



GCE A LEVEL

1420U40 – 1

THURSDAY, 13 JUNE 2024 – MORNING

**PHYSICS – A2 UNIT 4
FIELDS AND OPTIONS**

**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
Section A	1.	10	
	2.	6	
	3.	16	
	4.	18	
	5.	18	
	6.	12	
Section B	Option	20	
	Total	100	

(Turn over)

ADDITIONAL MATERIALS

In addition to this 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

This paper is in 2 sections, **A** and **B**.

Section A: 80 marks. Answer **ALL** questions. You are advised to spend about 1 hour 35 minutes on this section.

Section B: 20 marks. Options. Answer **ONE OPTION ONLY**. You are advised to spend about 25 minutes on this section.

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 **2**

Question 1 continued

1. (d) **DRAW A DIAGRAM** in the space below to show how you could combine three capacitors of **230 pF** to provide a capacitance of approximately **150 pF**.

[1 mark]

(Total for Question 1 = 10 marks)

(Turn over)

2. Describe how you would carry out an experiment to investigate the discharging of a capacitor through a resistor to determine the time constant.

(Turn over)

3. Refer to the graph for Question 3 in the separate Diagram Booklet. In the future, analysis of the **656 nm** red hydrogen line from a distant star might reveal the following Doppler variation in wavelength (the star would be viewed edge – on).

The mean wavelength is shorter than **656 nm** on average because of the mean radial velocity of the star but the sinusoidal variation is caused by an orbiting planet.

continued on the next page . . .

Question 3 continued

3. (b) Explain briefly whether the light is blue – shifted or red – shifted.

[1 mark]

(c) Show that the radius of the star’s orbit is approximately 2 000 km.

[3 marks]

continued on the next page . . .

(Turn over)

Question 3 continued

3. (d) The star has a mass of 2.07×10^{30} kg.

(i) Calculate the distance between the star and the planet.

[3 marks]

continued on the next page . . .

(Turn over)

Question 3 (d) continued

- 3. (d) (ii) Calculate the mass of the orbiting planet
(assume that the mass of the planet is much
smaller than the mass of the star).**

[2 marks]

continued on the next page . . .

(Turn over)

4. Refer to the diagram for Question 4 in the separate Diagram Booklet. Four point charges are placed at the corners of a square of length 1.20 m as shown. Point **P** is located at the centre of the square.

(a) (i) Define electric field strength.

[1 mark]

(ii) Show that the magnitude of the electric field strength at **P** due to any one of the four charges is approximately 520 kN C^{-1}

(Turn over)

[3 marks]

4. (a) (iii) Hence, calculate the resultant electric field strength at **P** and give its direction.

[3 marks]

continued on the next page . . .

(Turn over)

Question 4 continued

4. (b) A negative point charge is held at P and is free to move along the dotted line shown in the diagram with no resistive forces.

(i) Define electric potential.

[1 mark]

(ii) Explain briefly why the potential energy of the negative charge is zero at P.

[2 marks]

continued on the next page . . .

(Turn over)

Question 4 (b) continued

- 4. (b) (iii) Aled states “The negative charge initially accelerates to the right, then slows down but will just about reach infinity if no resistive forces act.” Discuss to what extent Aled’s points are correct.**

[3 marks]

continued on the next page . . .

(Turn over)

[5 marks]

(Total for Question 4 = 18 marks)

(Turn over)

5. Refer to the diagram for Question 5 in the separate Diagram Booklet. Michael carries out an experiment to determine how the magnetic field, B , due to a long current carrying wire varies with distance, a , from the wire.

His results are recorded in the table provided separately for Question 5 in the separate Diagram Booklet. A graph of $\ln(B)$ against $\ln(a)$ is plotted using the corrected B – field. This graph is provided for Question 5 (b) in the separate Diagram Booklet.

- (a) Explain why the corrected B – field, B must be obtained.

[1 mark]

continued on the next page . . .

(Turn over)

Question 5 continued

5. (b) **COMPLETE THE TABLE and PLOT THE MISSING POINT on the graph (no error bars are required).**

[3 marks]

- (c) The gradient of the steepest line is -1.03
Calculate the gradient of the least steep line.

[2 marks]

continued on the next page . . .

(Turn over)

Question 5 continued

5. (d) Use the equation $B = \frac{\mu_0 I}{2\pi a}$ to show that the

expected mean gradient is -1 and that the

expected $\ln(B)$ intercept is $\ln\left(\frac{\mu_0 I}{2\pi}\right)$

[2 marks]

continued on the next page . . .

(Turn over)

Question 5 continued

5. (g) Bethan analyses Michael's data by plotting a graph of B against $\frac{1}{a}$

The graph is provided for Question 5 (g) in the separate Diagram Booklet.

Explain briefly why Michael's log graph is more suitable than Bethan's graph for this data set (no calculations are required).

[2 marks]

Total for Question 5 = 18 marks)

(Turn over)

6. (a) Refer to the diagram for Question 6 (a) in the separate Diagram Booklet. The diagram shows a metal bar moving with velocity, v , through a uniform magnetic field, B .

Show that the rate of cutting of flux is Bvd .

[2 marks]

- (b) Refer to the diagram for Question 6 (b) in the separate Diagram Booklet. The diagram represents a square metal loop moving through a NON – UNIFORM B – field with the field coming out of the paper.

continued on the next page . . .

(Turn over)

Question 6 (b) continued

6. (b) (ii) The B – field, through which the square metal loop moves, increases with distance at a rate of $1 \cdot 20 \text{ T m}^{-1}$ (in the direction of the velocity). The square loop has sides of length $3 \cdot 8 \text{ cm}$ and moves at a speed of $8 \cdot 8 \text{ m s}^{-1}$. Show that the induced emf in the square metal loop is approximately 15 mV .

[2 marks]

continued on the next page . . .

(Turn over)

[5 marks]

(Total for Question 6 = 12 marks)

TOTAL FOR SECTION A = 80 MARKS

(Turn over)

SECTION B: OPTIONAL TOPICS**Option A – ALTERNATING CURRENTS****Option B – MEDICAL PHYSICS****Option C – THE PHYSICS OF SPORTS****Option D – ENERGY AND THE ENVIRONMENT****Answer the question on ONE TOPIC ONLY.**

Place a tick (✓) in one of the boxes above, to show which topic you are answering.

YOU ARE ADVISED TO SPEND ABOUT 25 MINUTES ON THIS SECTION.

(Turn over)

Option A – ALTERNATING CURRENTS

7. (a) Refer to the diagram for Question 7 (a) in the separate Diagram Booklet.

(i) Explain why the pd across the resistor decreases as the frequency of the supply increases.

[2 marks]

continued on the next page . . .

(Turn over)

Question 7 (a) continued

7. (a) (ii) Calculate the frequency when the pd across the resistor and inductor are equal.

[2 marks]

(iii) Calculate the rms pd across the resistor when it is equal to the rms pd across the inductor.

[2 marks]

continued on the next page . . .

(Turn over)

Question 7 continued

7. (b) Refer to the diagram for Question 7 (b) in the separate Diagram Booklet. A square coil of N turns and cross-sectional area, A , is rotated with angular velocity, ω , in a magnetic field of flux density, B .

The peak induced emf is given by the equation:

$$V = \omega BAN$$

- (i) Explain in terms of Faraday's law why the emf is proportional to each of B and A .

[3 marks]

continued on the next page . . .

(Turn over)

Question 7 (b) continued

7. (b) (ii) Explain at which point in the cycle the peak emf occurs.

[1 mark]

(c) Refer to the circuit for Question 7 (c) in the separate Diagram Booklet. Calculate the rms current in the circuit:

(i) at resonance;

[1 mark]

continued on the next page . . .

(Turn over)

[5 marks]

(Total for Question 7 = 20 marks)

(Turn over)

Option B – MEDICAL PHYSICS

8. (a) Refer to the set of axes for Question 8 (a) in the separate Diagram Booklet. On the axes, **SKETCH TWO GRAPHS** to show how the intensity of X – rays from an X – ray tube varies with wavelength for an X – ray tube operating at two different voltages, one at **30 kV** and the other at **50 kV**.

LABEL THE MAIN FEATURES of the graphs and also show which graph is at the higher voltage. Space for calculations.

[4 marks]

continued on the next page . . .

(Turn over)

Question 8 continued

8. (b) (i) **Ultrasound can be used to measure the speed of blood through an artery.**

If ultrasound of frequency 1.5 MHz travelling at an angle of 30° to the direction of blood flow shows a Doppler shift of 200 Hz, calculate the speed of blood flow. The speed of ultrasound through the blood is 1570 m s^{-1}

[2 marks]

continued on the next page . . .

(Turn over)

Question 8 (b) continued

8. (b) (ii) Suggest why it is important for doctors to monitor the rate of blood flow in a patient.

[1 mark]

(c) (i) A magnetic resonance scanner (MRI) can be used to detect tumours in a patient's body. Describe how an MRI scanner works.

[3 marks]

continued on the next page . . .

(Turn over)

Question 8 (c) continued

8. (c) (ii) The MRI scanner has a magnetic field of 1.4 T . Determine the wavelength of electromagnetic radiation that should be used to detect the tumour.

[2 marks]

continued on the next page . . .

(Turn over)

Question 8 continued

8. (d) (i) PET scanners are often used to diagnose tumours in patients. Calculate the energy of the emitted gamma rays

$$(m_{\text{positron}} = m_{\text{electron}} = 0.000\,549\, \text{u}, \\ 1\, \text{u} = 931\, \text{MeV}).$$

[2 marks]

- (ii) Explain why PET scanners are not commonly found in smaller hospitals.

[1 mark]

continued on the next page . . .

(Turn over)

Question 8 continued

8. (e) **Doctors are concerned about the growth of an unborn baby and have the choice of the following imaging techniques**

X – ray

fluoroscopy

ultrasound B – scan

ultrasound A – scan

CT scan

Evaluate the suitability of ALL FIVE types of imaging techniques for unborn babies.

