GCE A LEVEL

1420U40-1

FRIDAY, 10 JUNE 2022 – AFTERNOON

PHYSICS – A2 UNIT 4

FIELDS AND OPTIONS

1 hour 35 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**
1.	**8**	
2.	**9**	
3.	**14**	
4.	**13**	
5.	**22**	
6.	**14**	
Total	**80**	

ADDITIONAL MATERIALS

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

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 pages at the back of the booklet taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The total number of marks available for this paper is 80.

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 (b).

ANSWER ALL QUESTIONS.

1. (a) (i) Look at the diagram for Question 1 (a) (i) in the separate Diagram Booklet.

Lindsey calculates that a current of 3.57 A will produce a magnetic flux density of 0.121 T inside the long solenoid shown. Determine whether or not she is correct.

[3 marks]

Question 1 (a) continued

1. (a) (ii) State how the magnetic flux density inside the solenoid can be increased greatly without changing the current or the number of turns per unit length.

_____

_____

_____

[1 mark]

continued on the next page . . .

Question 1 continued

1. (b) Look at the diagram for Question 1 (b) in the separate Diagram Booklet.

A rectangular coil rotates at a constant angular velocity within a uniform magnetic field of 0.121 T. The coil has 70 turns and cross – sectional area 59 cm^2.

The diagram shows the coil, looking along the axis of rotation.

(i) Calculate the flux linkage of the coil when $\theta = 23°$.

[2 marks]

continued on the next page . . .

Question 1 (b) continued

1. (b) (ii) As the coil rotates, explain what values of θ provide the maximum AND minimum values of the induced emf.

[2 marks]

(Total for Question 1 = 8 marks)

2. (a) Look at the diagram for Question 2 (a) in the separate Diagram Booklet.

Draw 2 equipotentials and 4 field lines for both the ELECTRIC field of the positron and the GRAVITATIONAL field of the anti–neutron shown.

[3 marks]

(b) Describe and explain the similarities AND differences between electric AND gravitational fields.

[6 marks QER]

(Total for Question 2 = 9 marks)

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

Three stationary charges are located at the corners of an EQUILATERAL triangle and an electron is located at the centre, P, of the triangle as shown in the diagram. The electron is exactly 0.60 m from each charge.

(a) Draw arrows to show the 3 electric fields at P due to the 3 charges. Use these to explain why the electron will accelerate in the direction shown.

[4 marks]

continued on the next page . . .

Question 3 continued

3. (b) Calculate the initial acceleration of the electron.

[4 marks]

Question 3 continued

3. (c) Show CLEARLY that the initial potential energy of the electron is approximately -6×10^{-18} J.

[2 marks]

continued on the next page . . .

Question 3 continued

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

Determine whether or not the electron (initially at rest) will reach point R, shown in the diagram (both positive charges are 0.60 m from R).

Explain your reasoning.

[4 marks]

(Total for Question 3 = 14 marks)

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

The diagram represents a capacitor.

Calculate the capacitance of the capacitor.

[2 marks]

continued on the next page . . .

Question 4 continued

4. (b) (i) Calculate the pd across the terminals of a 5.0 mF capacitor when it stores 1.00 J of energy.

[2 marks]

continued on the next page . . .

Question 4 (b) continued

4. (b) (ii) In the space provided, draw a diagram to show how you would combine three 5.0 mF capacitors to produce a capacitance of 7.5 mF.

Space for diagram:

[2 marks]

continued on the next page . . .

Question 4 continued

4. (c) Look at the diagram for Question 4 (c) in the separate Diagram Booklet.
The diagram represents a charged capacitor.

The separation of the plates of a charged capacitor is increased by the application of a force, F. The capacitor is ISOLATED so the charges on the plates remain unchanged.

(i) State why a force must be exerted to separate the charged plates.

_____

_____

_____

[1 mark]

continued on the next page . . .

Question 4 (c) continued

4. (c) (ii) Explain why the capacitor stores more ENERGY when the separation of the plates is increased even though the charge remains constant.

_____

_____

_____

_____

_____

[2 marks]

continued on the next page . . .

Question 4 (c) continued

4. (c) (iii) Show that the energy stored by the capacitor is given by:

$$\text{energy stored} = \frac{1}{2}\frac{Q^2 d}{\varepsilon_0 A}$$

where Q is the charge stored,

d is the separation of the plates,

ε_0 is the permittivity of free space and

A is the area of the plates.

[2 marks]

continued on the next page . . .

Question 4 (c) continued

4. (c) (iv) Bethan states that the force, F, required to separate the plates is given by:

$$F = \frac{1}{2}\frac{Q^2}{\varepsilon_0 A}$$

Determine whether Bethan is correct to arrive at this conclusion.

[2 marks]

(Total for Question 4 = 13 marks)

5. (a) (i) Derive the expression for the critical density of a flat universe.

$$\rho_c = \frac{3H_0^2}{8\pi G}$$

[4 marks]

5. (a) (ii) Use this equation to show that the critical density of the universe corresponds to approximately 5 hydrogen atoms per m^3.

[2 marks]

continued on the next page . . .

Question 5 continued

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

A two – star system has two stars of equal mass as shown in the diagram.

(i) State or calculate the position of the centre of mass of the two – star system.

_____

_____

_____

[1 mark]

continued on the next page . . .

Question 5 (b) continued

5. (b) (ii) Calculate the period of orbit of the stars about their centre of mass.

[2 marks]

continued on the next page . . .

Question 5 (b) continued

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

The diagram is NOT drawn to scale.

Calculate the maximum red shift (or blue shift) of the hydrogen 434 nm line due to the orbital motion of the stars.

[3 marks]

Question 5 continued

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

The centre of mass of this two – star system is also the point where the resultant gravitational field strength is zero. Explain why these points only coincide when the stars have identical masses.

[2 marks]

continued on the next page . . .

Question 5 continued

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

A different star system consists of three stars all of equal mass. Two stars orbit around a stationary black hole and the black hole is always halfway between the two stars as shown in the diagram.

(i) Explain why the resultant force on the black hole is always zero.

_____

_____

_____

[1 mark]

continued on the next page . . .

