Question 1 (7 marks)

Defibrillators are used to apply an electric current to the heart. Defibrillators are made from two metal plates. During a charging process, one of the plates becomes positively charged and the other becomes negatively charged.

Question 1a (1 mark)

Select the particles that move to cause the charge on the defibrillator plates.

Select
- Select
- Atoms
- Electrons
- Neutrons
- Protons

Question 1b (3 marks)

Question 1c (1 mark)

Question 1b (3 marks)

A charged defibrillator with stored energy of 150 J applies a voltage of 300 V to an adult human. **Calculate** the current that would flow in 30 milliseconds.

Styles

Question 1c (1 mark)

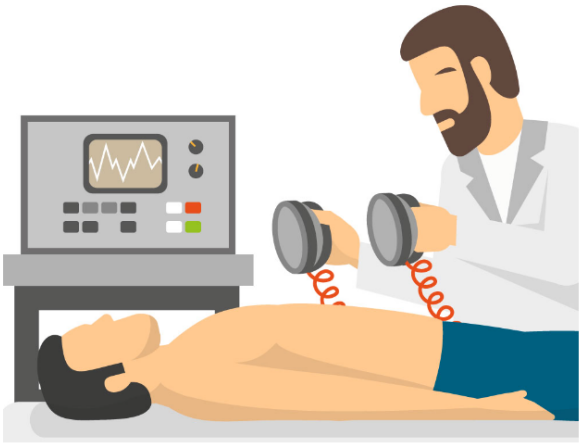
A gel is often applied between the plates and the patient's skin before using a defibrillator. **Suggest** why a gel is used.

Styles

Question 1d (2 marks)

One type of defibrillator uses charged plates which are stuck to the body of the patient with adhesive pads. Another type has plates that can be placed against the body of the patient by a doctor, who holds onto the plates using insulating grip handles. **Suggest** an advantage of each type of defibrillator.

Adhesive pads



Insulating handles

Question 2 (10 marks)

Refraction of light can help people to see more clearly but it can also cause optical illusions, as shown in the image below.

Question 2a (3 marks)

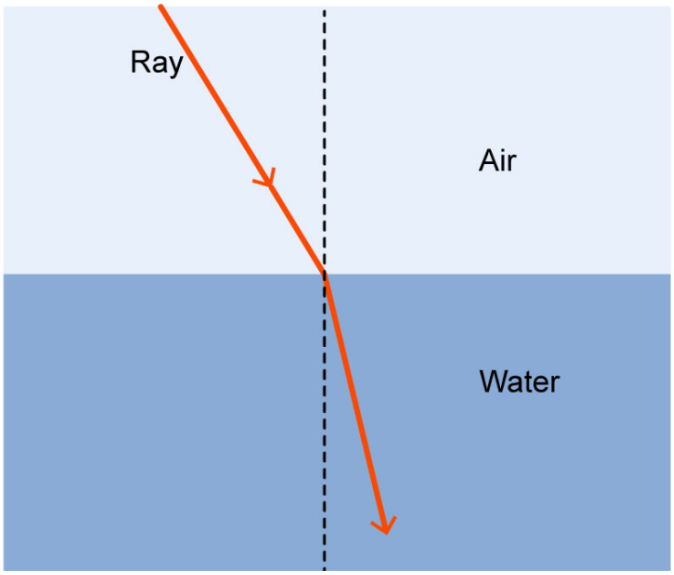
Yellow light has a wavelength of 550 nm. **Calculate** the frequency of yellow light. You should assume the speed of light = 3.0×10^8 m s^{-1}. Give your answer to two significant figures.

Question 2b (1 mark)

State one colour of visible light that has a longer wavelength than yellow light.

Question 2c (1 mark)

Light travels as waves. Refraction of light changes some of the characteristics of light.



Select one quantity that remains constant when light is refracted through transparent materials.

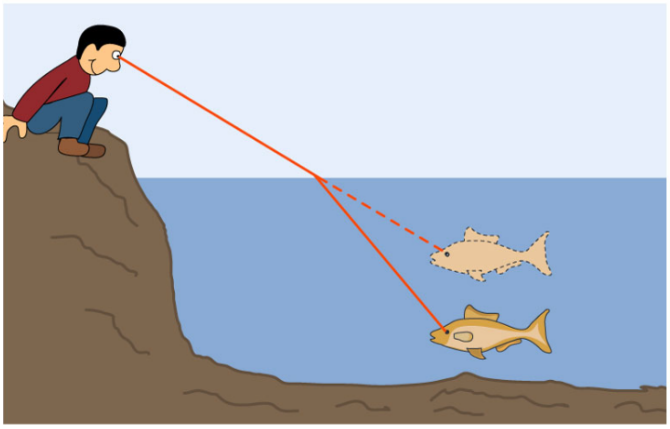
Select one quantity that remains constant when light is refracted through transparent materials.

Select
- Select
- Direction
- Frequency
- Speed
- Wavelength

(3 marks)

Question 2d (3 marks)

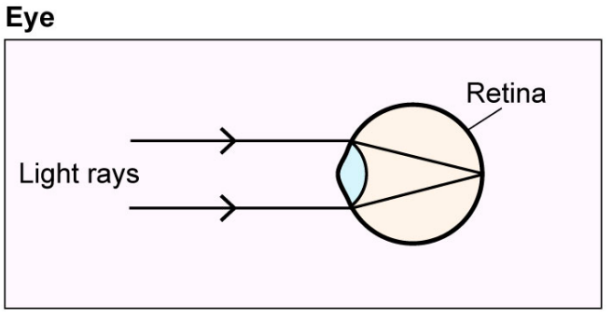
Refraction can make us believe that objects are in a location that is different to reality. Use the image below to **explain** why the person believes the fish is in a different location to where it really is.



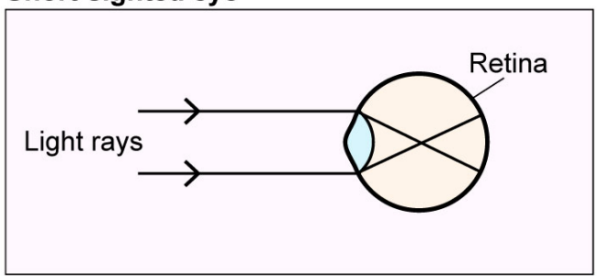
B I x_2 x^2 Styles

Question 2e (2 marks)

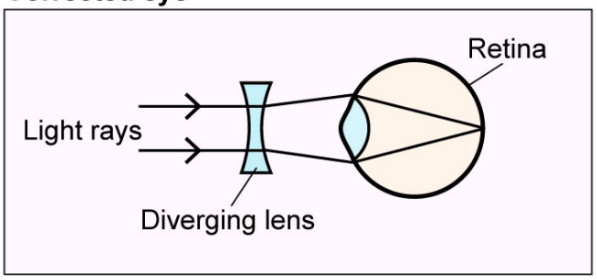
One use of refraction is to correct short-sightedness, which happens when light rays meet in front of the retina, as shown below. **Outline** how the use of a diverging lens helps to correct short-sightedness.



Short-sighted eye



Corrected eye



Question 3 (9 marks)

Nuclear energy is a possible solution to our growing energy demands.

Question 3a (1 mark)

State one problem with using fossil fuels as an energy resource.

Question 3b (1 mark)

In a nuclear power station, one process involves changing U-235 into U-236. The two forms of uranium are shown below.

$$^{235}_{92}U \qquad\qquad ^{236}_{92}U$$

State the difference between a nucleus of U-235 and a nucleus of U-236.

Question 3c (1 mark)

Nuclear power stations use nuclear fission to release energy. An example of a fission reaction is shown below.

Identify the number of neutrons that would balance this nuclear equation:

$$^{236}_{92}U \rightarrow {}^{140}_{54}Xe + {}^{93}_{38}Sr + \boxed{?}\,{}^{1}_{0}n$$

Question 3d (2 marks)

In part (c), each fission reaction releases 2.8×10^{-11} J of energy. The relationship between the mass and the energy of an object when it is not moving is given by $E = mc^2$, where E = energy, m = mass and c = the speed of light.

Use this equation to **calculate** the mass difference between U-236 and the fission products. You should assume that $c = 3.0 \times 10^8$ m s^{-1}.