(Turn over)

[5 marks]

(Total for Question 8 = 20 marks)

(Turn over)

Option C – THE PHYSICS OF SPORTS

9. (a) (i) Liam wishes to buy a baseball bat with a large moment of inertia and he chooses **BAT B** from the following list in a catalogue. Evaluate whether he has chosen the correct bat.

Bat	Mass/ kg	Length/ cm
A	1.00	85
B	1.10	82
C	1.05	85

[2 marks]

continued on the next page . . .

(Turn over)

Question 9 (a) continued

9. (a) (ii) Calculate the angular momentum of a baseball bat if it has a moment of inertia of 0.35 kg m^2 and is rotating at 63 rad s^{-1}

[2 marks]

continued on the next page . . .

(Turn over)

Question 9 (b) continued

9. (b) (ii) Calculate the rotational kinetic energy gained by the ball.

[2 marks]

continued on the next page . . .

(Turn over)

Question 9 (b) continued

9. (b) (iii) By considering both the linear and rotational motion, explain why baseball players wear a glove on the hand that they use to catch the ball.

[3 marks]

continued on the next page . . .

(Turn over)

Question 9 continued

9. (c) Refer to the diagram for Question 9 (c) in the separate Diagram Booklet. A fielder throws the ball towards a teammate. The ball is initially thrown from 1.60 m above the ground with a speed of 36 m s^{-1} at an angle of 3° below the horizontal. When the ball is caught it is 0.85 m above the ground and has a speed of 33 m s^{-1} at an angle of 7° below the horizontal.
- (i) Explain how the information in the diagram shows that air resistance must be acting on the ball.

[2 marks]

continued on the next page . . .

(Turn over)

Question 9 (c) continued

9. (c) (ii) Evaluate whether the vertical acceleration of the ball is equal to the acceleration due to gravity.

[3 marks]

continued on the next page . . .

(Turn over)

Question 9 (c) continued

9. (c) (iii) Explain why a spinning ball may travel further in air than a non – spinning ball.

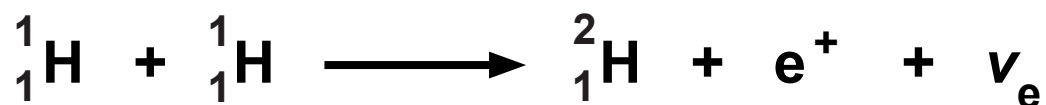
[2 marks]

(Total for Question 9 = 20 marks)

(Turn over)

Option D – ENERGY AND THE ENVIRONMENT

10. (a) The proton – proton chain accounts for the majority of the energy output from the Sun. The initial stage of the proton – proton chain is shown below.



- (i) State which force is responsible for this reaction.

[1 mark]

- (ii) Determine the energy released by one such reaction.

Masses: ${}^1_1\text{H} = 1.00728 \text{ u}$ ${}^2_1\text{H} = 2.01355 \text{ u}$
 $\text{e}^+ = 0.00055 \text{ u}$ $\nu_e = 0.00000 \text{ u}$

(Turn over)

[2 marks]

10. (b) (i) Define the 'solar constant'.

[2 marks]

(ii) Suggest why the solar constant is not considered to be a constant by the scientific community.

[1 mark]

continued on the next page . . .

(Turn over)

Question 10 (b) continued

- 10. (b) (iii) The temperature of the Sun's surface is 5780 K. Given that the surface area of the Sun is $6 \cdot 1 \times 10^{18} \text{ m}^2$, determine the intensity of the Sun's radiation at a distance of $1 \cdot 50 \times 10^{11} \text{ m}$ from its centre AND state the name of a law used in your calculation.**

[4 marks]

continued on the next page . . .

(Turn over)

Question 10 continued

10. (c) Refer to the graph for Question 10 (c) in the separate Diagram Booklet. The graph shows the absorption spectra for carbon dioxide and water vapour as a function of the wavelength of the radiation incident on the gas in our atmosphere.

Studies show that the greenhouse effect is being enhanced by increased levels of carbon dioxide and water vapour. Use the graph to explain this, assuming the Earth emits radiation as a black body with a mean temperature of 288 K.

(Turn over)

[4 marks]

10. (d) Nuclear fission of uranium fuel is used on Earth in order to generate electrical energy. Natural uranium is composed of U – 235 and U – 238 nuclei.

(i) Explain why enrichment of uranium is required before it is used in a fission reactor.

[2 marks]

continued on the next page . . .

(Turn over)

Question 10 (d) continued

10. (d) (ii) Refer to the diagram for Question 10 (d) (ii) in the separate Diagram Booklet. The diagram represents a gas centrifuge.

U – 235 and U – 238 are both reacted with fluorine to create $^{235}\text{UF}_6$ and $^{238}\text{UF}_6$ gas molecules. These gas molecules are then fed into a gas centrifuge consisting of a rotating drum where they undergo circular motion.

The diameter of the rotating drum is 30.0 cm and the speed of the outer surface of the rotating drum is 350 m s^{-1} . Calculate the number of revolutions per second made by the drum.

[2 marks]

continued on the next page . . .

(Turn over)

Question 10 (d) continued

10. (d) (iii) The output from the centrifuge has **1.15** times more $^{235}\text{UF}_6$ than was initially fed in. This enriched mixture is transferred into a series of identical centrifuges. Determine the number of centrifuges required to enrich the $^{235}\text{UF}_6$ in the gas mixture from **0.7 %** to **5.0 %**.

[2 marks]

(Total for Question 10 = 20 marks)

TOTAL FOR SECTION B = 20 MARKS

END OF PAPER

TOTAL FOR PAPER = 100 MARKS

(Turn over)



