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

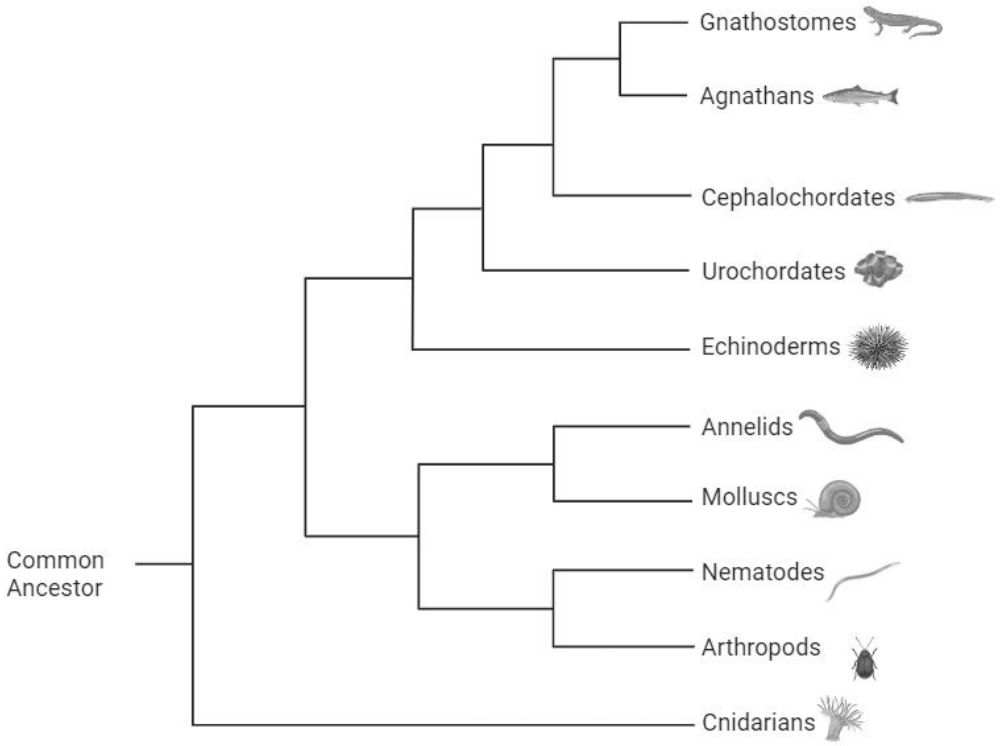
For examiners' use only:

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).

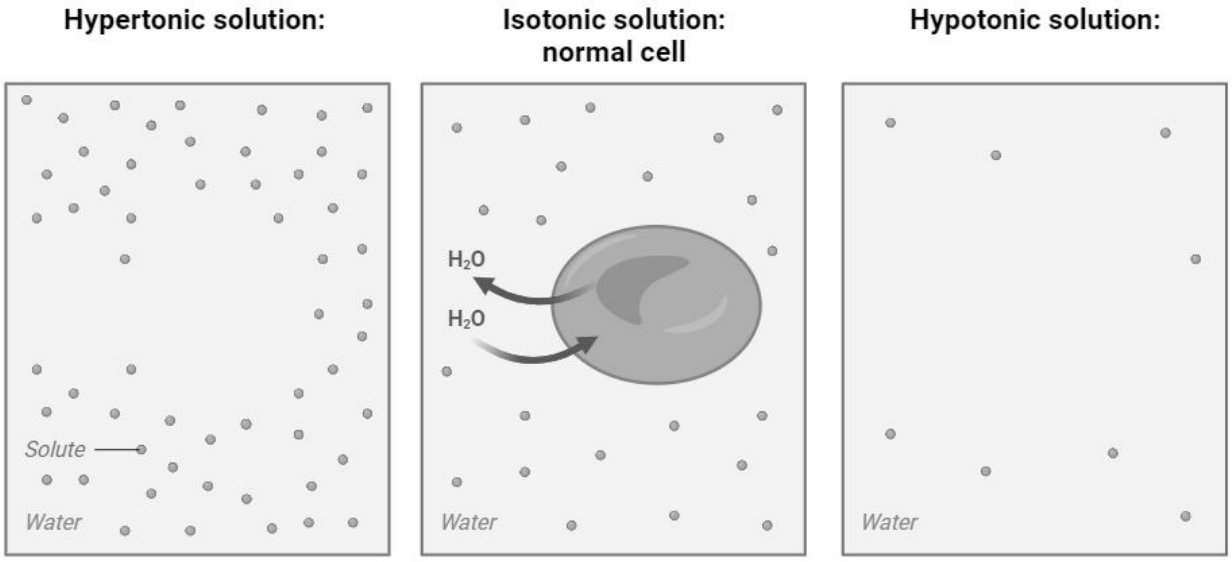
Water moves in and out of cells by a process called osmosis. Osmosis can be defined as:

