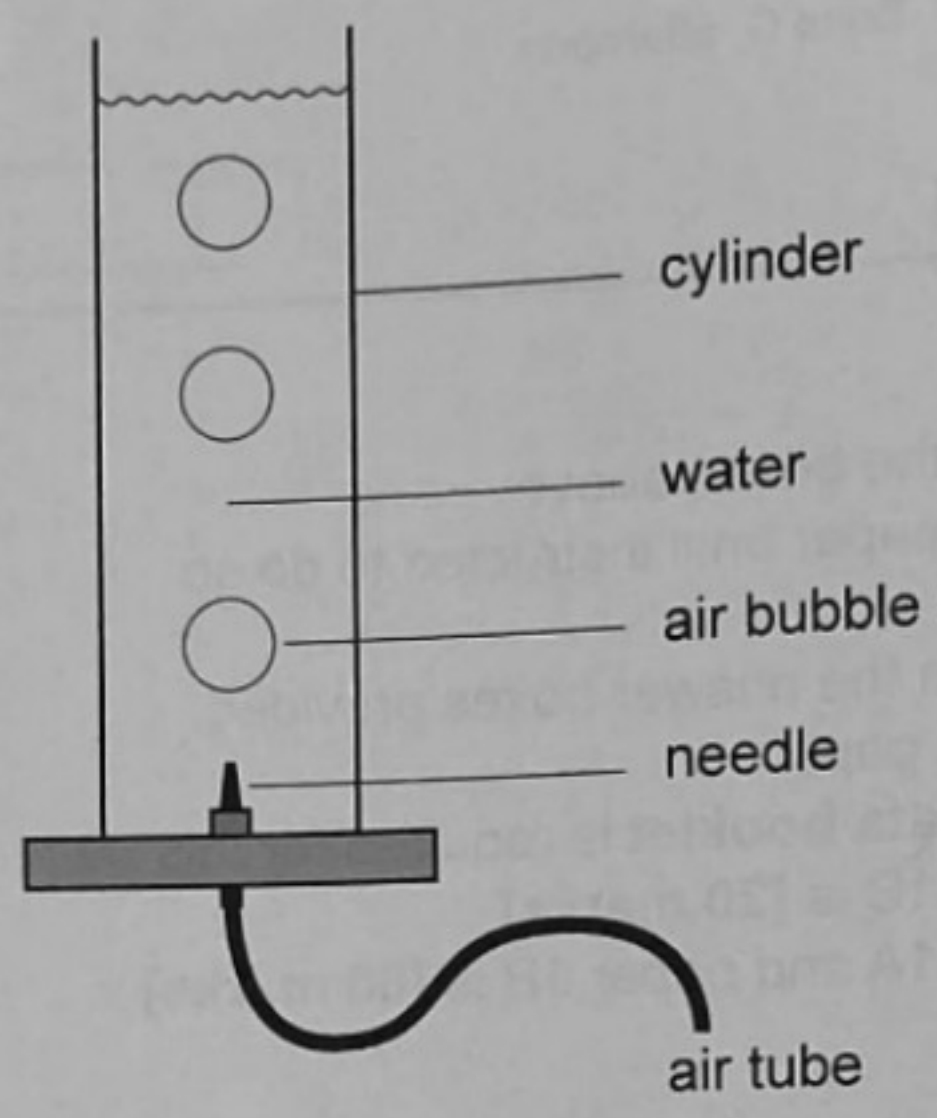


Answer all questions. Answers must be written within the answer boxes provided.

- 1. A student designs an experiment to determine the relationship between the diameter of an air bubble and its terminal speed in water. A needle is used to inject air bubbles one at a time into the bottom of a tall cylinder filled with water. The motion of the bubbles is captured by a video camera as they rise upwards.



- (a) State why the temperature of the water needs to be controlled during the investigation. [1]

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- (b) The student used the formula for viscous drag force to derive the following formula for the terminal speed  $v_t$  of a bubble as a function of its diameter  $d$ :

$$v_t = \frac{\rho g d^2}{18\eta}$$

- (i) Identify the quantities  $\rho$ ,  $g$ , and  $\eta$ . [1]

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**(Question 1 continued)**

(ii) Suggest how the student will know that the terminal speed has been reached. [2]

