



**GCE A LEVEL**



**A420U10-1**

**WEDNESDAY, 24 MAY 2023 – AFTERNOON**

**PHYSICS – A LEVEL COMPONENT 1**

**NEWTONIAN PHYSICS**

**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.    | 12                      |              |              |
|           | 2.    | 11                      |              |              |
|           | 3.    | 9                       |              |              |
|           | 4.    | 10                      |              |              |
|           | 5.    | 8                       |              |              |
|           | 6.    | 21                      |              |              |
|           | 7.    | 9                       |              |              |
| SECTION B | 8.    | 20                      |              |              |
|           | Total | 100                     |              |              |

(Turn over)

**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.**

**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**

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

**Section A: 80 marks.**

**You are advised to spend about 1 hour 35 minutes, plus your additional time allowance, on this section.**

**Section B: 20 marks. Comprehension.**

**You are advised to spend about 40 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 6 (c).**

**SECTION A****ANSWER ALL QUESTIONS.**

- 1. Look at the diagram for Question 1 in the separate Diagram Booklet.**

The diagram shows the set – up Lily uses to determine the weight,  $W$ , of a uniform metre ruler.

The ruler is suspended by a thread at the **0.100 m** mark and a newton meter at the **0.900 m** mark. Lily varies the position of the **0.60 kg** mass, each time adjusting the height of the newton meter until the ruler is horizontal. The reading on the newton meter is then recorded.

**continued on the next page . . .**

**Question 1 continued**

- 1. (a) Suggest how Lily should ensure that the ruler is horizontal.**

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**[1 mark]**

- (b) Define the centre of gravity of an object and clearly SHOW THE POSITION of the centre of gravity of the ruler on the diagram.**

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**[2 marks]**

**continued on the next page . . .**

**(Turn over)**

**Question 1 continued**

**1. (c) (i) State the principle of moments.**

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**[2 marks]**

**continued on the next page . . .**

**(Turn over)**

**Question 1 (c) continued**

1. (c) (ii) By taking moments, show that the tension,  $T$ , in the newton meter is given by:

$$T = ax + \frac{W}{2} \quad \text{in which} \quad a = 7.36 \text{ N m}^{-1}$$

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[2 marks]

continued on the next page . . .

(Turn over)

**Question 1 continued**

- 1. (d) Look at the table for Question 1 (d) in the separate Diagram Booklet. Lily's results are shown in the table.**

- (i) Using all the values in the table, Lily calculates the mean weight of the ruler to be  $(1.0 \pm 0.5)$  N.**

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

**The diagram shows a grid.**

**Evan suggests an alternative approach using a graphical method. Evan used Lily's original results and plotted the points on the grid.**

**By drawing a suitable line determine the weight of the ruler. Error bars are not required.**

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**[3 marks]**

**continued on the next page . . .**

**(Turn over)**

**Question 1 (d) continued**

- 1. (d) (ii) The actual weight of the ruler is known to be 1.18 N.**

**Evaluate the suitability of Lily and Evan's methods in determining the weight of the ruler,  $W$ .**

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**[2 marks]**

**(Total for Question 1 = 12 marks)**

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**(Turn over)**

Show that the rate of energy transfer by the heater when operating at **10.0 V** is approximately **20 W**.

[illegible]

**(Turn over)**

**Question 2 continued**

- 2. (b) Look at the diagram for Question 2 (b) in the separate Diagram Booklet.**

**The diagram shows how the heating coil is used inside a copper container to determine the specific heat capacity of water.**

- (i) Define the specific heat capacity of a material.**

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**[2 marks]**

**continued on the next page . . .**

**(Turn over)**

**Question 2 (b) continued**

2. (b) (ii) The heating coil is switched on for **5.0** minutes before being switched off. Use the following information to determine the specific heat capacity of water:

**Mass of copper container = 0.080 kg**

**Specific heat capacity of copper**

**= 380 J kg<sup>-1</sup> °C<sup>-1</sup>**

**Volume of water = 190 cm<sup>3</sup>**

**Density of water = 0.997 g cm<sup>-3</sup>**

**Temperature rise = 8.0°C**

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**[3 marks]**

**continued on the next page . . .**

**(Turn over)**

**Question 2 (b) continued**

2. (b) (iii) Zayn repeated the experiment and noted that the room temperature was **16.0°C**. Before he started the heating process, he cooled the apparatus to **12.0°C** in a refrigerator. Discuss whether this is good experimental practice.

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**[2 marks]**

**(Total for Question 2 = 11 marks)**

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**(Turn over)**

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

**The diagram is a graph.**

**The graph shows how a skydiver's vertical velocity changes with time during part of her descent.**

- (a) The skydiver is very close to her terminal velocity after 20 seconds. Explain, making reference to air molecules, how this velocity arises.**

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**[3 marks]**

**(Turn over)**

### Question 3 continued

- 3. (b) The mass of the skydiver is 68 kg.**

**Use the graph to determine an estimate for the vertical force of air resistance after 7.5 seconds.**

[illegible]

**[4 marks]**

**continued on the next page . . .**

**(Turn over)**

**Question 3 continued**

- 3. (c) NASA, funded by the American government, has developed parachutes that will safely land spacecraft on other planets. It has also been involved in the development of parachutes that can safely return a light aircraft to Earth in the event of a fault in flight.**

**Discuss whether you believe this to be an ethical use of the money.**

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**[2 marks]**

**(Total for Question 3 = 9 marks)**

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**(Turn over)**

4. (a) The first law of thermodynamics may be written as:

$$\Delta U = Q - W$$

A student INCORRECTLY defines the terms from the first law of thermodynamics as shown below:

$\Delta U$  = Increase in temperature

$W$  = Work done

$Q$  = Heat in a system

In each case, write the correct definition for the term.

$\Delta U$  = \_\_\_\_\_

\_\_\_\_\_

$W$  = \_\_\_\_\_

\_\_\_\_\_

$Q$  = \_\_\_\_\_

\_\_\_\_\_

[3 marks]

(Turn over)

**Question 4 continued**

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

**The diagram is a graph.**

**A cylinder with a leak proof piston contains  $0.10 \text{ mol}$  of an ideal monatomic gas. The gas is taken through the following processes that result in changes in pressure and volume, as shown in the graph.**

- (i) Confirm that the process  $A \rightarrow B$  is isothermal (i.e. it takes place at a constant temperature).**

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**[2 marks]**

**(Turn over)**

**Question 4 (b) continued**

4. (b) (ii) Show that the work done during the process  $A \rightarrow B$  is approximately **330 J**.

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**[2 marks]**

**continued on the next page . . .**

**(Turn over)**

**Question 4 (b) continued**

**4. (b) (iii) Joseph considers the whole process**

$$\mathbf{A \rightarrow B \rightarrow C \rightarrow A.}$$

**He calculates the heat flow into the system to be 150 J. Grace disagrees, and states that 150 J of heat would flow out of the system.**

**Determine if either Joseph or Grace is correct.**

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**[3 marks]**

**(Total for Question 4 = 10 marks)**

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**(Turn over)**

**5. (a) Define power.**

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**[1 mark]**

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

**The diagram represents a garden water feature.**

**In the garden water feature, water from a pool is pumped through a vertical pipe which is open to the air at its top end.**

**The rate of flow is  $0.15 \text{ kg s}^{-1}$ , and the height gained by the water in reaching the nozzle is **1.3 m**.**

**continued on the next page . . .**

**(Turn over)**

**Question 5 (b) continued**

- 5. (b) (i) Calculate the water's rate of gain of gravitational potential energy in rising through this height.**

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**[2 marks]**

**continued on the next page . . .**

**(Turn over)**

**Question 5 (b) continued**

5. (b) (ii) The speed at which water travels up the pipe is  $3.5 \text{ m s}^{-1}$

Leo claims that a significant amount of power is used to give the water kinetic energy. Evaluate Leo's claim.

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[2 marks]

continued on the next page . . .

(Turn over)

**Question 5 (b) continued**

5. (b) (iii) The pump is electric and is supplied with a pd of **12 V**. When it is pumping, the current through it is **0.65 A**. Calculate the efficiency of the pump.

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**[3 marks]**

**(Total for Question 5 = 8 marks)**

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**(Turn over)**

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

The diagram shows a simple pendulum of length  $l$  consisting of a small bob (a metal sphere), of mass  $m$ , hanging by a light thread from a fixed support.

Show that when the pendulum is at a SMALL ANGLE,  $\theta$ , to the vertical, the bob's acceleration,  $a$ , IN A DIRECTION AT RIGHT ANGLES TO THE THREAD is approximately:

$$a = g \theta$$

You may add to the diagram.

