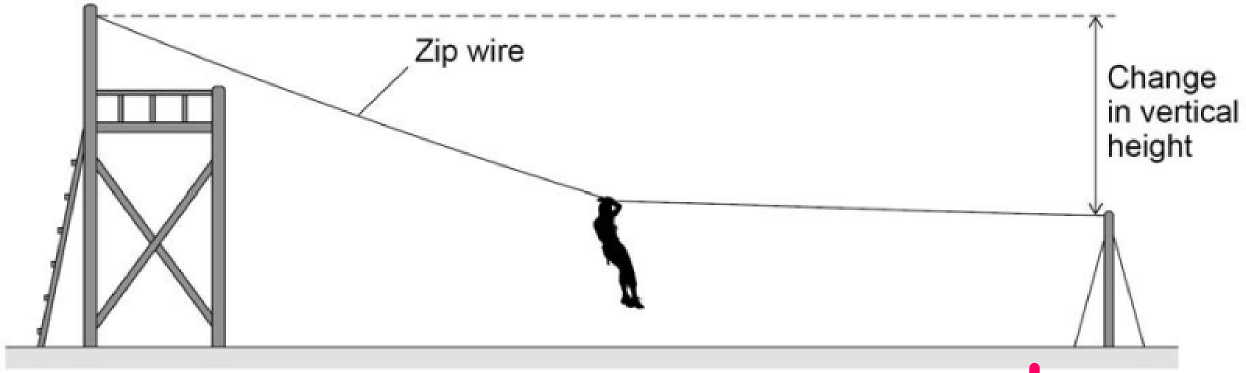
0 7 **Figure 9** shows a person sliding down a zip wire.

Figure 9



0 7 . 1 As the person slides down the zip wire, the change in the gravitational potential energy of the person is 1.47 kJ

The mass of the person is 60 kg

gravitational field strength = 9.8 N/kg

Calculate the change in vertical height of the person.

[3 marks]

convert ⇒ 1470 J

E_p → m, g, h

$E_p = mgh$

$1470 = 60 \times 9.8 \times h$

$\frac{1470}{60 \times 9.8} = h$

$h = 2.5\,m$

0 7 . 2 As the person moves down the zip wire her increase in kinetic energy is less than her decrease in gravitational potential energy.

Explain why.

[2 marks]

(work done against) air resistance or (work done against) friction (between zip line and pulley) causes thermal energy to be transferred to surroundings

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0 7 Kangaroos are large animals that travel by jumping.

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Figure 8 shows a kangaroo.

Figure 8

Each leg of a kangaroo has a tendon connected to a muscle. Each tendon can be modelled as a spring.

When a jumping kangaroo lands on the ground, the tendons stretch.

0 7 . 1 **Figure 9** shows a sketch graph of how the maximum tendon length during a jump changes with the speed of the kangaroo.

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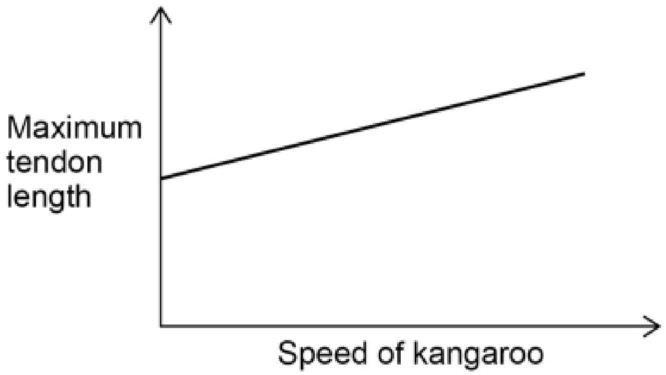
Figure 9



Explain why a kangaroo can jump higher as its speed increases.

[3 marks]

the (maximum tendon) extension increases (as speed increases) so the elastic potential energy increases which is transferred to gravitational potential energy

0 7 . 2 A kangaroo has a maximum gravitational potential energy during one jump of 770 J

When the kangaroo lands on the ground 14% of the maximum gravitational potential energy is transferred to elastic potential energy in one tendon.

