GCE A LEVEL

1420U40-1

THURSDAY, 15 JUNE 2023 – 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.	11	
	2.	14	
	3.	19	
	4.	17	
	5.	10	
	6.	9	
SECTION B	Option	20	
	Total	100	

ADDITIONAL MATERIALS

In addition to this examination paper, you will require a calculator and a DATA BOOKLET (provided by WJEC).

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.

Answer ALL questions.

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

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

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, plus your additional time allowance, on this section.

Section B: 20 marks. Options.

Answer ONE OPTION ONLY.

You are advised to spend about 25 minutes, plus your additional time allowance, 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 5 (b).

SECTION A

ANSWER ALL QUESTIONS.

1. (a) Look at the diagrams for Question 1 (a) in the separate Diagram Booklet. There are three diagrams, Diagram (i), Diagram (ii) and Diagram (iii).

Calculate the total capacitance of each of the following capacitor combinations.

Diagram (i) _____

_____

_____

_____

_____

Diagram (ii) _____

_____

_____

_____

_____

Diagram (iii) _____

_____

_____

_____

_____

[6 marks]

continued on the next page . . .

Question 1 continued

1. (b) Michael, a laboratory technician, must make a 2.7 μF capacitor using only two square sheets of aluminium of side 42.0 cm. Determine whether or not it is realistic for Michael to produce a capacitance of 2.7 μF using these two sheets of aluminium and no dielectric.

[4 marks]

Question 1 continued

1. (c) State what happens to the capacitance of a parallel plate capacitor when a dielectric is placed between the plates.

_____

_____

[1 mark]

(Total for Question 1 = 11 marks)

2. Look at the image for Question 2 in the separate Diagram Booklet.

Light from a spiral galaxy is analysed and the graph of velocity against distance from the centre of the galaxy is obtained.
The graph is shown in the image.

(a) Show that the speed, v, of an object in a circular orbit of radius, r, about a massive object of mass, M, is given by:

$$v = \sqrt{\frac{GM}{r}}$$

[3 marks]

2. (b) Hence, explain why the graph is considered to be evidence for dark matter.

[3 marks]

continued on the next page . . .

Question 2 continued

2. (c) The dotted curve in the graph suggests that an object a distance of 20 000 light years from the centre of the galaxy should have an orbital speed of approximately 50 km s^{-1}

Use this data to estimate the visible mass of the galaxy.

(1 light year = 9.46×10^{15} m)

[3 marks]

continued on the next page . . .

Question 2 continued

2. (d) The observed data at 30 000 light years from the galactic centre were obtained using microwaves of wavelength 21 cm. Calculate the approximate wavelength shift that was observed to obtain the data plotted at 30 000 light years.

[3 marks]

continued on the next page . . .

Question 2 continued

2. (e) Use the Hubble equation to calculate the distance, from Earth, for a galaxy to have the same recessional speed as that of part (d).

[2 marks]

(Total for Question 2 = 14 marks)

3. Look at the diagram for Question 3 in the separate Diagram Booklet.

Three planets of equal mass are arranged in an EQUILATERAL TRIANGLE as shown in the diagram.

(a) (i) Show that the gravitational force exerted by one planet on another is approximately 1.3×10^{20} N.

[2 marks]

continued on the next page . . .

Question 3 (a) continued

3. (a) (ii) Hence, explain why the resultant gravitational force experienced by any of the planets is approximately 2×10^{20} N towards the centre of the triangle in the diagram.

[4 marks]

continued on the next page . . .

Question 3 continued

3. (b) Look at the diagram for Question 3 (b) in the separate Diagram Booklet.

A star is located at the centre of the triangle, as shown in the diagram.

(i) By adding to the diagram, show that the distance between the star and any of the planets is given by:

$$\frac{4{\cdot}5 \times 10^{10}}{2 \times \cos 30^{\circ}}$$

[2 marks]

continued on the next page . . .

Question 3 (b) continued

3. (b) (ii) Rhodri states that the force calculated in part (a) (ii) is negligible compared with the gravitational force exerted on a planet by the star. Determine whether or not Rhodri is correct.

_____

_____

_____

_____

_____

[2 marks]

continued on the next page . . .

Question 3 continued

3. (c) (i) Show that the gravitational potential at the position of a planet due to the star and the other two planets is approximately -1×10^{10} J kg^{-1}

[3 marks]

continued on the next page . . .

Question 3 (c) continued

3. (c) (ii) Rhodri now states that, if an object with kinetic energy 7×10^{35} J struck one of the planets, the planet would gain enough energy to escape the gravitational pull of the star. Discuss to what extent Rhodri's statement might be correct.

[3 marks]

continued on the next page . . .

Question 3 continued

3. (d) Look at the diagram for Question 3 (d) in the separate Diagram Booklet.

The three planets, whilst orbiting the star, stay in an equilateral triangle. Delyth claims that these planets cannot be detected by the periodic Doppler shift of the star. Determine whether or not Delyth is correct.

[3 marks]

(Total for Question 3 = 19 marks)

4. Look at the diagram for Question 4 in the separate Diagram Booklet.

The set – up shown is used to investigate the force on a current – carrying wire in a magnetic field.

The part XY of the wire which is in the magnetic field, has been placed carefully so that the current is from front to back at 90° to the direction of the magnetic field.
When there is no current the balance is reset to display 000.00 g. When there is a current in the direction shown, the magnetic force results in a positive reading on the display of the balance.
However, this signifies an upward force on the wire.

continued on the next page . . .

Question 4 continued

4. (a) (i) Explain briefly why the magnetic force must be upward on the part XY of the wire.

_____

_____

_____

_____

_____

[2 marks]

(ii) ON THE DIAGRAM, indicate which is the North pole of the magnet AND state below which rule you used to obtain your answer.

_____

_____

[2 marks]

continued on the next page . . .

Question 4 (a) continued

4. (a) (iii) Explain why the vertical parts of the wire have no effect on the reading displayed by the electronic balance.

_____

_____

_____

[1 mark]

continued on the next page . . .

Question 4 continued

4. (b) Bronwen varies the length of XY and records the electronic balance reading each time when a current of 5.00 A flows. She records all her results in a table and plots a graph of magnetic force against length of wire.

(i) Look at the table and graph for Question 4 (b) (i) in the separate Diagram Booklet.

COMPLETE THE TABLE AND PLOT the two missing points on the graph.

[4 marks]

continued on the next page . . .

Question 4 (b) continued

4. (b) (ii) Look at the diagram for Question 4 (b) (ii) in the separate Diagram Booklet.

The region of uniform magnetic field between the poles of the magnet is of length 5 cm only. Evaluate whether or not Bronwen has drawn the line of best fit correctly.

[3 marks]

continued on the next page . . .

Question 4 (b) continued

4. (b) (iii) Determine the magnetic flux density, B, of the uniform magnetic field between the poles of the magnet and quote it to an appropriate number of significant figures. The current in the wire is 5.00 A. No uncertainty is required in your value of B.

[5 marks]

(Total for Question 4 = 17 marks)

5. (a) Look at the diagram for Question 5 (a) in the separate Diagram Booklet.

The diagram shows how conductors can be heated using a varying magnetic field.

Explain why the heated object gets hot AND why a high frequency alternating current is used.

[4 marks]

Question 5 continued

5. (b) Explain how a Hall voltage arises in a Hall probe, how it is measured AND how this can be used to measure the magnetic flux density. A diagram should be included in your answer.

Space for diagram:

[6 marks QER]

(Total for Question 5 = 10 marks)

6. Look at the diagram for Question 6 in the separate Diagram Booklet.

The diagram shows two small spheres of radius 1.0 cm carrying uniform charges of +9.0 nC and – 9.0 nC. Their centres are separated by a distance of 18.0 cm as shown in the diagram. Treat the charges as being at the centres of the spheres.

(a) (i) Show that the potential at the surface of the negative sphere is approximately – 7500 V.

[3 marks]

continued on the next page . . .

Question 6 (a) continued

6. (a) (ii) Look at the diagram for Question 6 (a) (ii) in the separate Diagram Booklet.

The diagram is a grid.

Sketch the graph for the electric potential between the two charges (the potential has been plotted for the surface of the negative charge).

[3 marks]

continued on the next page . . .

Question 6 continued

6. (b) Explain why the electric field on the right – hand surface of the negative sphere is approximately $810\,000\ \mathrm{N\,C^{-1}}$ and directed towards the left.

[3 marks]

(Total for Question 6 = 9 marks)

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 PLUS YOUR ADDITIONAL TIME ALLOWANCE ON THIS SECTION.

Option A – ALTERNATING CURRENTS

7. (a) Look at the diagram for Question 7 (a) in the separate Diagram Booklet.

The diagram shows a rotating coil in a magnetic field.

The coil rotates 50 times per second in a field of flux density $0.215\ \text{T}$.

The coil has $2\,650$ turns and cross – sectional area $2.35 \times 10^{-3}\ \text{m}^2$

(Note that $\theta = 0$ when $t = 0$)

continued on the next page . . .

Question 7 (a) continued

7. (a) (i) Calculate the peak induced emf in the coil.

_____

_____

_____

_____

_____

[2 marks]

continued on the next page . . .

Question 7 (a) continued

7. (a) (ii) Calculate the flux linkage of the coil when t = 5.0 ms.

[Hint: put your calculator in radian mode.]

[2 marks]

(iii) Calculate the induced emf in the coil when t = 5.0 ms.

[1 mark]

continued on the next page . . .

Question 7 (a) continued

7. (a) (iv) Vanessa states that her answers to parts (ii) and (iii) are consistent with the coil having completed a quarter of a cycle. Determine whether or not she is correct.

[3 marks]

continued on the next page . . .

Question 7 continued

7. (b) (i) Look at the diagram for Question 7 (b) (i) in the separate Diagram Booklet.

Calculate the resonance frequency of the circuit shown in the diagram.

[2 marks]

continued on the next page . . .

Question 7 (b) continued

7. (b) (ii) Explain why the rms current at resonance is approximately 14 mA.

_____

_____

_____

_____

_____

[2 marks]

continued on the next page . . .

Question 7 (b) continued

7. (b) (iii) Calculate the rms current in the circuit when the frequency is 105 kHz.

[4 marks]

continued on the next page . . .

Question 7 (b) continued

7. (b) (iv) Explain why your answers to parts (b) (i), (b) (ii) and (b) (iii) suggest that the circuit has a high *Q* factor.

_____

_____

_____

_____

_____

[2 marks]

continued on the next page . . .

Question 7 (b) continued

7. (b) (v) Thomas considers the effect, on this circuit, of increasing the capacitance only. He believes that this will decrease the Q factor. Determine whether or not he is correct.

[2 marks]

(Total for Question 7 = 20 marks)

Option B – MEDICAL PHYSICS

8. (a) Look at the diagram for Question 8 (a) in the separate Diagram Booklet.

The diagram shows a simplified diagram of the inside of an X – ray tube.

(i) State the main function of the heater AND explain why there must be a vacuum between the heater and the tungsten target.

