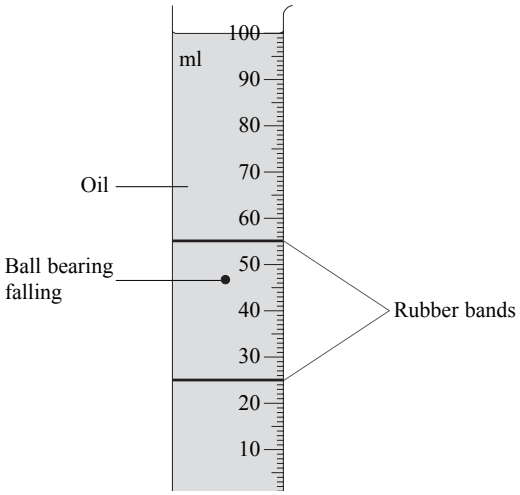
2 In an experiment to measure viscosity of oil, ball bearings are dropped into a long measuring cylinder full of oil.



(a) For one ball bearing, three measurements of its ball diameter are:

2.55 mm, 2.56 mm, 2.59 mm

Which of the following should be stated as the average result?

(1)

☐ **A** 2.56 mm

☐ **B** 2.566 mm

☐ **C** 2.567 mm

☐ **D** 2.57 mm

(b) Which of the following should be used to measure the diameter of the ball bearings?

(1)

☐ **A** metre rule

☐ **B** micrometer

☐ **C** scale on the measuring cylinder

☐ **D** tape measure

(c) Which of the following would minimise **parallax** error when timing the ball bearing as it falls through a fixed distance in the oil?

(1)

- ☒ **A** Ensure that the observer is at eye level with the ball bearing.
- ☒ **B** Use a metre rule rather than the scale on the measuring cylinder.
- ☒ **C** Use two parallel rubber bands around the measuring cylinder to indicate the fixed distance.
- ☒ **D** Start and stop the clock as the middle of the ball bearing passes through the start and finish points.

(Total for Question 2 = 3 marks)

3 A student carries out an experiment to determine the viscous drag on a sphere falling at constant speed through a liquid of known viscosity.

Which of the following quantities is **not** required?

- ☒ **A** diameter of sphere
- ☒ **B** height of fall
- ☒ **C** mass of sphere
- ☒ **D** time of fall

(Total for Question 3 = 1 mark)

4 In an experiment to measure the viscosity of motor oil a ball bearing is dropped into a long measuring cylinder full of the oil. The student needs to time how long the ball bearing takes to fall a set distance.

Which of the following would improve the accuracy of the measurements?

1 repeating the readings and calculating an average
2 ensuring that readings are taken at eye level
3 using a measuring cylinder with a smaller cross-sectional area

☒ **A** 1 only

☒ **B** 1 and 2 only

☒ **C** 2 and 3 only

☒ **D** 1, 2 and 3

(Total for Question 4 = 1 mark)

5 A student is measuring the diameter of a piece of wire with a micrometer. Her readings are

0.27 mm, 0.29 mm, 0.26 mm, 0.42 mm, 0.26 mm.

Which of the following is the best mean value for the diameter of the wire, stated with a suitable uncertainty?

☒ **A** 0.30 ± 0.08 mm

☒ **B** 0.27 ± 0.08 mm

☒ **C** 0.27 ± 0.02 mm

☒ **D** 0.267 ± 0.015 mm

(Total for Question 5 = 1 mark)

6 Which of the following is a unit for viscosity?

☒ **A** N m s^{-2}

☒ **B** N m^{-2} s^{-1}

☒ **C** N m^{-1} s^{-1}

☒ **D** N m^{-2} s

(Total for Question 6 = 1 mark)

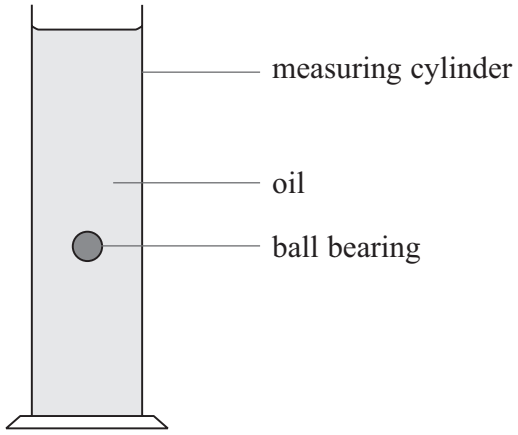
7 A student is asked to determine the viscosity of an oil at room temperature by dropping ball bearings into a long measuring cylinder filled with the oil.

