

Mark Scheme

Q1.

Question Number	Answer	Mark
	C is the correct answer A is incorrect because it give units of $\text{m}^3 \text{kg}^{-1}$ B is incorrect because it give units of $\text{m}^3 \text{kg N}^{-2}$ D is incorrect because it give units of $\text{N}^2 \text{kg}^{-1} \text{m}^{-3}$	(1)

Q2.

Question Number	Answer	Mark
	The only correct answer is C (Viscosity of oil increases; Terminal velocity of ball bearing decreases) A is not correct because viscosity increases as temperature decreases B is not correct because viscosity increases as temperature decreases and terminal velocity decreases when viscosity increases D is not correct because terminal velocity decreases when viscosity increases	1

Q3.

Question Number	Answer	Mark
	The only correct answer is D <i>A is not the correct answer as smaller particles of sand have a lower terminal velocity so take longer to reach the bottom of the beaker</i> <i>B is not the correct answer as a lower temperature would increase the viscosity and increase the time taken for the particles to reach the bottom of the beaker (lower terminal velocity)</i> <i>C is not the correct answer as the sand particles take longer to reach the bottom of the beaker with a smaller terminal velocity</i>	(1)

Q4.

Question Number	Answer	Mark
(a)	(Use balance to measure) mass and multiply mass by g to determine weight Or Use the balance set to read newtons to determine weight (of ball) (1) Measure the <u>diameter</u> (of the ball) (with the calliper) to determine volume (1) Identify upthrust with weight of fluid displaced (1) Calculate the weight of fluid displaced by multiplying the volume of the ball by the density of the liquid and g (1)	4
(b)	Use of $F = 6\pi \eta r v$ (1) $\eta = 2.2 \times 10^2 \text{ Pa s}$ (1) <u>Example of calculation</u> $1.1 \times 10^{-2} \text{ N} = 6\pi \times \eta \times 0.50 \times 10^{-2} \text{ m} \times 5.4 \times 10^{-4} \text{ m s}^{-1}$ $\eta = 1.1 \times 10^{-2} \text{ N} \div (6\pi \times 2.7 \times 10^{-6} \text{ m}^2 \text{ s}^{-1}) = 216 \text{ Pa s}$	2
Total for question		6

Q5.

Question Number	Answer	Mark																																								
*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content and lines of reasoning. <table><tr><th>IC points</th><th>IC mark</th><th>Max linkage mark available</th><th>Max final mark</th></tr><tr><td>6</td><td>4</td><td>2</td><td>6</td></tr><tr><td>5</td><td>3</td><td>2</td><td>5</td></tr><tr><td>4</td><td>3</td><td>1</td><td>4</td></tr><tr><td>3</td><td>2</td><td>1</td><td>3</td></tr><tr><td>2</td><td>2</td><td>0</td><td>2</td></tr><tr><td>1</td><td>1</td><td>0</td><td>1</td></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td></tr></table> <table><tr><th></th><th>Marks</th></tr><tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr></table> Indicative content: - Upthrust on a bulb is equal to weight of liquid displaced. (1) - When upthrust equals/exceeds weight of bulb / disc, bulb floats (1) - Weight of a bulb / disc is constant (1) - As temperature increases the weight of displaced liquid decreases (1) Or As temperature increases upthrust on bulb decreases (1) - Until weight of a bulb / disc exceeds the upthrust (1) - There is a resultant force and bulb will sink	IC points	IC mark	Max linkage mark available	Max final mark	6	4	2	6	5	3	2	5	4	3	1	4	3	2	1	3	2	2	0	2	1	1	0	1	0	0	0	0		Marks	Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2	Answer is partially structured with some linkages and lines of reasoning	1	Answer has no linkages between points and is unstructured	0	6
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Total for question		6																																								

Question Number	Answer	Mark
(a)	- Laminar/non-turbulent flow - Or Slow moving sphere	(1)
(b)	- Use of $W = mg$ $W = U + D$ - Use of $F = 6\pi\eta r v$ - Use of $W = U + D$ to obtain quantity to compare, e.g. $D = (-) 7.8 \times 10^{-3} \text{ (N)}$ - Comparison leading to valid conclusion from candidate's calculation. e.g. $F = 2.5 \times 10^{-5} \text{ N} \neq D$ or $v = 155 \text{ m s}^{-1} \neq 0.5 \text{ m s}^{-1}$ <i>et al.</i> <u>Example of calculation</u> $W = 9.1 \times 10^{-4} \text{ kg} \times 9.81 \text{ N kg}^{-1} = 9.0 \times 10^{-3} \text{ N}$ $\Sigma F = 9.0 \times 10^{-3} \text{ N} - 1.1 \times 10^{-3} \text{ N} - \text{drag} = 0$ $\text{Drag} = (-) 7.9 \times 10^{-3} \text{ N}$ $F = 6 \times \pi \times 3.0 \times 10^{-3} \text{ m} \times 8.9 \times 10^{-4} \text{ Pa s} \times 0.50 \text{ m s}^{-1}$ $F = 2.5 \times 10^{-5} \text{ N}$	(1) (1) (1) (1) (1)
		(5)