The tendon has an unstretched length of 35.0 cm → e ←

When the kangaroo lands on the ground the tendon stretches to a length of 42.0 cm

Calculate the spring constant of the tendon. $42 - 35 = 7\,cm$

[5 marks]

$e = 0.07\,m$

E_p: $\frac{14}{100} \times 770 = 107.8\,J$

$E_e = \frac{Ke^2}{2}$ So $K = \frac{2E_e}{e^2}$

$K = \frac{2 \times 107.8}{(0.07)^2} = 44000\,N/m$

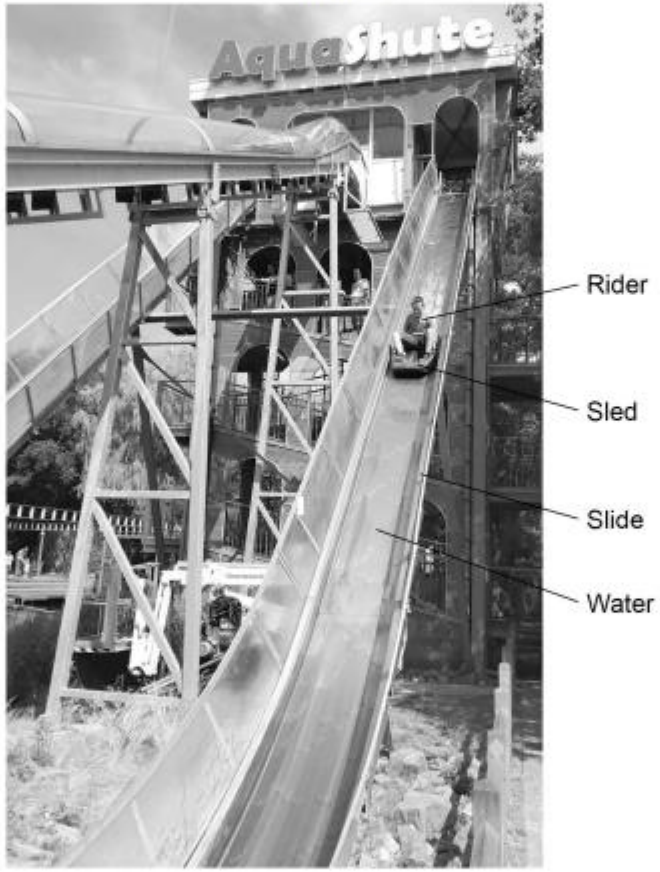
Spring constant = ______________ N/m

0 6

Figure 9 shows a theme park ride called AquaShute.

Riders of the AquaShute sit on a sled and move down a slide.

Figure 9



$v = \frac{s}{t}$ ← sled length ← time

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0 6 . 1 A light gate and data logger can be used to determine the speed of each rider and sled.

What two measurements are needed to determine the speed of a rider and sled?

[2 marks]

Tick (✓) **two** boxes.

Gravitational field strength	☐
Length of sled	✓
Mass of rider and sled	☐
Temperature of surroundings	☐
Time for sled to pass light gate	✓

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0 6 . 2 The decrease in gravitational potential energy of one rider on the slide was 8.33 kJ.

$E_p = 8330\,J$

The rider moved through a vertical height of 17.0 m. h

gravitational field strength = 9.8 N/kg g

Calculate the mass of the rider. m

[4 marks]

$E_p = m \times g \times h$ $\quad m = \frac{E_p}{g \times h}$

$m = \frac{8330}{9.8 \times 17} = 50\,kg$

Mass of rider = 50 kg

0 6 . 3 At the bottom of the slide, all riders and their sleds have approximately the same speed.

Explain why.