The student is given the equation:

$$v = \frac{2}{9} r^2 \frac{g}{\eta} (\rho_b - \rho_o)$$

Where

v = velocity of ball bearing
r = radius of ball bearing
η = viscosity of the oil



The student has been given values for the density of the oil ρ_o and the density of the ball bearings ρ_b.

Write a plan for an experiment which could be used to determine the viscosity of the oil using standard laboratory apparatus and a graphical method.

You should:

(a) list any additional apparatus required, you may add to the diagram if you wish,

(2)

(b) state the quantities to be measured,

(1)

(c) for **two** of these quantities state and explain your choice of measuring instrument,

(4)

(d) state which is the independent and which is the dependent variable,

(1)

(e) explain how the data collected will be used to find the viscosity,

(2)

(f) identify the main sources of uncertainty and/or systematic error,

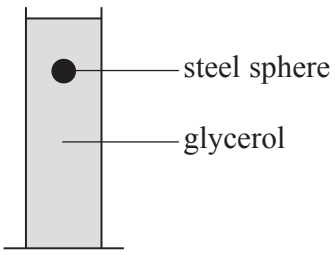
(2)

(g) comment on safety.

(1)

(Total for Question 7 = 13 marks)

8 In an experiment to measure the viscosity η of glycerol, steel spheres are timed falling through a column of glycerol.



The relationship to be used is

$$v = \frac{2r^2 g\left(\rho_s - \rho_g\right)}{9\eta}$$

where v is the terminal velocity of the sphere, r is the radius of the sphere, ρ_s is the density of steel, ρ_g is the density of glycerol and g is the acceleration of free fall.

The results are shown in the table. The radii of the spheres are taken from data provided by the manufacturer.

r / mm	r^2 /	v / m s^{-1}
1	1	0.0098
2	4	0.034
3		0.0781
4	16	0.15

(a) Complete the table with the missing value and unit.

(1)

(b) Criticise these results.

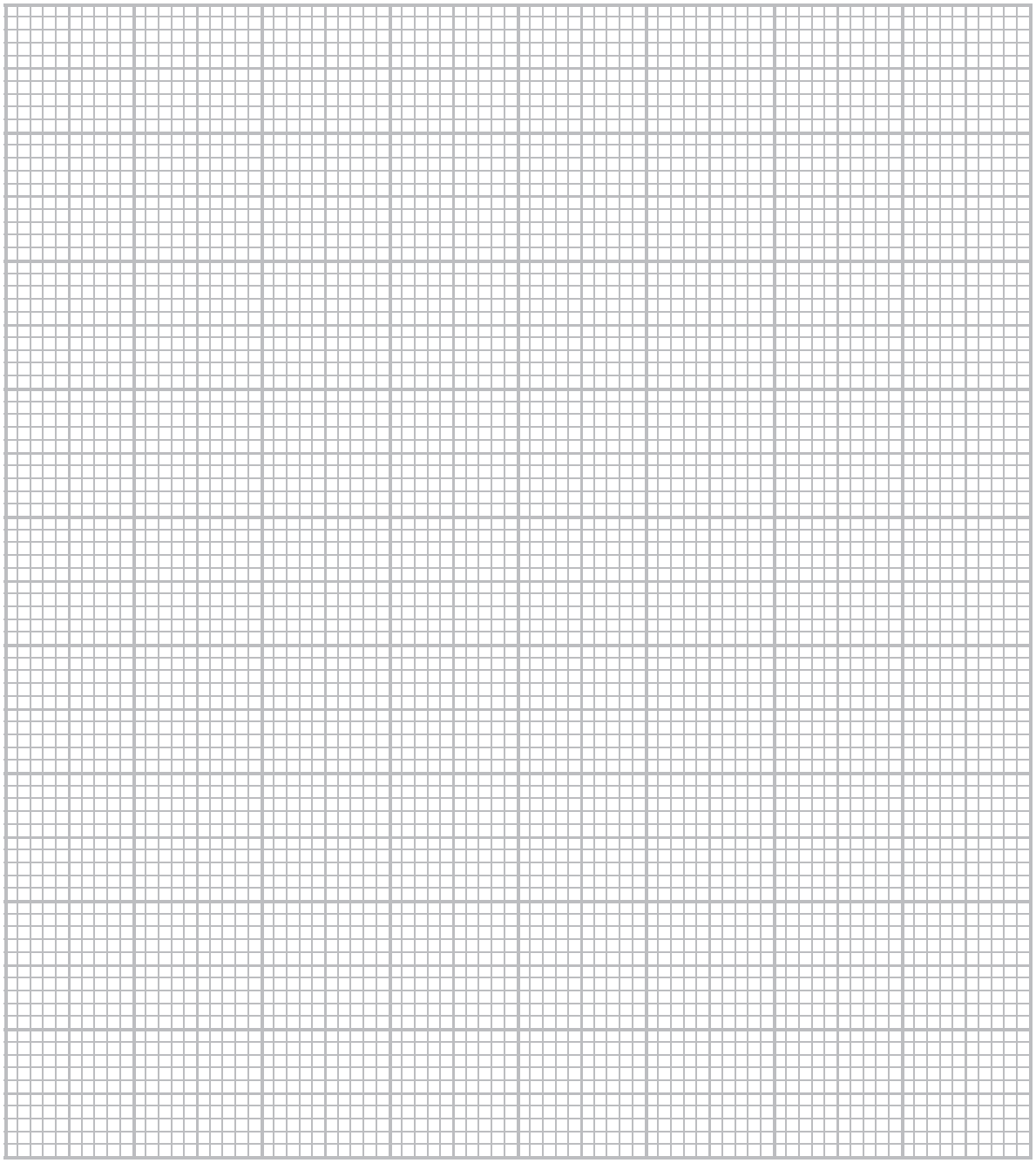
(2)

