WESTMINSTER SCHOOL

The Challenge (Core)

Specimen Paper First Examination 2027

SCIENCE

Time: 90 minutes

Please note this paper is in three sections:

Section 1	Physics	30 minutes
Section 2	Chemistry	30 minutes
Section 3	Biology	30 minutes

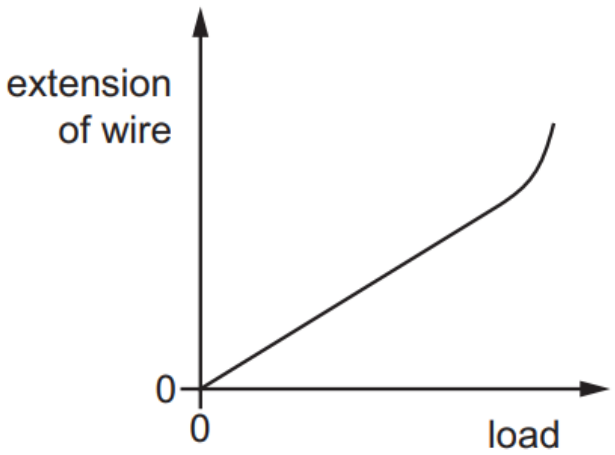
- You should answer all questions
- The marks for individual questions and parts of questions are shown in square brackets [ ].
- Any data needed will be given in the questions.
- You may use an electronic calculator.

Section 1: Physics

P1 (Multiple Choice – 10 marks)

Choose A,B,C,D or E for each of the following questions.

a) The graph shows the extension of a piece of copper wire as the load on it is increased. What does the graph show?



A: At a certain load, the wire becomes easier to extend.

B: At a certain load, the wire becomes harder to extend.

C: The load and the extension are directly proportional for all loads.

D: The load and the extension are inversely proportional for all loads.

E: There is an exponential relationship between the load and extension.

b) A substance consists of particles that are close together and moving past each other at random. The average speed of the particles is gradually increasing. What best describes the substance?

A: a gas being heated

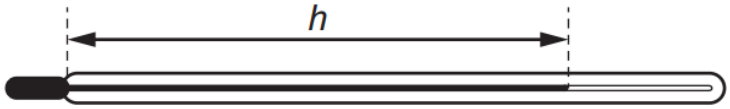
B: a liquid being heated

C: a liquid undergoing solidification

E: a gas condensing

D: a solid being heated

c) The mercury-in-glass thermometer shown has a linear scale.



At a temperature of 100°C, h has a value of 28 cm. At 80 °C, h has a value of 24 cm. What is the value of h when the temperature is 0°C?

A: 0.0 cm

B: 1.2 cm

C: 2.8 cm

D: 4.0 cm

E: 8.0 cm

d) A ship that is stationary on the surface of the sea sends pulses of sound vertically downwards towards the sea bed. Each pulse that reflects from the sea bed is received 1.0 s after it is sent out. A whale swims under the boat and a pulse is received 0.60 s after it is sent out. The speed of sound in sea water is 1500 m/s. What is the distance of the whale above the sea bed?

A: 300 m

B: 450 m

C: 600 m

D: 750 m

E: 1000 m

e) Which of these is not a unit for the measurement of speed:

A: metre per second

B: kilometre per hour

C: light year

D: mile per hour

E: knot

f) A charged plastic ball is at rest. Which fields are found in the region surrounding the ball? (Ignore the magnetic field of the Earth.)

A: electric only

B: electric, gravitational and magnetic

C: electric and gravitational only

D: electric and magnetic only

E: gravitational and magnetic only

g) Which of these is a renewable source of energy?

A: Coal

B: Biomass

C: Nuclear Fusion

D: Wind

E: Oil

h) When a person looks at their reflection in a plane (flat) mirror, how does the image appear?

A: Not inverted or rotated at all

B: Inverted vertically only

C: Inverted laterally only

D: Inverted both laterally and vertically

E: Rotated by 180°

i) Approximately how long does the Moon take to orbit the Earth once:

A: 1 hour

B: 1 day

C: 1 week

D: 1 month

E: 1 year

j) A certain mass m accelerates at 10 m/s^2 when the unbalanced force on it is F. What would the acceleration of half the mass be under the action of double the force?

A: 2.5 m/s^2

B: 5 m/s^2

C: 10 m/s^2

D: 20 m/s^2

E: 40 m/s^2

[10]

P2. The First Experiment

In the fifth century BC, Empedocles argued that everything in the cosmos was made of four elements: earth, air, fire and water. Three of those elements were easy to see and demonstrate but many people did not believe in air. To demonstrate the existence of air, Empedocles took a clepsydra (a jar with a spout), turned it upside down, put his thumb over the spout and immersed it in water. When he took his thumb off the spout, bubbles of air rose to the surface.

a) This is a picture of a celpsydra. Explain how it was used as a water clock by the ancient Egyptians.

[2]

b) Thousands of years later, Robert Boyle found the relationship between the volume and pressure of a fixed mass of gas at constant temperature before and after an expansion or compression:

Pressure before x Volume before = Pressure after x Volume after

(i) A bubble of air at pressure 101 000 Pa has volume 1.20 cm^3. What will its volume be if you double the pressure on the bubble? Show your working and give your answer with an appropriate unit and number of significant figures.