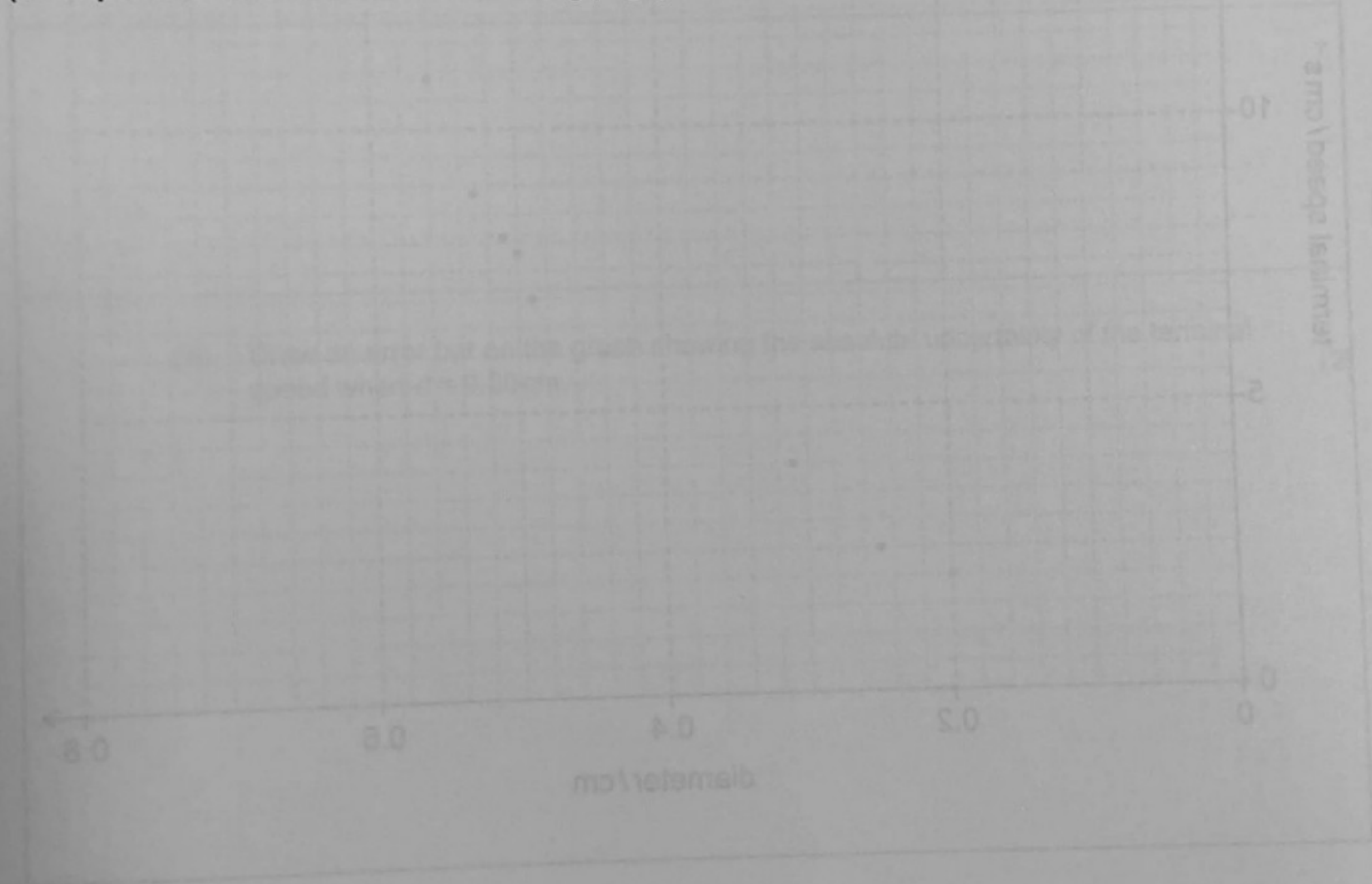
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