PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



MARK SCHEME

TOPIC 4: MATERIALS

FLUIDS

SCORE	PERCENTAGE
/303	%

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Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	
(i)	An explanation that makes reference to the following points: **Either** • Take readings in different positions/orientations along the wire (and calculate a mean) (1) • As wire diameter may not be uniform (1) **OR** • Check (and correct for) for zero error (1) • Zero error reduces the accuracy of the measurement (1) Or Zero error moves the value away from the true value	**Accept:** use ratchet to close up micrometer to avoid squashing the wire MP2 accept cross section for diameter MP2: accept to reduce the effect of random error MP2 accept systematic error not changed by repeat measurements	2

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• use of $\rho = m/V$ **and** $W = mg$ to calculate upthrust (1) • use of downward force of lid = upthrust – weight of diver (1) • downward force of lid = 0.021 (N) (1)	Example of calculation $m_{displaced} = 1.0 \times 10^3$ kg m^{-3} × 8.0×10^{-6} m^{-3} $= 8.0 \times 10^{-3}$ kg $U = 8.0 \times 10^{-3}$ kg × 9.81 N kg^{-1} = 0.0785 N $W = 0.0059$ kg × 9.81 N kg^{-1} = 0.0579 N Lid force = 0.0785 N - 0.0579 N = 0.0206 N	3

Question Number	Acceptable answers	Additional guidance	Mark
(b)	**Either** • use of force of lid = $V\rho g$ **(1)** • volume of air = 8.0×10^{-6} m^{-3} - their value **(1)** • volume of air = 5.9×10^{-6} (m^3) **(1)** **Or** • use of upthrust on diver = weight of diver **(1)** • use of upthrust = $V\rho g$ **(1)** • volume of air = 5.9×10^{-6} (m^3) **(1)**	Example of calculation volume = 0.0206 N ÷ 9.81 N kg^{-1} ÷ 1.0×10^3 kg m^{-3} = 2.1×10^{-6} m^{-3} new volume of air = 8.0×10^{-6} m^{-3} - 2.1×10^{-6} m^{-3} = 5.9×10^{-6} m^3	**3**

Question Number	Acceptable answers	Additional guidance	Mark
(c)	• use of pV = constant **(1)** • $p = 1.4 \times 10^5$ Pa **(1)**	Example of calculation $p_1 \times V_1 = p_2 \times V_2$ $p_2 = 1.01 \times 10^5$ N m^{-2} × 8.0×10^{-6} m^{-3} / 5.9×10^{-6} m^3 $p = 1.37 \times 10^5$ Pa	**2**

Q3.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Use of $V = \frac{4}{3}\pi r^3$ **(1)** • Use of $\rho = \frac{m}{V}$ **(1)** • $\rho = 2580$ (kg m^{-3}) **(1)**	Example of calculation $V = \frac{4}{3}\pi\left(\frac{5.06 \times 10^{-2}\text{ m}}{2}\right)^3 = 6.78 \times 10^{-5}\text{ m}^3$ $\rho = \frac{0.175\text{ kg}}{6.78 \times 10^{-5}\text{ m}^3} = 2580\text{ kg m}^{-3}$	**3**

Q4.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Use of half resolution to calculate % uncertainty (1) (1) • % uncertainty in $V = 3 \times$ % uncertainty in r (1) • % uncertainty in ρ = (% uncertainty in m + % uncertainty in V) (1) (1) • Use of % uncertainty to calculate upper value of density (1) • Upper value of density 2596 (kg m^{-3}) [2616 (kg m^{-3}) if "show that" value used] • Glass is in the range and Quartz isn't, so it may not be genuine Allow use of half resolution in either r or m to calculate minimum V and maximum m and then calculate maximum ρ for MP1 → MP4 ECF from (a)	% uncertainty in $r = \frac{0.005\text{ cm}}{5.06\text{ cm}} \times 100\ \% = 0.10\ \%$ % uncertainty in $m = \frac{0.5\text{ g}}{175\text{ g}} \times 100\ \% = 0.29\ \%$ % uncertainty in $\rho = (3 \times 0.1\%) + 0.29\% = 0.59\%$ Range $= \pm\frac{0.6}{100} \times 2580\text{ kg m}^{-3} = \pm 15.5\text{ kg m}^{-3}$ Density range = 2565 → 2596 kg m^{-3}	6

Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• Use a micrometer to measure y and/or z (1) • Use Vernier/digital calipers to measure x and/or (1) • Mass of slide(s) measured using (top pan) balance/scales (1) • Repeat and determine mean for at least one measurement (1)	**(Part (a) and (b) to be marked holistically** **MP1** accept <u>digital</u> calipers for a single slide Accept Vernier calipers if it is clear that the thickness of a number of slides is being measured. To award both MP1 & 2, *x*, *y* & *z* must all be referred to. MP4 can be awarded for a reference to averaging any of the measurements.	4

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	Check zero error on micrometer/callipers/balance **Or** measure *x*/*y*/*z* of slide in different places **Or** measure thickness/mass of multiple slides **(1)**	Accept 'tare' for zero error check on balance	**1**

Q6.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• drag + weight = upthrust (1) • use of $\rho = m/V$ **and** $W = mg$ (1) • use of $F = 6\pi\eta rv$ **and** $V = 4/3\pi r^3$ (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 $v = 2(\rho_{stout} - \rho_{gas})r^2g/9\eta$ (1) • use of $v = s/t$ (1) • time = 29 s (1) • comment on the difference with 120 seconds OR an attempt to account for the difference (1)	Example of calculation: $v = 2\ (1.007 \times 10^3\ kg\ m^{-3} - 1.223\ kg\ m^{-3}) \times (61 \times 10^{-6}\ m)^2 \times 9.81\ N\ kg^{-1} / 9 \times 2.06 \times 10^{-3}$ Pa s $= 3.96 \times 10^{-3}\ m\ s^{-1}$ $t = 0.115\ m / 3.96 \times 10^{-3}\ m\ s^{-1}$ $= 29\ s$ 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)**

Q7.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• use of mass = density × volume **(1)** • use of upthrust = weight of fluid displaced = $m \times g$ **(1)** • upthrust = 8.3×10^{-4} N **(1)**	Example of calculation: mass of liquid displaced = 1300 kg $m^{-3} \times 6.5 \times 10^{-8}$ m^3 mass of liquid displaced = 8.45×10^{-5} kg upthrust = 8.45×10^{-5} kg × 9.81 m s^{-1}	**3**
	• viscous force = weight – upthrust **(1)** • use of $F = 6\pi\eta rv$ **(1)** • viscosity = 18 (kg m^{-1} s^{-1}) **(1)**	Example of calculation: viscous force = $W - U$ = 4.8×10^{-3} N - 8.3×10^{-4} N = 3.97×10^{-3} N $\eta = 3.97 \times 10^{-3}$ N / ($6 \times 3.14 \times 4.6 \times 10^{-3}$ m $s^{-1} \times 2.5 \times 10^{-3}$) η = 18 kg m^{-1} s^{-1}	**3**

Q8.