Question 3e (2 marks)

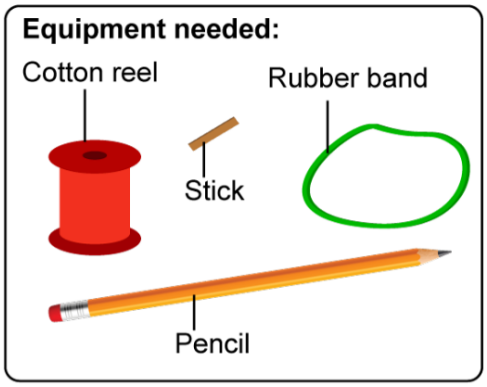
Each fission reaction releases 2.8×10^{-11} J. In a developed country, one family used 9.7 GJ of energy in a year. **Calculate** how many fission reactions would be required to meet the energy needs of this family.

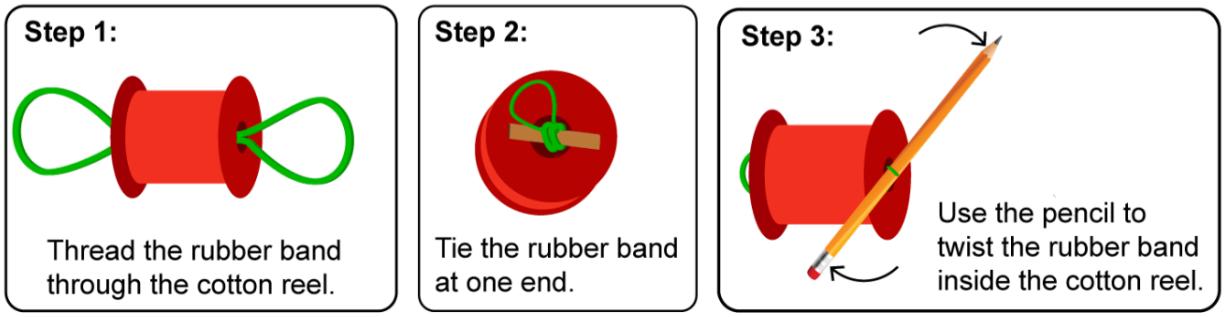
Question 3f (2 marks)

A nuclear power station operates with an efficiency of 35 %. If the station generates 1.5×10^9 W of electrical power, **calculate** the total power released through nuclear fission in the nuclear reactor.

Question 4 (10 marks)

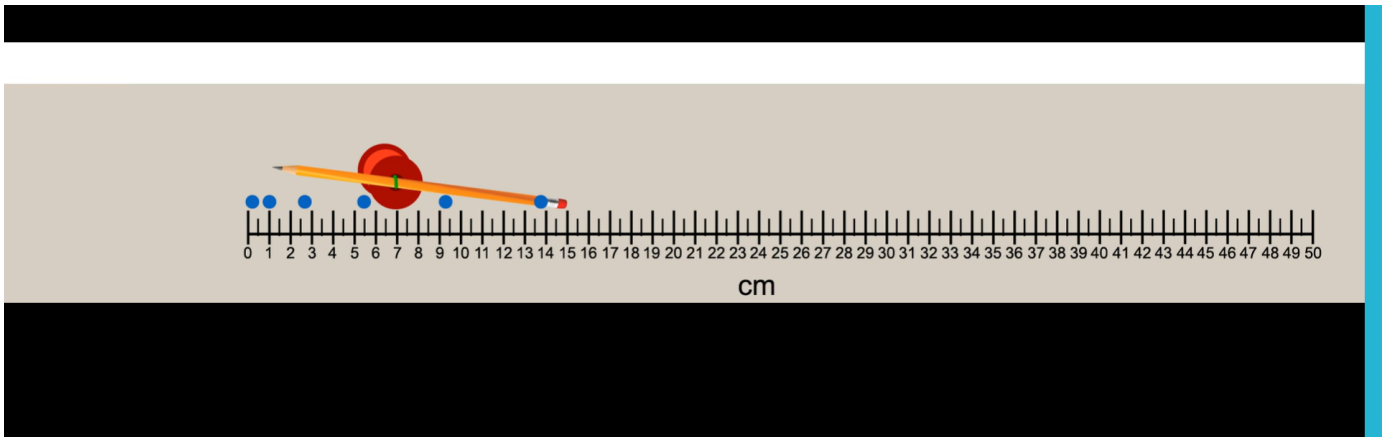
An MYP student decides to investigate the motion of a simple model car made from a cotton reel. The image shows details of how the model was made.

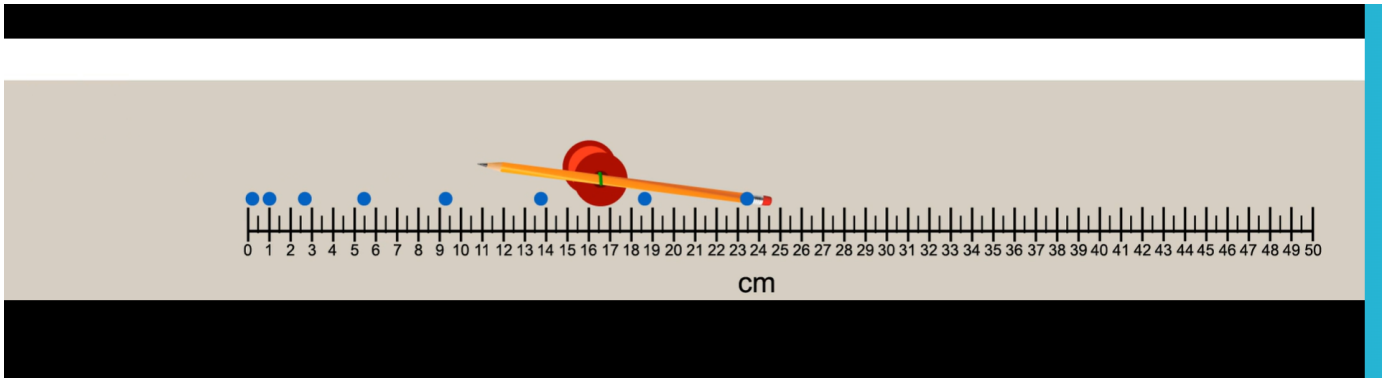


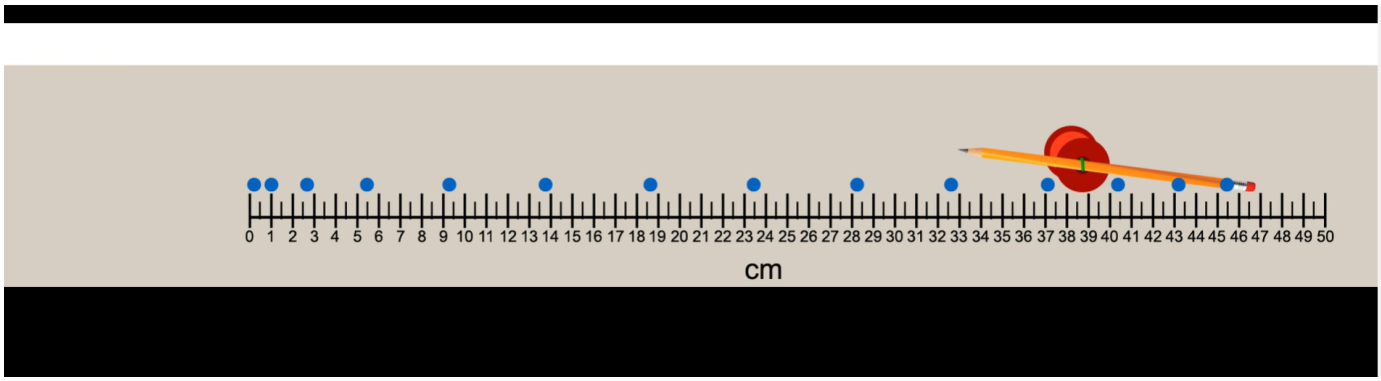


After building the model car, the student turns the elastic band to wind it up and releases it. The model car travels along a horizontal tabletop.

As the model car is set in motion, video analysis software is used to track its movement frame by frame by placing dots on the screen at the end of the pencil. The software places one dot every 0.10 s.