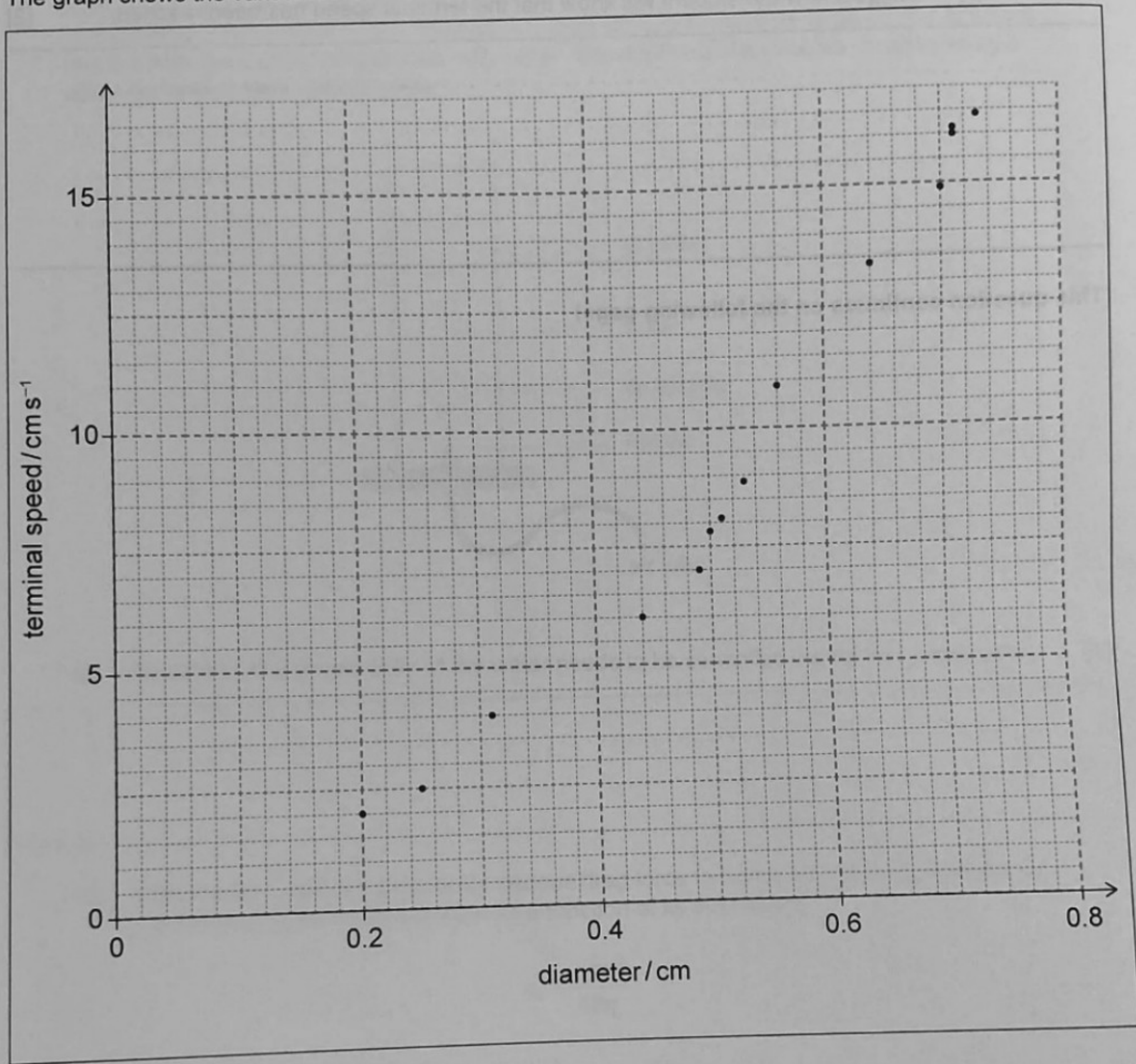