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	Example of calculation mass of oil displaced = 9.20×10^{2} kg $m^{-3} \times 1.41 \times 10^{-8}$ m^3 = 1.30×10^{-5} kg upthrust = 1.30×10^{-5} kg × 9.81 m s^{-2} = 1.27×10^{-4} N weight of sphere = 1.10×10^{-4} kg × 9.81 m s^{-2} = 1.08×10^{-3} N weight = upthrust + drag 1.08×10^{-3} N = ($6\pi \times \eta \times 1.5 \times 10^{-3}$ m × 0.849 m s^{-1}) + 1.27×10^{-4} N $\eta = 3.97 \times 10^{-2}$ Pa s	**4**

Q9.

(a)(i)	Use of density = $\frac{\text{mass}}{\text{volume}}$ **Or** see upthrust = ρVg	(1)	
	Use of upthrust = mass of water displaced x g	(1)	
	Upthrust = 0.026 N	(1)	
	Idea that the effect of the upthrust is more significant for the nylon than for the copper (e.g. a quantitative comparison made between the 2 net forces **Or** a sensible comment linking the upthrust to the 2 weights)	(1)	
	Or		
	Use of density = $\frac{\text{mass}}{\text{volume}}$	(1)	
	Use of weight = mass × g	(1)	
	Density $_{\text{copper}}$ = 8625 kg m^{-3} **Or** density $_{\text{nylon}}$ = 1098 kg m^{-3}	(1)	
	Comparison of the densities of both copper and nylon to that of sea water e.g. the density of nylon is only just greater than that of sea water so it almost floats whilst the density of copper is much greater than that of sea water so it will fall rapidly	(1)	**4**
	<u>Example of calculations</u> Mass of water displaced by either line = 1030 kg m^{-3} × 1.30 × 10^{-7} m^2 × 20.0 m = 2.68 × 10^{-3} kg Upthrust = 2.68 × 10^{-3} kg × 9.81 N kg^{-1} = 0.0263 N Net downwards force on Copper = 0.220 N – 0.0263N = 0.194 N Net downwards force on nylon = 0.0280 N – 0.0263 N = 0.00170 N		

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(a)(ii)	Use of either stress $= \frac{\text{load}}{\text{cross sectional area}}$ **Or** strain $= \frac{\text{extension}}{\text{original length}}$ (1) **Or** see $E = \frac{Fx}{A\triangle x}$ Use of Young modulus $= \frac{\text{stress}}{\text{strain}}$ **Or** use of $E = \frac{Fx}{A\triangle x}$ (1) Extension = 0.0775 m (1) Example of calculation Stress $= \frac{65.0\text{ N}}{1.30 \times 10^{-7}\text{ m}^2} = 5.00 \times 10^8$ Pa **Or** strain $= \frac{\text{extension}}{20.0\text{ m}}$ 129×10^9 Pa $= 5.00 \times 10^8$ Pa $\div \frac{\text{extension}}{20.0\text{ m}}$ Extension = 0.0775 m	**3**
(b)(i)	Loading graph to include elastic(straight) line and some plastic(curved) section (1) Unloading line showing a permanent extension (1) Unloading line to be parallel to the loading line (1)  	**3**
(b)(ii)	Line becomes more sensitive **Or** all work done is used to reel in fish **Or** no/less work done on extending the line **Or** all force supplied pulls in fish **Or** less force required (to reel in fish) **Or** less (elastic /plastic) stretch **Or** elastic limit increases (1)	**1**
	Total for question	**11**

Q10.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• use of density = mass / volume	(1)	Example of calculation: $V = 1.0 \times 10^{13}$ kg ÷ 470 kg m^{-3} $= 2.13 \times 10^{10}$ m^3 $= 4/3\ \pi r^3$ $r = \sqrt[3]{(2.13 \times 10^{10}\ \text{m}^3 \times 3) \div 4\pi}$ $= 1720$ m	**(3)**
	• use of $V = 4/3\ \pi r^3$	(1)		
	• $r = 1720$ m	(1)		

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• use of $g = GM/r^2$	(1)	Example of calculation: $g = 6.67 \times 10^{-11}$ N m^2 kg^{-2} × 1.0×10^{13} kg / (1720 m)^2 $g = 2.25 \times 10^{-4}$ N kg^{-1}	**(2)**
	• $g = 2.3 \times 10^{-4}$ N kg^{-1}	(1)		

Question Number	Acceptable answers		Additional guidance	Mark
(c)	• use of $s = ½\ gt^2$	(1)	Example of calculation: $s = 0.5 \times 2.25 \times 10^{-4}$ m s^{-2} × (3300 s)^2 $= 1.2 \times 10^3$ m	**(2)**
	• $s = 1.2 \times 10^3$ m	(1)		

Question Number	Acceptable answers		Additional guidance	Mark
(d)	An explanation that makes reference to the following:			**(3)**
	• the calculated height is comparable with the radius (of asteroid)	(1)		
	• the field should be considered as radial rather than parallel, so the gravitational field strength is decreasing significantly for the probe	(1)		
	OR $g = GM/r^2$ the change in r is comparable with the radius, so there will be a significant change in g	(1)		
	• acceleration is less, so the actual height would be less	(1)		

Q11.

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

Q12.