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**[3 marks]**

**continued on the next page . . .**

**(Turn over)**

**Question 6 continued**

- 6. (b) Look at the diagram for Question 6 (b) in the separate Diagram Booklet.**

**The diagram shows a graph of velocity,  $v$ , against time,  $t$ , for a simple pendulum swinging through small angles.**

- (i) Show that the length of the pendulum is approximately 0.5 m.**

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**[3 marks]**

**continued on the next page . . .**

**(Turn over)**

**Question 6 (b) continued**

**6. (b) (ii) The mass of the bob is 0.12 kg.**

- I. Show that the maximum kinetic energy of the bob is approximately 2 mJ.**

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**[2 marks]**

**continued on the next page . . .**

**(Turn over)**

**Question 6 (b) (ii) continued**

- 6. (b) (ii) II. Look at the diagram for Question 6 (b) (ii) II. in the separate Diagram Booklet. The diagram shows a graph and a blank grid.**

**ON THE BLANK GRID, SKETCH A GRAPH of the bob's gravitational potential energy (GPE) against time (the upper graph is provided for reference). Take the GPE to be zero when the bob is at its lowest point.**

**[3 marks]**

**continued on the next page . . .**

**Question 6 (b) continued**

- 6. (b) (iii) I. Calculate the centripetal acceleration of the bob at the bottom of its swing.**

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**[2 marks]**

- II. At the bottom of the swing the tension in the thread is greater than the weight of the bob. Explain why this is so.**

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**[2 marks]**

**(Turn over)**

**Question 6 continued**

- 6. (c) Look at the diagram for Question 6 (c) in the separate Diagram Booklet.**

**The diagram shows an experimental set – up.**

**Describe briefly how you would investigate FORCED oscillations using a mass and spring as the oscillating system, as in the set – up shown, and describe carefully what you would expect to find out about the amplitude of the forced oscillations.**

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**(Total for Question 6 = 21 marks)**

**(Turn over)**

7. (a) Explain why, according to the kinetic theory, a gas exerts a pressure on the walls of its container. You will need to use the idea of momentum as well as that of pressure.

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[3 marks]

continued on the next page . . .

(Turn over)

## Question 7 continued

7. (b) At one instant, three molecules in a sample of a gas have speeds in  $\text{m s}^{-1}$  of 394, 453 and 527  
Calculate their rms speed.

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[2 marks]

continued on the next page . . .

(Turn over)

## Question 7 continued

7. (c) The speed of sound,  $v_s$ , in nitrogen at three temperatures is given below.

| Temperature / K         | 100 | 200 | 300 |
|-------------------------|-----|-----|-----|
| $v_s / \text{m s}^{-1}$ | 204 | 288 | 353 |

There is a simple mathematical relationship between  $v_s$  and  $c_{\text{rms}}$ , the rms speed of nitrogen molecules at the same temperature.

continued on the next page . . .

(Turn over)

### Question 7 (c) continued

**Determine this relationship, showing your reasoning. (Relative molecular mass of nitrogen molecule = 28)**

[illegible]

**[4 marks]**

**(Total for Question 7 = 9 marks)**

**(Turn over)**

**SECTION B**

**ANSWER ALL QUESTIONS.**

- 8. Read through the following article carefully.**

**BULGES AND SUPERMASSIVE BLACK HOLES**

**PARAGRAPH 1**

**It could be argued that dark matter was first predicted by Lord Kelvin in 1884.**

**He concluded that “many of our stars, perhaps a great majority of them, may be dark bodies” after he analysed the variation of velocity of stars in the Milky Way with distance from the centre. Modern astrophysicists tend to agree with Lord Kelvin but they generally accept that the “dark bodies” are some kind of dark matter.**

**continued on the next page . . .**

**(Turn over)**

**Question 8 continued**

**PARAGRAPH 2**

**Look at Diagram 1 for Question 8  
in the separate Diagram Booklet.**

**The diagram shows a spiral galaxy and its  
central bulge.**

**PARAGRAPH 3**

**We can actually get an insight into the effect  
of the galactic central bulge by using A level  
physics if we assume that the bulge is uniform  
and spherical.**

**continued on the next page . . .**

**Question 8 continued****PARAGRAPH 4**

**Our standard equation for the motion of an object in orbit around a spherical mass is:**

**EQUATION 1**

$$\frac{mv^2}{r} = \frac{GMm}{r^2}$$

**where  $G$  is the gravitational constant,  $r$  is the radius of the object's orbit and  $M$  is the mass being orbited. This also applies for objects in orbit around the centre of a galaxy. It turns out that the effects of a uniform distribution of mass outside the object's orbit will all cancel and we only have to consider the mass inside the orbit. Furthermore, we can consider the mass of the bulge inside the orbit as being a point mass at the centre of the galaxy.**

**continued on the next page . . .**

**(Turn over)**

**Question 8 continued****PARAGRAPH 5**

If we assume that the galactic bulge has a density of  $\rho$ , then the mass of the bulge inside a radius  $r$  is:

**EQUATION 2**

$$M = \frac{4}{3} \pi r^3 \rho$$

**PARAGRAPH 6**

When Equations 1 and 2 are combined, you expect the orbital velocity of stars inside the galactic bulge to be proportional to this orbital radius.

continued on the next page . . .

**Question 8 continued****PARAGRAPH 7**

However, when we look at the actual orbital velocities as a function of distance from the centre of the Milky Way (radius of orbit), we get something slightly different:

Look at Diagram 2 for Question 8 in the separate Diagram Booklet.

The diagram is a plot of  $\log_{10} (v / \text{m s}^{-1})$  against  $\log_{10} (r / \text{m})$ .

continued on the next page . . .

**Question 8 continued****PARAGRAPH 8**

For the  $\log_{10}(v / \text{m s}^{-1})$  against  $\log_{10}(r / \text{m})$  plot shown in Diagram 2, the steepest part on the right side has a gradient of approximately **+ 1** as you would expect because this part is inside the galactic bulge of the Milky Way. However, the left side of the plot has a gradient of approximately **– 0.5**

This is evidence that there is a supermassive black hole of mass approximately

**$8 \times 10^{36}$  kg** (four million times more massive than our Sun) in the centre of the galaxy.

continued on the next page . . .

**Question 8 continued****PARAGRAPH 9**

The supermassive black hole has a name – Sagittarius  $A^*$  – and is responsible for two enormous bubbles that were belched out around 6 – 9 million years ago.

This is represented in Diagram 3 for Question 8 in the separate Diagram Booklet.

**PARAGRAPH 10**

These bubbles were discovered in 2010 and it is estimated that they have a total mass very close to the actual mass of Sagittarius  $A^*$  (an impressive burp!). Although Diagram 3 is only an artist's impression of the jets and Fermi bubbles, a particularly photogenic jet can be seen in galaxy M87 (see Diagram 4 for Question 8 in the separate Diagram Booklet).

continued on the next page . . .

(Turn over)

**Question 8 continued****PARAGRAPH 11**

**There is a second jet travelling in the opposite direction but it can't be seen as visible light due to the Doppler effect.**

**PARAGRAPH 12**

**Now, some bright sparks among you might be thinking that the Fermi bubbles in Diagram 3 might be able to provide enough of a gravitational force to account for dark matter. Unfortunately, their mass is around 100 000 times too small. But what if there have been 100 000 burps? Could these jets from supermassive black holes be the answer to life, the Universe and everything?**

**continued on the next page . . .**

**Question 8 continued**

**Answer the following questions in your own words. Direct quotes from the original article will not be awarded marks.**

- 8. (a) Explain the meanings of the left – hand side and right – hand side of Equation 1.**

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**[2 marks]**

**continued on the next page . . .**

**(Turn over)**

**Question 8 continued**

- 8. (b) Use forces to explain why it is feasible that the bulge inside the star's orbit affects its orbit whereas the bulge outside its orbit does not (see Diagram 5 for Question 8 in the separate Diagram Booklet and paragraph 4).**

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**[2 marks]**

**continued on the next page . . .**

**(Turn over)**

**Question 8 continued**

- 8. (c) Derive an expression for the velocity of stars inside the bulge as a function of radius and the density of the bulge (see Equations 1 and 2 and paragraph 6).**

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**[3 marks]**

**continued on the next page . . .**

**(Turn over)**

**Question 8 continued**

8. (d) (i) Explain why you would expect the gradient of the **LEFT SIDE** of the graph to be **– 0.5**
- (See paragraph 8, Diagram 2 and HINT: you should explain why using the equation  $v = \sqrt{\frac{GM}{r}}$  is valid.)

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**[3 marks]**

**continued on the next page . . .**

**(Turn over)**

**Question 8 (d) continued**

8. (d) (ii) Use the data point with the smallest radius to determine whether, or not, the central supermassive black hole has a mass of approximately  $8 \times 10^{36}$  kg.

(See paragraph 8 and use the relationship for a mass orbiting a

central large mass  $v = \sqrt{\frac{GM}{r}}$  ).