_____

_____

_____

_____

_____

[2 marks]

continued on the next page . . .

Question 8 (a) continued

8. (a) (ii) The electron beam has a current of 100 mA. Determine how many electrons arrive at the tungsten target per second.

[2 marks]

continued on the next page . . .

Question 8 (a) continued

8. (a) (iii) Estimate the velocity of an electron in the X – ray tube as it hits the target.

[3 marks]

continued on the next page . . .

Question 8 (a) continued

8. (a) (iv) Determine the minimum wavelength, λ_{min}, of the X-rays produced by this tube.

[3 marks]

continued on the next page . . .

Question 8 continued

8. (b) (i) An ultrasound probe can be used to study the speed of blood flow from the heart. Explain how the probe produces ultrasound AND how the speed of blood flow can be determined.

[3 marks]

continued on the next page . . .

Question 8 (b) continued

8. (b) (ii) In measuring the speed of blood flow, the frequency of ultrasound used is $2.0\ \text{MHz}$ and it travels through the blood at $1570\ \text{m s}^{-1}$

A frequency shift of $0.23\ \text{kHz}$ is measured when the ultrasound is incident at an angle of 37° to the blood flow. Calculate the speed of the blood flow.

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_____

_____

_____

_____

[2 marks]

continued on the next page . . .

Question 8 continued

8. (c) Doctors are concerned that a patient is suffering from an overactive thyroid gland (hyperthyroidism). They have the choice of the following techniques to help diagnose this.

X – RAY
MRI
ULTRASOUND
CT SCAN
RADIOACTIVE TRACERS

Evaluate the suitability of ALL FIVE types of imaging techniques for detecting an overactive thyroid gland.

[5 marks]

(Total for Question 8 = 20 marks)

Option C – THE PHYSICS OF SPORTS

9. (a) Look at the diagram for Question 9 (a) in the separate Diagram Booklet.

An athlete lifts a dumbbell of weight, 74.0 N as shown in the diagram.

Calculate the magnitude of the force, F, that the biceps muscle exerts on the athlete's forearm assuming that the elbow can be modelled as a pivot.

[2 marks]

continued on the next page . . .

Question 9 continued

9. (b) Look at the diagram for Question 9 (b) in the separate Diagram Booklet.

A rugby player of mass $117\ kg$ runs at a tackle pad with an initial velocity $7.75\ m\,s^{-1}$

In the collision with the tackle pad, the player experiences a mean force of $5500\ N$ for a contact time of $0.176\ s$.

This force is in the exact opposite direction to the initial velocity.

Calculate the final velocity of the rugby player after the collision.

[3 marks]

continued on the next page . . .

Question 9 continued

9. (c) (i) Look at the diagram for Question 9 (c) (i) in the separate Diagram Booklet.

During a rugby match, a player wishes to kick the ball as far as possible. Describe the factors that affect the drag force on the ball. You may use the following diagrams to support your answer.

[3 marks]

continued on the next page . . .

Question 9 (c) continued

9. (c) (ii) A kicking coach thinks that, if the number of revolutions per second of the ball is doubled, then the rotational kinetic energy of a rugby ball will also double. Evaluate whether or not the coach is correct.

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_____

_____

_____

_____

[2 marks]

continued on the next page . . .

Question 9 (c) continued

9. (c) (iii) Look at the table for Question 9 (c) (iii) in the separate Diagram Booklet.

The rugby ball is dropped on to two playing surfaces, A and B. Evaluate whether the playing surfaces are different.

[3 marks]

continued on the next page . . .

Question 9 (c) continued

9. (c) (iv) When a rugby ball is kicked it gains an angular velocity of $37.7\ \text{rad s}^{-1}$ in a time of $17.0\ \text{ms}$.

The moment of inertia of the rugby ball is $0.0028\ \text{kg m}^2$

Calculate the torque exerted on the ball by the kicker's foot.

_____

_____

_____

_____

_____

[2 marks]

continued on the next page . . .

Question 9 (c) continued

9. (c) (v) Look at the diagram for Question 9 (c) (v) in the separate Diagram Booklet.

A player throws a ball from a height of $2.0\ m$ with an initial speed of $12\ m\ s^{-1}$ at an angle of 32° to the horizontal. The maximum height reached by the player catching the ball is $4.4\ m$ and he is standing $6.2\ m$ away from the thrower. Explain why it is possible for the catcher to catch the ball.

[5 marks]

(Total for Question 9 = 20 marks)

Option D – ENERGY AND THE ENVIRONMENT

10. (a) (i) The mean temperature of the Earth is 288 K. Assuming it behaves as a black body, show that the wavelength of the peak emission of radiation is in the infra – red region of the electromagnetic spectrum.

_____

_____

_____

_____

_____

[2 marks]

continued on the next page . . .

Question 10 (a) continued

10. (a) (ii) Carbon dioxide, methane and water vapour are greenhouse gases. Describe the role these gases play in the greenhouse effect.

[3 marks]

continued on the next page . . .

Question 10 continued

10. (b) (i) The Greenland ice sheet is the second largest ice sheet in the world. Over the last two decades the mean decrease in volume of Greenland's ice is $3.0 \times 10^{11}\ m^3\ year^{-1}$

Estimate the volume of water released into the surrounding ocean in this time period.

[$\rho_{ice} = 920\ kg\ m^{-3}$,

$\rho_{water} = 1000\ kg\ m^{-3}$]

[2 marks]

continued on the next page . . .

Question 10 (b) continued

10. (b) (ii) Satellite images show that the edge of the Greenland ice sheet appears brown in places. Scientists report that this discolouration is due to microscopic plants flourishing in the melting ice. Explain the effect this could have on the rate at which the ice melts.

[2 marks]

continued on the next page . . .

Question 10 continued

10. (c) Look at the diagram for Question 10 (c) in the separate Diagram Booklet.
The diagram is a graph.

The graph shows how renewable sources have contributed to the electricity generated in the UK between 2000 and 2018.

(i) Compare the contribution of solar photovoltaic (Solar PV) with hydroelectric power since 2010 AND suggest a reason for this difference.

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_____

_____

_____

_____

[2 marks]

continued on the next page . . .

Question 10 (c) continued

10. (c) (ii) **Look at the diagram for Question 10 (c) (ii) in the separate Diagram Booklet.**

The diagram is a graph.

A solar panel provides electrical power for a load resistor. The graph below shows the current – potential difference characteristics of a solar panel operating under an intensity of $600\ W\,m^{-2}$

The solar panel has a surface area of $1.2\ m^2$

Determine the efficiency of the solar panel when it is operating at its maximum power output.

[4 marks]

continued on the next page . . .

Question 10 continued

10. (d) (i) The ground floor of a house has an area of $60\ m^2$

The floor is made from concrete of thickness $120\ mm$. If the top surface of the concrete is $19^\circ C$ and the lower surface is $5^\circ C$, show that the rate of heat flow through the concrete is approximately $5000\ W$.

$K_{concrete} = 0.700\ W\,m^{-1}\,K^{-1}$

[2 marks]

continued on the next page . . .

Question 10 (d) continued

10. (d) (ii) Look at the diagram for Question 10 (d) (ii) in the separate Diagram Booklet.

The diagram is NOT drawn to scale.

A carpet fitting company adds underlay and carpet on to the concrete as shown in the diagram.

It is stated by the carpet fitting company that the rate of heat flow through the floor will reduce to a quarter of the value calculated in part (d) (i). Evaluate if this claim is correct.

[3 marks]

(Total for Question 10 = 20 marks)

END OF PAPER

TOTAL 100 MARKS

Question number	Additional pages, if required. Write the question number(s) in the left-hand margin.

Question number	Additional pages, if required. Write the question number(s) in the left - hand margin.

Question number	Additional pages, if required. Write the question number(s) in the left - hand margin.

GCE A LEVEL

1420U40-1

THURSDAY, 15 JUNE 2023 – 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 (a)

Diagram (i)

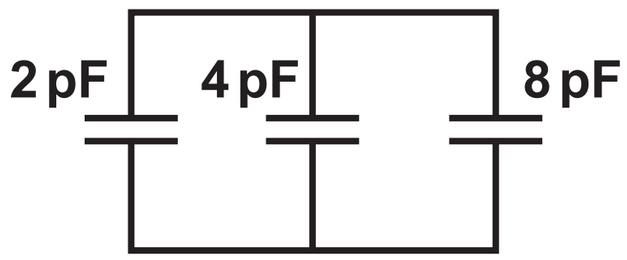
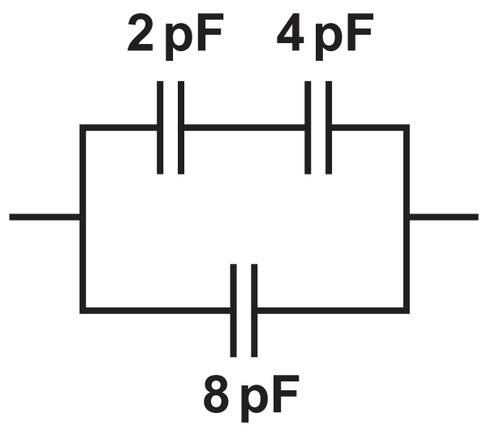
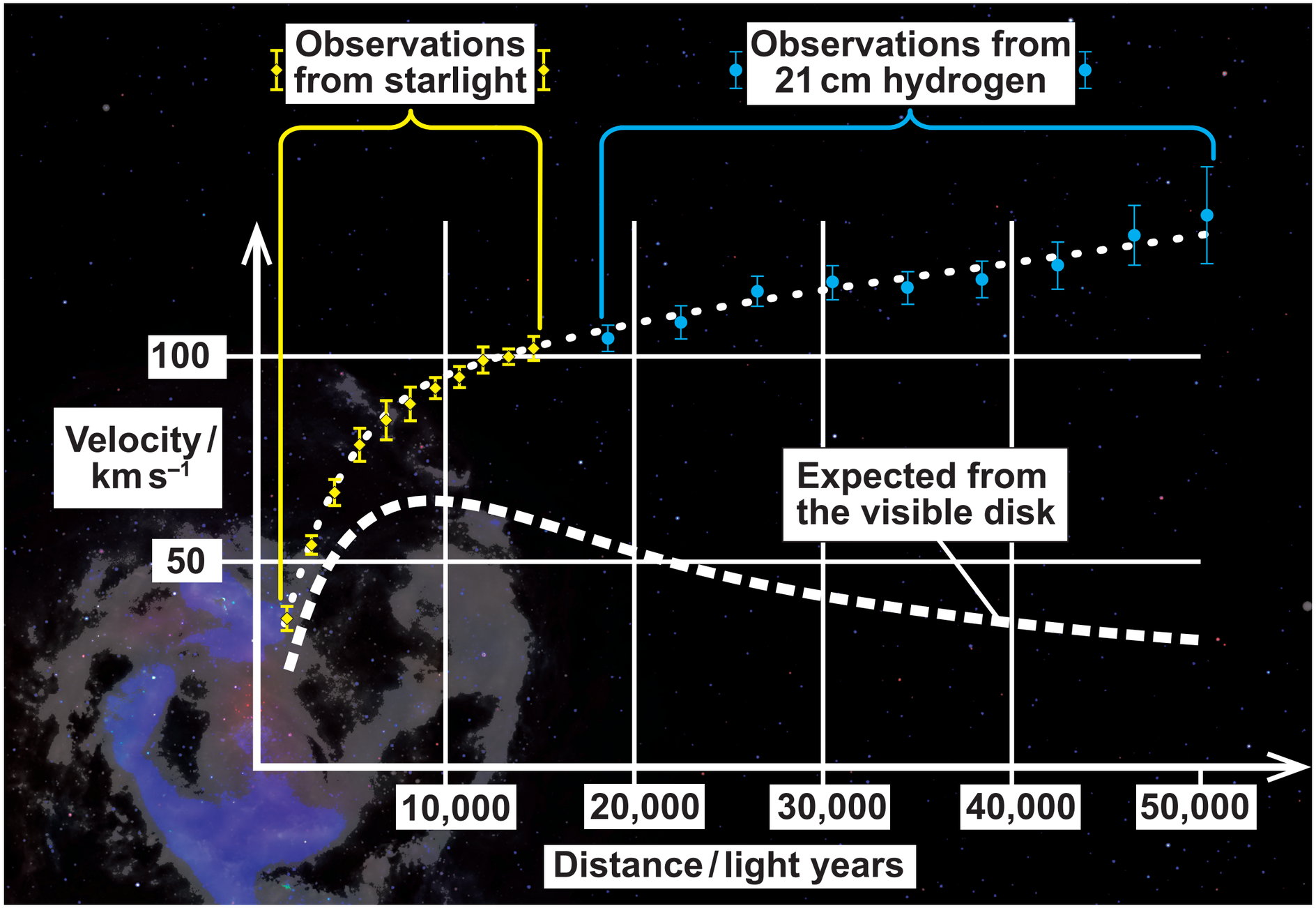


