



GCE A LEVEL



A420U30 – 1

MONDAY, 17 JUNE 2024 – MORNING

**PHYSICS – A LEVEL COMPONENT 3
LIGHT, NUCLEI AND OPTIONS**

**2 hours 15 minutes 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.	13	
	2.	13	
	3.	13	
	4.	14	
	5.	21	
	6.	5	
	7.	10	
	8.	11	
Section B	Option	20	
	Total	120	

(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

This paper is in 2 sections, A and B.

Section A: 100 marks. Answer ALL questions. You are advised to spend about 1 hour 50 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 (c).

(Turn over)

SECTION A

Answer ALL questions.

- 1. Refer to the diagram for Question 1 in the separate Diagram Booklet. Morwenna and Dave carry out an experiment to show that the metal railings outside a school can act as a diffraction grating for sound waves. She uses a loudspeaker and Dave detects the sounds on the other side of the metal railings.**
- (a) When the frequency of the sound waves is 550 Hz, Dave states that he doesn't hear much sound from the loudspeaker and that there are no areas of loud sound as he walks backwards and forwards along the direction shown. Explain why the diffraction grating does not work at this frequency. The speed of sound is 342 m s^{-1}**

(Turn over)

[4 marks]

continued on the next page . . .

(Turn over)

Question 1 continued

1. (b) Morwenna increases the frequency of the sound waves to **5500 Hz** and Dave says that there are **5 DIRECTIONS** of very loud sound on the other side of the metal railings. Using a calculation, explain why this is to be expected.

[3 marks]

continued on the next page . . .

(Turn over)

Question 1 continued

1. (c) Refer to the diagram for Question 1 (c) in the separate Diagram Booklet. Calculate all the angles, θ , at which you would expect the loud sounds to occur.

[3 marks]

continued on the next page . . .

(Turn over)

Question 1 continued

1. (d) Dave states, “The metal railings are very similar to a polariser for microwaves so the sound waves I’m detecting must be polarised.” Determine to what extent Dave’s statement is correct.

[3 marks]

(Total for Question 1 = 13 marks)

(Turn over)

2. Refer to the diagram for Question 2 in the separate Diagram Booklet. Robin and Eilir investigate stationary waves using sound waves and a wall as shown in the diagram.

- (a) Explain why a stationary wave is produced between the loudspeaker and the wall.

[3 marks]

continued on the next page . . .

(Turn over)

Question 2 continued

2. (b) Refer to the diagram for Question 2 (b) in the separate Diagram Booklet. While moving in the direction shown, Robin places a chalk line on the floor at each place where he detects a loud sound. The lines he places on the floor are shown in the diagram.

Calculate the frequency of sound used
(speed of sound = 342 m s^{-1}).

(Turn over)

[4 marks]

2. (c) State the differences between progressive and stationary waves. In your answer you should refer to amplitude, energy and phase.

(Turn over)

(Total for Question 2 = 13 marks)

(Turn over)

3. (a) Refer to the diagram for Question 3 (a) in the separate Diagram Booklet. A ray of light is incident upon a water droplet of refractive index 1.33

- (i) Calculate the angle of refraction.

[2 marks]

- (ii) COMPLETE THE DIAGRAM for Question 3 (a) by showing the ray passing through the droplet and out of the other side. LABEL THE ANGLES WITH THEIR VALUES.

[3 marks]

continued on the next page . . .

(Turn over)

Question 3 continued

- 3. (b) Refer to the diagram for Question 3 (b) in the separate Diagram Booklet. A ray of light enters an optical fibre as shown in the diagram.**
- (i) Show that refraction does not occur at A.**

[3 marks]

continued on the next page . . .

(Turn over)

Question 3 (b) continued

- 3. (b) (ii) Explain how ‘multimode dispersion’ arises and outline the problem that it causes.**

[3 marks]

continued on the next page . . .

(Turn over)

Question 3 (b) continued

- 3. (b) (iii) Explain how the problem of ‘multimode dispersion’ is solved in practice.**

[2 marks]

(Total for Question 3 = 13 marks)

(Turn over)

4. Refer to the diagram for Question 4 in the separate Diagram Booklet. If other factors are kept constant, the current detected in the following circuit is proportional to the light intensity incident on the photocell.

- (a) Explain why the current is proportional to the light intensity.

[3 marks]

continued on the next page . . .

(Turn over)

Question 4 continued

- 4. (b) State the TWO factors that should be kept constant for the current to be proportional to the light intensity for this photocell.**

[2 marks]

continued on the next page . . .

(Turn over)

Question 4 continued

4. (c) Light of wavelength 410 nm is incident on the photocell.

- (i) Calculate the work function of the metal of the photocell, given that the maximum speed of the photoelectrons is $3.9 \times 10^5 \text{ m s}^{-1}$**

[3 marks]

continued on the next page . . .

(Turn over)

Question 4 (c) continued

4. (c) (ii) The total light power incident on the photocell is $0.36 \mu\text{W}$. Calculate the current in the circuit, stating any assumption that you make.

[3 marks]

continued on the next page . . .

(Turn over)

Question 4 continued

4. (d) The photoelectric effect is evidence of light behaving like particles. In 1802, Thomas Young carried out an experiment that was evidence of light behaving like a wave. In 1704, Newton had argued that light was made of particles whose size varied with colour. Explain how the scientific community has decided which of these theories to adopt.

[3 marks]

(Total for Question 4 = 14 marks)

(Turn over)

5. Refer to the table for Question 5 in the separate Diagram Booklet. Lawrence carries out an experiment to model the decay of radioactive nuclei using ten thousand 10^4 coins. He uses the symbol, T , to represent the throw number, the symbol, N , to represent the number of remaining coins and the symbol, A , to represent the number of coins “decaying” in the throw. His results are shown in the table.

(a) State briefly how he carried out the experiment.

(Turn over)

[4 marks]

5. (b) (i) State what you would expect the half-life of the 10 p coins to be.

[1 mark]

continued on the next page . . .

(Turn over)

Question 5 (b) continued

5. (b) (ii) The equations linking N , A and T are:

$$N = N_0 e^{-\lambda T} \quad \text{and} \quad A = A_0 e^{-\lambda T}$$

where N_0 is the initial number of coins (10 000), A_0 is the initial number of coins decaying (expected to be 5000) and λ is a decay constant related to the half-life.

Show that the expected gradient of the graph of $\ln N$ against T is $-\ln 2$

[3 marks]

continued on the next page . . .

(Turn over)

Question 5 continued

5. (c) Refer to the diagram for Question 5 (c) in the separate Diagram Booklet. Lawrence plots graphs of both $\ln N$ against T and $\ln A$ against T on the same axes using the data in the table.

Discuss to what extent the data in both graphs agree with theory.

(Turn over)

[6 marks]

continued on the next page . . .

(Turn over)

Question 5 continued

5. (d) The absolute uncertainty in the activity is related to the square root of the activity, A itself.

The error bars in the graph were calculated using:

$$\text{absolute uncertainty in } A = 4 \times \sqrt{A}$$

- (i) Use the data for throw 5 to calculate the absolute uncertainty in A for throw 5.

[2 marks]

continued on the next page . . .

(Turn over)

Question 5 (d) continued

- 5. (d) (ii) Hence, determine whether the error bar for throw 5 is correct on the graph of $\ln A$ against T .**

[3 marks]

continued on the next page . . .

(Turn over)

Question 5 (d) continued

5. (d) (iii) The error bars gradually increase in size on the graph of $\ln A$ against T . Explain what would happen to the error bars if a graph of A against T were plotted.

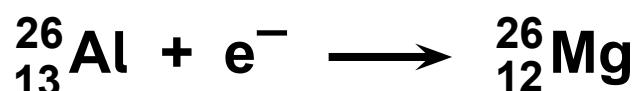
[2 marks]

(Total for Question 5 = 21 marks)

(Turn over)

6. Aluminium – 26 undergoes a process called electron capture to become magnesium – 26

Lee states that this must be an electromagnetic force reaction. He then writes the following to represent the reaction:



Using conservation laws, explain to what extent Lee's conclusions are correct. (Note that the nucleon and proton numbers are correct for aluminium and magnesium.)

(Turn over)

[5 marks]

(Total for Question 6 = 5 marks)

(Turn over)

7. (a) Refer to the diagram for Question 7 (a) in the separate Diagram Booklet. The long solenoid shown in the diagram, has a magnetic flux density of $58 \cdot 2 \text{ mT}$ in its centre. Calculate the current in the solenoid.

[3 marks]

continued on the next page . . .

(Turn over)

Question 7 continued

- 7. (b) (i) Refer to the diagram for Question 7 (b) (i) in the separate Diagram Booklet.**

Explain how the Hall voltage arises.

[3 marks]

continued on the next page . . .

(Turn over)

Question 7 (b) continued

- 7. (b) (ii) The drift velocity of electrons in a Hall wafer is 13.0 cm s^{-1} and the width of the Hall wafer is 0.58 cm . Calculate the expected Hall voltage when this Hall wafer is placed in the long solenoid where the maximum magnetic flux density is 58.2 mT .**

[2 marks]

continued on the next page . . .

(Turn over)

Question 7 (b) continued

- 7. (b) (iii) The actual measured Hall voltage is significantly below the value in (b) (ii) even though all values quoted are correct. Suggest what a competent experimental physicist should do to obtain the correct Hall voltage reading on the probe.**

[2 marks]

(Total for Question 7 = 10 marks)

(Turn over)

8. Refer to the diagram for Question 8 in the separate Diagram Booklet. When a strong magnet is dropped through a hollow copper tube, the magnet quickly reaches a low terminal velocity. It continues to fall slowly until it emerges from the copper tube.

Copper is a good conductor but is not a magnetic material.

- (a) Explain why the magnet reaches a low terminal velocity while inside the copper tube.

[5 marks]

8. (b) The inner diameter of the copper tube is 1.50 cm , its outer diameter is 1.60 cm and its length is 1.205 m . Calculate the mass of the copper tube.

Density of copper = 8960 kg m^{-3}

[3 marks]

continued on the next page . . .

(Turn over)

Question 8 continued

8. (c) The mass of the magnet is **325 g** and the specific heat capacity of copper is **$389 \text{ J K}^{-1} \text{ kg}^{-1}$** Calculate the rise in temperature of the copper tube when the magnet falls through it.