"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.

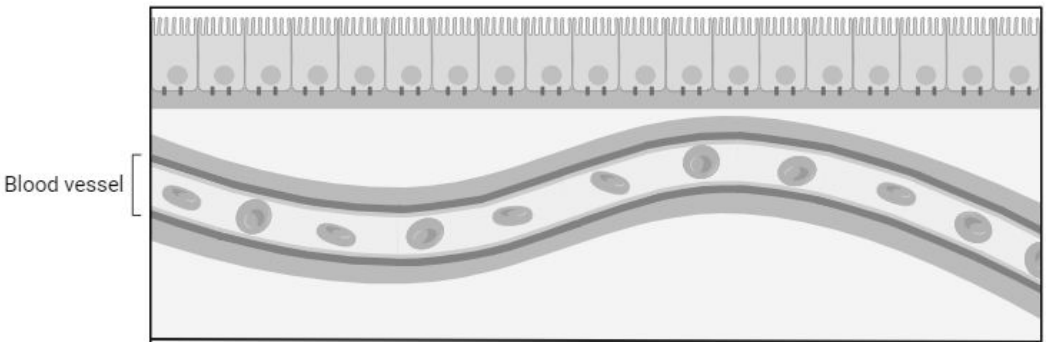
1._____

_____

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._____

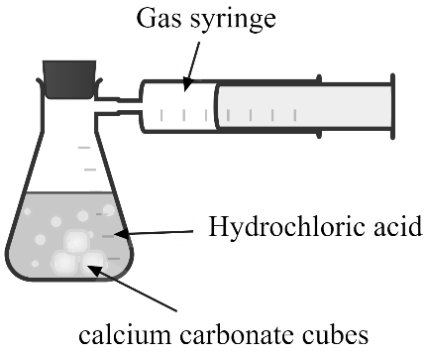
2._____

3._____ **[3]**

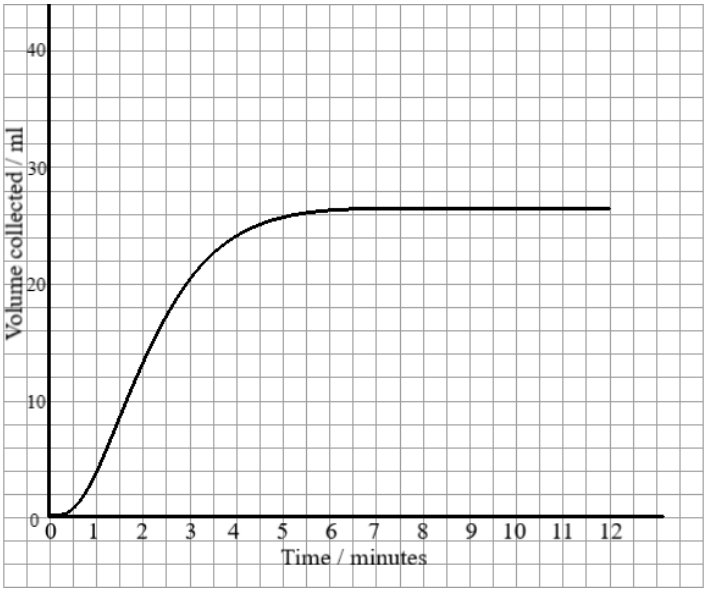
2. This question is about rates of reaction.