Diagram (ii)

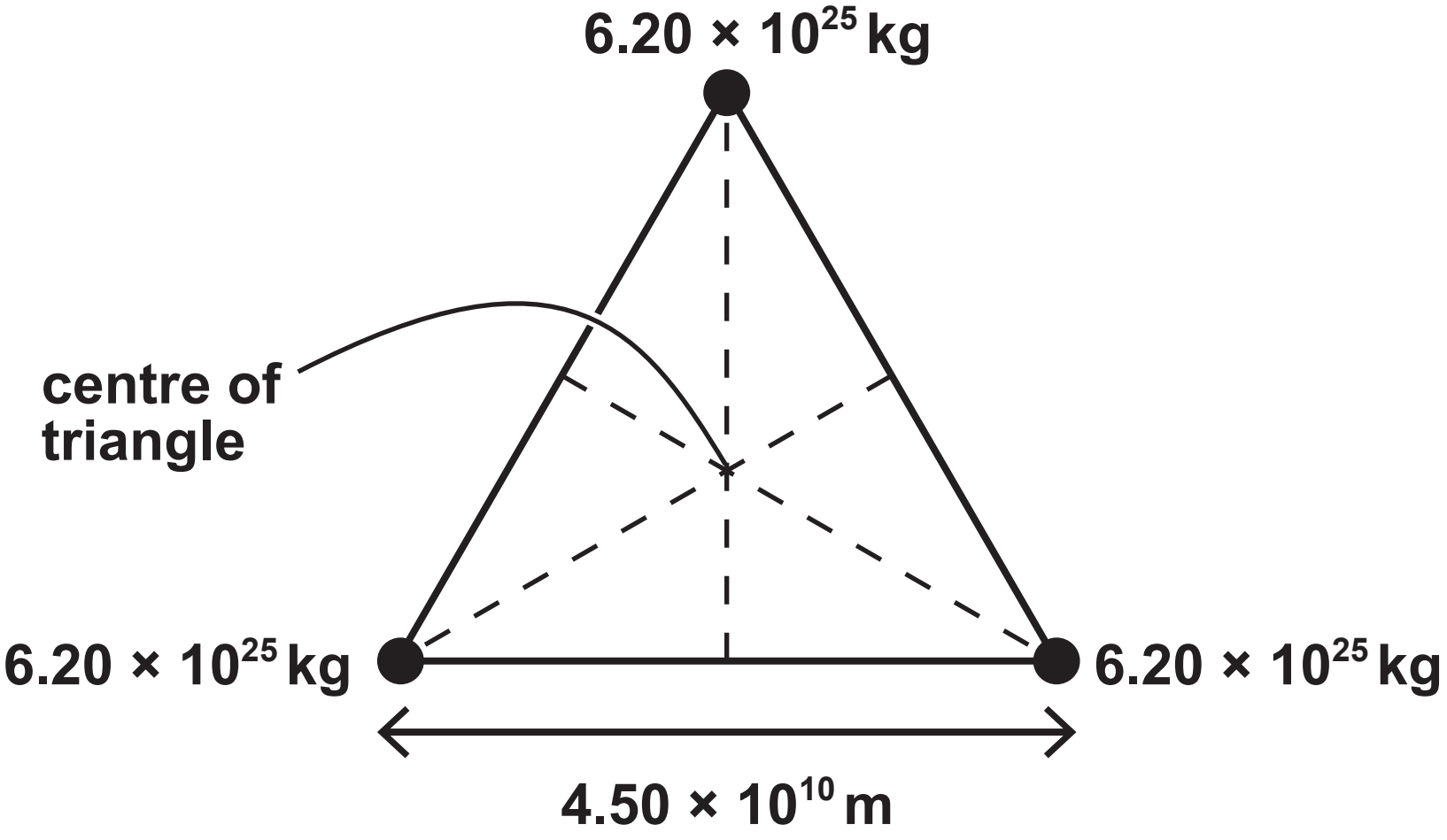
Diagram (iii)



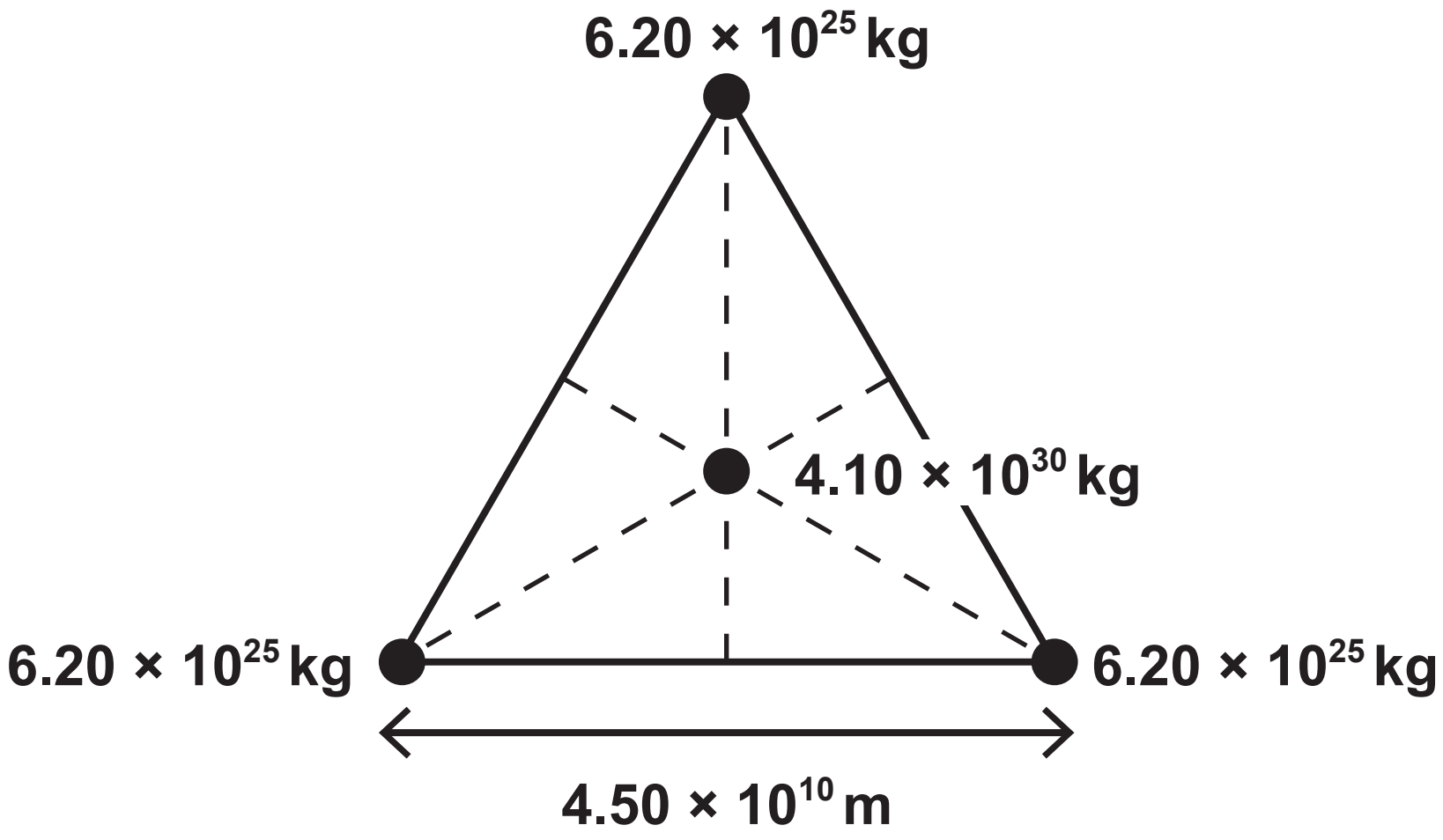
Question 2


Observations from starlight
Observations from 21 cm hydrogen
100
50
Velocity / km s⁻¹
Expected from the visible disk
10,000
20,000
30,000
40,000
50,000
Distance / light years

