



GCE A LEVEL



A420U20 – 1

THURSDAY, 6 JUNE 2024 – MORNING

**PHYSICS – A LEVEL COMPONENT 2
ELECTRICITY AND THE UNIVERSE**

2 hours plus your additional time allowance

Surname: _____

First name(s): _____

Centre Number: _____

Candidate Number: 2 _____

For Examiner's Use Only		
Question	Maximum Mark	Mark Awarded
1.	16	
2.	8	
3.	10	
4.	12	
5.	15	
6.	10	
7.	15	
8.	14	
Total	100	

(Turn over)

ADDITIONAL MATERIALS

In addition to this examination paper you will require a calculator and a DATA BOOKLET.

ITEMS INCLUDED WITH QUESTION PAPER

A separate Diagram Booklet.

The Diagram Booklet **MUST** be handed in to the invigilators and sent for marking.

INSTRUCTIONS TO CANDIDATES

Use black ink, black ball – point pen, black felt tip or your usual method.

Write your name, centre number and candidate number in the spaces on the front cover.

Answer **ALL** questions.

Write your answers in the spaces provided. If you run out of space, use the additional page(s) at the back of this booklet, taking care to number the question(s) correctly.

(Turn over)

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part – question.

The assessment of the quality of extended response (QER) will take place in question 5(a).

Answer ALL questions.

1. (a) State 'Ohm's law'.

[2 marks]

(b) Refer to the diagram for Question 1 (b) in the separate Diagram Booklet. Tom investigates the electrical properties of a lamp with a metal filament. He varies the potential difference across the lamp and measures the corresponding current in it.

A graph of his results is shown in the diagram.

continued on the next page . . .

(Turn over)

Question 1 (b) continued

1. (b) (i) Tom states the following:

**“Ohm’s law does apply between
0 V and 0.5 V, but not for the full
range given.”**

**Explain HOW THE GRAPH confirms the
statement.**

[2 marks]

continued on the next page . . .

(Turn over)

Question 1 (b) continued

1. (b) (ii) Show by calculation, that the resistance of the lamp is different when the pd across it is 2.5 V and when it is 5.0 V , and explain, in terms of particles, why this is to be expected.

[5 marks]

continued on the next page . . .

(Turn over)

Question 1 continued

1. (c) Tom connects the lamp in series with **THREE** identical cells, each of emf **1.2 V** .
He measures the pd across the lamp to be **3.0 V** . Show that the internal resistance of each cell is approximately **$0.5\ \Omega$** .

[3 marks]

continued on the next page . . .

(Turn over)

Question 1 continued

1. (d) In the early **20th** century physicists started investigating the effects of very low temperatures on the resistance of metals. These experiments led to the discovery of superconductors.

(i) What is superconductivity?

[1 mark]

continued on the next page . . .

(Turn over)

Question 1 (d) continued

1. (d) (ii) A material becomes superconducting when it is placed in liquid helium. **SKETCH A GRAPH** of resistance against temperature for this material, labelling any key features of your graph.

Space for diagram.

[3 marks]

(Total for Question 1 = 16 marks)

(Turn over)

2. (a) Refer to the diagram for Question 2 (a) in the separate Diagram Booklet.

For the circuit shown in the diagram, with the switch open (as shown), the ammeter reads 0.50 A .

Show that $R_1 = 12.0 \text{ } \Omega$.

[1 mark]

continued on the next page . . .

(Turn over)

Question 2 continued

2. (b) (i) With the switch closed the ammeter reading increases to 0.75 A . Show that this current is consistent with $R_1 = R_2$

[2 marks]

- (ii) With the 6.0Ω resistor still in place, further identical resistors are placed in parallel with R_1 and R_2 until a current of 1.2 A is measured by the ammeter. Calculate the total number of parallel resistors.

(Turn over)

[3 marks]

2. (b) (iii) A student makes the following comment:

“No matter how many resistors are added in parallel with R_1 and R_2 , the reading on the ammeter will not go above a certain value.”

Discuss the validity of this statement.

[2 marks]

(Total for Question 2 = 8 marks)

(Turn over)

3. Refer to the diagram for Question 3 in the separate Diagram Booklet. Emma carries out an experiment to determine the resistivity of a sample of nichrome in the form of a wire. She uses the apparatus shown in the diagram to take measurements of the resistance of various lengths of wire.

Emma repeats her readings and plots a graph of resistance, R , versus length, l , along with error bars determined from the uncertainties in her readings. Refer to GRAPH 3.1 in the separate Diagram Booklet.

- (a) (i) Emma draws lines of maximum and minimum gradients. She also draws an estimated line of best fit through the data points (DOTTED LINE) and notices that it does not pass through the origin. Emma's teacher states that this is due to a systematic error in her procedure or in the apparatus. Suggest TWO possible sources for the systematic error.
-
-
-

[2 marks]

3. (a) (ii) The teacher also states that the systematic error need not affect the result for the resistivity. State why the teacher is correct.

[1 mark]

- (b) Emma determines the cross – sectional area of the wire to be $(4.8 \pm 0.4) \times 10^{-8} \text{ m}^2$
Determine the resistivity of nichrome along with its **ABSOLUTE** uncertainty, giving your answer to an appropriate number of significant figures.

(Turn over)

(Total for Question 3 = 10 marks)

4. Refer to the diagram for Question 4 in the separate Diagram Booklet. The diagram shows a circuit and a graph. A student carries out an experiment to investigate the discharge of a capacitor, C , through a resistor, R . He uses the circuit shown in the diagram.

The switch is closed, and the capacitor allowed to charge fully. The switch is then opened at time $t = 0$ seconds and the capacitor allowed to discharge through R . The graph shows how the reading on the milliammeter changes with time.

- (a) Use the graph to confirm that the charge on the capacitor is approximately 100 mC at time $t = 0 \text{ s}$.

[2 marks]

continued on the next page . . .

(Turn over)

Question 4 continued

4. (b) The following equation represents the voltage, V , across the capacitor as a function of time, t , for this circuit:

$$V = V_0 e^{-\frac{t}{CR}}$$

- (i) Using information from the diagram and graph, determine values for V_0 , C and R .

[3 marks]

continued on the next page . . .

(Turn over)

Question 4 (b) continued

4. (b) (ii) Hence determine the pd across the capacitor when t is equal to the time constant, and confirm that your answer is consistent with the milliammeter reading at this time.

[3 marks]

continued on the next page . . .

(Turn over)

Question 4 continued

4. (c) (i) $U = \frac{1}{2} QV$ is a formula for the energy, U , stored in a capacitor.

