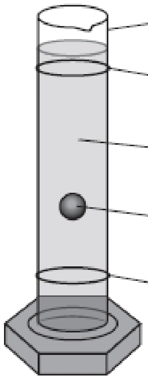
Fluids

Q1.

A student carried out an experiment to determine the viscosity of some honey. He filled a tall glass cylinder with honey as shown, and timed a ball bearing as it fell through the honey.



The student placed rubber bands near the top and bottom of the cylinder. He started a stopwatch when the ball bearing passed the first band and stopped the stopwatch when the ball bearing passed the second band. He repeated this several times to determine a mean time.

Criticise the student's method.

(2)

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(Total for question = 2 marks)

Q2.

A student carries out an experiment to determine the viscosity of glycerol. She does this by determining the terminal velocity of a steel sphere falling through glycerol.

(i) The student drops a steel sphere with a radius of 4.0 mm into a cylinder of glycerol.

The sphere reaches terminal velocity and takes 3.9 s to fall 0.50 m.

Calculate the viscosity of glycerol.

density of steel = 7800 kg m^{-3}
density of glycerol =1300 kg m^{-3}

(4)

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Viscosity of glycerol = ...

(ii) There are two cylinders available for the student to use. One cylinder has a diameter of 1.5 cm and the other has a diameter of 5.0 cm.

State and justify which cylinder the student should use in order to gain a more accurate value for the viscosity of glycerol.

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(Total for question = 6 marks)

Q3.

The photograph shows a type of drink known as stout.

When the drink is poured, it contains many spherical bubbles of gas which rise and form the foamy 'head' at the top of the drink. The manufacturers of the drink state "It takes 120 seconds for the head to form".

For the smallest bubbles, the uniform upward velocity can be calculated using the equation

$$v = \frac{2(\rho_{stout} - \rho_{gas})r^2 g}{9\eta}$$

(i) Derive this equation by considering the forces acting on a bubble.

(3)

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(ii) State an assumption you have made.

(1)

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(iii) Evaluate the statement from the manufacturers that it takes 120 seconds for the head to form.

You should consider the time for a bubble to travel from the bottom of the glass to the top.
height of glass = 11.5 cm
density of gas = 1.22 kg m^{-3}
density of stout = 1.01×10^3 kg m^{-3}
viscosity of stout = 2.06×10^{-3} Pa s
diameter of bubble = 122 μm

(4)

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Q4.

The viscosity of fluids varies with temperature.

Which line of the table correctly shows the change in viscosity with increasing temperature?

		Oil	Dry air
☐	**A**	decreases	decreases
☐	**B**	decreases	increases
☐	**C**	increases	decreases
☐	**D**	increases	increases

(Total for question = 1 mark)

Q5.

The photograph shows a type of drink known as stout.

When the drink is poured, it contains many spherical bubbles of gas which rise and form the foamy 'head' at the top of the drink. The manufacturers of the drink state "It takes 120 seconds for the head to form".

A bubble, initially at rest in the liquid, accelerates until it achieves a uniform upward velocity.

Explain the motion of the bubble.

(4)

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Q6.

A student investigated the terminal velocity of steel spheres falling through oil.

The student obtained the following results.

radius of steel sphere = 1.50 mm
volume of steel sphere = 1.41×10^{-8} m^3
mass of steel sphere = 1.10×10^{-4} kg
maximum speed of sphere = 0.849 m s^{-1}

The student had the following table.

Type of oil	Density at 26 °C / kg m^{-3}	Viscosity at 26 °C / Pa s
Corn	918	0.0447
Hazelnut	918	0.0504
Sunflower	918	0.0414

Identify which type of oil the student used.

(4)

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(Total for question = 4 marks)

Q7.

In an investigation to determine the viscosity of water, a student drops a small sphere into a cylinder of water. The student uses a stopwatch to record the time it takes for the sphere to fall through the water.

Assess whether the stopwatch is suitable for measuring the time in this investigation.