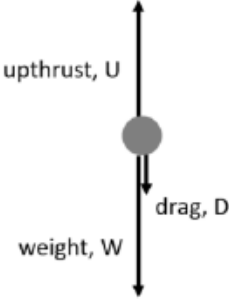
Q7.

Question Number	Answer	Mark
(a)	The weight of the grain is equal to the sum of the drag and upthrust acting on it Or Resultant force = 0 Or The sum of the upward forces is equal to the sum of the downward forces Or The (vector) sum of the forces is zero	1
(b)	Use of weight = upthrust + drag Use of viscous drag = $6\pi\eta rv$ $v = 1.7 \text{ m s}^{-1}$ and comparison with 0.050 m s^{-1} and consistent conclusion. (allow correctly calculated values for other quantities given in the question, with consistent conclusion) <u>Example of calculation</u> Drag = $4.3 \times 10^{-5} \text{ N} - 1.5 \times 10^{-5} \text{ N} = 2.8 \times 10^{-5} \text{ N}$ $v = \frac{2.8 \times 10^{-5} \text{ N}}{6 \times \pi \times 1.2 \times 10^{-3} \text{ Pa s} \times \left(\frac{1.5 \times 10^{-3} \text{ m}}{2}\right)} = 1.65 \text{ m s}^{-1}$ $1.65 \neq 0.05$ so Stokes' law does not apply	3

(c)	As temperature increases, viscosity decreases	(1)	
	So (value of) <u>terminal</u> velocity increases (to make drag equal to weight) (dependent on MP1)	(1)	2
	Allow converse argument		
	Total for question		6

Q8.

Question Number	Answer	Mark
(a)	Max 2 Object must be a sphere (1) Low speed/velocity (1) Laminar flow (1)	2
(b)(i)	Use of $F = 6\pi \eta r v$ (1) Subtraction of two forces (1) Resultant force = $7 \times 10^{-6} \text{ N}$ (1) <u>Example of calculation</u> drag force = $6\pi \times 7.1 \times 10^{-2} \text{ Pa s} \times 2.25 \times 10^{-3} \text{ m} \times 5.2 \times 10^{-3} \text{ m s}^{-1}$ = $1.6 \times 10^{-5} \text{ N}$ Resultant force = $2.3 \times 10^{-5} \text{ N} - 1.6 \times 10^{-5} \text{ N} = 0.7 \times 10^{-5} \text{ N}$	3
(b)(ii)	Use of $F = 6\pi \eta r v$ with $F = 2.3 \times 10^{-5} \text{ N}$ (1) $v = 7.6 \times 10^{-3} \text{ m s}^{-1}$ (1) <u>Example of calculation</u> $2.30 \times 10^{-5} \text{ N} = 6\pi \times 7.10 \times 10^{-2} \text{ Pa s} \times 2.25 \times 10^{-3} \text{ m} \times v$ $v = 2.30 \times 10^{-5} \text{ N} \div (6\pi \times 7.10 \times 10^{-2} \text{ Pa s} \times 2.25 \times 10^{-3} \text{ m}) = 7.64 \times 10^{-3} \text{ m s}^{-1}$	2
(c)	Larger diameter gives larger drag force (at given speed) (1) Or Larger diameter gives a lower speed (for the same constant force) (1) Lower temperature so viscosity is greater Greater viscosity gives larger drag force (at given speed) Or Greater viscosity gives lower speed (for the same constant force) (1) Maximum speed will decrease (dependent on MP1 and MP3) (1)	4
	Total for question	11