0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
cm


0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
cm


0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
cm

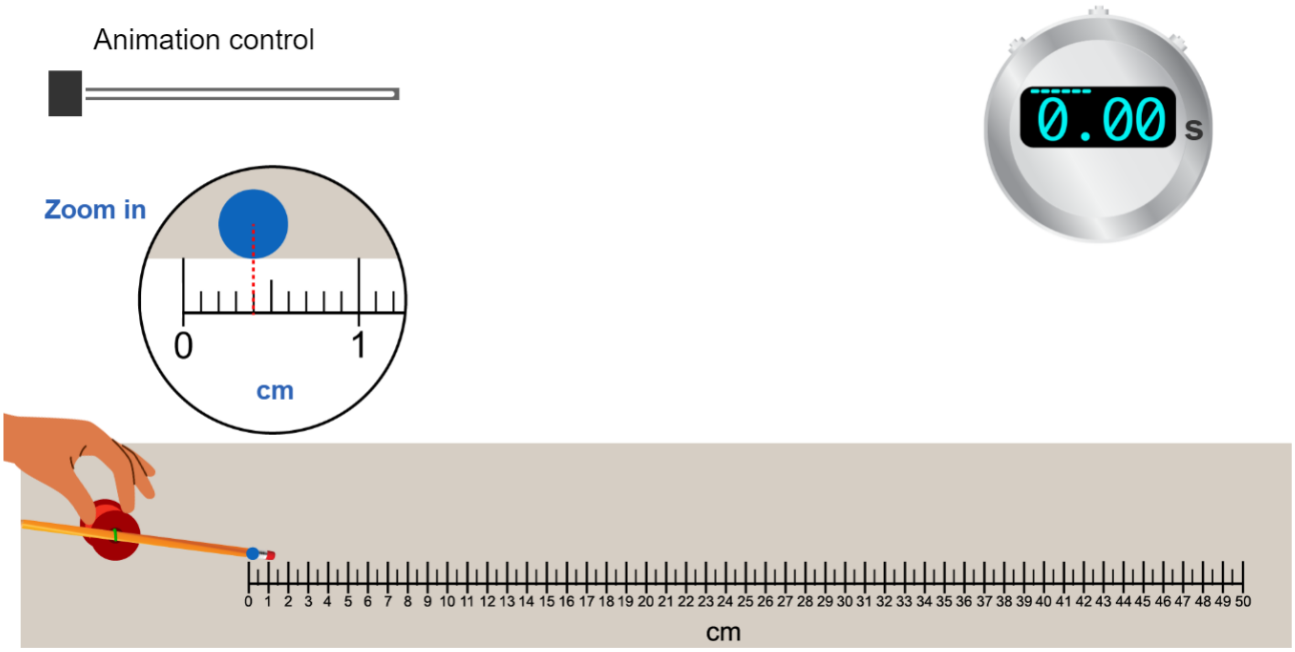
Question 4a (2 marks)

Calculate the frequency with which the dots are placed.

Question 4b (1 mark)

The following animation shows the cotton reel's motion.

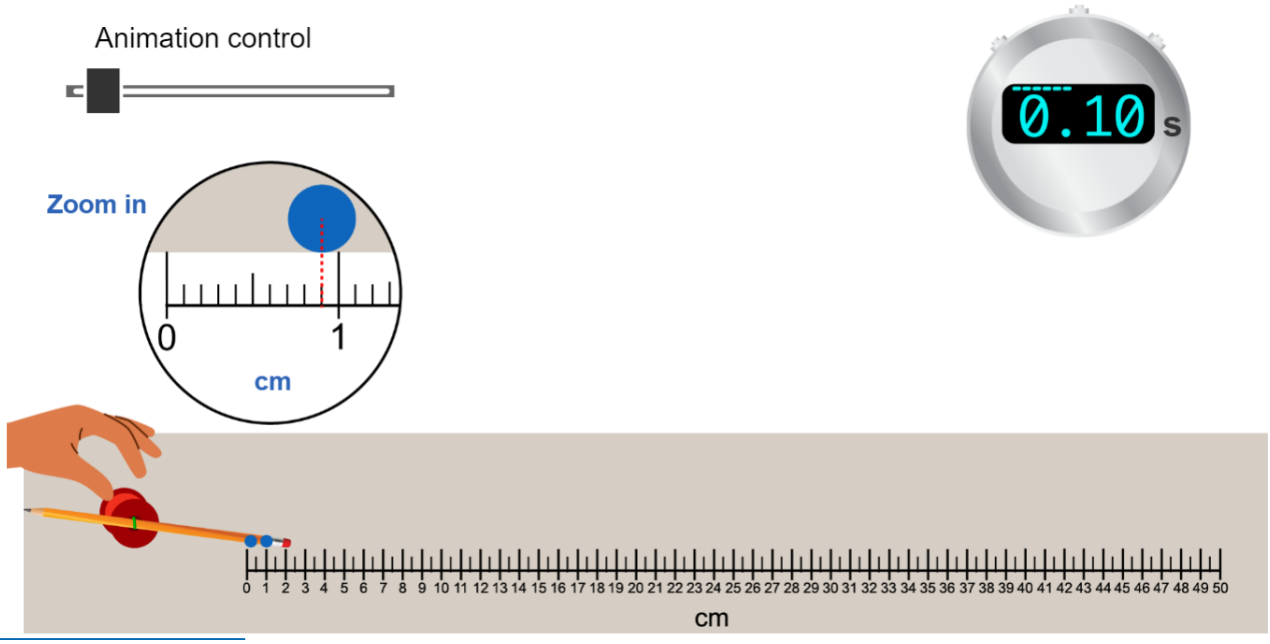
This media is interactive



Question 4b (1 mark)

The following animation shows the cotton reel's motion.

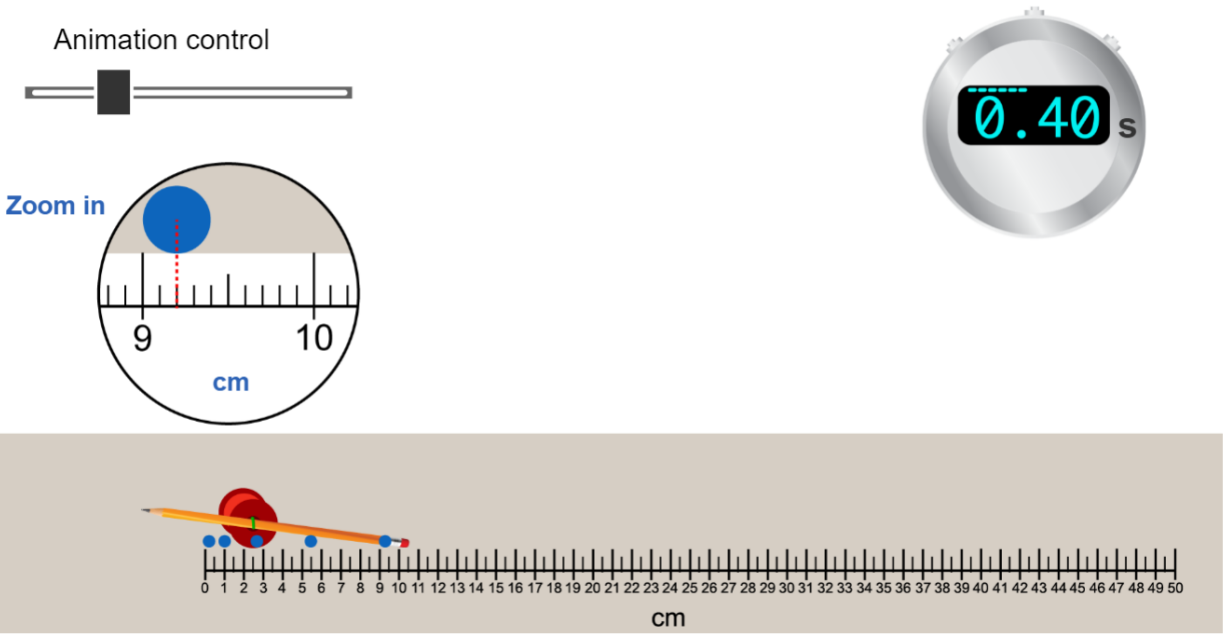
This media is interactive



Question 4b (1 mark)

The following animation shows the cotton reel's motion.