(c) Explain why a graph of v on the y-axis against r^2 on the x-axis should be a straight line with a gradient of $\frac{2g(\rho_s - \rho_g)}{9\eta}$

(2)

(d) Plot a graph of v on the y-axis against r^2 on the x-axis on the grid provided and draw a line of best fit.

(5)



(e) Use your graph to determine a value for the gradient.

(3)

Gradient = ...

(f) Use your value for the gradient to calculate a value for η.

(3)

$\rho_s = 7800 \text{ kg m}^{-3}$ ρ_g (at room temperature) $= 1200 \text{ kg m}^{-3}$

η = ...

(g) Suggest **two** factors in the experiment that would affect the value of η.

(2)

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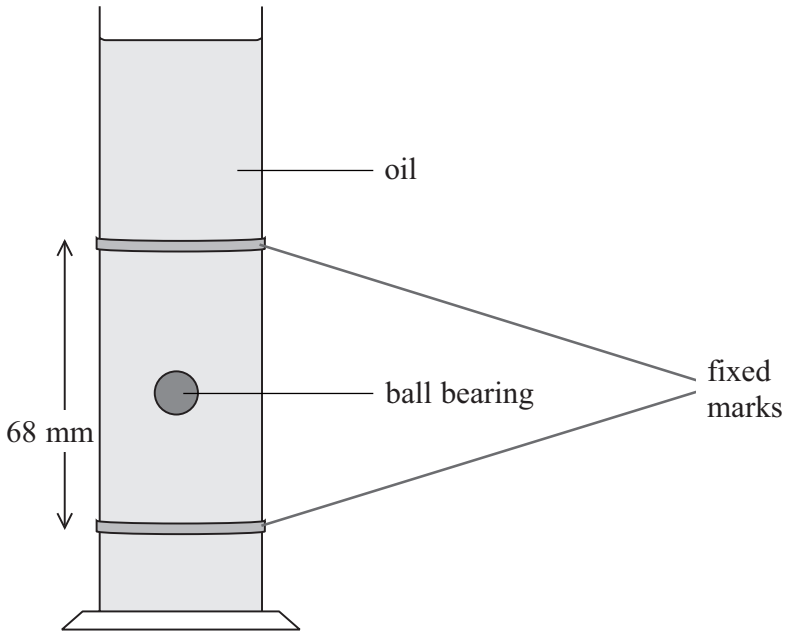
(Total for Question 8 = 18 marks)

TOTAL FOR SECTION B = 35 MARKS

TOTAL FOR PAPER = 40 MARKS

9 A student does an experiment to determine the viscosity of an oil. She drops ball bearings of different diameters into a tube of the oil. She timed the ball bearings between two fixed marks.