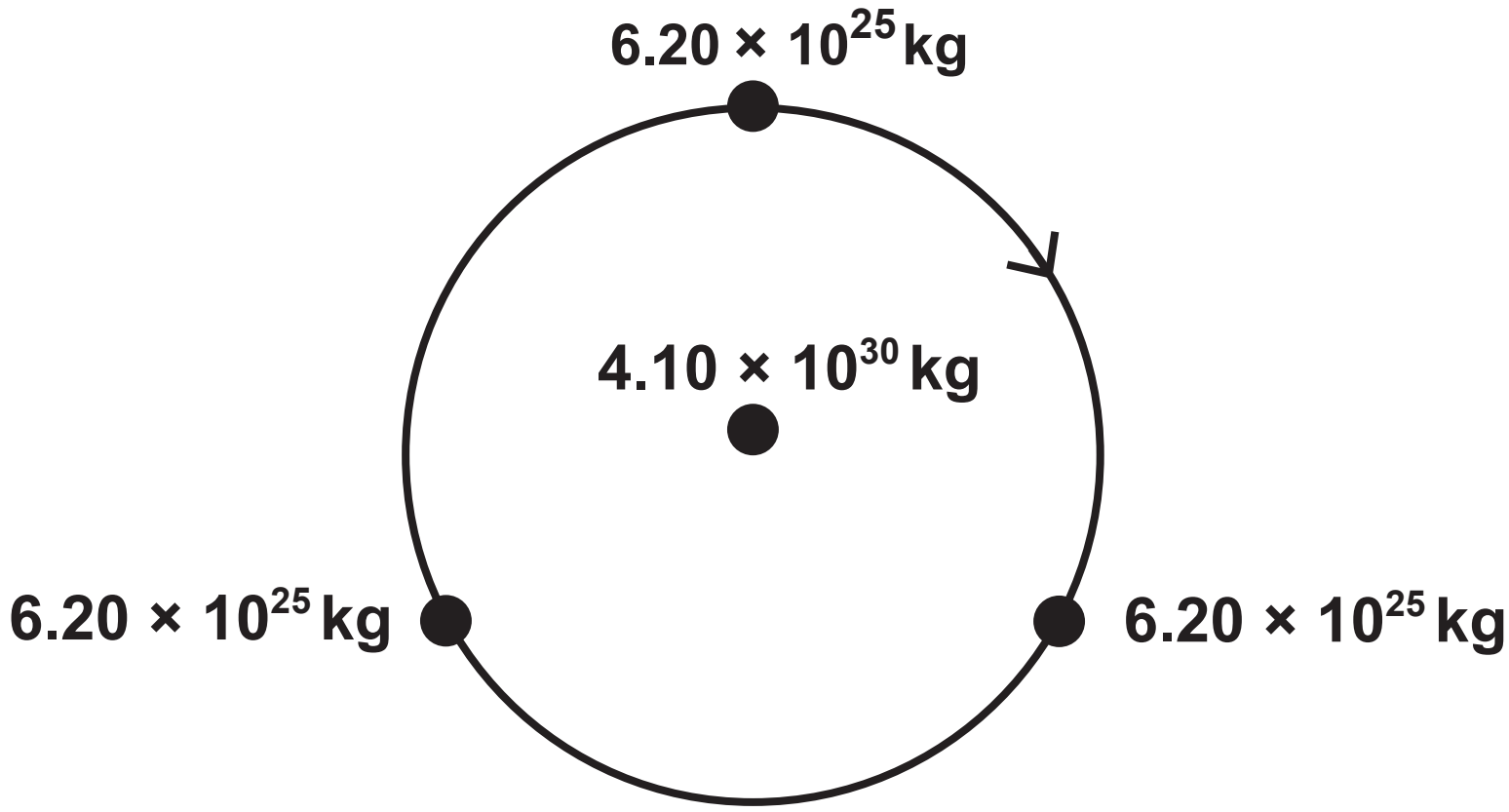
Question 3


6.20 × 10^25 kg
centre of triangle
6.20 × 10^25 kg
6.20 × 10^25 kg
4.50 × 10^10 m

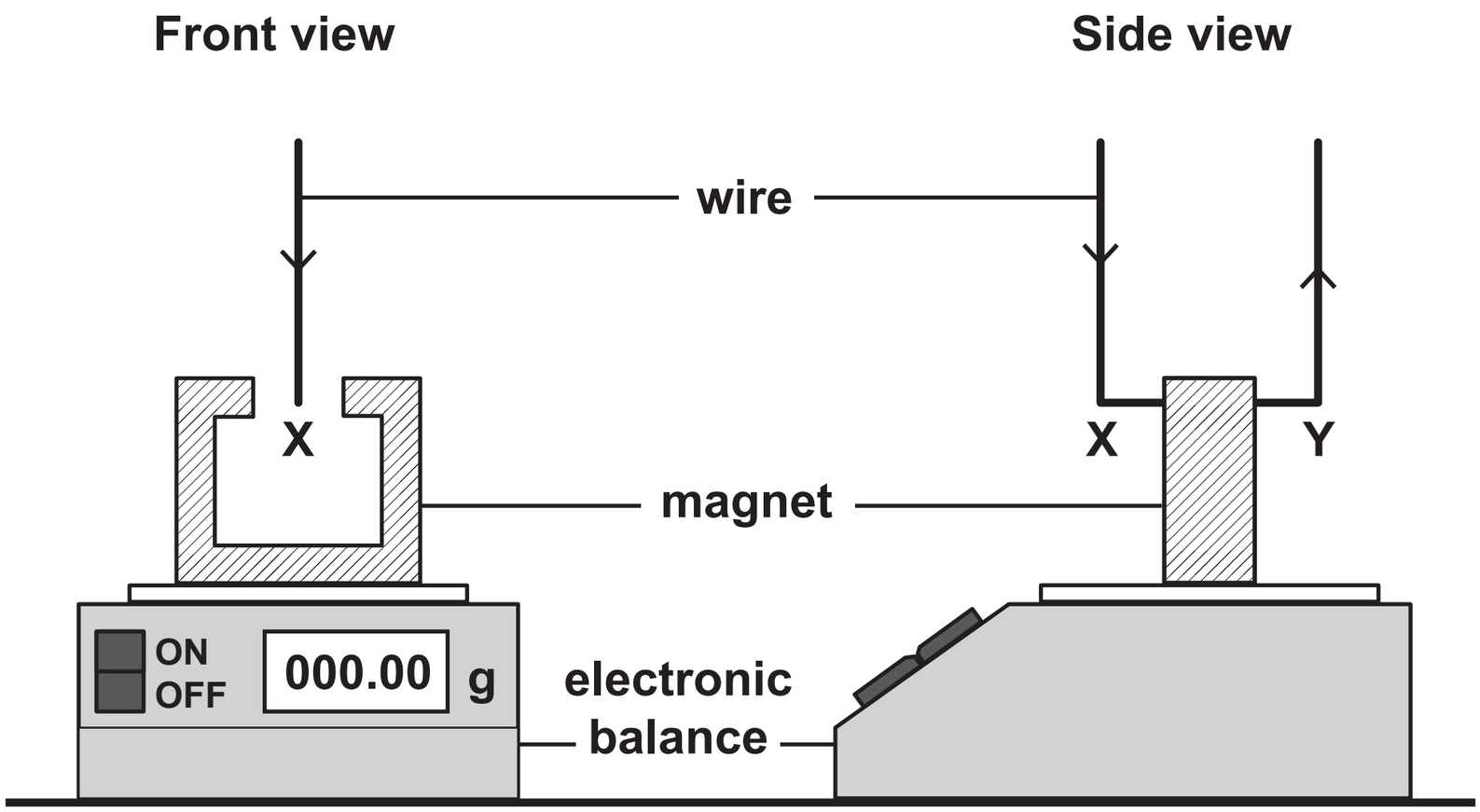
Question 3 (b)



Question 3 (d)


6.20×10^{25} kg
4.10×10^{30} kg
6.20×10^{25} kg
6.20×10^{25} kg

Question 4

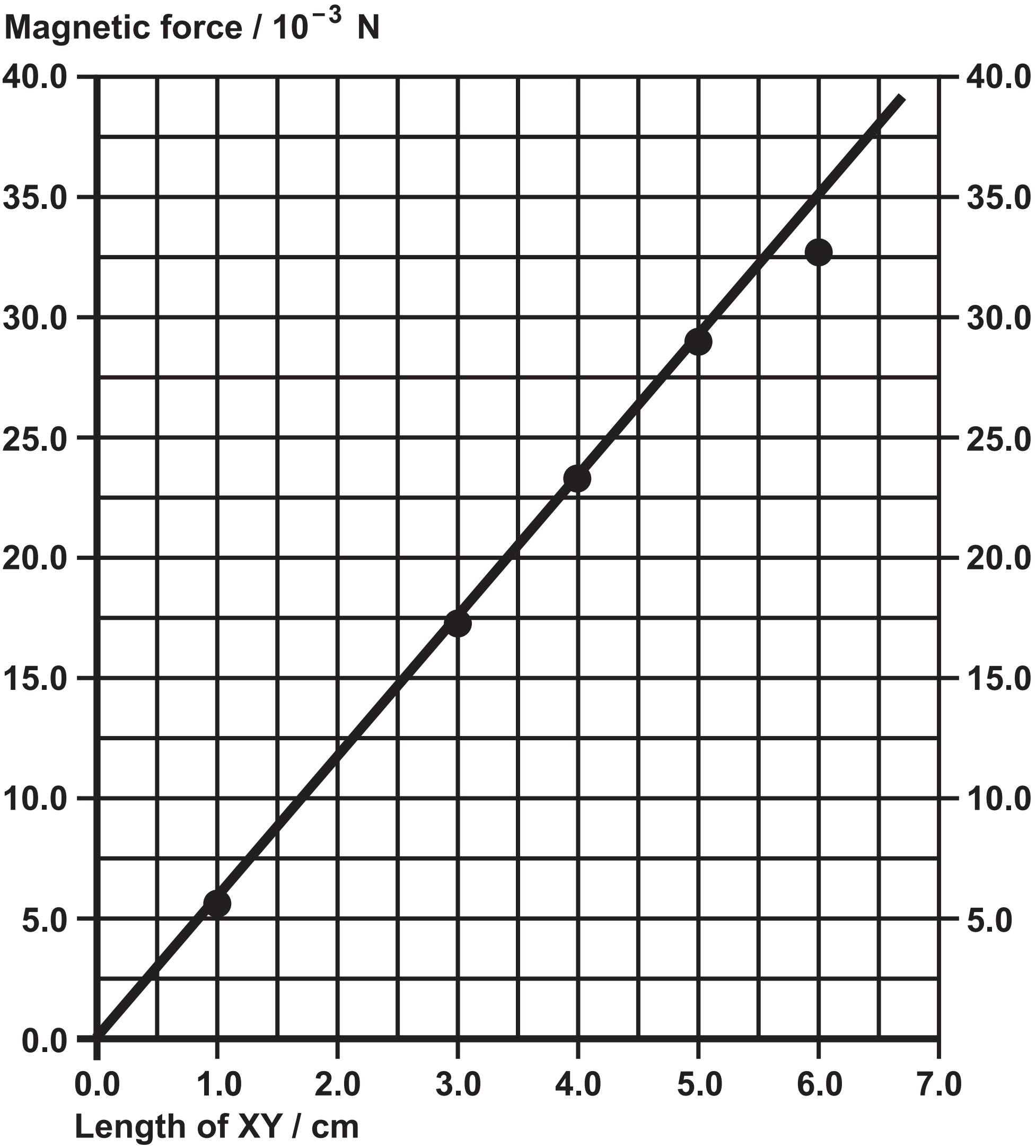

Front view
Side view
wire
X
X
Y
magnet
ON
OFF
000.00
g
electronic
balance

Question 4 (b) (i)

