13+ PAST PAPER PACK

Eton College 13+ Science 2024

Complete Past Paper Pack

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Eton College King's Scholarship Examination 2024

SCIENCE 1 (Theory)

(60 minutes)

Candidate Number:………………………………………………………

<u>Please write your candidate number on EVERY sheet</u>.

Please answer on the paper in the spaces provided.

You must attempt ALL questions.

The maximum mark for each question or part of a question is shown in square brackets.

Calculators are allowed. In questions involving calculations, all your working must be shown.

Total Marks Available: 70

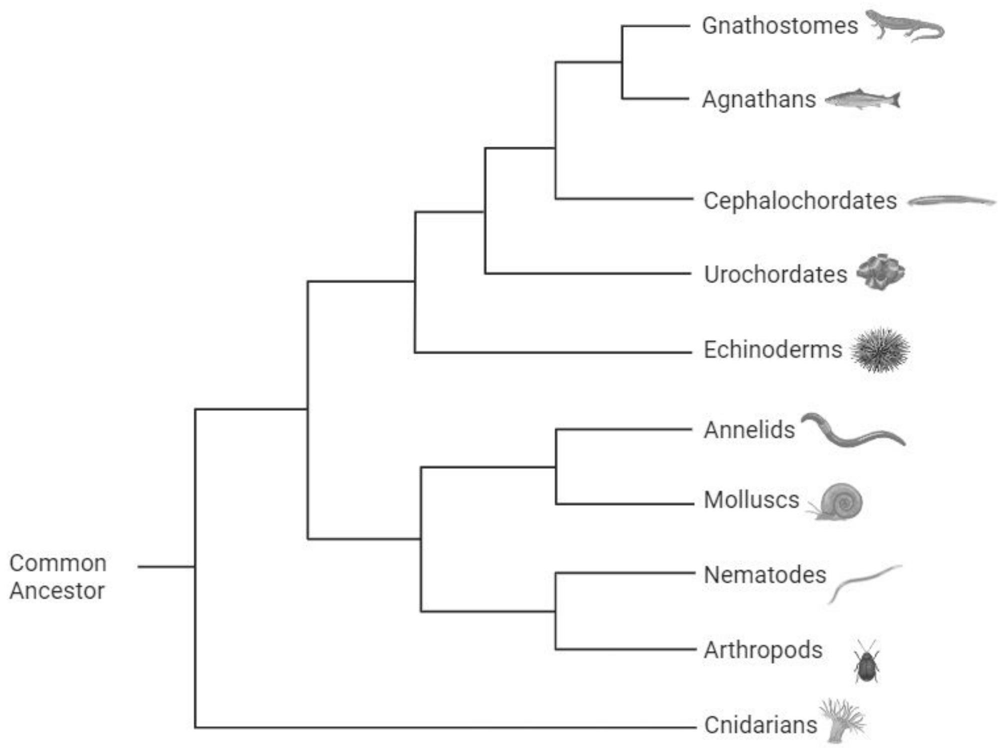
For examiners' use only:

1	2	3	4	5	Total [70]

Do not turn over until told to do so.

1. This question is about animals.

The diagram below is a phylogenetic tree. It shows different groups of animals, and the evolutionary relationships between them.



(a) Which group of animals is most distantly related to the Cephalochordates?

____ **[1]**

In the 18th century, a Swedish botanist called Carl Linnaeus began to classify the organisms on earth into different groups. Organisms that looked extremely similar or shared adaptations were considered the same species. Different species could belong to the same genus e.g. The red fox (*Vulpes vulpes)* and the Arctic fox (*Vulpes lagopus*) both belong to the *Vulpes* genus.

(b) Which group do all the organisms in the diagram above belong to?

____ **[1]**

Linnaeus completed his work in the 1700s before much modern biology was discovered. Since then, scientists have changed many of his original ideas so we can classify organisms more accurately.

(c) Suggest three reasons why Linnaeus' original classifications (the groups he put different organisms in) might have needed to be changed to fit with our modern understanding of biology.

1.____

____

2.____

____

3.____

____ **[3]**

All of the animals shown in the phylogenetic tree share some qualities at a cellular level.

(d) Complete the table below with a **tick** or a **cross** in each box to show which structures we would expect their cells to have.

Cell Structure	**Present in cells?**
Cell Membrane	
Nucleus	
Ribosomes	
Chloroplasts	
Mitochondria	
Cytoplasm	
Permanent Vacuole	

[1]

One of the features that separates animals from plants is that animal cells do not have a cell wall. Plant cells have a rigid cell wall made of cellulose. This is to prevent them from bursting if the plant takes in too much water. Animals usually have other adaptations to remove excess water from their bodies (e.g. filtering it out using the kidneys).

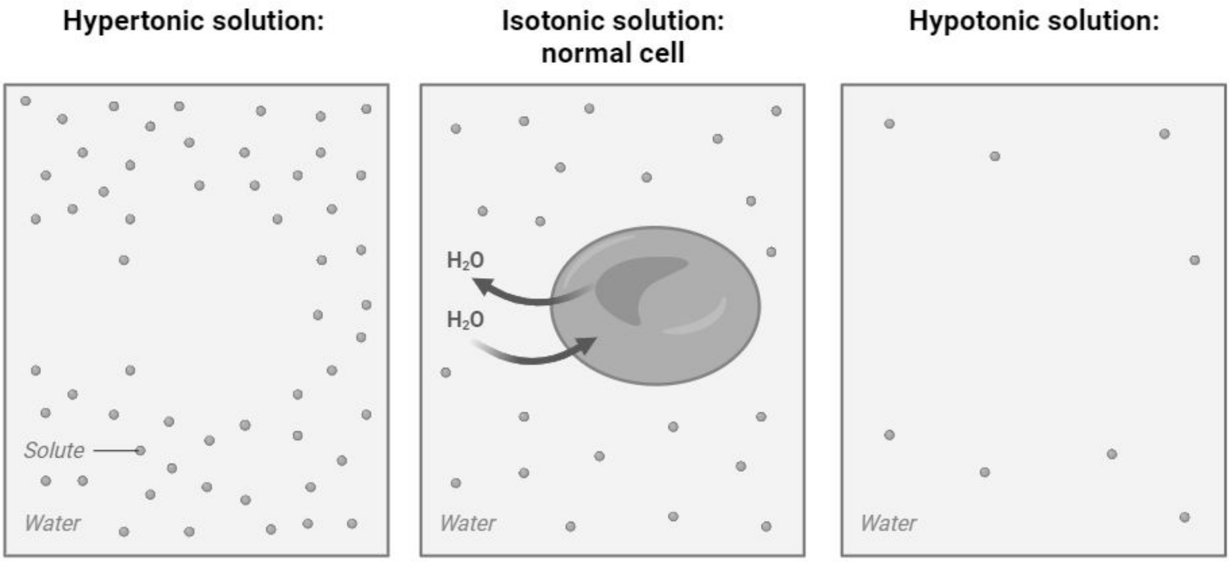
Water moves in and out of cells by a process called osmosis. Osmosis can be defined as:

"The movement of water across a partially permeable membrane."