[2]

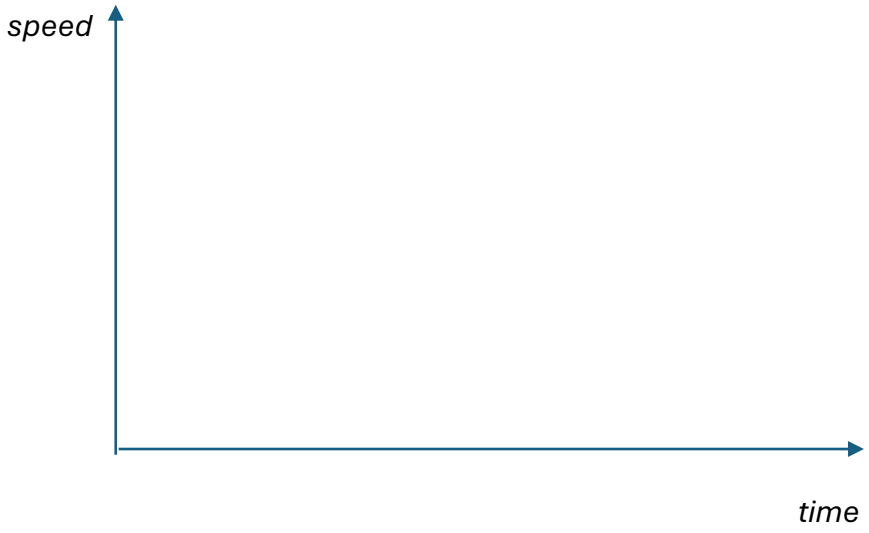
(ii) State and explain what you expect to have happened to each bubble's size as it rose to the surface in Empedocles' experiment.

[2]

c) This is a bubble from the clepsydra that is rising through water. Add arrows to show the forces acting on it. Label the arrows.

[2]

d) On the following axes, sketch a graph to show the speed of a bubble from the moment it leaves the clepsydra. You do not need to include any numbers. Annotate your graph to justify the shape that you have drawn.



[4]

e) You have the benefit of modern technology and knowledge. Describe an experiment that you could do to prove the existence of air. You are encouraged to include appropriate diagrams.

[3]

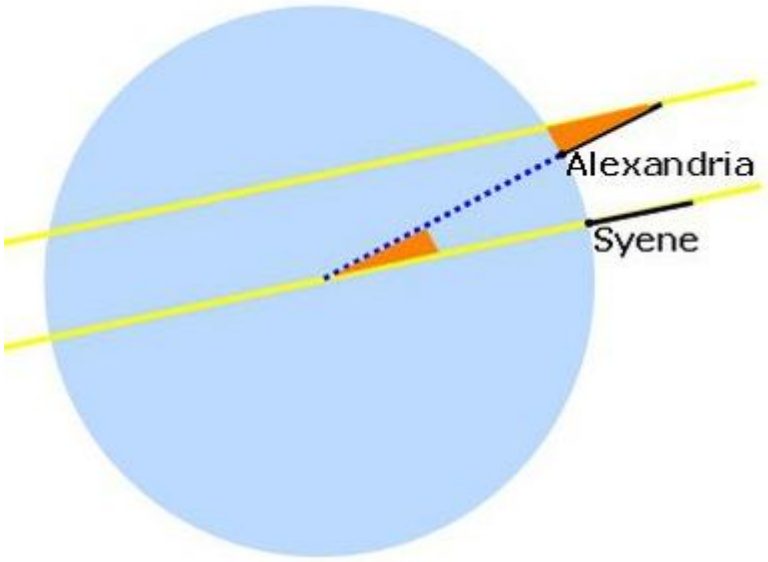
f) At the end of his life, Empedocles is said to have decided to test whether he was immortal. He jumped into Mount Etna. If he were mortal he would die; if immortal he would live. Nothing was found of him but for one sandal.

This is a picture of Mount Etna.

Bonus question: which island do you think Empedocles came from?

P3. In 200 BC, Eratosthenes estimated the Earth's circumference. Based in Alexandria in Egypt, he read that there was a well in a city named Syene, South of Alexandria, in which the sun's reflection could be seen at noon on a particular day of the year. This told him that the sun was directly overhead.

The figure below shows how he put identical sticks (of length 100 cm) into the ground at Syene and at Alexandria and measured the length ***L*** of the shadow cast by the stick at Alexandria at mid-day. The yellow lines represent parallel sun rays. The distance ***d*** between Alexandria and Syene was measured using a trundle wheel.



a) Indicate length ***L*** and distance ***d*** on the figure above.

[1]

b) Use the following data to calculate a value for the circumference of the Earth.

L = 12.3 cm
d = 5000 stadia (where **1 stadia = 155 m)**

[2]

c) Eratosthenes's measurement was 46,250 km.

(i) Calculate the circumference of the planet using today's measurement of Earth's radius (6400 km).

[1]

(ii) By what percentage was Eratosthenes's measurement wrong?

[1]

End of Physics Section

Section 2: Chemistry

C1. This multiple choice section is about some general chemistry.