(2)

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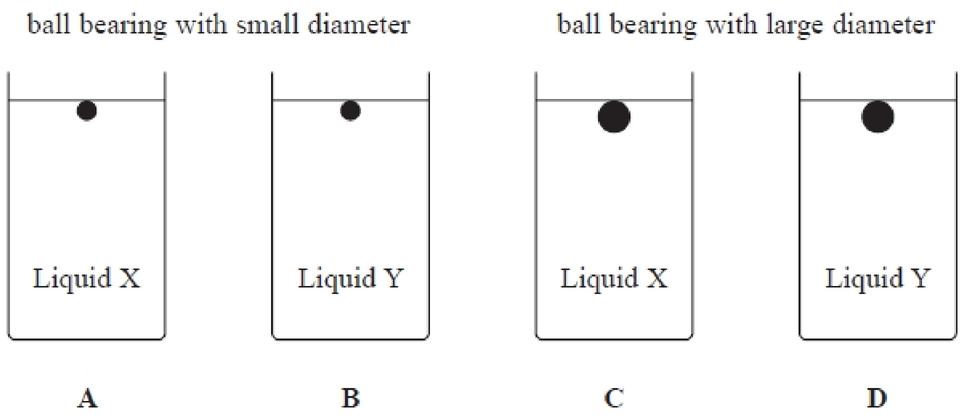
(Total for question = 2 marks)

Q8.

In a falling-ball method to investigate the viscosity of a liquid, ball bearings with two different diameters are allowed to fall through two different liquids, X and Y.

The viscosity of liquid X is greater than the viscosity of liquid Y.

In which set-up shown below will the ball bearing have the greatest terminal velocity?



☐ **A**
☐ **B**
☐ **C**
☐ **D**

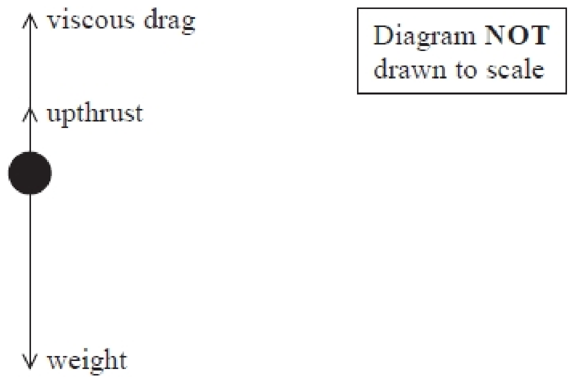
(Total for question = 1 mark)

Q9.

Weather stations monitor the position of storm clouds.

(i) A raindrop is falling vertically through the air.

The free-body force diagram shows the forces acting on the raindrop.



The raindrop is travelling at terminal velocity. The raindrop is spherical with a radius of 0.10 mm and a weight of 4.1×10^{-8} N .

Calculate the magnitude of the terminal velocity.

viscosity of air = 1.3×10^{-5} Pa s density of air = 1.2 kg m^{-3}

(4)

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Magnitude of terminal velocity = ...

(ii) The value of terminal velocity calculated using the data in (i) is greater than the actual terminal velocity of the raindrop.

Explain why the calculation in (i) may not be valid.

(2)

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(Total for question = 6 marks)

Q10.

A bubble of air is rising through a vertical column of water.

Which statement, about the motion of the bubble, is correct to a good approximation?

(1)

☒ **A** The bubble has a constant velocity because its weight equals the viscous drag.
☒ **B** The bubble has a constant velocity because the upthrust is equal to the viscous drag.
☒ **C** The bubble has an acceleration because its weight is greater than the upthrust.
☒ **D** The bubble has an acceleration because the viscous drag is greater than the upthrust.

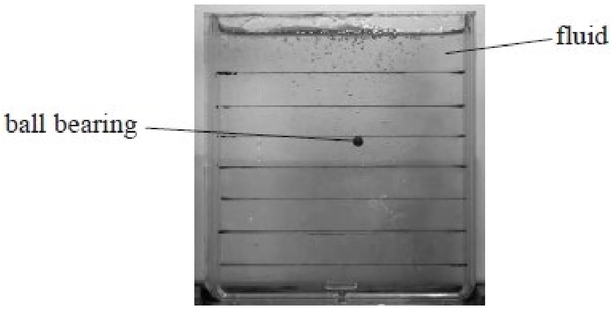
(Total for question = 1 mark)

Q11.

A student carried out an experiment to identify a fluid from its viscosity at room temperature.

A ball bearing of diameter *d* was released at the top of a container containing the fluid. The motion of the ball bearing was recorded using a video camera and hence the terminal velocity *v* of the ball bearing was determined.

This was repeated for ball bearings of increasing diameter with the fluid at a constant temperature.



(a) To determine the viscosity η, the student used the equation $$v = \frac{d^2 g(\rho_b - \rho_f)}{18\eta}$$

where ρ_b = density of the material of the ball bearing
ρ_f = density of the fluid.