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.

_____

_____ **[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)?

_____

_____

_____

_____ **[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?

_____

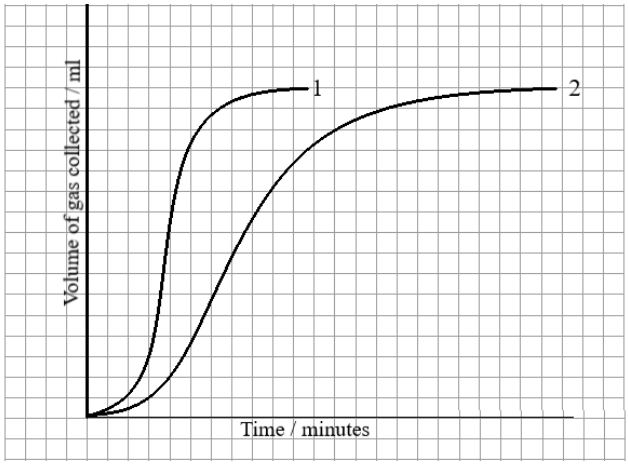
_____

_____ **[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.

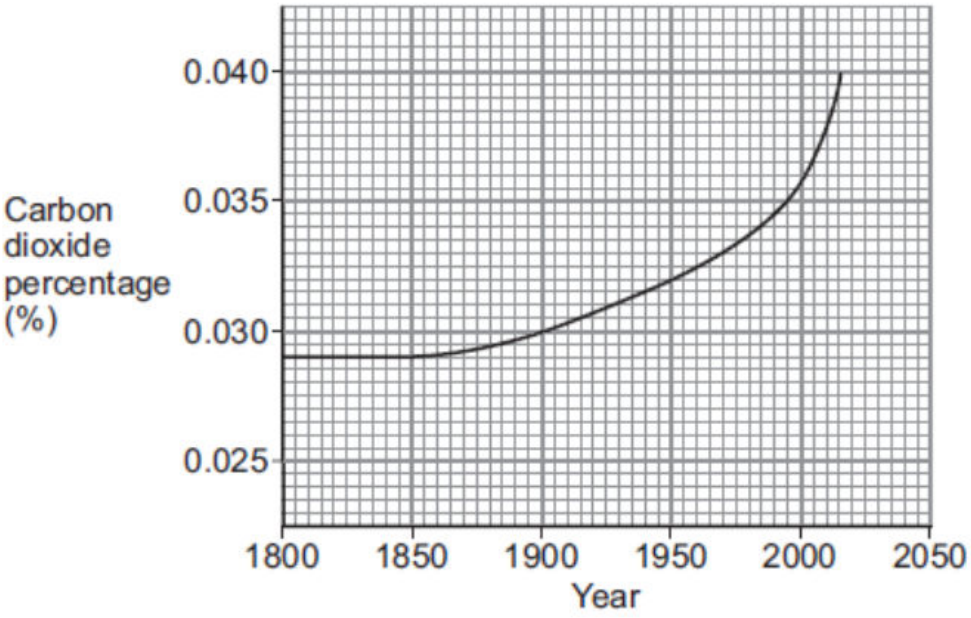
_____

_____

_____ **[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.

_____

_____

_____ **[2]**

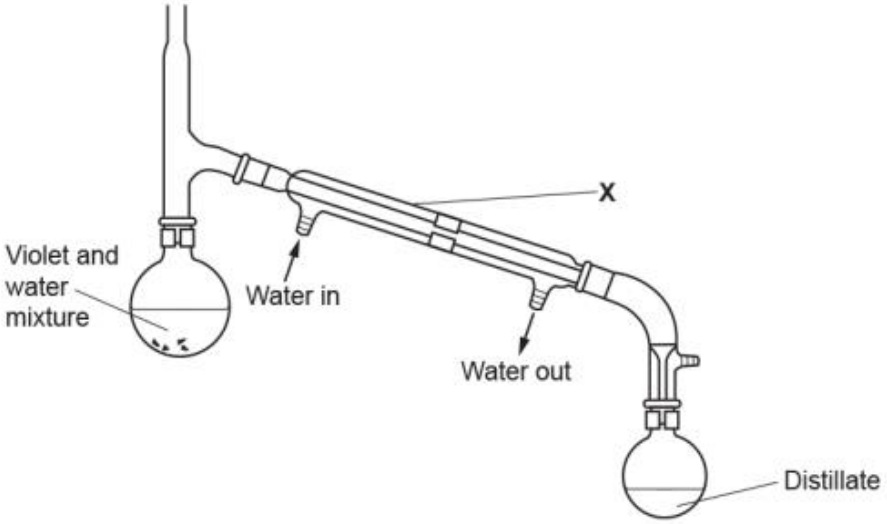
(c) Suggest **two** reasons for the change in the carbon dioxide percentage from 1850 to 2015.