Circle the letter that corresponds to your chosen answer.

a) This diagram shows the result of dropping a purple crystal (potassium permanganate) into a beaker of water

Which processes take place in this experiment?

	chemical reaction	diffusing	dissolving
A	✓	✓	✗
B	✓	✗	✗
C	✗	✗	✓
D	✗	✓	✓

b) Which of the following processes would be most appropriate to separate a mixture of iron filings and sulfur powder?

A Chromatography

B Simple distillation

C Filtration

D Magnetic separation

c) Compounds are formed from elements. An element is:

A A substance that only contains individual atoms

B A substance with more than one type of atom chemically joined together

C A substance with more than one type of atom mixed together

D A substance with only one type of atom

d) Electrolysis of water produces hydrogen and oxygen gas. This is an example of what sort of reaction?

A Reduction

B Neutralisation

C Decomposition

D Displacement

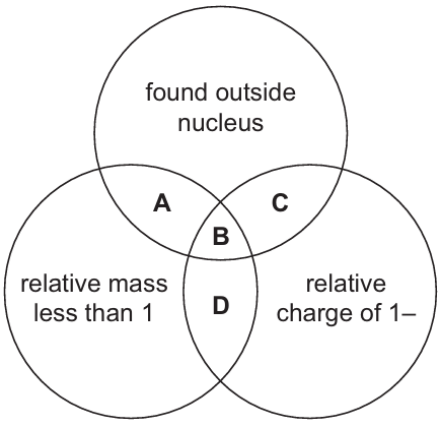
e) The diagram shows a cup of tea.

Which row describes the water particles in the air above the cup compared

	moving faster	closer together
A	✓	✓
B	✓	✗
C	✗	✓
D	✗	✗

with the water particles in the cup?

f) The diagram shows some properties of particles in an atom.
To which labelled part of the diagram do the electrons belong?



[Total: 6]

C2. This question is about hydrogen peroxide.

Hydrogen peroxide (H_2O_2) is a versatile chemical liquid compound known for its strong oxidising properties. It's commonly used as a disinfectant and bleaching agent. In aqueous solutions, it decomposes into water and oxygen making it useful for applications ranging from wound cleaning to rocket propellant. Its ability to break down into harmless byproducts makes it environmentally friendly.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

This decomposition process into water and oxygen is slow. A student was asked to investigate a range of catalysts to speed up the reaction by using a method which involves the collection of oxygen gas.

Catalysts increase rates of reactions without being used-up.

The student was provided with the following metal oxides as catalysts: copper(II) oxide, manganese(IV) oxide, lead(II) oxide and iron(III) oxide.

a) State the independent and dependent variables in the experiment

[2]

b) State any two variables which would need to be controlled

[2]

c) Propose a labelled diagram to illustrate the apparatus used for these catalyst experiments. You may include some of the following equipment, and water can also be used. Any other valid scientific equipment will also be credited.





Measuring cylinder Bung Side-arm flask Silicone tubing Water tub

[3]

c) Suggest another method to investigate these reactions which does not include the collection of oxygen gas.

[1]

d) Once the reaction has finished, how could the student demonstrate that the metal oxide catalyst had not been affected by the reaction?

[2]

e) Hydrogen peroxide can be sold as a solution in weak acid which increases its shelf-life.

Suggest why this would cause a problem in this particular experiment.

[2]

f) Hydrogen peroxide solution is usually stored with a small hole in the lid of the bottle.

Suggest why this is necessary.

[1]

The liver contains an enzyme called **catalase**, which plays a crucial role in breaking down hydrogen peroxide into water and oxygen. This process is essential because hydrogen peroxide is a byproduct of various metabolic reactions and can be harmful to cells if it accumulates. Catalase helps protect the liver and other tissues from oxidative damage by rapidly decomposing hydrogen peroxide.

A student put a 1 cm^3 cube of chicken liver into an aqueous solution of hydrogen peroxide and collected the oxygen gas produced. Their results were as follows:

Time (mins)	Volume of oxygen (cm^3)
0.0	0.0
1.4	2.5
2.9	4.5
4.3	6.2
4.8	7.5
7.1	8.5
8.6	9.2
10.0	9.8

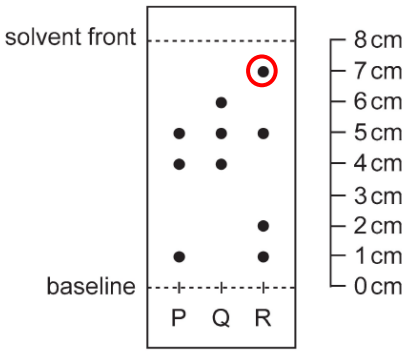
g) i) Plot a graph on the grid of the volume of oxygen produced against time. Use a cross (**x**) to plot each data point

[2]

ii) There is an anomaly in this data set, you should circle the point. Draw the line of best fit and do not include the anomaly in your line.

[2]

iii) Suggest one reason why this anomaly may have occurred in this experimental procedure.



[1]

C3. This question is about chromatography.

Mixtures of amino acids (protein building blocks) can be separate using paper chromatography. In one such experiment, three mixtures **P**, **Q** and **R** were separated, giving the chromatogram shown on the right.

The R_f value of a component in a mixture is defined as the distance travelled by the component divided by the distance travelled by the solvent.