Explain why a graph of v on the y-axis and d^2 on the x-axis should be a straight line through the origin.

(3)

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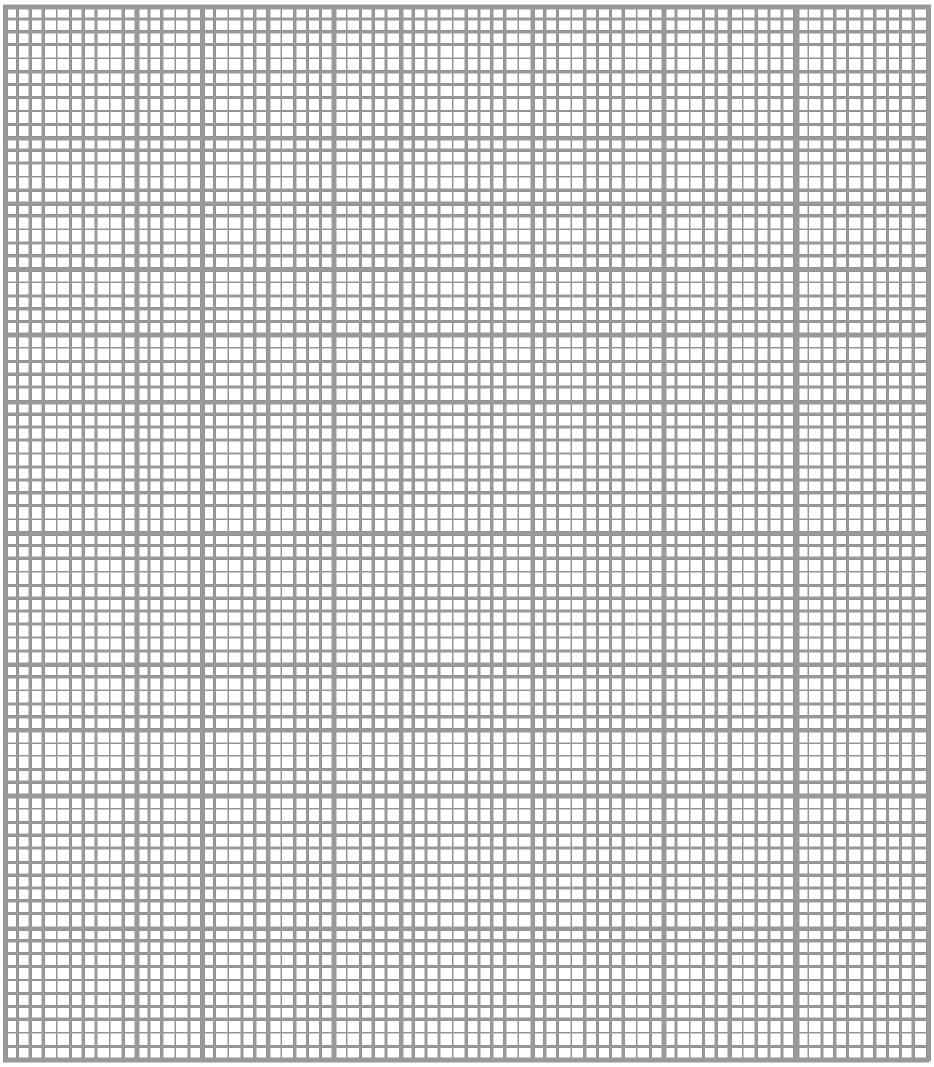
(b) The student obtained the following data.

d / 10^{-3} m	d^2 / 10^{-6} m^2	v / 10^{-3} m s^{-1}
1.0	1.0	2.3
2.0	4.0	11
3.0	9.0	23
4.0	16.0	39
5.0	25.0	64

Plot the graph of v against d^2.

(4)



(c) The table shows the viscosity of some different fluids.

Fluid	Viscosity at room temperature / Pa s
castor oil	1.0
glycerol	1.2
corn syrup	1.4
honey	1.9

Use the graph to deduce which fluid the student used.

density of ball bearing = 8000 kg m^{-3}

density of fluid = 1260 kg m^{-3}

(4)

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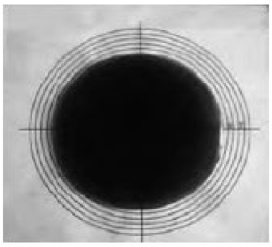
(Total for question = 11 marks)

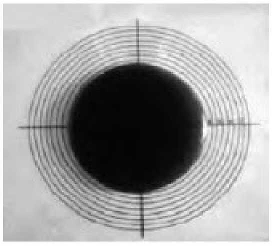
Q12.