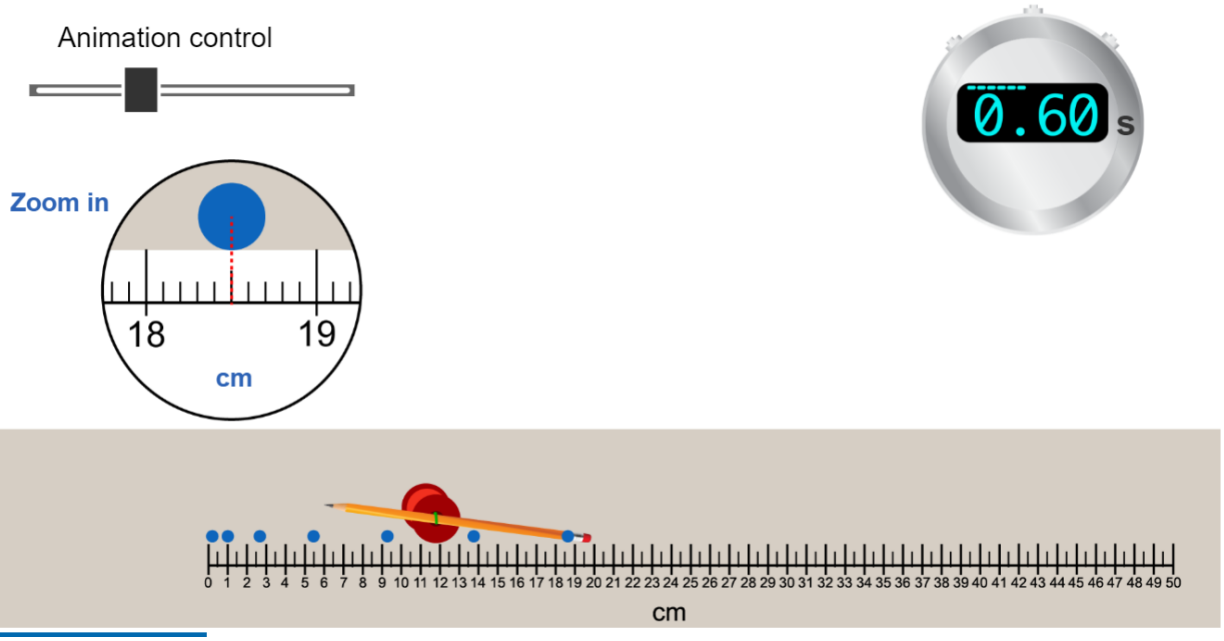
This media is interactive



Question 4b (1 mark)

The following animation shows the cotton reel's motion.

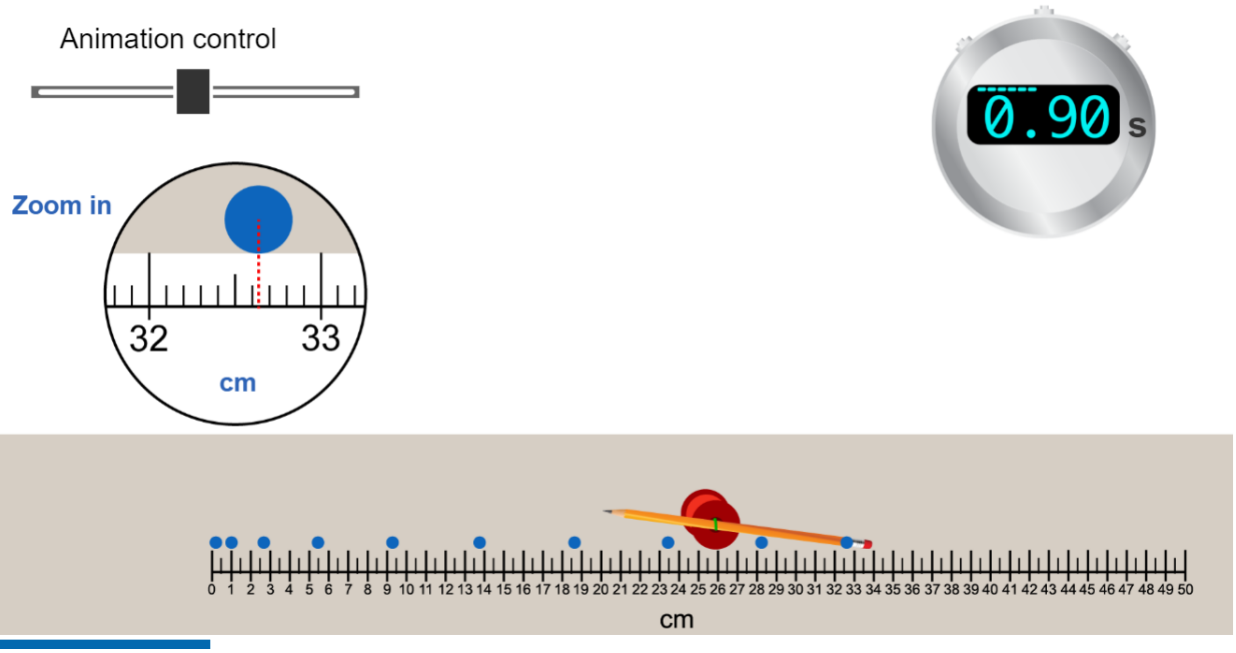
This media is interactive



Question 4b (1 mark)

The following animation shows the cotton reel's motion.

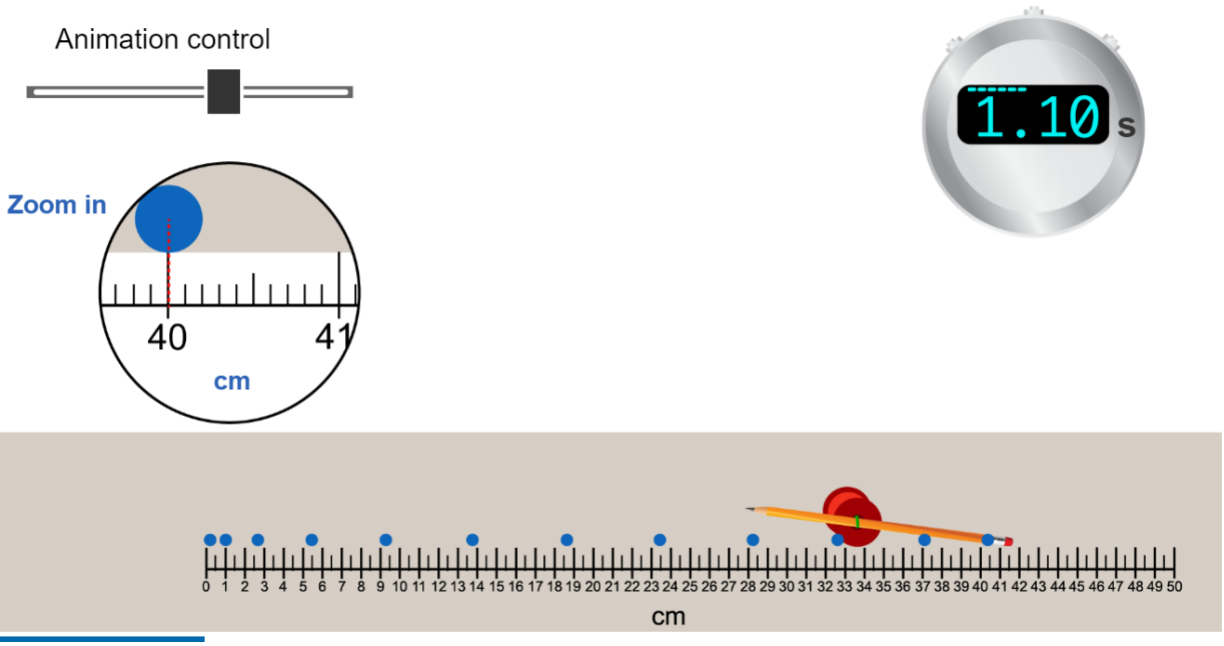
This media is interactive



Question 4b (1 mark)

The following animation shows the cotton reel's motion.