Show clearly that $U = \frac{1}{2} CV^2$ is an equivalent formula.

[2 marks]

continued on the next page . . .

(Turn over)

Question 4 (c) continued

4. (c) (ii) Determine the energy stored in the capacitor at $t = 60 \text{ s}$.

[2 marks]

(Total for Question 4 = 12 marks)

(Turn over)

- 5. (a) Gravitational fields and electric fields have many features in common but also have several differences. For both gravitational and electric fields, describe their common features and their differences. In your answer you should consider:**
- the force acting between particles;**
 - gravitational field strength and electric field strength;**
 - gravitational potential and electric potential.**

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

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(Turn over)

Question 5 continued

5. (b) Refer to the diagram for Question 5 (b) in the separate Diagram Booklet. A small sphere of mass **24 mg** is suspended by an insulating string of length, L , in a uniform electric field produced by two vertical metal plates connected to a **1.0 kV** power supply. The plates are separated by a distance, $d = 10 \text{ cm}$. The sphere is made to touch the negative plate where it receives a charge. It is then repelled from the negative plate and hangs in equilibrium when the angle, θ , between the vertical and the string is **15°** as shown in the diagram.

- (i) Show that the electric field strength between the plates is **10 kN C^{-1}**

continued on the next page . . .

[1 mark]
(Turn over)

Question 5 (b) continued

- 5. (b) (ii) ON THE DIAGRAM, DRAW ARROWS to represent the THREE forces acting on the sphere. Label each arrow with the name of the force it represents.**

[3 marks]

- (iii) Hence calculate the charge on the sphere.**

[4 marks]

continued on the next page . . .

(Turn over)

Question 5 continued

5. (c) A physics student comments:

“The charge on the sphere corresponds to trillions of electrons being placed on it.”

Determine whether the student’s comment is justified. [Take trillion to mean 10^{12}]

[1 mark]

(Total for Question 5 = 15 marks)

(Turn over)

6. (a) A metal cylinder is subjected to an increasing tension until it fractures. The sample exhibits **NECKING** at the point of fracture.
- (i) Sketch a diagram to illustrate the term **NECKING**, indicating the direction of the stretching forces.

Space for diagram

[1 mark]

continued on the next page . . .

(Turn over)

Question 6 (a) continued

- 6. (a) (ii) Explain, in terms of stress, why the metal fractures at this point.**

[2 marks]

- (b) Refer to the diagram for Question 6 (b) in the separate Diagram Booklet. Two wires, one made from steel and the other from titanium, are firmly clamped together at their ends. The wires have the SAME DIAMETER and UNSTRETCHED LENGTH. One of the clamped ends is fixed to a rigid support, while a force, F , is applied to the other end so that the wires hang vertically. The wires are firmly clamped together so that the extension in each wire is THE SAME.**

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(Turn over)

Question 6 (b) continued

6. (b) (i) Show that:

$$\frac{F_{\text{titanium}}}{F_{\text{steel}}} = 2$$

where F_{titanium} and F_{steel} are the respective forces on the titanium and steel wires.

$$[E_{\text{titanium}} = 400 \text{ GPa and } E_{\text{steel}} = 200 \text{ GPa}]$$

[2 marks]

continued on the next page . . .

(Turn over)

Question 6 (b) continued

6. (b) (ii) The diameter of each wire is 1.4 mm and the unstretched length is 1.2 m .

Determine the extension produced in one of the wires when $F = 30 \text{ N}$.

[3 marks]

continued on the next page . . .

(Turn over)

Question 6 (b) continued

- 6. (b) (iii) A physics student assumes that, since the wires extend by the same amount, they must possess the same amount of elastic potential energy. Determine whether the student's assumption is correct.**

[2 marks]

(Total for Question 6 = 10 marks)

(Turn over)

7. (a) (i) Refer to the diagram for Question 7 (a) (i) in the separate Diagram Booklet. A planet is in an elliptical orbit around a star as shown. **MARK ON THE DIAGRAM** with the letter **X** another possible location for the star.
- (ii) Refer to the diagram for Question 7 (a) (ii) in the separate Diagram Booklet. In the diagram, the area of section **A** = area of section **B**.

Referring to Kepler's 2nd law of planetary motion, describe the motion of the planet as it passes through sections **A** and **B**.

[2 marks]

continued on the next page . . .

(Turn over)

Question 7 continued

7. (b) The table below shows data about two of Jupiter's moons, Io and Ganymede.

Moon	Period of orbit, T / s	Mean radius of orbit, r / m
Io	1.53×10^5	4.22×10^8
Ganymede	6.15×10^5	1.07×10^9

- (i) Show that the data are consistent with Kepler's 3rd law of planetary motion.

[2 marks]

continued on the next page . . .

(Turn over)

Question 7 (b) continued

7. (b) (ii) Determine the mass of Jupiter.

[3 marks]

(c) Refer to the diagram for Question 7 (c) in the separate Diagram Booklet. The diagram shows a spiral galaxy. A spiral galaxy is estimated to have a mass of 2×10^{42} kg.

continued on the next page . . .

(Turn over)

Question 7 (c) continued

- 7. (c) (i) Calculate the orbital speed of a dust particle at a distance of 8.2×10^{20} m from the centre of the galaxy.**

[2 marks]

continued on the next page . . .

(Turn over)

Question 7 (c) continued

- 7. (c) (ii) The observed velocity is GREATER than the calculated velocity. Explain how the Higgs boson was thought by some to be responsible for the difference in the velocities.**

[3 marks]

continued on the next page . . .

(Turn over)

Question 7 continued

- 7. (d) Look at the article for Question 7 (d) in the separate Diagram Booklet. The article is from 2021 and was released by the Royal Astronomical Society.**

Suggest how the scientific community should proceed.

[2 marks]

(Total for Question 7 = 15 marks)

(Turn over)

8. Refer to the diagram for Question 8 in the separate Diagram Booklet. All the planets in our solar system orbit around the Sun. Planets that orbit around other stars are called exoplanets. A rocky exoplanet orbits a red dwarf star $28 \cdot 5$ light years from Earth. The diagram showing the system is not to scale.

- (a) The star and planet orbit their mutual centre of mass. Show that the distance of the centre of mass from the centre of the star is approximately 400 km.

[2 marks]

Question 8 continued

8. (b) The maximum shift in wavelength measured by astronomers on Earth, when light of wavelength **656 nm** from the star is analysed, is found to be about **0.20 pm** . Using your answer from part (a), show that this wavelength shift is consistent with the mutual orbital period of the system, which is over **7 hours**.