The photograph shows an image of two "pancake" volcanoes on the surface of the planet Venus. Scientists believe these types of volcano are formed from lava spreading out in all directions onto a flat landscape.

A student investigated the formation of pancake volcanoes. She observed the flow of a viscous liquid at two different temperatures as it spread out from a central spot. The photographs below show the liquid at both temperatures after it had been flowing for the same length of time.



High temperature test



Low temperature test

Scientists believe that the high temperature of lava when it erupts is one factor that allows the lava to spread out over a large area.

Explain how the student's investigation supports this idea.

(2)

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(Total for question = 2 marks)

Q13.

An object of volume *V* made from a material of density ρ_1 is placed into a fluid of density ρ_2.

Which of the following gives the upthrust on the object?

- ☐ **A** $\rho 1\ V g$
- ☐ **B** $\rho 2\ V g$
- ☐ **C** $(\rho_2 - \rho_1)\ V g$
- ☐ **D** $\frac{(\rho_2 + \rho_1)}{2} Vg$

(Total for question = 1 mark)

Q14.

A small helium balloon is released into the air. The balloon initially accelerates upwards.

The resultant force *F* on the balloon is given by

$$F = \text{upthrust} - \text{weight} - \text{viscous drag}$$

Eventually the balloon reaches a constant upwards speed.

Calculate a value for the viscous drag force acting on the balloon at this speed. The balloon may be considered as a sphere with radius 12 cm.

(4)

density of air = 1.2 kg m^{-3}

mass of unfilled balloon = 4.0 g

mass of helium in balloon = 1.2 g

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Viscous drag force = ...

(Total for question = 4 marks)

Q15.

A small helium balloon is released into the air. The balloon initially accelerates upwards.

The resultant force F on the balloon is given by

$$F = \text{upthrust} - \text{weight} - \text{viscous drag}$$

The viscosity of the air decreases as the balloon rises.

On a warmer day a balloon of the same total mass and radius rises at a lower constant upwards speed.

Give a reason why.

(1)

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(Total for question = 1 mark)

Q16.

A student carries out an experiment to determine the viscosity of glycerol. She does this by determining the terminal velocity of a steel sphere falling through glycerol.

The equation shows how the terminal velocity of a solid sphere falling through a liquid depends on the density of both the solid and the liquid.

$$v = \frac{Vg(\rho_s - \rho_l)}{6\pi r\eta}$$

where

ρ_l = density of liquid
ρ_s = density of solid
r = radius of sphere
V = volume of sphere
η = viscosity of liquid
v = terminal velocity

The derivation of the equation for terminal velocity has been started below.
Complete the derivation.

(3)

At terminal velocity: weight of solid sphere = drag + upthrust

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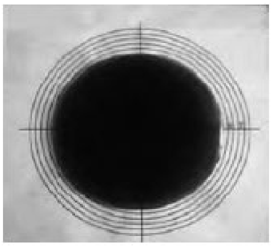
(Total for question = 3 marks)

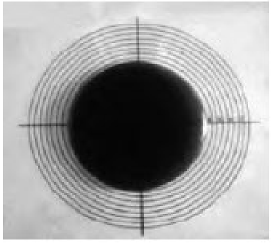
Q17.

The photograph shows an image of two "pancake" volcanoes on the surface of the planet Venus. Scientists believe these types of volcano are formed from lava spreading out in all directions onto a flat landscape.

A student investigated the formation of pancake volcanoes. She observed the flow of a viscous liquid at two different temperatures as it spread out from a central spot. The photographs below show the liquid at both temperatures after it had been flowing for the same length of time.



High temperature test



Low temperature test

The student carried out an experiment to determine the viscosity of the liquid at room temperature. She observed a steel sphere falling through the liquid.

She had the following equipment:

- a long, wide cylindrical tube
- two steel spheres with diameters 7.0 mm and 22.0 mm
- video camera
- metre rule

The student observed the sphere with a diameter of 7.0 mm falling through the liquid. The sphere fell 0.80 m in 5.3 s at a constant velocity.

The viscosity η of the liquid can be calculated using the equation

$$\eta = \frac{Vg(\rho_s - \rho_l)}{6\pi r v}$$

providing Stokes' law applies.

