Scientific method

Prescribed focus area

The nature and practice of science

You will be required to produce a report based on your work and findings, whichever type of investigation and topic you choose. The following is the basis of the scientific method you need to help you in **designing, conducting** and **reporting** your investigation.

Aim

The **aim** outlines the idea or scientific question you are trying to test.

Hypothesis

A **hypothesis** is a prediction or 'educated guess' about what you might find in an experiment. A hypothesis is something that can be tested in measurable terms.

Variables

Identify all the variables that may affect your results. Remember that variables can be classified into three groups:

- **independent variable**—the variable that is changed
- **dependent variable**—the variable that is being measured
- **controlled variables**—the variables that are kept the same throughout the experiment.

Equipment

List all the equipment and materials that you need.

Method

The **method** is a step-by-step set of instructions that other scientists at your level of experience could follow to accurately repeat your experiment.

When writing the instructions, include the following information:

- the one variable that you are going to change
- how you are going to change it and by how much
- how you are going to control all the other variables
- how you are going to measure the changes
- how you are going to record the changes, such as in a results table, diagrams, drawings or photographs.

Your experimental method should be **replicated** a number of times so that a more accurate conclusion can be drawn. This makes your investigation 'reliable'.

Results

Results can be of two types.

- Results or data that are numerical are called **quantitative** as they usually measure amounts or quantities.
- If you are using your senses to observe, you are making **observations. Qualitative** observations are written down as a description or recorded as a picture or diagram.

You should also record any other things you notice, particularly any problems you may have had with your investigation. If appropriate, include a photographic essay of your project steps or results. These will assist in your final analysis.

You may be asked to keep a detailed process diary ('Log book') of observations, data, and results while completing your experiment.

Discussion

In the discussion you should **analyse** and **evaluate** your results in detail.

- Analyse and present your data or observations in different ways to show any patterns or trends. This is where a graph may be useful. Line graphs should be used when both the independent and dependent variables are numerical.
- Explain any trends or patterns in your observations, data and results.
- Explain why the results occurred and what they demonstrated.
- Outline any errors that may have affected your results. Errors are unavoidable, but mistakes are because of clumsiness. Report your errors, not your mistakes.
- Evaluate the success of your investigation, explaining how your experiment could be improved to gain better or more dependable results.
- Describe any difficulties or problems you had in doing the investigation.

Conclusion

A conclusion is simply a summary of the results of your experiment. A good conclusion will:

- answer your aim
- identify whether your experiment proved or disproved your hypothesis. Use any trends you saw in the results as proof
- identify any changes that you would make if you had to repeat this investigation.

(1) You have been asked to design an experiment to test the amount of light that can pass through different types of glass. You have the following equipment available. different glass samples including transparent, opaque, translucent and coloured; a light sensor and data logger; torch; ruler.

a **Construct** an aim for this experiment.

b **Construct** a hypothesis.

c **Identify** the independent and dependent variables.

d **List** the variable(s) that would need to be controlled.

e **Outline** any observations you would make.

f **Outline** any measurements you would make.

g **Propose** a method for this experiment.

h **Design** a table in which you could record your results.

(2) Marika completed an experiment to test the effect of fertiliser on the growth of plants, using the equipment shown in Figure 9.2.6.

a **Identify** the independent variable.

b **Identify** the dependent variable.

c **List** the controlled variables.

d **Propose** a hypothesis for this experiment.

Amount of fertiliser (grams)	Height of plant (cm)					
	Day 1	Day 2	Day 4	Day 6	Day 8	Day 10
0	5.0	6.0	6.5	6.5	6.5	6.5
5	5.0	6.5	8.6	10.5	12.8	14.7
10	5.0	6.4	8.2	9.2	11.0	12.1

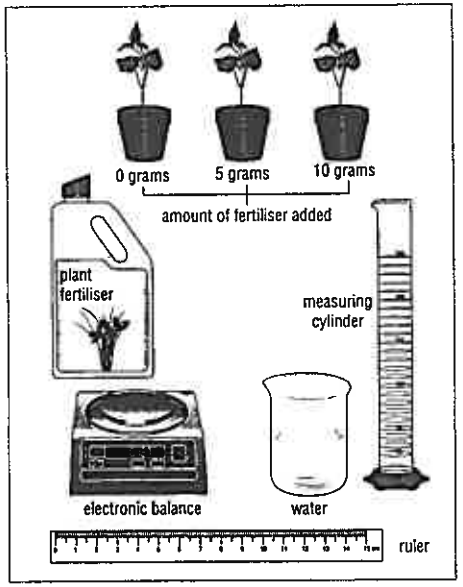


Fig 9.2.6

Marika recorded the results shown in the table above.

e **Construct** a line graph to show these results. You will need three lines on the one graph. N

f **Describe** any patterns and trends that you see in the results.

g **Use** these results to deduce what effect the fertiliser had on the height of the plants.

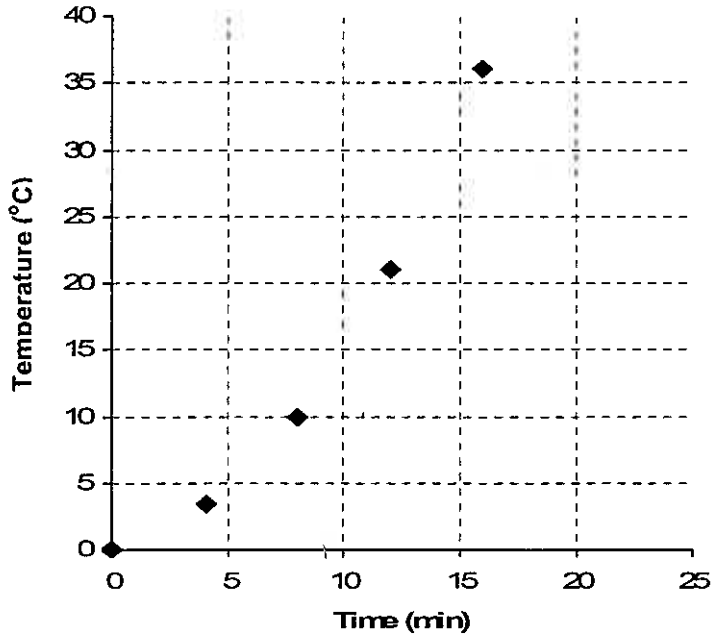
h Could you rely on these results, or believe any conclusion based on them? **Justify** your answer.

i **Evaluate** the experiment to decide if it is a fair test.

j **Propose** any improvements to the experiment.