[4 marks]

continued on the next page . . .

(Turn over)

Question 8 continued

8. (c) The temperature at the surface of the star is 3522 K.

(i) Calculate the luminosity of the star.

[2 marks]

continued on the next page . . .

(Turn over)

Question 8 (c) continued

8. (c) (ii) Hence determine the intensity of the radiation from the star at the Earth's surface.

[1 light year = 9.5×10^{15} m.]

[3 marks]

continued on the next page . . .

(Turn over)

Question 8 (c) continued

- 8. (c) (iii) With the aid of a calculation, explain why the star appears red in colour.**

[3 marks]

(Total for Question 8 = 14 marks)

END OF PAPER

TOTAL FOR PAPER = 100 MARKS

(Turn over)

[illegible]

(Turn over)

[illegible]

(Turn over)

[illegible]



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ELECTRICITY AND THE UNIVERSE

**The Diagram Booklet MUST be handed in
to the invigilators and sent for marking.**

Diagram Booklet

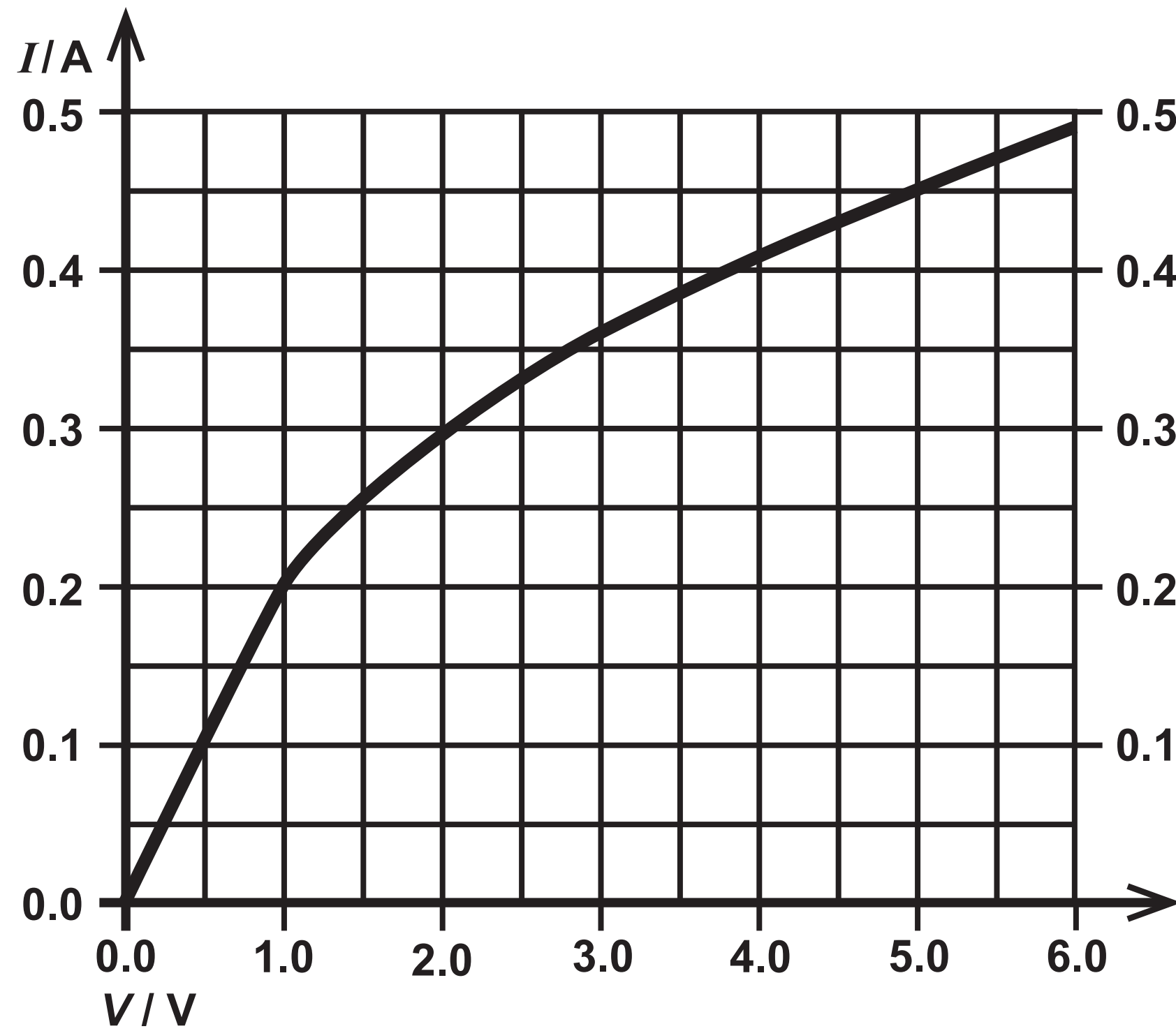
Surname: _____

First name(s): _____

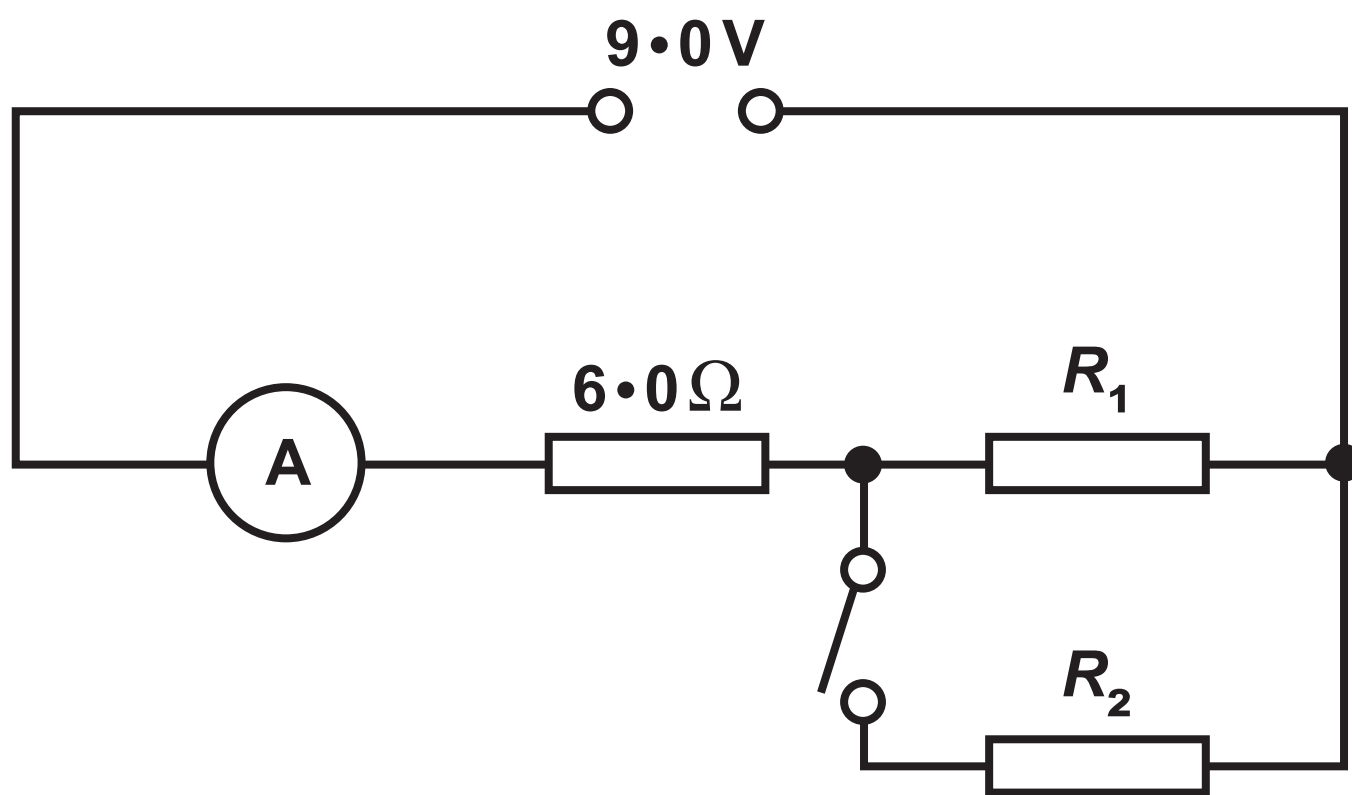
Centre Number: _____

Candidate Number: 2 _____

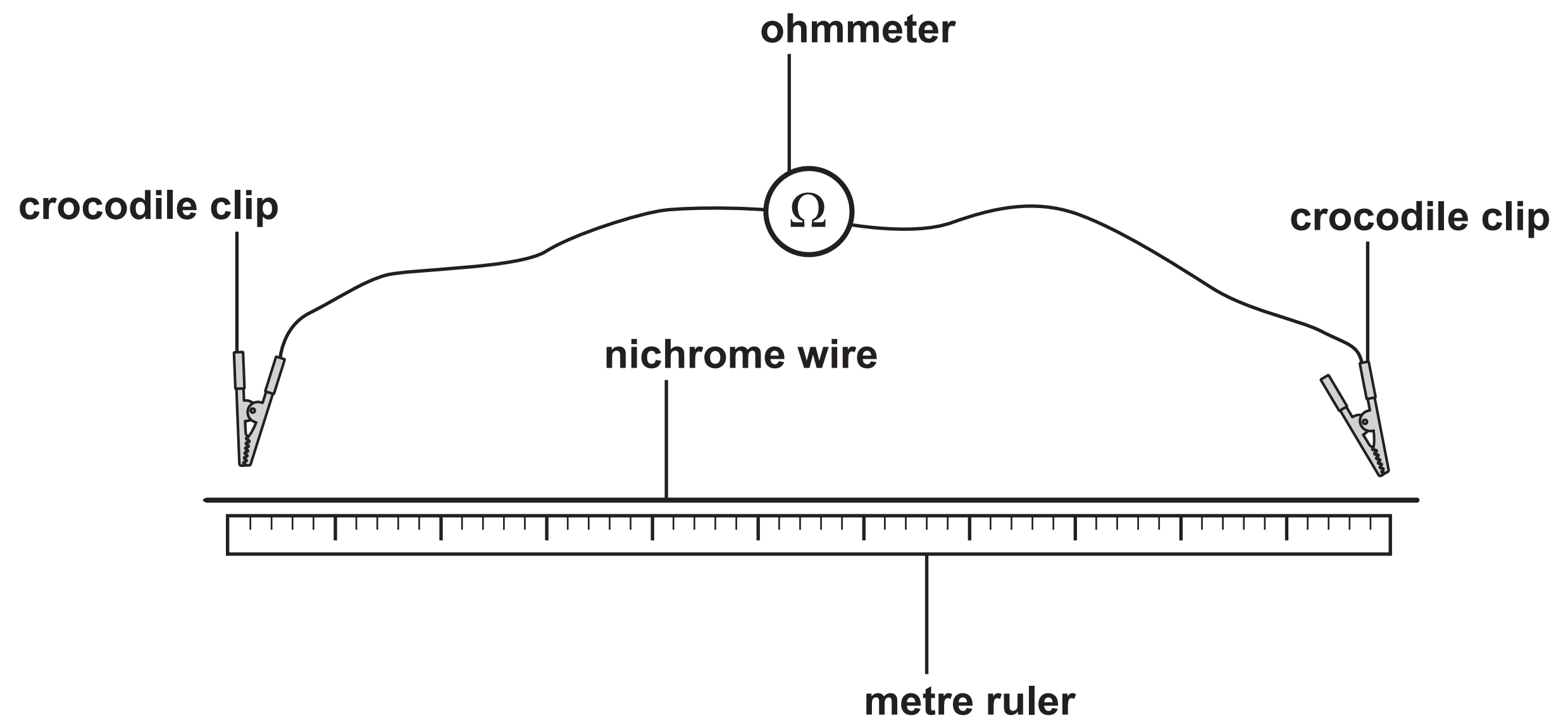
Question 1 (b)