(i) Calculate the viscosity of the liquid.

density of liquid ρ_1 = 1430 kg m^{-3}
density of steel ρ_s = 7800 kg m^{-3}

(4)

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Viscosity of liquid = ... Pa s

(ii) If the student had used the larger sphere, the equation would not have produced the correct answer.
Explain why.

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(iii) The student used the video camera to record the sphere falling through the liquid.
State **one** benefit of using the video camera to record the motion of the sphere.

(1)

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(Total for question = 7 marks)

Q18.

A seiche is a standing wave that can form on the surface of a lake in strong winds, causing flooding and erosion.

The temperature of the lake decreases with depth.

Explain how this may affect the rate at which a particle falls.

(2)

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(Total for question = 2 marks)

Q19.

A small sphere is falling through a liquid. The viscous drag force acting on the sphere will increase if the

- ☐ **A** density of the liquid decreases.
- ☐ **B** radius of the sphere decreases.
- ☐ **C** temperature of the liquid decreases.
- ☐ **D** viscosity of the liquid decreases.

(Total for question = 1 mark)

Q20.

A seiche is a standing wave that can form on the surface of a lake in strong winds, causing flooding and erosion.

Erosion causes clay particles to be washed into the lake, making the lake cloudy. The lake can remain cloudy to a depth of about 4 m for more than 6 months.

One spherical clay particle has a radius of 2.5×10^{-7} m.

Deduce whether this particle takes more than 6 months to fall 4 m.
You should assume that the water in the lake remains still.

viscosity of water = 1.0×10^{-3} kg m^{-1} s^{-1}
density of water = 1000 kg m^{-3}
density of clay = 2650 kg m^{-3}

(6)

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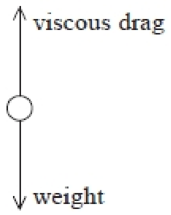
(Total for question = 6 marks)

Q21.

A student used steel ball bearings falling through a viscous liquid to investigate the relationship between the terminal velocity *v* of a ball bearing and its radius *r*.

A free body force diagram for a ball bearing of radius 5.00 mm falling through the liquid is shown. The upthrust on the ball bearing has been ignored.

Diagram **NOT** to scale



(i) Show that the weight of a ball bearing with a radius of 5.0 mm is about 4×10^{-2} N.

density of steel = 8.0×10^3 kg m^{-3}

(3)

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(ii) Calculate the terminal velocity of the ball bearing as it falls through the liquid. You may ignore the upthrust on the ball bearing.

viscosity of liquid = 1.8 Pa s

(2)

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Terminal velocity = ...

(Total for question = 5 marks)

Mark Scheme - Fluid

Q1.

Question Number	Acceptable Answer	Additional Guidance
	• The first rubber band is too near the surface of the honey (so the ball won't be at its terminal velocity) **(1)** • There is no method for checking that the ball is falling at terminal velocity (when he times) **(1)**	Accept statements for how procedure could be improved consistent with MP1 and MP2 e.g. there should be multiple bands for timing e.g. they haven't videoed the falling ball

Q2.

Question Number	Acceptable Answers	Additional guidance	Mark
(i)	• Use of $v = \frac{s}{t}$ (1) • Use of $V = \frac{4}{3}\pi r^3$ (1) • Use of $v = \frac{Vg(\rho_s - \rho_l)}{6\pi r \eta}$ (1) • η =1.8 Pa s (1)	<u>Example of Calculation</u> $v = \frac{0.5}{3.9} = 0.13\ (\mathrm{m\ s^{-1}})$ $\eta = \frac{\frac{4}{3}\pi(4 \times 10^{-3})^3 \times 9.81 \times (7800 - 1300)}{6\pi \times 4 \times 10^{-3} \times 0.13} = 1.8\ \mathrm{Pa\ s}$ Accept kg $m^{-1}s^{-1}$ / N s m^{-2}	4

Question Number	Acceptable Answers	Additional guidance	Mark
(ii)	5cm (no mark) • Laminar flow **Or** less/no turbulent flow (1) • So Stoke's law applies **Or** sphere falls at a more constant rate (1)	Accept wider for 5.0 cm	2

Q3.