Question 3 (6 marks)

The graph shows how temperature of a frozen food changed over time as the food was heated.



(a) Complete the graph by drawing in an appropriate 'line of best fit'. **2**

(b) Complete the data table using your graph by inserting temperature values for times 14 and 17 minutes. **2**

Time (min)	Temperature (°C)
14	
17	

(c) Comment on the accuracy of the temperature values you have added to the table above. Justify your answer. **2**

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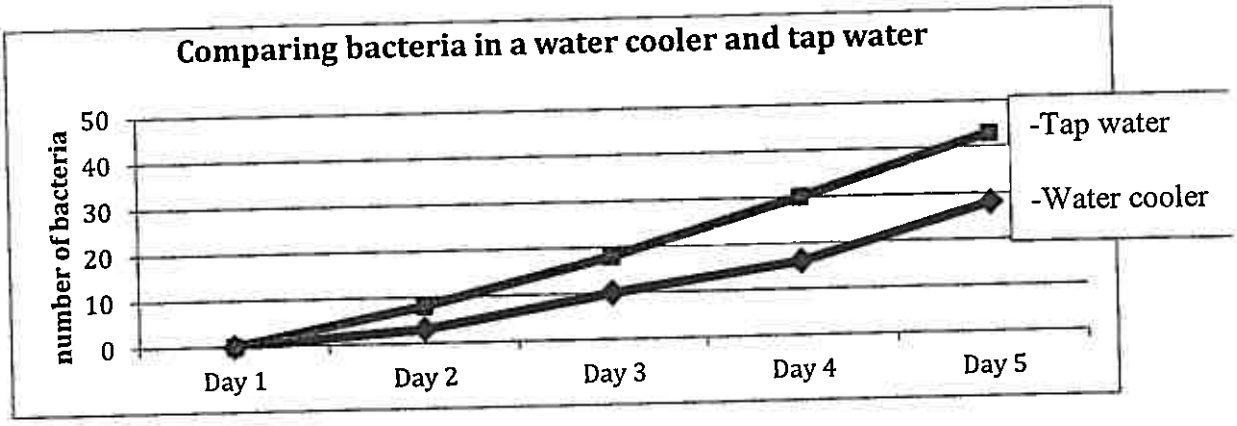
Question (4) (7 marks)

The graph shows the result of an experiment on bacterial growth in water. A student proposed the following two hypotheses before doing this experiment:

(i) Bacterial growth will increase as time passes.
(ii) There will be more bacteria in tap water than in water from the cooler.



(a) Suggest the purpose of the experiment.

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(b) Identify TWO factors that would need to be controlled for this experimental design to be valid.

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(c) Evaluate the student's TWO hypotheses in terms of the results of the experiment.

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(d) On the basis of these results the student commented in a report that it would be safer for us to drink cooler water rather than water from a tap.
Comment on the validity this statement.

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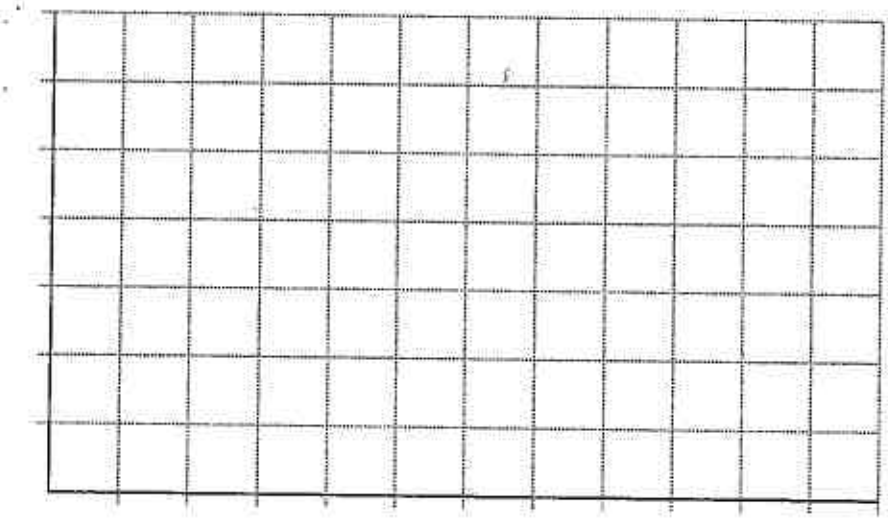
Question 5 (7 marks) **Marks**

The information below was obtained in an experiment using *resistor X*.

Applied Voltage (V)	*Current in resistor X (A)*
0	0
1.5	0.7
3.0	1.4
4.5	2.2
7.5	3.8
9.0	4.4

In the experiment, a student applied the indicated voltage across the resistor and measured the current flowing through it. The values for each current were recorded.