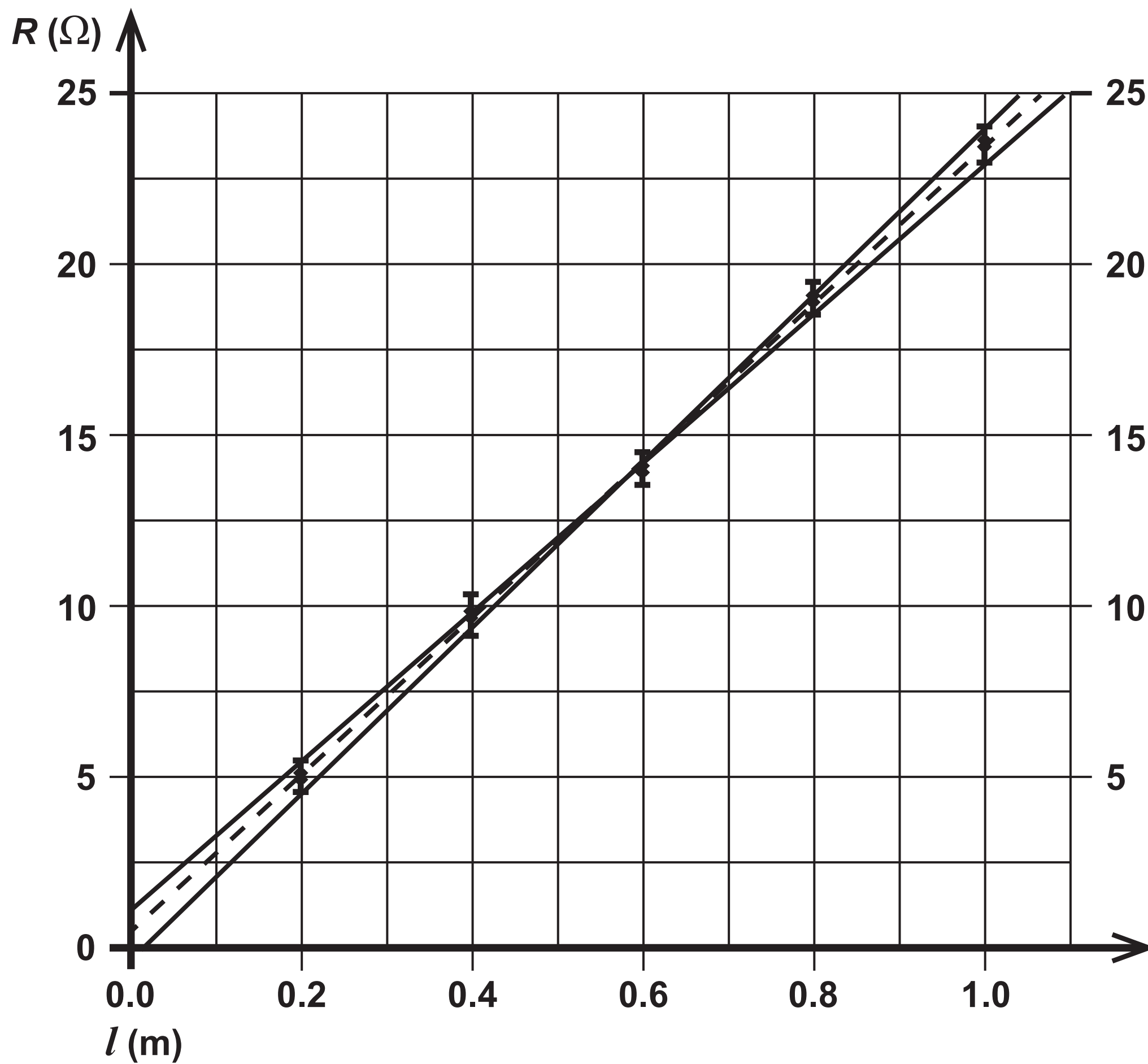
Question 2 (a)