[3 marks]

(Total for Question 8 = 11 marks)

TOTAL FOR SECTION A = 100 MARKS

END OF SECTION A

(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

continued on the next page . . .

(Turn over)

Option A – ALTERNATING CURRENTS

9. (a) Refer to the diagram for Question 9 (a) in the separate Diagram Booklet. A sinusoidal alternating pd is applied across a resistor, R .
- (i) Calculate the mean power dissipated in the resistor.

[3 marks]

continued on the next page . . .

(Turn over)

Question 9 (a) continued

- 9. (a) (ii) Calculate the energy dissipated per cycle in the resistor.**

[2 marks]

- (iii) Determine the number of times per second the instantaneous power dissipation in the resistor reaches a maximum.**

[2 marks]

continued on the next page . . .

(Turn over)

Question 9 continued

9. (b) Refer to the diagram for Question 9 (b) in the separate Diagram Booklet. The same alternating pd is now connected across a different component, **X**, and the graphs shown in the diagram for Question 9 (b) are produced.

State how the graphs show that component **X** is an inductor.

[1 mark]

continued on the next page . . .

(Turn over)

Question 9 continued

9. (c) The resistor and inductor are now connected in series. The same alternating pd is applied across the combination.

(i) Use a labelled phasor diagram to show that the impedance, Z , of the circuit is given by:

$$Z = \sqrt{X_L^2 + R^2}$$

[3 marks]

continued on the next page . . .

(Turn over)

Question 9 (c) continued

- 9. (c) (ii) Morgan knows that no power is dissipated in an inductor with zero resistance.**

He therefore claims that adding the inductor will not affect the mean power dissipated in the circuit. Determine whether Morgan is correct.

[4 marks]

continued on the next page . . .

(Turn over)

Question 9 continued

9. (d) Refer to the diagram for Question 9 (d) in the separate Diagram Booklet. Morgan now sets up the circuit shown in the diagram.

(i) Calculate the rms current in the circuit.

[2 marks]

continued on the next page . . .

(Turn over)

Question 9 (d) continued

9. (d) (ii) Hence, calculate the value of the capacitor.

[3 marks]

(Total for Question 9 = 20 marks)

(Turn over)

Option B – MEDICAL PHYSICS

10. (a) Electrons are accelerated in an X–ray tube.

(i) Describe the energy changes that occur inside an X–ray tube.

[3 marks]

continued on the next page . . .

(Turn over)

Question 10 (a) continued

- 10. (a) (ii) Calculate the frequency of the X-rays at the cut-off wavelength of 48 pm.**

[2 marks]

- (iii) The accelerating voltage is 25 kV. Use this value to determine the maximum energy of the X-ray photons in J.**

[2 marks]

continued on the next page . . .

(Turn over)

Question 10 (a) continued

10. (a) (iv) Use the information to obtain a value for the Planck constant, h .

[2 marks]

continued on the next page . . .

(Turn over)

Question 10 continued

10. (b) Doctors are concerned that a patient has developed deep vein thrombosis (blood clots) in their legs. They have decided to investigate this further and have the choice of the following forms of imaging:

X-ray

MRI

ultrasound

fluoroscopy

CT scan

Evaluate the suitability of ALL FIVE types of imaging techniques for diagnosing the patient.

(Turn over)

[5 marks]

continued on the next page . . .

(Turn over)

Question 10 continued

- 10. (c) A small volume of Human serum albumin (HSA) labelled with iodine-125 of activity 160 Bq is injected into the bloodstream of a patient. A sample of 0.6 ml of blood is taken a few hours later and is found to have an activity of 0.020 Bq. Calculate the volume of blood in ml in the patient, STATING ANY ASSUMPTIONS YOU MAKE. (The half-life of iodine-125 is several months.)**
-
-
-
-
-

[2 marks]

continued on the next page . . .

(Turn over)

Question 10 continued

**10. (d) (i) Define 'equivalent dose' AND
'effective dose'.**

[2 marks]

continued on the next page . . .

(Turn over)

Question 10 (d) continued

- 10. (d) (ii) The effective dose for alpha particles incident on the skin is 2.2 mSv and the equivalent dose is 0.22 Sv . Determine the tissue weighting factor, W_T , for skin.**

[2 marks]

(Total for Question 10 = 20 marks)

(Turn over)

Option C – THE PHYSICS OF SPORTS

11. (a) Refer to the photograph for Question 11 (a) in the separate Diagram Booklet. The following photograph shows a skier taking part in a downhill race.

(i) State the TWO factors that increase a skier's stability against toppling.

[2 marks]

continued on the next page . . .

(Turn over)

Question 11 (a) continued

11. (a) (ii) The speed of a downhill skier changes from u to $1.25u$. At the same time, the effective cross-sectional area of the skier changes from A to $0.85A$. Calculate how the drag force on the skier will change, stating any assumptions you make.

[4 marks]

continued on the next page . . .

(Turn over)

Question 11 (a) continued

- 11. (a) (iii) A skier of mass 72 kg moving at a speed of 25 m s^{-1} crashes into a barrier and is brought to rest in a time of 0.89 s . Determine the force exerted on the skier by the barrier.**

[2 marks]

- (b) Refer to the photograph for Question 11 (b) in the separate Diagram Booklet. A puck used in an ice hockey match is a circular disk of mass 160 g and diameter 80 mm. A puck and hockey stick are shown in the diagram.**

continued on the next page . . .

(Turn over)

Question 11 (b) continued

- 11. (b) (i) Calculate the angular velocity of a puck with rotational kinetic energy of 1.3 J .**

The moment of inertia of a puck is given by the equation

$$I = \frac{1}{2} mr^2$$

[3 marks]

continued on the next page . . .

(Turn over)

Question 11 (b) continued

- 11. (b) (ii) Refer to the photo for Question 11 (b) (ii) in the separate Diagram Booklet. An ice hockey player takes a shot at goal from a distance of 15 m. The puck is hit at an angle of 25° to the horizontal and with an initial speed of 23 m s^{-1} . Evaluate whether a goal can be scored if the height of the goal is 1.2 m. Ignore the effects of air resistance.**

(Turn over)

[5 marks]

continued on the next page . . .

(Turn over)

Question 11 continued

- 11. (c) An ice skater is rotating with both arms outstretched. His arms are now pulled in. Explain why the rate of rotation of the skater will increase.**

[4 marks]

(Total for Question 11 = 20 marks)

(Turn over)

Option D – ENERGY AND THE ENVIRONMENT

- 12. (a) (i) A student incorrectly writes the Archimedes principle as:**

‘An object wholly immersed in a liquid experiences a force equal to the mass of the fluid dispersed by the object’.

Write the correct version of this principle.

[2 marks]

continued on the next page . . .

(Turn over)

Question 12 (a) continued

12. (a) (ii) Ice has a density of 920 kg m^{-3}

A FRESHWATER iceberg floats in

SEAWATER of density 1020 kg m^{-3}

Starting from the Archimedes principle,

determine the fraction of the volume of the iceberg that will be below the surface.

Show your reasoning clearly.

[3 marks]

continued on the next page . . .

(Turn over)

Question 12 continued

12. (b) Refer to the diagram for Question 12 (b) in the separate Diagram Booklet. The diagram shows a wind turbine and a graph of its electrical power output. The electrical power output from a wind turbine varies with wind speed, as shown in the graph.

- (i) The efficiency of the turbine in transferring the power from the wind to electrical power is 42% at a wind speed of 10 m s^{-1} . Determine the rotor diameter given the density of air is 1.2 kg m^{-3} .**

(Turn over)

[4 marks]

12. (b) (ii) Account for the low efficiency in transferring the maximum power from the wind to electrical power.

[2 marks]

continued on the next page . . .

(Turn over)

Question 12 (b) continued

- 12. (b) (iii) The UK – based JET laboratory produced 59 MW of electrical power for a few seconds through nuclear fusion. Calculate the number of wind turbines needed to produce this amount of power if they are operating at their maximum power output.**

[1 mark]

continued on the next page . . .

(Turn over)

Question 12 (b) continued

12. (b) (iv) Explain briefly the difficulties associated with producing sustained nuclear fusion power.

[3 marks]

continued on the next page . . .

(Turn over)

Question 12 continued

- 12. (c) Refer to the diagram for Question 12 (c) in the separate Diagram Booklet. Plasterboard has a thermal conductivity value of $0.18 \text{ W m}^{-1} \text{ K}^{-1}$ Brick has a thermal conductivity value of $0.55 \text{ W m}^{-1} \text{ K}^{-1}$ An internal wall consists of a 15 mm layer of plasterboard either side of a 110 mm brick as shown in the diagram. The temperature difference between the two sides of the wall is 7°C .**

Charlene calculates the rate of heat transfer per unit area through the wall to be 19 W m^{-2} Determine whether Charlene is correct.

(Turn over)

[5 marks]

(Total for Question 12 = 20 marks)

TOTAL FOR SECTION B = 20 MARKS

END OF PAPER

TOTAL FOR PAPER = 120 MARKS

(Turn over)

[illegible]

(Turn over)

[illegible]

(Turn over)

[illegible]