Question Number	Acceptable Answer		Additional Guidance	Mark
	Use of $V = \pi r^2 t$	(1)	Example of calculation $V = \pi r^2 t = \pi\left(\frac{1.3\times10^{-2}\ \text{m}}{2}\right)^2 \times 2\times10^{-3}\text{m}$	
	Use of $\rho=\frac{m}{V}$ to find m	(1)	$\therefore V = 2.65\times10^{-7}\text{m}^3$ $m = \rho V = 7900\ \text{kg m}^{-3} \times 2.65\times10^{-7}\text{m}^3$	
	Use of 0.5% to find total mass needed	(1)	$\therefore m = 2.10\times10^{-3}\text{kg}$ $\frac{0.1\ \text{g}}{M} = 0.5\%$	
	Number of discs = 10	(1)	$\therefore M = \frac{0.1\ \text{g}}{0.5/100} = 20\ \text{g}$ $\therefore$ number of discs $= \frac{20\ \text{g}}{2.10\ \text{g}} = 9.5$	4

Q13.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of $\rho = \frac{m}{V}$ (1) with $V = \pi r^2 L$ • $\mu = 1.09 \times 10^{-3}$ (kg m^{-1}) (to at least 3 sf) (1)	For MP1, accept use of ρA Example of calculation: $\mu = \frac{m}{L} = \frac{V\rho}{L} = \frac{\pi r^2 L \rho}{L} = \pi r^2 \rho$ $\therefore \mu = \pi\left(\frac{1.14 \times 10^{-3}\text{ m}}{2}\right)^2 \times 1070\text{ kg m}^{-3}$ $\mu = 1.09 \times 10^{-3}\text{ kg m}^{-1}$	2

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• Use of $L = \frac{\lambda}{2}$ (1) • Use of $v = f\lambda$ (1) • Use of $v = \sqrt{\frac{T}{\mu}}$ (1) • $T = 140$ N (ecf from (a)(i)) (1)	Example of calculation: $\lambda = 2 \times 0.41\text{ m} = 0.82\text{ m}$ $v = 440\text{ Hz} \times 0.82\text{ m} = 361\text{ m s}^{-1}$ $361\text{ m s}^{-1} = \sqrt{\frac{T}{1.09 \times 10^{-3}\text{ kg m}^{-1}}}$ $\therefore T = (361\text{ m s}^{-1})^2 \times 1.09 \times 10^{-3}\text{ kg m}^{-3}$ $T = 142$ N	4

Q14.

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

Q15.

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

Mark Scheme

Q1.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• use of $\rho = m/V$ **and** $W = mg$ to calculate upthrust	(1)	Example of calculation $m_{displaced} = 1.0 \times 10^3$ kg m^{-3} $\times$ 8.0×10^{-6} m^{-3} $= 8.0 \times 10^{-3}$ kg $U = 8.0 \times 10^{-3}$ kg $\times$ 9.81 N kg^{-1} = 0.0785 N W = 0.0059 kg $\times$ 9.81 N kg^{-1} = 0.0579 N Lid force = 0.0785 N - 0.0579 N = 0.0206 N	3
	• use of downward force of lid = upthrust – weight of diver	(1)		
	• downward force of lid = 0.021 (N)	(1)		

Question Number	Acceptable answers	Additional guidance	Mark
(b)	**Either** • use of force of lid = $V\rho g$ **(1)** • volume of air = 8.0×10^{-6} m^{-3} - their value **(1)** • volume of air = 5.9×10^{-6} (m^3) **(1)** **Or** • use of upthrust on diver = weight of diver **(1)** • use of upthrust = $V\rho g$ **(1)** • volume of air = 5.9×10^{-6} (m^3) **(1)**	Example of calculation volume = 0.0206 N ÷ 9.81 N kg^{-1} ÷ 1.0×10^3 kg m^{-3} = 2.1×10^{-6} m^{-3} new volume of air = 8.0×10^{-6} m^{-3} - 2.1×10^{-6} m^{-3} = 5.9×10^{-6} m^3	**3**

Question Number	Acceptable answers	Additional guidance	Mark
(c)	• use of pV = constant **(1)** • $p = 1.4 \times 10^5$ Pa **(1)**	Example of calculation $p_1 \times V_1 = p_2 \times V_2$ $p_2 = 1.01 \times 10^5$ N m^{-2} × 8.0×10^{-6} m^{-3} / 5.9×10^{-6} m^3 $p = 1.37 \times 10^5$ Pa	**2**

Q2.

Question Number	Answer	Mark
(i)	(Stokes' law is only for) small (solid) spheres **Or**(Stokes' law is only for) laminar flow **Or** there is turbulent flow **(1)** Additional/less drag due to the bubbles having a non-stationary surface **Or** Stokes' law cannot be applied to a gas bubble because they have a non-stationary surface **Or** sides of container too close to bubbles **Or** volume/shape changes as it rises **(1)**	**2**
* (ii)	(QWC – work must be clear and organised in a logical manner using technical terminology where appropriate) **Either: Resultant forces method 4 marks** Measure the diameter/radius of the sphere (from the photograph) **(1)** Use of $4\pi r^3/3$ to find the volume of the sphere **(1)** Use $V\rho g$ to find the upthrust / weight of the bubble **(1)** Drag = upthrust – weight **(1)** **Or: Stokes' law method 2 marks** Measure the diameter/radius of the sphere (from the photograph) **(1)** Calculate the (terminal) velocity using $v = s/t$ **and** substitute into $F = 6\pi r\eta v$ **(1)**	**4**

Q3.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• use of mass = density × volume **(1)** • use of upthrust = weight of fluid displaced = $m \times g$ **(1)** • upthrust = 8.3×10^{-4} N **(1)**	Example of calculation: mass of liquid displaced = 1300 kg $m^{-3} \times 6.5 \times 10^{-8}$ m^3 mass of liquid displaced = 8.45×10^{-5} kg upthrust = 8.45×10^{-5} kg × 9.81 m s^{-1}	**3**
	• viscous force = weight – upthrust **(1)** • use of $F = 6\pi\eta rv$ **(1)** • viscosity = 18 (kg m^{-1} s^{-1}) **(1)**	Example of calculation: viscous force = $W - U$ = 4.8×10^{-3} N - 8.3×10^{-4} N = 3.97×10^{-3} N $\eta = 3.97 \times 10^{-3}$ N / ($6 \times 3.14 \times 4.6 \times 10^{-3}$ m $s^{-1} \times 2.5 \times 10^{-3}$) η = 18 kg m^{-1} s^{-1}	**3**

Q4.