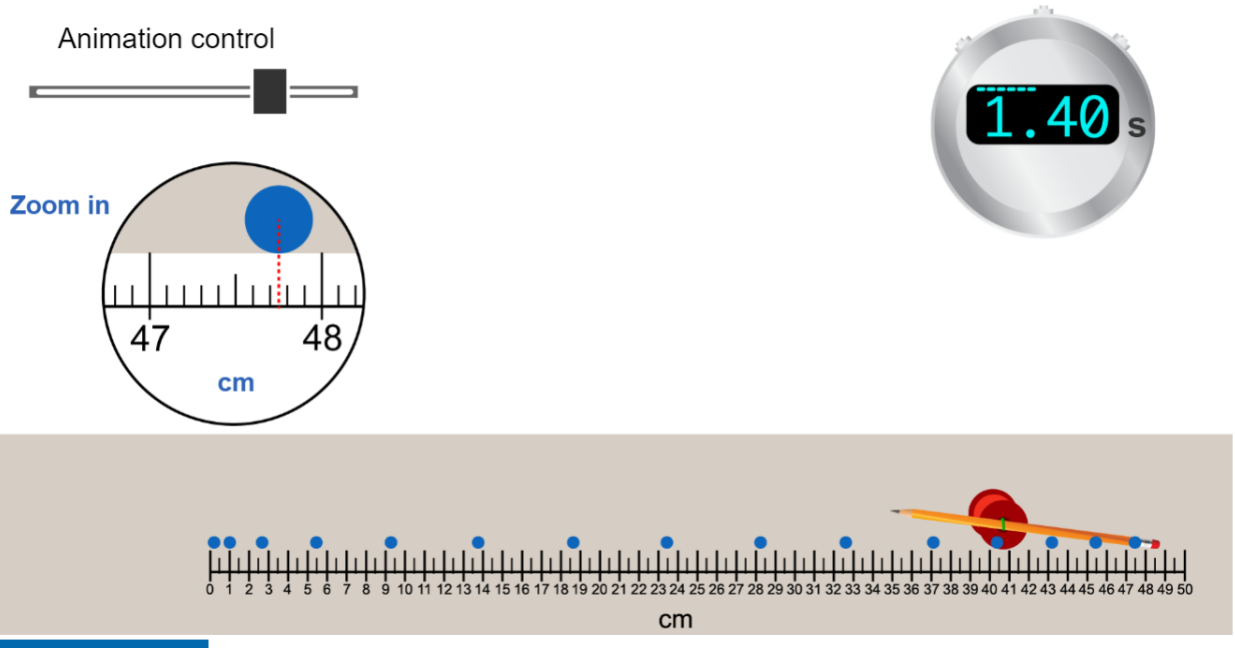
This media is interactive



Question 4b (1 mark)

The following animation shows the cotton reel's motion.

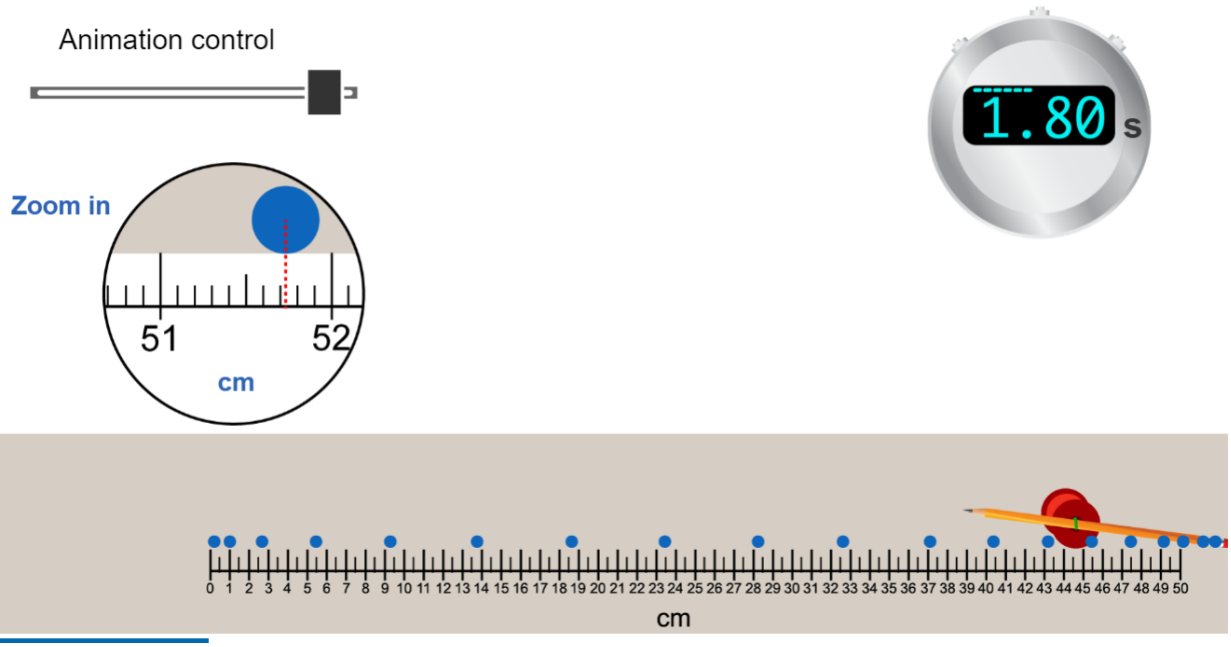
This media is interactive



Question 4b (1 mark)

The following animation shows the cotton reel's motion.

This media is interactive



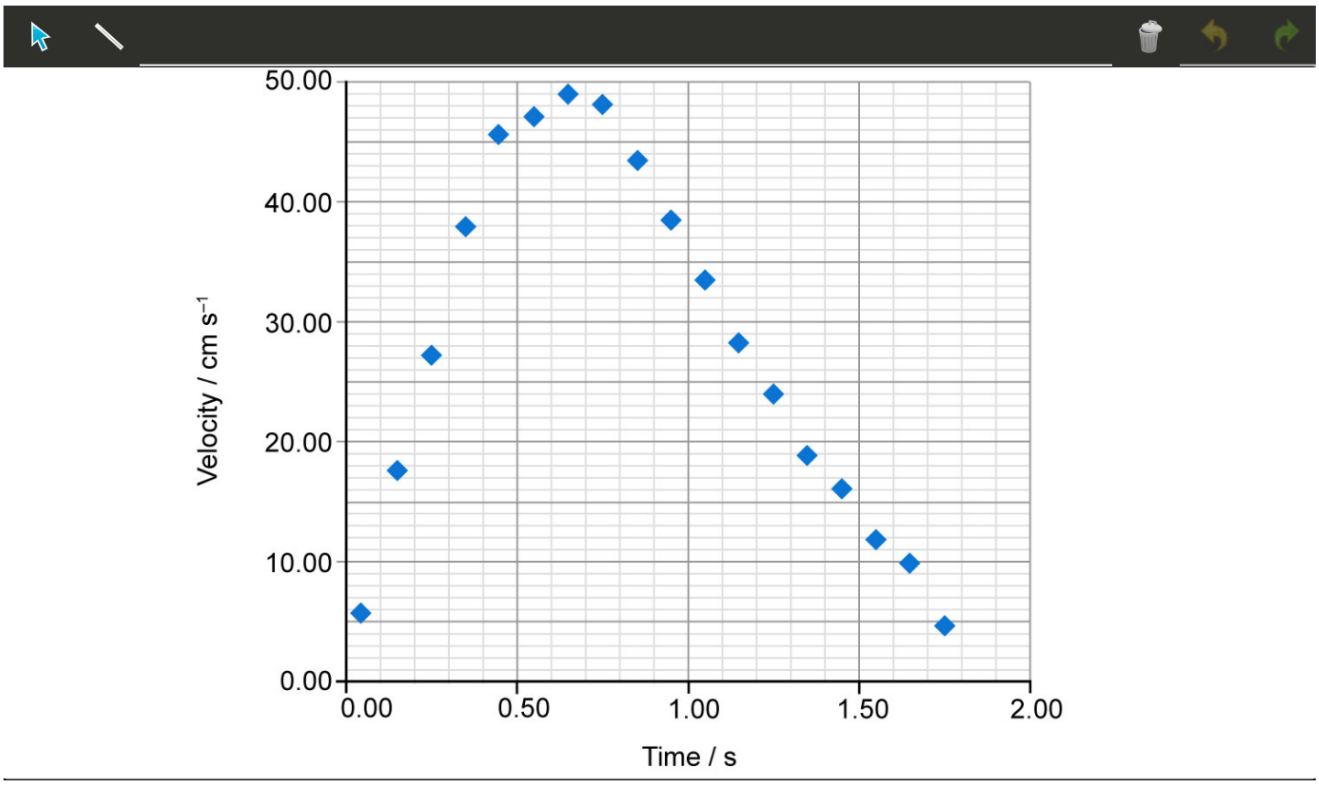
Use the animation to **measure** the position of the end of the pencil when time = 0.3 s and complete the table below.