[4 marks]

v

$E_p = E_k$ at bottom

$\cancel{m} \times g \times h = \frac{\cancel{m} \times v^2}{2}$

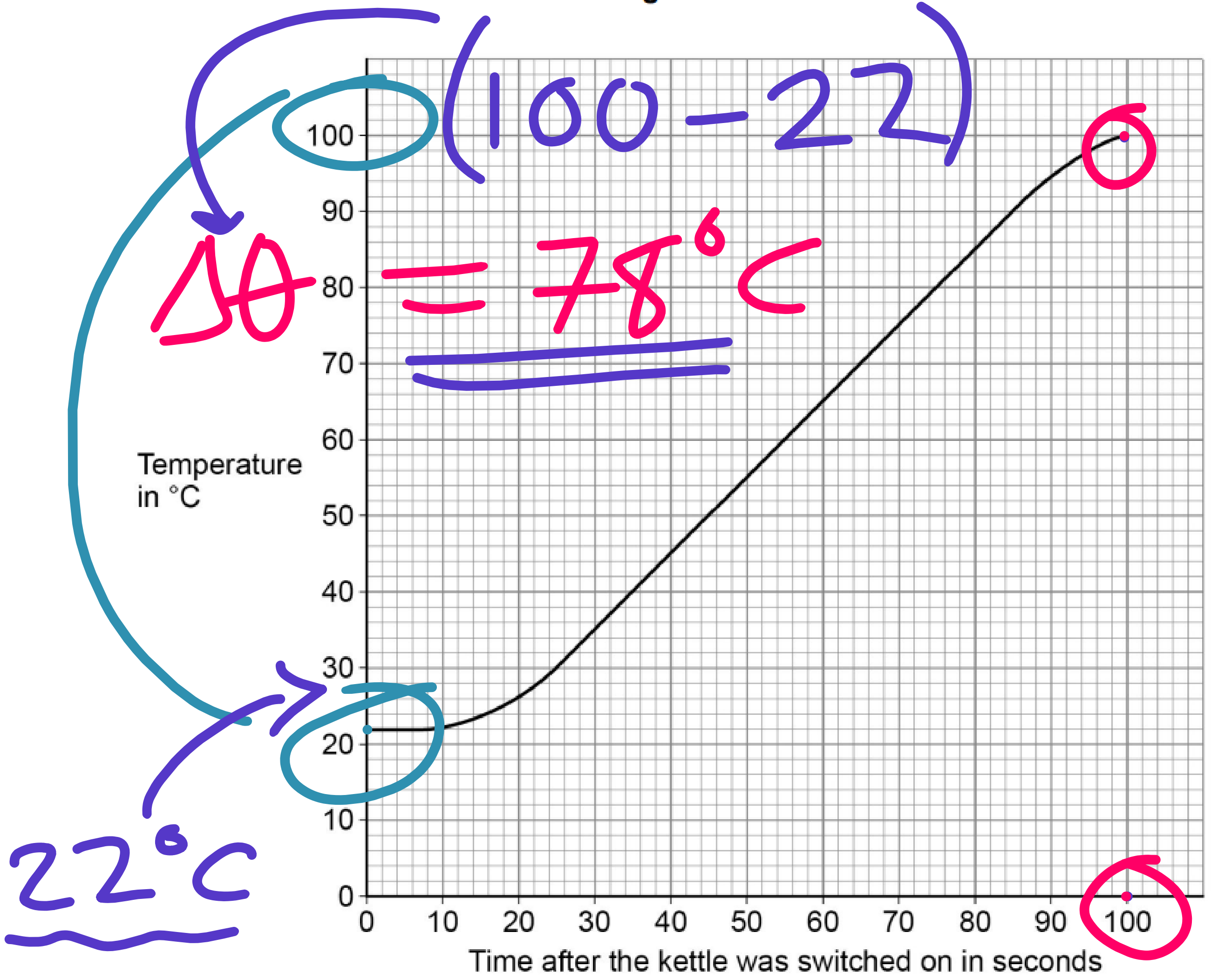
$v = \sqrt{2gh}$

(final) speed only depends on vertical height (and gravitational field strength)

0 7 An electric kettle was switched on.

Figure 10 shows how the temperature of the water inside the kettle changed.

Figure 10



0 7 . 2 The energy transferred to the water in 100 seconds was 155 000 J.

E

t

specific heat capacity of water = 4200 J/kg °C

c

Determine the mass of water in the kettle.

m

Use **Figure 10**.

Give your answer to 2 significant figures.

[5 marks]

See Graph. ($\Delta\theta$)

$\Delta E = mc\Delta\theta$

$155000 = m \times 4200 \times 78$

$m = \frac{155000}{(4200 \times 78)} = 0.47\,kg$

Mass of water (2 significant figures) = 0.47 kg

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See graph below . . .