(a) **Graph** the results on the grid below. **2**



(b) Use your graph to predict the *currents* through resistor X, for applied voltages of 6 V and 12 V. **2**

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(c) Compare the two *predicted values* in terms of how accurate they might be. Justify your answer. **2**

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(d) Suggest ONE way to improve this experiment. **1**

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(6) **Radiometric C-14 dating**

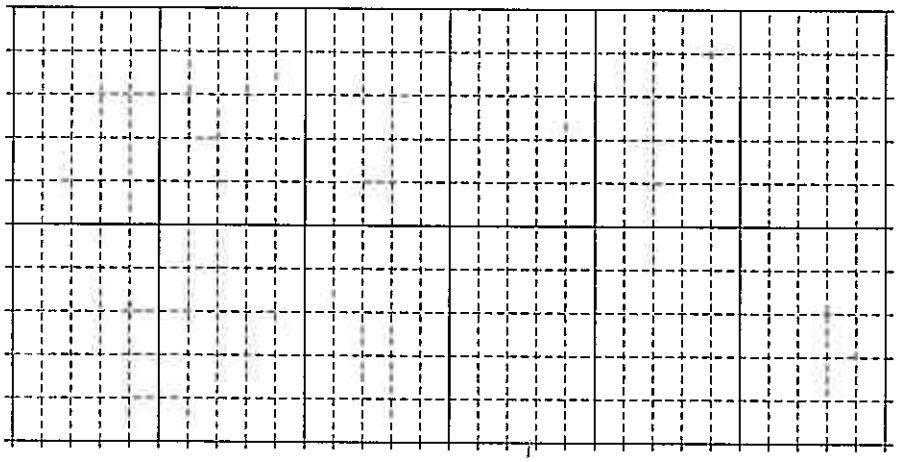
The absolute ages of recent carbonaceous fossils can be determined using radiocarbon dating.

The half-life of carbon-14 (a radioactive isotope) is 5730 years. The following table shows how the percentage of C-14 present in a fossil decreases over time.

Time (years)	0	5730	11 460	17 190	22 920	28 650
% C-14 remaining	100	50		12.5	6.25	3.125

(a) Complete the table.

(b) Plot a line graph of this data on the grid below.



(c) The C-14 content of a fossil was found to have decreased by 36% since the organism died. Determine the approximate age of the fossil.

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(d) A fossil is approximately 10 000 years old. What percentage of C-14 still remains?

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Ironing out the problems

Many people spray their clothes before ironing them. Hank bought three different brands of non-pressurised ironing sprays at a supermarket. He also bought four identical, empty, trigger-action spray containers. Each of the three brands was poured into an empty spray container and water was put in the fourth. Hank then set up the apparatus shown in Figure 5.14.

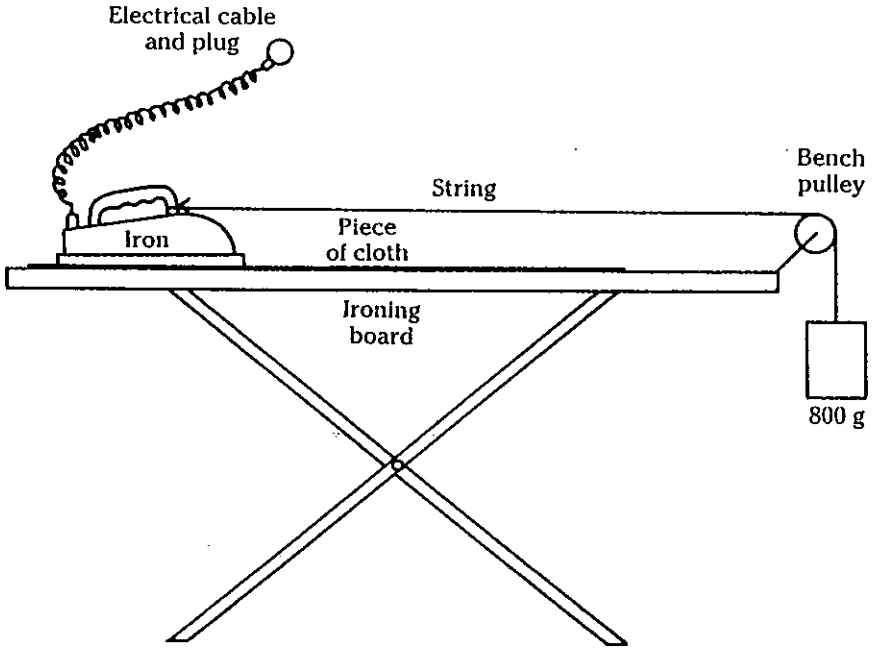


Figure 5.14

Hank used four different pieces of the same cloth. Each piece of cloth was sprayed with a different spray container. Each piece of cloth was sprayed by holding the container 30 cm from the cloth and giving the trigger two quick squeezes. After each piece of cloth was sprayed, it was placed on the ironing board and Hank timed how long it took the iron to move 50 cm.

1 Write the aim of Hank's experiment.
2 Write out the method for this experiment in clear and concise steps.
3 What is the control experiment in Hank's experiment?
4 Hank measured the iron moving across the material once for each type of spray. What could Hank do to increase the validity of his experiment?
5 a What two steps did Hank take to make sure that the same amount of spray was used each time ?
b What other step did Hank take to make sure that the spray was spread similarly on the different pieces of cloth?
6 a What is the purpose of the 800 g mass?
b What might happen if the mass is 10 g?

Bridget said Hank's experiment would be interesting if four different types of material were used. Hank told Bridget that if he used different materials, the experiment would have two sets of variables. Bridget still wanted to test the different types of material.

7 What is the aim of Bridget's experiment?
8 How would Bridget change Hank's experiment to achieve her aim?

(8.)

What rot!

Theo's family recycles fruit and vegetable scraps at home. Theo was interested in which conditions most quickly turned the scraps into compost. He did the experiments summarised in the following table. Column 2 shows that Theo used two different types of scraps in his experiments. Apart from the types of scraps there were three variables in each experiment.