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)**

Q5.

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	Example of calculation mass of oil displaced $= 9.20 \times 10^{2}$ kg m^{-3} $\times$ 1.41×10^{-8} m^{3} $= 1.30 \times 10^{-5}$ kg upthrust = 1.30×10^{-5} kg $\times$ 9.81 m s^{-2} $= 1.27 \times 10^{-4}$ N weight of sphere = 1.10×10^{-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**

Q6.

(a)(i)	Use of density = $\frac{\text{mass}}{\text{volume}}$ **Or** see upthrust = ρVg	**(1)**	
	Use of upthrust = mass of water displaced x g	**(1)**	
	Upthrust = 0.026 N	**(1)**	
	Idea that the effect of the upthrust is more significant for the nylon than for the copper (e.g. a quantitative comparison made between the 2 net forces **Or** a sensible comment linking the upthrust to the 2 weights)	**(1)**	
	Or		
	Use of density = $\frac{\text{mass}}{\text{volume}}$	**(1)**	
	Use of weight = mass $\times$ g	**(1)**	
	Density $_{\text{copper}}$ = 8625 kg m^{-3} **Or** density $_{\text{nylon}}$ = 1098 kg m^{-3}	**(1)**	
	Comparison of the densities of both copper and nylon to that of sea water e.g. the density of nylon is only just greater than that of sea water so it almost floats whilst the density of copper is much greater than that of sea water so it will fall rapidly	**(1)**	**4**
	Example of calculations Mass of water displaced by either line $= 1030$ kg m^{-3} $\times$ 1.30×10^{-7} m^{2} $\times$ 20.0 m $= 2.68 \times 10^{-3}$ kg Upthrust = 2.68×10^{-3} kg $\times$ 9.81 N kg^{-1} = 0.0263 N Net downwards force on Copper = 0.220 N – 0.0263N = 0.194 N Net downwards force on nylon = 0.0280 N – 0.0263 N = 0.00170 N		

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(a)(ii)	Use of either stress $= \frac{\text{load}}{\text{cross sectional area}}$ **Or** strain $= \frac{\text{extension}}{\text{original length}}$ **Or** see $E = \frac{Fx}{A\triangle x}$	**(1)**	
	Use of Young modulus $= \frac{\text{stress}}{\text{strain}}$ **Or** use of $E = \frac{Fx}{A\triangle x}$	**(1)**	
	Extension = 0.0775 m	**(1)**	**3**
	<u>Example of calculation</u> Stress $= \frac{65.0\text{ N}}{1.30 \times 10^{-7}\text{ m}^2} = 5.00 \times 10^8$ Pa **Or** strain $= \frac{\text{extension}}{20.0\text{ m}}$ 129×10^9 Pa $= 5.00 \times 10^8$ Pa $\div \frac{\text{extension}}{20.0\text{ m}}$ Extension = 0.0775 m		
(b)(i)	Loading graph to include elastic(straight) line and some plastic(curved) section	**(1)**	
	Unloading line showing a permanent extension	**(1)**	
	Unloading line to be parallel to the loading line	**(1)**	**3**
			
(b)(ii)	Line becomes more sensitive **Or** all work done is used to reel in fish **Or** no/less work done on extending the line **Or** all force supplied pulls in fish **Or** less force required (to reel in fish) **Or** less (elastic /plastic) stretch **Or** elastic limit increases	**(1)**	**1**
	Total for question		**11**

Q7.

Question Number	Answer	Mark
	B	**1**

Q8.

Question Number	Answer	Mark
	C	**1**

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Q9.

Question Number	Acceptable Answers		Additional guidance	Mark
(i)	• Recognises resultant force on raindrop = 0 **Or** Uses $W=F(+U)$	(1)	Example of Calculation $W=F+U$	
	• Use of $F = 6\pi\eta rv$ • Use of U = weight of air displaced **Or** $U=\frac{4}{3}\rho_a\pi r^3 g$ **Or** $U=\rho_a Vg$ **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)	$F = 6\pi \times 1.3 \times 10^{-5}\text{Nm}^{-2} \times 1.0 \times 10^{-4} \times v = (2.45 \times 10^{-8}\, v)$ (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)	
	• 1.7 m s^{-1}	(1)	$v=\frac{4.1\times10^{-8}\ \text{N} - 4.9\times10^{-11}\ \text{N}}{2.45\times10^{-8}} = 1.7\ \text{m s}^{-1}$	4
(ii)	turbulent flow (so) Stokes law does not apply	(1) (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	Answer	Additional Guidance	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**. • There is an upthrust on the rock (as the rock displaces water) • Hence the net downward force on the rock is reduced • *F* decreases to a minimum once the rock is fully submerged • The rock pushes downwards on the water • So there is an extra force on the balance • Hence *R* increases to a maximum once the rock is fully submerged	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**	**6**

Q12.

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

Q13.

Question Number	Answer		Mark
(a) (i)	Each **row** of the table contains a suitable method. One mark for each column, do not allow a mix and match of methods (rows)	(1) (1) (1) (1)	

Distance measured with the metre rule	**<u>Corresponding</u> time**	**<u>Correct</u> use of measurements referred to in columns 1 and 2**	**To calculate g use:** (formula/expression seen)
Record the position on the **rule** for each frame	Time between frames	Plot distance against t^2	$g = 2$ x gradient
Measure distance between (successive) frames against a metre **rule**	Time between frames	Calculate the speed each frame using distance /time and plot against time	g = gradient
Use metre **rule** to measure: (total) distance ball falls through **Or** height from which the ball was dropped (e.g. 1 m)	Number of frames × time between frame **Or** total time of journey recorded/found	Use of: $s = ut + ½ at^2$ **Or** $s = ½ at^2$ **Or** $s = ½ gt^2$	$g = 2s/t^2$ **Or** Re-arrange $s = ½ gt^2$ substituting in s and t to find g.
Measure distance between frames (at beginning and) end of drop using the **rule**	Time between frames known and count frames **Or** if stated $u = 0$ then time for ball to fall and the time between frames.	Use speed = $\Delta s/\Delta t$ to find their final velocity using correct time interval [may take u as 0]	$g = (v-u)/t$ **Or** $a = (v-u)/t$
Record the position on the **rule** each frame	Time between frames	Calculate the speed each frame using d/t and plot a graph of v^2 against s.	Gradient/2 = acceleration