GCE A LEVEL



A420U30–1

MONDAY, 17 JUNE 2024 – MORNING

PHYSICS – A LEVEL COMPONENT 3

LIGHT, NUCLEI AND OPTIONS

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

Diagram Booklet

Surname: _____

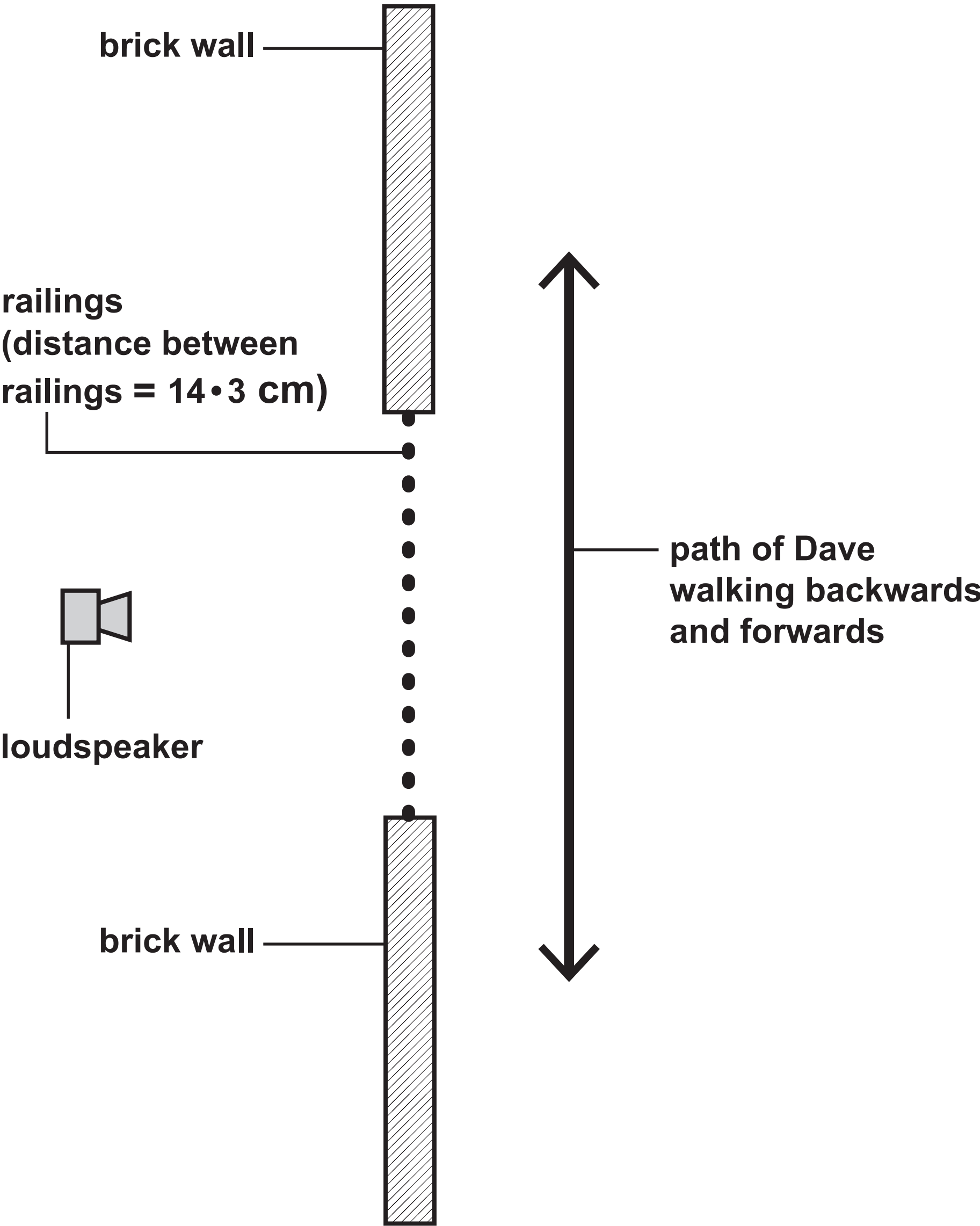
First name(s): _____

Centre Number: _____

Candidate Number: 2 _____

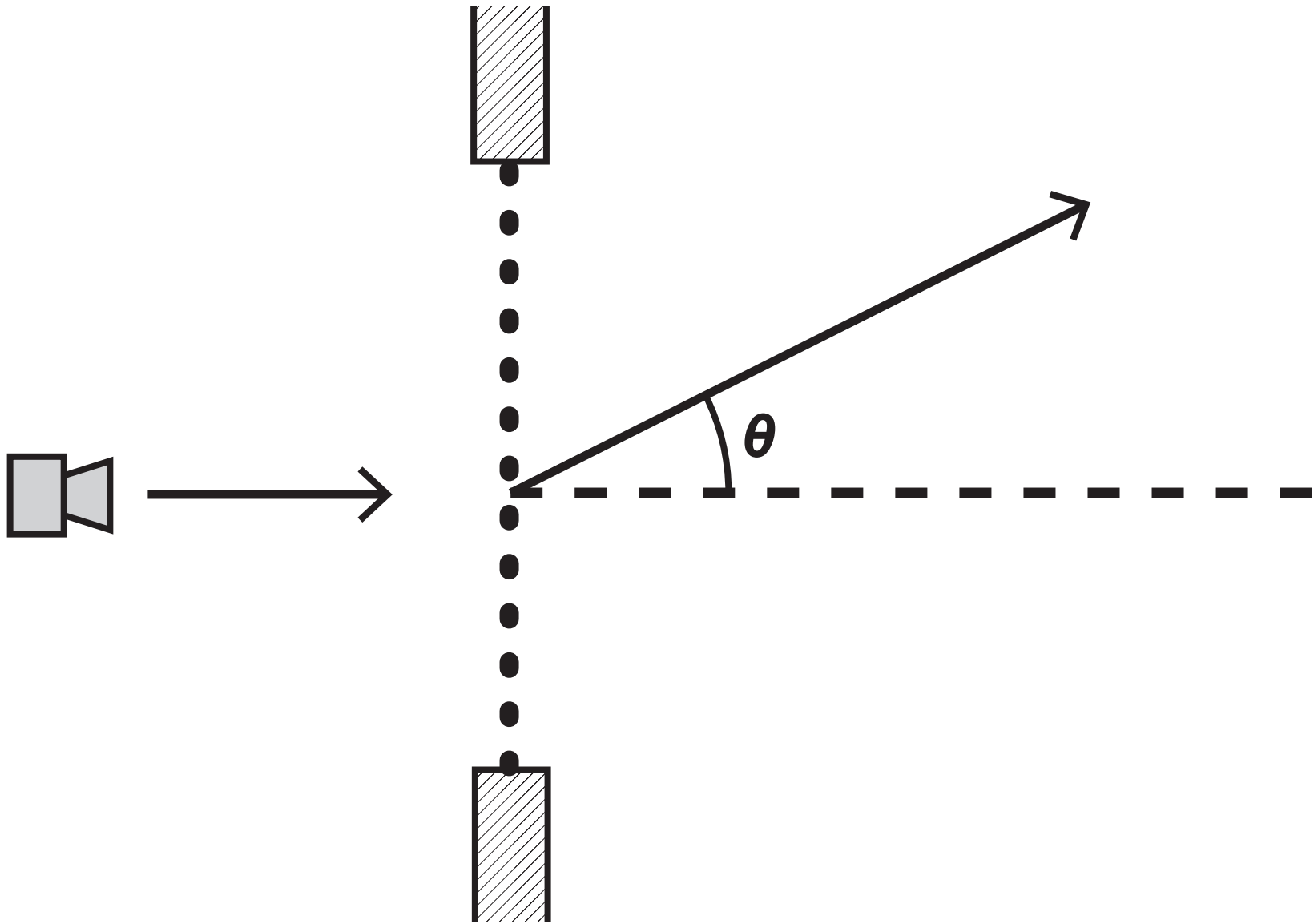
Question 1

View from above



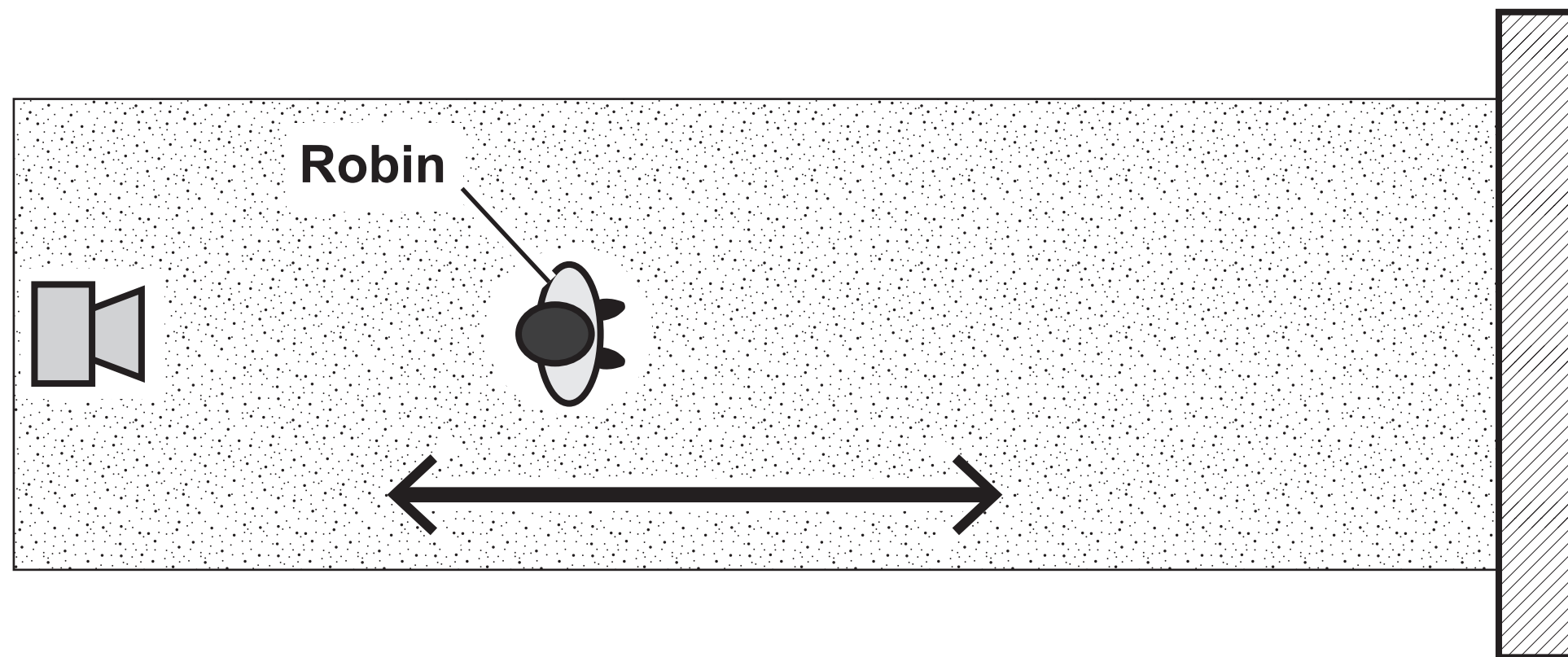
Question 1 (c)