GCE A LEVEL

1420U40 – 1

THURSDAY, 13 JUNE 2024 – MORNING

**PHYSICS – A2 UNIT 4
FIELDS AND OPTIONS**

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

Diagram Booklet

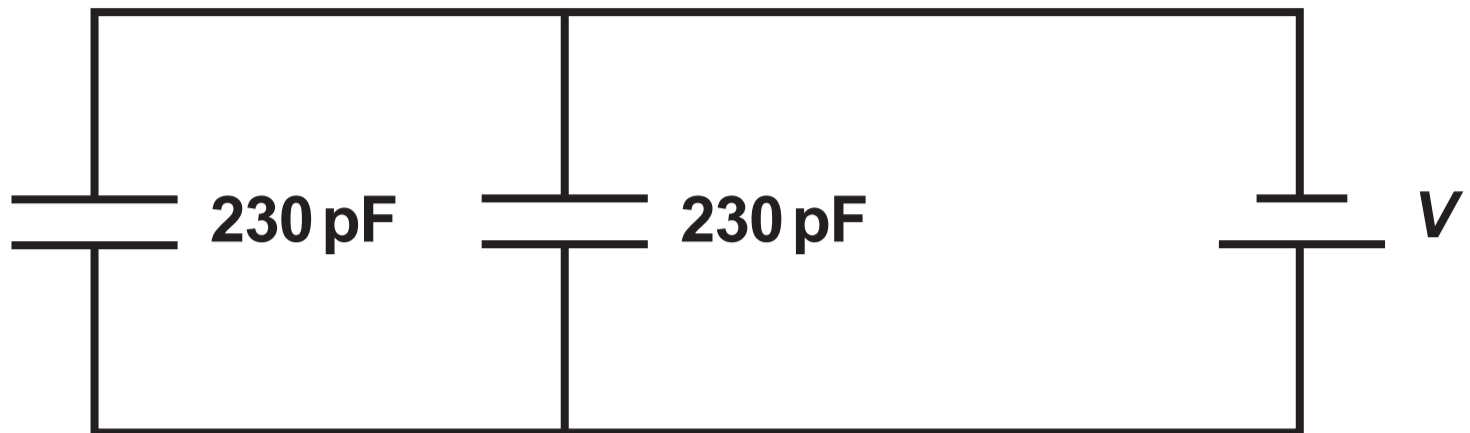
Surname: _____

First name(s): _____

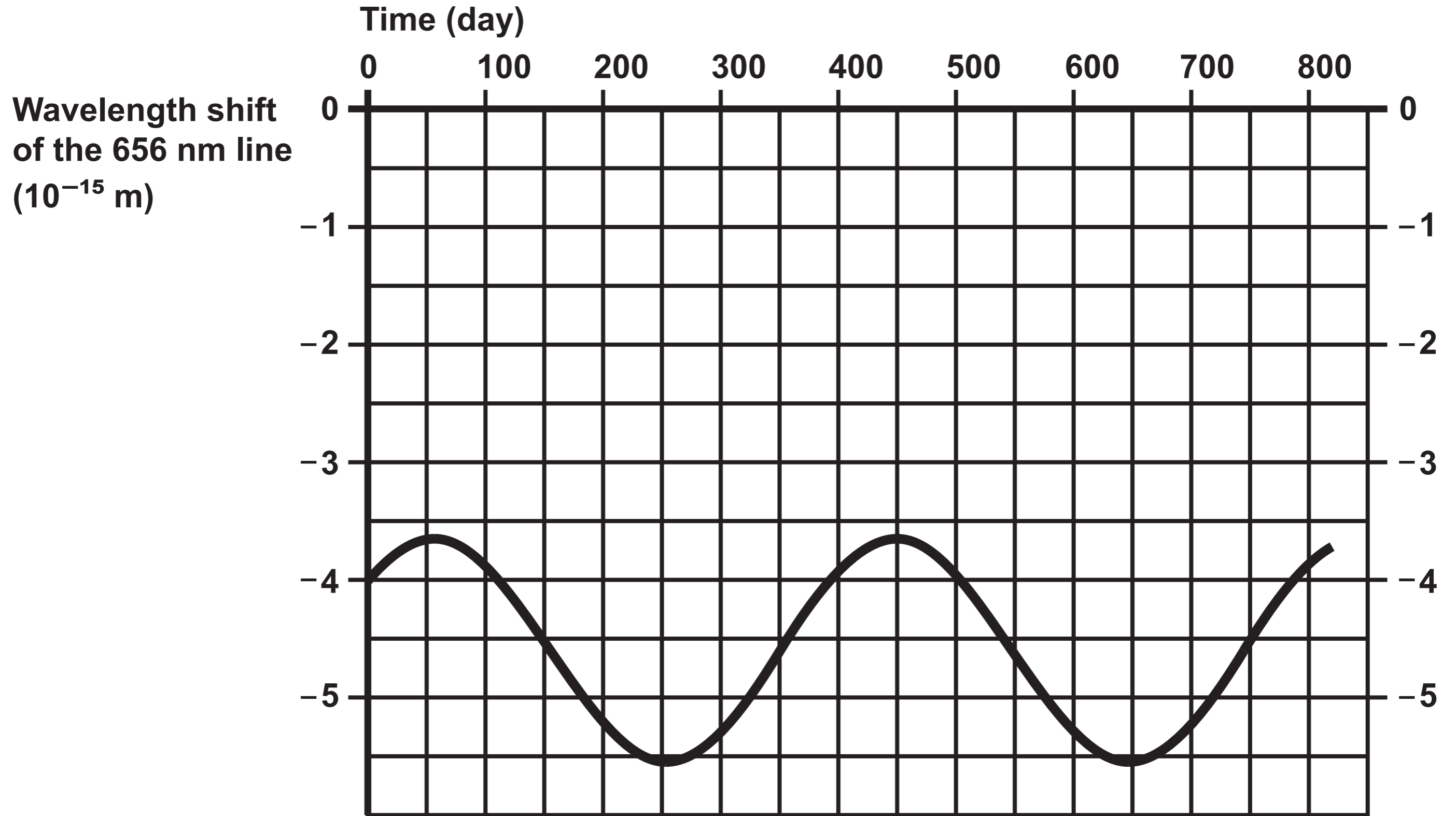
Centre Number: _____

Candidate Number: 2 _____

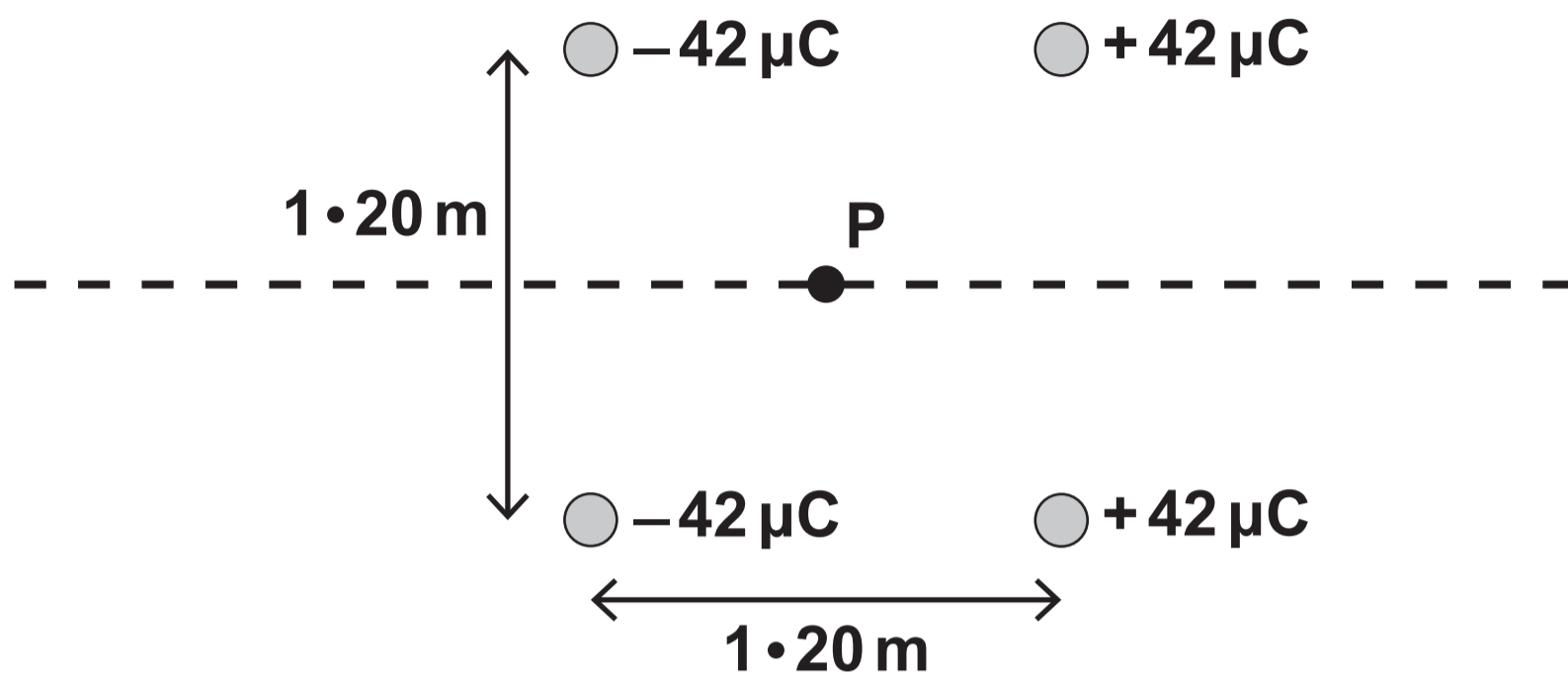
Question 1 (c)



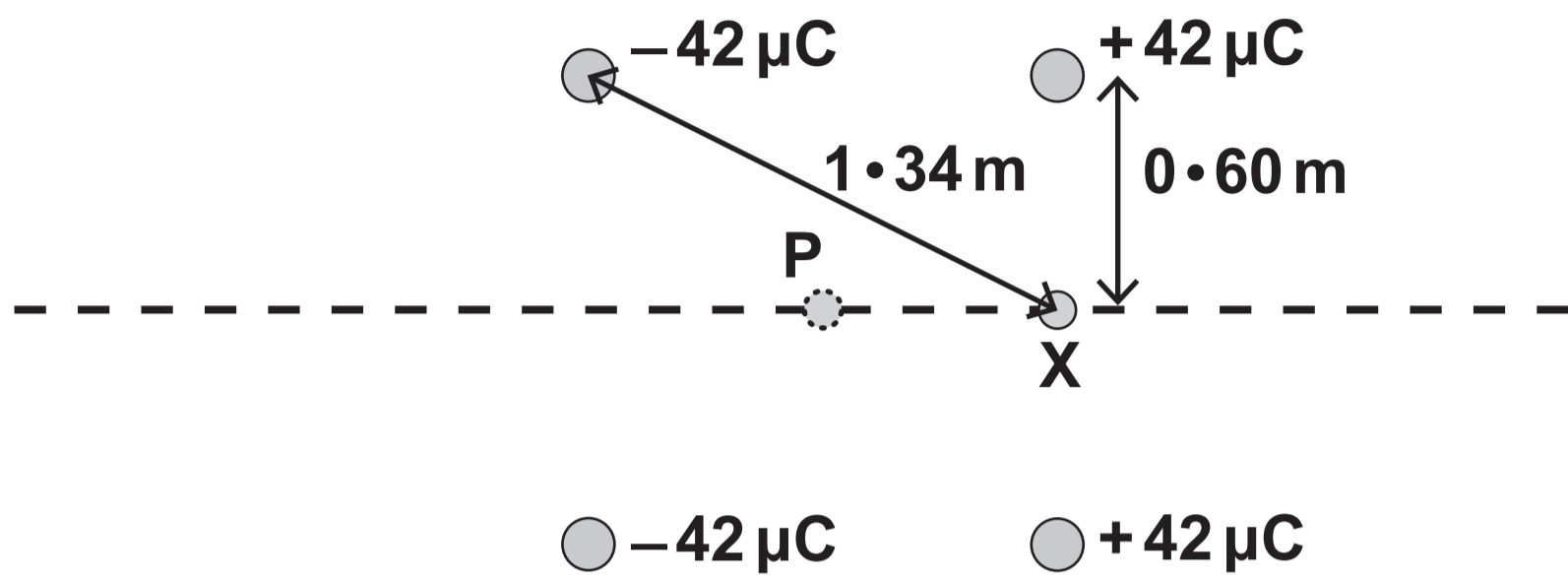
Question 3



Question 4

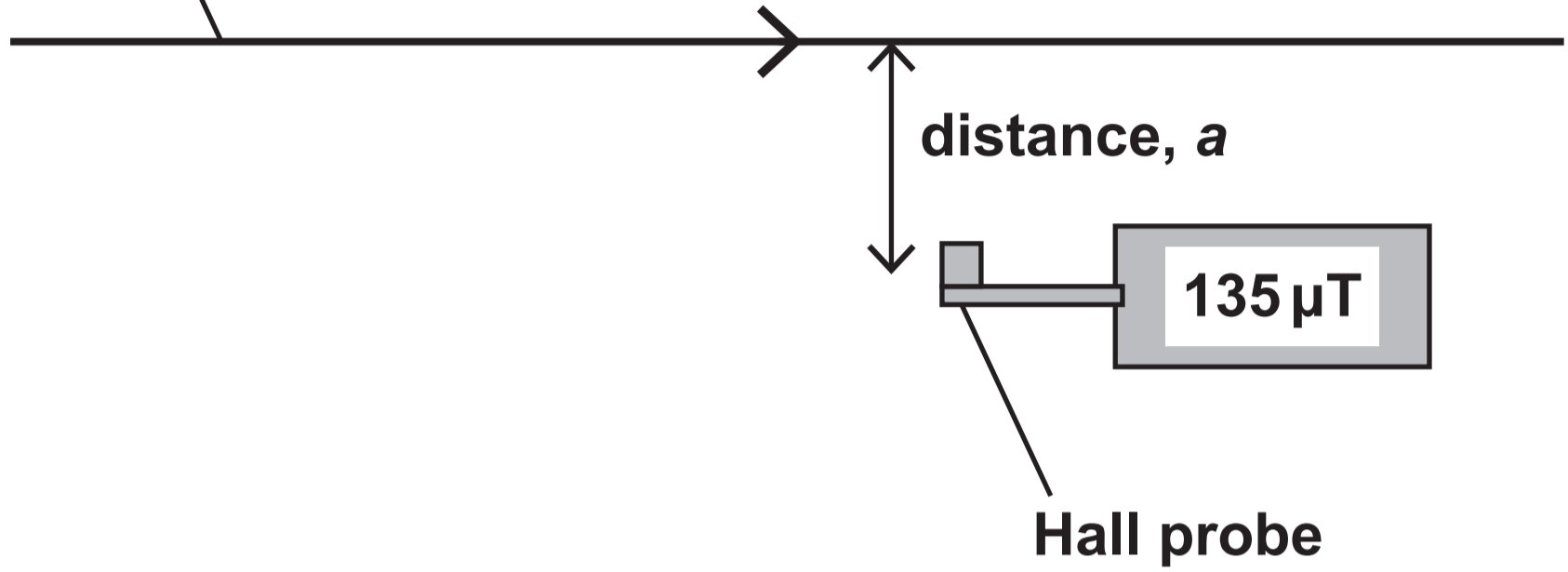


Question 4 (b) (iv)