Question Number	Answer	Mark
(a)	- Weight Or W, downwards - Drag Or D, downwards 	(1) (1) 2
(b)	- Use of $V = \frac{4}{3}\pi r^3$ - Use of $\rho = \frac{m}{V}$ and $W = mg$ - Upthrust = 3.06×10^{-4} (N) <u>Example of calculation</u> Volume of bead = $\frac{4}{3} \times \pi \times (2.00 \times 10^{-3} \text{ m})^3 = 3.35 \times 10^{-8} \text{ m}^3$ Weight of displaced fluid = $930 \text{ kg m}^{-3} \times 3.35 \times 10^{-8} \text{ m}^3 \times 9.81 \text{ N kg}^{-1}$ = $3.06 \times 10^{-4} \text{ N}$	(1) (1) (1) 3
(c)(i)	- The flow must be laminar - Or There must be no turbulent flow	(1) 1
(c)(ii)	- States $D = U - W$ - Use of $F = 6\pi\eta rv$ $v = 0.16 \text{ (m s}^{-1}\text{)}$ - Calculate $v_R = 0.13 \text{ (m s}^{-1}\text{)}$ - Comparison of v with v_R and correct conclusion (ecf from (b)) Alternative method of comparison of $F(0.13)$ with D scores full marks. <u>Example of calculation</u> $U - W = 3.06 \times 10^{-4} - 1.05 \times 10^{-5} = 2.96 \times 10^{-4} \text{ N}$ $v = 2.96 \times 10^{-4} \text{ N} / (6\pi \times 4.9 \times 10^{-2} \text{ Pa s} \times 2.0 \times 10^{-3} \text{ m}) = 1.60 \times 10^{-1} \text{ m s}^{-1}$ $v_R = 10 \times 4.9 \times 10^{-2} \text{ Pa s} / (930 \text{ kg m}^{-3} \times 4.0 \times 10^{-3} \text{ m}) = 1.32 \times 10^{-1} \text{ m s}^{-1}$	(1) (1) (1) (1) (1) 5
Total for question		11

Question Number	Answer	Mark
(a)(i)	The layers of fluid flow past each other without mixing Or <u>Velocity</u> at a fixed point (relative to the drop) remains constant (1)	1
(a)(ii)	Resultant force is zero Or Sum of the vertical forces is zero (1) (Accept $W - U = D$ or $W = U + D$ with terms defined)	1
(b)(i)	Use of $\rho = \frac{m}{V}$ (1) Use of $W = mg$ (1) Weight = 3.3×10^{-4} N (1) <u>Example of calculation</u> $1.00 \times 10^3 \text{ kg m}^{-3} = m \div 3.35 \times 10^{-8} \text{ m}^3$ $m = 1.00 \times 10^3 \text{ kg m}^{-3} \times 3.35 \times 10^{-8} \text{ m}^3 = 3.35 \times 10^{-5} \text{ kg}$ $W = mg = 3.35 \times 10^{-5} \text{ m}^3 \times 9.81 \text{ N kg}^{-1} = 3.29 \times 10^{-4} \text{ N}$	3
(b)(ii)	Use of upthrust = weight of fluid displaced (1) Upthrust = 3.1×10^{-4} (N) (1) <u>Example of calculation</u> $0.94 \times 10^3 \text{ kg m}^{-3} = m \div 3.35 \times 10^{-8} \text{ m}^3$ $m = 0.94 \times 10^3 \text{ kg m}^{-3} \times 3.35 \times 10^{-8} \text{ m}^3 = 3.15 \times 10^{-5} \text{ kg}$ $U = mg = 3.15 \times 10^{-5} \text{ m}^3 \times 9.81 \text{ N kg}^{-1} = 3.09 \times 10^{-4} \text{ N}$	2

(b)(iii)	Uses upthrust and weight to determine the viscous force F (1) Use of $V = \frac{4}{3} \pi r^3$ to determine r (1) Use of $F = 6\pi\eta rv$ (1) $v = 4.8 \times 10^{-3} \text{ m s}^{-1}$ (ecf from (b)(i) and (b)(ii)) (1) <u>Example of calculation</u> $W = U + 6\pi\eta rv \rightarrow W - U = 6\pi\eta rv$ $W - U = (3.29 - 3.09) \times 10^{-4} \text{ N} = 2.0 \times 10^{-5} \text{ N}$ $r = \sqrt[3]{\frac{3}{4} \times 3.35 \times 10^{-8} \text{ m}^3 \div \pi} = 2.0 \times 10^{-3} \text{ m}$ $2.0 \times 10^{-5} \text{ N} = 6\pi \times 0.11 \text{ Pa s} \times 2.0 \times 10^{-3} \text{ m} \times v$ $v = 2.0 \times 10^{-5} \text{ N} \div (6\pi \times 0.11 \text{ Pa s} \times 2.0 \times 10^{-3} \text{ m}) = 4.82 \times 10^{-3} \text{ m s}^{-1}$	4
Total for question		11