View from above

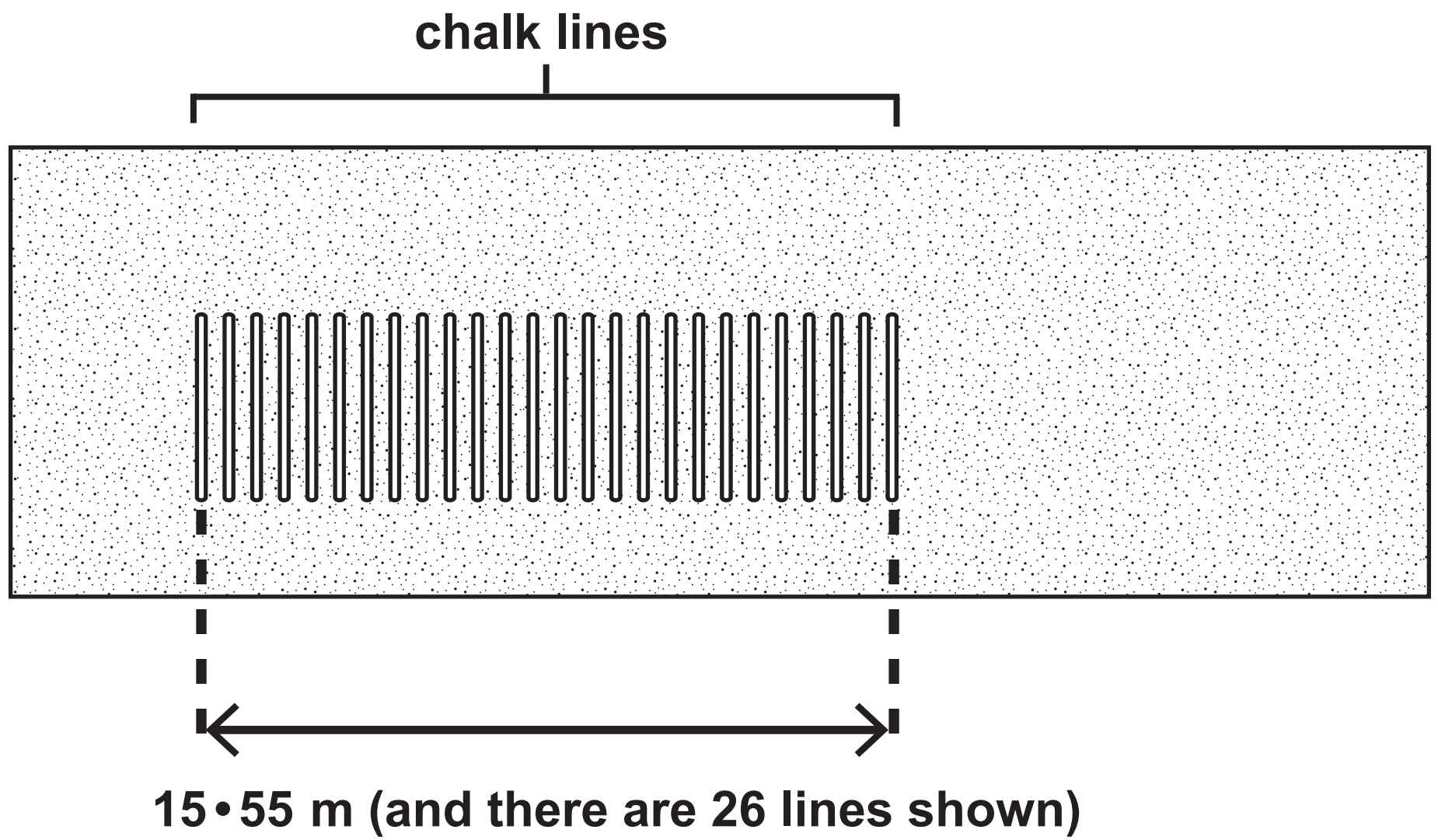


Question 2

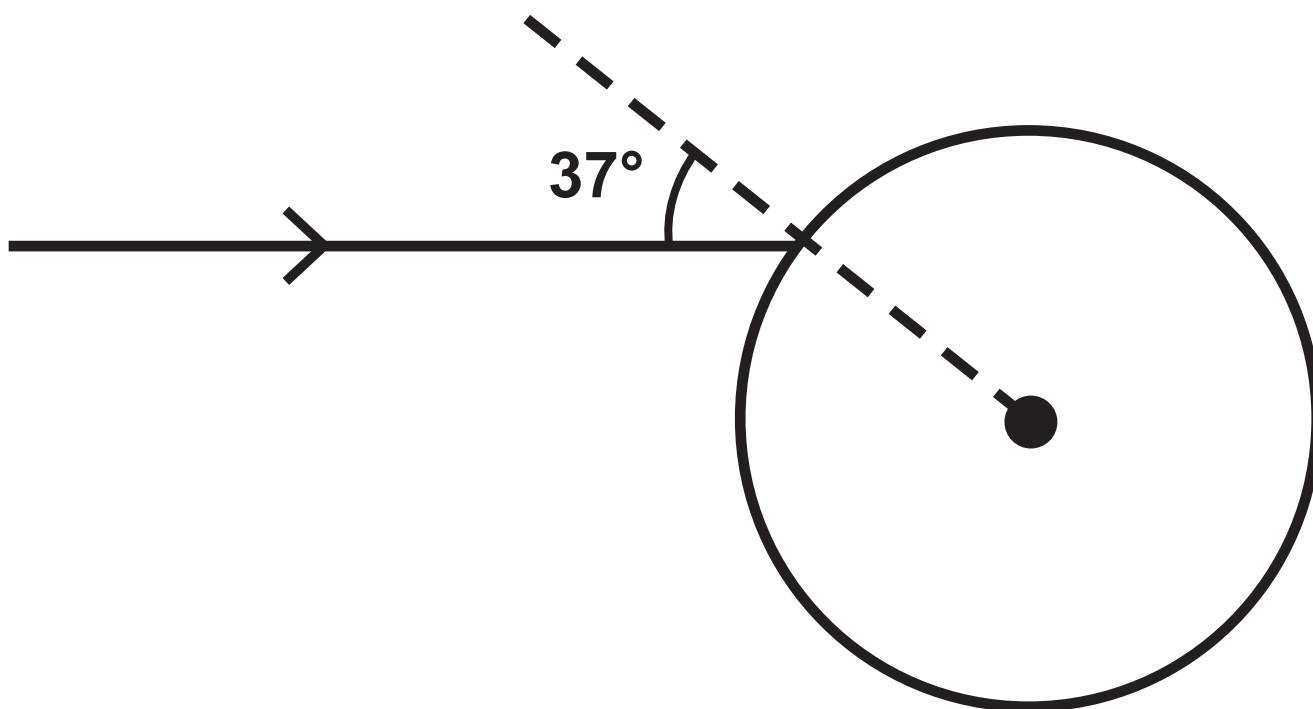
View from above



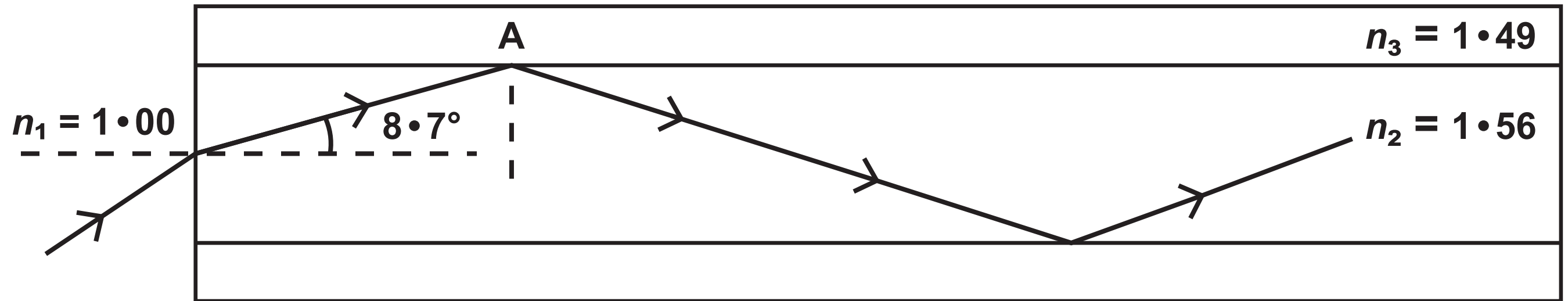
Question 2 (b)



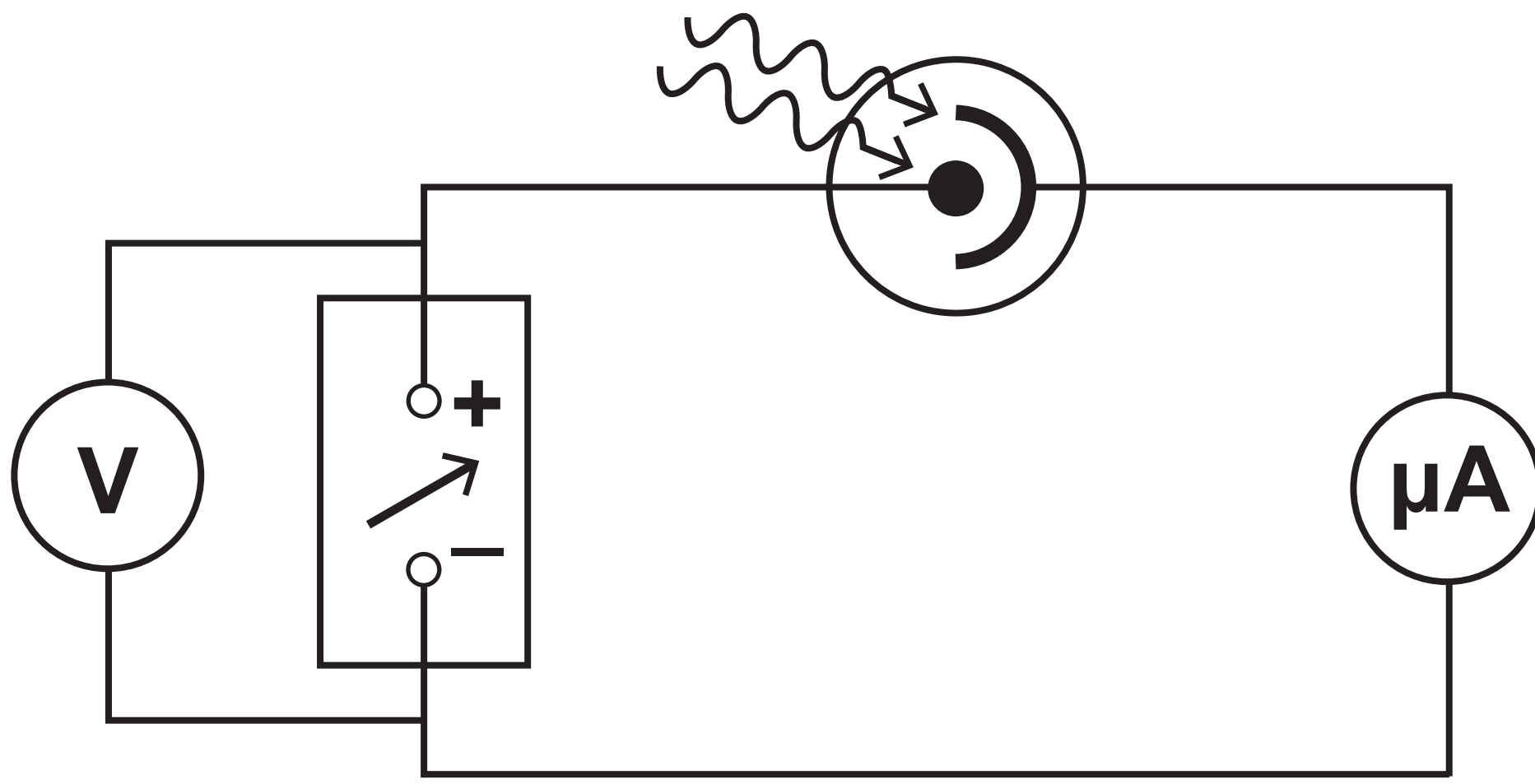
Question 3 (a)