There will be a net movement of water molecules until the concentrations of the solutions on both sides of the membrane are equal. After this, there is no **net** movement.

The diagram below shows three solutions. A red blood cell is placed in each. The cells are permeable to water, but they are not permeable to the solute in the solution.

(e) Draw a red blood cell in the left box and the right box, showing what will happen to its shape when placed in that solution. You should label each cell to show how it differs from the normal cell in the centre.



[2]

Red blood cells are a strange example of an animal cell because they do not contain any organelles and possess a unique shape.

(f) Describe and explain **two** ways in which a red blood cell is adapted to its function.

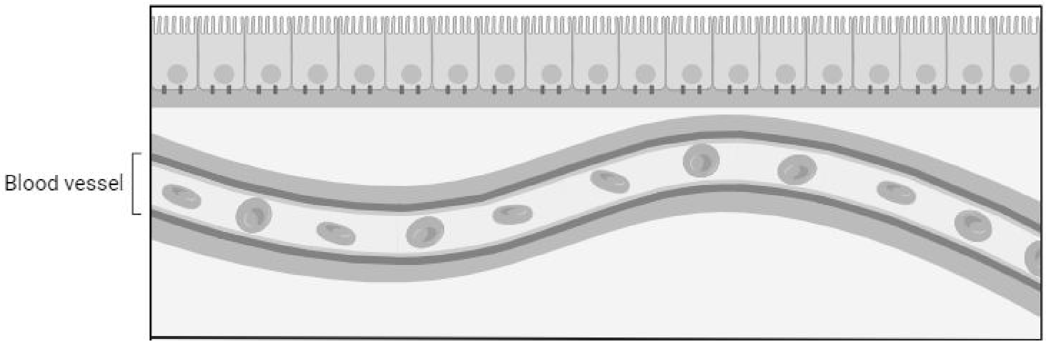
1.____

____

2.____

____ **[2]**

Because animals are multicellular organisms, it is important that oxygen and nutrients can be transported to every cell. To achieve this, most animals have a circulatory system of some sort. Below is an example of part of the human circulatory system.



A blood vessel full of red blood cells delivering oxygen and nutrients to a neighbouring tissue.

Circulatory systems tend to be adapted to maximise the rate at which molecules diffuse into and out of the system.

Increasing the temperature is a factor that would increase the rate of diffusion.

(g) Suggest why increasing the temperature of a circulatory system in an animal could be problematic.

____

____ **[1]**

Circulatory systems also rely on exchange surfaces to pick up and drop off vital molecules, such as oxygen. These exchange surfaces are often highly specialised to carry out this function.

(h) If you were to design an exchange surface from scratch, which features should it have in order to maximise the rate of diffusion?

1.____

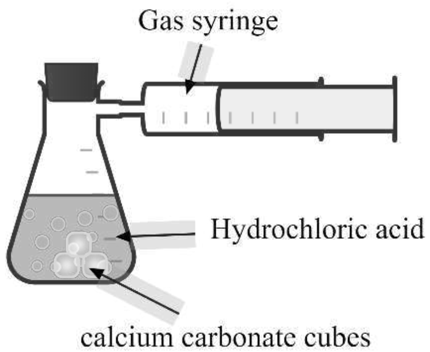
2.____

3.____ **[3]**

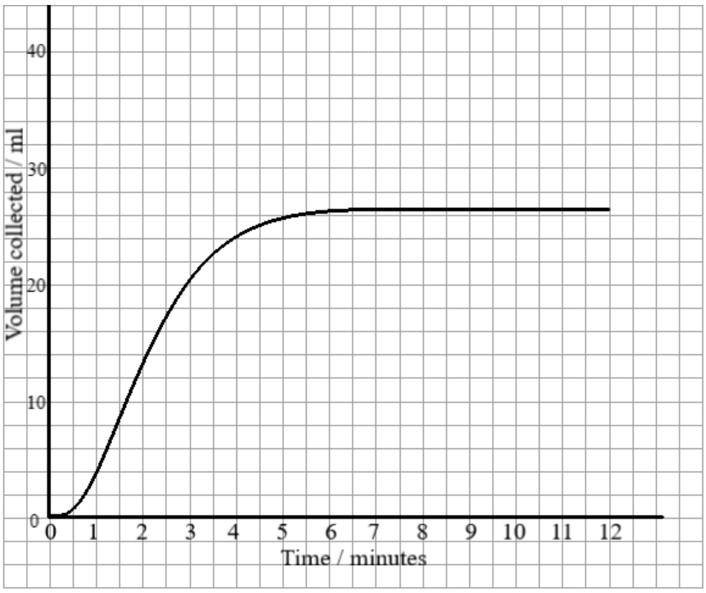
2. This question is about rates of reaction.

A student performs an experiment to investigate the rate of reaction between calcium carbonate cubes and hydrochloric acid of various concentrations.

The equipment is set up as below. The gas syringe is used to measure the volume of carbon dioxide gas given off by the reaction.



Readings are collected from the gas syringe at regular time intervals and a graph of the results is plotted. The student observes that there is still some left-over solid calcium carbonate when the reaction has finished.



(a) Explain why the graph eventually levels out.

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____ **[2]**

(b) Indicate, by drawing a cross on the graph, the point on the curve where the reaction is happening the fastest and estimate the time at which this occurs.

____ **[1]**

The student repeats the experiment, keeping all quantities and volumes the same. However, this time the acid is twice as concentrated as before. There is still left-over solid at the end. A graph is drawn again.

(c) In which two ways would the new graph differ from the original graph at the time you noted in part (b)?

____

____

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____ **[2]**

(d) Would you expect the reaction to finish at the same time as before, or sooner, or later? Explain your answer.

____

____

____ **[2]**

The student notices that right at the beginning of the reaction there is a curve to the graph. He thinks that this is to do with carbon dioxide being slightly soluble in water.

