

Mark Scheme

Q1.

Question Number	Answer	Mark
	B is the only correct answer A is incorrect because a greater viscosity would reduce terminal velocity giving a lower gradient C is incorrect because because a greater viscosity would reduce terminal velocity giving a lower gradient D is incorrect because because a greater viscosity would reduce terminal velocity giving a lower gradient	1

Q2.

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

Q3.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	Mass of the ball-bearing (1)	Allow weight of ball-bearing Allow mass / weight of (a known volume of) oil Allow volume of (a known mass of) oil Allow density of oil Ignore radius / diameter / volume of ball-bearing Ignore density of ball-bearing Ignore temperature of oil	1
(b)	Use of $s = ut + \frac{1}{2}at^2$ with $a = 0$ (1) Use of $F = 6\pi\eta rv$ (1) $\eta = 0.031 \text{ (Pa s)}$ (1)	Example calculation $v = \frac{0.20 \text{ m}}{1.3 \text{ s}} = 0.154 \text{ m s}^{-1}$ $\eta = \frac{5.6 \times 10^{-5} \text{ N}}{6 \times \pi \times \frac{1.24 \times 10^{-3}}{2} \times 0.154 \text{ m s}^{-1}} = 0.0311 \text{ Pa s}$	3
(c)	(At a lower temperature) the oil has a greater viscosity (1) (So) the ball falls at a smaller (terminal) velocity (1) (So) time taken is greater (for the ball to fall 20.0 cm) (1)	MP3 dependent on MP1 or MP2	3

Q4.

Question Number	Answer	Mark
(a)(i)	The sphere will be <u>accelerating</u> (in the oil) initially Or Sphere needs time/distance to <u>accelerate</u> The sphere falls a distance (through the oil) before reaching constant/terminal <u>velocity</u> Or Sphere needs to reach terminal <u>velocity</u> before timing begins	(1) (1) 2
(a)(ii)	Either - Adding a rubber band enables more than one distance to be timed (for the sphere to fall) (1) - An average/mean value for the time/speed can then be calculated (1) Or - Can compare times/velocities for more than one distance (1) - To determine whether terminal velocity achieved (1)	(1) (1) 2 (1) (1)
(b)(i)	Weight of (solid) sphere	(1) 1
(b)(ii)	Weight of oil displaced (by the sphere) Or upthrust	(1) 1
(b)(iii)	<u>Viscous</u> drag or <u>viscous</u> force	(1) 1
(b)(iv)	The temperature (of the oil) was greater than 24 °C/had increased - do not accept temperature of the room. Or the measured diameter of the sphere was less than true value Or the time measured (to determine the terminal velocity) was less than true value Or the measured distance between bands was greater than true value Do not accept sphere too close to the edge of cylinder or the flow around the sphere is turbulent or densities used were incorrect	(1) 1
Total for question		8

Q5.

Question Number	Answer	Mark
(a)	(Initially) weight is greater than upthrust (+ drag) Or (Initially) there is a resultant force downwards (1) (so) the sphere accelerates Or (so) the speed / velocity of the sphere increases (1) drag increases (and upthrust remains constant) (dependent on MP2) (1) (until) the resultant force becomes 0 (and the sphere moves at constant / terminal velocity) (1)	4
(b)(i)	Use of $s = ut + \frac{1}{2}at^2$ with $a = 0$ (1) Use of $F = 6\pi\eta rv$ (1) $F = 2.2 \times 10^{-4}\text{N}$ (1) <u>Example calculation</u> $u = \frac{0.45\text{ m}}{7.3\text{ s}} = 0.0616\text{ m s}^{-1}$ $F = 6\pi \times 2.1 \times 10^{-1}\text{ Pa s} \times 0.90 \times 10^{-3}\text{ m} \times 0.0616\text{ m s}^{-1}$ $= 2.19 \times 10^{-4}\text{N}$	3
(b)(ii)	(For the larger sphere at the same speed) drag is greater (because drag is proportional to radius) Or drag is proportional to diameter / radius (1) But upthrust and weight increase by a greater factor than drag Or Weight and upthrust are both proportional to diameter / radius cubed, (1) (So) the new sphere had a greater (terminal) velocity, and therefore time taken (for the new sphere) was less (1)	3
Total for question		10

Q6.

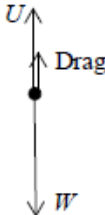
Question Number	Answer	Mark
(a)	Small spherical object Or Spherical object moving at low speed (1) Laminar flow [allow non-turbulent flow] (1)	2
(b)(i)	Max 3 Initially the velocity is zero so gradient is zero (1) As velocity increases the gradient changes (1) As velocity increases, drag increases (1) 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) 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> $\text{Radius} = \frac{1.6 \times 10^{-3} \text{ m}}{20.9} = 8 \times 10^{-4} \text{ m}$ $\text{Gradient} = \frac{11.5}{1.15 - 0.60} = 20.9$ $v = 0.209 \text{ m s}^{-1}$ $\eta = \frac{1.45 \times 10^{-4} \text{ N}}{6\pi \times 8 \times 10^{-4} \text{ m} \times 0.209 \text{ m s}^{-1}} = 0.0460 \text{ Pa s}$	4
(b)(iii)	At higher temperature the viscosity will be less (1) $F = 6\pi\eta rv$ 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)	4
Total for question		13