Question 3 (b)



Question 4

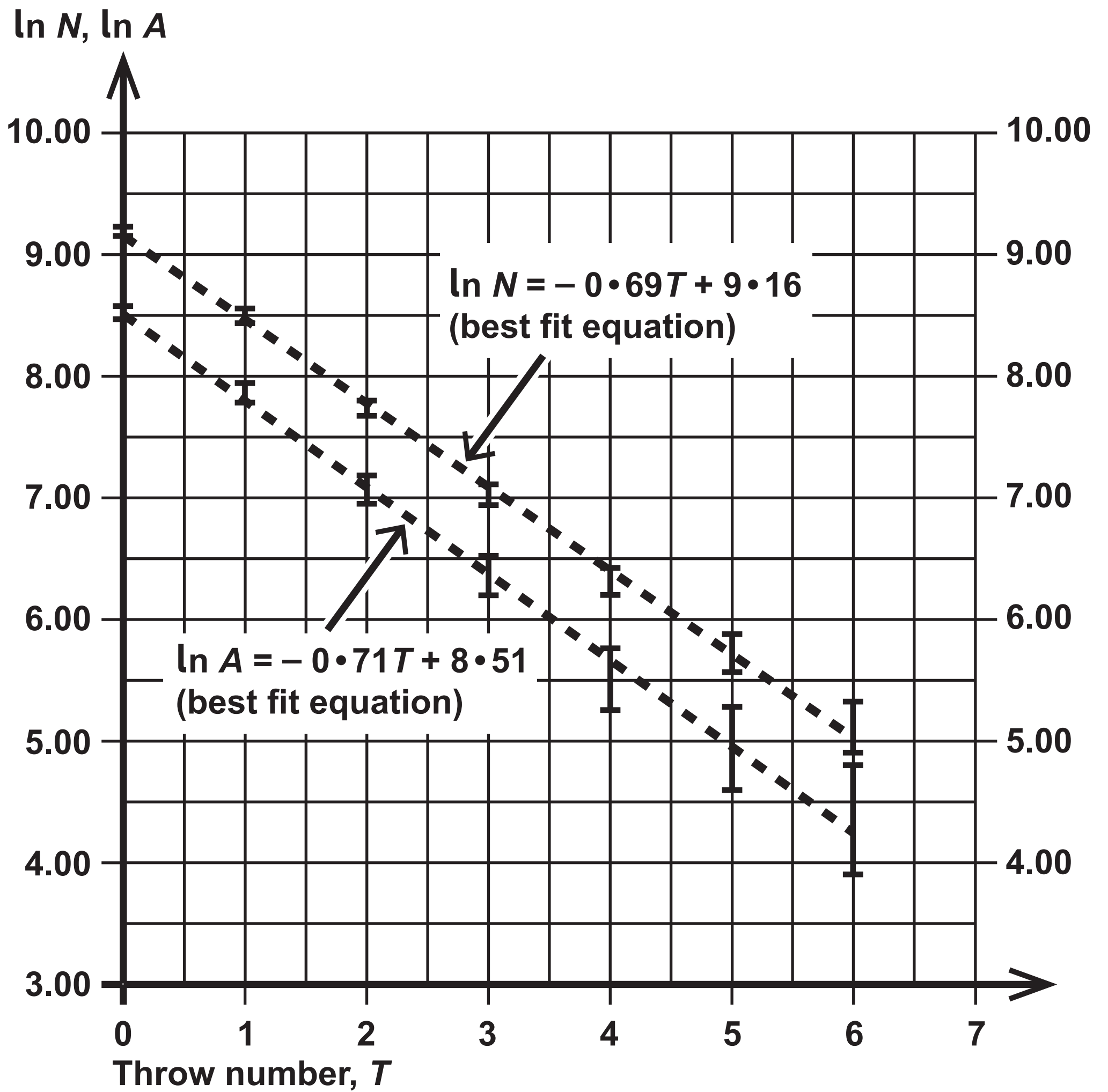


Question 5

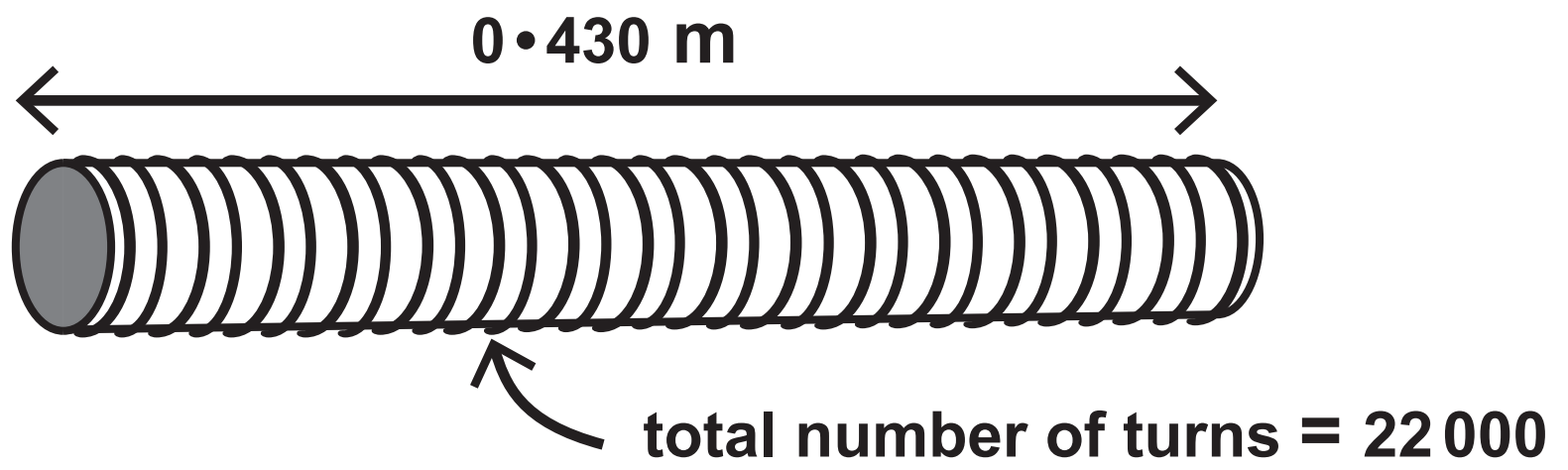
Table

Throw number, T	Number of remaining coins before throw, N	Number of coins that decayed, A	$\ln N$	$\ln A$
0	10 000	5170	9•21	8•55
1	4830	2347	8•48	7•76
2	2483	1256	7•82	7•14
3	1227	614	7•11	6•42
4	613	302	6•42	5•71
5	311	153	5•74	5•03
6	158	68	5•06	4•22

Question 5 (c)