He repeats the experiment, but this time, before starting, he bubbles carbon dioxide through the acid for a while.

(e) Why should bubbling carbon dioxide through the water before starting the reaction have an effect on the shape of the graph, assuming the student is correct?

____

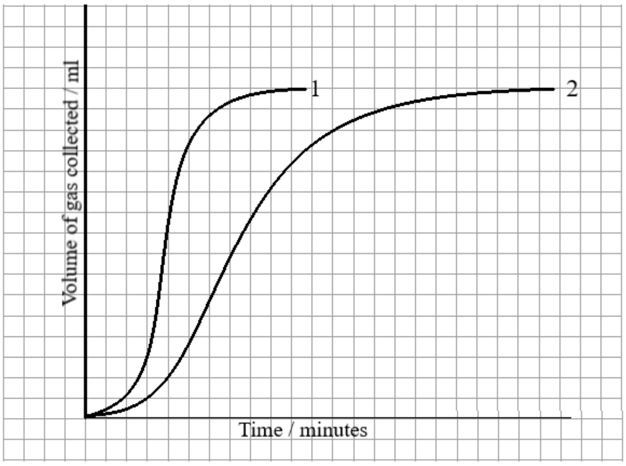
____

____ **[2]**

The student repeats the experiment again but changes the reaction to that of magnesium ribbon with hydrochloric acid. He knows that the hydrogen gas produced is insoluble in water. This reaction gives out more heat than the reaction between calcium carbonate and hydrochloric acid.

He performs the reaction twice, with two different concentrations of acid, the first more concentrated than the second. All other factors are kept constant. Each time it is the magnesium ribbon which runs out.

The graph plots he obtains are shown below:



(f) Explain in terms of particles why reaction 1 is faster.

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____ **[3]**

(g) The graph still shows a curve at the beginning. Suggest what is causing this.

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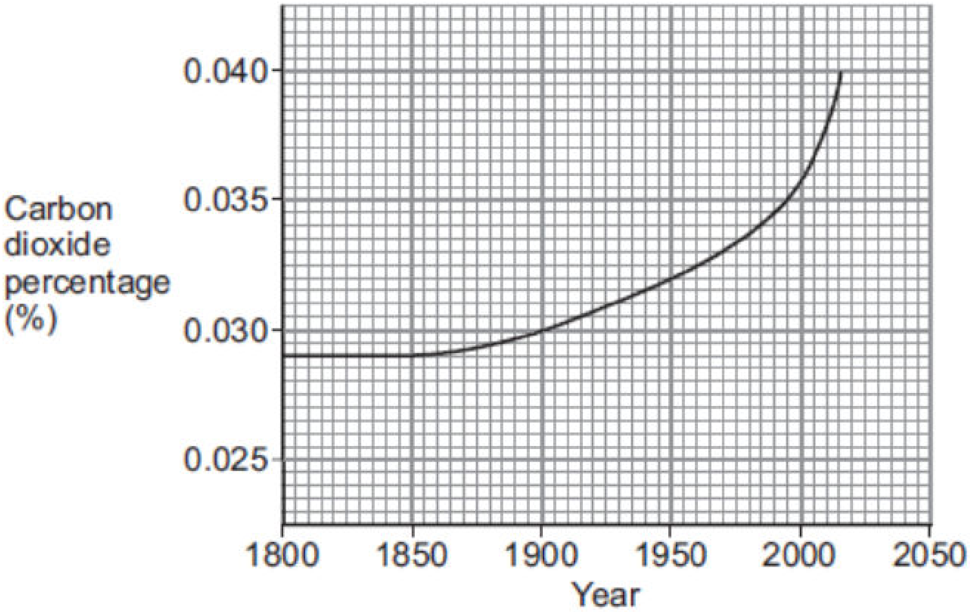
____ **[2]**

3. This question is about investigations in chemistry.

Carbon dioxide is a gas found in the Earth's atmosphere. The graph below shows the percentage (%) of carbon dioxide in the Earth's atmosphere since the year 1800.



(a) What was the carbon dioxide percentage in 1950?

____ [1]

(b) Describe, in detail, how the carbon dioxide percentage changed from 1850 to 2015.

____

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____ [2]

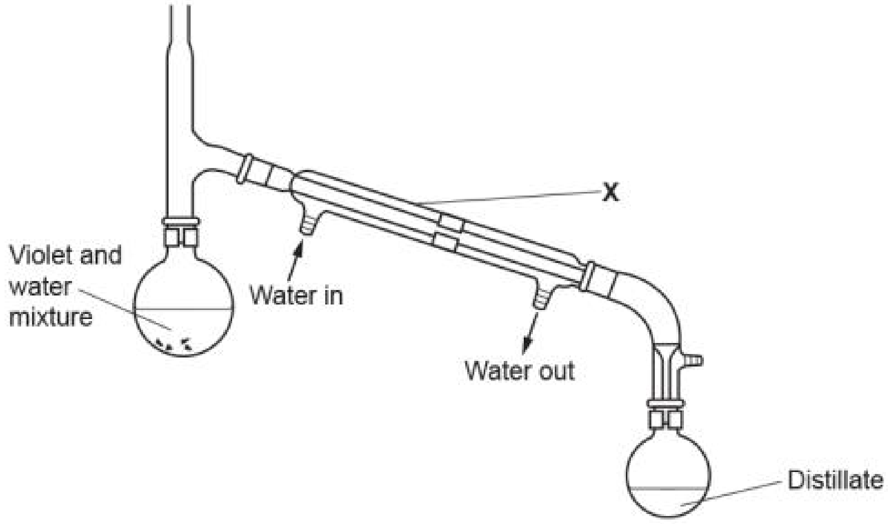
(c) Suggest **two** reasons for the change in the carbon dioxide percentage from 1850 to 2015.

____

____ [2]

A student is making a perfume using violet flowers.

The student does an experiment to extract the perfume from the flowers using the apparatus shown below.



Their teacher says that the apparatus is not set up correctly.

(d) What is the name of the piece of apparatus labelled **X**?

____ **[1]**

(e) What property of the chemicals in violets, used in the perfume, enables them to be extracted using this method?