Question 5 (d) continued

5. (d) (ii) Explain why the gravitational force acting on either of the orbiting stars is five times greater in this three – star system than the two – star system of part (b).

_____

_____

_____

_____

_____

_____

[2 marks]

continued on the next page . . .

Question 5 (d) continued

5. (d) (iii) Joseff claims that the stars in the three – star system will provide a red shift that is five times larger than that of the two – star system of part (b). Evaluate whether or not he is correct.

[3 marks]

Question 5 continued

5. (e) A recent theoretical publication suggests that the decay of the Higgs Boson will give direct evidence for dark matter. Suggest what needs to be done for this theory to be generally accepted by scientists in the future.

[2 marks]

(Total for Question 5 = 22 marks)

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

Catrin carries out a Hall effect experiment to find out the number of free electrons per unit volume in a certain metal.
She places a wafer of the metal in a known magnetic field and passes a current through it (as shown in the diagram).

(i) By considering the forces acting on free electrons passing through the wafer, explain why a Hall voltage is measured on the voltmeter shown.

[4 marks]

continued on the next page . . .

Question 6 (a) continued

6. (a) (ii) By equating the magnetic and electrical forces, show that the Hall voltage, V_H, is given by:

$$V_H = Bvd$$

where B is the magnetic flux density, d is the width of the wafer and v is the drift velocity.

[3 marks]

Question 6 (a) continued

6. (a) (iii) Catrin states that her measured Hall voltage of 68.0 nV is consistent with a drift velocity of approximately 0.07 mm s^{-1}. Determine whether, or not, she is correct.

_____

_____

_____

_____

_____

[2 marks]

continued on the next page . . .

Question 6 (a) continued

6. (a) (iv) Calculate the number of free electrons per unit volume for the metal.

[3 marks]

continued on the next page . . .

Question 6 continued

6. (b) After repeating the same experiment on a different metal, Catrin obtains a value of $(5.85 \pm 0.19) \times 10^{28}\ m^{-3}$, for the number of free electrons per unit volume. Look at the table below.

Element	Free electron density / $10^{22}\ cm^{-3}$
Aluminium	18.1
Barium	3.15
Copper	8.47
Gold	5.90
Iron	17.0
Silver	5.86

She is given this table of values in order to determine which metal has been used in the experiment.

continued on the next page . . .

Question 6 (b) continued

Explain which metal(s) she should conclude has been used in the experiment.

[2 marks]

(Total for Question 6 = 14 marks)

END OF PAPER

TOTAL 80 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.