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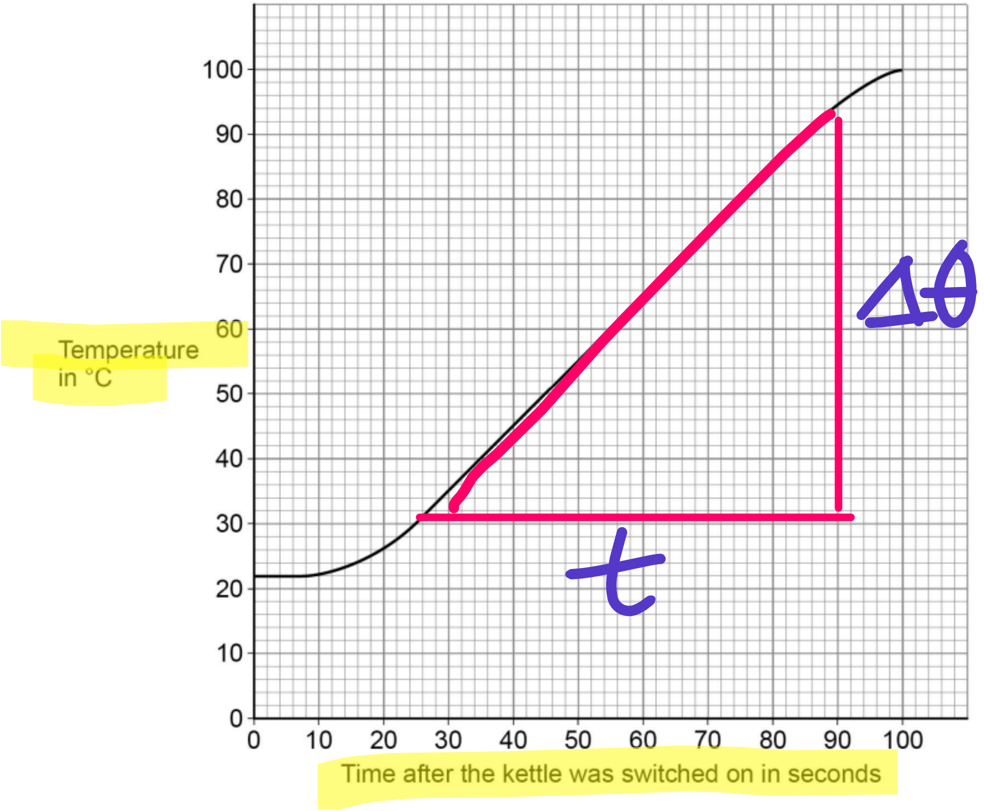
07.3 The straight section of the line in **Figure 10** can be used to calculate the useful power output of the kettle.

Explain how.

[3 marks]



$E = P \times t$

$mc\Delta\theta = P \times t$

$\left(\frac{mc\Delta\theta}{t}\right) = P$

gradient

0 3 **Figure 4** shows a sailing boat crossing an ocean.

Figure 4

There is a wind turbine on the boat.

0 3 . 4 The kinetic energy of the boat is 81 kJ.

$E_k = 81000\,J$

mass of boat = 8000 kg

m

Calculate the speed of the boat.

v

[4 marks]

$$E_k = \frac{m \times v^2}{2} \quad \text{so} \quad \sqrt{\frac{2E_k}{m}} = v$$

$$v = \sqrt{\frac{2 \times 81000}{8000}} = \sqrt{20.25}\ m/s$$

Speed = 4.5 m/s

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0 3 . 5 As the boat passes over a wave, the gravitational potential energy of the boat increases by 19 600 J. E_p

mass of boat = 8000 kg m

gravitational field strength = 9.8 N/kg g

Calculate the change in height of the centre of mass of the boat as it passes over the wave. h

[3 marks]

$E_p = m \times g \times h$

$h = \frac{E_p}{m \times g} = \frac{19600}{8000 \times 9.8}$

Change in height = 0.25 m

0 1 **Figure 1** shows a large wind farm off the coast of the UK.

Figure 1

The mean power output of the wind farm is 696 MW, which is enough power for 580 000 homes.