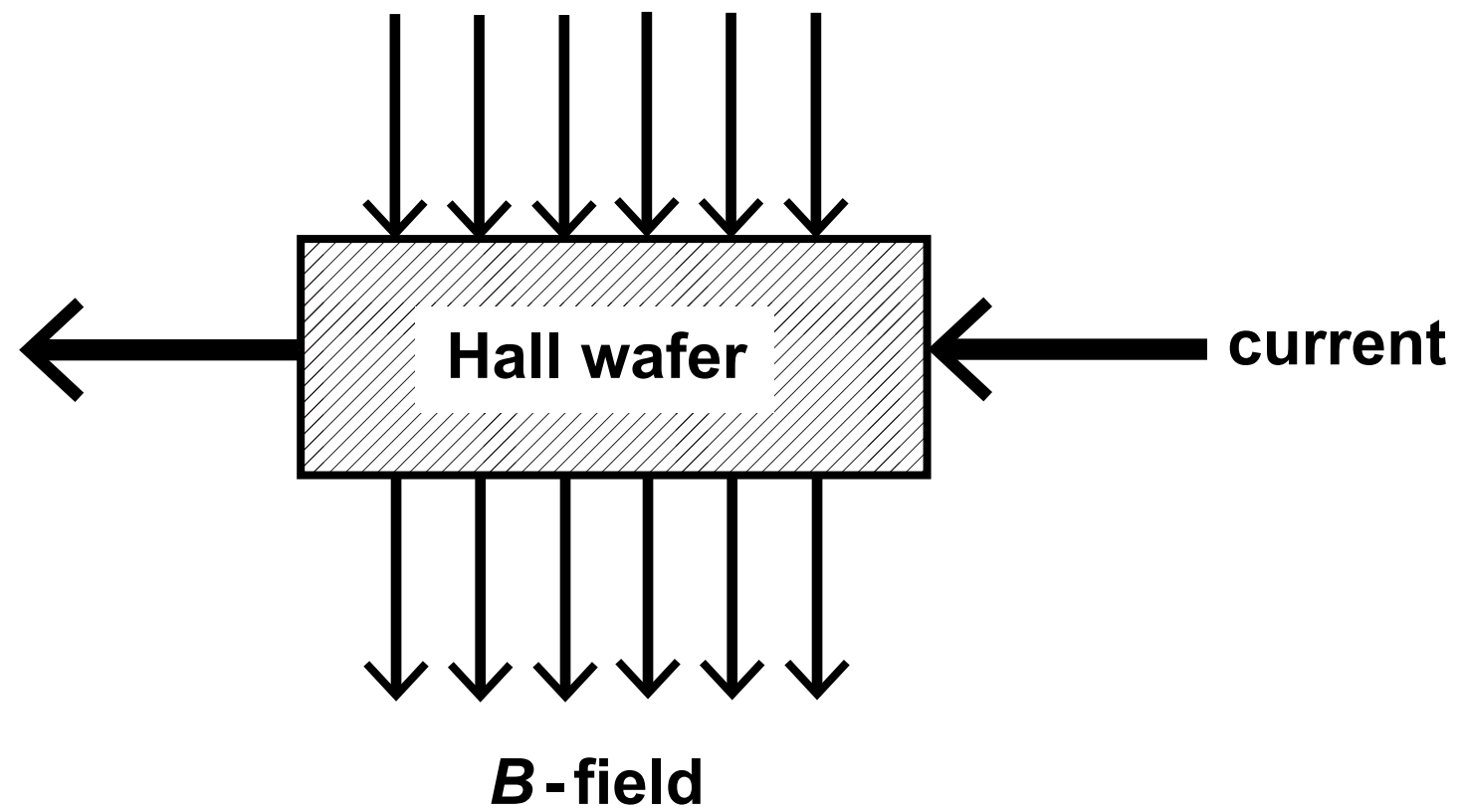


Question 7 (a)

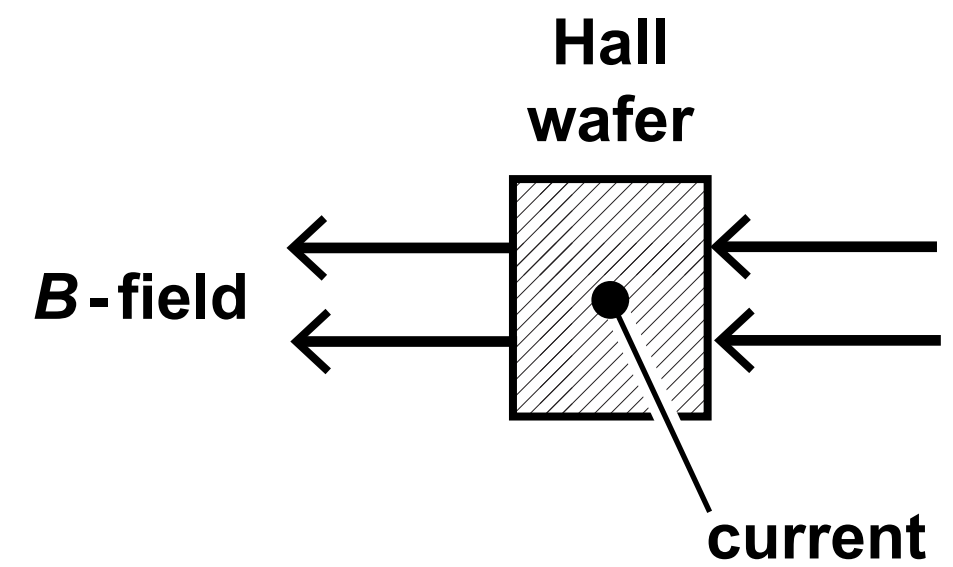


Question 7 (b) (i)