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**[4 marks]**

**continued on the next page . . .**

**(Turn over)**

**Question 8 continued**

- 8. (e) Assuming that the Fermi bubbles (belched gas) came from the central supermassive black hole over a period of 2 million years, calculate the rate of ejection of mass IN SOLAR MASSES PER YEAR (see paragraphs 8 and 10).**

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**[2 marks]**

**continued on the next page . . .**

**(Turn over)**

**Question 8 continued**

8. (f) In your own words, explain why the  
**2nd jet from galaxy M87** can't be seen  
(see paragraph 11).

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**[2 marks]**

**continued on the next page . . .**

**(Turn over)**

**Question 8 continued**

8. (g) In the last paragraph, the author suggests that Fermi bubbles and gas ejected from supermassive black holes might account for dark matter. Comment on whether you think this is feasible and what steps might be taken to prove / disprove this theory.

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[2 marks]

(Total for Question 8 = 20 marks)

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**END OF PAPER**

**TOTAL 100 MARKS**

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(Turn over)

| <b>Question<br/>number</b> | <b>Additional pages, if required. Write the<br/>question number(s) in the left - hand margin.</b>                                   |
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[illegible]



**GCE A LEVEL**



**A420U10-1**

**WEDNESDAY, 24 MAY 2023 – AFTERNOON**

**PHYSICS – A LEVEL COMPONENT 1**

**NEWTONIAN PHYSICS**

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

# **Diagram Booklet**

**Surname:** \_\_\_\_\_

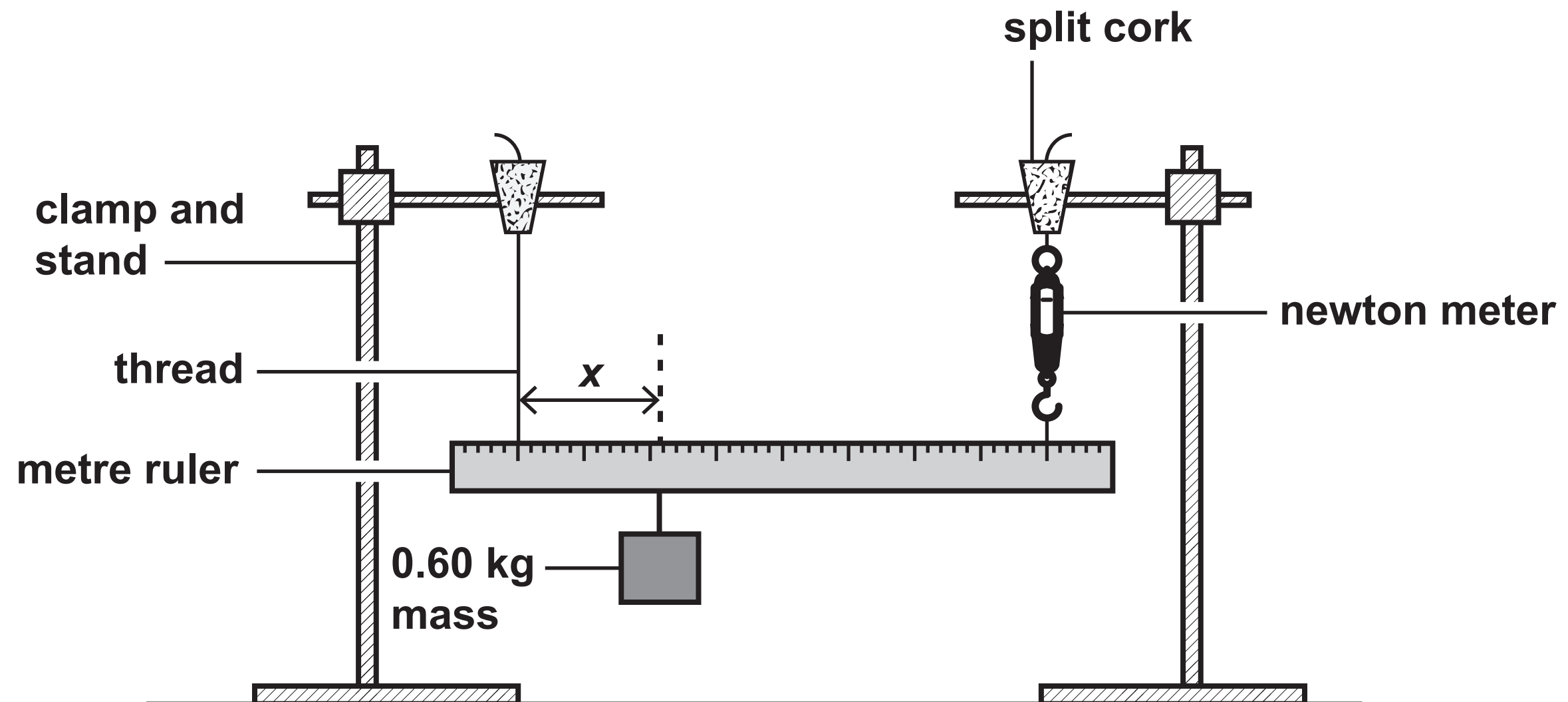
**First name(s):** \_\_\_\_\_

**Centre Number:** \_\_\_\_\_

**Candidate Number:** 2 \_\_\_\_\_

## Question 1

Diagram NOT drawn to scale

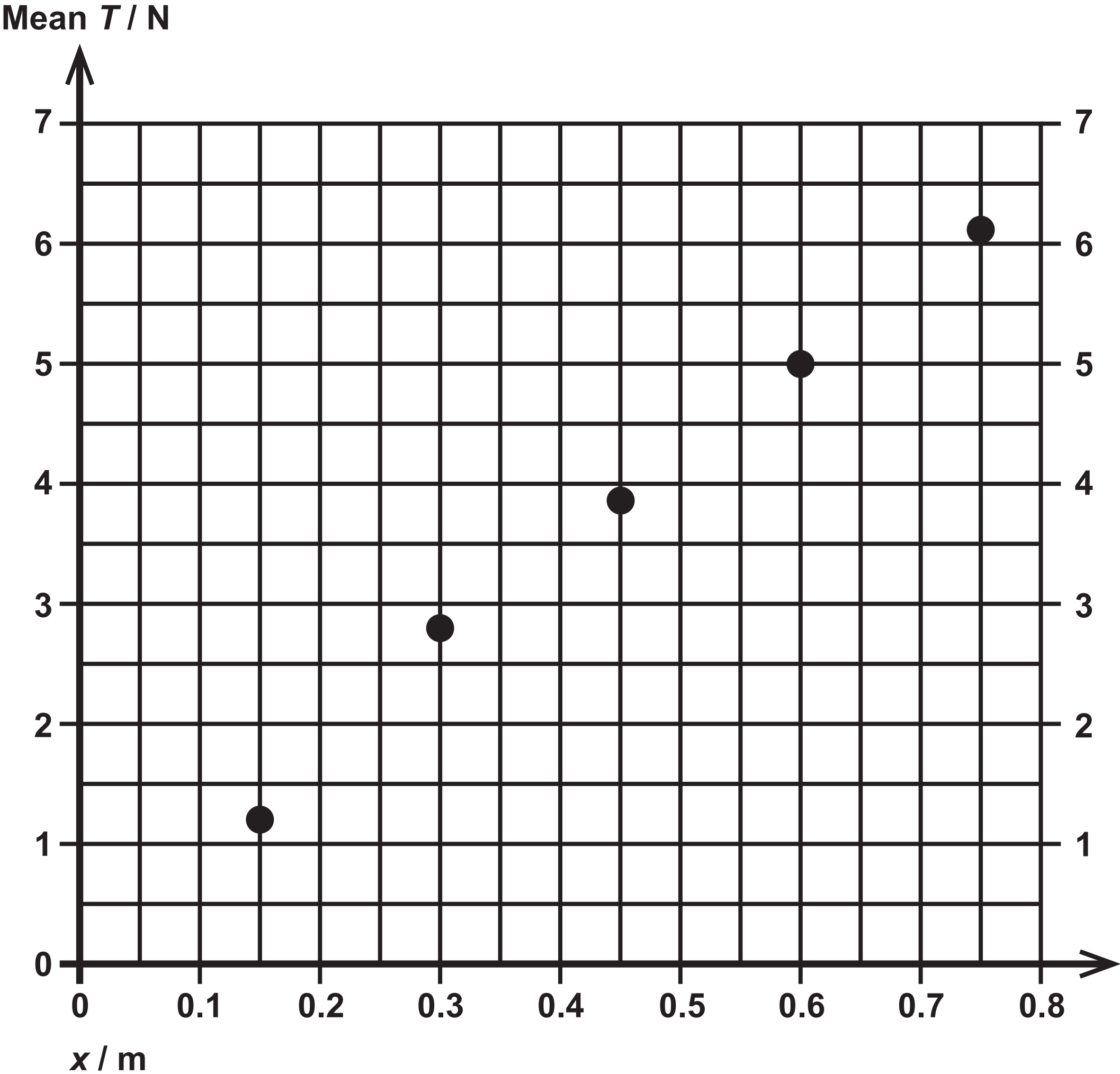


### Question 1 (d)

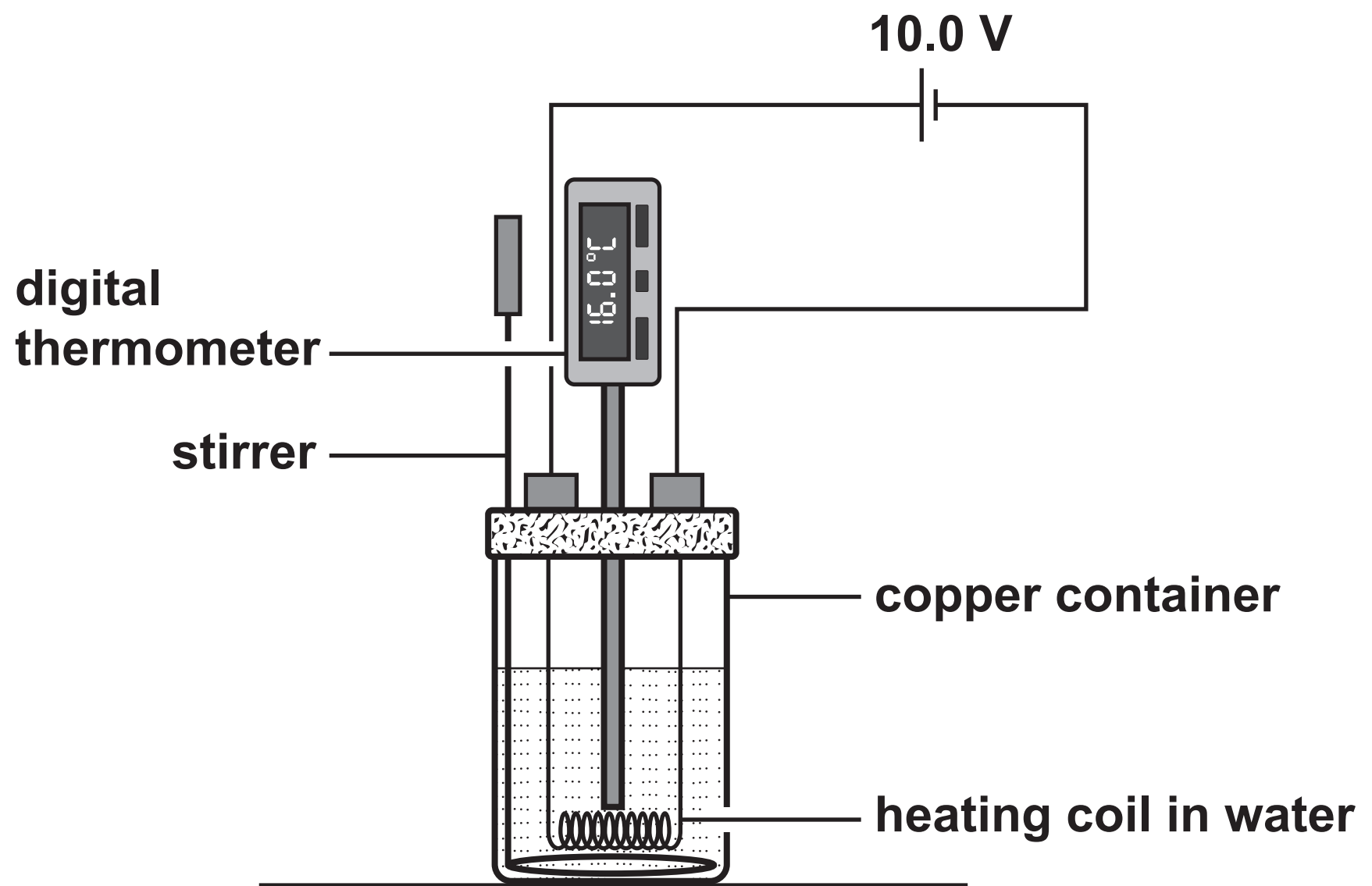
Table

| $x/\text{m}$ | $T/\text{N}$ |           |      |
|--------------|--------------|-----------|------|
|              | Reading 1    | Reading 2 | Mean |
| 0.150        | 1.2          | 1.2       | 1.2  |
| 0.300        | 2.8          | 2.8       | 2.8  |
| 0.450        | 3.9          | 3.9       | 3.9  |
| 0.600        | 5.0          | 4.9       | 5.0  |
| 0.750        | 6.1          | 6.1       | 6.1  |

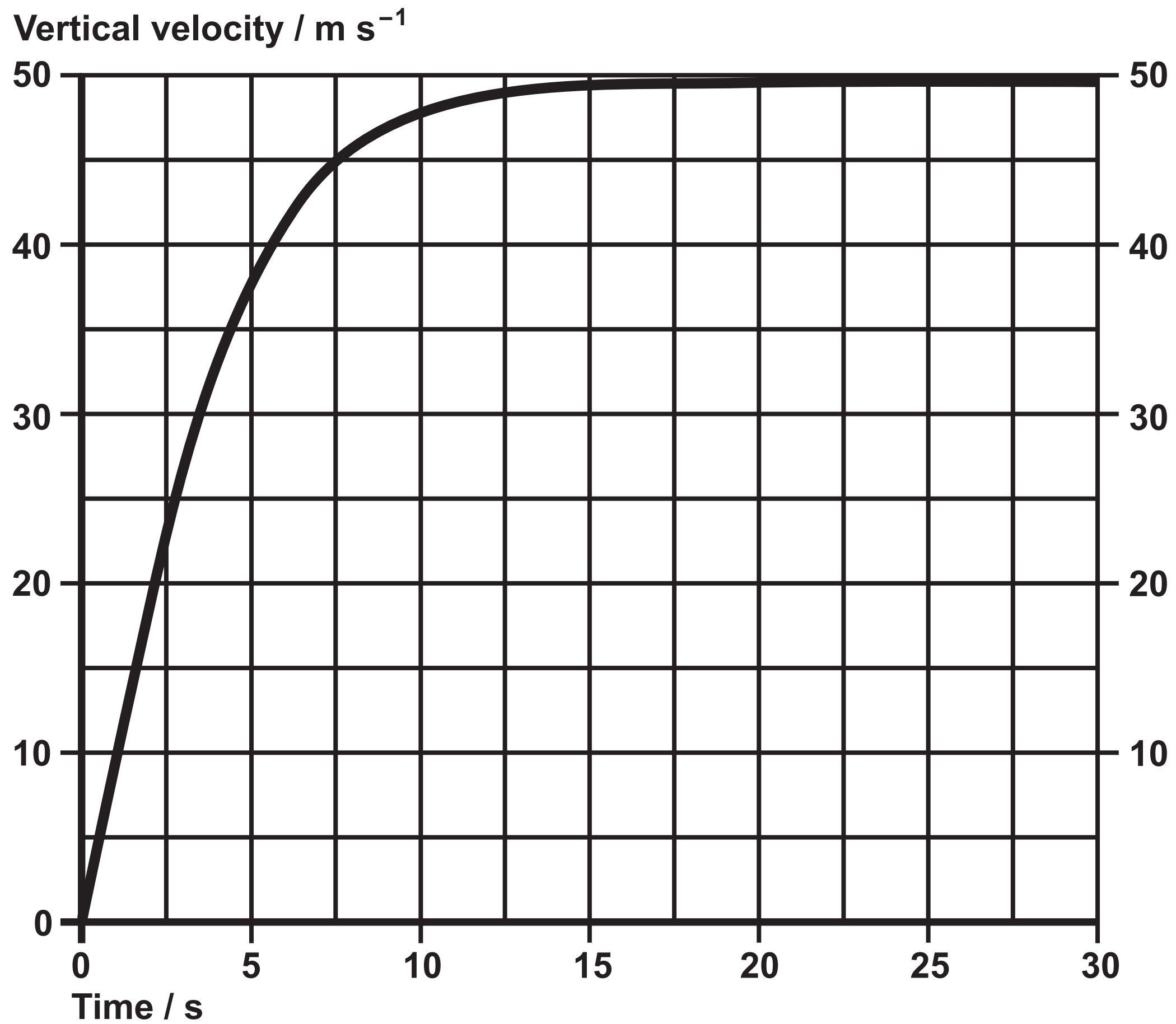
Question 1 (d) (i)