The R_f value of the component circled on the right is calculated as:

$$R_f = \frac{distance\ travelled\ by\ component}{distance\ travelled\ by\ solvent} = \frac{7cm}{8cm} = 0.875$$

a) State how many distinct amino acids were present in the experiment in total.

[1]

b) Suggest why different amino acids travel different distances.

[1]

c) Calculate the following values:

(i) The R_f value of the common component of the mixtures.

[1]

(ii) The R_f value of the most mobile (farthest moving) component of mixture Q.

[1]

(iii) The average R_f value of the mixture with the most components.

[1]

d) R_f values are constant for any experiment performed under the same conditions.

The test was repeated with the same mixtures and solvent, but this time the distance travelled by the common component of the mixtures was 7.5cm.

(i) Apart from using the same solvent, suggest two other factors that must have been kept constant for the second test.

[2]

(ii) Calculate the distance travelled by the least mobile component of mixture P in the second test.

[3]

[Total: 10]

End of Chemistry Section

Section 3 – Biology

Please write your answers to questions **B**1 to B10 in the grid below.

B1	
B2	
B3	
B4	
B5	
B6	
B7	
B8	
B9	
B10	

B1. The following statements relate to cellular processes:

1. Completed in the mitochondria.
2. Affected by temperature.
3. Release oxygen.

Which of the statements are correct for aerobic respiration?

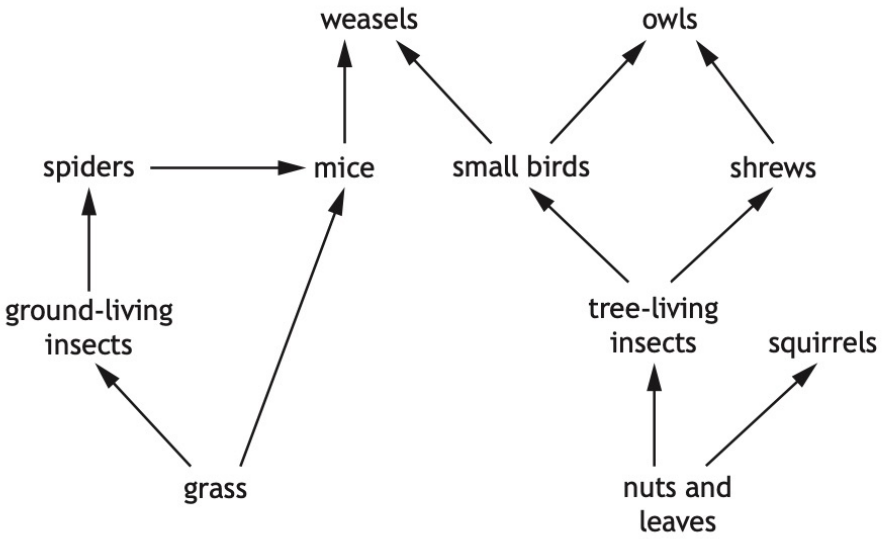
A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

D 1, 2 and 3

B2. Some feeding relationships of organisms in a woodland ecosystem are shown in the food web.



Due to extreme weather conditions, the populations of tree-living and ground-living insects were greatly reduced.

This could lead to:

A an increase in small birds and a decrease in spiders

B an increase in squirrels and a decrease in spiders

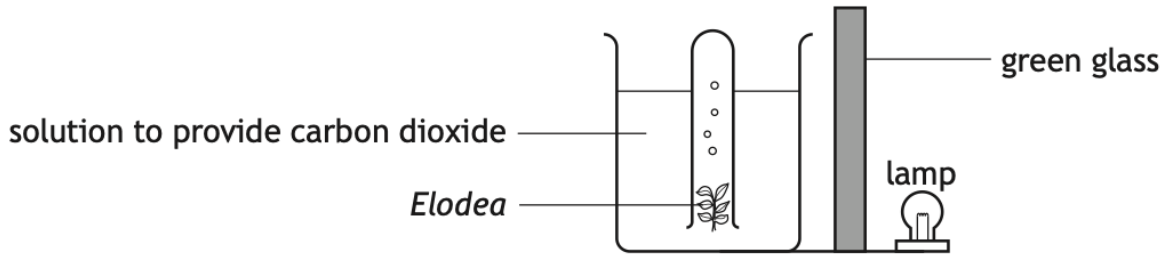
C a decrease in nuts and leaves and an increase in small birds

D a decrease in weasels and an increase in owls.

B3. Which row in the table describes changes in conditions that may improve the growth of plants in a greenhouse?

	Light intensity	Carbon dioxide concentration
A	decrease	decrease
B	decrease	increase
C	increase	decrease
D	increase	increase

B4. An experiment was carried out to investigate the effect of green light on the rate of photosynthesis in the pondweed, *Elodea*.



Which of the following changes would provide a suitable control for this experiment?

A Replace the solution with water.

B Increase the brightness of the lamp.

C Use a different species of pondweed.

D Replace green glass with clear glass.

B5. An investigation was carried out to measure the change in body mass in a population of adult locusts kept in a tank at 25 °C. The percentage of food converted into body mass was recorded over a three-week period.