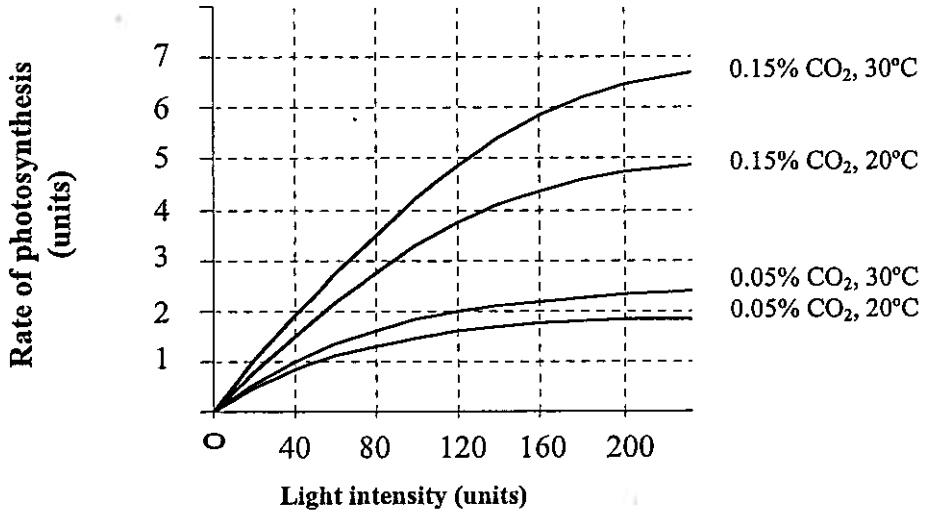
Experiment	Type of scraps	Container	Where put	Other comments
1	Banana skins	Glass jar	Sunny place	Lid put on jar
2	Banana skins	Plastic jar	Sunny place	Lid put on jar
3	Potato peel	Glass jar	Sunny place	Lid put on jar
4	Potato peel	Glass jar	Sunny place	No lid on jar
5	Potato peel	Plastic jar	In shade	No lid on jar

1 List the three variables for each experiment.
2 What is the aim of experiments 1 and 2?
3 What is the aim of experiments 3 and 4?
4 Experiment 5 is of no use on its own. Theo wanted to test if potato peelings become compost faster in the sun or in the shade. Suggest one change Theo must make to experiment 5 so it can be compared with experiment 4.

Figure 5.10

Use the following information to answer Questions 9 + 10

The graph shows some information about the *rate of photosynthesis* in a plant species, under different conditions.



9. What is the rate of photosynthesis when carbon dioxide concentration is 0.15%, air temperature is 30°C and light intensity is 120 units?

(A) 2.0 units

(B) 3.8 units

(C) 4.9 units

(D) 6.6 units

10. Which conclusion can be drawn from this data?

(A) Rate of photosynthesis is affected most by temperature.

(B) Rate of photosynthesis is directly proportional to light intensity.

(C) Light intensity is affected by rate of photosynthesis and temperature.

(D) Rate of photosynthesis is affected by the light intensity range tested.

Use the following information to answer Questions 11 – 14

'Brand A' claims that its dry cell battery delivers more energy than brands 'B', 'C' and 'D'. Students decided to test this claim.

The students put a 'brand A' battery in a toy car, 'W'.
Brands B, C and D's dry cell batteries were placed in three different toy cars (X, Y and Z respectively).
The cars were operated around a circular track. The number of laps each car completed before battery discharge was recorded as results.

The same experiment was repeated with a second battery from each brand.

Battery used	*Results using first battery*	*Results using second battery*
A	Car W - 47 laps	Car W - 43 laps
B	Car X - 42 laps	Car X - 27 laps
C	Car Y - 35 laps	Car Y - 48 laps
D	Car Z - 49 laps	Car Z - 40 laps

11. Which choice correctly identifies the *dependent* and *independent* variables in this experiment?

	Dependent variable	*Independent variable*
(A)	Number of laps completed	Brand of battery used
(B)	Number of laps completed	Type of car used
(C)	Brand of battery used	Number of laps completed
(D)	Type of car used	Number of laps completed

12. Which statement about *reliability* of the experiment is correct?

(A) The experiment is reliable, because the results for car W were almost the same for each battery.

(B) The experiment is reliable, because more than one set of readings was taken for each battery.

(C) The experiment is **not** reliable, because laps varied greatly between the first and second batteries for some brands.

(D) The experiment is **not** reliable, because the number of laps done by each brand varied.

13. Which statement best describes the *validity* of this experiment?

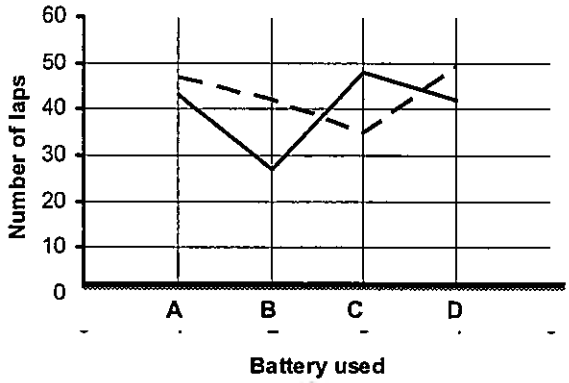
(A) The experiment is valid, because the number of laps for each car is a good indicator of the amount of energy stored in the battery.

(B) The experiment is **not** valid, because results between battery brands differ.

(C) The experiment is valid, because repeated measurements are made for each toy car.

(D) The experiment is **not** valid, because some variables, (such as the type of toy car) are not controlled.

14. The graph shows the students' results.



Which statement is best supported by these results?