Question 5

long current-carrying wire

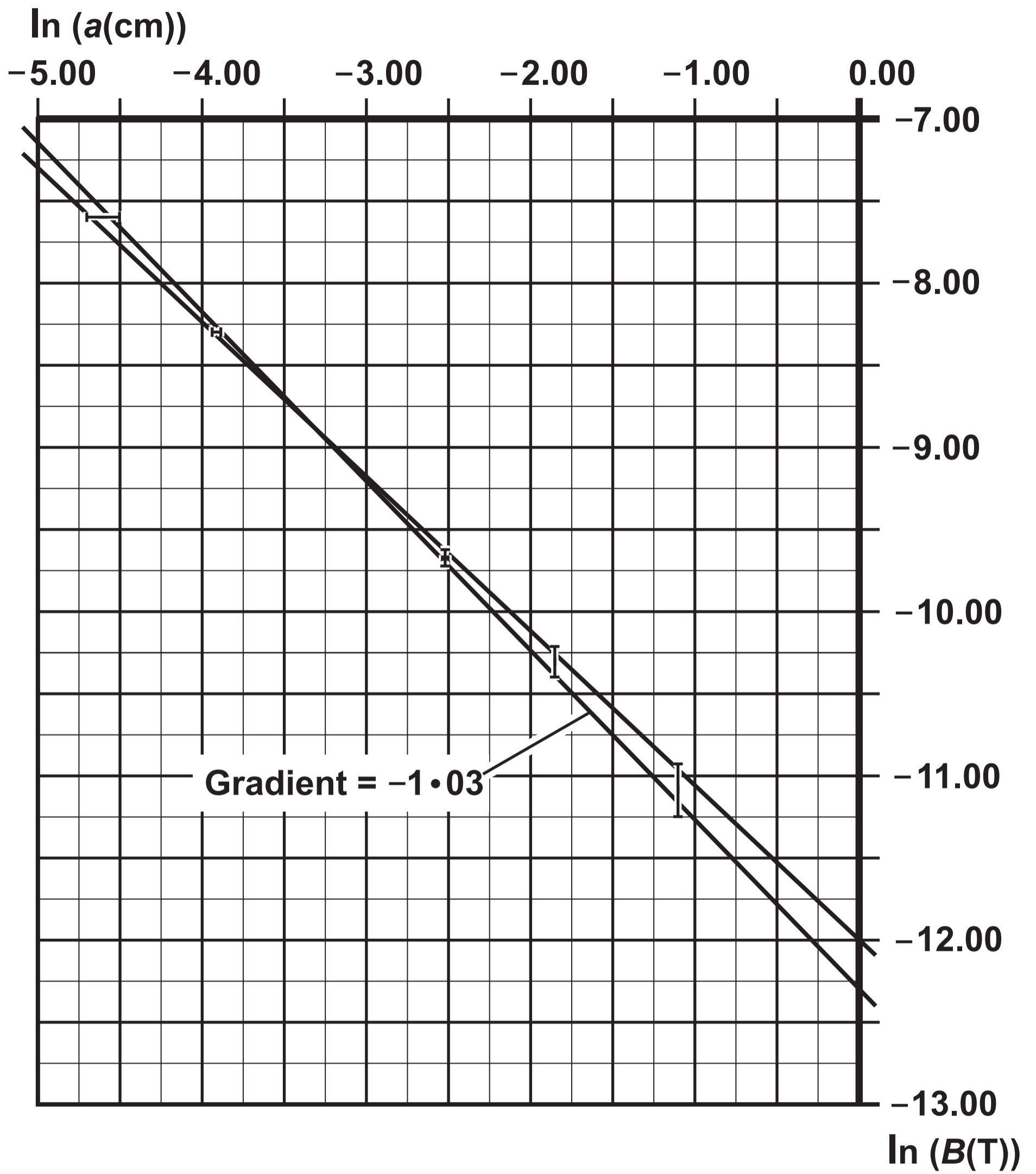


Question 5

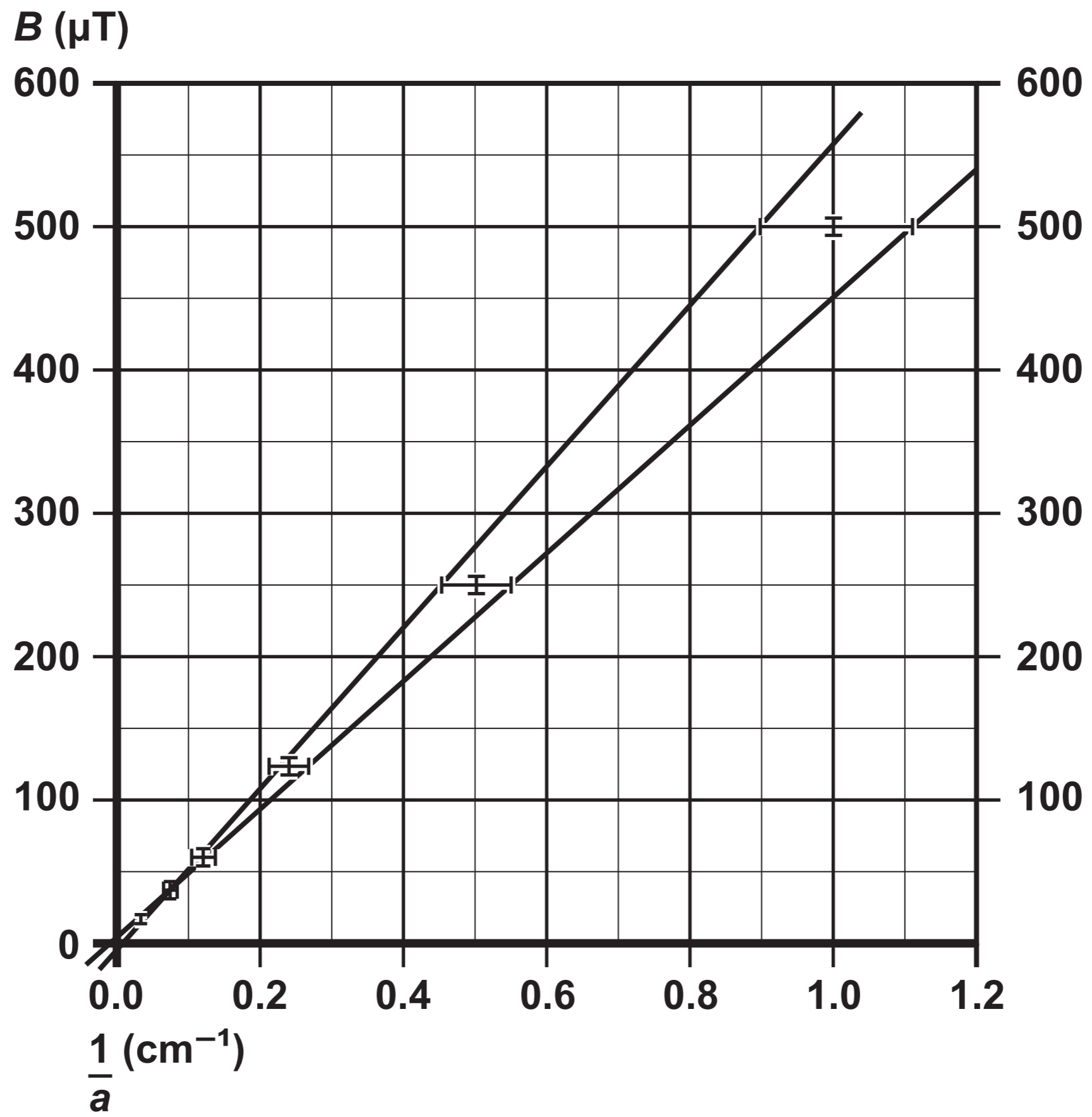
TABLE

a (m)	Measured B -field (T)	Corrected B -field B (T)	$\ln(a$ (m))	$\ln(B$ (T))
0.010	0.000 529	0.000 499	- 4.61	- 7.60
0.020	0.000 279	0.000 249	- 3.91	- 8.30
0.040	0.000 157	_____	_____	_____
0.080	0.000 092	0.000 062	- 2.53	- 9.69
0.160	0.000 063	0.000 033	- 1.83	- 10.32
0.300	0.000 046	0.000 016	- 1.20	- 11.04