The reliability of the results could be improved by:

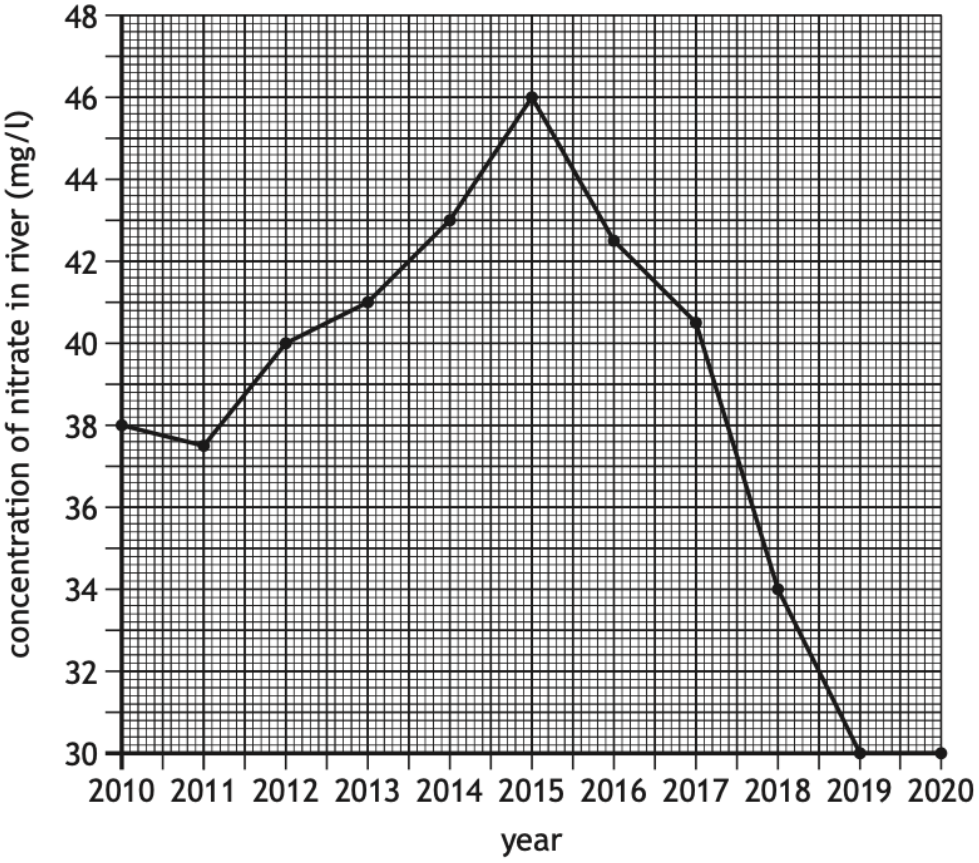
A decreasing the length of time of the investigation

B increasing the mass of food given to the locusts

C increasing the number of locusts in the tank

D decreasing the temperature in the tank.

B6. The graph shows the concentration of nitrate in a river measured on the first day of each year.



A valid conclusion from this data would be:

A nitrate concentration increased every year between 2010 and 2014

B there was a greater increase in nitrate concentration between 2011–2012 compared to between 2014–2015

C no nitrates were present in river water between 2019 and 2020

D the greatest decrease in nitrate concentration was between 2017 and 2018.

B7. An earthworm with a mass of 7 g uses up 3.5 cm^3 of oxygen in 25 minutes.

Calculate the volume of oxygen used by this earthworm in 1 minute.