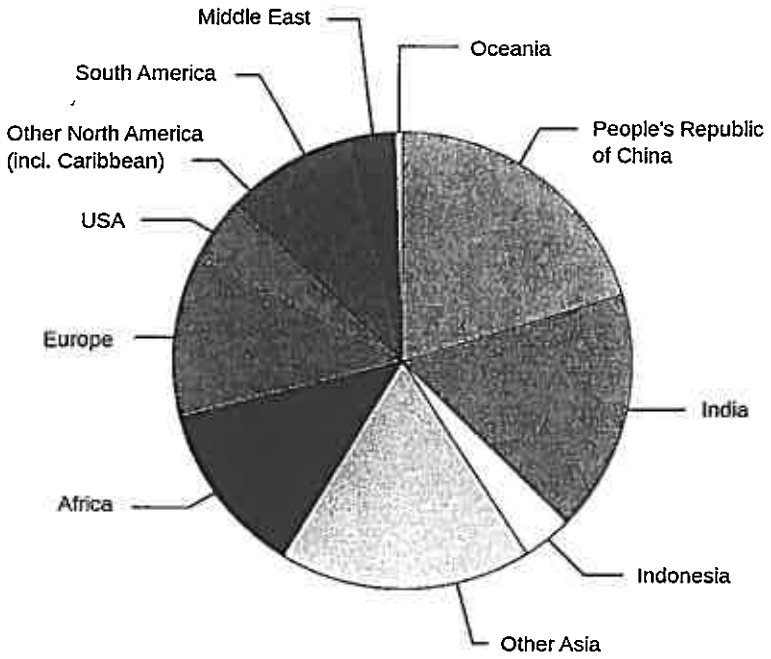
(A) Battery D is much better than the other three batteries.

(B) Battery C is the most efficient battery.

(C) The efficiency of the batteries varied widely.

(D) The results are inconclusive. Improved testing is required.

15. The pie chart shows the distribution of the world's population in 2005.



Approximately what proportion of the world's population was in Europe in 2005?

(A) 6%

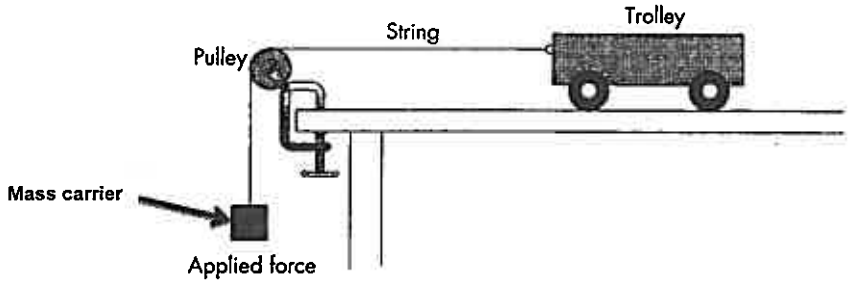
(B) 11%

(C) 33%

(D) 40 %

Use the following information to answer Questions 16 – 20.

A trolley was connected to a mass carrier by a piece of string, over a pulley. The mass carrier applied a force to the trolley.



During this experiment, students varied the force applied by the mass carrier and measured the time it took the trolley to travel 1.0 m across the bench top.
The students used their results to calculate the acceleration of the trolley.

(16.) What is the most suitable *aim* for this experiment?

(A) To find the relationship between the force applied to the trolley and its acceleration

(B) To find the relationship between the mass of the trolley and its speed across the surface.

(C) To measure the speed of the trolley across the surface

(D) To find the relationship between the force applied to the trolley and its final speed

(17) If the experiment is to be a *valid* test, what things need to be controlled?

(A) The mass of the trolley and the applied force

(B) The mass of the trolley and its initial speed

(C) The initial speed of the trolley and the applied force

(D) The mass of the trolley and the time it takes to travel the 1.0 m

(18) Which variable is **NOT** to be controlled in this experiment?

(A) The mass of the trolley

(B) Size of the pulley

(C) The force applied to the trolley

(D) The distance the trolley travelled

(19) What were the measured *variables* in this experiment?

(A) The mass of the trolley and the applied force

(B) The force applied to the trolley and the distance travelled

(C) The initial speed of the trolley and its mass

(D) The time the trolley took to travel 1.0 m and the applied force

(20.) Which of the following is an appropriate *safety precaution* students should take when doing this experiment?

(A) Ensure that students do **not** put their hands between the trolley and the pulley.

(B) Make sure that the height of the bench is more than a metre from the floor, so that the accelerating masses do not touch the floor.

(C) Make repeated measurements for each accelerating force; and use an average value in their calculations, so that the results are more reliable.

(D) Make sure that the pulley is lubricated, so that it does **not** increase friction during each run of the experiment.

Refer to the following information to answer Questions 21 + 22.

The table compares some properties of two fruit juice drinks.

Drink	*Sugar content (g/100 mL)*	*Protein (g/100 mL)*	*Energy content (kJ per 100 mL)*
Brand *X* orange	11.1	Less than 0.5	180
Brand *Y* strawberry	4.4	Less than 0.3	75

21. Which statement about these two juices is supported by the information in the table?

(A) The orange juice will be better to drink before exercise than the strawberry juice.

(B) The orange juice has less "goodness" in it than the strawberry juice.

(C) The orange juice has about 240% of the energy content of strawberry juice.

(D) The orange juice is less healthy to drink than the strawberry juice.

22. Which of the following statements is supported by the data in the table?

(A) The energy content of the juice is linked to its sugar content.

(B) The energy content of the juice is linked to its protein content.

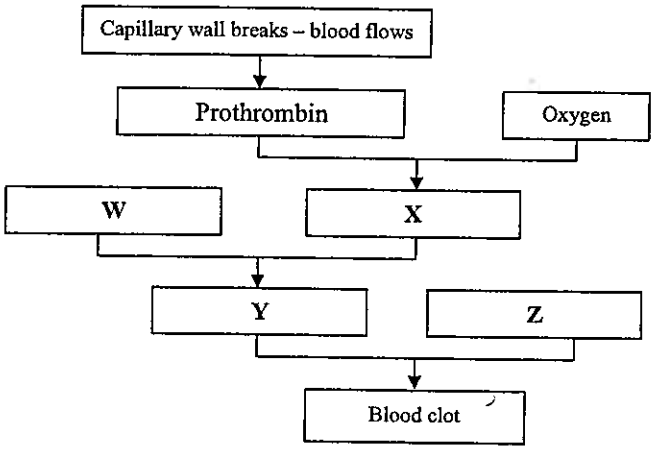
(C) There is *no* connection between sugar content of a juice and its energy content.

(D) The more sugar a juice contains, the less protein it will have.