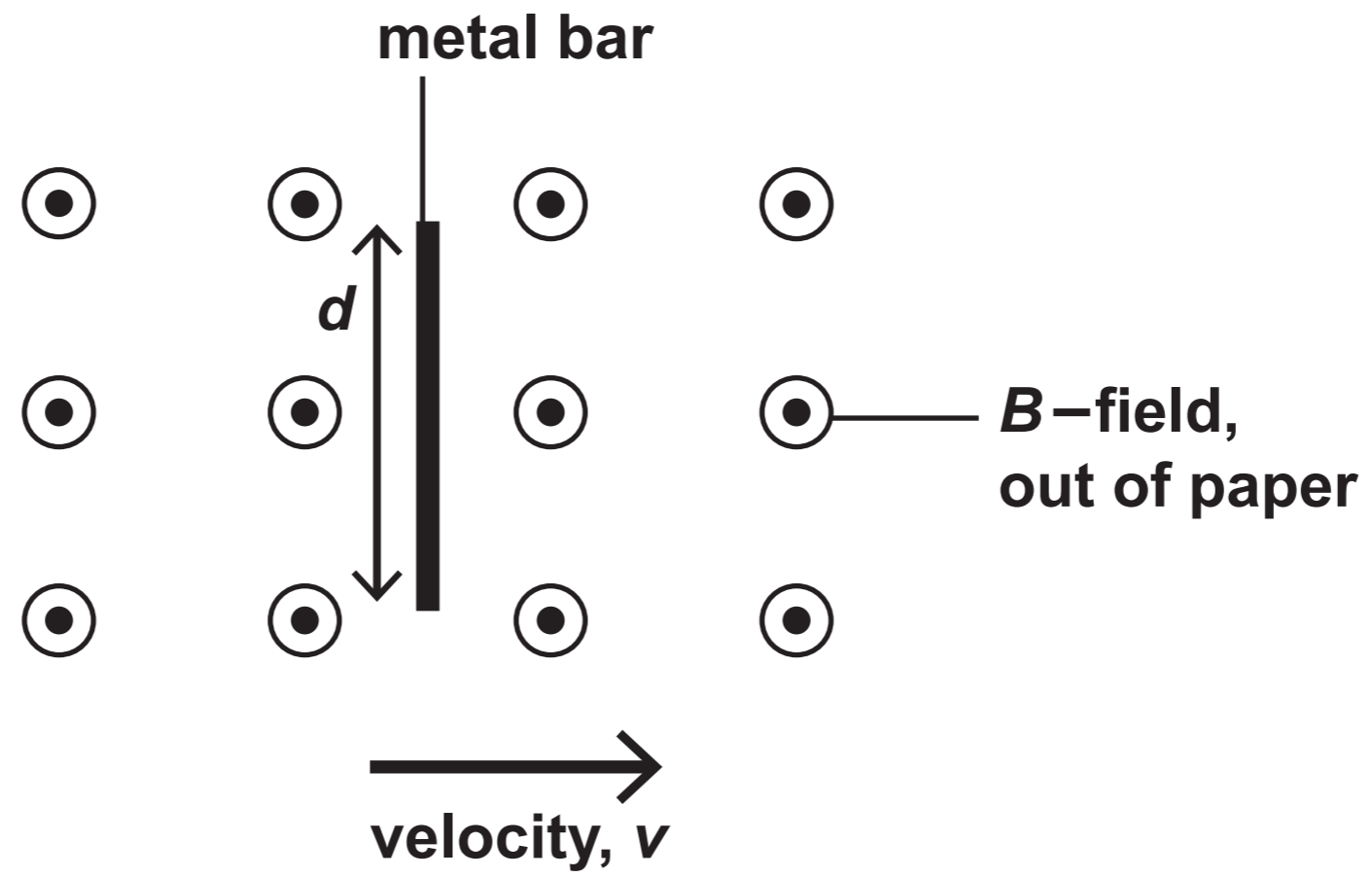
Question 5 (b)



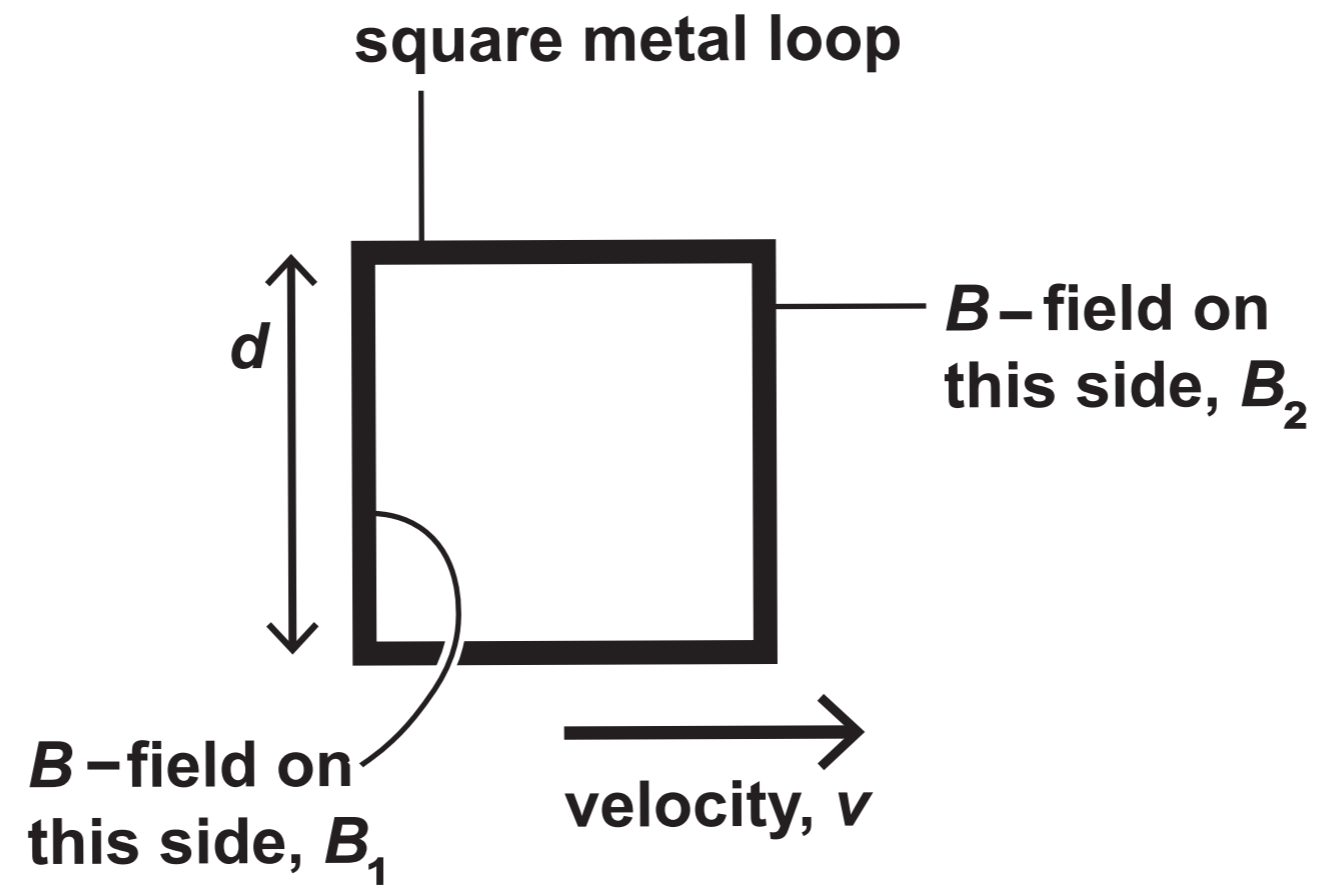
Question 5 (g)



Question 6 (a)



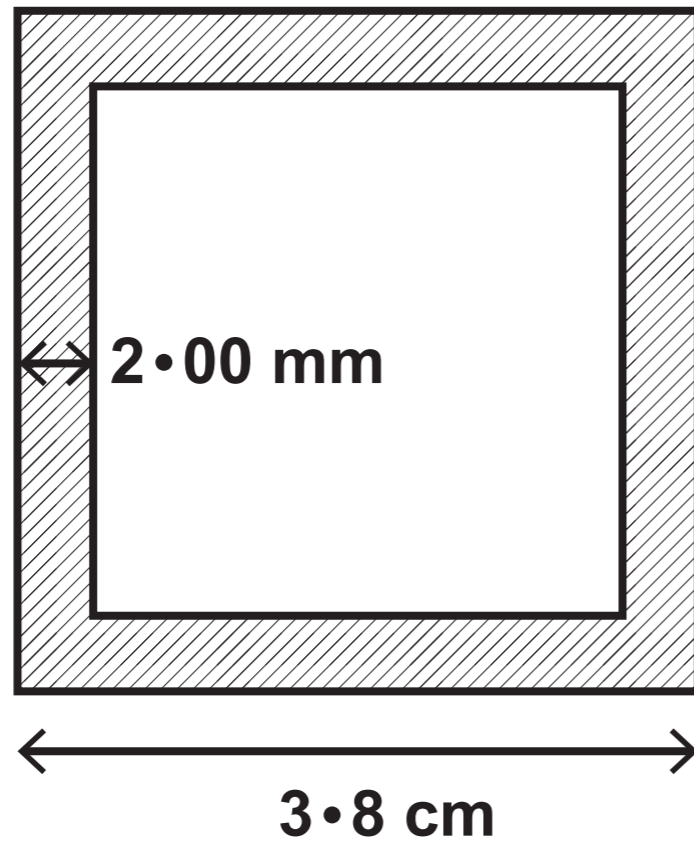
Question 6 (b)



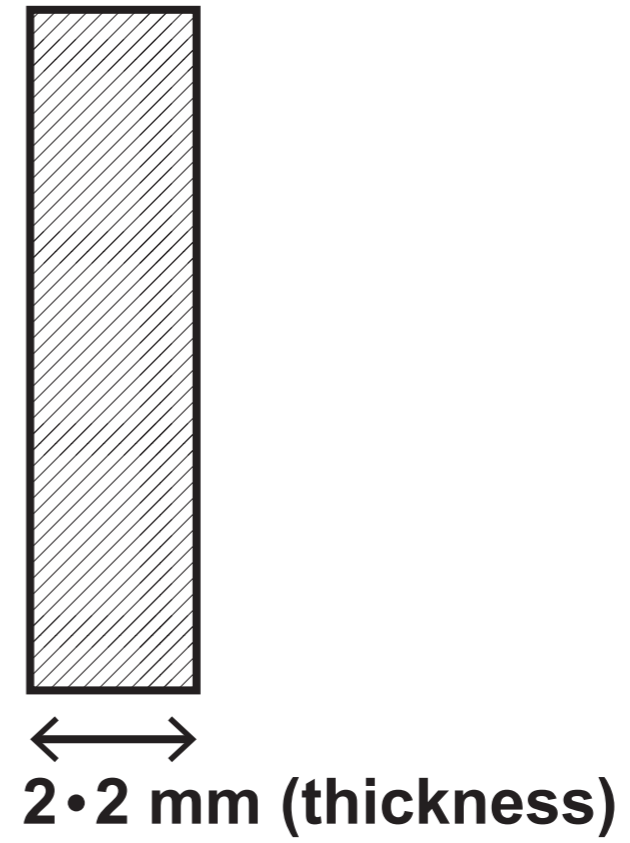
Question 6 (b) (iii)