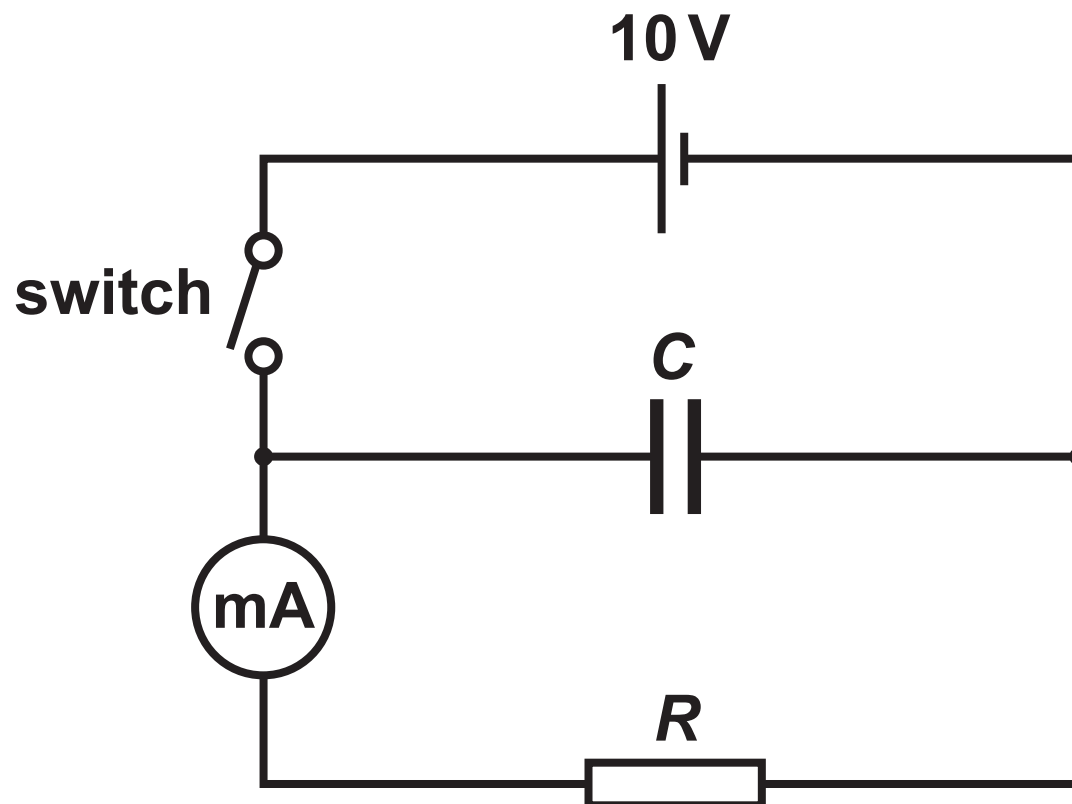
Question 3



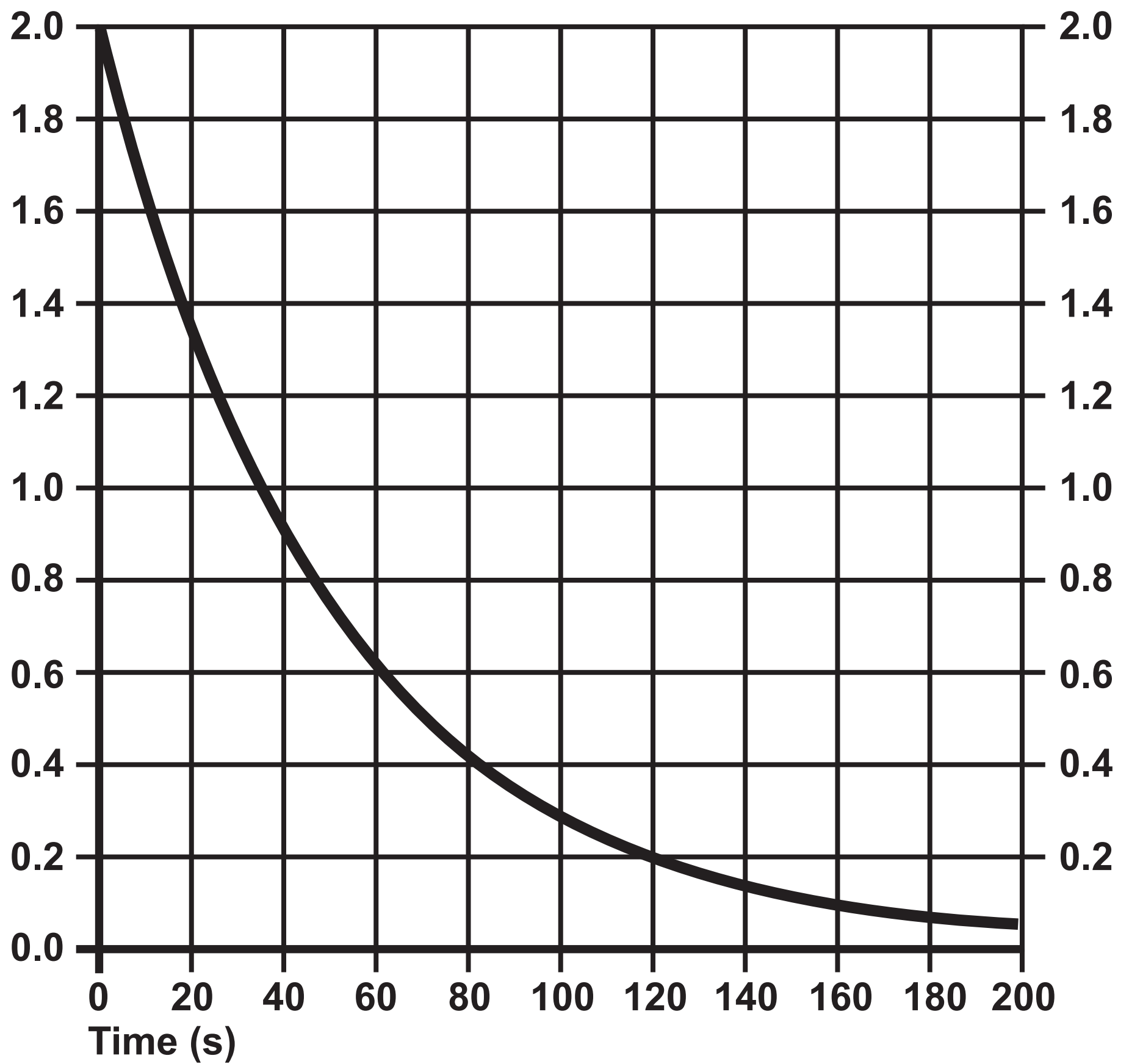
GRAPH 3.1



Question 4

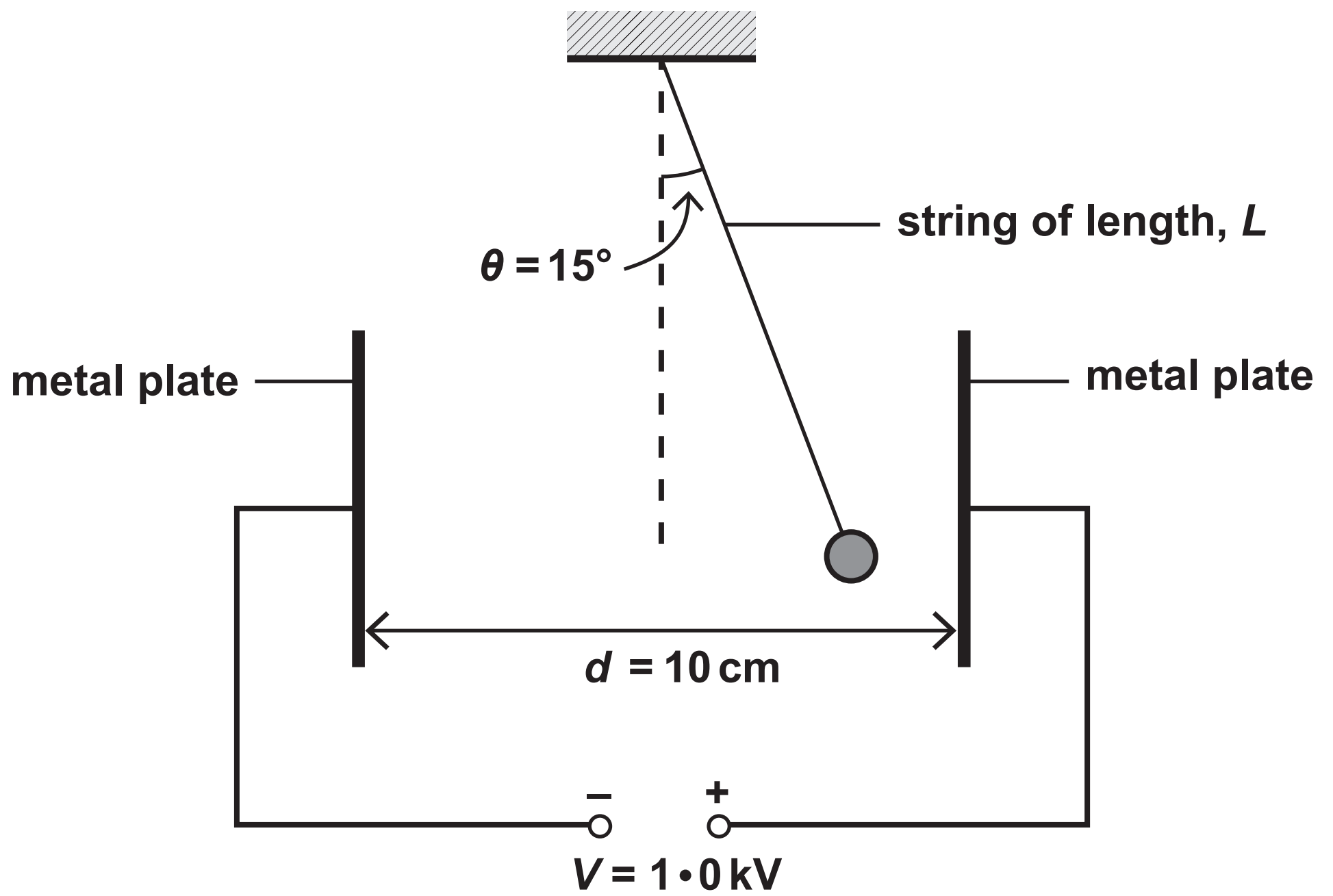


Current (mA)