23. The passage describes the clotting of blood.

> *When you cut yourself, capillaries break and blood flows. Oxygen in the air causes prothrombin to change into thrombin. Thrombin combines with fibrinogen to produce fibrin. Fibrin, and the protein FSF, form an insoluble, mesh-like molecule which makes the blood clot.*

The information could be put into a diagram like the partially completed *flow diagram* below:

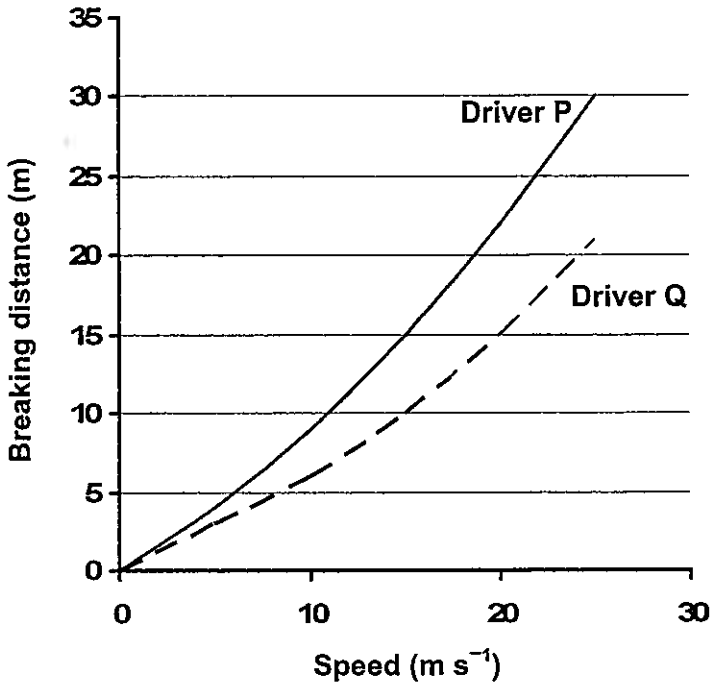


Which choice correctly identifies the names of the chemicals that should be placed in boxes *W*, *X*, *Y* and *Z* respectively?

	W	*X*	*Y*	*Z*
(A)	Thrombin	Fibrinogen	Fibrin	FSF
(B)	Thrombin	FSF	Fibrinogen	Fibrin
(C)	Fibrinogen	Fibrin	FSF	Thrombin
(D)	Fibrinogen	Thrombin	Fibrin	FSF

Refer to the following information to answer Questions 24-26

The graph shows the stopping distance from various initial speeds for two car drivers. Both drivers drive the same car over the same test course. Driver P (full line graph) is 60 years old and driver Q (dashed line graph) is 30 years old.



24. According to this data, what would be the stopping distance for the 60-year-old driver (Driver P), if he was initially moving at 23 m s^{-1}?

(A) 25 m

(B) 28 m

(C) 33 m

(D) Unable to estimate from this data

25. Which conclusion ***cannot*** be drawn from this data?

(A) The 60 year old driver has slower reflexes than the 30 year old driver.

(B) The stopping distance is larger for the older driver at any speed measured.

(C) The faster a car is going, the longer the stopping distance for both drivers.

(D) Driver P takes longer to stop than driver Q.

26. What implication does this data have for car drivers?

(A) The faster you drive, the more stopping distance you need.

(B) Younger drivers are likely to be safer drivers than older drivers.

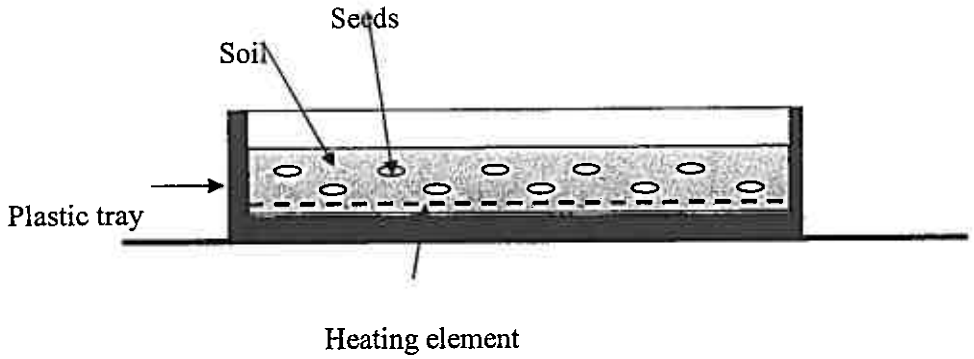
(C) Younger drivers have fewer end-on collisions than older drivers.

(D) It is safer to drive much more slowly than the speed limit.

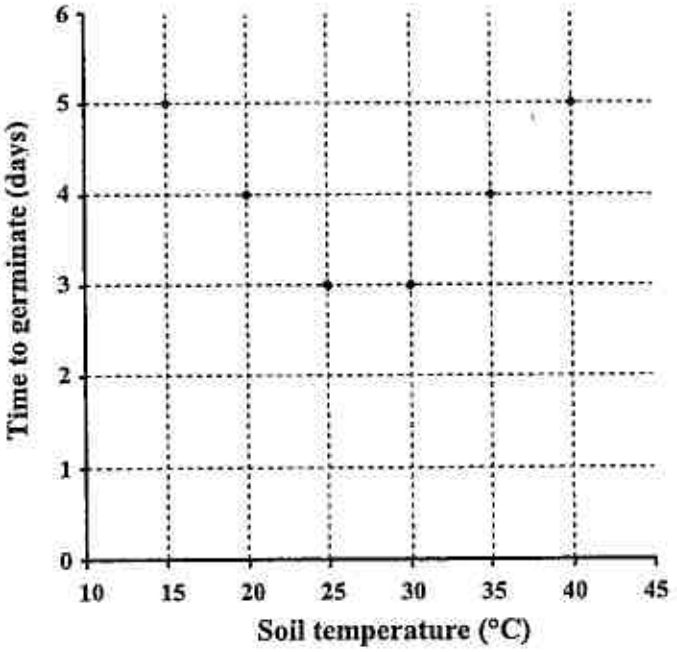
Refer to the following information to answer Questions 27-32

A student tested the effect of soil temperature on the rate of germination. The student used 1.0 kg of soil in each of six identical plastic containers. In each container, soil was kept moist by adding 15 mL of water each day and under-soil heating elements were adjusted to different temperatures. The diagram shows one of the six containers.