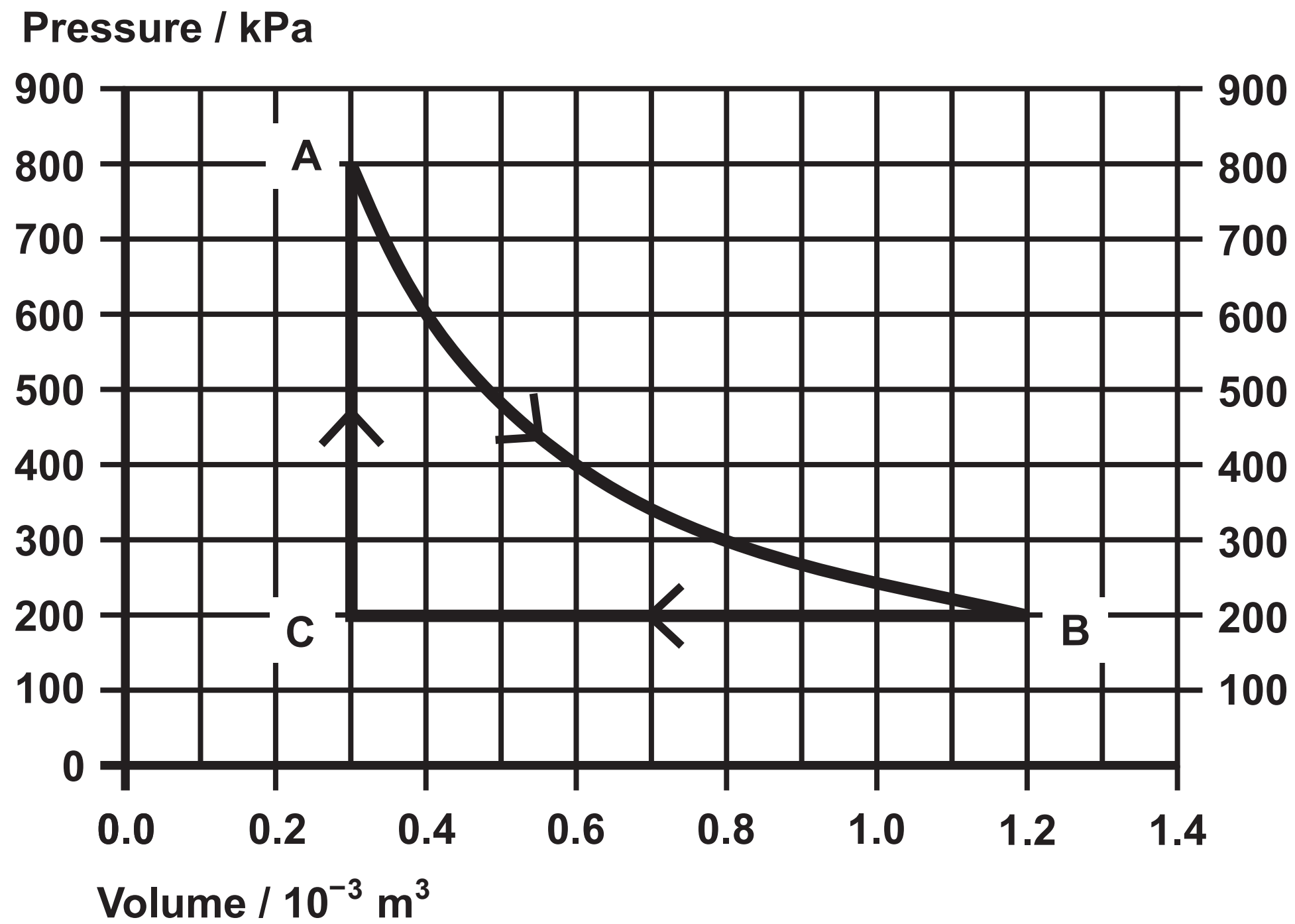
## Question 2 (b)



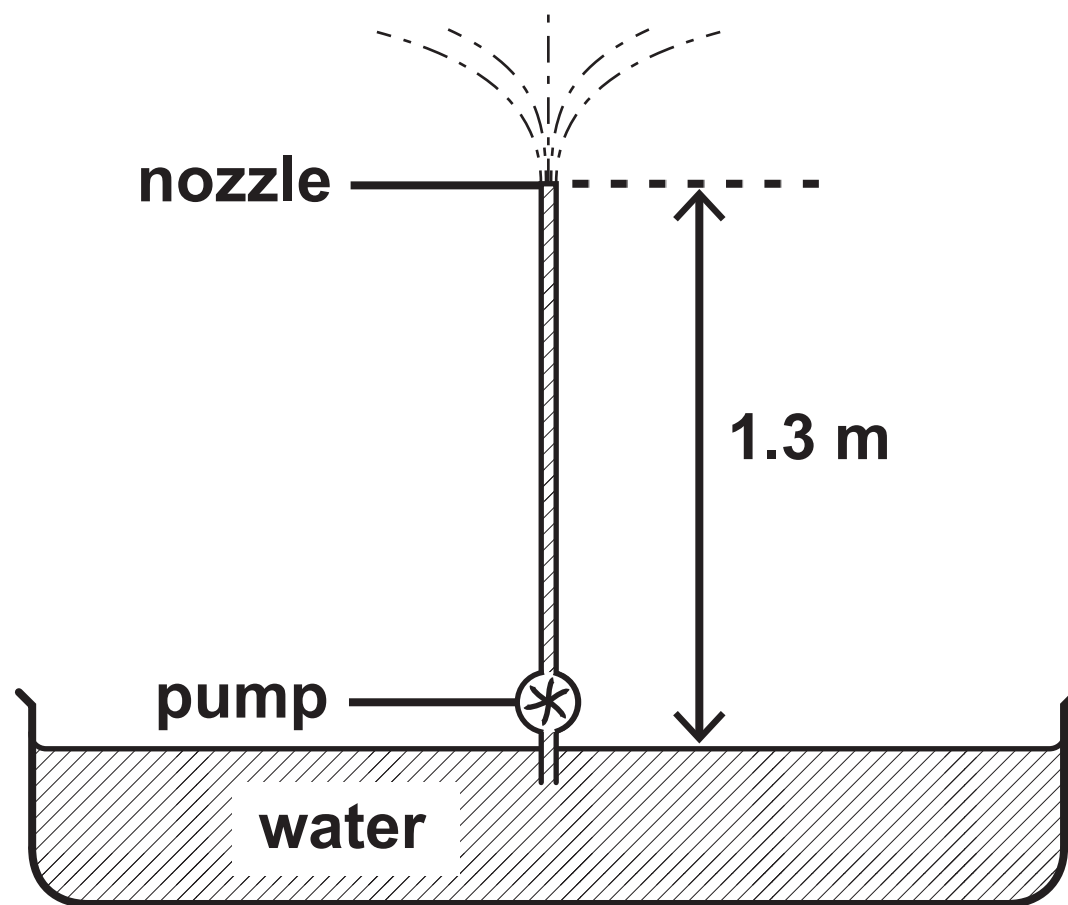
### Question 3



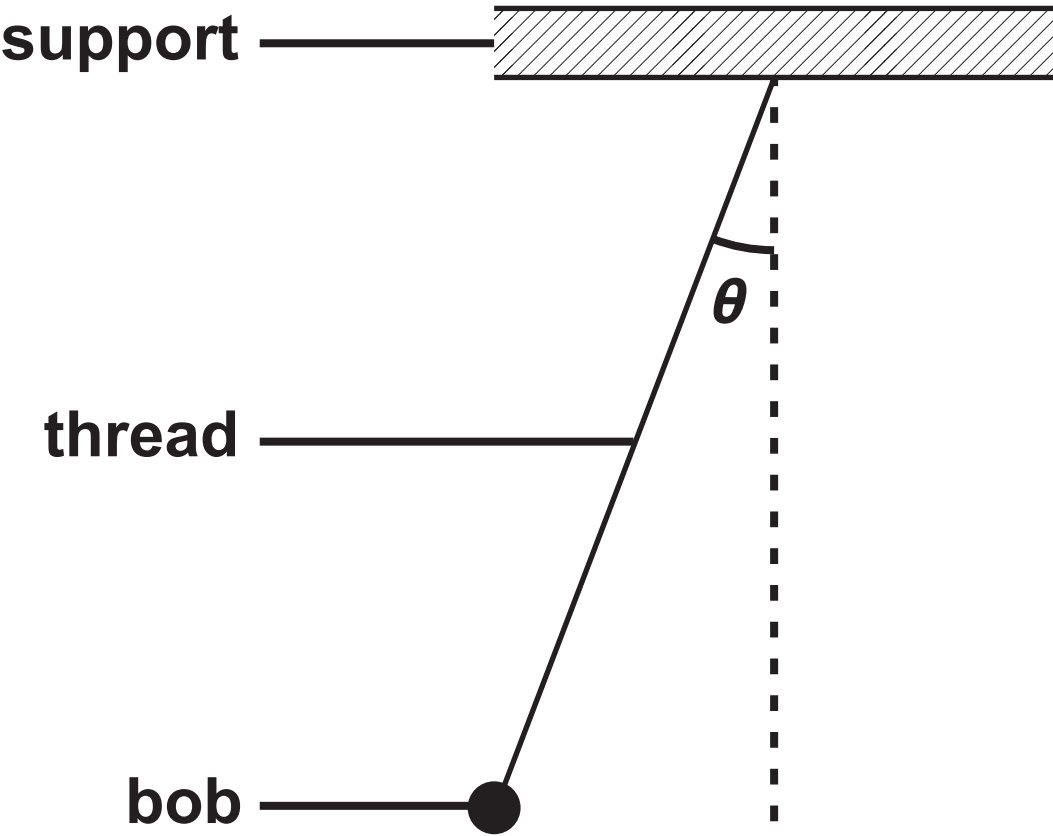
### Question 4 (b)