Question Number	Acceptable Answers		Additional Guidance	Mark
(i)	• drag + weight = upthrust • use of $\rho = m/V$ and $W = mg$ • use of $F = 6\pi\eta rv$ and $V = 4/3\pi r^3$	(1) (1) (1)	Example of calculation: drag + weight = upthrust drag = upthrust - weight $6\pi\eta rv = 4\pi r^3\rho_{stout}g/3 - 4\pi r^3\rho_{gas}g/3$ $v = 2(\rho_{stout} - \rho_{gas})r^2g/9\eta$	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	• low speed OR laminar flow OR not turbulent flow		**(1)**

Question Number	Acceptable Answers		Additional Guidance	Mark
(iii)	• use of $v = 2(\rho_{stout} - \rho_{gas})r^2g/9\eta$ • use of $v = s/t$ • time = 29 s • comment on the difference with 120 seconds OR an attempt to account for the difference	(1) (1) (1) (1)	Example of calculation: $v = 2\ (1.007 \times 10^3\ \text{kg m}^{-3} - 1.223\ \text{kg m}^{-3}) \times (61 \times 10^{-6}\ \text{m})^2 \times 9.81\ \text{N kg}^{-1} / 9 \times 2.06 \times 10^{-3}\ \text{Pa s}$ $= 3.96 \times 10^{-3}\ \text{m s}^{-1}$ $t = 0.115\ \text{m} / 3.96 \times 10^{-3}\ \text{m s}^{-1}$ = 29 s Actual time much less than the manufacturers time therefore not a valid statement OR reference time to reach terminal velocity OR there is turbulent flow	**(4)**

Q4.

Question Number	Acceptable Answers	Additional Guidance	Mark
	B		1

Q5.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• initially upthrust greater than weight **and** drag is zero (1) • unbalanced force, so accelerates upwards (1) • as velocity increases drag increases (1) • until drag + weight = upthrust, so resultant is zero and acceleration is zero (and velocity is constant) (1)		**(4)**

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $\rho = m/V$ (1) • Use of relationship upthrust = weight of liquid (1) • Use of $F = 6\pi\eta rv$ (1) • $\eta = 3.97 \times 10^{-2}$ (Pa s) so it is sunflower oil (1)	Example of calculation mass of oil displaced $= 9.20 \times 10^2$ kg m^{-3} $\times 1.41 \times 10^{-8}$ m^3 $= 1.30 \times 10^{-5}$ kg upthrust $= 1.30 \times 10^{-5}$ kg $\times 9.81$ m s^{-2} $= 1.27 \times 10^{-4}$ N weight of sphere $= 1.10 \times 10^{-4}$ kg $\times$ 9.81 m s^{-2} $= 1.08 \times 10^{-3}$ N weight = upthrust + drag 1.08×10^{-3} N = ($6\pi \times \eta \times 1.5 \times 10^{-3}$ m $\times$ 0.849 m s^{-1}) + 1.27×10^{-4} N $\eta = 3.97 \times 10^{-2}$ Pa s	4

Q7.

Question Number	Answer	Additional Guidance	Mark
	• The idea that human reaction time is large (compared to the short time to be measured) • Giving a greater %U in measurements of time so not suitable		2

Q8.

Question Number	Answer	Mark
	D larger ball bearing in liquid with lower viscosity	1
	Incorrect Answers: **A** smaller ball bearing in higher viscosity will fall most slowly **B** ball bearing in higher viscosity will fall the more slowly than in lower viscosity **C** smaller ball bearing will fall more slowly than a larger ball bearing	

Q9.

Question Number	Acceptable Answers	Additional guidance	Mark
(i)	• Recognises resultant force on raindrop = 0 **Or** Uses $W=F(+U)$ (1) • Use of $F = 6\pi\eta rv$ (1) • Use of U = weight of air displaced **Or** $U = \frac{4}{3}\rho_a \pi r^3 g$ **Or** $U = \rho_a V g$ and $V = \frac{4}{3}\pi r^3$ **Or** $U = mg$ and $\rho = \frac{m}{V}$ and $V = \frac{4}{3}\pi r^3$ **Or** states upthrust is negligible (1) • 1.7 m s^{-1} (1)	Example of Calculation $W=F+U$ $F = 6\pi \times 1.3 \times 10^{-5}\,\text{Nm}^{-2} \times 1.0 \times 10^{-4} \times v = (2.45 \times 10^{-8}\, v)$ (N) $U = 1.225\ \text{kg m}^{-3} \times \frac{4}{3}\pi(0.0001\ \text{m})^3 \times 9.81\text{m s}^{-2} = 4.9 \times 10^{-11}$ (N) $v = \frac{4.1\times10^{-8}\ \text{N} - 4.9\times10^{-11}\ \text{N}}{2.45\times10^{-8}} = 1.7\ \text{m s}^{-1}$	4
(ii)	turbulent flow (1) (so) Stokes law does not apply (1)		2

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
	B The bubble has a constant velocity because upthrust is equal to viscous drag.		1

Q11.