Accept metre stick or ruler in place of metre rule
(The candidate may refer to the acceleration of free fall as '*a*' or 'g')

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<table>
<tr><td>(a) (ii)</td><td>Ball may be released between 1st and 2nd images (so times used all too long because they include a short time before it is dropped)
Or ball released before the 1st image so u is not 0
Or the ruler is not vertical/straight
Or the idea that the camera has not been calibrated correctly i.e. runs too fast/slow
Or the idea that there is a parallax error from camera to object

(Parallax alone is insufficient)
(Do not award a mark for air resistance)</td><td>(1)</td><td>1</td></tr>
<tr><td>(b)</td><td>Small / dense / streamlined shape / smooth surface / shiny

Correct explanation, e.g.:
Small surface area– minimise drag
Dense – weight > upthrust Or weight > drag
Streamlined /aerodynamic– minimise drag Or ensure laminar flow
Smooth surface – minimise drag Or ensure laminar flow
Shiny – easy to see on the recording
Small – easier to read scale (precisely)

(Sphere is not acceptable for a property but statement such as ‘sphere to minimise drag’ can score 2nd mark)</td><td>(1)

(1)</td><td>2</td></tr>
<tr><td>(c)</td><td>Advantage
Explanation
(to score both marks the explanation must be linked to the advantage. Accept reverse arguments. Human error is not sufficient for reaction time).

<table><tr><th>Advantage</th><th>Explanation</th></tr><tr><td>No reaction time</td><td>Reduces uncertainties Or (time recorded) more precise/accurate</td></tr><tr><td>Can be paused /stopped to take readings.</td><td>Measurements taken at exact times
Or positions against rule recorded more accurately.
Or velocities can be calculated frame by frame (more readings</td></tr><tr><td>Allows repeated playback Or rewinding</td><td>Allows values to be checked/confirmed
Or values obtained are more reliable</td></tr></table></td><td>(1)
(1)</td><td>2</td></tr>
</table>

Q14.

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

Q15.

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

Mark Scheme

Q1.

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)**	Example of Calculation $v = \frac{0.5}{3.9} = 0.13\ (\text{m s}^{-1})$ $\eta = \frac{\frac{4}{3}\pi(4\times10^{-3})^3 \times 9.81 \times (7800 - 1300)}{6\pi \times 4 \times 10^{-3} \times 0.13} = 1.8\ \text{Pa s}$ 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**

Q2.

Question Number	Answer	Mark
	Viscosity is lower at higher/room temperature (1) (Butter at a higher temperature:) requires less force/friction/resistance (to spread) **Or** less work needs to be done (to spread the butter) (1) (Accept converse answer for MP1 and MP2)	**2**

Q3.

Question Number	Answer	Mark
(i)	(Stokes' law is only for) small (solid) spheres **Or**(Stokes' law is only for) laminar flow **Or** there is turbulent flow (1) Additional/less drag due to the bubbles having a non-stationary surface **Or** Stokes' law cannot be applied to a gas bubble because they have a non-stationary surface **Or** sides of container too close to bubbles **Or** volume/shape changes as it rises (1)	**2**
* **(ii)**	(QWC – work must be clear and organised in a logical manner using technical terminology where appropriate) **Either: Resultant forces method 4 marks** Measure the diameter/radius of the sphere (from the photograph) (1) Use of $4\pi r^3/3$ to find the volume of the sphere (1) Use $V\rho g$ to find the upthrust / weight of the bubble (1) Drag = upthrust – weight (1) **Or: Stokes' law method 2 marks** Measure the diameter/radius of the sphere (from the photograph) (1) Calculate the (terminal) velocity using $v = s/t$ **and** substitute into $F = 6\pi r\eta v$ (1)	**4**

Q4.

Question Number	Acceptable Answers	Additional Guidance	Mark
	B		**1**

Q5.

Question Number			Mark
(a) (i)	Use of equation of motion suitable for a, e.g. $v = u + at$	(1)	
	$a = 16.3$ m s^{-2} (2.1 ×10^5 km h^{-2} or 58.7 km h^{-1} s^{-1})	(1)	**2**
	Example of calculation $a = \frac{37.5 \text{ m s}^{-1} - 0}{2.3 \text{ s}}$ $a = 16.3$ m s^{-2}		
(a) (ii)	Use of $E_k = ½ mv^2$	(1)	
	Use of $P = E/t$	(1)	
	Power = 3.1×10^6 W	(1)	
	Or		
	Use of $F = ma$ (must be a from (i)) **and** Use of equation to find distance **and** use of work done = Fd	(1)	
	Use of $P = E/t$	(1)	
	Power = 3.1 × 10^6 W (distance = 43 m)	(1)	**3**
	Examples of calculations $E_k = ½ \times 10\,000 \text{ kg} \times (37.5 \text{ m s}^{-1})^2 = 7.03 \times 10^6$ J Power = 7.03 × 10^6 J / 2.3 s = 3.1 × 10^6 W		
(a) (iii)	Energy transferred by heating **Or** energy transferred due to friction **Or** work done against friction **Or** idea that more energy required (due to energy transfer) due to friction.	(1)	**1**
	(do not accept 'lost' but accept air resistance as an alternative to friction)		
***(b)**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)		
	larger force is needed **Or** the (same) force is insufficient	(1)	
	need same acceleration/ (max) velocity **OR** acceleration/(max) velocity is too small	(1)	
	more energy needed (to reach top) **Or** insufficient energy (to reach top)	(1)	**3**
(c)	Viscosity of oil decreases (with increasing temperature) **Or** the (warm) oil is less viscous (accept a reverse argument e.g. when cold oil is more viscous)	(1)	
	Lower frictional/resistive force **Or** less viscous drag	(1)	**2**
	Total for question		**11**

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Q6.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• use of mass = density × volume **(1)** • use of upthrust = weight of fluid displaced = $m \times g$ **(1)** • upthrust = 8.3×10^{-4} N **(1)**	Example of calculation: mass of liquid displaced = 1300 kg $m^{-3} \times 6.5 \times 10^{-8}$ m^3 mass of liquid displaced = 8.45×10^{-5} kg upthrust = 8.45×10^{-5} kg × 9.81 m s^{-1}	**3**
	• viscous force = weight – upthrust **(1)** • use of $F = 6\pi\eta rv$ **(1)** • viscosity = 18 (kg m^{-1} s^{-1}) **(1)**	Example of calculation: viscous force = $W - U$ = 4.8×10^{-3} N - 8.3×10^{-4} N = 3.97×10^{-3} N $\eta = 3.97 \times 10^{-3}$ N / ($6 \times 3.14 \times 4.6 \times 10^{-3}$ m $s^{-1} \times 2.5 \times 10^{-3}$) η = 18 kg m^{-1} s^{-1}	**3**

Q7.