The square metal loop

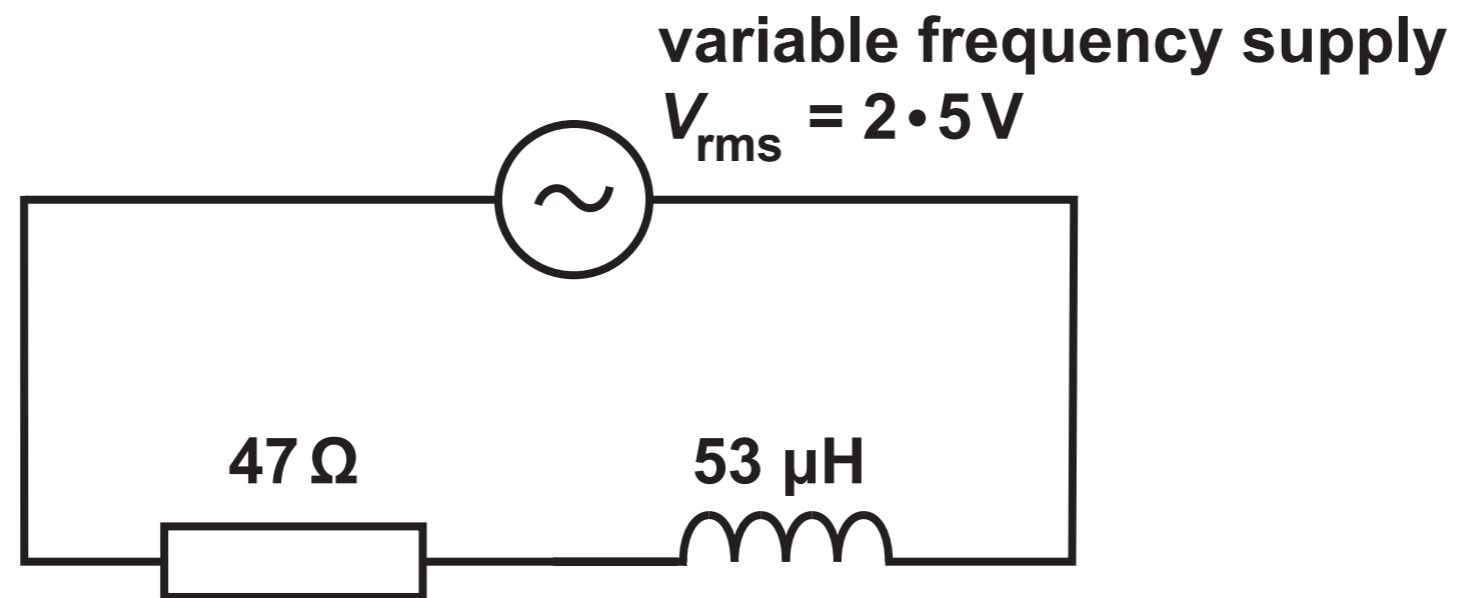
front view



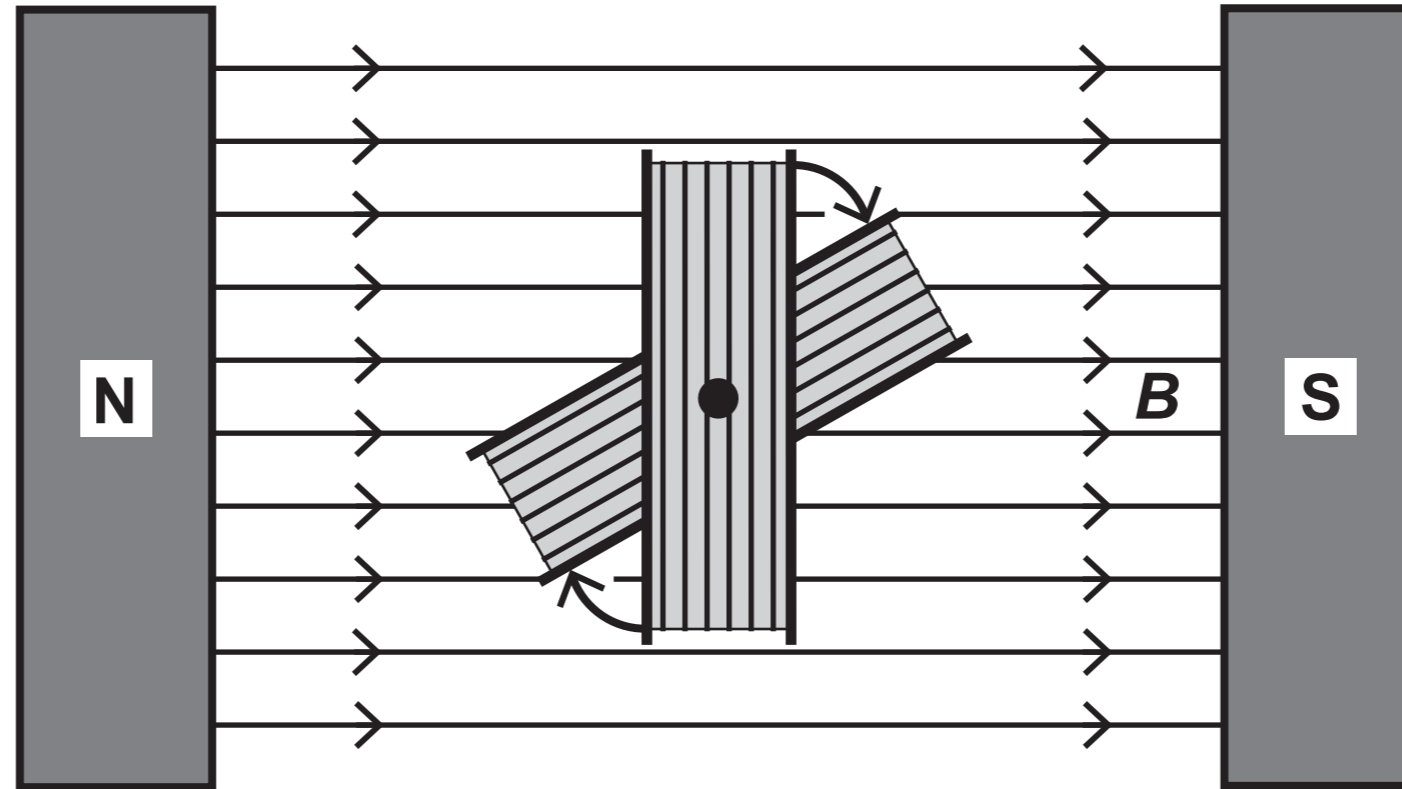
side view



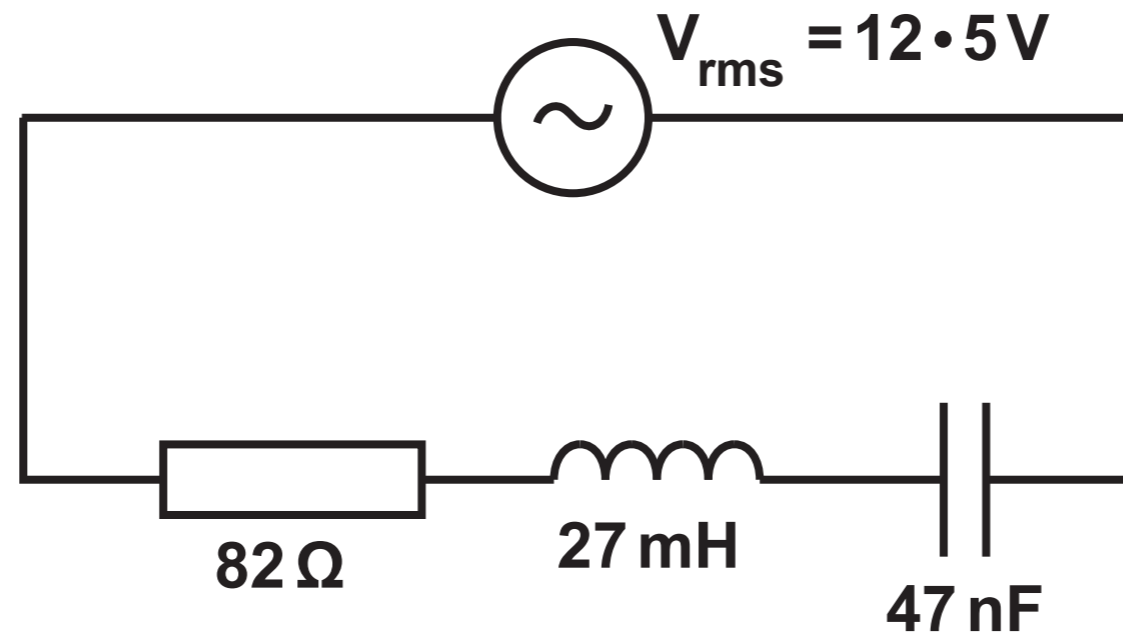
Question 7 (a)