Time / s	0.00	0.10	0.20	0.30	0.40	0.50	0.60
Position / cm	0.4	0.9	2.7		9.2	13.8	18.5

Reset

Question 4c (3 marks)

The student processed their data to calculate the velocity of the model car and drew a velocity-time graph, as shown below.


50.00
40.00
30.00
20.00
10.00
0.00
Velocity / cm s⁻¹
0.00
0.50
1.00
1.50
2.00
Time / s

The velocity-time graph shows the motion of the model car between 0.00 and 1.80 s. Add a line of best fit to the graph between 0.05 and 0.35 s. **Calculate** the gradient of this line of best fit, give the unit, and **state** the quantity that the gradient represents.

Question 4d (2 marks)

The student repeated the experiment using twice as many turns of the elastic band. **Predict** how the line of best fit you drew in part (c) would change. **Justify** your answer.

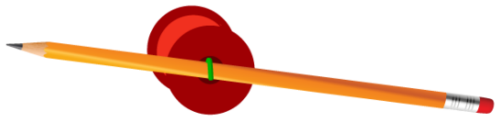
Question 4e (2 marks)

A second student collects data using a ruler and a stopwatch. **Outline** two limitations of this second student's data compared to the data obtained using video analysis.

Question 5 (17 marks)

Question 5a (16 marks)

After completing the first experiment investigating the motion of a model car, a student wants to extend their investigation by measuring a different dependent variable.



Design a method to investigate the effect of changing the number of turns of the elastic band on the time taken for a model car to travel a fixed distance. In your plan, you must include:

- the independent variable, dependent variable, and one control variable
- a hypothesis
- details of any additional measuring equipment you will need to perform the experiment
- a detailed method for how you will collect the data
- details of how you will collect sufficient data.

B I U x_2 x^2 Styles

Question 5b (1 mark)

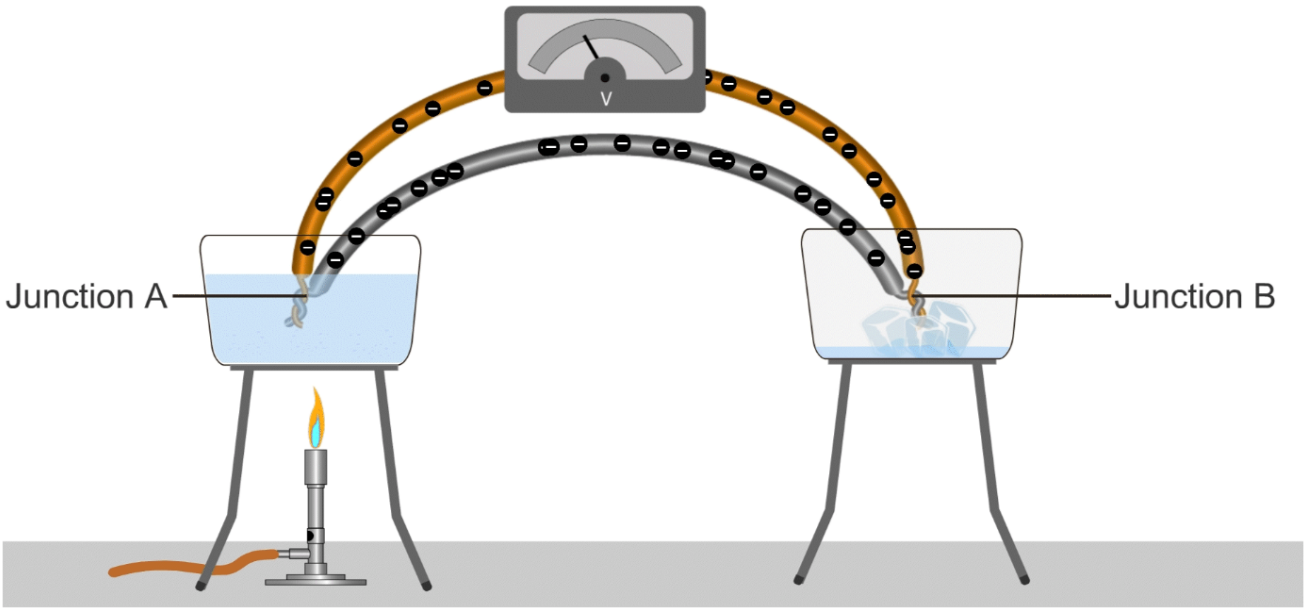
The research question of the student in part (a) was:

> How does the number of turns of the elastic band affect
> the time taken for a model car to travel a fixed distance?

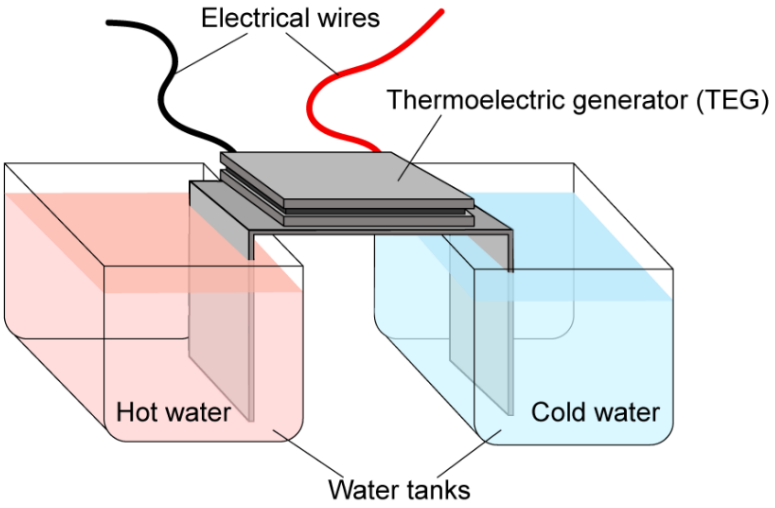
Another student wants to carry out a different investigation using a similar model car.
Suggest an alternative research question.

Question 6 (23 marks)

The Seebeck effect is a phenomenon that happens when we connect two different metals to each other to form two junctions. When these metals are at different temperatures, a voltage is produced which causes an electric current to flow.


V
Junction A
Junction B

A student has a kit that uses the Seebeck effect to function. The kit contains a thermoelectric generator (TEG) which comprises two wires made of different metals. There are also two water tanks for hot and cold water.



The student wants to investigate the relationship between the voltage (V) produced by the Seebeck effect and the temperature difference (ΔT).

Question 6a (1 mark)

State a research question that would be tested in this investigation.

Question 6b (2 marks)

Identify two pieces of measuring equipment you would need to perform this experiment.