0 1 . 1 Calculate the mean power needed for 1 home.

Give your answer in watts.

[2 marks]

696 MW ≡ 696000000 W

1 home → $\frac{696000000}{580000}$

Mean power needed for 1 home = 1200 W

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0 1 . 2 On one day the demand for electricity in the UK was 34 000 MW.

Suggest **two** reasons why wind power was not able to meet this demand.

[2 marks]

1 • wind is unreliable

2 • wind turbines don't turn when the wind is too strong/weak

• there are not enough wind turbines (in the UK)

0 1 . 3 Some of the energy from the wind used to rotate a wind turbine is wasted.

An engineer oils the mechanical parts of a wind turbine.

Explain how oiling would affect the efficiency of the wind turbine.

[3 marks]

the efficiency would increase because the percentage / proportion / amount of energy usefully transferred would increase or because the percentage / proportion / amount of energy wasted would decrease (because) less (work is done against) friction

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0 1 . 4 In most homes in the UK there are many different electrical devices.

Explain why people should be encouraged to use energy efficient electrical devices.

[2 marks]

more efficient devices waste less energy or more efficient devices need a lower energy input (for the same energy output) which would minimise the electricity / energy demand or which would minimise the environmental impact from (fossil fuel) electricity generation

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0 3 . 3 What equation links efficiency, total power input and useful power output?

[1 mark]

Tick (✓) **one** box.

$$\text{Efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$ ✓

$$\text{Efficiency} = \frac{\text{total power input}}{\text{useful power output}}$$

Efficiency = useful power output × total power input

0 3 . 4 The tiles are used to power LED lights in the pavement.

An LED light has a total power input of 4.0 W.

The efficiency of the LED light is 0.85

Calculate the useful power output of the LED light.

[3 marks]

$$\text{Eff} = \frac{\text{useful}}{\text{input}}$$

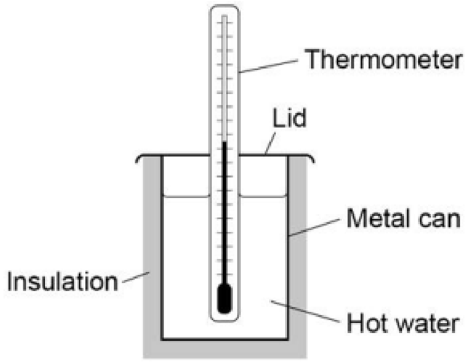
$$0.85 = \frac{\text{useful}}{4.0\text{W}} = 4.0 \times 0.85 = \text{useful}$$

Useful power output = 3.4 W

0 4 A student investigated the insulating properties of different materials.

Figure 4 shows some of the equipment used by the student.

Figure 4



This is the method used:

1. Wrap insulating material around the can.
2. Put a fixed volume of boiling water in the can.
3. Place the lid on the top of the can.
4. Measure the time taken for the temperature of the water to decrease by a fixed amount.
5. Repeat steps 1–4 using the same thickness of different insulating materials.

0 4 . 1 Identify the independent variable and the dependent variable in this investigation.

[2 marks]

Independent variable independent variable: (type of) insulation / material

Dependent variable dependent variable: time

The student used two different types of thermometer to measure the temperature changes.

Figure 5 shows a reading on each thermometer.

Figure 5

Thermometer **A** Thermometer **B**

0 4 . 2 What is the resolution of thermometer **B**?

[1 mark]

Resolution = 0.1 °C

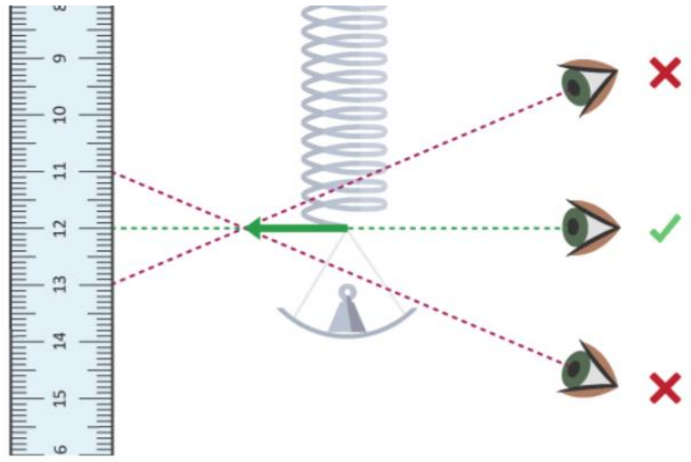
0 4 . 3 Thermometer **A** is more likely to be misread.