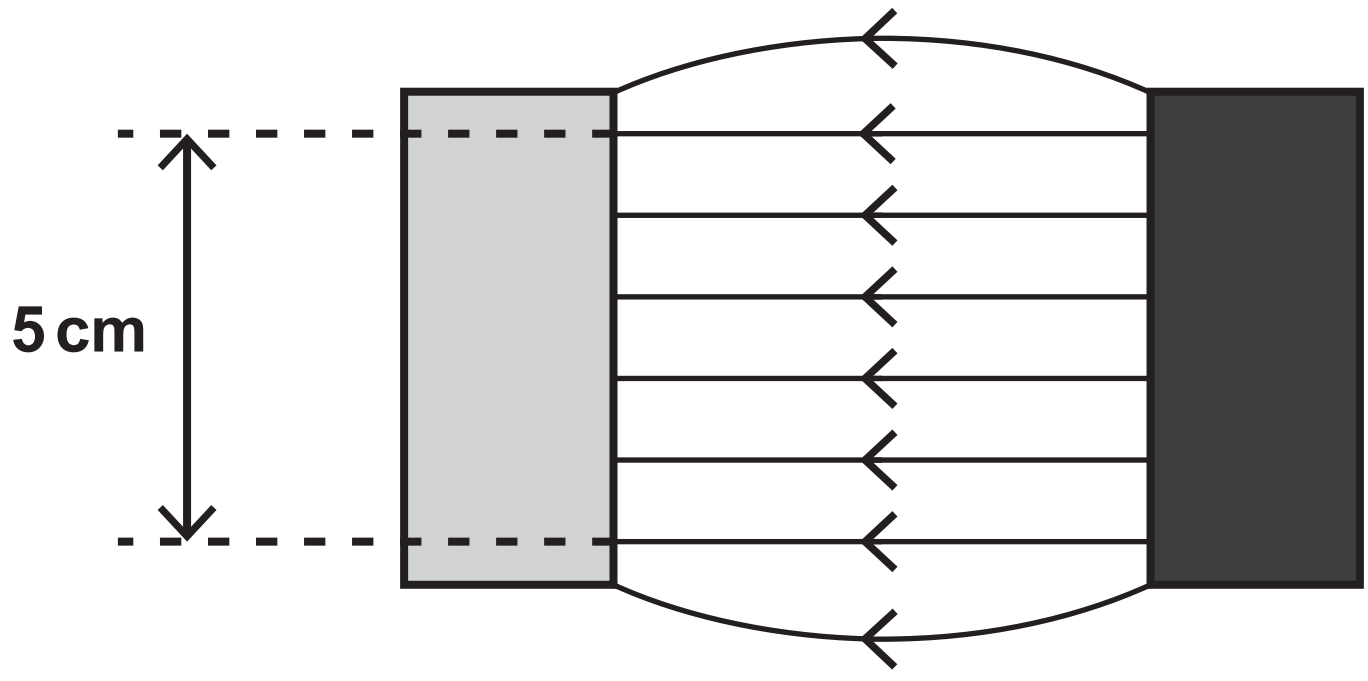
Table

Length of XY / cm	Balance reading / g	Magnetic force / 10^{-3} N
1.0	0.56	5.5
2.0	1.22	
3.0	1.75	17.2
4.0	2.36	23.1
5.0	2.89	28.4
6.0	3.32	32.6
7.0		35.8

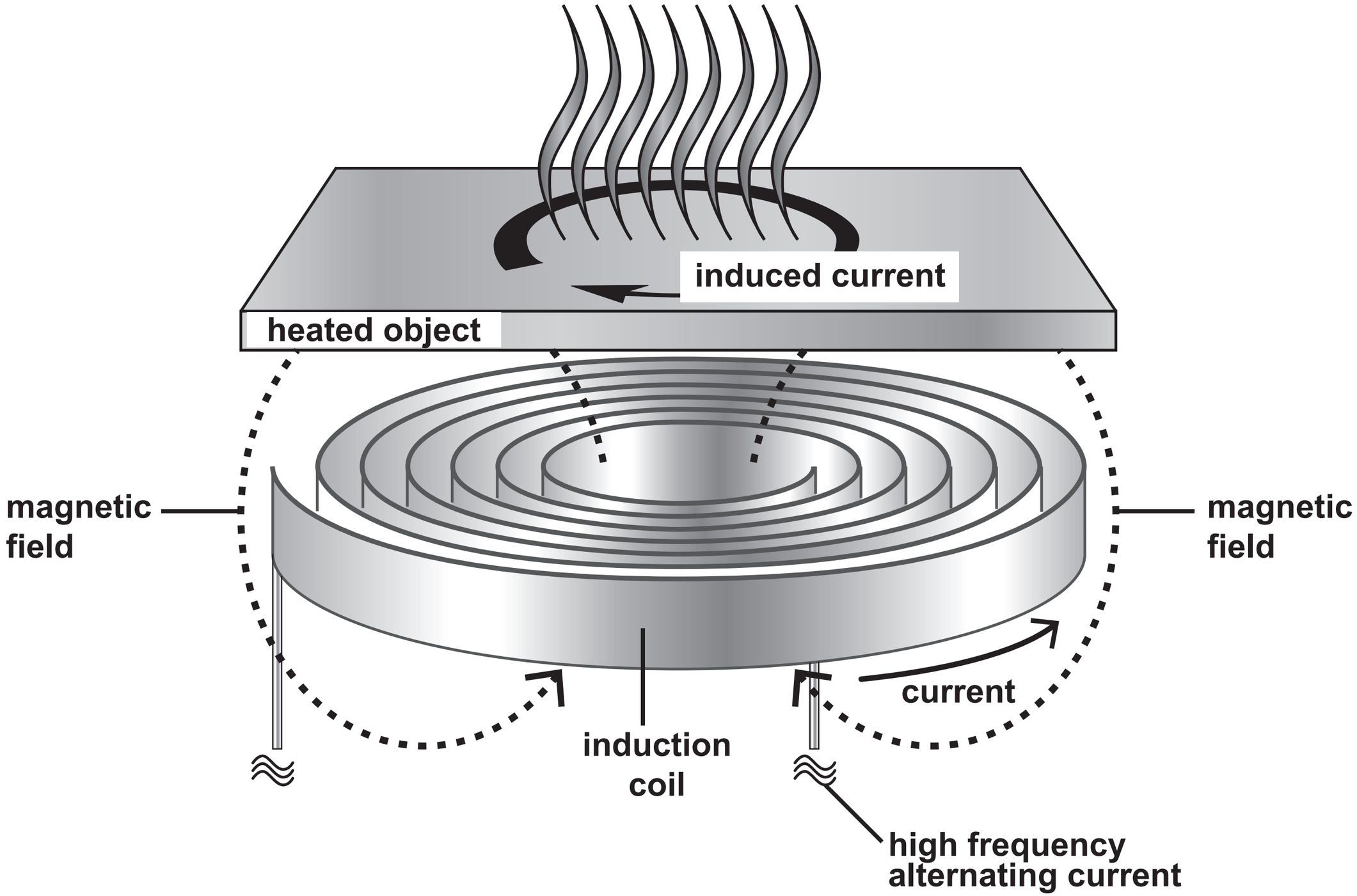
Question 4 (b) (i)



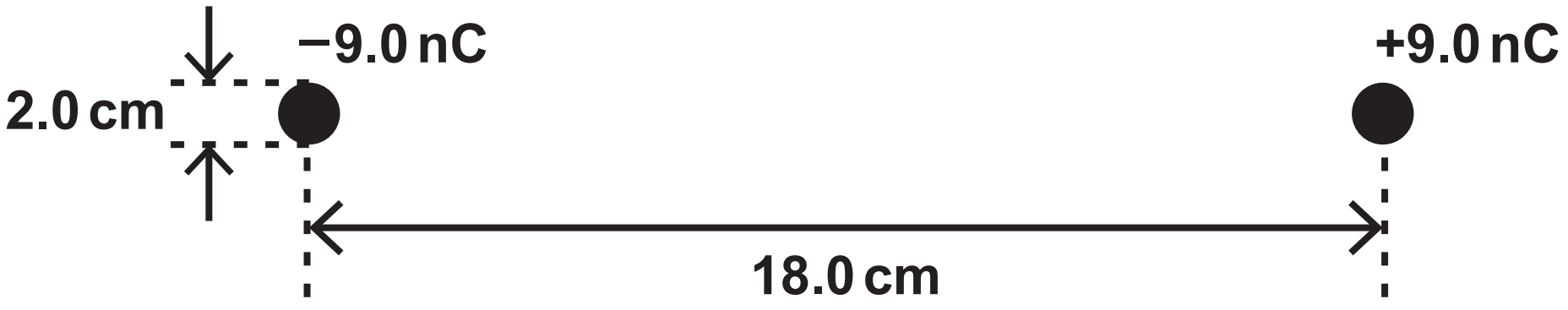
Question 4 (b) (ii)



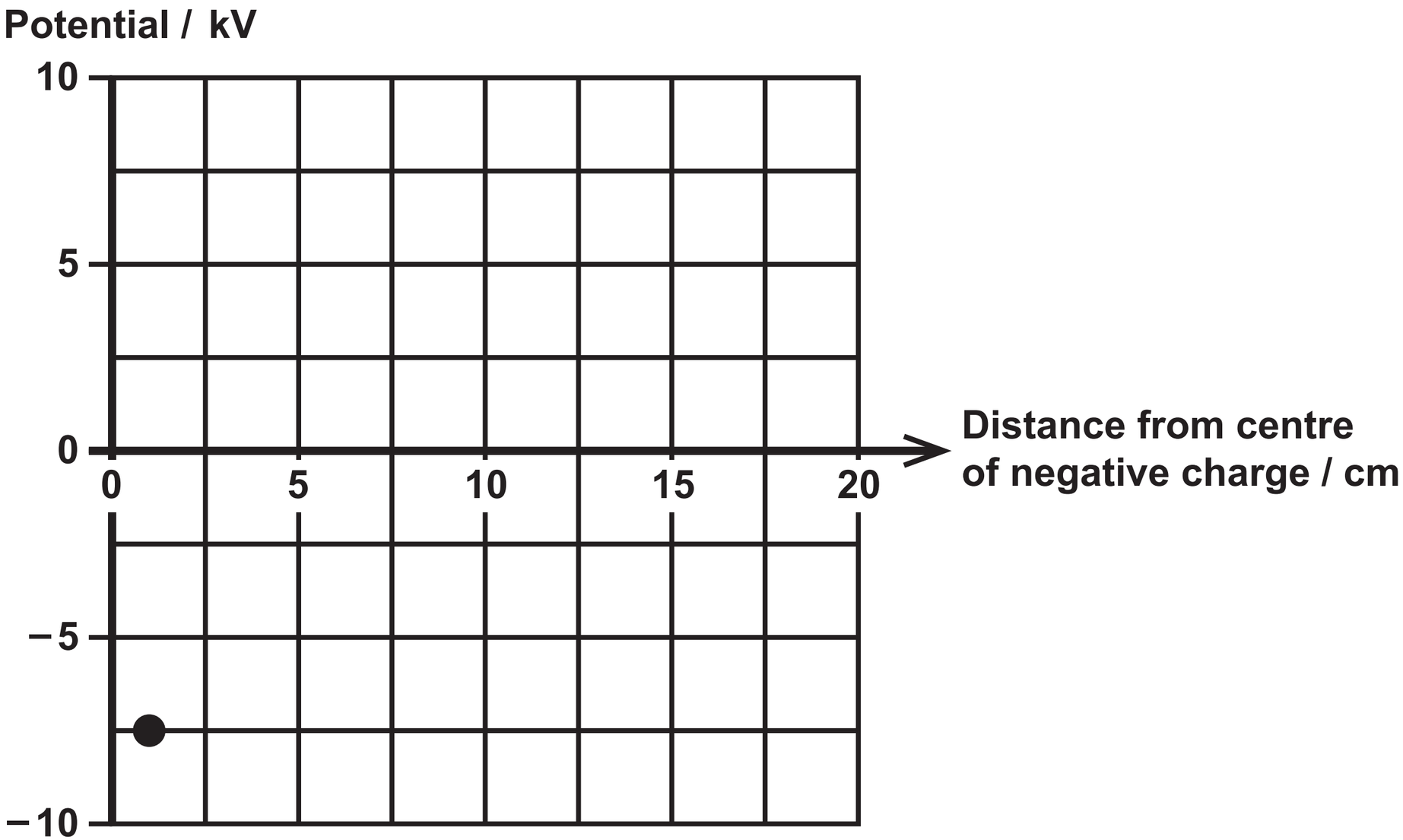
Question 5 (a)


induced current
heated object
magnetic field
magnetic field
induction coil
current
high frequency alternating current