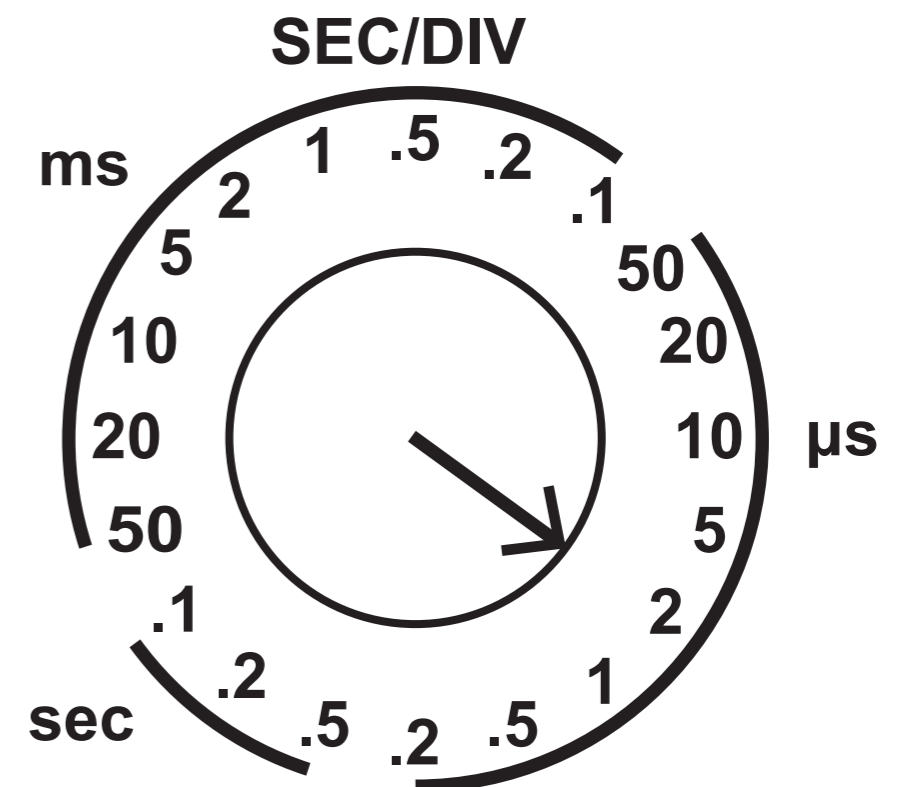
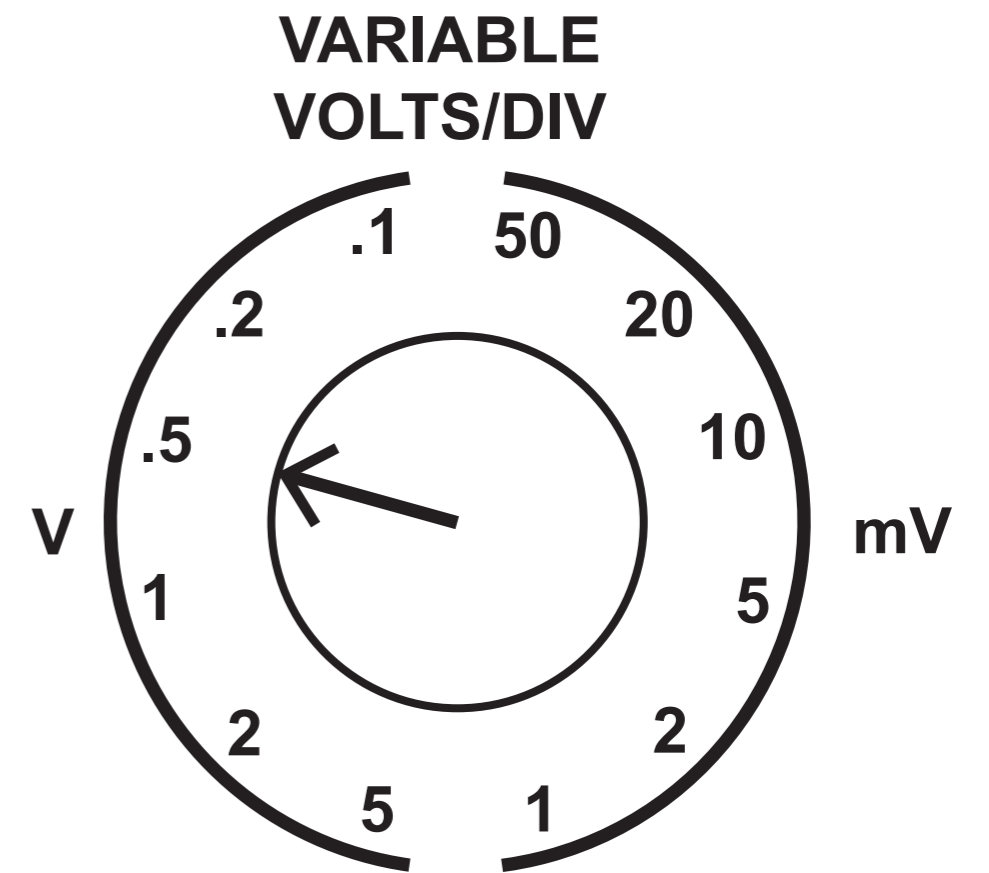
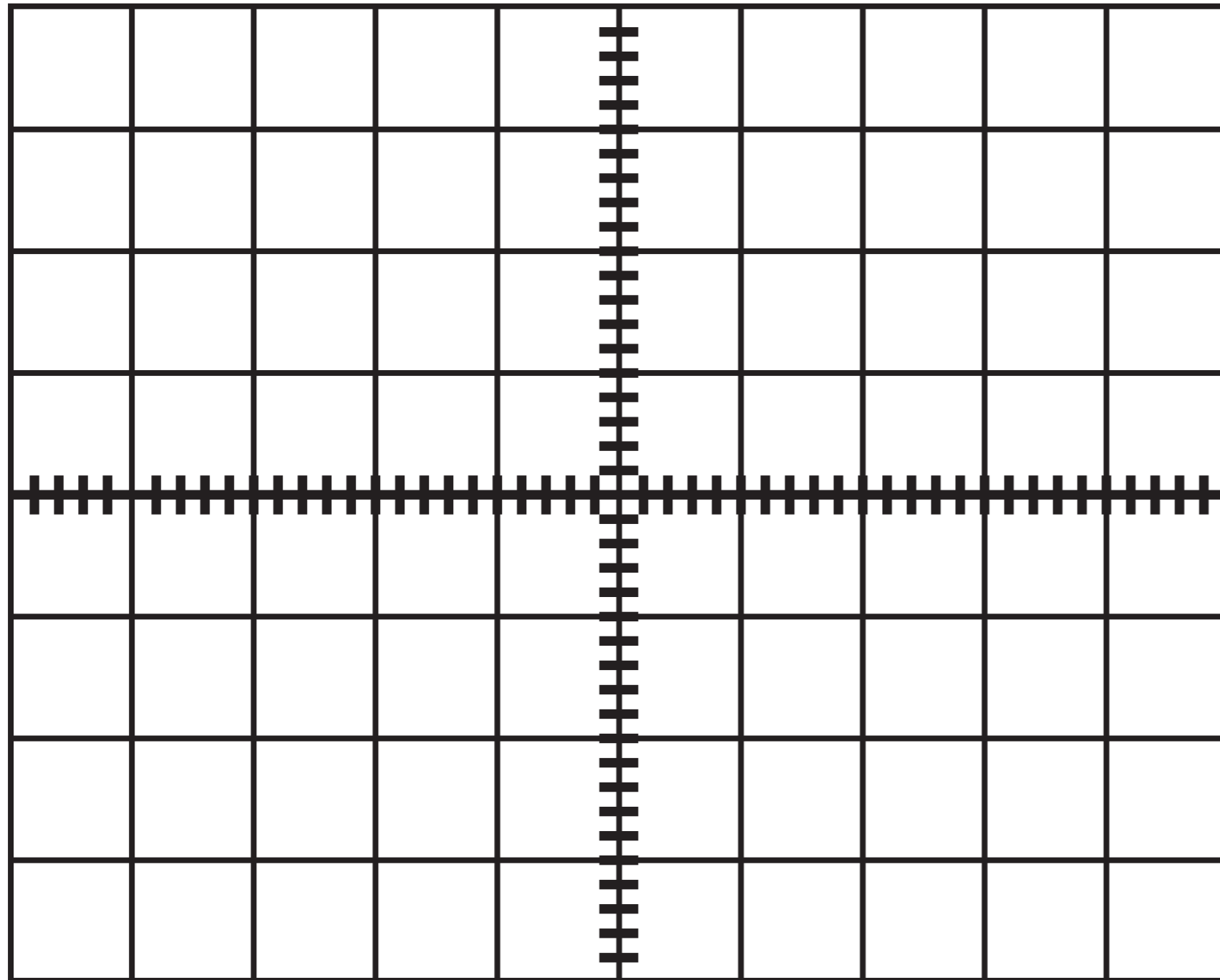
Question 7 (b)