GCE A LEVEL

1420U40-1

FRIDAY, 10 JUNE 2022 – AFTERNOON

PHYSICS – A2 UNIT 4

FIELDS AND OPTIONS

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

Diagram Booklet

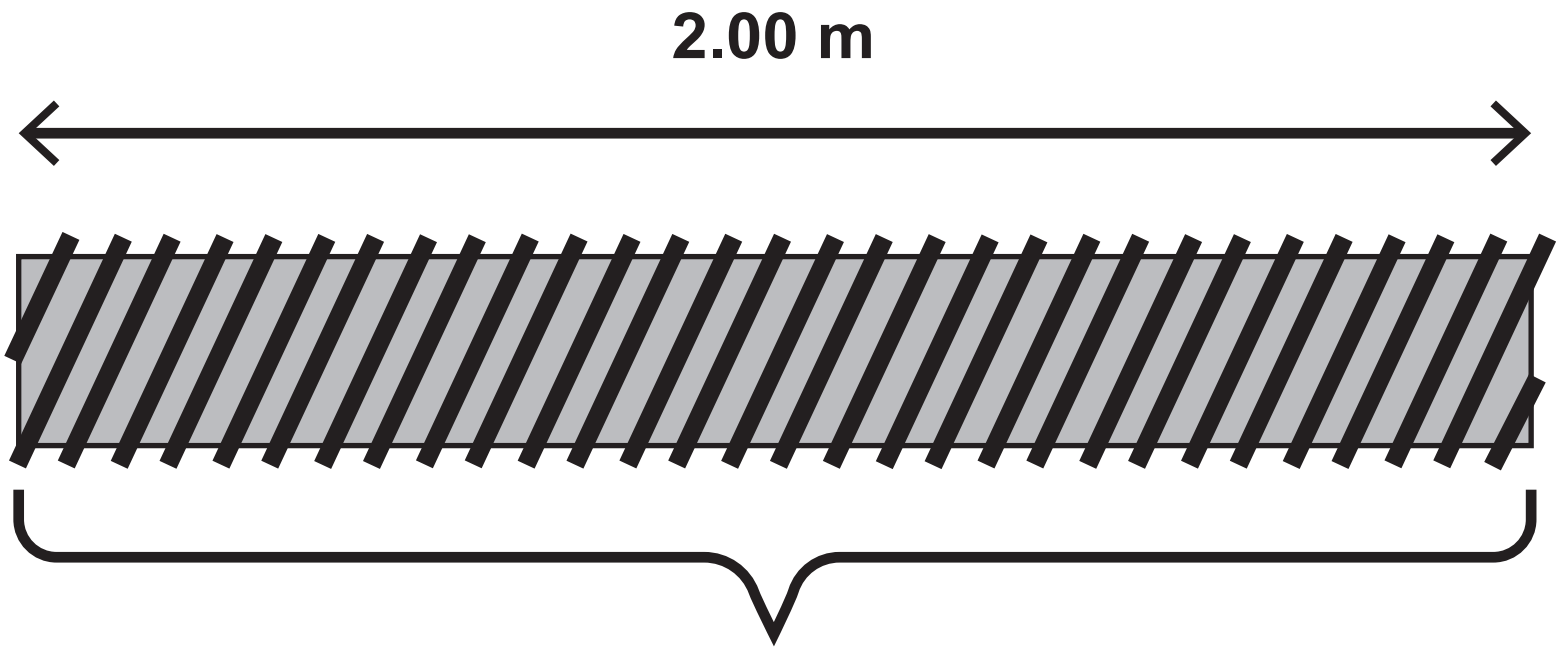
Surname: _____

First name(s): _____

Centre Number: _____

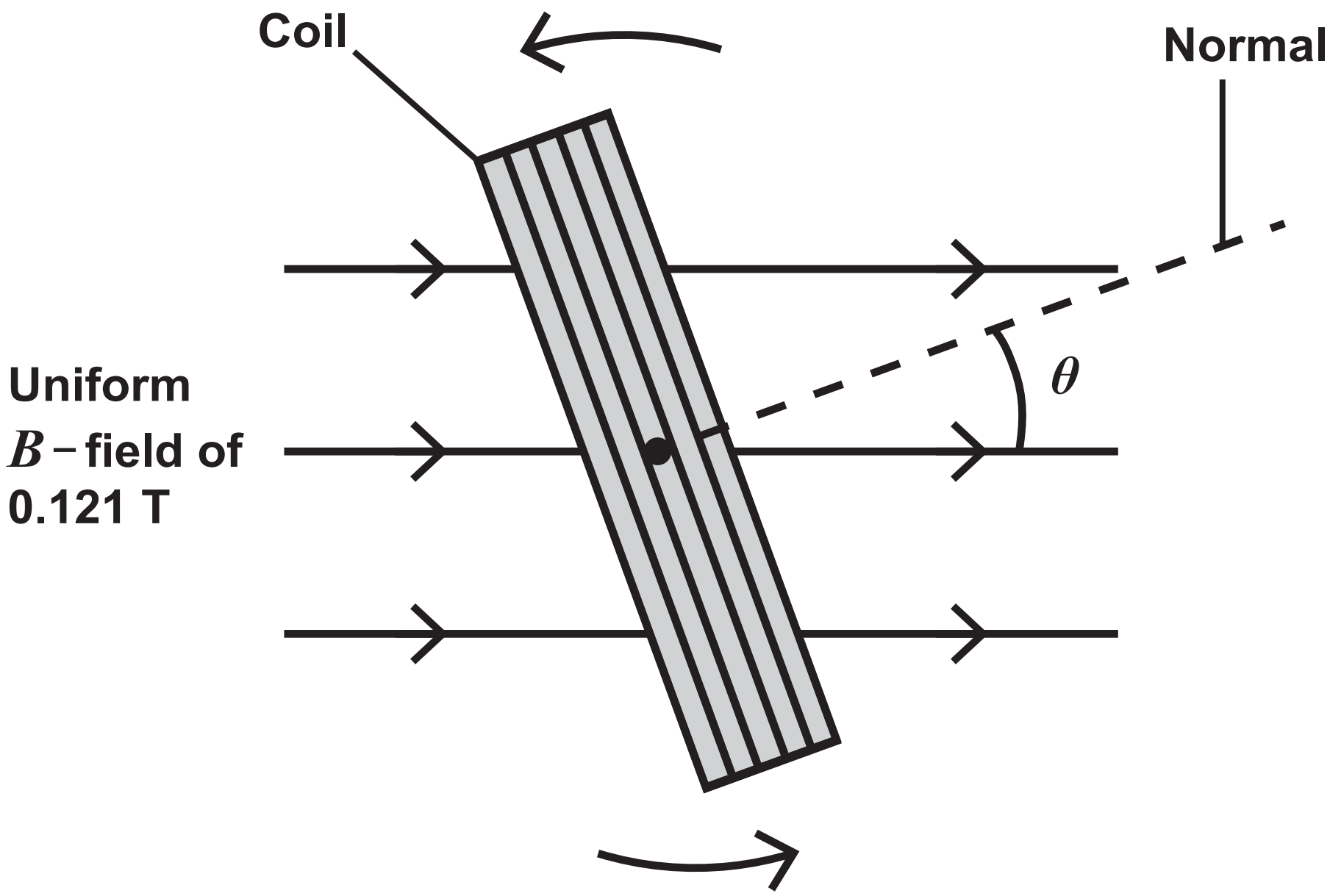
Candidate Number: 2 _____

Question 1 (a) (i)