____ **[1]**

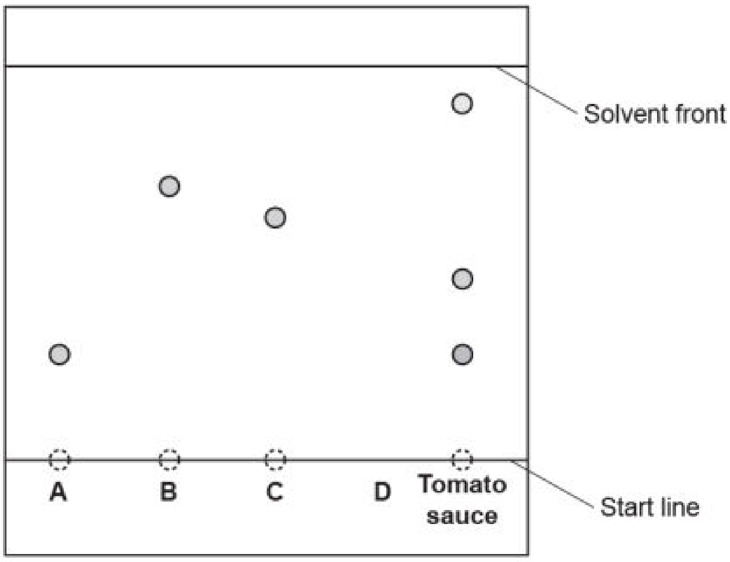
(f) Suggest **two** changes that need to be made to the set-up of the apparatus so that it is set up correctly.

____

____ **[2]**

A scientist analyses a sample of tomato sauce using chromatography.

The tomato sauce is compared to four known food additives **A**, **B**, **C**, and **D** as shown in the chromatogram.



(g) The start line is **not** drawn in ink. Explain why.

____ **[1]**

Food additive **D** is insoluble in the solvent used.

(h) **Draw** on the diagram the spot for food additive **D** at the end of the experiment. **[1]**

(i) Which additive is in the tomato sauce?

____ **[1]**

(j) Calculate the R_f value for additive **C** using the equation provided.

$$R_f = \frac{\text{distance travelled by substance}}{\text{distance travelled by solvent}}$$

Give your answer to **2** significant figures.

____

____ **[2]**

4. This question is about measuring temperatures.

A practical temperature scale needs two defined points that can be reproduced reliably, and some measurable property that changes smoothly with temperature. Celsius defines 0ºC as the melting point of water and 100ºC as the boiling point of water at standard atmospheric pressure. The expansion of a thread of coloured liquid in a thin glass tube is a typical measurable property. The property is measured at these two points, and then at the temperature that we wish to measure.

A scientist needs to know the temperature of his laboratory, but has no thermometer. However, he does have a balloon filled with air, which expands and contracts with temperature, and he has water, ice, a kettle, and a measuring cylinder.

He immerses the balloon in a mixture of ice and water, and he measures the volume of the balloon as 3000 cm^3. When he immerses it in boiling water he measures the volume as 4100 cm^3. When the balloon is at the temperature of his laboratory the volume is 3264 cm^3.

(a) What is the temperature of the laboratory, in degrees Celsius? Show your reasoning.

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____**[3]**

(b) What assumption have you had to make?

____

____**[1]**

(c) If the scientist had measured the **diameter** of the balloon and used that instead of volume as his measure of temperature, would the temperature he calculated be the same as your answer to part (a), higher than it, or lower than it? Explain your answer.

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____**[3]**

The scientist decides to define a new temperature scale, (which he calls 'Tipsy'), based on alcohol. He defines 0^o Tipsy as the melting point of alcohol, and 100^o Tipsy as the boiling point of alcohol. These points are -115^oC and 78^oC respectively.

(d) If an object increases its temperature by 1.0^o Tipsy, by how much does its temperature increase in Celsius?

____ **[1]**

(e) What are the melting point and boiling point of water, on the Tipsy scale?

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____ **[3]**

(f) If the scientist's body temperature is 80.0^o Tipsy, what is this in Celsius?

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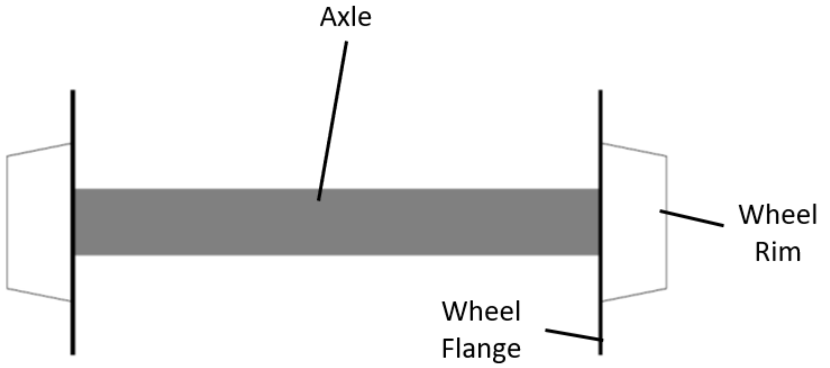
____ **[2]**

(g) Give one practical difficulty that might be presented by basing a temperature scale on the melting and boiling points of alcohol.

____ **[1]**

5. This question is about railway wheels.

A railway wheelset consists of two wheels joined by a rigid axle, as shown in the diagram below.



The wheels are made from steel and have flanges on their inner edges. It is sometimes thought that the flanges are necessary for the wheelset to follow a curved track. However, this is not the case: the wheelset would follow a curved track even without the flanges.

(a) When a used wheelset is inspected, the rim of the wheel is found to be highly polished and shiny. The flange, on the other hand, is comparatively rough. Explain briefly how this is evidence that the flange is *not* used to steer the wheelset around curved tracks.

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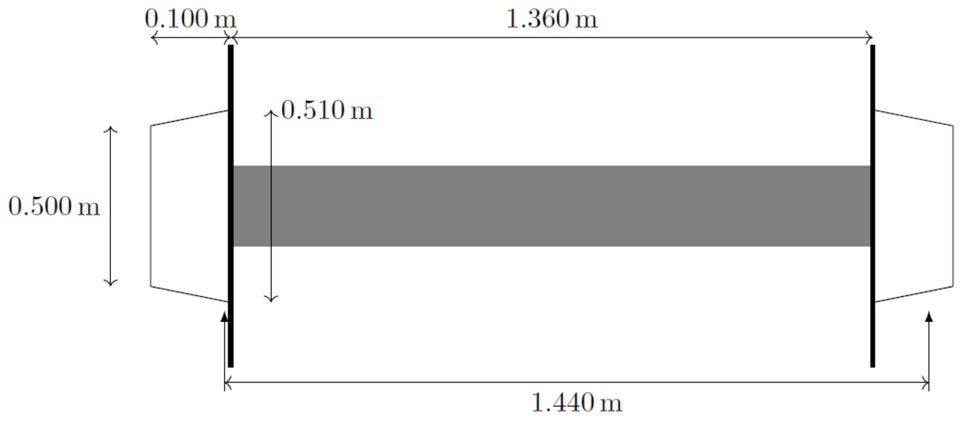
____ **[2]**

The wheel rims have a conical profile. This means that if the wheelset is displaced to one side on the rails, then the circumferences of the parts of the wheels that are in contact with the rails will be different on the left- and right-hand sides. This will cause the wheelset to change direction and to travel in a curved path.