Give **one** reason why.

[1 mark]

viewing angle affects measurement or parallax error

Parallax error



Parallax error is caused by a student not reading the measurement at eye level. It can lead to the reading being too high or too low.

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0 4 . 4 For one type of insulating material, the temperature of the water decreased from 85.0 °C to 65.0 °C.

$\Delta\theta = 20\,°C$

The energy transferred from the water was 10.5 kJ.

$\Delta E = 10500\,J$

specific heat capacity of water = 4200 J/kg °C

$c = 4200\,\frac{J}{kg\,°C}$

Calculate the mass of water in the can.

Use the Physics Equations Sheet.

m

[3 marks]

$\Delta E = m \times c \times \Delta\theta$

$m = \frac{\Delta E}{c \times \Delta\theta} = \frac{10500}{4200 \times 20} =$

Mass = 0.125 kg

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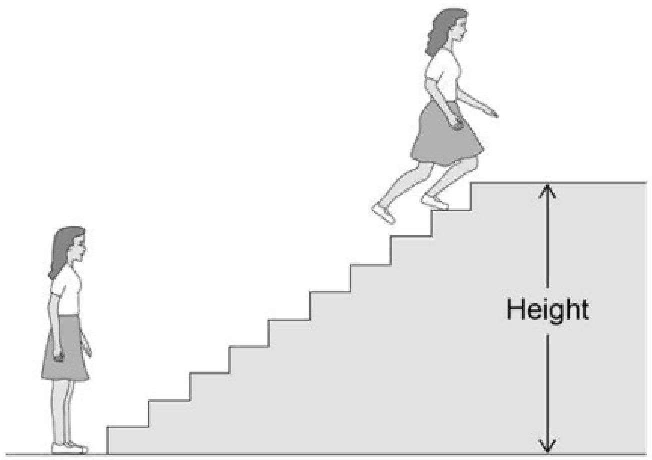
0 9 **Figure 10** shows a girl doing an experiment to determine her power output by running to the top of some stairs.

Figure 10



0 9 . 1 The mass of the girl was 60.0 kg. (m)

The height of the stairs was 175 cm. (h) (1.75 m)

The girl ran to the top of the stairs in 1.40 s. (t)

gravitational field strength = 9.8 N/kg (g)

Calculate the power output of the girl. (P)

Use the Physics Equations Sheet.

$$E_p = m \times g \times h$$

$$E_p = 60 \times 9.8 \times 1.75$$

$$E = 1029\ J$$

$$E = P \times t \qquad P = \frac{E}{t}$$

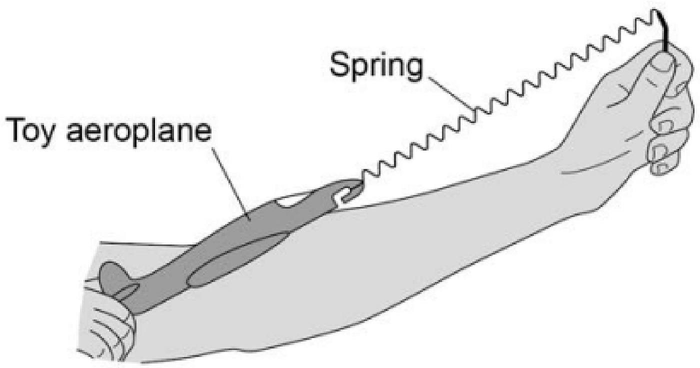
$$P = \frac{1029}{1.4} = 735\ W$$

[5 marks]

1 0 **Figure 11** shows a student launching a toy aeroplane.

To launch the aeroplane, the student pulls on it to stretch the spring and then releases it.