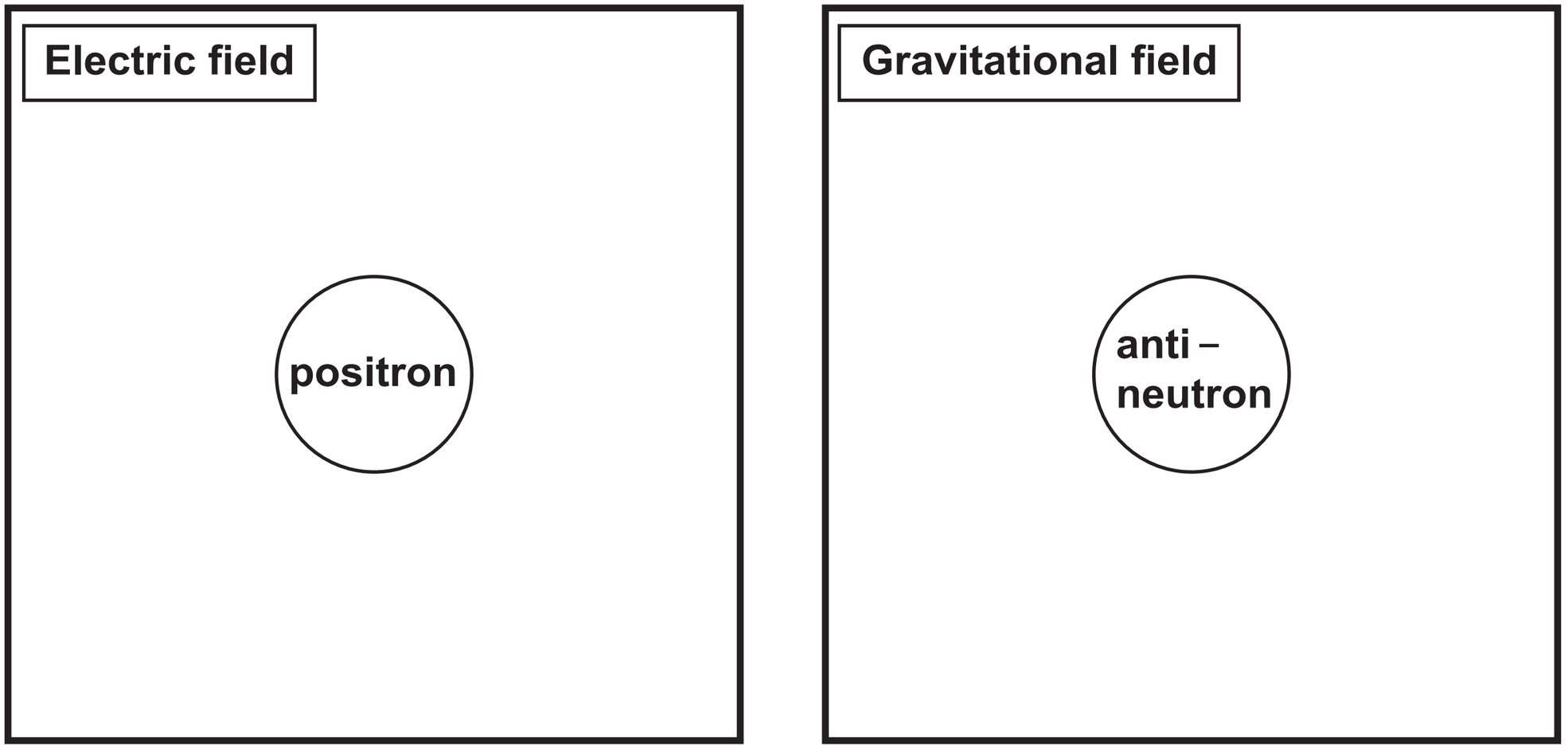


Total number of turns = 27 000

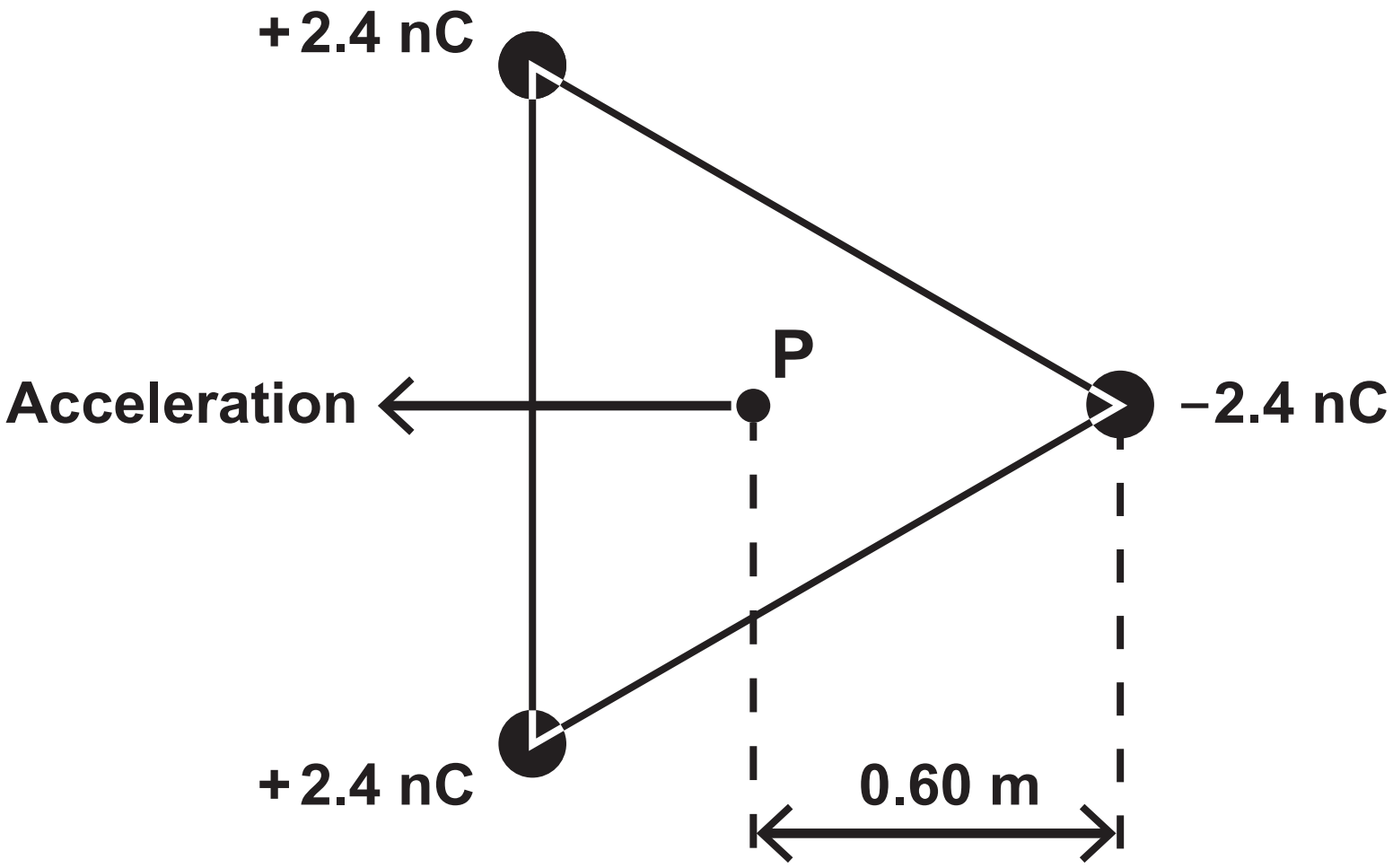
Question 1 (b)