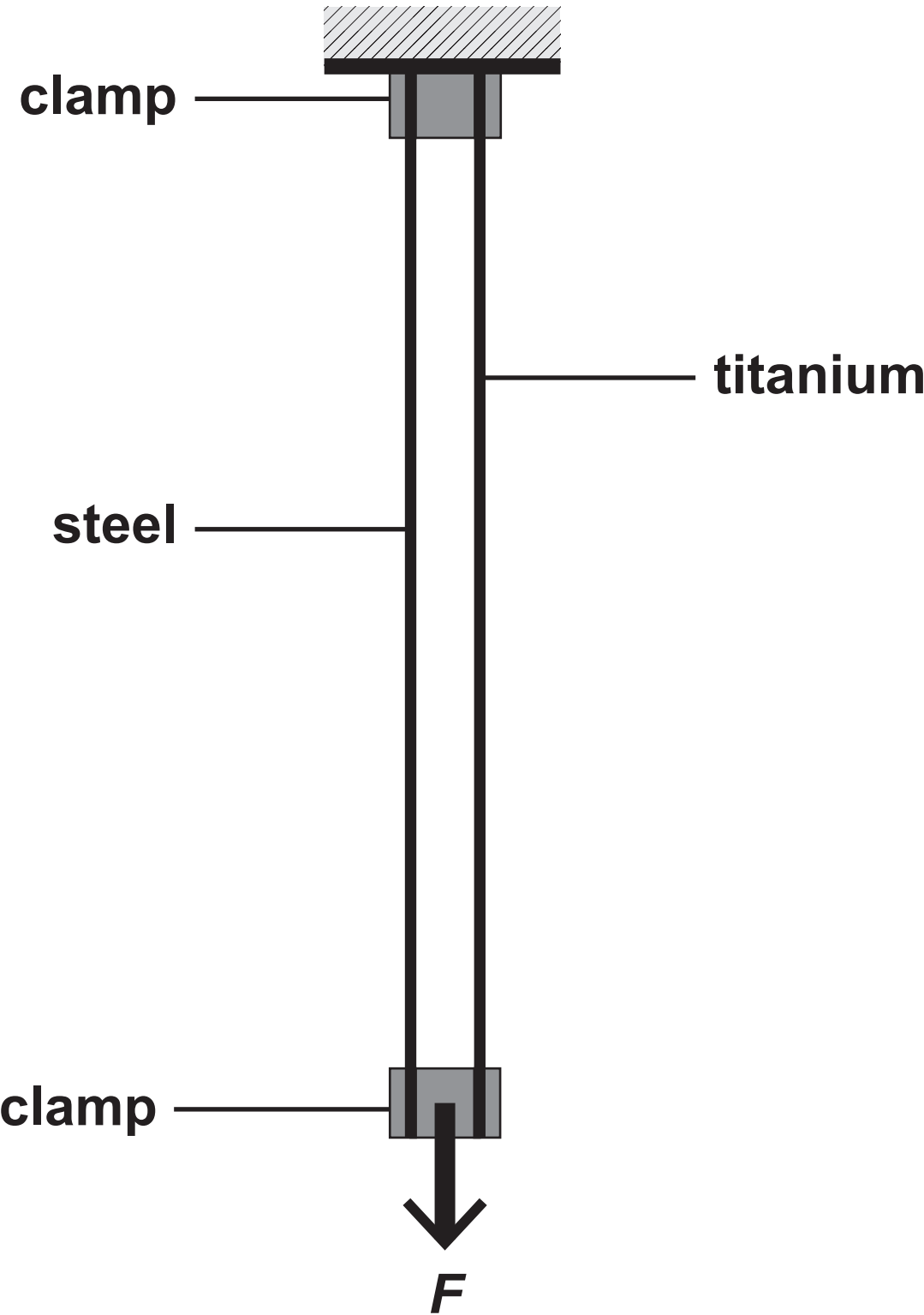


Question 5 (b)