Figure 11



1 0 . 1 Just before the toy aeroplane is released, the spring has an extension of 0.12 m. e

mass of aeroplane = 0.020 kg m

spring constant of the spring = 50 N/m k

Calculate the maximum speed of the toy aeroplane just after it is launched. v

Use the Physics Equations Sheet.

Give the unit.

[6 marks]

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

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

$$E_e = \frac{50 \times (0.12)^2}{2}$$

$$E_e = 0.36\ \text{J}$$

$$0.36 = \frac{0.02 \times v^2}{2}$$

$$v = \sqrt{\frac{2 \times 0.36}{0.02}}$$

$$v = 6\ \text{m/s}$$

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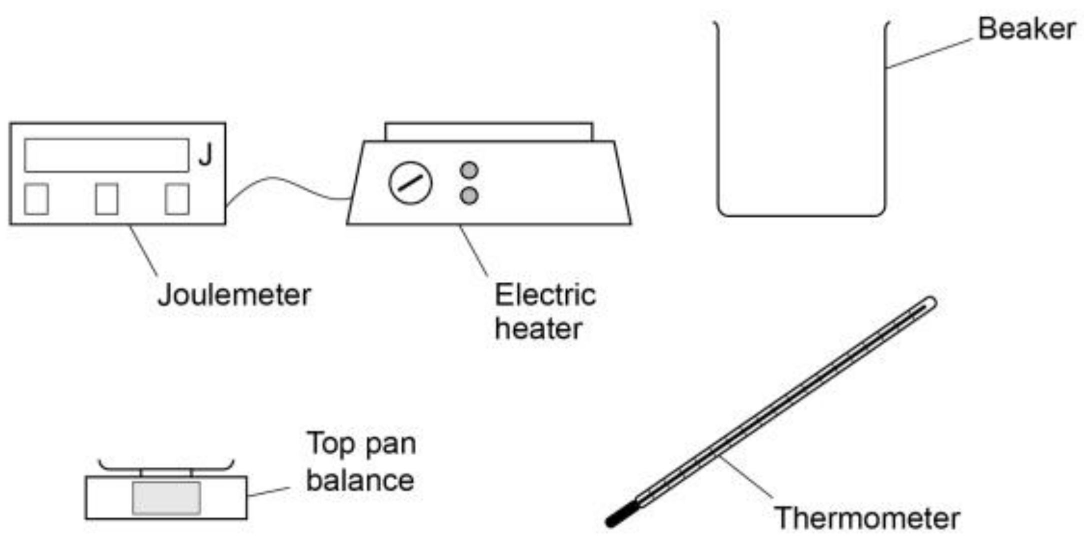
0 2 A student made measurements to determine the specific heat capacity of vegetable oil.

Figure 2 shows the equipment used.

Figure 2



0 2 . 1 Describe how the student could use the equipment shown in **Figure 2** to determine the specific heat capacity of vegetable oil.

[6 marks]

- measure mass of oil using the top pan balance
- measure start temperature of oil using the thermometer
- place beaker of oil on heater
- switch on heater to heat oil
- measure final temperature of oil using the thermometer
- measure energy transferred using joulemeter
- calculate increase in temperature ($\Delta\theta$)
- use the equation $E = mc\Delta\theta$ to determine c

0 2 . 3 Write down the equation linking energy transferred (*E*), power (*P*) and time (*t*).

[1 mark]

$E = P \times t$

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0 2 . 4 The electric heater had a power output of 50 watts.

Calculate the time taken for the electric element to transfer 4750 joules of energy to the vegetable oil.

[3 marks]