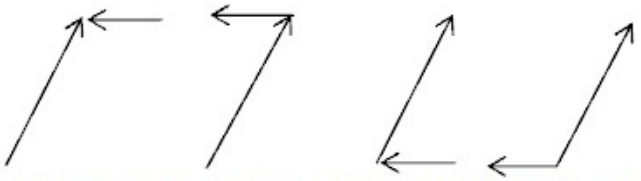
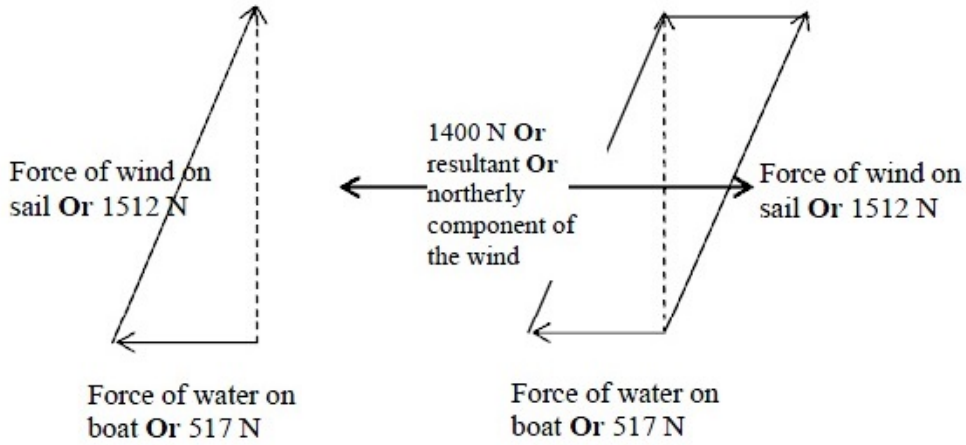
Question Number	Acceptable answers	Additional guidance	Mark
	• feathers will cause turbulent air flow **(1)** **Or** feathers increase surface area • this results in (high) drag force **(1)** • horizontal velocities decrease **(1)** **Or** vertical acceleration is no longer g		**3**

Q8.

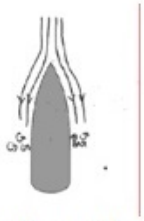
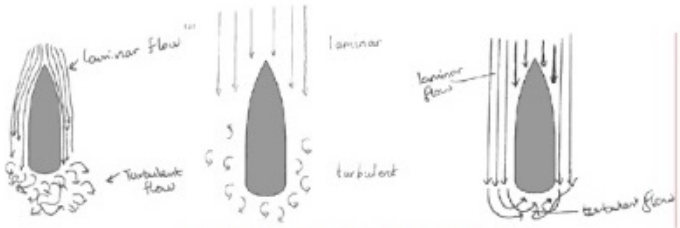
Question Number	Acceptable answers		Additional guidance	Mark
	• Use of $\rho = m/V$ • Use of relationship upthrust = weight of liquid • Use of $F = 6\pi\eta rv$ • $\eta = 3.97 \times 10^{-2}$ (Pa s) so it is sunflower oil	(1) (1) (1) (1)	Example of calculation mass of oil displaced $= 9.20 \times 10^{2}$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

Q9.

Question Number	Answer		Mark
(a)(i)	Use of force = area x force per unit area Correct use of trigonometric function for component of force Force = 1420 (N) Example of calculation Force = 84 N m^{-2} x 18 m^{2} = 1512 (N) component of force = 1512 N x cos 20° = 1420 N	(1) (1) (1)	3
(a)(ii)	Wind/air causes boat to push against water Due to Newton's third law the water exerts an opposite force **Or** force in westerly direction on the boat due to Newton's third law **Or** In east-west direction: no acceleration **Or** no resultant force Water exerts a force on the boat to balance out (component) of wind's force from the east (A bold statement of N3 without an application to the context scores 0)	(1) (1) (1) (1)	2

(a)(iii)	The wind and water forces labelled and in the correct directions (2 adjoining labelled lines with arrows) e.g.  (Label for the horizontal line as shown above = Force of water on boat **Or** 517 N Label for the angled line as shown above = Force of wind on sail **Or** 1512 N)	**(1)**	
	Triangle or parallelogram completed to show resultant force with direction  (Due to taking some words as being included in the stem the minimum labelling would be: Wind in place of: Force of wind on sail **Or** 1512 N Water in place of: Force of water on boat Or 517 N)	**(1)**	**2**

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(a)(iv)	Use of $F = ma$ Acceleration = 3.6 m s^{-2} (allow ecf from (a)(i) if answer rounds to 1400 N) Example of calculation a = 1420 N / 400 kg = 3.6 m s^{-2}	**(1)** **(1)**	**2**
(b) (i)	Idea that the relative speed of wind to sail is lower e.g. As the boat is moving at 5 m s^{-1}, the (relative) speed of the wind on the sail is only 5 m s^{-1}	**(1)**	**1**
(b)(ii)	Use of $s = d/t$ or use of work done = force × displacement Rate of energy transfer = 1900 W or J s^{-1} Example of calculation Distance = speed x time = 5 m s^{-1} x 1 s = 5 (m) Power = 380 N x 5 m / 1 s = 1900 W (accept P = 380 N x 5 m s^{-1} = 1900 W)	**(1)** **(1)**	**2**
(b)(iii)	Diagram shows labelled laminar flow Diagram shows labelled turbulent flow with a continuous transition from laminar  (2)  (1, no labels)  (1, no labels)  (0. no transition and no labels)  (all score 1, no transition) (Unlabelled diagram with the correct flow lines 1 mark max. Laminar and turbulent wrong way round but fully labelled scores 1 max)	**(1)** **(1)**	**2**

Q10.