(b) For the wheel profiles shown in the diagram above, calculate the diameter of the wheel at the point of contact on the right-hand side, given that the left-hand side makes contact immediately next to the flange (the points of contact are indicated by the vertical arrows beneath the rims). You may take the separation of the rails (the 'gauge') to be 1.440 m.

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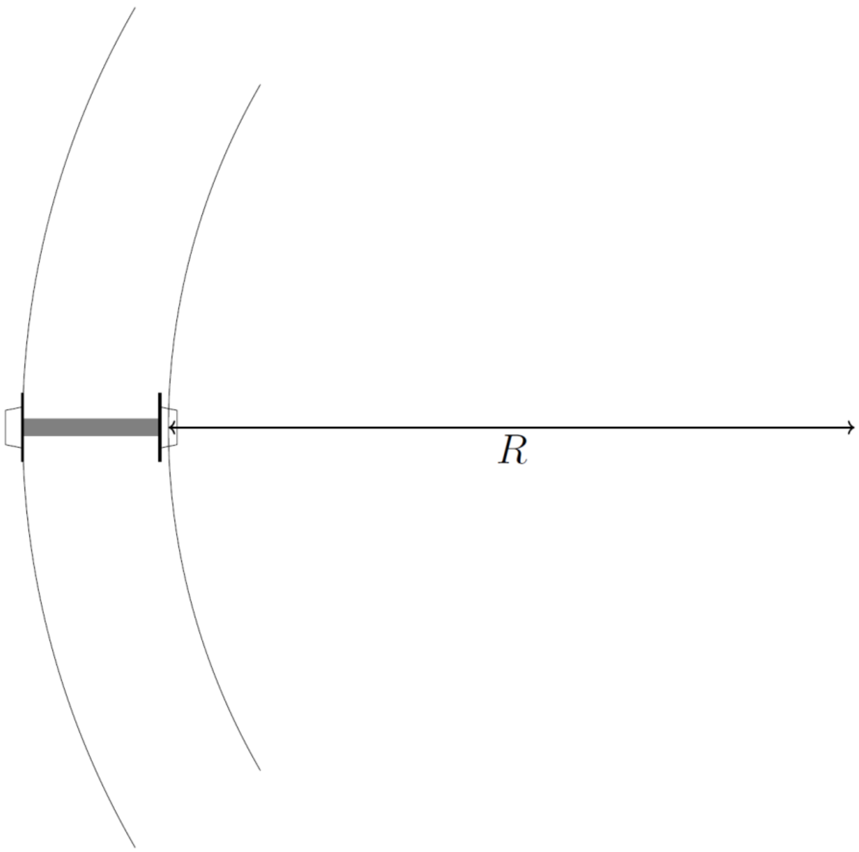
____**[3]**

The wheelset is offset from the centre of the rails which allows it to follow the curve of the rails. The rails have a radius of curvature R as defined in the diagram below.



(c) Using your answer from the previous question, calculate the radius of curvature, R. Consider the fact that both wheels will have travelled a full circumference in the same time.

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____**[3]**

The force required to turn the train depends on the speed of the train, v, the mass of the train, m, and radius of the curve, R, according to the formula

$$F = \frac{mv^2}{R}$$

In the situation we are considering (a track with no camber), this force is provided by the friction between the wheels and the rail. The maximum frictional force that can be thus provided is given by the following formula

$$F = \mu mg$$

where the coefficient of friction $\mu = 0.4$, and $g = 9.8$ N/kg.

(d) Using the formulae, calculate the maximum speed (in m/s) that a locomotive, with a mass of $m = 100\ 000$ kg, could go around a curve of radius 200 m.

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____ **[3]**

(e) State and justify what would happen to the value of the maximum speed that the train can go around the curve if wet leaves fall on the rails.

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____

____ **[1]**

For a front-wheel drive car, in which the front axle is driven by the engine, a device called a 'differential' connects the driveshaft to the front axle. It allows the left and right wheels to rotate at different rates while still being powered by the engine.

(f) Explain why the car front axle requires a differential, but a railway axle does not.

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____ **[2]**

Paper Notes: 13+ Science Question Paper (13+ Science Past Paper (2024))

Compiled by SATs-Papers.co.uk to help you get the most from this paper.

Overview

This is the **Science 1 (Theory)** paper from the **Eton College King's Scholarship Examination 2024**, a 60-minute test carrying **70 marks** in total. The paper is designed for candidates sitting the **13+ entrance examination** (Year 9 entry) and covers a broad sweep of science topics across biology, chemistry, and physics.

The questions are structured to assess both factual recall and the ability to apply scientific principles to unfamiliar contexts. Students encounter a phylogenetic tree and animal classification, rates of reaction experiments, chromatography and distillation apparatus, a novel temperature scale problem, and the physics of railway wheelsets. The paper expects candidates to show all working in calculations and to write in the spaces provided.

This examination is aimed at academically able students preparing for selective independent school entry. The questions demand not only curriculum knowledge but also problem-solving insight, the ability to interpret graphs and diagrams, and confidence in manipulating formulae. Calculators are permitted, and the mark scheme rewards clear, logical reasoning alongside correct answers.

How this paper is organised

The paper comprises **five numbered questions** of varying length and difficulty, each subdivided into lettered parts (a, b, c, and so on). **Question 1** focuses on biology and carries approximately 14 marks, covering animal classification, cell structure, osmosis, red blood cells, and exchange surfaces. **Question 2** explores rates of reaction through a series of experiments with calcium carbonate and magnesium, totalling around 14 marks. **Question 3** addresses chemistry investigations (carbon dioxide trends, distillation, chromatography) and also carries approximately 14 marks.

Question 4 tests temperature scales and proportional reasoning, worth about 14 marks, while **Question 5** examines the physics of railway wheelsets (conical wheel profiles, friction, circular motion) and similarly contributes around 14 marks. Each part-question shows its mark allocation in square brackets, guiding students on how much detail to provide. The paper is printed on 16 pages with ample space for written answers and diagrams, and candidates must write their candidate number on every sheet.