Question 6c (1 mark)

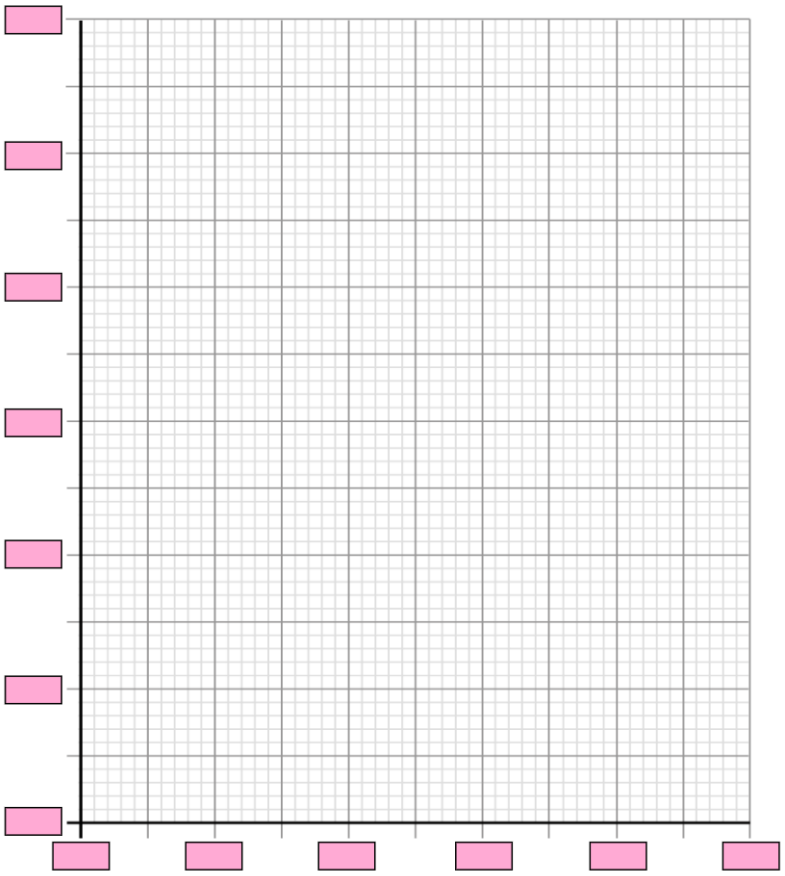
The following data was collected from the experiment. **Calculate** the missing temperature difference and add your value to the table.

Temperature 1 / °C	Temperature 2 / °C	Temperature difference / °C	Voltage / V
52.6	7.6	45.0	0.298
47.0	7.0	40.0	0.251
43.4	7.8	35.6	0.206
36.9	8.1	28.8	0.131
32.1	12.1		0.054

Question 6d (4 marks)

Present the voltage versus temperature difference data in part (c) in a graph and add a line of best fit.

Draggable items:



Scroll down to continue

x axis label:

y axis label:

Question 6e (2 marks)

The student claims that the voltage is directly proportional to the temperature difference. Use the data in part (c) or the graph in part (d) to **comment** on the validity of the student's claim. **Justify** your answer.

Question 6f (2 marks)

The Seebeck coefficient (S) measures how well a material can change a temperature difference into an electric voltage. It provides important information about the material's thermoelectric properties.

It is given by the following equation:

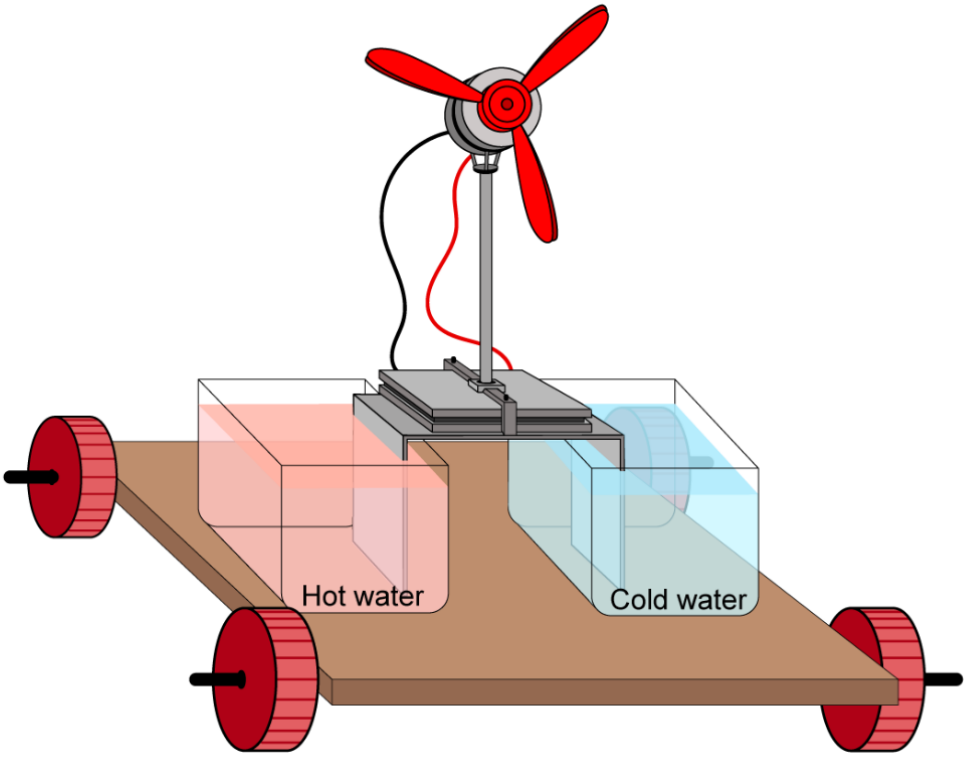
$$S = -\frac{\Delta V}{\Delta T}$$

where ΔV represents the change in voltage and ΔT represents the difference in temperature.

Outline how you would use the graph in part (d) to calculate the Seebeck coefficient.

Question 6g (2 marks)

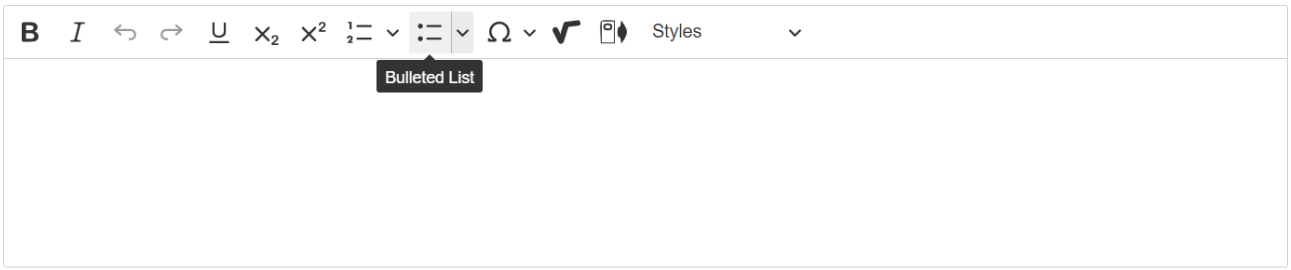
The student builds a propeller-driven car by connecting a motor and propeller to the TEG kit and mounts this onto a flat base with wheels, as shown below.


Hot water
Cold water

At a voltage of 0.397 V, the current through the motor is 0.11 A. Using information from the formula sheet, **calculate** the motor's power. You must include an appropriate unit in your answer.

Question 6h (2 marks)

The student noticed that the propeller-driven car did not accelerate forwards. **Suggest** an improvement to the car's design that could increase its acceleration. **Justify** your answer by referring to scientific principles.

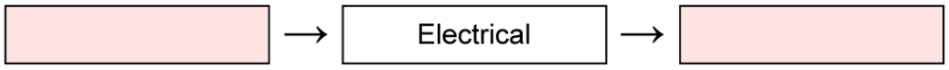


Question 6i (1 mark)

Select the useful energy transformations that occur when the propeller-driven car moves horizontally.

Draggable items:

Gravitational	Kinetic	Light	
Heat	Elastic		



Question 6j (4 marks)

Identify the variables for an investigation using the propeller-driven car.

Independent variable:

Control variable 1:

Dependent variable:

Control variable 2:

Question 6k (2 marks)

Formulate a hypothesis for the investigation in part (j).

If:

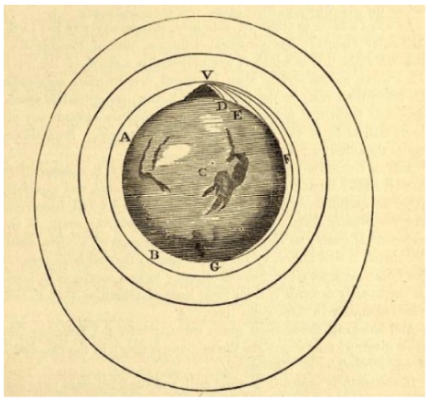
Then:

Then:

Because:

Question 7 (16 marks)

In 1728, Isaac Newton conducted a thought experiment often referred to as Newton's cannonball. In this thought experiment, a cannonball is fired from a cannon placed at the top of a very tall mountain. If the only force experienced by the cannonball is the gravitational force, then the path followed by the cannonball would depend on its initial horizontal speed.