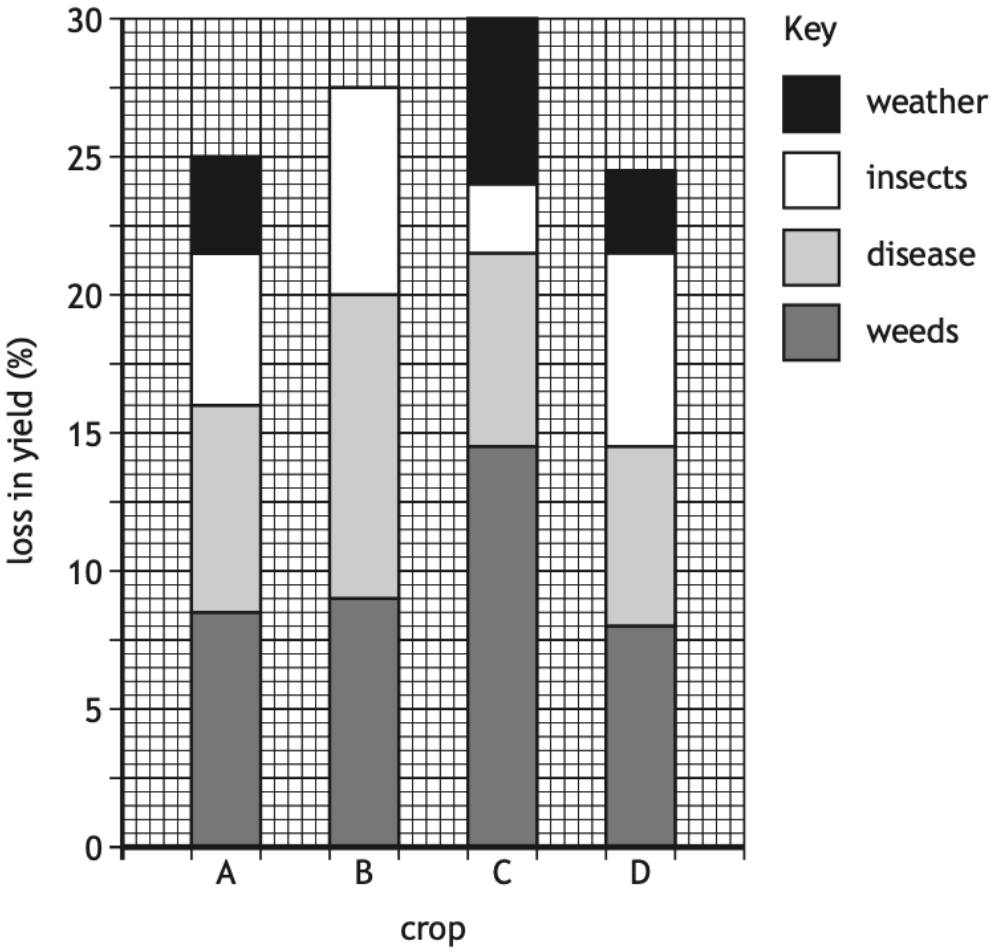
A 0.02 cm^3

B 0.14 cm^3

C 0.5 cm^3

D 1.02 cm^3

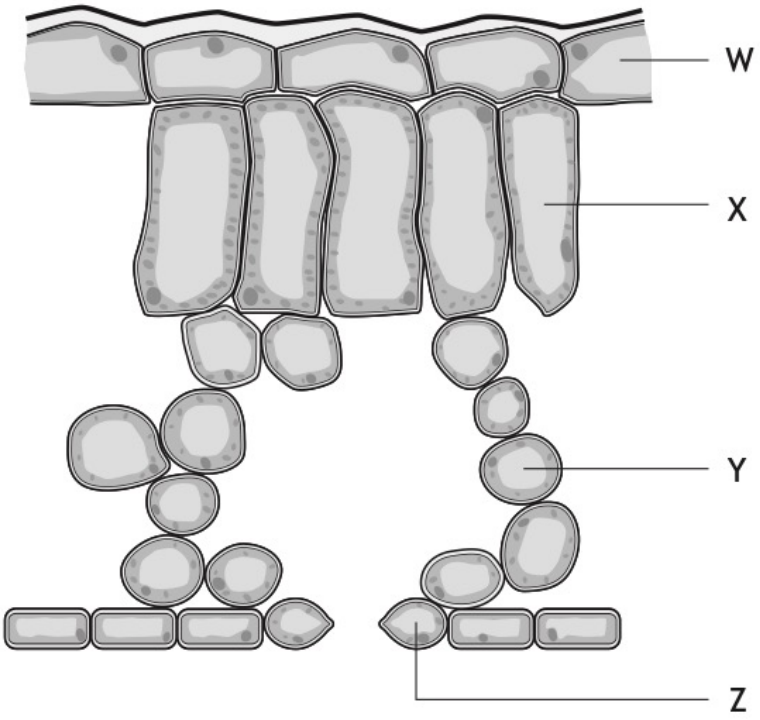
B8. The bar chart shows the percentage loss in yield of four crops and the cause of loss.



To reduce losses, pesticides can be sprayed onto the crops to kill weeds and insects.

Predict which crop is most likely to show the greatest percentage increase in yield, when the crops are sprayed with pesticides.

B9. The diagram shows a cross-section of a leaf.



Which row in the table identifies the parts of the leaf?

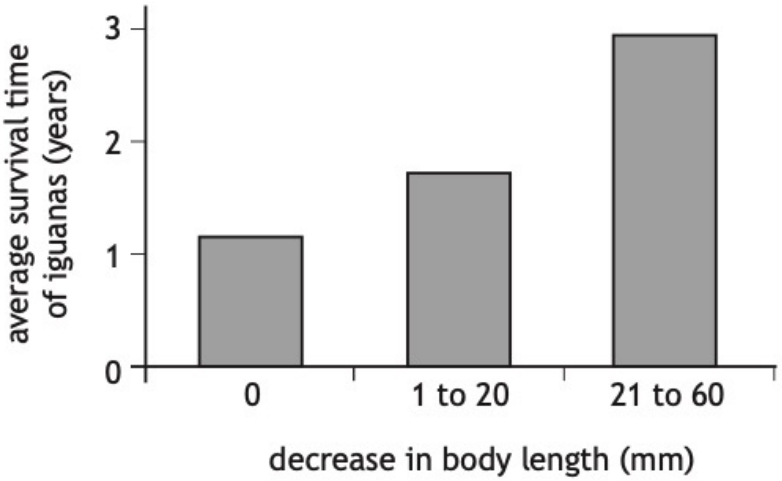
	Palisade mesophyll	Spongy mesophyll	Upper epidermis	Guard cell
A	X	Y	Z	W
B	Y	X	W	Z
C	W	X	Z	Y
D	X	Y	W	Z

B10. A weather event called El Niño occurs in the Galapagos Islands every three years.

During this event, the iguanas on the islands can decrease in body length due to lack of food.

Scientists calculated the decrease in body length of the iguanas and recorded their survival time.

The results are shown in the graph.



Which of the following statements is true?

A The iguanas that had the least decrease in body length survived for the longest time.

B The decrease in body length made no difference to the survival time of the iguanas.

C The iguanas that had the greatest decrease in body length survived for the longest time.