Question Number	Answer	Mark
(a)(i)	Small, spherical object Or Spherical object with low speed (1) laminar flow Or flow is not turbulent (1)	2
(a)(ii)	Use of $v = \frac{s}{t}$ (1) Use of $V = \frac{4}{3}\pi r^3$ (1) Use of $F = 6\pi\eta r v$ (1) $F = 0.035 \text{ N}$ (1) comparison of their calculated force with 4.6 (N) and consistent conclusion (1) <u>Example calculation</u> $v = \frac{25 \text{ m}}{0.36 \text{ s}} = 69.4 \text{ m s}^{-1}$ $r = \sqrt[3]{\frac{3 \times 45 \times 10^{-6} \text{ m}^3}{4 \times \pi}} = 0.0221 \text{ m}$ $F = 6 \times \pi \times 1.2 \times 10^{-3} \text{ Pa s} \times 0.0221 \text{ m} \times 69.4 \text{ m s}^{-1} = 0.0347 \text{ N}$ $0.0347 \text{ N} < 4.6 \text{ N}$ so Stokes' law does not apply.	5

(b)(i)	The areas between the line and the x-axis should be determined Or The area between the line and the x-axis represents displacement (1) The diver will be at the surface if the area below the x-axis (before 25 s) is equal to the area above the x-axis (after 25 s). Or The diver will be at the surface if the total (positive and negative values of) area is equal to zero (1)	2
(b)(ii)	Draws tangent at 70 s (1) Determines values for Δv and Δt (1) Acceleration = $(-0.008 \text{ m s}^{-2})$ (allow an answer in the range $(-0.007 \text{ m s}^{-2})$ to (-0.01 m s^{-2})) (1) <u>Example calculation</u> $\text{Acceleration} = \frac{-0.50 \text{ m s}^{-1}}{65 \text{ s}} = -0.0077 \text{ m s}^{-2}$	3
Total for question		12

Question Number	Answer	Mark
(a)(i)	Use of $\rho = m / V$ (1) Identifies upthrust is equal to weight of fluid displaced (1) Use of $W = m g$ (1) Use of $D = W - U$ (1) 1.8×10^2 (N) (1) <u>Example of calculation</u> $m = 1030 \text{ kg m}^{-3} \times 1.60 \times 10^{-2} \text{ m}^3 = 16.5 \text{ kg}$ $U = 16.5 \text{ kg} \times 9.81 \text{ N kg}^{-1} = 162 \text{ N}$ $W = 35 \text{ kg} \times 9.81 \text{ N kg}^{-1} = 343 \text{ N}$ $D = W - U = 343 \text{ N} - 162 \text{ N} = 181 \text{ N}$	5
(a)(ii)	Use of $D = k v^2$ (1) $v = 9.1 \text{ m s}^{-1}$ (allow ecf from (a)(i)) (1) <u>Example of calculation</u> $D = 181 \text{ N} = 2.2 \text{ N s}^2 \text{ m}^{-2} \times v^2$ $v = \sqrt{(181 \text{ N} \div 2.2 \text{ N s}^2 \text{ m}^{-2})} = 9.1 \text{ m s}^{-1}$	2
(a)(iii)	Object might not be spherical (1) Flow might not be laminar (1)	2
(b)	Drag force increases as velocity increases (1) Until drag force plus weight equals upthrust (1) (Resultant force is then zero) so the object stops accelerating (1)	3
Total for question		12

Q13.

Question Number	Answer	Mark
(a)	Small spherical object Or Spherical object moving at low speed (1) Laminar flow [allow non-turbulent flow] (1)	2
(b)(i)	Max 3 Initially the velocity is zero so gradient is zero (1) As velocity increases the gradient changes (1) As velocity increases, drag increases (1) Until terminal / constant velocity when the gradient becomes constant. (1) [If no other mark scored, allow 1 mark for velocity increases until terminal velocity is reached.]	3

(b)(ii)	Determines radius of ball bearing	(1)	4
	Determines gradient	(1)	
	Use of $F = 6\pi\eta rv$	(1)	
	$\eta = 0.046 \text{ (Pa s)}$ [allow a range from 0.044 (Pa s) to 0.048 (Pa s)]	(1)	
	<u>Example calculation</u> $\text{Radius} = \frac{1.6 \times 10^{-3} \text{ m}}{2} = 8 \times 10^{-4} \text{ m}$ $\text{Gradient} = \frac{11.5}{1.15 - 0.60} = 20.9$ $v = 0.209 \text{ m s}^{-1}$ $\eta = \frac{1.45 \times 10^{-4} \text{ N}}{6\pi \times 8 \times 10^{-4} \text{ m} \times 0.209 \text{ m s}^{-1}} = 0.0460 \text{ Pa s}$		
(b)(iii)	At higher temperature the viscosity will be less	(1)	4
	$F = 6\pi\eta rv$ and r is constant	(1)	
	Drag force is less (at a given speed)		
	Or Drag force (at terminal velocity) is unchanged	(1)	
	<u>Terminal</u> velocity is greater (and ball-bearing takes less time to fall)	(1)	
Total for question			13