(c) On the graph draw the line of best fit for the data. [1]

(d) Suggest how the variables shown on the axes of the graph could be manipulated to obtain a straight line of best fit. [1]

(Question 1 continued)

The graph shows the variation of a bubble's terminal speed compared to its diameter.



- (c) On the graph, draw the line of best fit for the data. [1]
- (d) Suggest how the variables shown on the axes of the graph could be manipulated to obtain a straight line of best fit. [1]

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(Question 1 continued)

(e) A 0.30 cm bubble moved  $(1.7 \pm 0.1)$  cm in 10 frames as it moved at terminal speed. The frame rate of the video was  $(24 \pm 1)$  frames per second.

(i) Calculate the terminal speed of the 0.30 cm bubble. [1]

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(ii) Calculate the percentage uncertainty of your answer to (e)(i). [2]

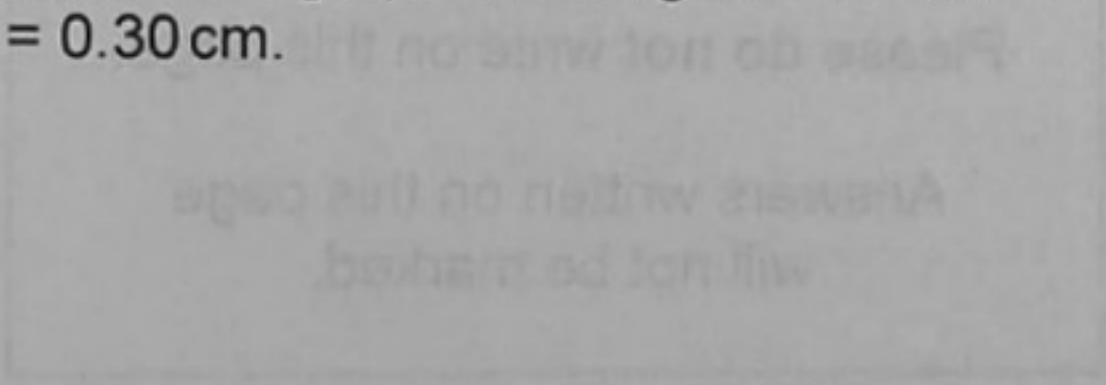
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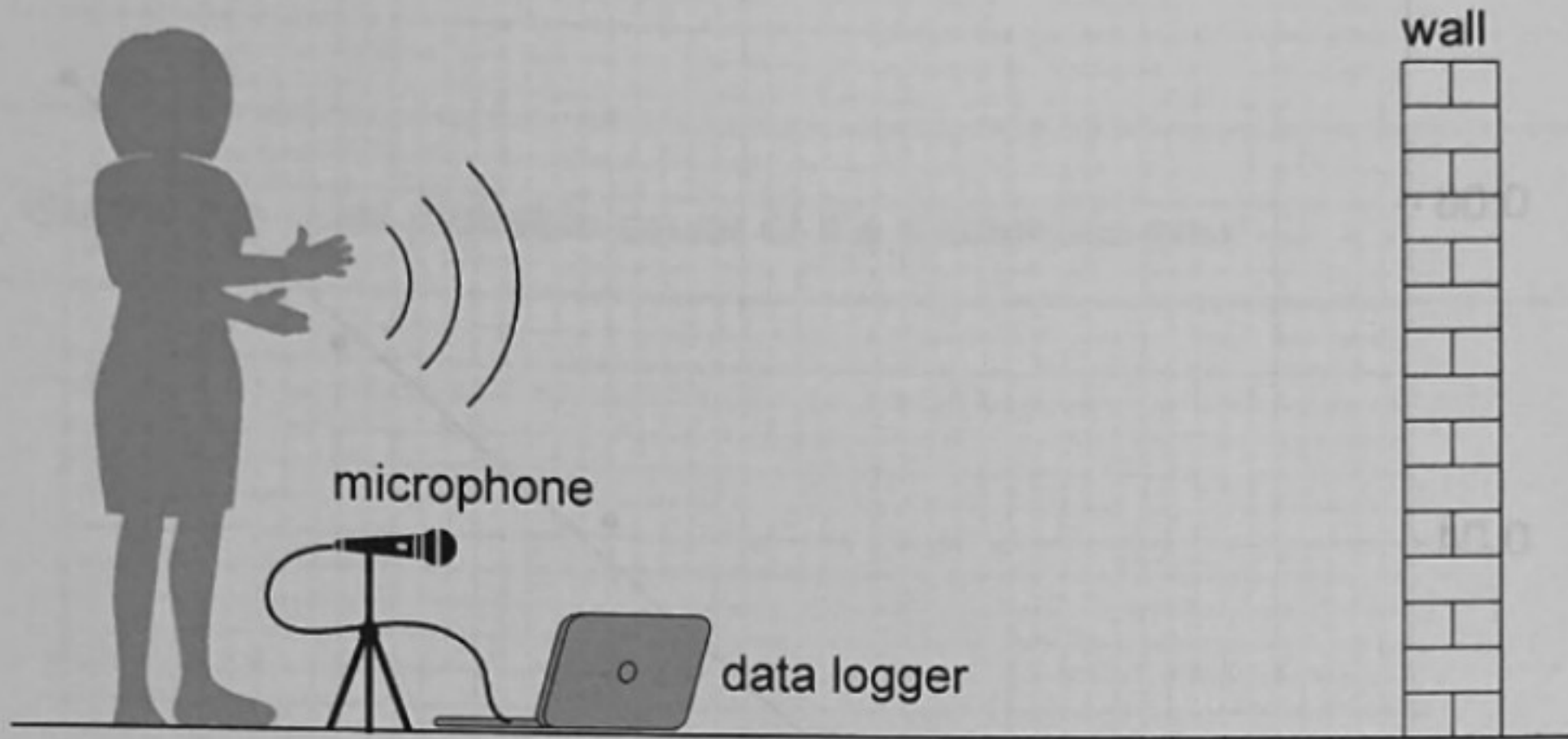
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(iii) Draw an error bar on the graph showing the absolute uncertainty of the terminal speed when  $d = 0.30$  cm. [2]



2. A group of students conduct an experiment to measure the speed of sound using echoes.

One of the students stands beside a data logger that is a measured distance from a wall and makes an audio recording of clapping two blocks together along with its echo. They then move to a new distance and repeat the experiment.