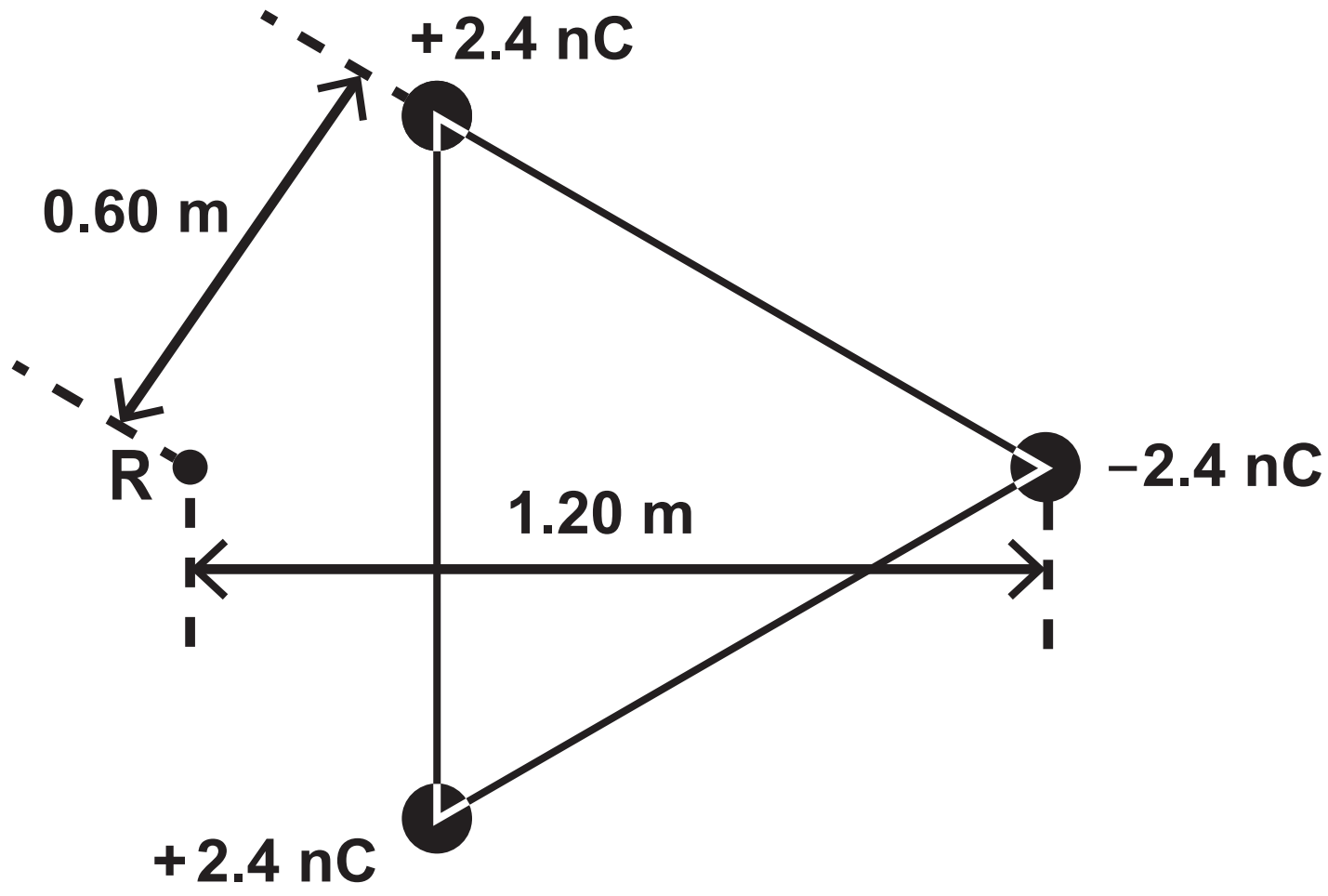
Question 2 (a)