_____

_____ **[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]**

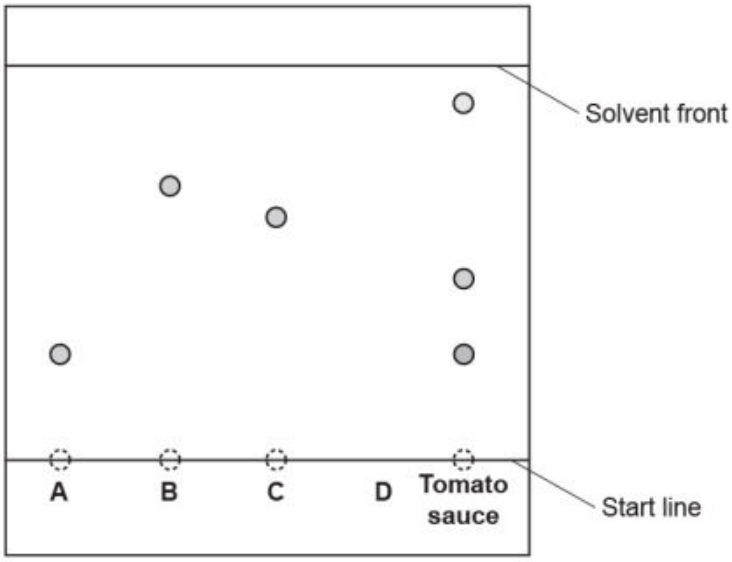
(f) Suggest **two** changes that need to be made to the set-up of the apparatus so that it is set up correctly.

_____

_____ **[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?

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_____**[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°C and 78°C 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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_____