$E = P \times t \qquad t = \frac{E}{P}$

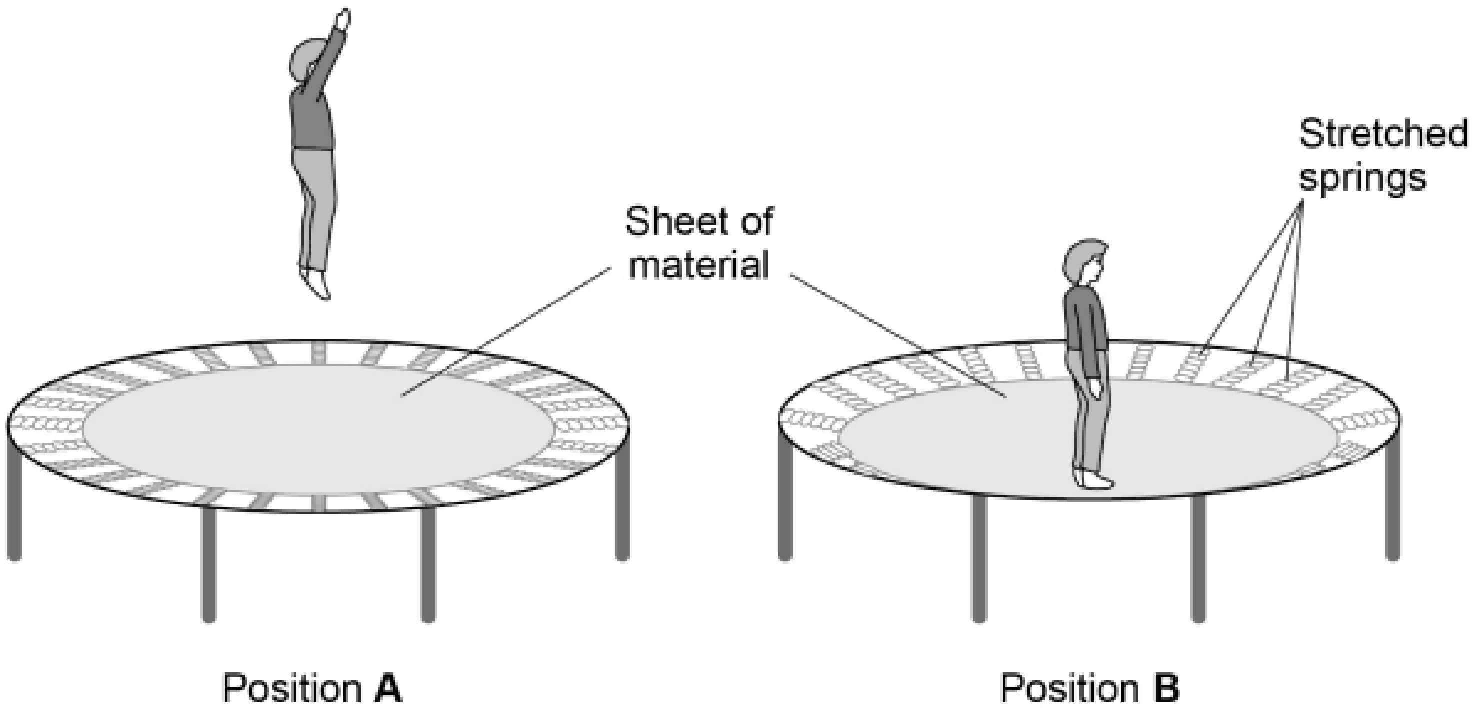
$t = \frac{4750}{50}$

Time taken = 95 s

0 3 A trampoline is made from a sheet of material held in place by stretched springs.

Figure 5 shows a child on a trampoline.

Figure 5



0 3 . 1 Position **A** shows the child's maximum height above the trampoline.

Position **B** shows the lowest position reached by the child when landing on the trampoline.

Describe the changes to the stores of energy of the:

- child
- springs
- surroundings

as the child moves from position **A** to position **B**.

[4 marks]

Child

Child gravitational potential energy decreases

kinetic energy increases and then decreases (to zero)

Springs

Springs elastic potential energy increases

Surroundings

Surroundings internal / thermal store of energy increases

0 3 . 2 When the child is at position A, each trampoline spring is stretched by 0.056 m

The elastic potential energy of each spring is 4.9 J

When the child is at position B, the elastic potential energy of each spring increases to 8.1 J

Calculate the extension of each spring when the child is at position B.

Use the Physics Equations Sheet.

[5 marks]

$E_e = \frac{Ke^2}{2}$

$8.1 = \frac{3125 \times e^2}{2}$

$e = \sqrt{\frac{2 \times 8.1}{3125}} = 0.072\,m$

Extension = ______ m

e

E_e

$E_e = \frac{Ke^2}{2}$

$4.9 = \frac{K \times (0.056)^2}{2}$

$K = 3125\,\frac{N}{m}$