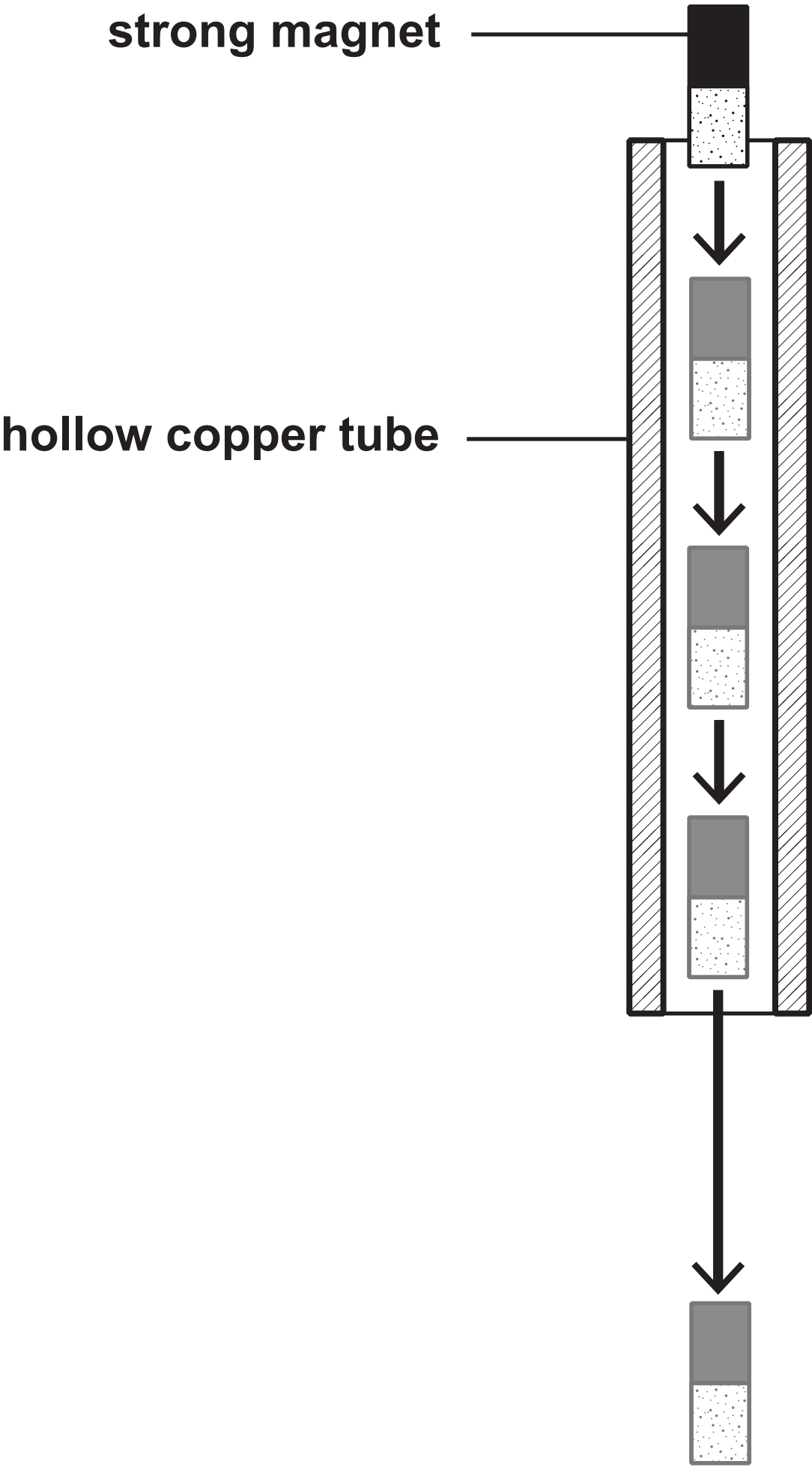
TOP VIEW



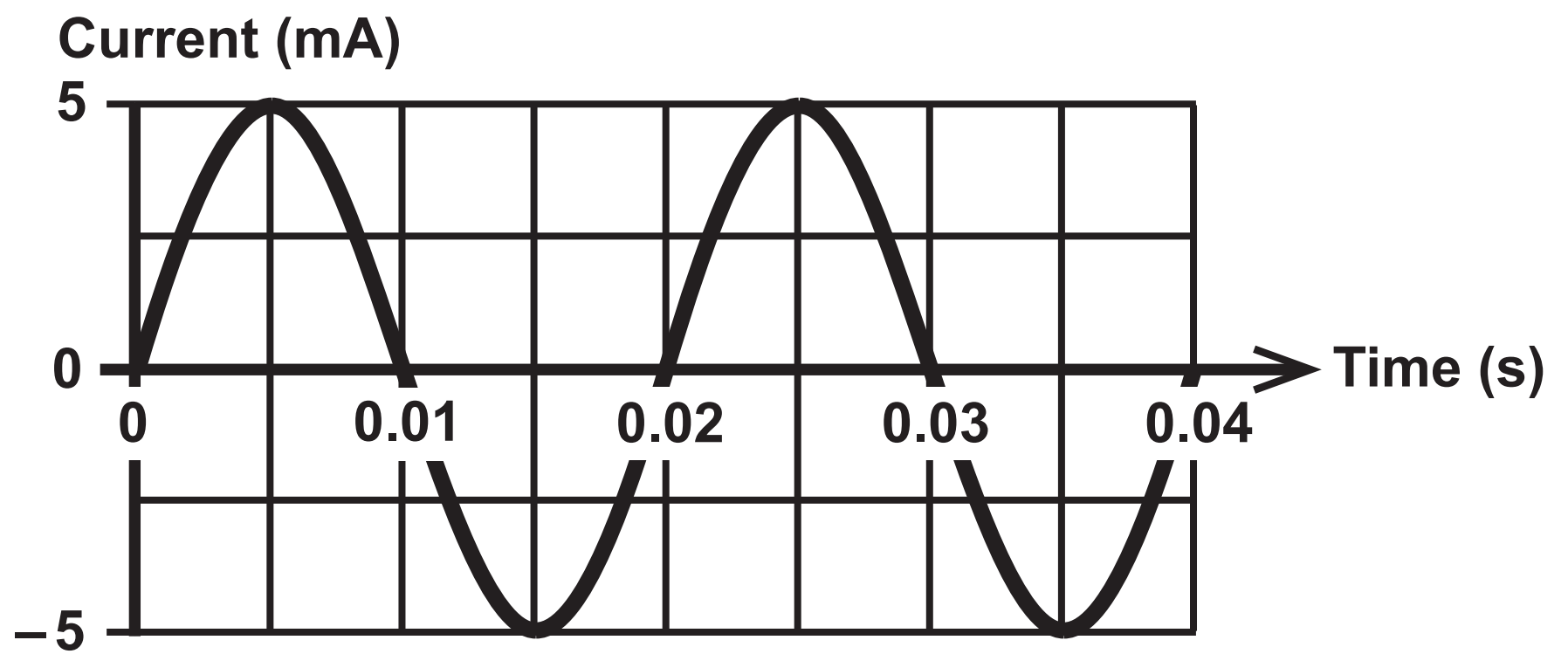
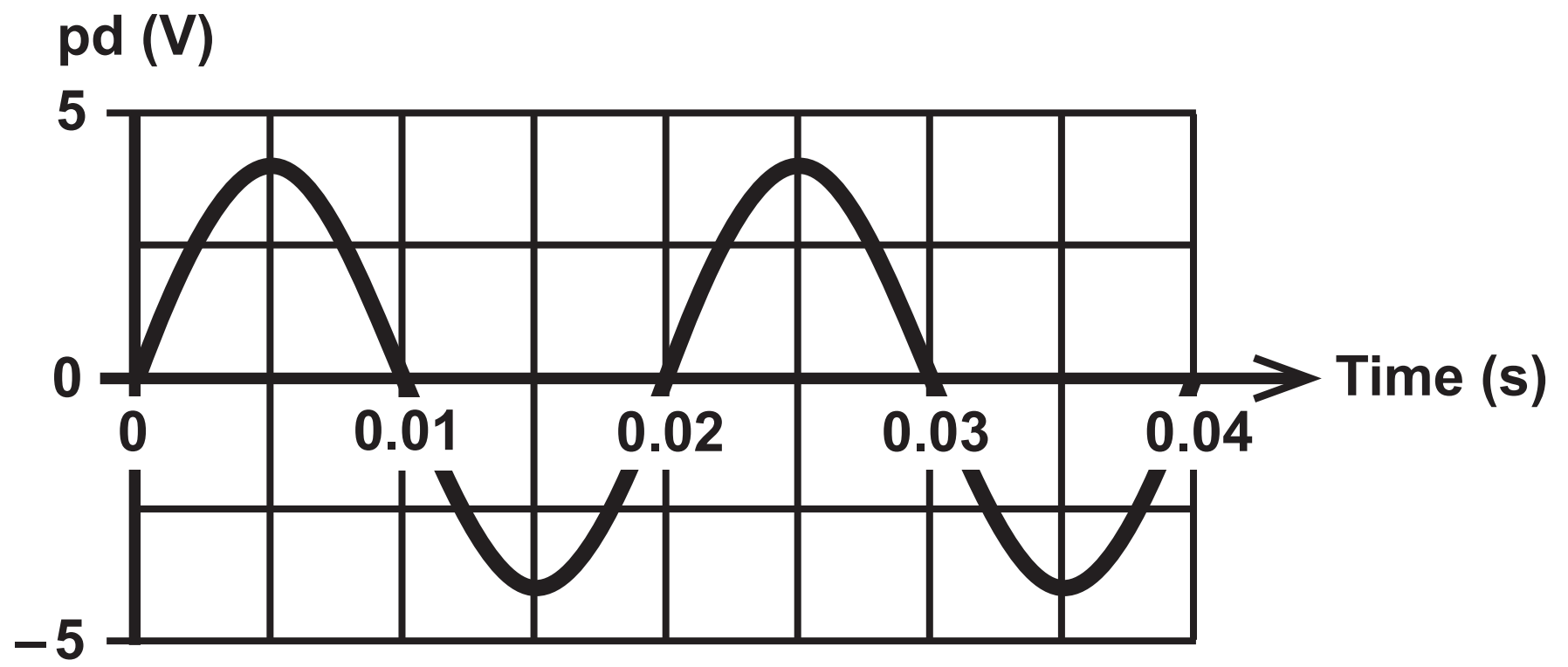
SIDE VIEW



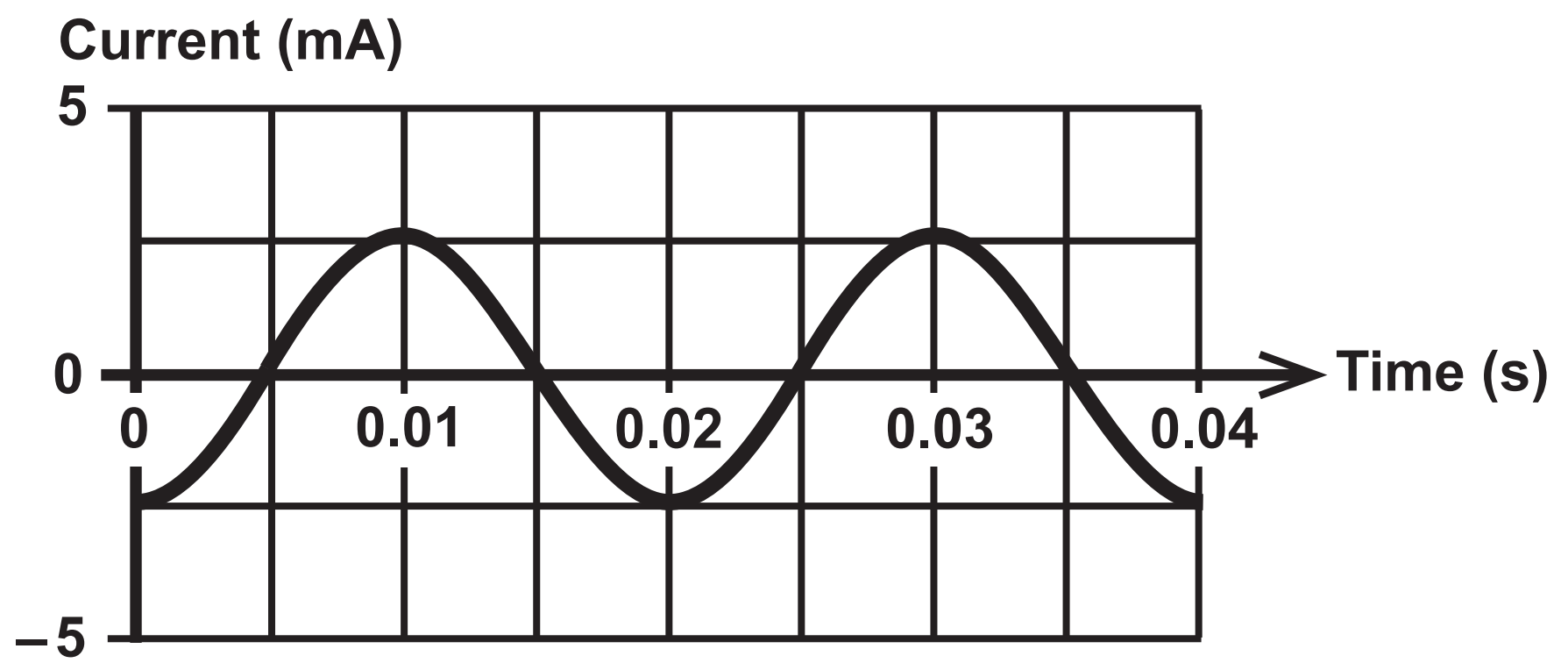
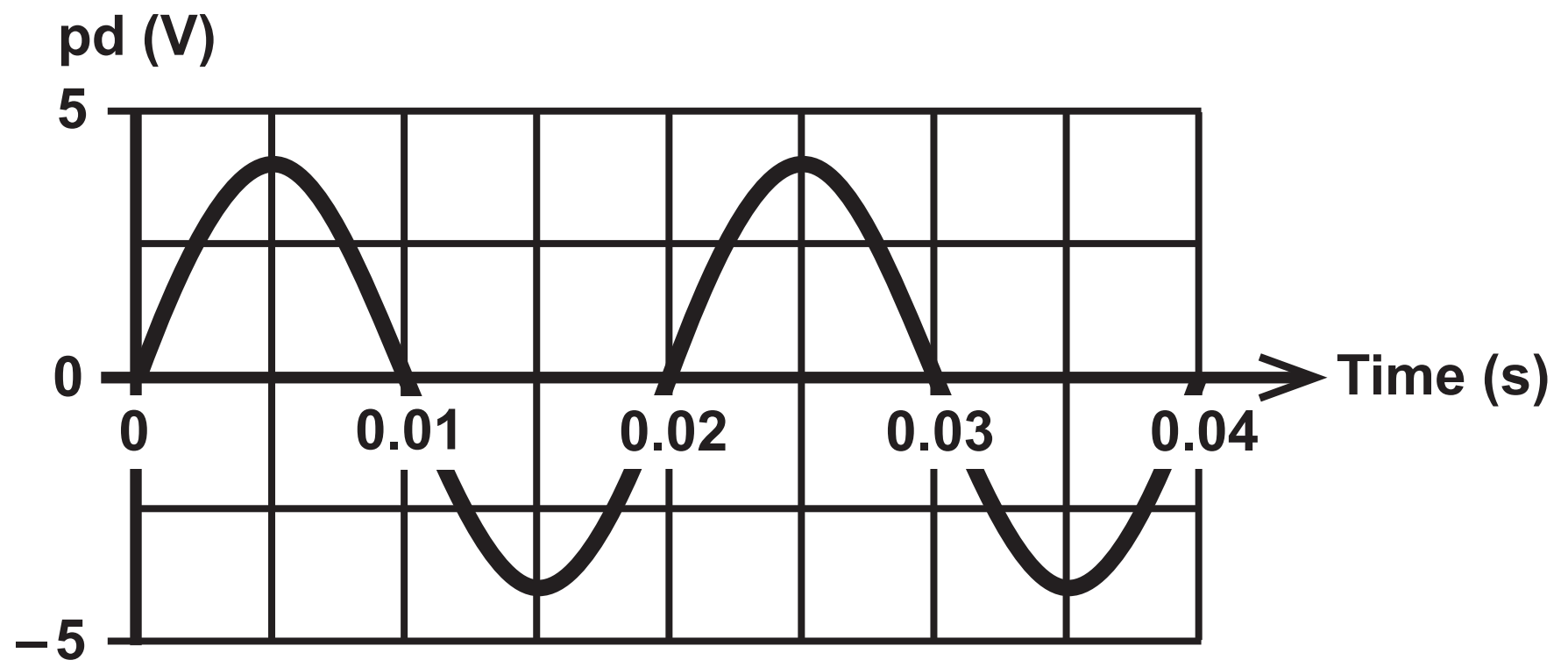
Question 8