Electric field
positron
Gravitational field
anti –
neutron

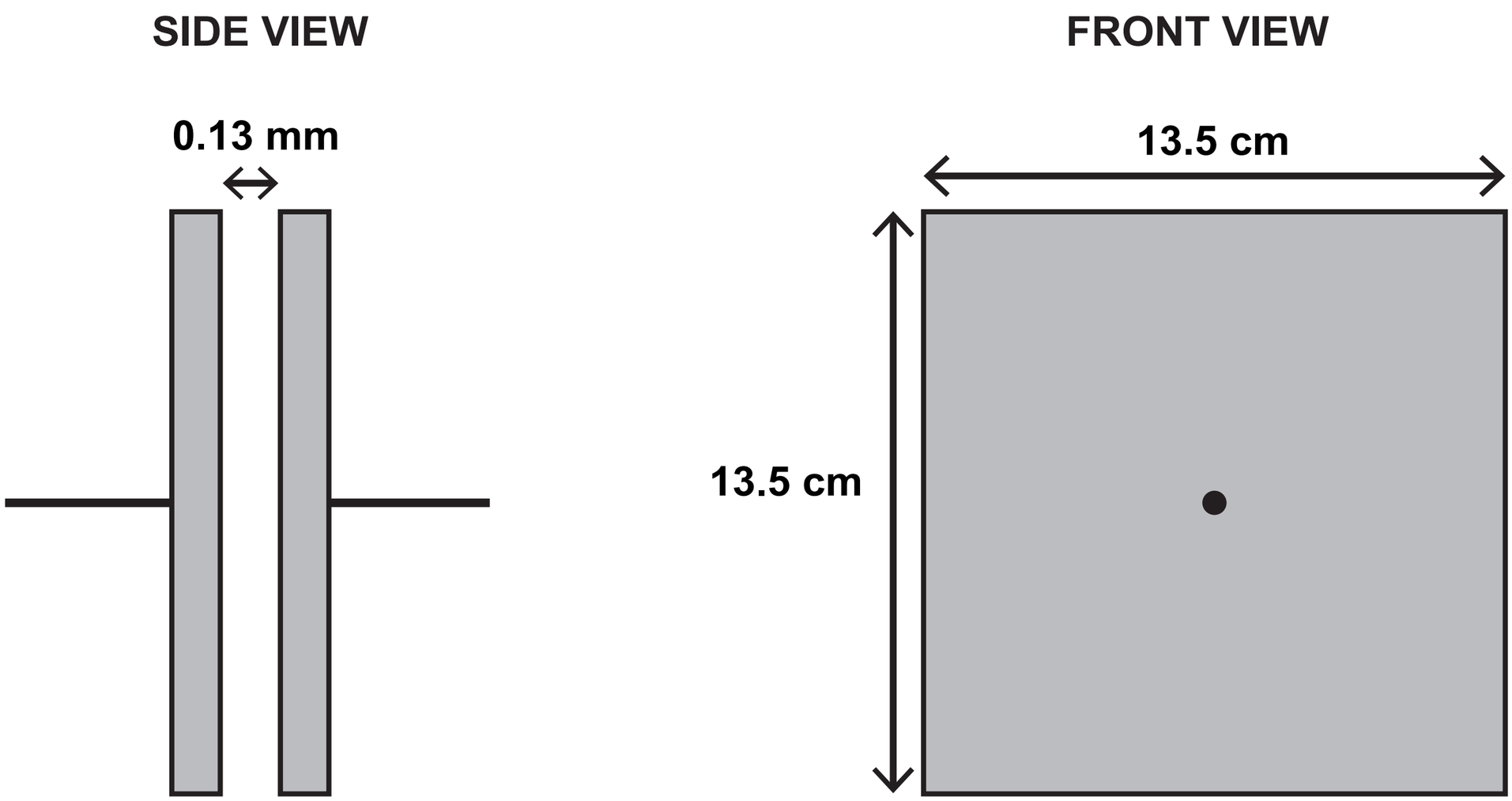
Question 3



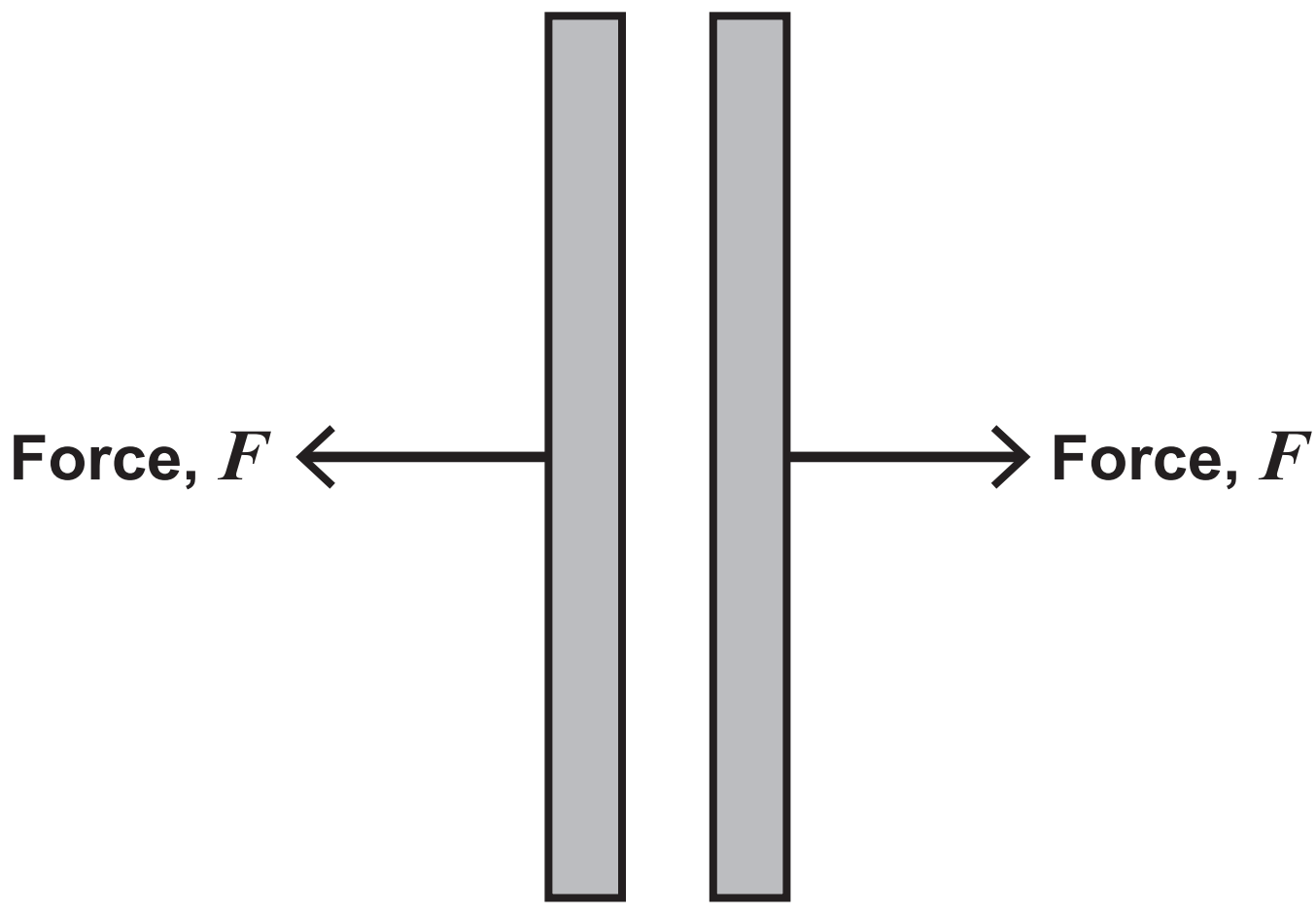
Question 3 (d)



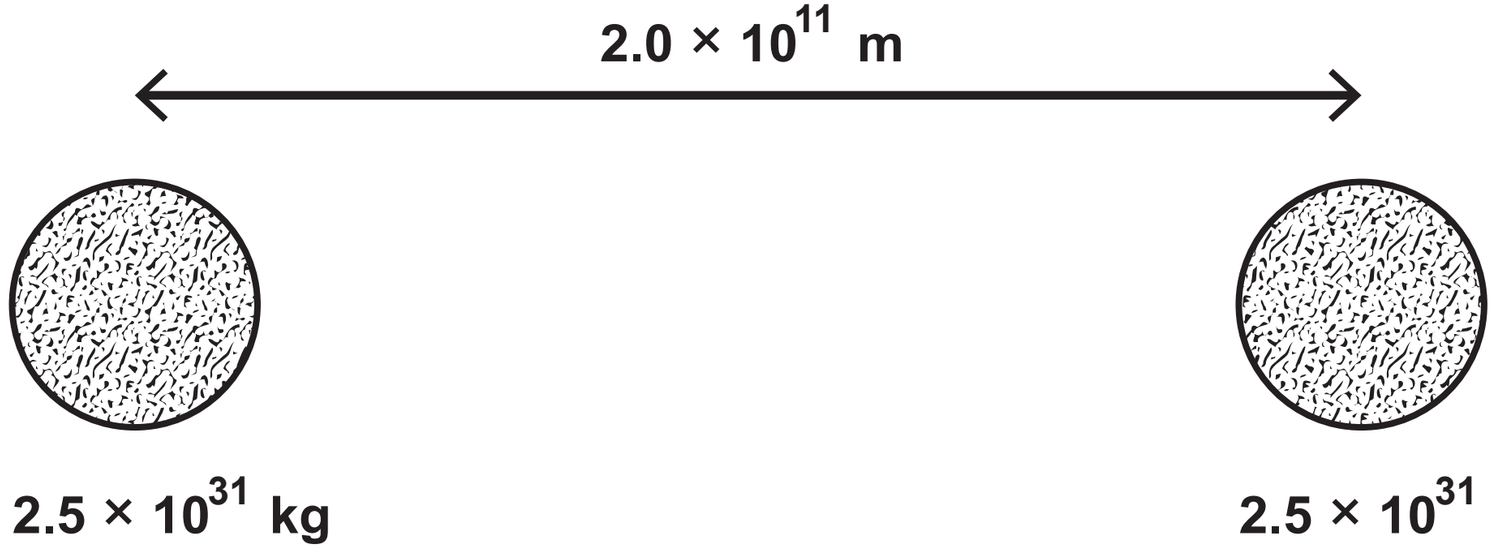
Question 4 (a)