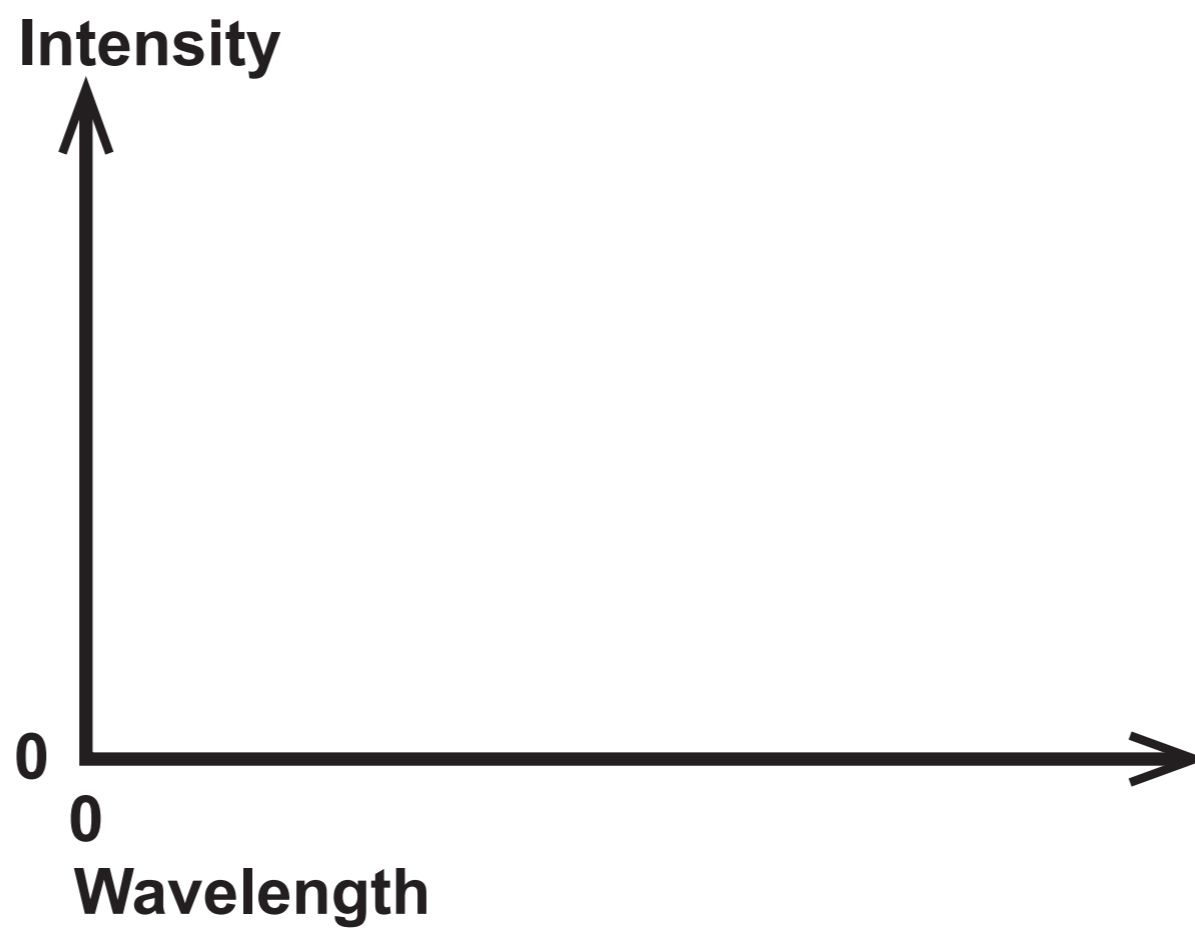
Question 7 (c)



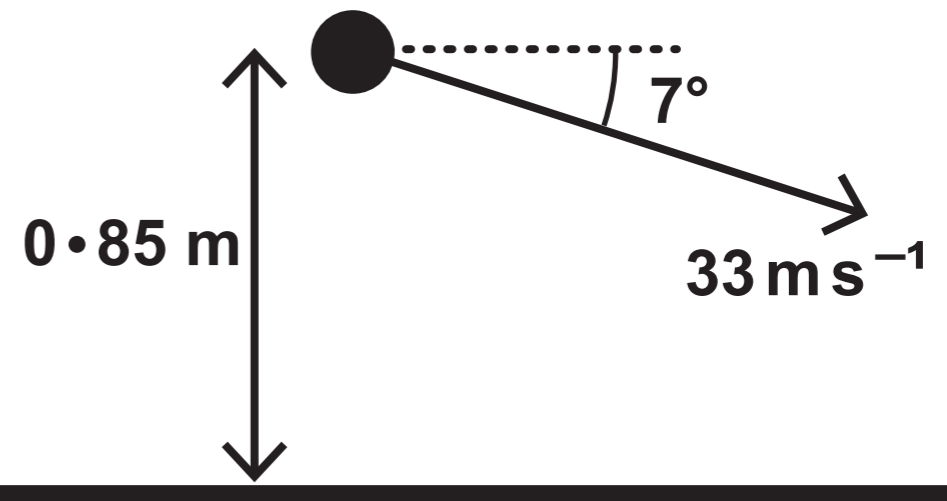
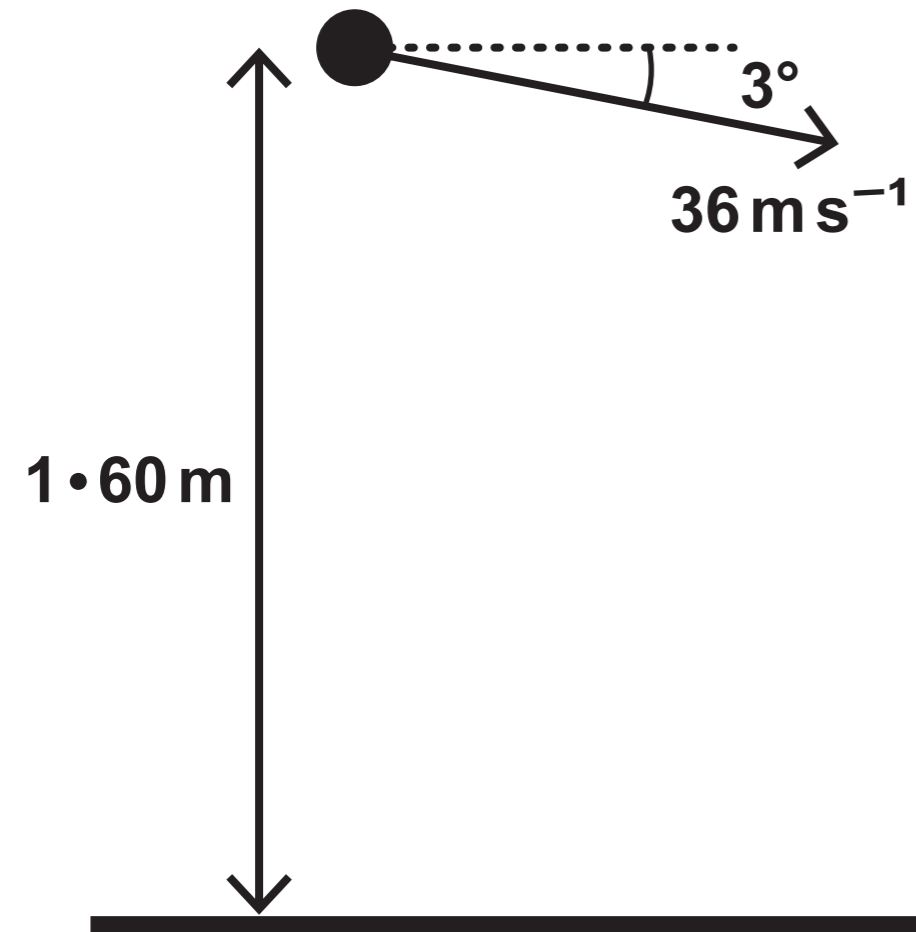
Question 7 (d)



Question 8 (a)

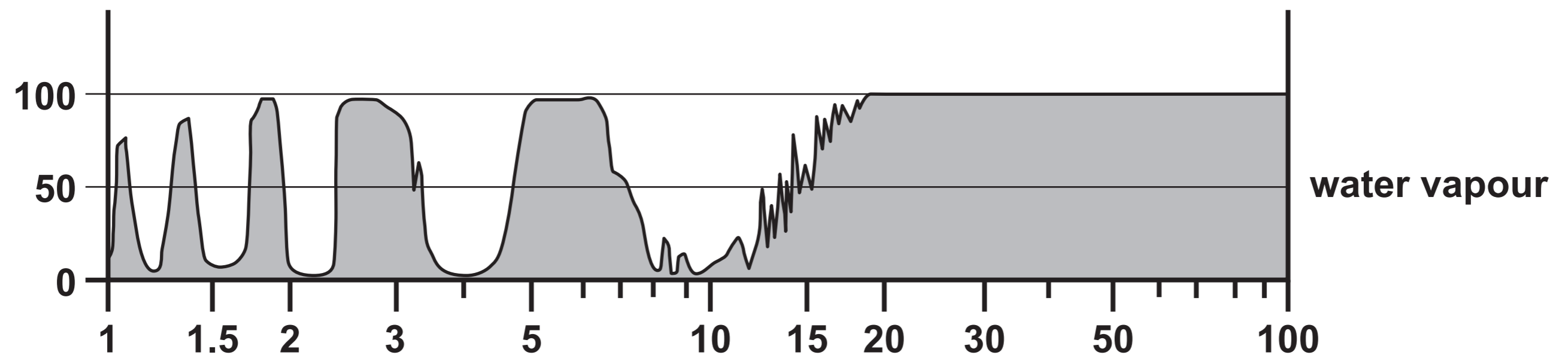
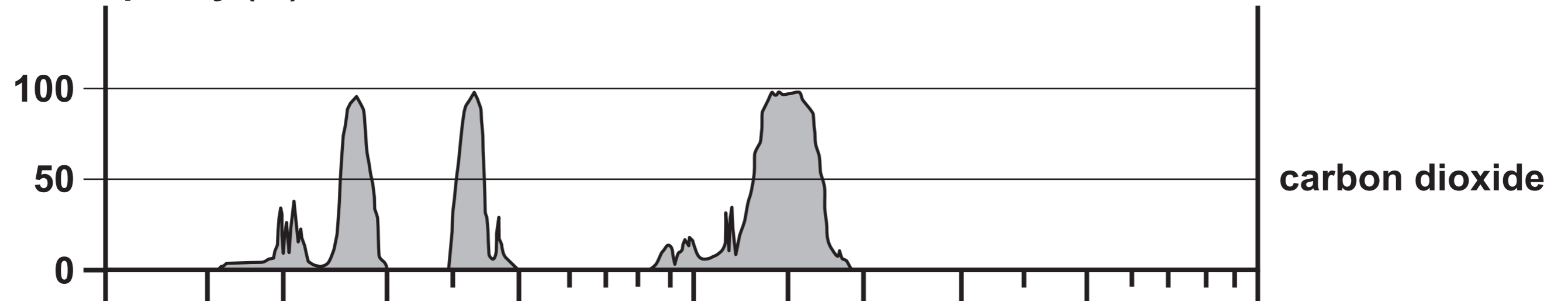


Question 9 (c)



Question 10 (c)

Absorptivity (%)



Wavelength (μm)

Question 10 (d) (ii)