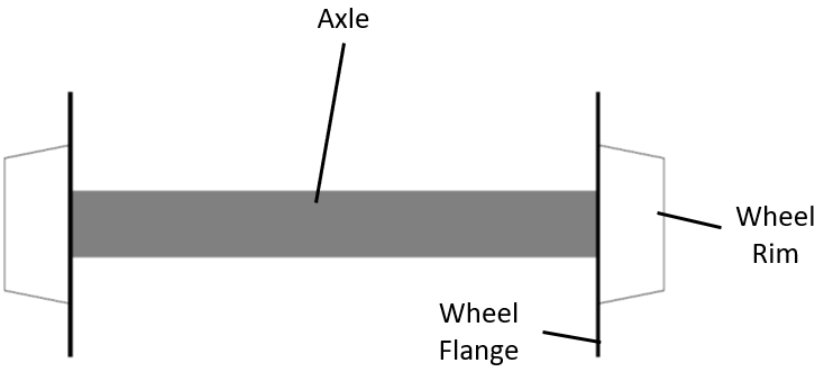
_____**[2]**

(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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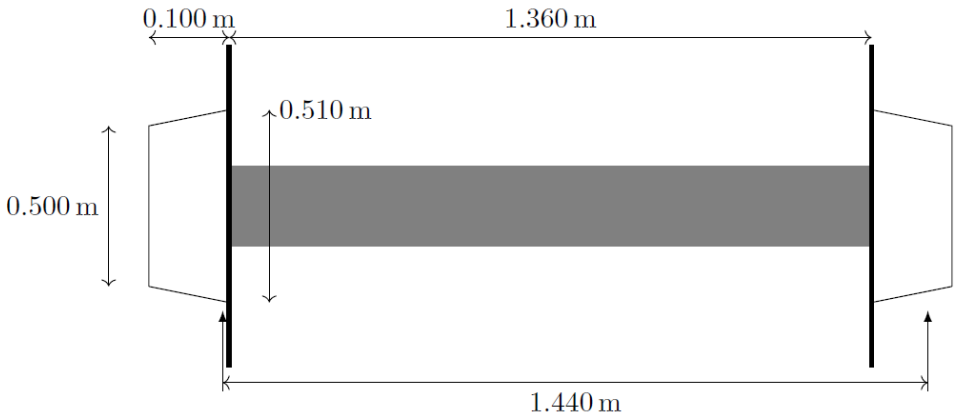
_____**[2]**

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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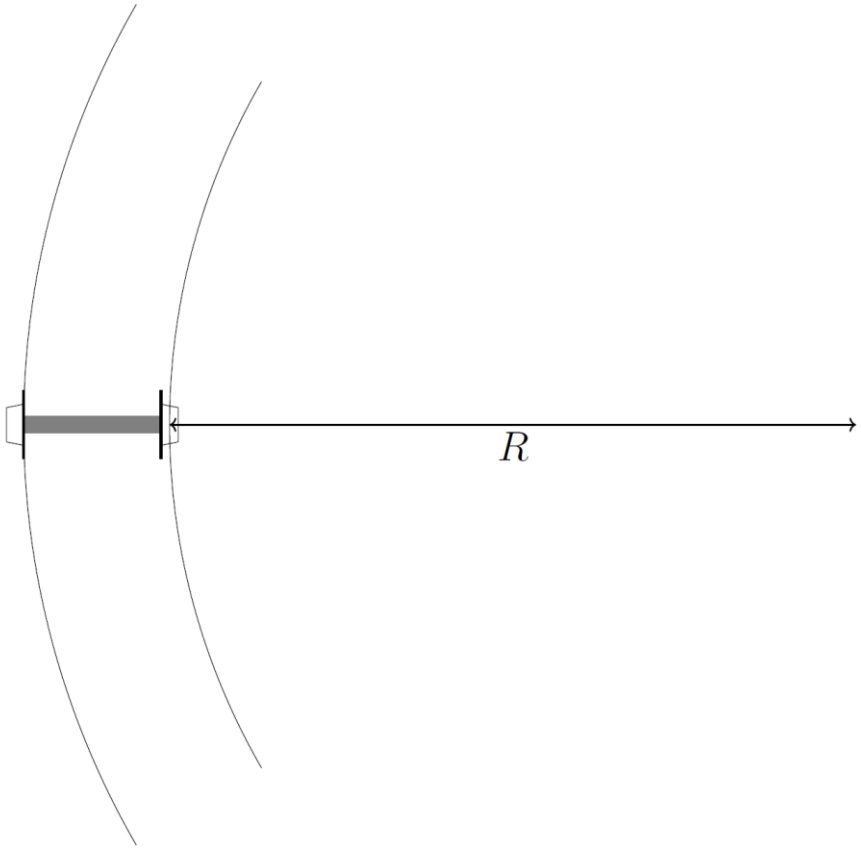
_____**[3]**

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]**