Question Number	Answer	Mark
	B	1

Q11.

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

Q12.

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

Q13.

Question Number	Answer	Mark
	A	1

Q14.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• Weight and drag force are equal for terminal velocity stated or implied (1) • Quotes $F = 6\pi\eta rv$ and $mg = 4(\pi r^3)\rho g/3$ and suitable working to obtain $v = \frac{2g\rho r^2}{9\eta}$ (1)		2

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• Use of $v = \frac{2g\rho r^2}{9\eta}$ (1) • $v = 760$ (m s^{-1}) (1)	Example of calculation $v = 2 \times 9.81$ N kg$^{-1} \times 1.0 \times 10^3$ kg m^{-3} $\times (2.5 \times 10^{-3}$ m$)^2 / 9 \times 1.8 \times 10^{-5}$ Pa s $v = 757$ m s^{-1}	2

Question Number	Acceptable answers	Additional guidance	Mark
(c)	• Measured value much less than calculated value (1) **Max 2 from** • The raindrop is moving very fast so Stokes' law does not apply (1) • Flow is not laminar so Stokes' law does not apply (1) • Raindrops not small so Stokes' law does not apply (1) • Raindrops not spherical so Stokes' law does not apply (1) • Argument based on increased upward force if upthrust taken into account so it doesn't apply (1)		3

Q15.

Question Number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to the following points: **(1)** • at a lower temperature viscosity is increased • there would be a lower maximum speed **(1)** **Or** one of the other oils could have been identified		**2**

Q16.

Question Number	Acceptable Answers	Mark
(a)	As the temperature increases the viscosity decreases **(1)** at a decreasing rate **Or** the rate of decrease is greater at lower temperatures **Or** exponentially **(1)** (do not accept quicker/slower in place of greater/smaller) (a statement that quantities are inversely proportional can score MP1 only)	**2**

Question Number	Acceptable Answers	Mark
(b)(i)	F = N **Or** F = kg m s^{-2} **Or** Pa m^2, r = m and v = ms^{-1} seen **(1)** Pa = N m^{-2} clearly shown **(1)** Example of calculation $\eta = \frac{\text{N}}{\text{m} \times \text{m s}^{-1}} = \text{N m}^{-2}\ \text{s} = \text{Pa s}$	**2**

Question Number	Acceptable Answers	Mark
(b)(ii)	Reading from graph of viscosity: 1.09 to 1.13 ($\times 10^{-3}$)(Pa s) **(1)** Use of $F = mg$ **and** $F = 6\pi r\eta v$ **Or** use of $mg = 6\pi r\eta v$ **(1)** v =3.7 to 3.8 (m s^{-1}) (must be at least 2 sig figs) **(1)** Example of calculation $v = \frac{4.0 \times 10^{-6}\ \text{kg} \times 9.81\ \text{N kg}^{-1}}{6 \times \pi \times 5.0 \times 10^{-4}\ \text{m} \times 1.11 \times 10^{-3}\ \text{Pa s}}$ v = 3.75 (m s^{-1})	**3**

Question Number	Acceptable Answers	Mark
*(c)	**(QWC – work must be clear and organised in a logical manner using technical terminology where appropriate)** **Max 3** Viscosity of biodiesel is high **Or** viscosity of biodiesel higher than diesel **Or** viscosity of biodiesel needs reducing **(1)** Freezing point of biodiesel is high **Or** freezing point of biodiesel is higher than diesel **(1)** Adding ethanol/blending reduces η/freezing point **Or** adding ethanol/blending makes η/freezing point closer to that for diesel **(1)** Ethanol/ alcohol alone has too low an energy content **(1)**	**3**
	Total for question	**10**

Q17.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• Comparison to $y = mx + c$ **(1)** • Identify that η, ρ_s, ρ_f and g are constants **(1)** • $c = 0$ so the graph passes through the origin **Or** when $d^2 = 0$, $v = 0$ so would pass through the origin **(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 (1) • Suitable scale (1) • Correct plotting (1) • Line of best fit (judged by eye) (1)	MP1: v / 10^{-3} m s^{-1} on y-axis and d^2 / 10^{-6} m^2 on x-axis 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	4

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

Q18.

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 (1) **Or** (since) at a higher temperature the liquid has a lower viscosity	MP1 Must be an indication of speed. MP2 Accept solidifying as an indication of in a given time	2

Q19.

Question Number	Answer		Mark
(a) (i)	Each **row** of the table contains a suitable method. One mark for each column, do not allow a mix and match of methods (rows)	(1) (1) (1) (1)	

Distance measured with the metre rule	**Corresponding time**	**Correct use of measurements referred to in columns 1 and 2**	**To calculate g use:** (formula/expression seen)
Record the position on the **rule** for each frame	Time between frames	Plot distance against t^2	$g = 2$ x gradient
Measure distance between (successive) frames against a metre **rule**	Time between frames	Calculate the speed each frame using distance /time and plot against time	g = gradient
Use metre **rule** to measure: (total) distance ball falls through **Or** height from which the ball was dropped (e.g. 1 m)	Number of frames × time between frame **Or** total time of journey recorded/found	Use of: $s = ut + ½ at^2$ **Or** $s = ½ at^2$ **Or** $s = ½ gt^2$	$g = 2s/t^2$ **Or** Re-arrange $s = ½ gt^2$ substituting in s and t to find g.
Measure distance between frames (at beginning and) end of drop using the **rule**	Time between frames known and count frames **Or** if stated $u = 0$ then time for ball to fall and the time between frames.	Use speed = $\Delta s/\Delta t$ to find their final velocity using correct time interval [may take u as 0]	$g = (v-u)/t$ **Or** $a = (v-u)/t$
Record the position on the **rule** each frame	Time between frames	Calculate the speed each frame using d/t and plot a graph of v^2 against s.	Gradient/2 = acceleration