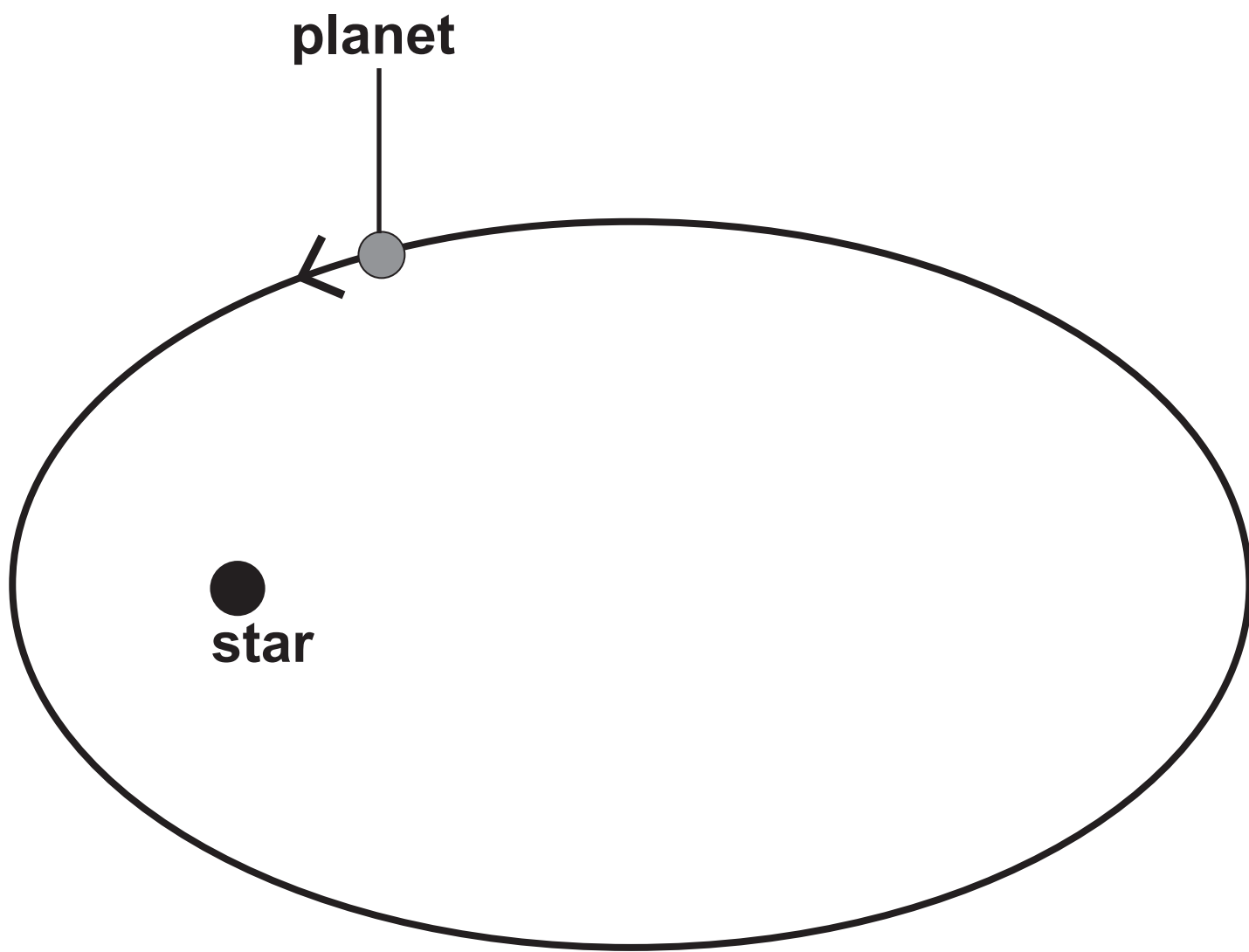
Diagram NOT drawn to scale



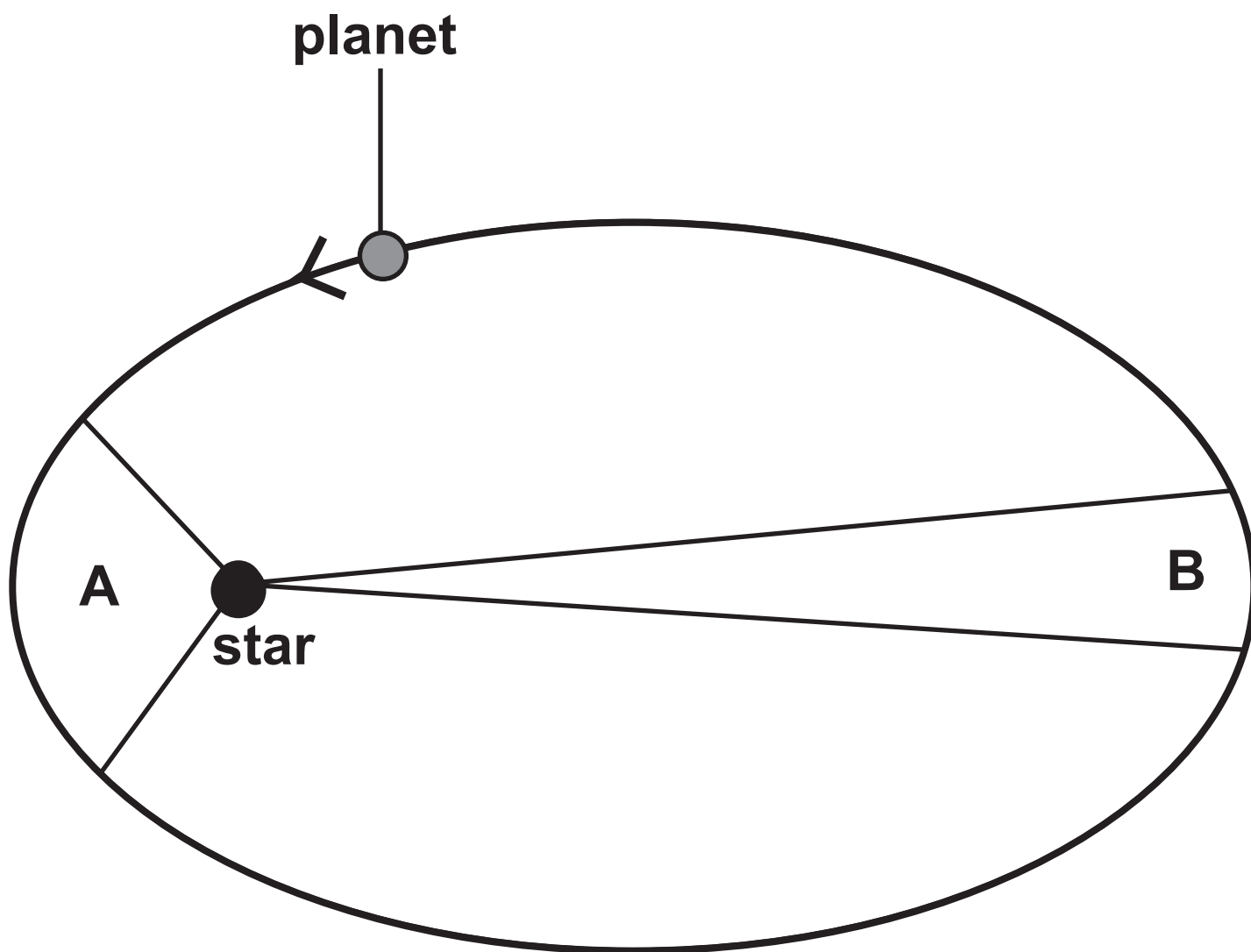
Question 6 (b)



Question 7 (a) (i)



Question 7 (a) (ii)



Question 7 (c)

A spiral galaxy with an estimated mass of 2×10^{42} kg



Question 7 (d)

EVIDENCE EMERGES FOR DARK – MATTER FREE GALAXIES

Date: December 6, 2021

Source: Royal Astrological Society

Astronomers have found no trace of dark matter in the galaxy AGC 114905, despite taking detailed measurements over a course of forty hours with state – of – the – art telescopes.

The astronomers concluded that the motions of the gas in AGC 114905 can be completely explained by just normal matter.

They commented: “This is, of course, what we thought and hoped for because it confirms our previous measurements, but now the problem remains that the theory predicts that there must be dark matter in AGC 114905, but our observations say there isn’t. In fact, the difference between theory and observation is only getting bigger.”

Question 8

Diagram NOT drawn to scale.