Time management is crucial: with 60 minutes for 70 marks, students have slightly less than one minute per mark and must pace themselves accordingly, leaving time to review calculations and written explanations at the end.

Topics covered

- Phylogenetic trees and evolutionary relationships between animal groups (Gnathostomes, Agnathans, Cephalochordates, Urochordates, Echinoderms, Annelids, Molluscs, Nematodes, Arthropods, Cnidarians)
- Linnaeus's classification system and the reasons modern biology has revised historical taxonomies (discovery of DNA, evolutionary theory, microscopy)
- Animal cell structure: presence and absence of cell membrane, nucleus, ribosomes, chloroplasts, mitochondria, cytoplasm, and permanent vacuole
- Osmosis in hypertonic, isotonic, and hypotonic solutions; drawing and labelling cells that have undergone plasmolysis or lysis
- Adaptations of red blood cells (biconcave shape for increased surface area, lack of nucleus to maximise haemoglobin content)
- Features of effective exchange surfaces (large surface area, thin walls, good blood supply, concentration gradients)
- Rates of reaction: interpreting graphs of volume collected over time, identifying the point of maximum rate, explaining why reactions level out when a reactant is used up
- Effect of concentration and temperature on reaction rate; particle collision theory and activation energy
- Solubility of gases in liquids and its effect on the initial shape of reaction-rate curves
- Atmospheric carbon dioxide trends from 1800 to 2015; causes of increase (fossil fuel combustion, deforestation, industrialisation)
- Distillation apparatus (naming a condenser, understanding volatility, identifying errors in setup such as incorrect water flow direction)
- Chromatography: explaining why the start line is drawn in pencil, interpreting solvent fronts, calculating Rf values, identifying insoluble substances
- Constructing temperature scales from two fixed points (melting and boiling points); interpolating intermediate temperatures by proportional reasoning
- Converting between the Celsius and a hypothetical 'Tipsy' scale; understanding that a 1° change on one scale corresponds to a different increment on another
- Conical wheel profiles on railway wheelsets; calculating wheel diameters from gauge measurements and conical geometry
- Radius of curvature from the ratio of wheel circumferences; centripetal force, friction, and maximum safe speed on curves ($F = mv^2/R$ and $F = \mu mg$)
- Comparing rigid railway axles with car differentials; explaining why cars need differentials but trains do not

How to use this paper for revision

- Revise **phylogenetic trees** and be comfortable reading them left to right or bottom to top, identifying common ancestors and the sequence in which groups diverged.
- Practise **drawing and labelling cells** in different osmotic environments; remember that animal cells burst in hypotonic solutions because they lack a cell wall.
- Master the **particle theory of reaction rates**: higher concentration and temperature both increase collision frequency and energy, speeding up reactions.
- For **chromatography Rf calculations**, measure from the baseline to the centre of the spot, not the top edge, and express your answer to the correct number of significant figures.
- When tackling **temperature scale conversions**, set up a proportion linking the two scales' ranges, then solve for the unknown; always check your arithmetic twice.
- In **circular motion problems**, equate centripetal force (mv^2/R) with the available friction (μmg) to find maximum speed, and cancel mass on both sides before solving.
- Review **distillation setup**: water enters the condenser at the bottom and exits at the top (countercurrent flow), and the thermometer bulb sits at the side-arm junction to measure vapour temperature.

Common mistakes to avoid

- Confusing osmosis with diffusion: osmosis is specifically the movement of water across a partially permeable membrane, not the movement of solute particles.
- Forgetting that **animal cells lack chloroplasts and permanent vacuoles**; these are plant cell features, and ticking them on an animal cell table loses marks instantly.
- Reading a reaction-rate graph and stating the reaction is fastest at the end when the graph levels out; in fact, the steepest gradient (usually near the start) indicates maximum rate.
- Drawing the start line of a chromatogram in **ink**: ink dissolves in the solvent and interferes with the separation, so pencil must be used instead.
- Calculating Rf values without **measuring from the start line**, or forgetting to divide by the solvent front distance, leading to incorrect or impossibly large Rf values.
- Assuming that doubling the concentration of acid in a reaction doubles the total volume of gas produced, when the limiting reactant stays the same; doubling concentration affects rate, not final yield if the other reactant is in excess.

Exam technique

Start by reading through the entire paper quickly to identify questions that play to your strengths, then tackle those first to bank marks confidently. For questions involving calculations (rates of reaction, temperature scales, railway physics), **always show your working step by step**; even if your final answer is wrong, you can earn method marks for correct reasoning.

Pace yourself carefully: with 70 marks in 60 minutes, you have slightly less than one minute per mark. If a question part is worth 3 marks, aim to spend around 3 minutes on it, writing enough detail to justify that allocation. For longer written explanations (2 or 3 marks), structure your answer in clear sentences rather than single words, and refer explicitly to scientific principles (collision theory, osmosis, friction) to demonstrate understanding.

Leave time at the end to review your answers, especially numerical work. Check that units are correct, that you have simplified fractions or rounded to the requested number of significant figures, and that diagrams are fully labelled. If you are unsure about a question, make an educated guess rather than leaving it blank, as partial credit is often available for sensible reasoning.

What to revise alongside this paper

To prepare fully for this paper, revise **cell biology** in detail: not only the structures listed here but also how cells specialise for different functions (nerve cells, root hair cells, sperm cells). Deepen your understanding of **rates of reaction** by practising with different reactants (marble chips and acid, sodium thiosulfate and acid) and learning how to draw tangents to curves to find instantaneous rates.

Study **separation techniques** beyond chromatography: fractional distillation of crude oil, filtration, crystallisation. For the physics sections, review **circular motion** (including banked tracks and vertical loops) and **friction** (static vs kinetic, factors affecting μ). Practise setting up and solving **proportional relationships** in unfamiliar contexts, such as calibrating instruments or converting between non-standard units.

Finally, read around the **history of science** (Linnaeus, Darwin, the development of the periodic table) to appreciate why classification systems evolve, and explore real-world applications of the chemistry and physics you study, such as pharmaceutical manufacturing and railway engineering. This broader perspective often helps in tackling synoptic questions.