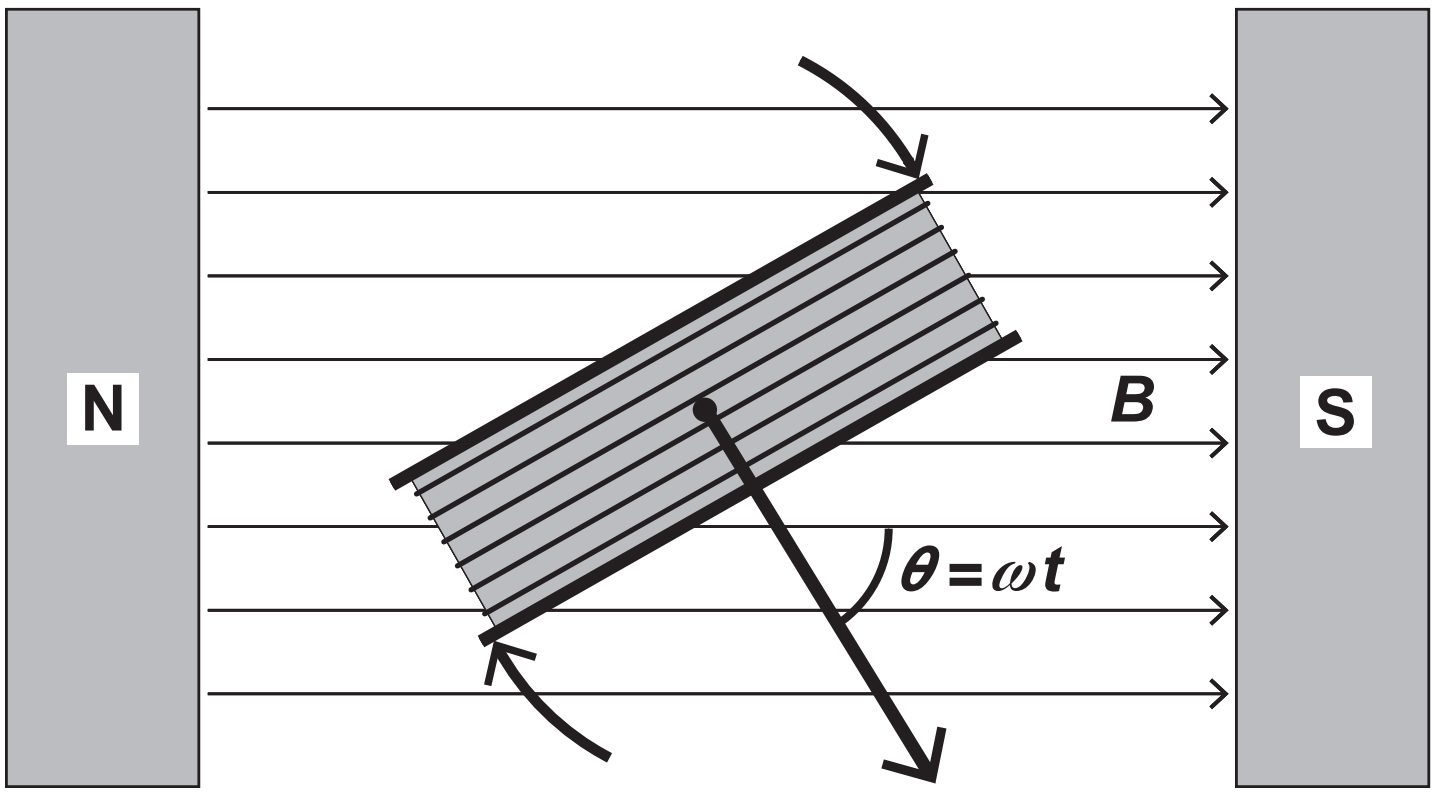
Question 6



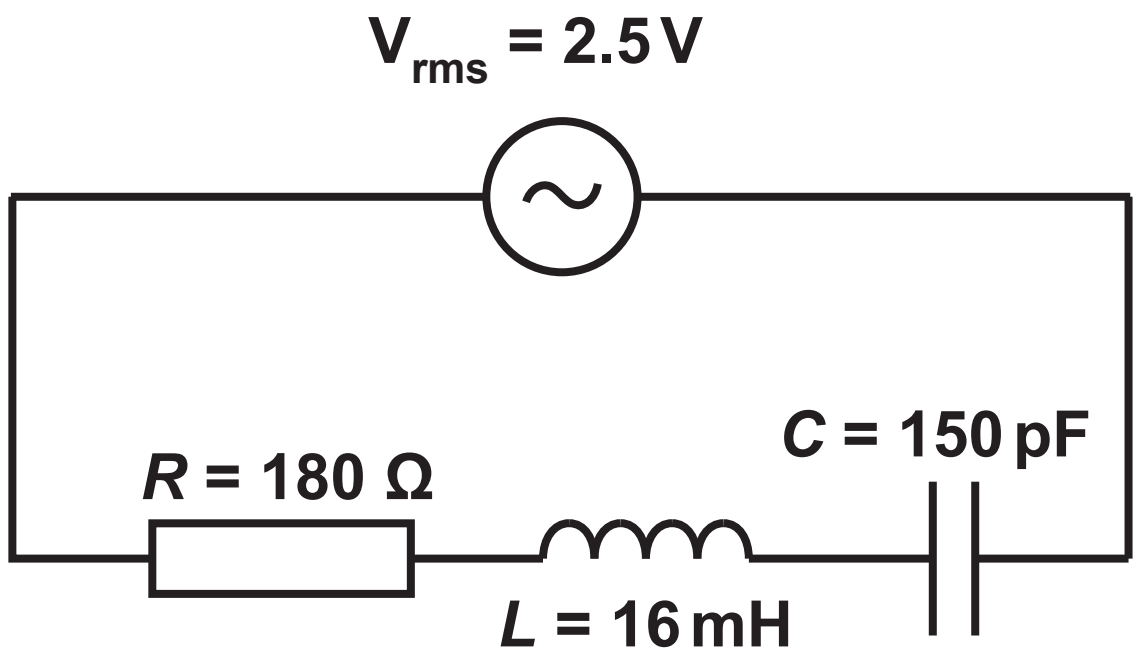
Question 6 (a) (ii)



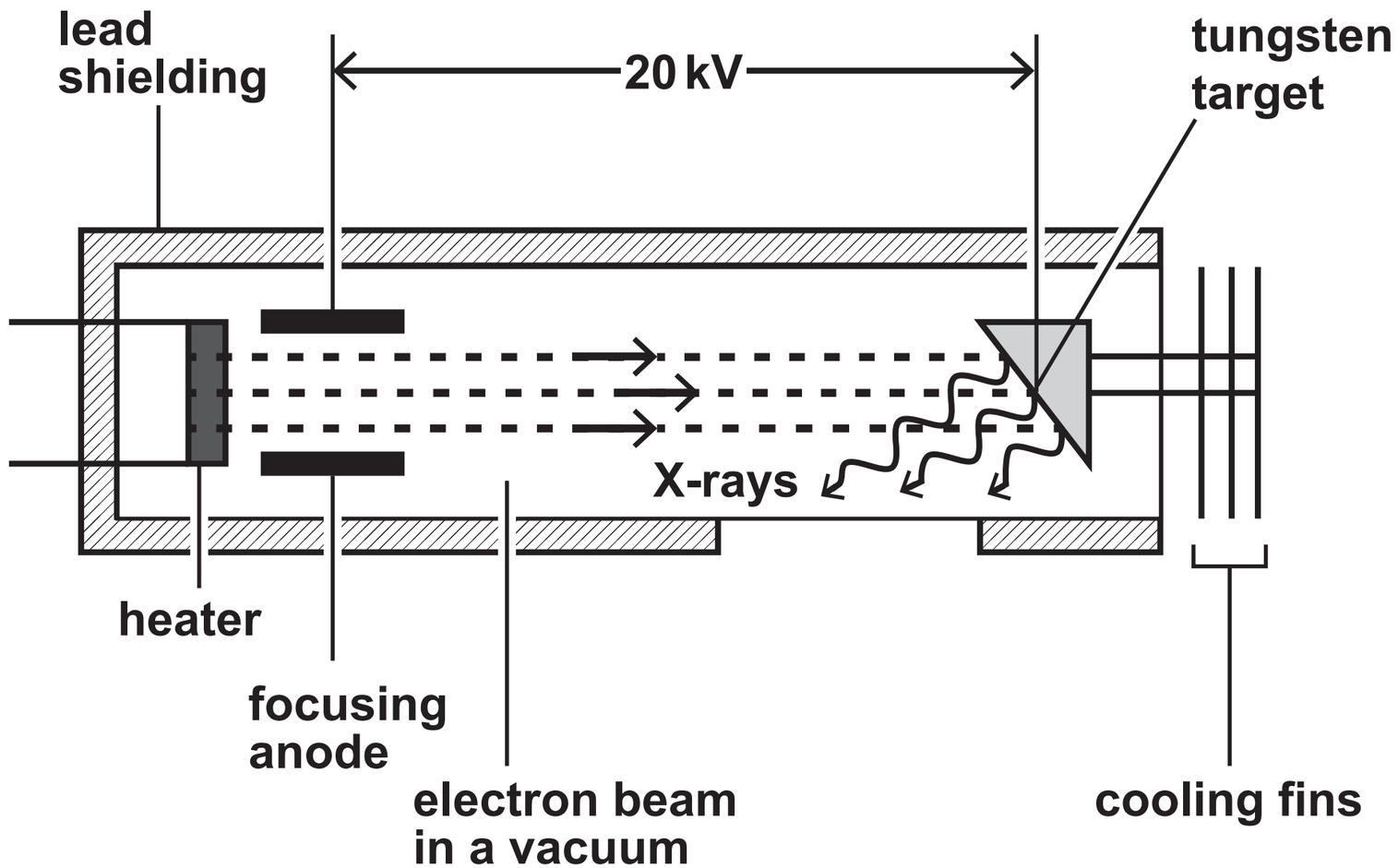
Question 7 (a)