The student recorded the day on which the first green shoots broke through the soil surface at germination.



The student plotted her data and showed it to her teacher before completing the graph.



(27) Which choice correctly identifies the *dependent* and *independent* variables for the results shown in the graph?

	Dependent variable	*Independent variable*
(A)	Height of plant growth	Soil temperature
(B)	Time to germinate	Height of plant growth
(C)	Soil temperature	Time to germinate
(D)	Time to germinate	Soil temperature

28. What information in the diagram of the plastic tray may indicate a problem with experimental design?

(A) Not enough seeds have been used in each tray.

(B) Not enough water has been used to ensure the plants survive.

(C) No indication of the temperatures of the heating elements has been given.

(D) The depth of planting the seeds has not been controlled.

29. What error has the student made in how 'time to germinate' was measured?

(A) The student has dotted grid lines and replication was not used.

(B) There is no mention of averaging the results, or how many shoots needed to appear before being recorded.

(C) The temperature should have been cycled to mimic natural variations of temperature from day to night.

(D) Variation in sunlight should have been added to the experiment.

30. Which is the most appropriate conclusion for these results?

(A) The higher the soil temperature, the faster the seeds germinate.

(B) The seeds germinate fastest at 27.5°C

(C) Germination of seeds is independent of soil temperature.

(D) Germination of seeds occurs more rapidly between 23°C and 32°C.

31. There is at least one other reason that the experimental design needs improving.

Which of the following identifies an *error* in the experiment?

(A) Water would evaporate from the warmer containers much more quickly, thus causing variation.

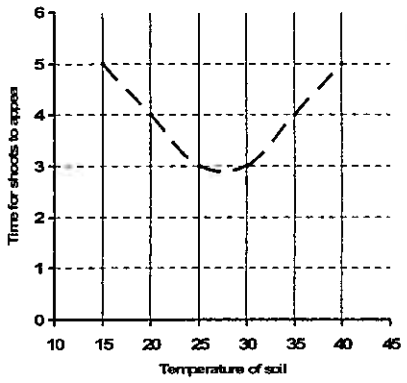
(B) At higher than 40°C the apparatus was probably too hot to handle safely and may have prevented germination.

(C) The thermometer is easier to read if it starts somewhere below 10°C.

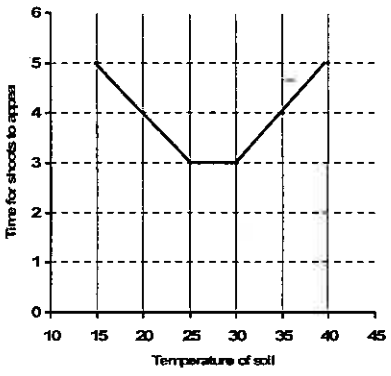
(D) The temperature should have been kept constant.

32. How should the student complete the graph?

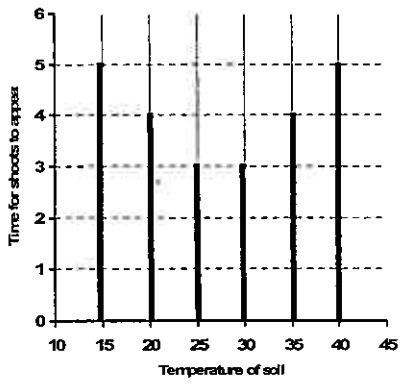
(A)



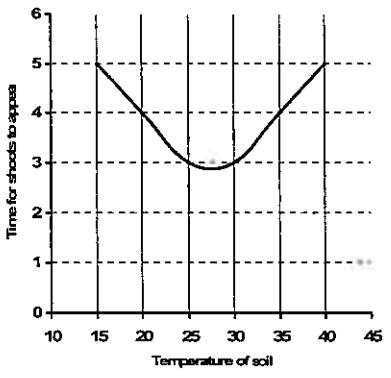
(B)



(C)



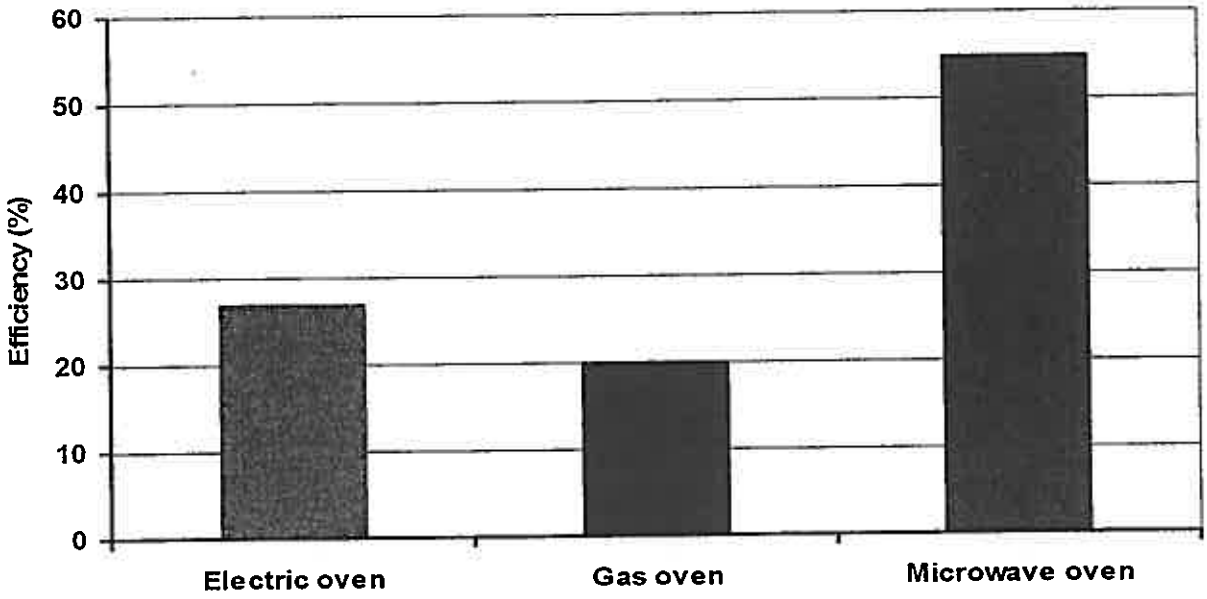
(D)



Refer to the following information to answer Questions 33-34

The graph shows information on the efficiency of three different types of ovens.