Key terms

> **Phylogenetic tree**, **Linnaeus classification**, **Osmosis**, **Hypertonic, isotonic, hypotonic**, **Red blood cell adaptations**, **Exchange surface**, **Rate of reaction**, **Collision theory**, **Distillation**, **Condenser**, **Chromatography**, **Rf value**, **Temperature scale**, **Proportional reasoning**, **Conical wheel profile**, **Centripetal force**, **Coefficient of friction**

Eton College King's Scholarship Examination 2024

SCIENCE 2 (Data Analysis)

(30 minutes)

Candidate Number:……………………………………………………

<u>Please write your candidate number on EVERY sheet</u>.

Please answer on the paper in the spaces provided.

You must attempt ALL questions.

The maximum mark for each question or part of a question is shown in square brackets.

Calculators are allowed. In questions involving calculations, all your working must be shown.

Total Marks Available: 30

<u>ADDITIONAL MATERIALS</u>: **INSERT**

For examiners' use only:

1	2	Total [30]

Do not turn over until told to do so.

Rainfall patterns have changed in recent years due to the effects of climate change. Understanding the impact these changes are having on ecology is a scientific problem currently being investigated. As our planet contends with new shifts caused by climate change, exploring the correlation between fluctuating rainfall patterns and the effect on ecosystems and biodiversity becomes more urgent. Notably, data suggest a concerning decline in butterfly populations, which serve as an indicator of environmental disruption.

1. Measuring rainfall serves as a fundamental method to quantify precipitation patterns and understand seasonal variations. The table below shows the rainfall per month in the years 2020 and 2021.

Month	**Rainfall in 2020 / mm**	**Rainfall in 2021 / mm**
Jan	121	140
Feb	214	105
March	79	87
April	30	21
May	33	121
Jun	108	45
July	96	75
Aug	122	67
Sept	77	82
Oct	183	168
Nov	105	81
Dec	167	114
Total rainfall		
Range		

Fig 1. *A table showing rainfall in 2020 and 2021 in the UK.*

(a) Calculate the total rainfall for 2020 and 2021. Write your answers in the table above. **[1]**

(b) Calculate the range for 2020 and 2021. Write your answers in the table above. **[1]**

(c) Calculate the percentage change in the total rainfall from 2020 to 2021.

Percentage change: _____________**[2]**

(d) Plot the data from Figure 1 in a suitable graph using the grid below. **[5]**

(e) State which month shows the biggest change in rainfall from 2020 to 2021.

____ **[1]**

(f) Identify two trends that can be observed from your graph.

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____ **[2]**

This part of the question focuses on butterfly numbers from **2021.**

Butterflies in the UK, monitored by the UK Butterfly Monitoring Scheme, serve as crucial environmental indicators. By investigating butterfly populations the data generated can be used to evaluate climate change impacts and governmental biodiversity conservation efforts.

2. A hypothesis is an educated guess or prediction made by a scientist before conducting an experiment or investigation. It is a statement that suggests an expected outcome based on available knowledge or observations and can be tested through experiments or further observations to see if it is supported or not.

   (a) Write a hypothesis for the investigation to analyse the impact of changing rainfall on butterfly populations.

____

____

____ **[1]**

Below are the data for five species of butterfly. Images of the 5 species analysed are shown on the insert.

Butterfly species	Number of sites monitored	% change in abundance from 2020 to 2021
Small White	2585	-35
Criptic Wood White	15	-47
Chalk Hill Blue	303	48
Common Blue	2253	-9
Holly Blue	1911	-50

Fig 1. *A table showing changes in abundance of five different butterfly species.*

   (b) Why has the data been presented as percentage change?

____

____

____ **[2]**

   (c) Suggest the unit that the raw data may have been collected in.

____ **[2]**

The majority of sites are investigated using butterfly transects, a method also known as 'Pollard walks'. The standard transect method involves weekly butterfly counts along fixed routes through the season made under strict criteria.

(d) Suggest what equipment might be needed in order to gather the data.

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____[1]

(e) Suggest which 'strict criteria' should be applied to the sampling.

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____[3]

(f) One scientist concluded that **'decreasing rainfall caused a decrease in butterfly populations'**. Discuss this conclusion.

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____[4]

Citizen science in wildlife surveys, such as butterfly counts, involves the work of volunteers. Often, these are members of the public contributing to scientific research by actively participating in data collection and observation of wildlife in their natural habitats. This could include local woodland or the volunteers' gardens. The insert is an example of an identification chart that the volunteers are provided with.

(g) Evaluate the use of citizen science to collect data in this study.

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____ **[3]**

Ecologists are now using advanced technology like Artificial Intelligence (AI) to monitor wildlife more effectively. By analysing camera footage, AI helps identify and track various species. Programs like Google DeepMind can predict ('nowcast') weather patterns within 2-6 hour windows.

(h) Suggest why using AI might be more beneficial than citizen science in monitoring butterfly numbers.

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____ **[2]**

END OF PAPER

Paper Notes: 13+ Science Question Paper (13+ Science Past Paper (2024))

Compiled by SATs-Papers.co.uk to help you get the most from this paper.

Overview

This is **Science 2 (Data Analysis)**, published by **Eton College** as part of the **King's Scholarship Examination 2024**. The paper is designed for candidates applying for the prestigious King's Scholarship at Eton, taken by pupils in Year 8 sitting the **13+ entrance examination**. It is a 30-minute assessment worth **30 marks**, with calculators permitted and an additional insert providing visual materials.

The paper focuses on **data interpretation and scientific thinking** through a real-world ecological scenario. Candidates must analyse rainfall data from 2020 and 2021, plot and interpret graphs, then explore the relationship between changing precipitation patterns and butterfly population trends. Questions require both quantitative skills (calculating totals, ranges, percentage changes) and qualitative scientific reasoning (writing hypotheses, evaluating methodologies, discussing conclusions).

This assessment suits high-achieving pupils aiming for academic scholarships, particularly those comfortable with handling complex datasets and articulating scientific arguments. The paper tests not just calculation ability but also critical thinking about experimental design, data reliability, and the limitations of scientific conclusions. The ecological theme is contemporary and relevant, requiring candidates to engage with climate change science and biodiversity monitoring.

How this paper is organised

The paper contains **two main questions**, subdivided into multiple parts, with all working and answers written directly onto the question paper. Question 1 (parts a-f) addresses rainfall data analysis, beginning with straightforward calculations (totals and ranges, worth 1 mark each) before progressing to percentage change (2 marks) and graph plotting (5 marks). The graph construction task is the most heavily weighted single item in the question.