She planned to plot a graph to determine the viscosity of the oil. All her results are shown in the table below.

Diameter/mm	Time/s	Time/s	Time/s	Average time/s
3	27.97	29.91	26.12	28
4	8.75	7.97	7.53	8.08
6.01	4.22	4.37	4.16	4.25
12.03	2.19	2.40	2.37	2.32

(a) Criticise the set of results.

(2)

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.....

.....

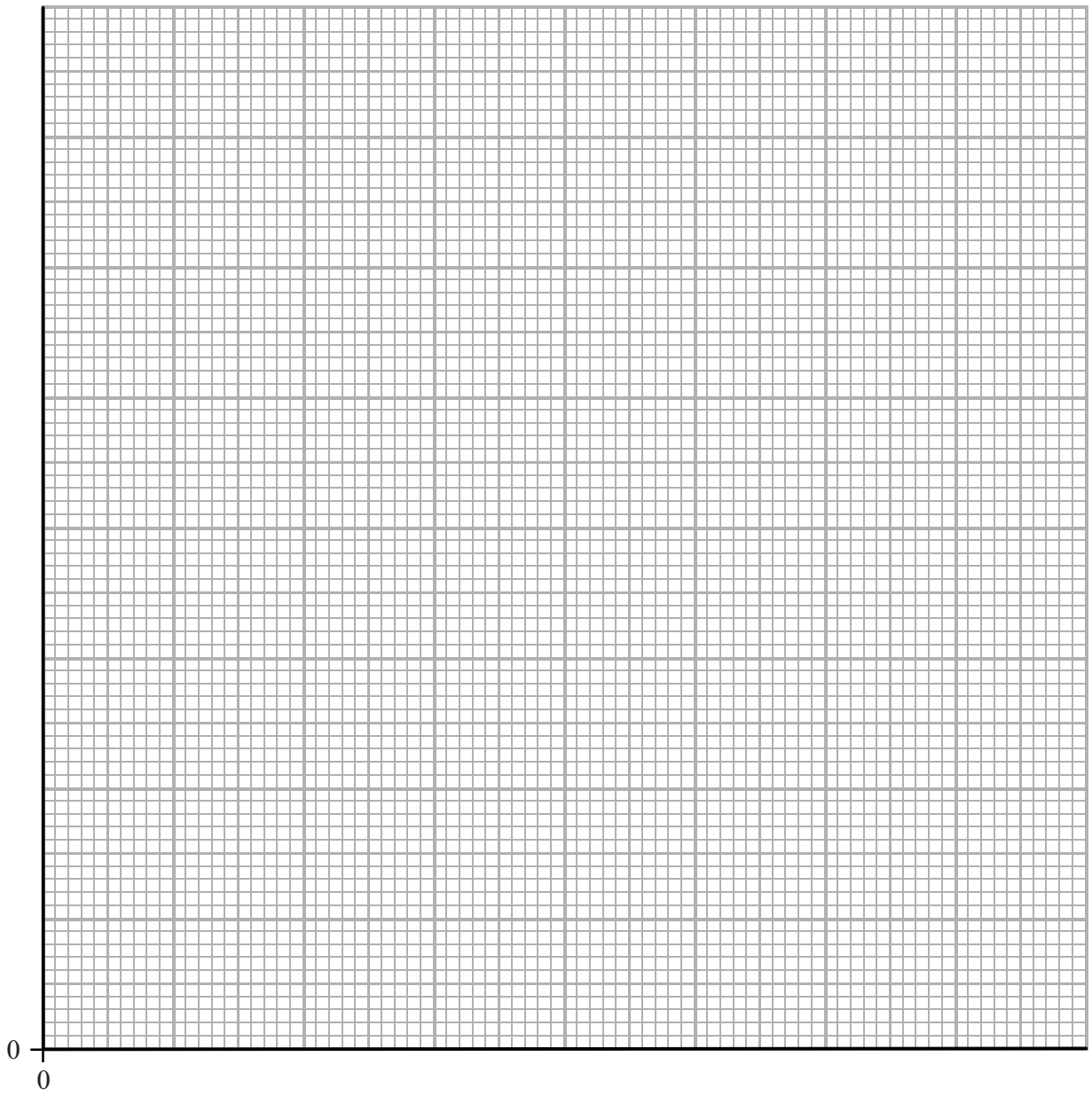
(b) The ball bearings were timed falling a distance of 68 mm. Complete the table below.