Efficiency is a measure of the amount of energy absorbed by the food, compared to the amount of energy used by the oven as the food inside is heated.



33. Based on this information, which statement is correct?

(A) The electric oven is more efficient than the microwave oven at heating the same item.

(B) The gas oven uses more energy to heat the same item compared to the electric oven.

(C) The most efficient fuel is gas, followed by electricity, then microwave.

(D) The microwave oven uses the most energy to heat the same food item.

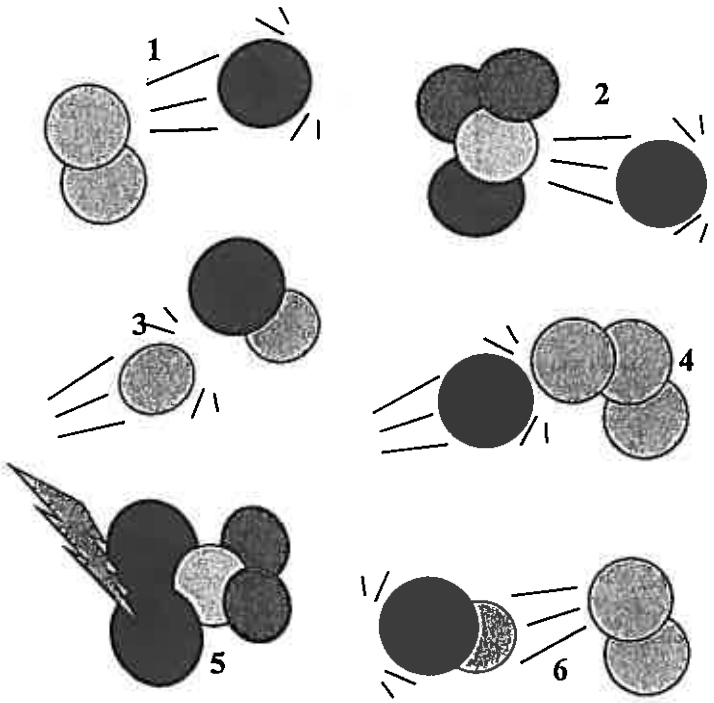
34. If 10 000 kJ of energy was supplied to each oven, what quantity of this energy would be *wasted* in each oven?

	Electric oven	*Gas oven*	*Microwave oven*
(A)	2800	2000	5400
(B)	28%	20%	54%
(C)	7200	8000	4600
(D)	28%	80%	64%

Refer to the following information to answer Questions 35

The processes and diagrams below describe how chlorofluorohydrocarbons (CFCs) affect the ozone layer in the atmosphere.

K UV light hits a CFC molecule.
L Chlorine atom breaks away from the CFC molecule.
M Chlorine atom hits ozone molecule.
N Chlorine atom takes one oxygen atom away from the ozone molecule, leaving a molecule of oxygen and forming a molecule of chlorine monoxide.
O Oxygen atom hits a chlorine monoxide molecule.
P The two oxygen atoms form an oxygen molecule and release the chlorine atom to repeat the process.



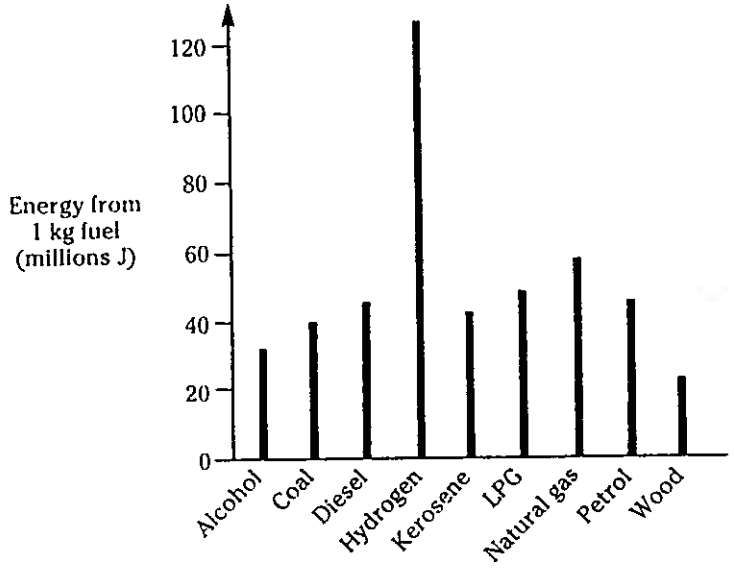
35. Which choice best matches the diagrams to the processes K to P?

	K	*L*	*M*	*N*	*O*	*P*
(A)	5	2	4	6	3	1
(B)	5	2	6	4	3	1
(C)	5	4	2	6	3	1
(D)	5	6	2	4	3	1

36. # Fuel to burn

The graph, Figure 3.13, shows the amounts of energy given out when 1 kg of each fuel burns completely.

Energy released by burning fuels



1 Which fuel produces the least amount of energy per kilogram?
2 How many joules will be released by 2 kg of coal?
3 In many countries petrol and alcohol are mixed in equal amounts as fuel for cars. How much energy would be released by 1 kg of this mixture?