Question 4 (c)

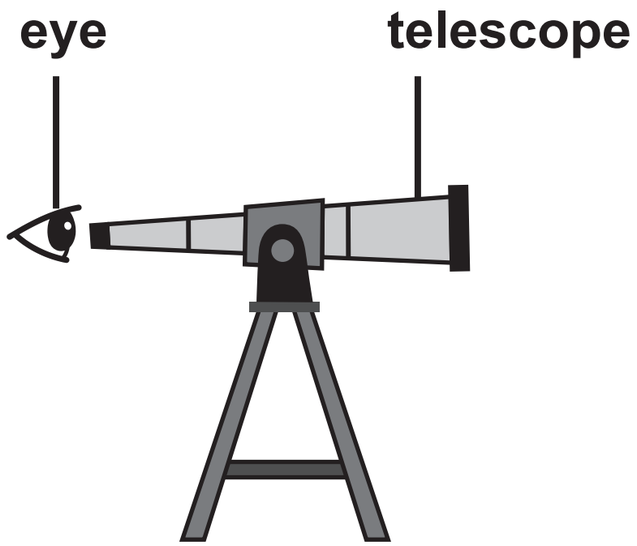


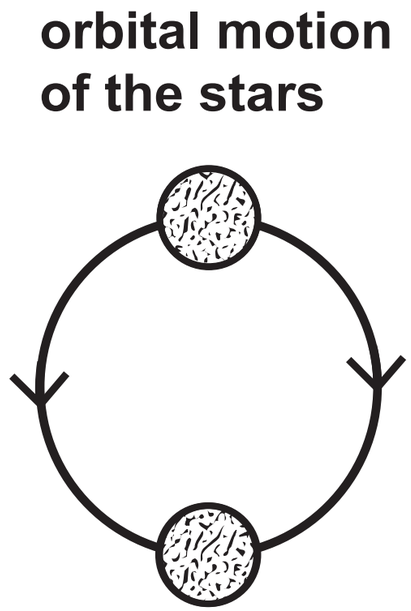
Question 5 (b)



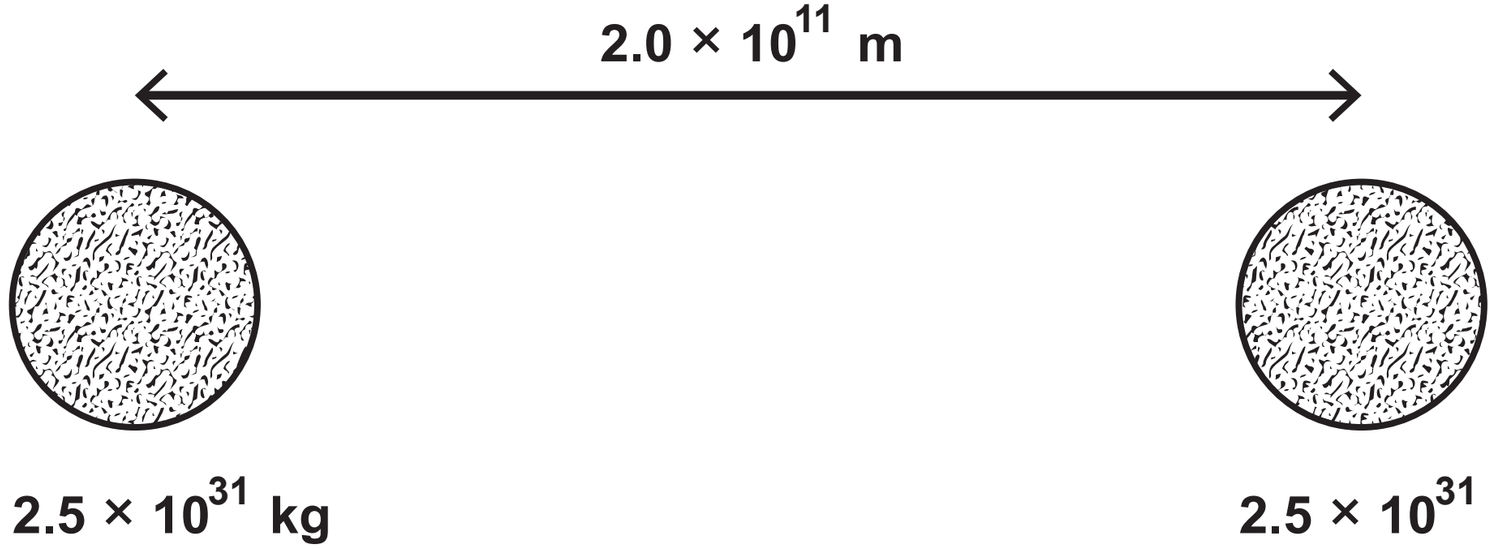
Question 5 (b) (iii)