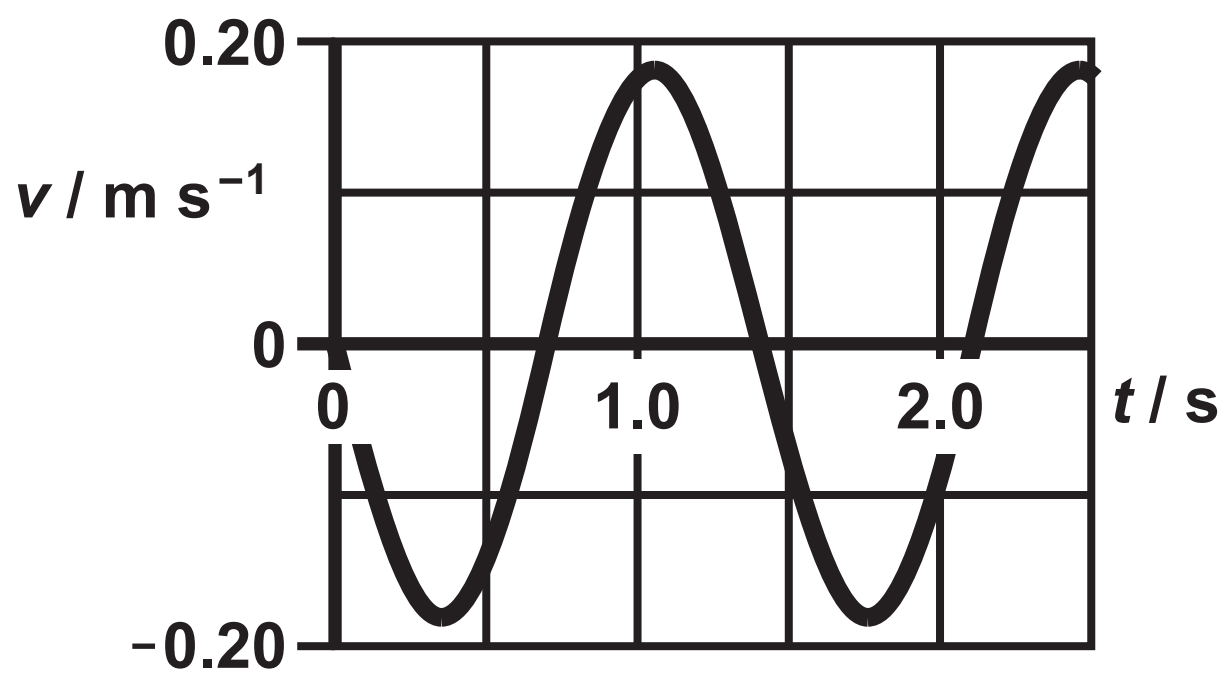
### Question 5 (b)



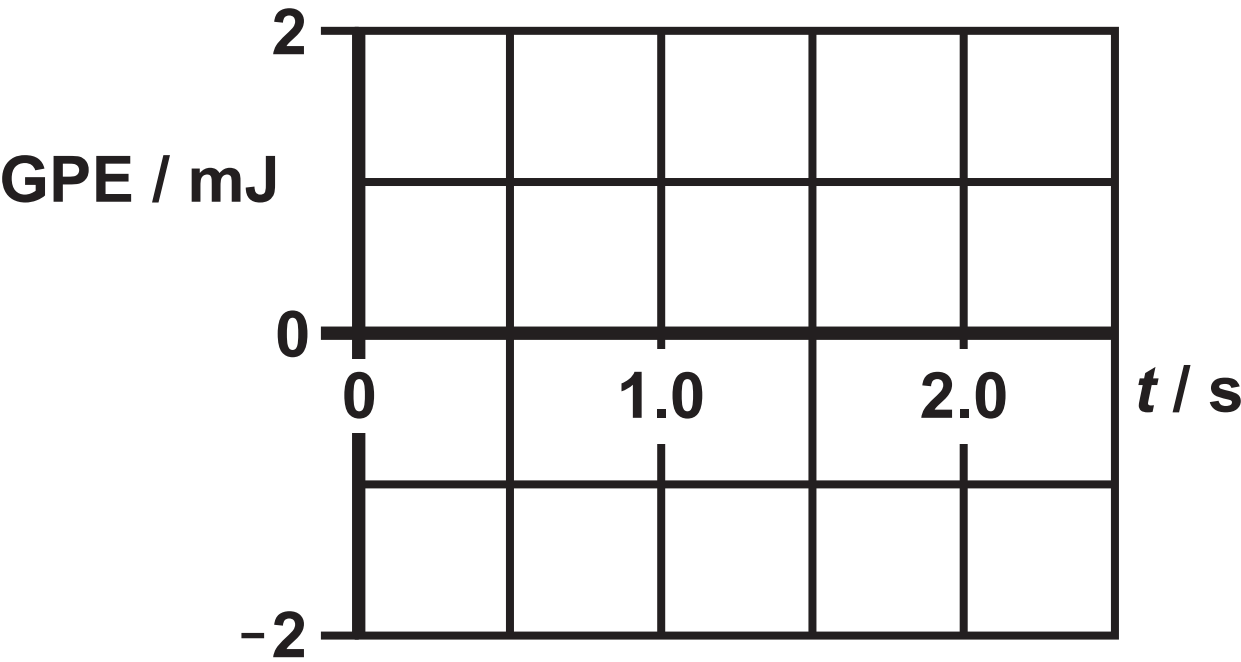
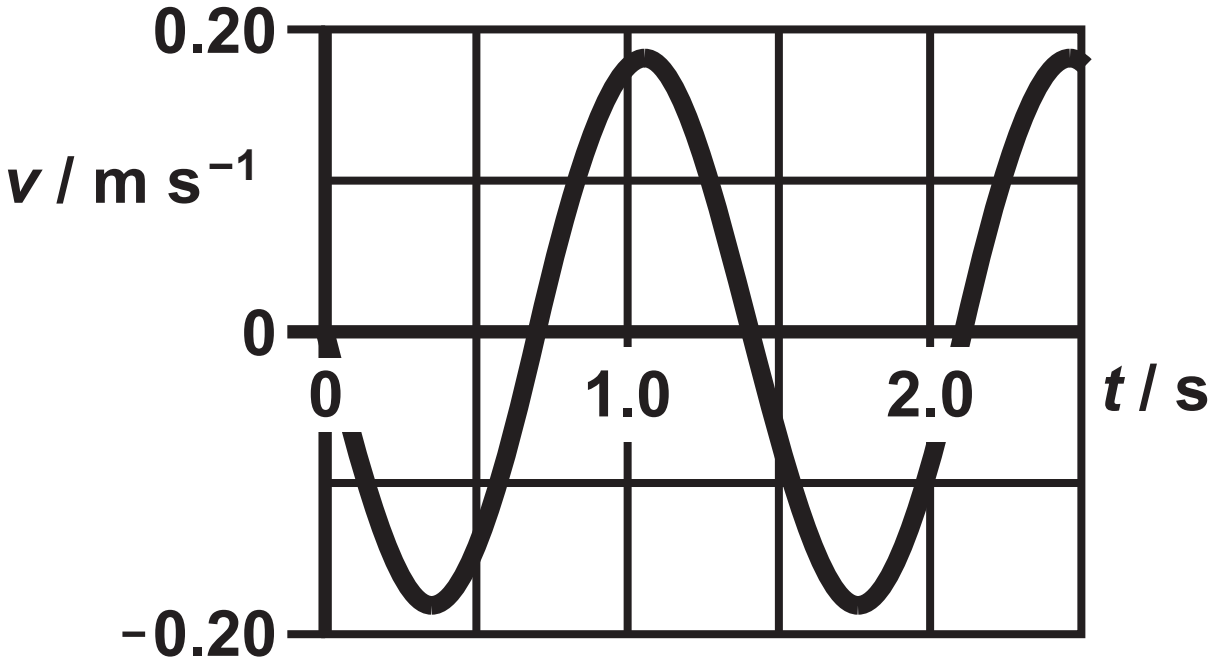
Question 6 (a)