Question Number	Answer	Mark
(a)	The constant maximum velocity reached by an object falling (through a fluid) (1) When the resultant force equals zero Or when the drag plus the upthrust equals the weight (1)	2
(b)	Use of $V = \frac{4}{3}\pi r^3 / 3$ (1) Use of upthrust $U = \text{weight of fluid displaced } W$ (1) Use of $\rho = m / V$ and $W_s = mg$ (1) Use of $D = W - U$ (1) $D = 0.24 \text{ (N)}$ (1) <u>Example of calculation</u> $V = \frac{4}{3}\pi \times (0.0175 \text{ m})^3 = 2.24 \times 10^{-5} \text{ m}^3$ $U = 2.24 \times 10^{-5} \text{ m}^3 \times 1.43 \times 10^3 \text{ kg m}^{-3} \times 9.81 \text{ N kg}^{-1} = 0.314 \text{ N}$ $W = 2.24 \times 10^{-5} \text{ m}^3 \times 2.52 \times 10^3 \text{ kg m}^{-3} \times 9.81 \text{ N kg}^{-1} = 0.554 \text{ N}$ $D = 0.554 \text{ N} - 0.314 \text{ N} = 0.240 \text{ N}$ $D = W - U = (2.52 - 1.43) \times 10^3 \text{ kg m}^{-3} \times 9.81 \text{ N kg}^{-1} \times \frac{4}{3}\pi \times (0.0175 \text{ m})^3 = 0.24 \text{ N}$	5

(c)(i)	All data points are close to the straight line through origin Or Best fit straight line goes through origin (1) This consistent with Stokes' Law. (1) Stokes' Law implies laminar flow (for the spheres). (1)	3
(c)(ii)	Determines gradient of graph (1) Uses large triangle. (1) $k = 5.8 \text{ to } 6.2 \text{ m}^{-1}\text{s}^{-1}$ (1)	3
(c)(iii)	Use of $k = \frac{(\rho_g - \rho_s)g}{18\eta}$ (1) $\eta = 99 \text{ Pa s}$ (allow ecf from (c)(ii)) (1) <u>Example of calculation</u> $\eta = \frac{(\rho_g - \rho_s)g}{18k} = \frac{(2.52 - 1.43) \times 10^3 \text{ kg m}^{-3} \times 9.81 \text{ N kg}^{-1}}{18 \times 6 \text{ m}^{-1}\text{s}^{-1}} = 99.0 \text{ Pa s}$	2
Total for question		15

Question Number	Answer	Mark
(a)(i)	Place two or more rubber bands or markers (on the cylinder) (accept markers correctly placed and labelled on diagram) (1) The top band should be far enough below the surface for terminal velocity to have been reached Or have more than 2 markers and check velocity is constant. (1) Measure time for the sphere to fall a given distance (using the stopwatch) and measure distance fallen (using the metre rule) (1) Either Reference to repeated measurements and averaging (1) (terminal velocity =) $\frac{\text{distance between markers}}{(\text{average}) \text{ time between markers}}$ (1) Or measure the times for different distances (1) (terminal velocity =) gradient of graph of distance against time (1)	(5)
(a)(ii)	A larger sphere would have a greater (terminal) velocity (1) Weight is greater Or terminal velocity is proportional to r^2 Or takes more time to reach terminal velocity (1) The time of falling would be less (1) The (absolute) uncertainty in the time is the same Or Resolution of the stopwatch is the same Or Reaction time is the same (or they are a greater proportion of the (measured) time) (1)	(4)

(b) (i)	Upthrust/ U up	(1)	(3)
	Drag/friction/ D up	(1)	
	Weight/ W/mg down	(1)	
	(-1 for each extra force over 3) (-1 if any arrow does not touch the dot) (-1 if any arrow is not close to vertical) (Accept single line up with two labelled arrow heads. Ignore the length of the arrows.) Examples:  		
(b) (ii)	Weight = (upthrust +) drag with indication that $W=3.5 \times 10^{-2}$ N	(1)	(4)
	Use of upthrust = $\rho V g$	(1)	
	Use of drag = $6\pi r \eta v$	(1)	
	$\eta = 2.1$ (Pa s)	(1)	
	<u>Example of calculation</u> $V = \frac{4}{3}\pi(4.8 \times 10^{-3} \text{ m})^3 = 4.63 \times 10^{-7} \text{ m}^3$ Upthrust = $1.1 \times 10^3 \text{ kg m}^{-3} \times 4.63 \times 10^{-7} \text{ m}^3 \times 9.81 \text{ N kg}^{-1} = 5.00 \times 10^{-3} \text{ N}$ $3.5 \times 10^{-2} \text{ N} = 5.0 \times 10^{-3} \text{ N} + 6\pi(4.8 \times 10^{-3} \text{ m} \times \eta \times 0.160 \text{ m s}^{-1})$ $\eta = 2.07 \text{ Pa s}$		
Total for question			16