Diagram NOT drawn to scale

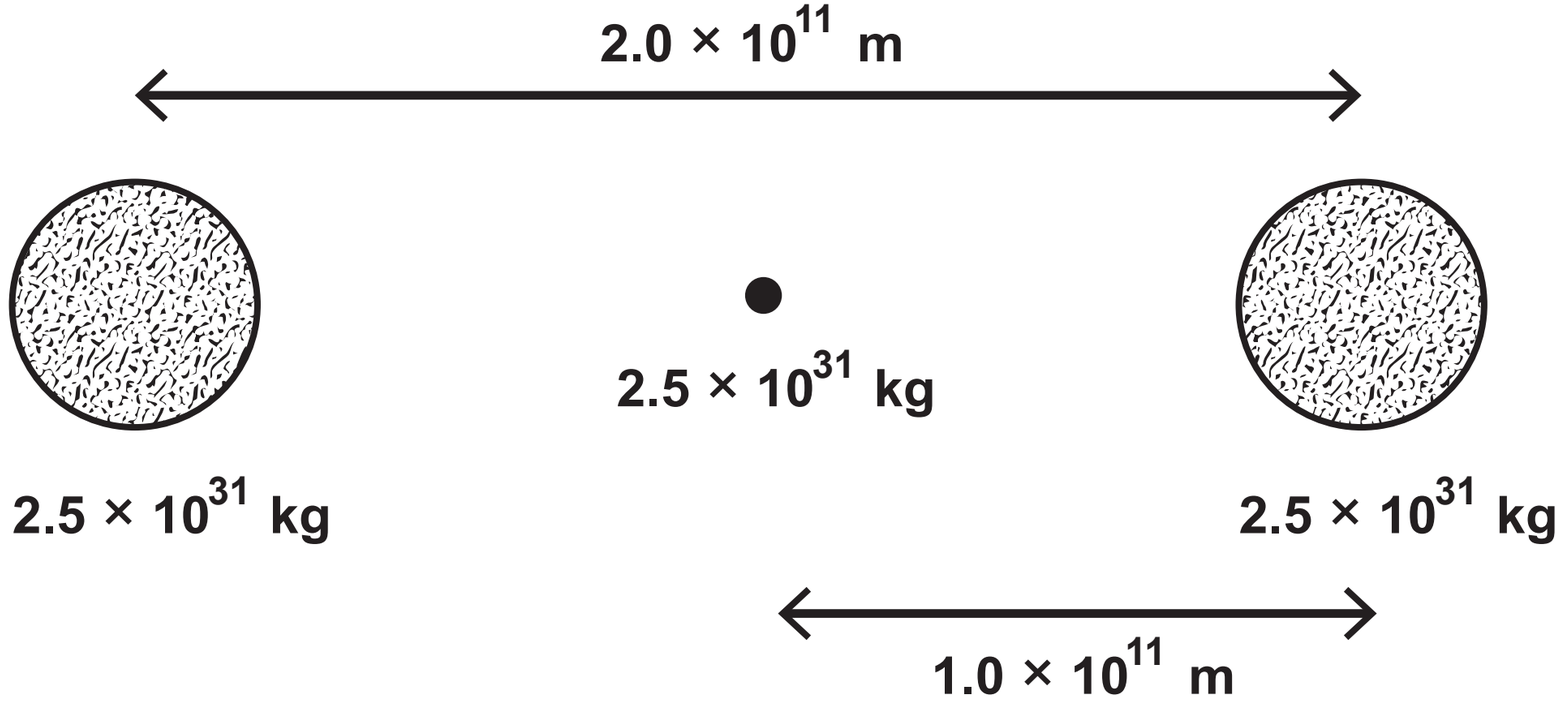




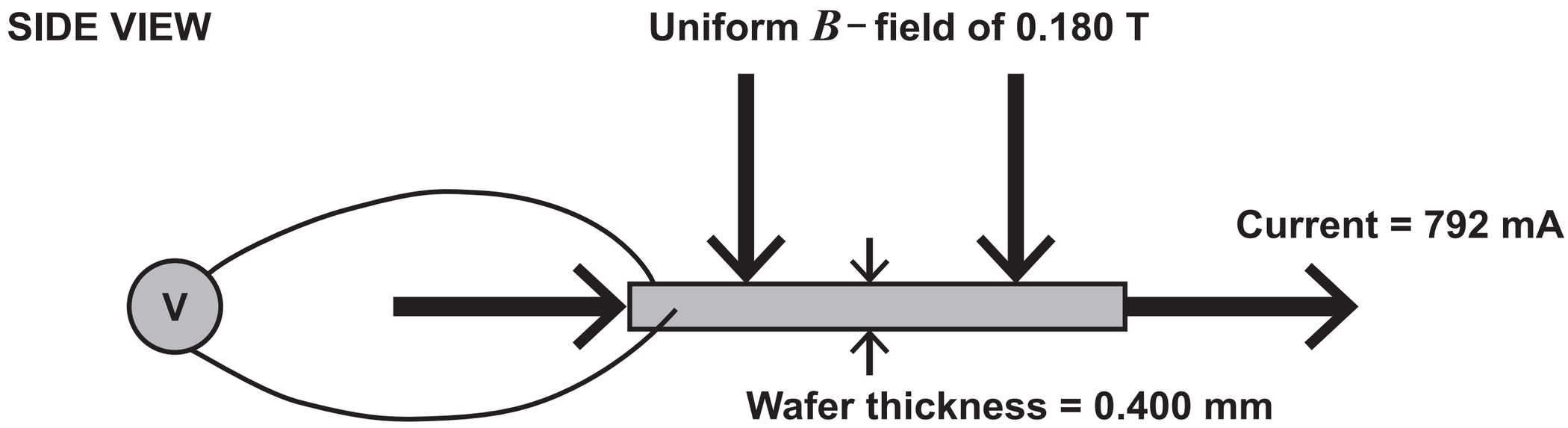
Question 5 (c)



Question 5 (d)


2.0×10^{11} m
2.5×10^{31} kg
2.5×10^{31} kg
2.5×10^{31} kg
1.0×10^{11} m

Question 6 (a)


SIDE VIEW
Uniform B – field of 0.180 T
V
Current = 792 mA
Wafer thickness = 0.400 mm
VIEW FROM ABOVE
V
Wafer width
= 5.20 mm
Current = 792 mA