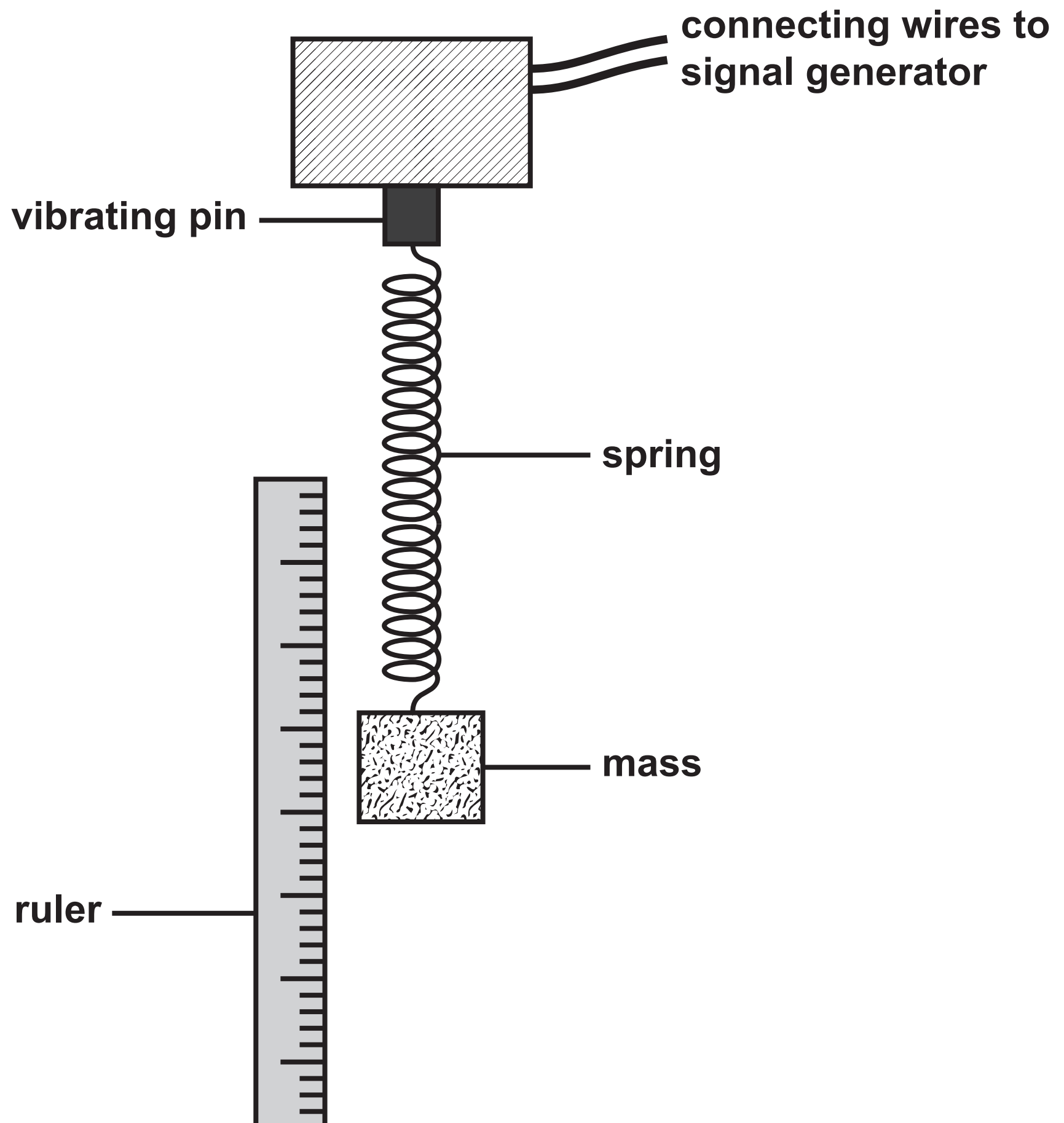
### Question 6 (b)



Question 6 (b) (ii) II.