Question 7 (b) (i)

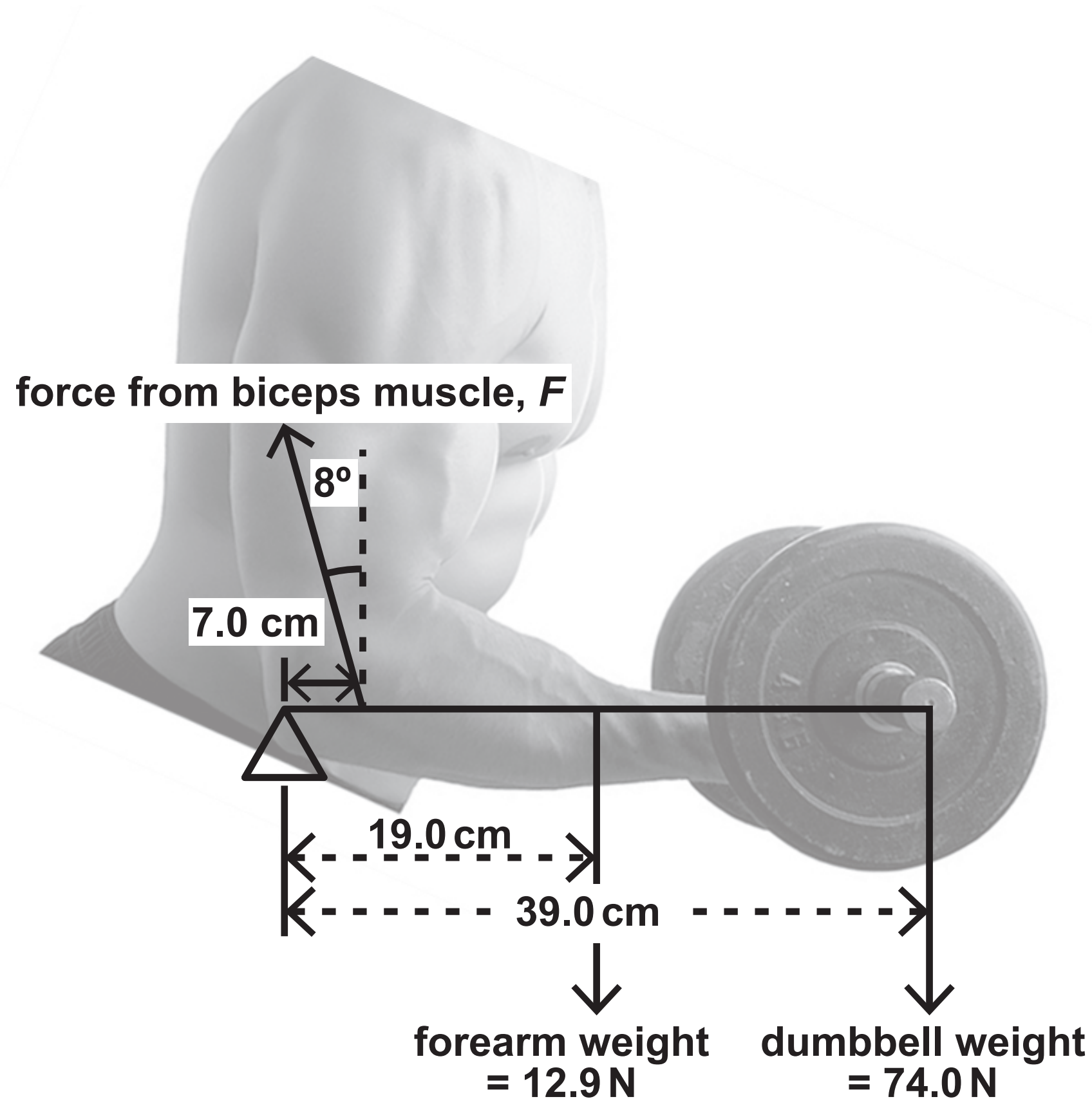


Question 8 (a)

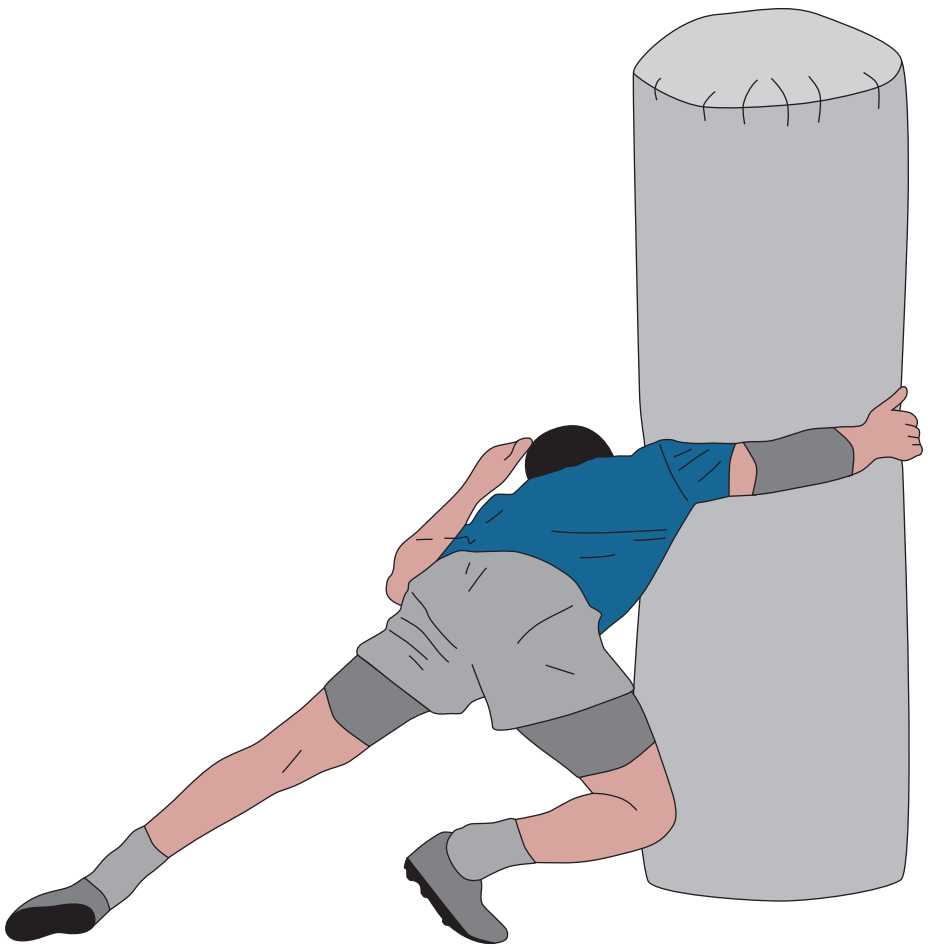

lead shielding
20 kV
tungsten target
X-rays
heater
focusing anode
electron beam in a vacuum
cooling fins

Question 9 (a)

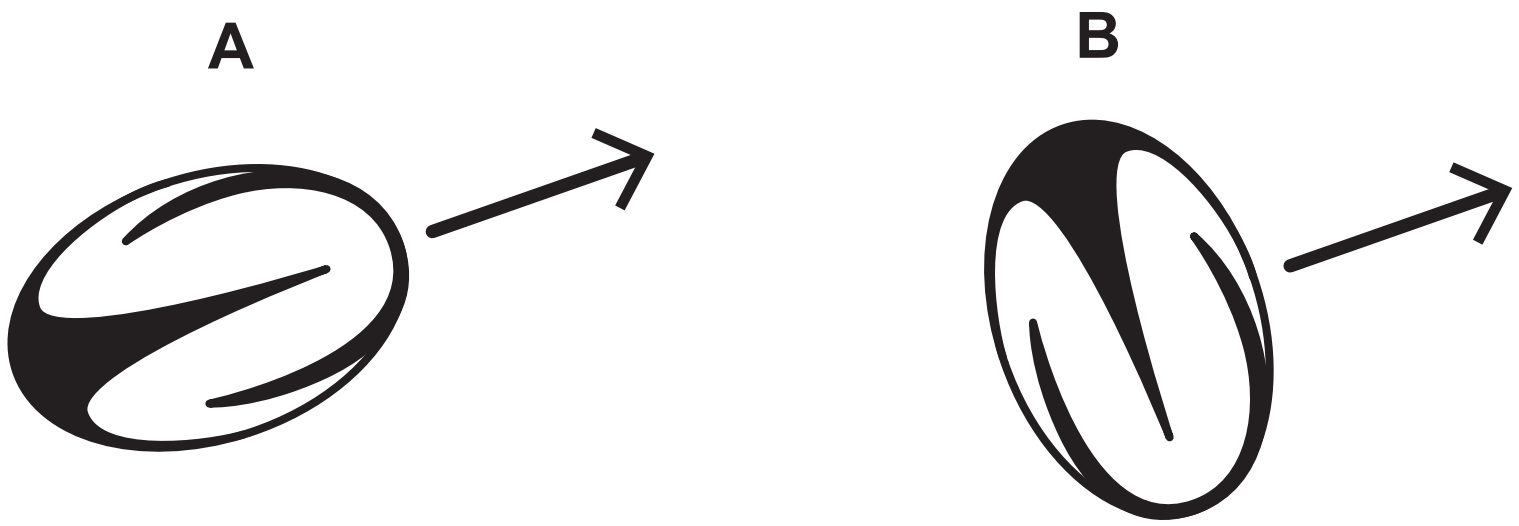
Diagram NOT drawn to scale



Question 9 (b)



Question 9 (c) (i)