(4)

Diameter/mm	Radius/mm	Radius^2/mm^2	Average time/s	Velocity/
3	1.5	2.3	28	2.4
4	2.0	4.0	8.08	8.4
6.01			4.25	
12.03	6.0	36.0	2.32	29.3

(c) Use your values to plot a graph of velocity against radius squared on the grid below.

(5)



(d) The student expected to obtain a straight line graph.

Suggest **one** possible reason for the apparent error in her measurements.

(1)

.....

.....

(Total for Question 9 = 12 marks)

TOTAL FOR SECTION B = 35 MARKS

TOTAL FOR PAPER = 40 MARKS

You may not need to use all of the materials provided.

For Examiner's Use

2 In this experiment, you will investigate how the speed of a glass ball falling through oil depends on its size.

The apparatus has been set out for you as shown in Fig. 2.1.

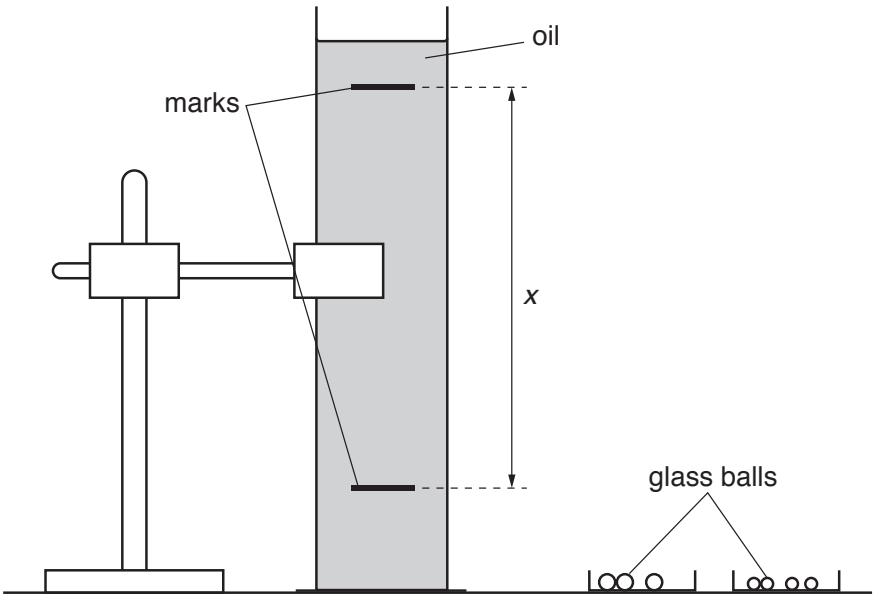


Fig. 2.1

(a) Measure and record the distance x between the upper and lower marks on the measuring cylinder.

x = ...

(b) **(i)** You have been provided with two different sizes of glass ball: large and small. Take measurements to determine the diameter d of the small glass balls.

For Examiner's Use

d = ... mm

(ii) Take measurements to determine the time t for a small glass ball to fall distance x through the oil.
Do not remove any balls from the oil. You may ask for more glass balls if needed.

t = ... s

(c) Estimate the percentage uncertainty in your value of t.

percentage uncertainty = ...

(d) Calculate the speed v of a small glass ball falling distance x through the oil.
$\left(v = \frac{x}{t}\right)$

v = ...

[Turn over

(e) Repeat **(b)** and **(d)** for the large glass balls.

For Examiner's Use

d = ... mm

t = ... s

v = ...

(f) It is suggested that the relationship between v and d is

$$v = kd^2$$

where k is a constant.

(i) Using your data, calculate two values of k.

first value of k = ...

second value of k = ...

(ii) Explain whether your results support the suggested relationship.

.....

.....

.....

(iii) Justify the number of significant figures that you have given for your values of k in **(i)**.

.....

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.....

(g) (i) Describe four sources of uncertainty or limitations of the procedure in this experiment.

For Examiner's Use

1. .....

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2. .....

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3. .....

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4. .....

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(ii) Describe four improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures.

1. .....

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2. .....

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3. .....

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4. .....

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