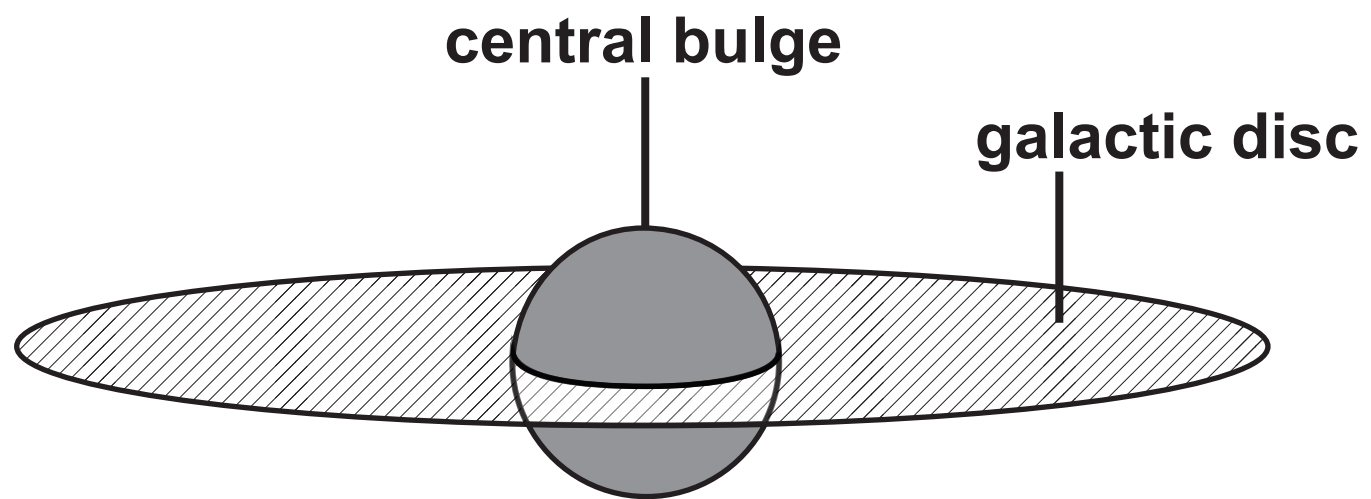


### Question 6 (c)



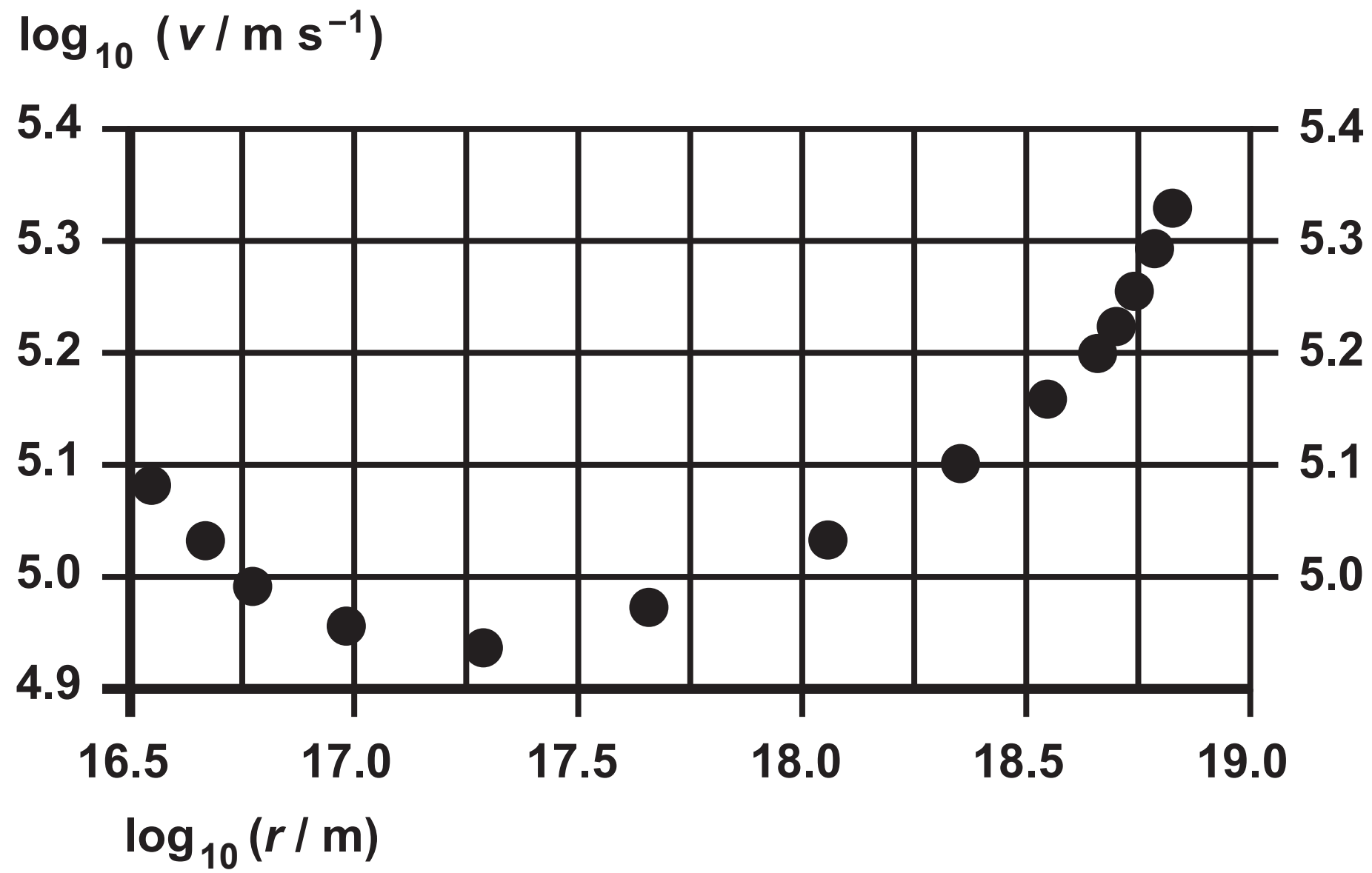
## Question 8

### Diagram 1



## Question 8

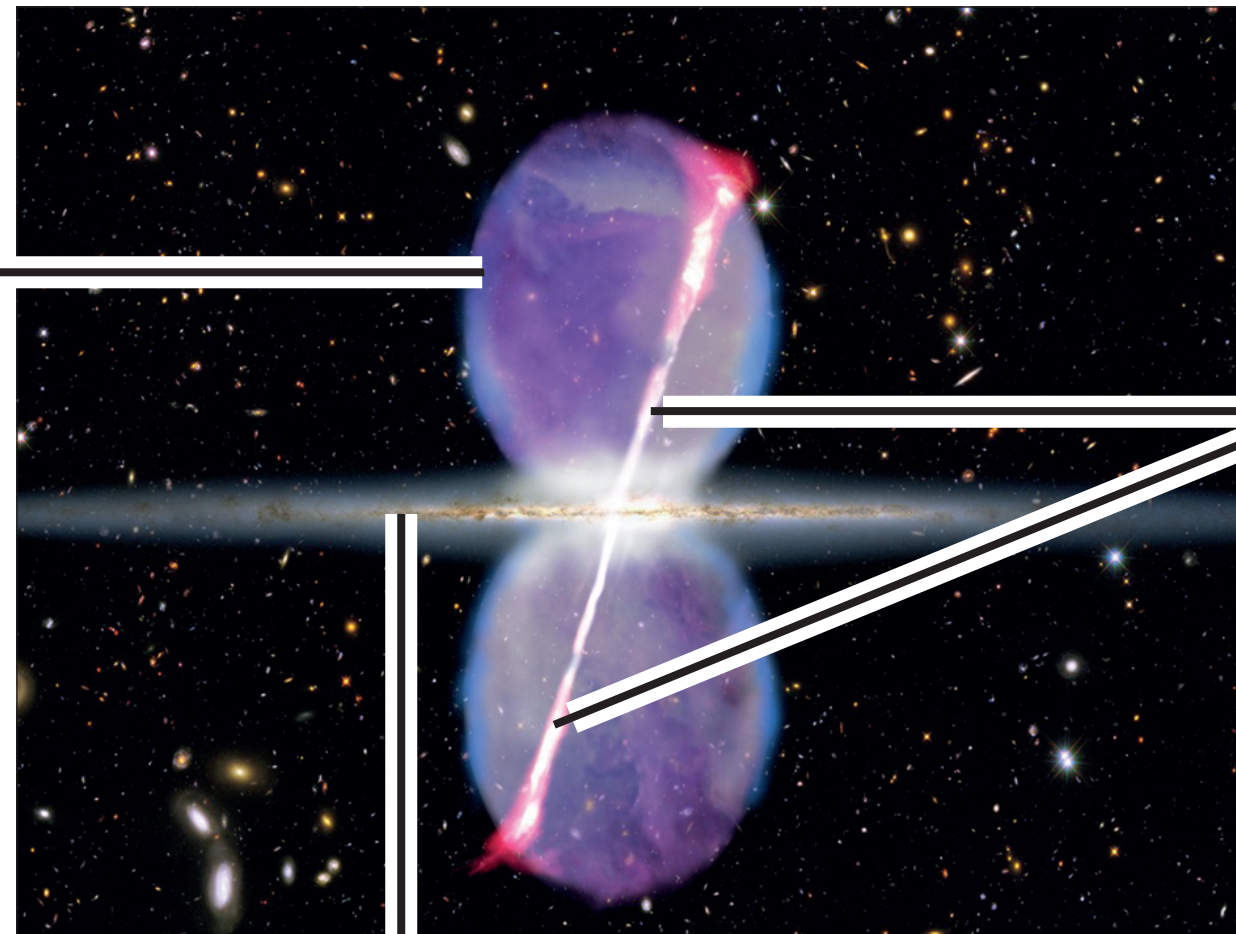
### Diagram 2



## Question 8

### Diagram 3

belched gas, known  
as Fermi Bubble

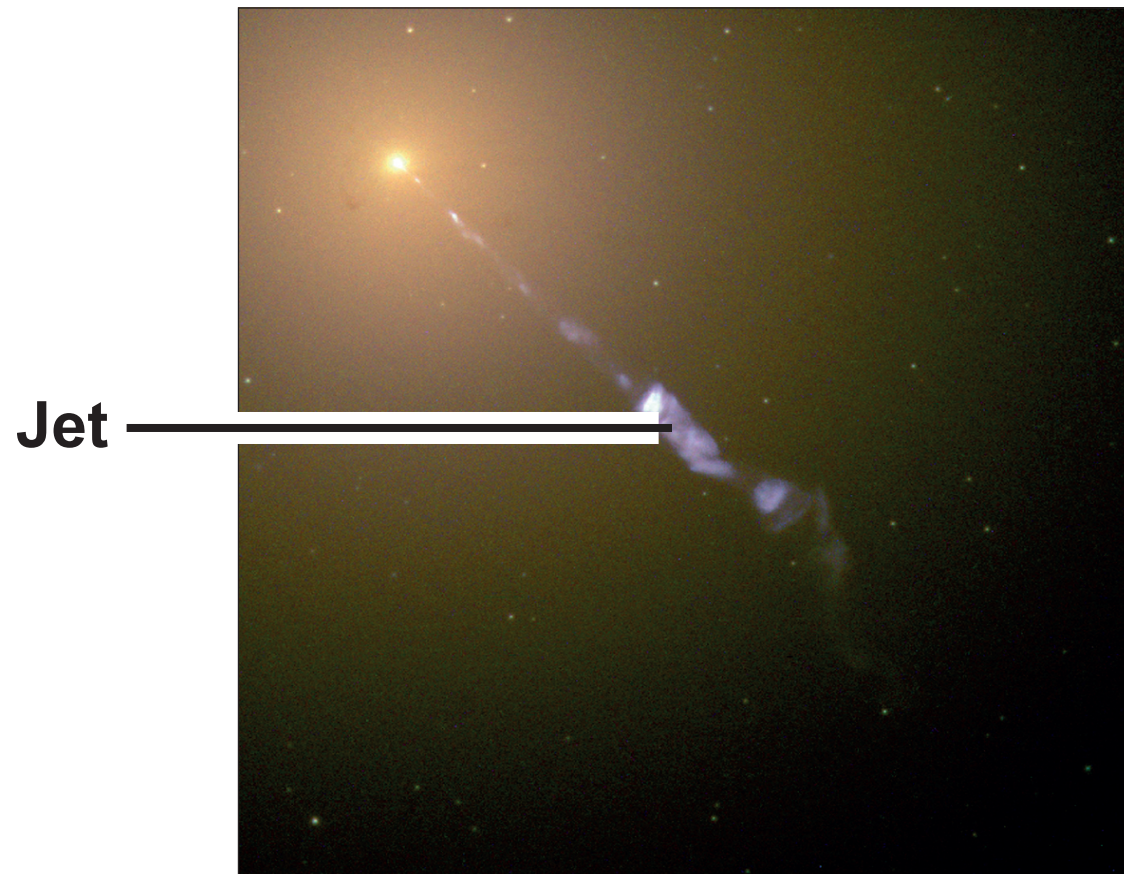


jets emitted  
6 – 9 million years  
ago by  
Sagittarius A\*

Milky Way

## Question 8

### Diagram 4



## Question 8

### Diagram 5