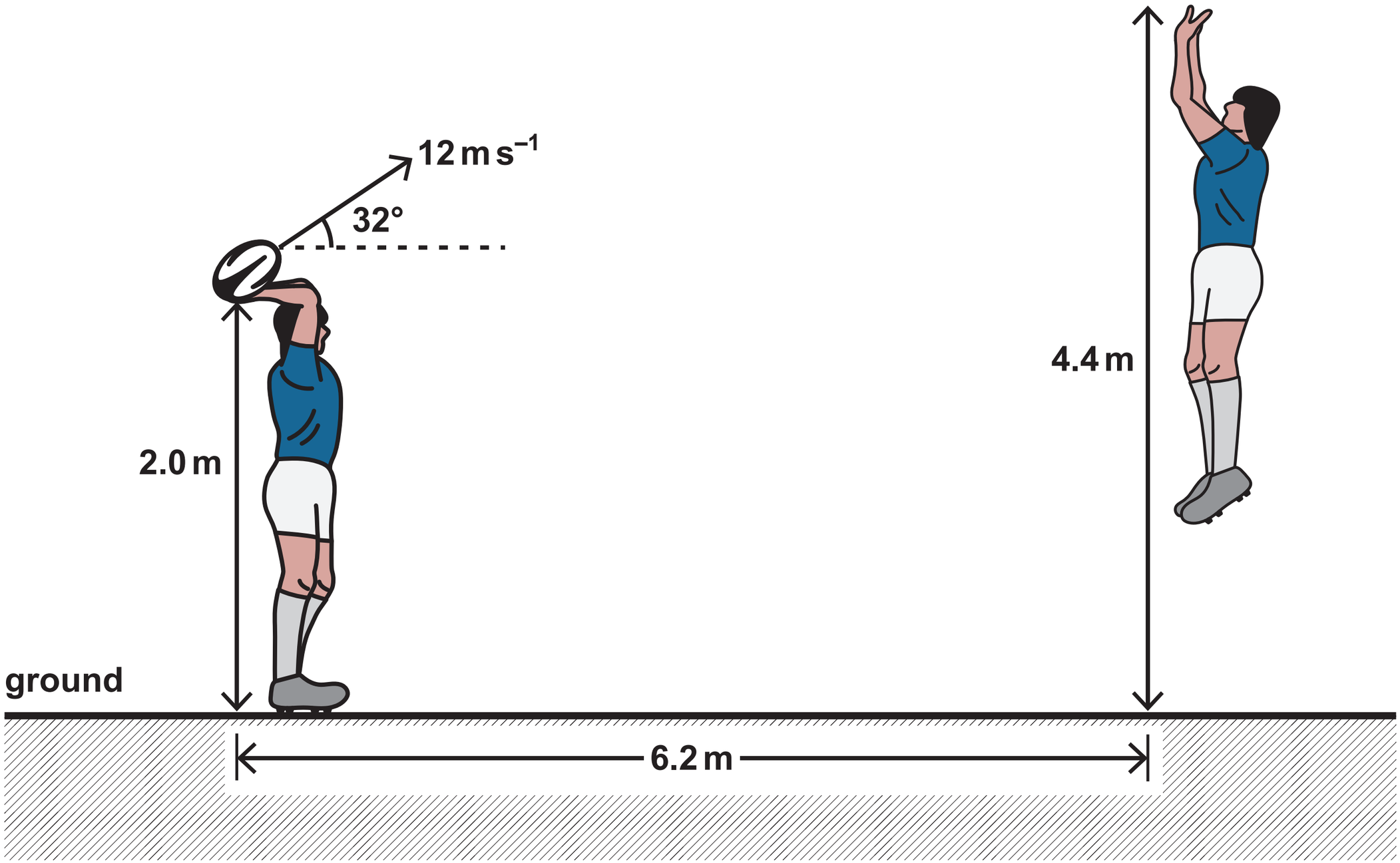


Question 9 (c) (iii)

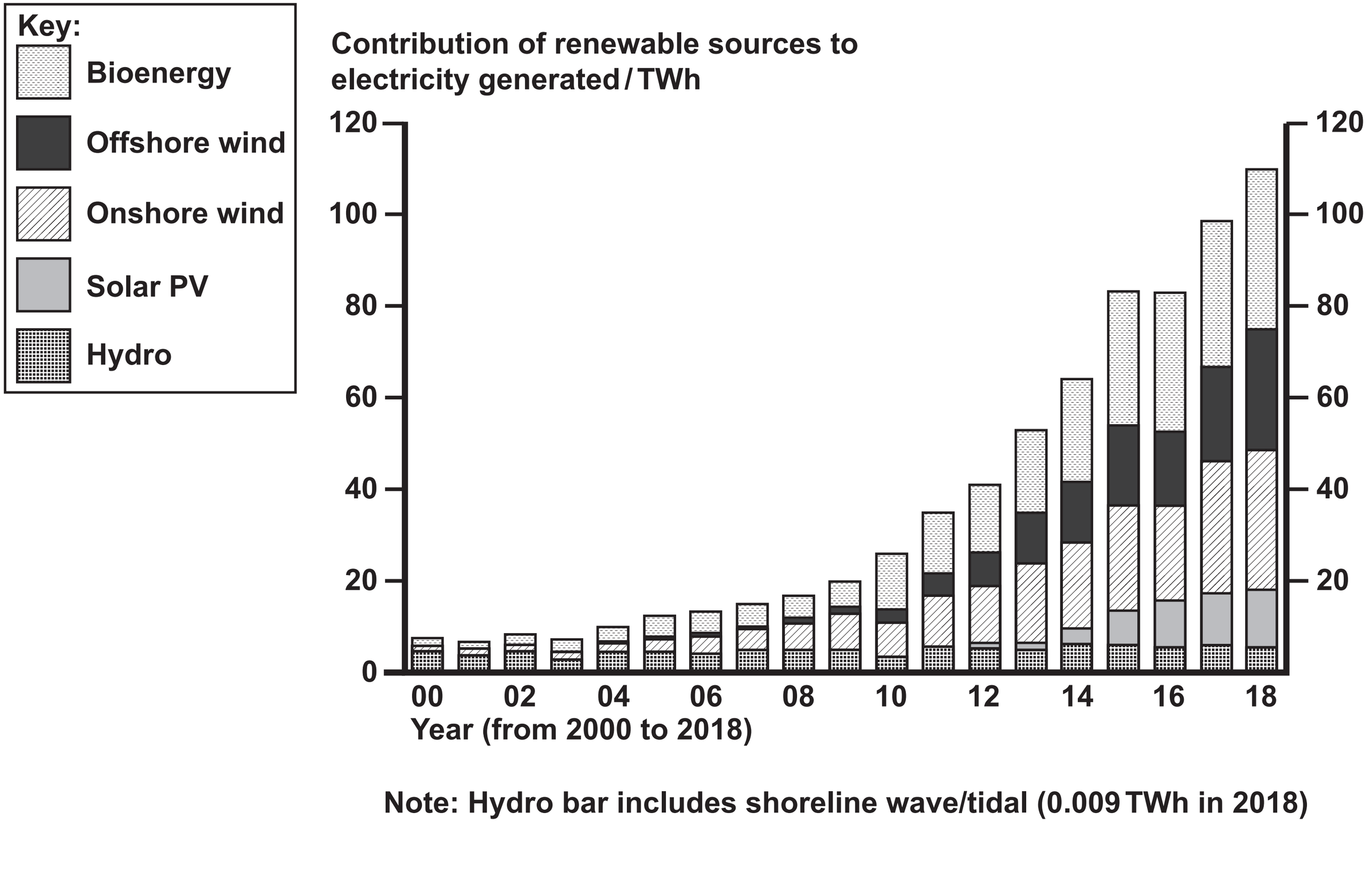
Table

Playing surface	Initial height / m	Bounce height / m
A	7.8	1.2
B	4.5	0.7

Question 9 (c) (v)

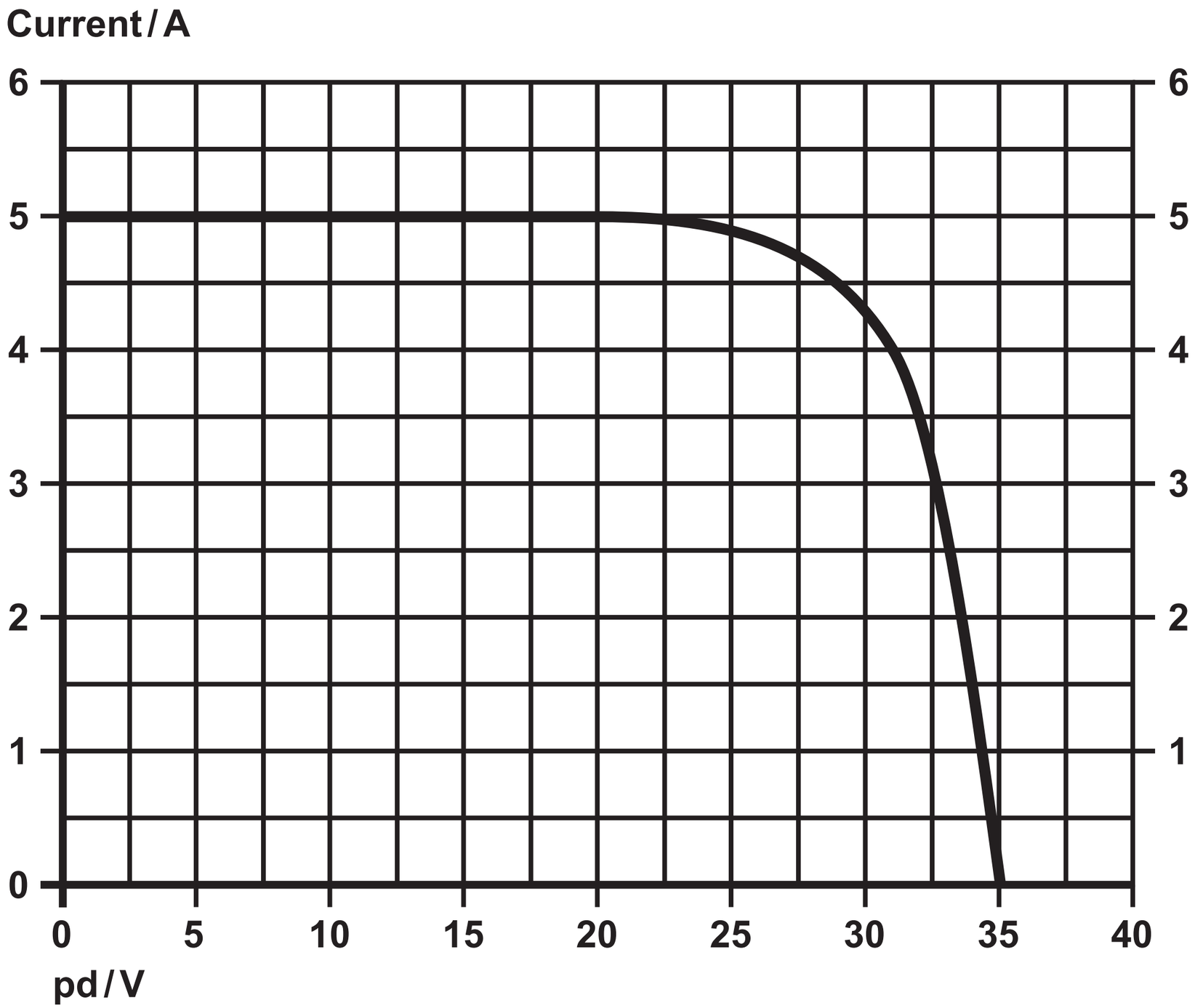


Question 10 (c)



Note: Hydro bar includes shoreline wave/tidal (0.009 TWh in 2018)

Question 10 (c) (ii)



Question 10 (d) (ii)

Diagram not drawn to scale