Question Number	Acceptable Answer		Additional Guidance	Mark
(a)	• Comparison to $y = mx + c$ • Identify that η, ρ_s, ρ_f and g are constants • $c = 0$ so the graph passes through the origin **Or** when $d^2 = 0$, $v = 0$ so would pass through the origin	(1) (1) (1)	MP1 e.g. $y = mx + c$ so $v = \left(\frac{g(\rho_b - \rho_f)}{18\eta}\right) \times d^2\ (+0)$	3

Question Number	Acceptable Answer		Additional Guidance	Mark
(b)	• Axes labelled with quantities and units • Suitable scale • Correct plotting • Line of best fit (judged by eye)	(1) (1) (1) (1)	MP1: v / 10^{-3} m s^{-1} on y-axis and d^2 / 10^{-6} m^2 on x-axis	4

d^2 / 10^{-6} m^2	v / 10^{-3} m s^{-1}
1.0	2.3
4.0	11
9.0	23
16.0	39
25.0	64

Question Number	Acceptable Answer		Additional Guidance	Mark
(c)	• Attempt to find gradient, at least half drawn line used • Use of $\eta = \frac{g(\rho_s - \rho_f)}{18} \times \frac{1}{\text{gradient}}$ • $\eta =$ 1.4 – 1.5 (Pa s) • Corn syrup identified as the fluid	(1) (1) (1) (1)	MP4 to be consistent with calculated value for η Example of calculation $\eta = \frac{9.81\text{ N kg}^{-1} \times (8000\text{ kg m}^{-3} - 1260\text{ kg m}^{-3})}{18 \times 2.52 \times 10^{3}\text{ m}^{-1}\text{ s}^{-1}}$ $\eta = 1.46$ Pa s	4

Q12.

Question Number	Acceptable Answers	Additional guidance	Mark
	• experiment shows the liquid flows faster at higher temperature (1) • (if lava behaves similarly) lava will flow a long way (covering a large area) in a given time **Or** (since) at a higher temperature the liquid has a lower viscosity (1)	MP1 Must be an indication of speed. MP2 Accept solidifying as an indication of in a given time	2

Q13.

Question Number	Acceptable answer	Additional guidance	Mark
	B	The only correct answer is **B**: Upthrust is density of fluid × volume of object × *g* A is not the correct answer because density of object has been used, so this is the gravitational force acting on the object C is not the correct answer because this is the resultant force D is not the correct answer because this is the mean of the magnitude of the forces in A and B	1

Q14.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Recognises that $F=0$ **Or** Uses $D = U - W$ (1) • Use of $W = mg$ with $m =$ 5.2 g (1) • Use of $U =$ weight of air displaced by balloon **Or** $U = \frac{4}{3}\rho_a \pi r^3 g$ **Or** $U = \rho_a V g$ and $V = \frac{4}{3}\pi r^3$ **Or** $U = mg$ and $\rho = \frac{m}{V}$ and $V = \frac{4}{3}\pi r^3$ (1) • 0.034 N (1)	<u>Example of calculation</u> $D = (\frac{4}{3}\pi \times (0.12\text{ m})^3 \times 1.2\text{ kg m}^{-3} \times 9.81\text{ m s}^{-2}) - ((4+1.2)\text{ kg} \times 9.81\text{ m s}^{-2})$ $= 0.034\text{ N}$	4

Q15.

Question Number	Acceptable Answers	Additional guidance	Mark
	Viscosity of air increases as temperature increases (1) **Or** (1) Density of air is lower so upthrust is smaller		1

Q16.

Question Number	Acceptable Answers	Additional guidance	Mark
	• See drag = $6\pi r\eta v$ (1) • see Upthrust $= \rho_l V g$ (1) • see weight of sphere = $\rho_s V g$ (1)	Accept F or D for drag Do not accept $U = \rho_s V g$ for MP2 Accept ρ_f for ρ_l Example of Calculation At terminal velocity: Weight = Drag + Upthrust Therefore $m_s g = 6\pi r\eta v + m_l g$ $\rho_s V g = 6\pi r\eta v + \rho_l V g$ Rearranging $v = \frac{\rho_s V g - \rho_l V g}{6\pi r\eta}$ $v = \frac{V g(\rho_s - \rho_l)}{6\pi r\eta}$	3

Q17.