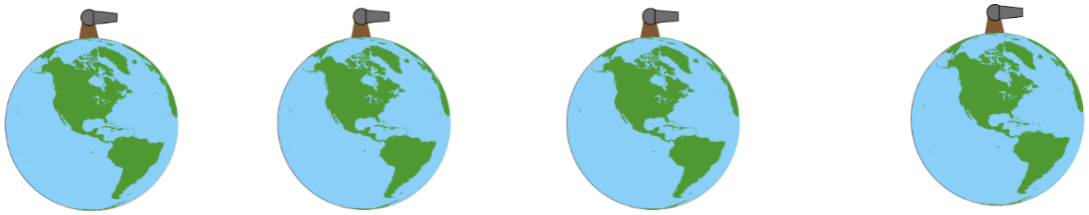
©

Question 7a (1 mark)

Identify the path of the cannonball for each of the horizontal speeds shown.

Diagram not to scale

A. Select **B.** Select **C.** Select **D.** Select

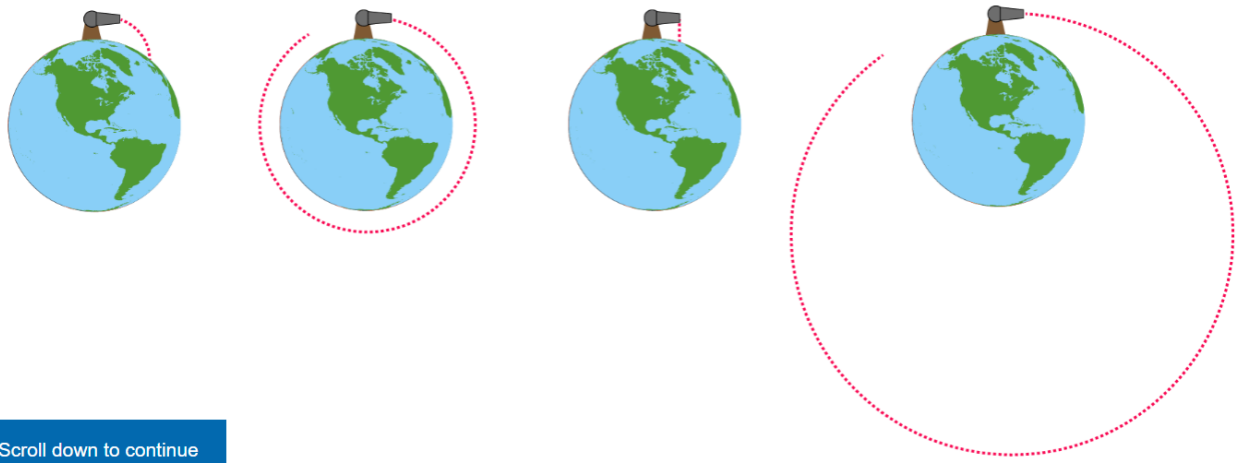


Question 7a (1 mark)

Identify the path of the cannonball for each of the horizontal speeds shown.

Diagram not to scale

A. Select **B.** Select **C.** Select **D.** Select



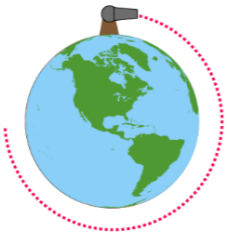
Scroll down to continue

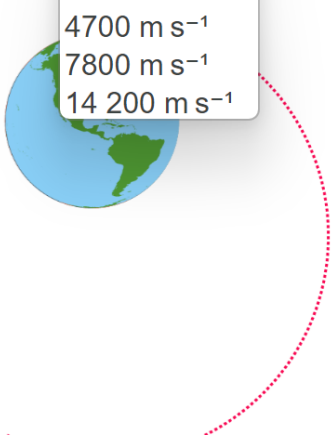
Question 7a (1 mark)

Identify the path of the cannonball for each of the horizontal speeds shown.

Diagram not to scale

A. Select **B.** Select **C.** Select **D.** Select

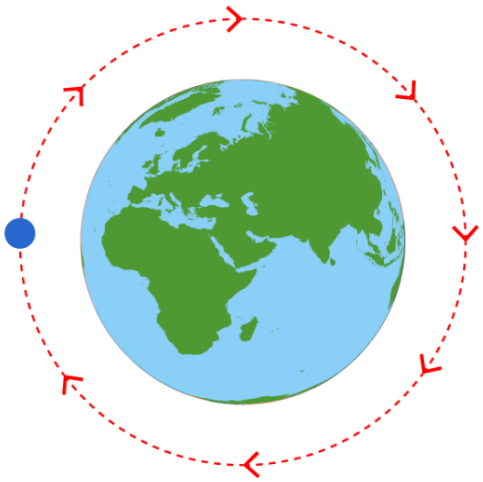


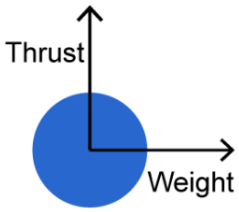


Select
0 m s⁻¹
4700 m s⁻¹
7800 m s⁻¹
14 200 m s⁻¹

Question 7b (1 mark)

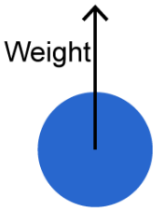
Identify the free-body force diagram that shows the force or forces acting on Newton's cannonball at the position shown.





A. ○

B. ○



C. ○

D. ○

Question 7c (14 marks)

Newton's thought experiment enabled scientists to understand how artificial satellites could be placed in orbit. In 1945, science-fiction writer Arthur C Clarke suggested that artificial satellites orbiting the Earth could be used for a global communication system.

Geostationary satellites orbit the Earth once every 24 hours and permanently appear in the same location above the Earth's equator.

These satellites have to be placed at a specific distance from the Earth at an altitude of around 36 000 km, a region of space which is known as the 'Clarke Belt' after Arthur C Clarke.

Reaching this location is challenging and, due to the increase in global demand for satellite communication, this region is becoming increasingly crowded.

To work correctly, satellites must maintain a safe distance from each other. Spaces for new satellites are assigned by the International Telecommunication Union, an agency of the United Nations. This agency helps to settle disputes between countries or companies if satellites start to interfere with each other, which happens when they get too close together.

In 2022, there were estimated to be 539 satellites in this increasingly crowded area.

Most satellites in space are owned and operated by one company, SpaceX. In 2021, the company set a new record by launching 143 satellites into orbit on one rocket.

The prospect of one company having so much control over worldwide communication has raised concerns.

Satellites have wide-ranging applications in the modern world, such as wildfire control, espionage, wildlife tracking, surveillance and other civil or military applications.

Discuss and **evaluate** the development of the global communication system using satellites. In your answer, you must include:

- the scientific and technological challenges of putting a satellite into orbit
- the political implications for governments of the global communication system
- the positive and negative economic implications of private companies controlling access to the limited space in the Clarke belt
- a concluding appraisal.

Question 8 (8 marks)

Satellites are put into orbit using rockets. However, space elevators have been proposed as an alternative method of putting objects into space.

If a cable was dropped from a large satellite in a geostationary orbit, it could be secured at one end to the Earth at the equator. The other end of the cable, out in space, could then be secured to a weight. If successful, the cable would stay straight due to the spinning motion of the Earth.

This cable could be used as part of a lifting device for a space elevator. A space elevator is one way that scientists believe objects could be lifted into space using electricity.

One of the main reasons why a space elevator has not been developed yet is that no material has been made that can withstand the extreme forces and environmental conditions involved.

In 2005, NASA launched a competition with a $2 million dollar prize to see if anyone could develop a material strong enough to withstand the extreme forces, but none succeeded. Continuing research by countries including China, Russia, the United States and Japan has seen progress.

A super-strong material made from carbon nanotubes could make the space elevator a reality.

Japan has tested moving a robotic device between two satellites linked together with a cable, modelling the movement of a future space elevator.

China is believed to have done similar experiments, although the results have not been shared.

Discuss and **evaluate** the benefits and limitations of a country spending significant amounts of government money to construct the first space elevator.