- (a) One of the students suggested taking measurements at 0.2 m and 30 m from the wall. Suggest why these distances were not suitable. [2]

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- (b) Describe one condition of the experimental space needed to take accurate readings. [1]

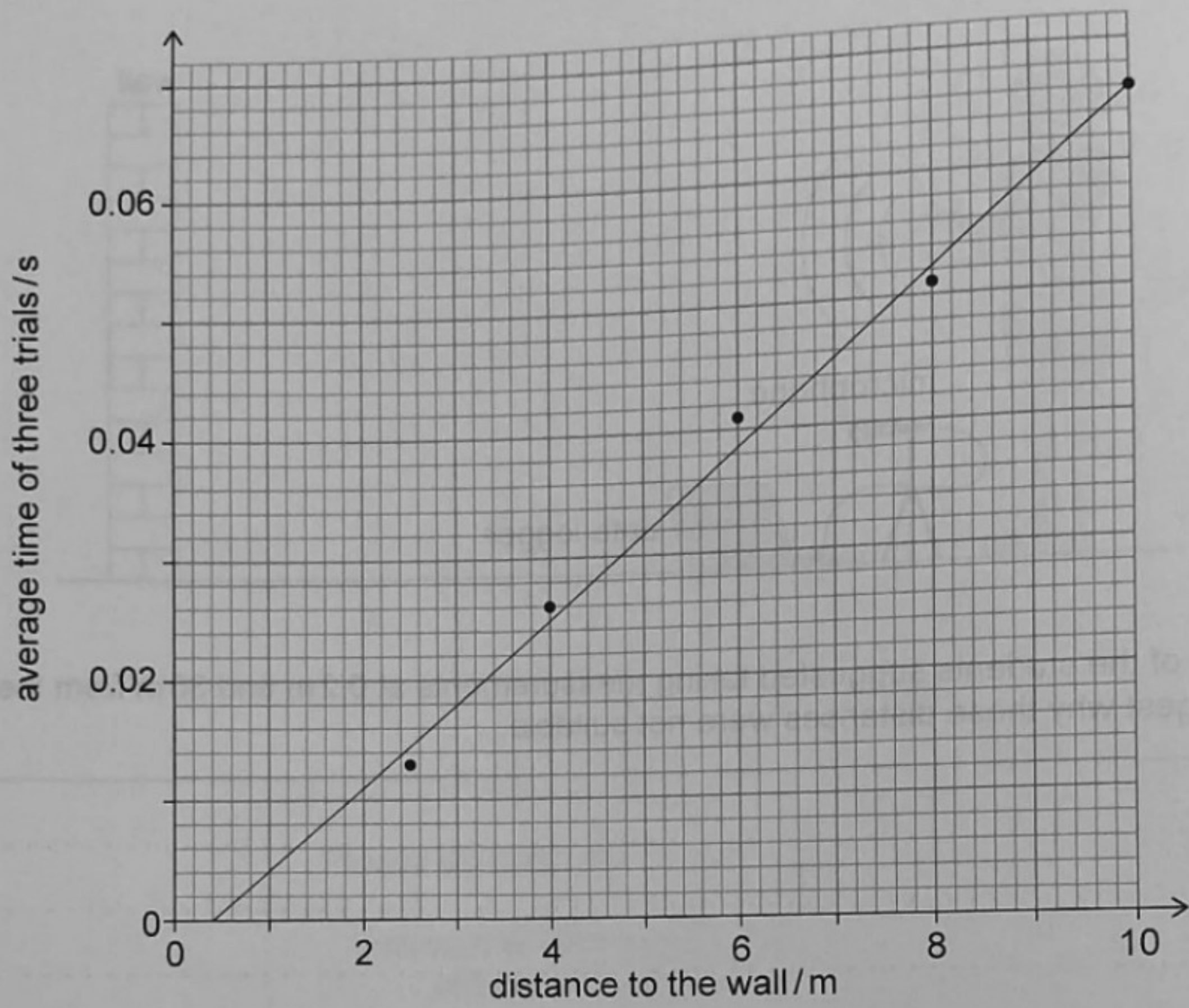
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**(Question 2 continued)**

The graph shows the relationship between the distance of the microphone to the wall and the time between the initial clap and its echo.



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**(Question 2 continued)**

(c) (i) From the graph, identify the evidence for a systematic error in the data. [1]

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(ii) Outline the most probable cause of the systematic error. [2]

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(d) Using the graph, determine the speed of sound. [3]

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