Question 9 (a)

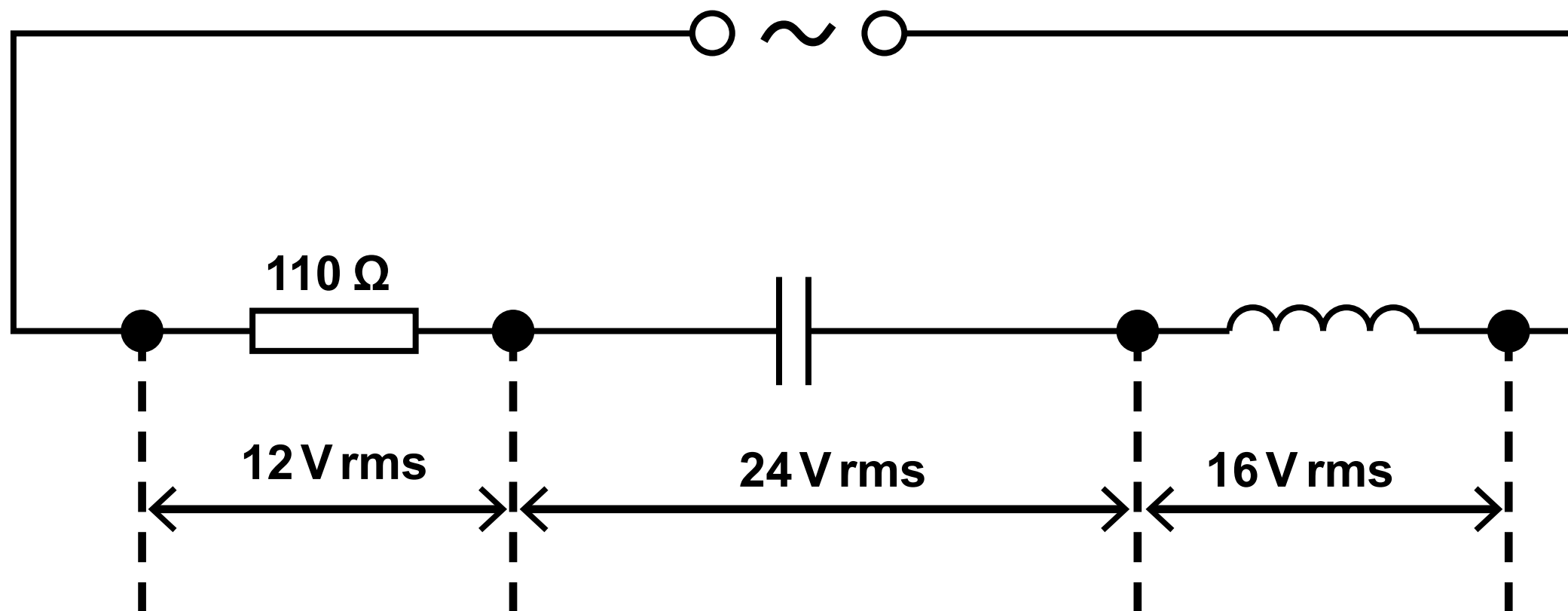


Question 9 (b)



Question 9 (d)

supply frequency of 60 Hz



Question 11 (a)



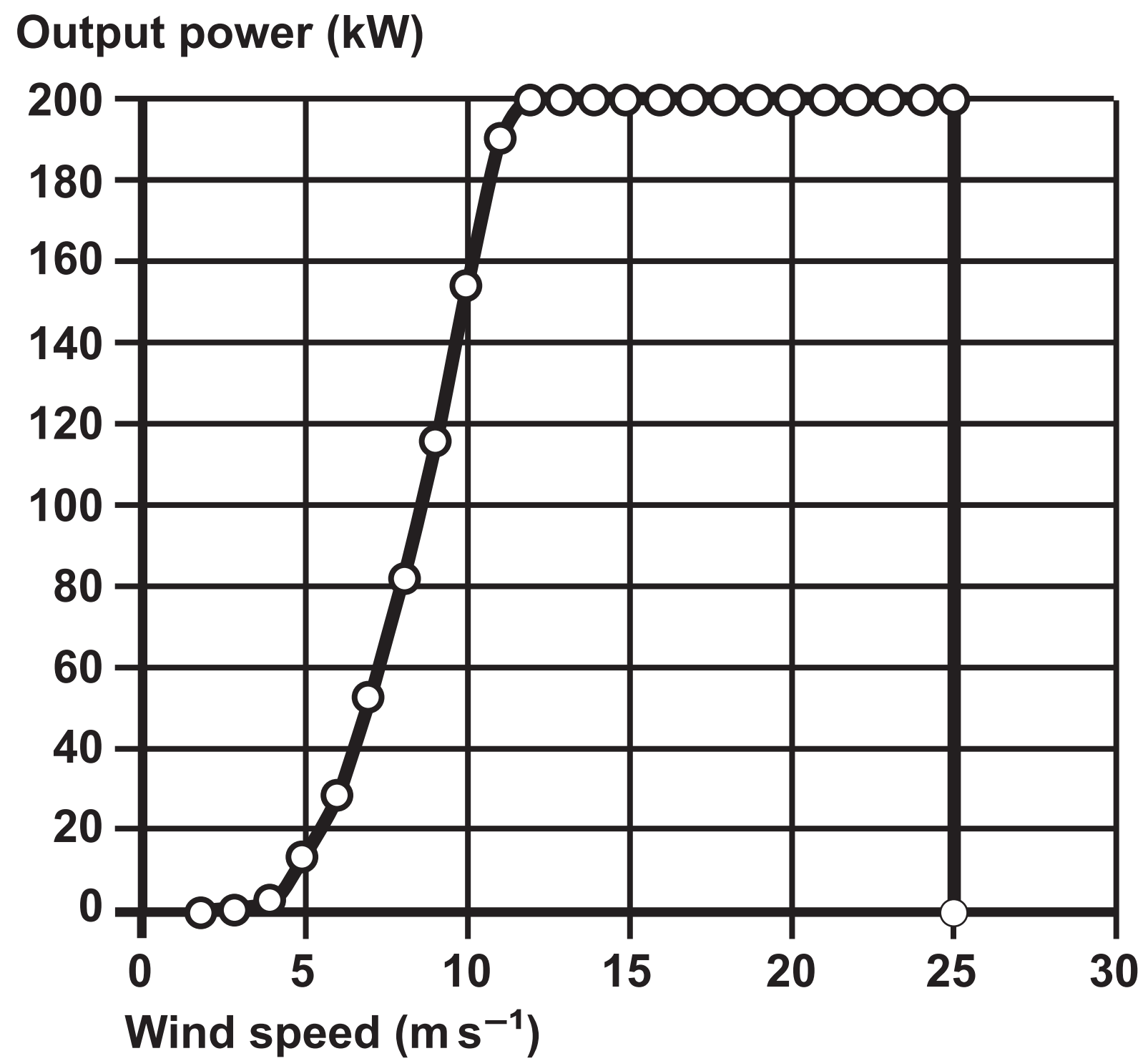
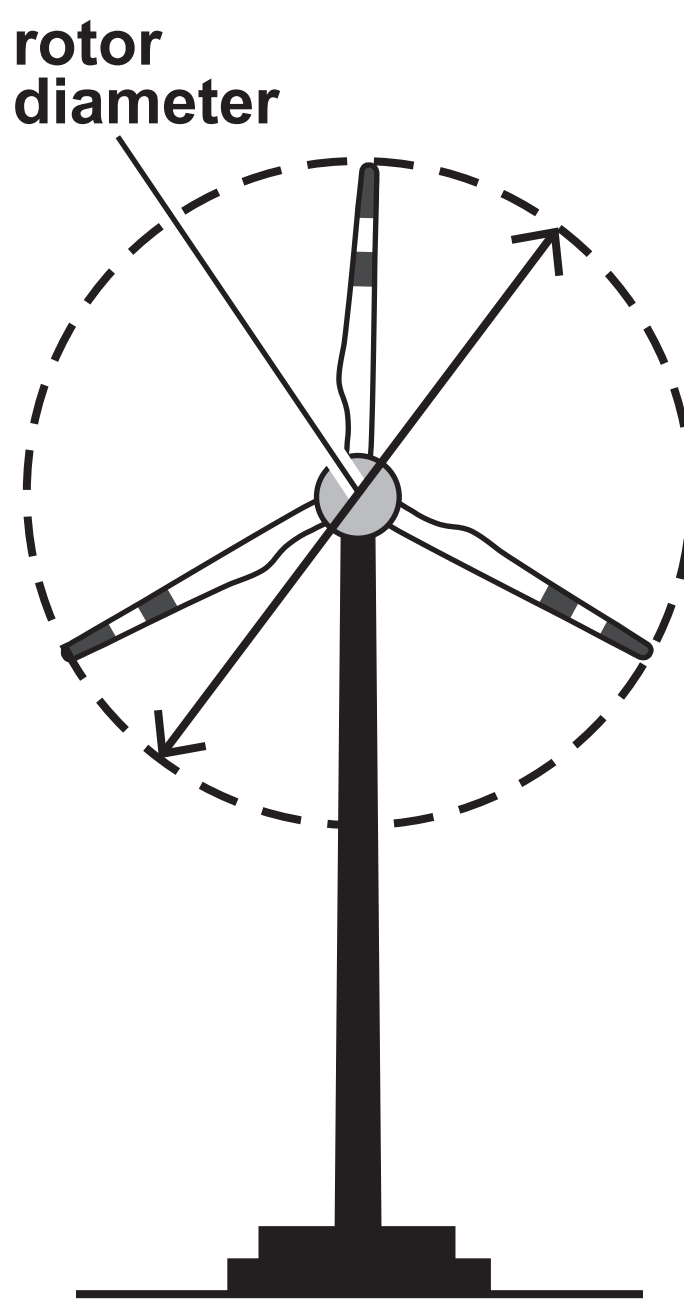
Question 11 (b)



Question 11 (b) (ii)



Question 12 (b)



Question 12 (c)

Diagram NOT drawn to scale