Accept metre stick or ruler in place of metre rule
(The candidate may refer to the acceleration of free fall as '*a*' or 'g')

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<table>
<tr><td>(a) (ii)</td><td>Ball may be released between 1st and 2nd images (so times used all too long because they include a short time before it is dropped)
Or ball released before the 1st image so u is not 0
Or the ruler is not vertical/straight
Or the idea that the camera has not been calibrated correctly i.e. runs too fast/slow
Or the idea that there is a parallax error from camera to object

(Parallax alone is insufficient)
(Do not award a mark for air resistance)</td><td>(1)</td><td>1</td></tr>
<tr><td>(b)</td><td>Small / dense / streamlined shape / smooth surface / shiny

Correct explanation, e.g.:
Small surface area– minimise drag
Dense – weight > upthrust Or weight > drag
Streamlined /aerodynamic– minimise drag Or ensure laminar flow
Smooth surface – minimise drag Or ensure laminar flow
Shiny – easy to see on the recording
Small – easier to read scale (precisely)

(Sphere is not acceptable for a property but statement such as ‘sphere to minimise drag’ can score 2nd mark)</td><td>(1)

(1)</td><td>2</td></tr>
<tr><td>(c)</td><td>Advantage
Explanation
(to score both marks the explanation must be linked to the advantage. Accept reverse arguments. Human error is not sufficient for reaction time).

<table><tr><th>Advantage</th><th>Explanation</th></tr><tr><td>No reaction time</td><td>Reduces uncertainties Or (time recorded) more precise/accurate</td></tr><tr><td>Can be paused /stopped to take readings.</td><td>Measurements taken at exact times
Or positions against rule recorded more accurately.
Or velocities can be calculated frame by frame (more readings</td></tr><tr><td>Allows repeated playback Or rewinding</td><td>Allows values to be checked/confirmed
Or values obtained are more reliable</td></tr></table></td><td>(1)
(1)</td><td>2</td></tr>
</table>

Q20.

Question Number	Answers	Mark
	The only correct answer is A ***B** is incorrect because the drag force increases as the skydiver falls through the air* ***C** is incorrect because the drag force increases as the skydiver falls through the air* ***D** is incorrect because the drag force increases as the skydiver falls through the air*	1

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Q21.

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

Q22.

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

Q23.

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

Q24.

Question Number	Answer		Mark
	Statement describing the relationship between viscosity and temperature. e.g. Viscosity increases with decreasing temperature **Or** viscosity decrease with increasing temperature **Or** viscosity is inversely proportional to temperature	(1)	
	Statement describing either what happens between the oil and the (engine) parts when it gets too hot or too cold e.g. If too cold, the oil could be too viscous/thick to spread sufficiently **Or** if too hot, the oil would run off **Or** if too hot oil would not stick to parts	(1)	2

Q25.

Question Number	Answer		Mark
(a)(i)	Identifies that the two chocolates on the graph are at different temperatures	(1)	
	The greater the temperature of the chocolate, the lower the viscosity	(1)	2
(a)(ii)	Marked anywhere vertically above 10^{1} Pa s.	(1)	1
(b)	Use of drag = upthrust	(1)	
	Use of $F = 6\pi r\eta v$	(1)	
	$v = 2.0 \times 10^{-4}$ m s^{-1}	(1)	3
	Example of calculation $v = \frac{3.7 \times 10^{-5}\ \text{N}}{6 \times \pi \times 1.0 \times 10^{-8}\ \text{m} \times 10\ \text{Pa s}}$ $v = 1.96 \times 10^{-4}$ m s^{-1}		
(c)	Problem: Bubbles forming and not rising to the surface to break		
	Solution: Reduce the viscosity of the chocolate **Or** heat up the chocolate	(1)	
	Explanation: The greater the viscosity: the greater the viscous drag **Or** the lower the (terminal) velocity	(1)	
	The bubbles rise slower	(1)	
	OR		
	The lower the viscosity: the lower the viscous drag **Or** the greater the (terminal) velocity	(1)	
	The bubbles are able to rise to the top quicker **Or** the bubblies rise to the top in time before the chocolate sets	(1)	3
	(The 3 marking points can be awarded if seen anywhere within part (c))		
	Total for question		9

Q26.

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

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Q27.

Question Number	Acceptable answers	Additional guidance	Mark
	C		1

Q28.

Question Number	Answer	Additional Guidance	Mark
	• Use of $F = 6\pi\eta r v$ (1) • Use of $U = mg$ **and** $\rho = \frac{m}{V}$ (1) **and** $V = \frac{4}{3}\pi r^3$ • 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} $\times$ 2.5×10^{-7} m $\times$ v $V = \frac{4}{3}\pi(2.5 \times 10^{-7}\text{ m})^3 = 6.5\times10^{-20}$ m^3 $U = \rho_w Vg = 1000$ kg m^{-3} $\times$ 6.5×10^{-20} m^3 $\times$ 9.81 m s^{-1} $U = 6.4\times10^{-16}$ 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

Q29.

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)	Example of Calculation $W = 8.0 \times 10^3$ 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)	Example of Calculation 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**

Q30.

Question Number	Acceptable answers	Additional guidance	Mark
	• There is (damping due to) air resistance and this (damping) force is the same for both (since they have the same shape, area and speed initially) (1) • For large mass the force due to air resistance produces a smaller negative acceleration since $a = F/m$ (1) • The speed will decrease less for each swing, so there is less effect on the amplitude **Or** It will take longer for the (maximum) speed to decrease (to zero) so the pendulum will oscillate for a longer time (1) **OR** • There is air resistance and the force is the same for both (1) • The work done by air resistance per swing is the same for both masses (1) • Initially the larger mass has greater quantity of energy shared between its kinetic and potential energy stores, so the proportion of KE transferred to the thermal energy store of the sphere and the surroundings is less per swing, so there is less effect on the amplitude **Or** Larger mass has greater total energy so fraction dissipated per swing is smaller so the pendulum will oscillate for a longer time (1)		3

	OR There is air resistance and this force is the same for both (1) • For both masses the change in momentum per swing is the same (1)		

	• The larger mass has greater initial momentum so it will take longer for the (maximum) momentum to decrease (to zero) so the pendulum will oscillate for a longer time (1)		