D The iguanas that had the greatest decrease in body length survived for the shortest time.

B11. Read the information below on the concept of 'dormancy' and answer the questions that follow.

Surviving adverse conditions

Many environmental conditions, such as temperature, go beyond those that an organism is able to withstand and would halt normal metabolic activity. Organisms have adapted to avoid or survive in these adverse conditions.

A common way in which an organism can survive during adverse conditions is by reducing their metabolic activity through dormancy. This is part of some organisms' life cycle to allow survival when the cost of continued normal metabolic activity would be too high.

Dormancy is a period when an organism's metabolic activity decreases and allows for the conservation of energy.

During dormant periods there is a decrease in the following:

- organisms metabolic rate
- heart rate
- breathing rate
- body temperature

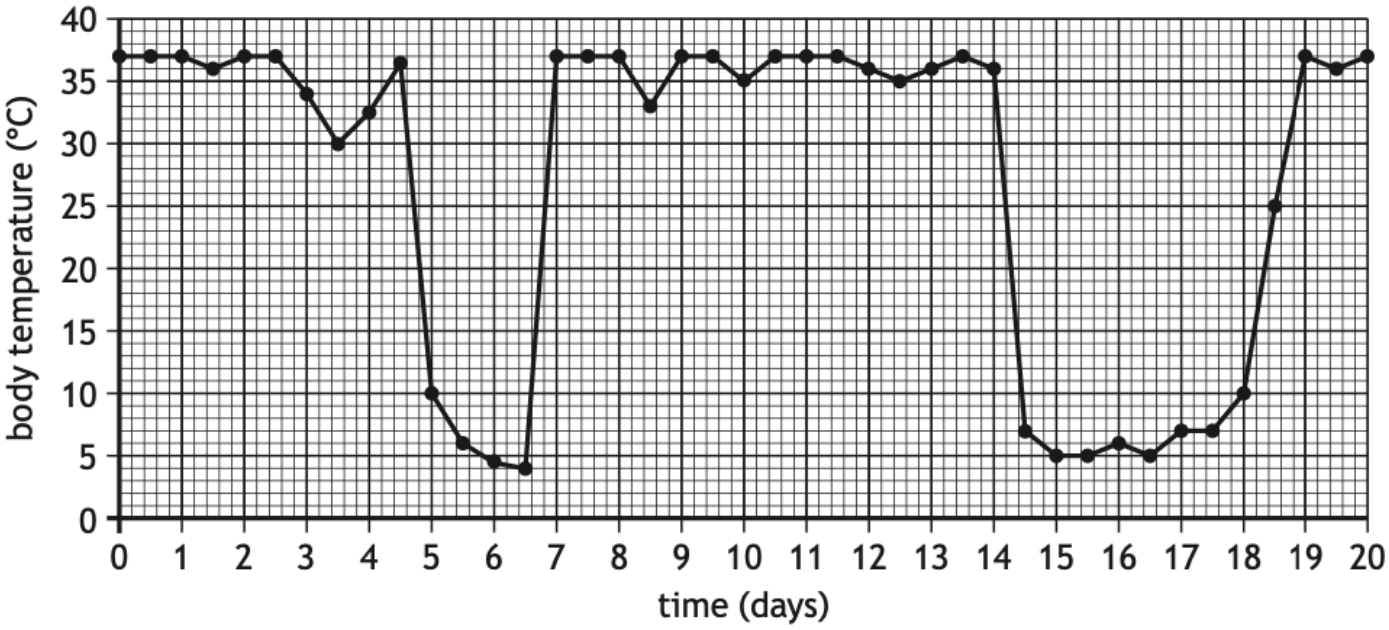
There are two types of dormancy:

- Predictive – where the organism enters dormancy **before** the onset of the adverse conditions.
- Consequential – where the organism enters dormancy **after** the onset of the adverse conditions.

(a) Arctic ground squirrels are found in Alaska and survive low winter temperatures by becoming dormant for short periods of time.

To study dormancy in an Arctic ground squirrel, its body temperature was measured over a period of 20 days in winter.

The results are shown in the graph.



(i) Calculate the total time that the Arctic ground squirrel's body temperature was 10 °C or below. **1**

Space for calculation

_____ days

(ii) Apart from decreasing body temperature, state another change that may be observed in an Arctic ground squirrel during dormancy. **1**

_____

(b) The Alaskan brown bear hibernates during winter. The average monthly air temperatures in Alaska are shown in the table.

Month	Average air temperature (°C)
January	–28
February	–29
March	–28
April	–21
May	–9
June	–1
July	2
August	2
September	–2
October	–11
November	–20
December	–25

(i) Calculate the average monthly decrease in air temperature over the four-month period from the beginning of August until the end of November. **1**

Space for calculation

_____ °C per month

(ii) Alaskan brown bears hibernate between August and April.

Use information in the table to identify the type of dormancy.