Question Number	Acceptable Answers	Additional guidance	Mark
(i)	• Use of $v = \frac{s}{t}$ (1) • Use of $V = \frac{4}{3}\pi r^3$ (1) • Use of $v = \frac{Vg(\rho_s - \rho_l)}{6\pi r\eta}$ (1) • $\eta = 1.1$ (Pa s) (1)	Example of Calculation $\eta = \frac{\frac{4}{3}\pi\left(\frac{7.0\times10^{-3}\text{ m}}{2}\right)^3 \times 9.81\text{ m s}^{-2} \times (7800 - 1430)\text{kg m}^{-3}}{6\pi \times \frac{7.0\times10^{-3}\text{m}}{2} \times \frac{0.8\text{ m}}{5.3\text{ s}}}$ $\eta = 1.13$ Pa s	4
(ii)	• With the large sphere the speed will be greater so Stokes' law won't apply (1) • The flow is turbulent or not laminar (1)		2
(iii)	**Any one** • Can eliminate human reaction time • Can playback to measure time more accurately • Can check that terminal velocity is reached (1)		1

Q18.

Question Number	Answer	Additional Guidance	Mark
	• Viscosity increases with decreasing temperature (1) **Or** Viscosity or viscous drag increases with depth • (so) rate at which the particle falls decreases with depth (1)	MP2 dependent on MP1	2

Q19.

Question Number	Acceptable answers	Additional guidance	Mark
	C		1

Q20.

Question Number	Answer	Additional Guidance	Mark
	• Use of $F = 6\pi\eta r v$ (1) • Use of $U = mg$ and $\rho = \frac{m}{V}$ and $V = \frac{4}{3}\pi r^3$ (1) • Recognises $W = F + U$ (1) • Use of $v = \frac{s}{t}$ (1) **Either** • $t = 1.7 \times 10^7$ s (1) • comparison with 6 months and conclusion consistent with their answer **Or** • $s = 3.3 - 3.6$ m (1) • comparison with 4 m and conclusion consistent with their answer	Example of calculation $F = 6\pi \times 1.0 \times 10^{-3}$ kg m^{-1} s^{-1} $\times 2.5 \times 10^{-7}$ m $\times v$ $V = \frac{4}{3}\pi(2.5 \times 10^{-7}$ m$)^3 = 6.5 \times 10^{-20}$ m^3 $U = \rho_w V g = 1000$ kg m^{-3} $\times$ 6.5×10^{-20} m^3 $\times 9.81$ m s^{-1} $U = 6.4 \times 10^{-16}$ N $W = 2650$ kg m^{-3} $\times$ 6.5×10^{-20} m^3 $\times$ 9.81 m s^{-1} $W = 1.7 \times 10^{-15}$ N $F = 1.7 \times 10^{-15}$ N - 6.4×10^{-16} N $F = 1.1 \times 10^{-15}$ N $v = \frac{1.1 \times 10^{-15}\ \text{N}}{6\pi \times 1.0 \times 10^{-3}\text{kg m}^{-1}\text{s}^{-1} \times 2.5 \times 10^{-7}\ \text{m}}$ $v = 2.3 \times 10^{-7}$ m s^{-1} $t = \frac{4\ \text{m}}{2.3 \times 10^{-7}\ \text{m s}^{-1}} = 1.7 \times 10^7$ s t =197 days which is 6.6 months accept 1 month = 28 to 31 days giving t = 6.3 to 7.0 months	6

Q21.

Question Number	Answers	Additional guidance	Mark
i	• Use of $V = \frac{4}{3}\pi r^3$ (1) • Use of $\rho = \frac{m}{V}$ **and** $W = mg$ (1) • $W = 4.1 \times 10^{-2}$ (N) (1)	<u>Example of Calculation</u> $W = 8.0 \times 10^3$ kg m^{-3} $\times$ $\frac{4}{3}\pi(0.005\ \text{m})^3 \times 9.81$ m s^{-2} $W = 4.11 \times 10^{-2}$ N	**3**
ii	• Use of $F = 6\pi r\eta v$ (1) • $v = 0.24$ m s^{-1} (1)	<u>Example of Calculation</u> 4.1×10^{-2} N $= 6\pi \times 0.005$ m $\times$ 1.78 N s m^{-2} $\times v$ $v = \frac{4.1 \times 10^{-2}\ \text{N}}{6\pi \times 0.005\ \text{m} \times 1.78\ \text{N s m}^{-2}}$ $v = 0.24$ m s^{-1}	**2**