Question 2 (parts a-h) shifts to butterfly population data and scientific methodology. It opens with hypothesis writing (1 mark), then moves through data interpretation (2 marks each for parts b and c), equipment and sampling criteria (1 and 3 marks respectively), and culminates in extended response tasks: a 4-mark discussion of a causal conclusion and a 3-mark evaluation of citizen science. The final part (h) asks for a 2-mark comparison with AI monitoring methods.

The mark distribution favours extended reasoning over simple recall. Graph work, discussion of scientific conclusions, and evaluation of methods together account for 12 marks (40% of the total). The paper includes an **insert** with butterfly identification images, referenced in question 2 but not reproduced in the main exam booklet.

Topics covered

- Data handling and table completion: calculating totals, ranges, and percentage changes from rainfall datasets spanning two years
- Graph construction: selecting appropriate axes, scales, and formats to plot monthly rainfall data for comparison between years
- Data interpretation: identifying specific months with maximum change and describing trends visible in plotted data
- Scientific hypothesis writing: formulating testable predictions about the relationship between rainfall patterns and butterfly abundance
- Understanding percentage change as a standardised measure for comparing species with different baseline population sizes
- Ecological fieldwork methods: the Pollard walk transect method for butterfly monitoring and associated sampling protocols
- Experimental design and controls: identifying strict criteria (weather conditions, time of day, observer consistency) needed for reliable data collection
- Critical evaluation of scientific conclusions: assessing whether correlation implies causation, considering confounding variables and data limitations
- Citizen science methodology: weighing advantages (large sample size, public engagement) against disadvantages (training variability, identification errors)
- Technology in ecological monitoring: comparing AI-based species identification with traditional volunteer survey approaches

How to use this paper for revision

- Practise calculating percentage change using the formula (difference divided by original, multiplied by 100) and remember to show your working clearly, as the mark scheme will reward method marks even if the final answer contains an arithmetic slip.
- When plotting graphs, take time to choose sensible scales that use most of the grid provided. Label both axes with quantities and units, add a title, and use a ruler for neat lines or clear points with a key if plotting multiple data series.
- For hypothesis questions, structure your answer as 'If [independent variable changes], then [dependent variable] will [predicted change] because [brief scientific reason]'. Avoid vague statements; be specific about the direction of predicted change.
- Extended response questions (4 marks or more) require balanced answers. For 'discuss' questions, present multiple viewpoints: what the data show, what they might not show, and what other factors could be involved. Aim for at least three distinct points.
- When asked to 'evaluate', always give both strengths and limitations. For citizen science, think about sample size and geographical coverage (strengths) versus training, consistency, and potential identification errors (limitations).
- Remember that correlation does not prove causation. In ecological questions, multiple variables interact: temperature, rainfall, habitat loss, pesticide use, and predation may all influence butterfly numbers simultaneously.
- Familiarise yourself with ecological vocabulary: 'transect', 'abundance', 'biodiversity', 'indicator species'. Use precise terminology in your answers to demonstrate scientific literacy and gain credit for quality of written communication.

Common mistakes to avoid

- Confusing range (maximum minus minimum) with mean or total. Range measures spread, not central tendency. For the 2020 data, the range is 214 minus 30, not the sum of all months.
- Calculating percentage change incorrectly by using the wrong year as the baseline. The change from 2020 to 2021 requires the 2020 total as the denominator, not 2021 or an average of both years.
- Plotting graphs with poor scale choices that squash all the data into one corner, or choosing scales that make it impossible to plot certain values. Check the range of your data before selecting axis intervals.
- Writing hypotheses that are vague or not testable, such as 'Rainfall affects butterflies' instead of 'If rainfall decreases, butterfly abundance will decrease because less rainfall reduces nectar-producing plant growth'.
- Giving one-sided answers to 'evaluate' or 'discuss' questions. These command words require balance. If you only give advantages of citizen science without mentioning training issues or identification errors, you lose marks.
- Stating that decreasing rainfall 'causes' butterfly decline without acknowledging that the data show only correlation. Scientific conclusions require controlled experiments or consideration of confounding variables before causation can be claimed.

Exam technique

Start by skimming the entire paper to gauge the balance between calculation and extended writing. The **first question** progresses from simple arithmetic to graph construction, so pace yourself: aim to complete parts (a) to (c) in under five minutes, allowing ten minutes for careful graph plotting. Use a ruler and sharp pencil for the graph, and remember to check your axes before you begin marking points.

For **extended response questions** (parts 2f, 2g, 2h), allocate time according to the mark tariff. A 4-mark question such as 'discuss this conclusion' should receive at least four distinct points or two well-developed arguments. Read the question carefully: 'discuss' requires you to consider multiple perspectives (e.g. supporting evidence, limitations, alternative explanations), not just describe. Plan your answer briefly in the margin if space allows.

Manage the 30-minute time limit by keeping answers concise and focused. Each mark typically corresponds to one clear point or correct calculation step. If a calculation question is worth 2 marks, one mark usually rewards the method and the other the correct final answer, so always show full working. Leave questions you find difficult and return to them if time permits; there is no negative marking, and it is better to secure marks on accessible questions than to spend excessive time on a single challenging part.

What to revise alongside this paper

To consolidate your data handling skills, practise constructing different graph types (bar charts, line graphs, scatter plots) and choosing the most appropriate format for continuous versus categorical data. Work through datasets requiring multiple calculations (mean, median, mode, range) and percentage change problems from various contexts. Familiarise yourself with **experimental design principles**: independent and dependent variables, control variables, sample size, and repeatability.

For the ecological content, revise food webs, interdependence in ecosystems, and how abiotic factors (temperature, light, water availability) affect populations. Understand the role of **indicator species** in environmental monitoring and why changes in insect populations can signal broader ecological problems. Read about current conservation challenges, particularly habitat loss, climate change impacts, and the decline of pollinators.

Broaden your scientific literacy by exploring real-world applications of citizen science (bird surveys, weather recording, astronomical observations) and the increasing use of technology in fieldwork. Consider the ethical and practical dimensions of AI in ecology: accuracy, cost, accessibility, and the value of public engagement in science. These themes bridge biology, geography, and data science, reflecting the interdisciplinary nature of modern environmental research.

Key terms

> **Percentage change**, **Range**, **Hypothesis**, **Transect (Pollard walk)**, **Abundance**, **Correlation**, **Causation**, **Citizen science**, **Biodiversity**, **Indicator species**, **Sampling criteria**, **Confounding variable**, **Climate change**, **Ecosystem**, **Artificial Intelligence (AI) monitoring**