Give a reason for your answer. **2**

Type of dormancy _____

Reason _____

_____

(iii) State one advantage of hibernation to Alaskan brown bears. **1**

_____

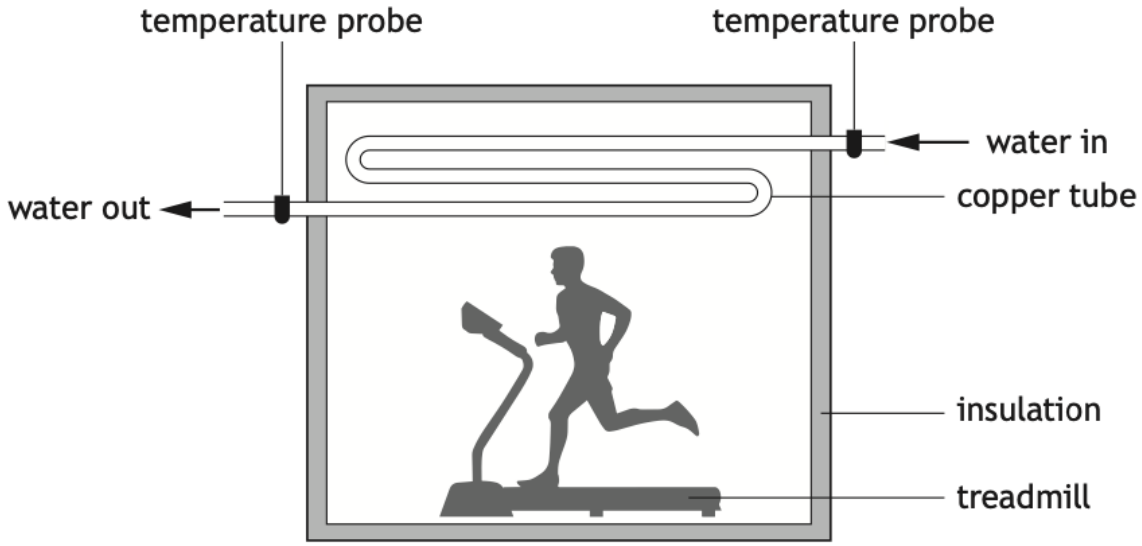
B12. Read the information below and answer the questions that follow.

Metabolism - the chemical processes that occur within a living organism that maintain life.

Calorimeter - an apparatus for measuring the amount of heat involved in a chemical reaction

An investigation was carried out to study the effect of intensity of exercise on metabolic rate.

A calorimeter was used to determine metabolic rate as shown in the diagram.



An individual walked on a treadmill in the calorimeter for 30 minutes and the temperature increase of the water was calculated every 5 minutes.

The procedure was repeated in another calorimeter with a different individual who ran on the treadmill.

The results are shown in the table.

	Temperature increase of the water (°C)	
Time (minutes)	**Walking**	**Running**
0	0	0
5	0.2	0.4
10	0.3	0.6
15	0.5	0.9
20	0.8	1.1
25	1.1	1.3
30	1.4	1.6

(a) Explain how the design of the calorimeter allowed metabolic rate to be determined. **2**

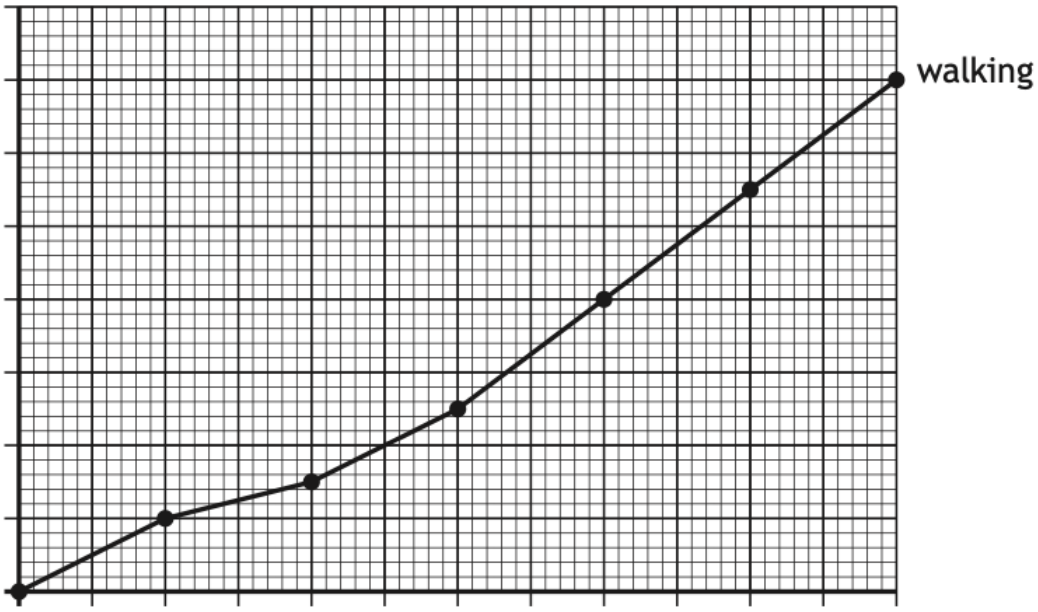
(b) Name the independent variable in this investigation. **1**

(c) Identify two variables, not already mentioned, that should be controlled for a valid conclusion to be drawn. **2**

1. _____

2. _____

(d) (i) On the grid, complete the line graph to show the results for **running**. **2**



(ii) Predict the temperature increase after 35 minutes of walking on the treadmill. **1**

_____ °C

(e) Draw a conclusion from the results of this investigation. **1**

_____

_____

End of Questions