Mark Scheme

Q1.

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

Q2.

Question Number	Answer	Mark
	A	1

Q3.

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

Q4.

Question Number	Answer	Mark
	C	1

Q5.

Question Number	Answer	Mark
	B	**1**

Q6.

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

Q7.

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 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) (1)	**2**

Q8.

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 $v = \frac{\rho_s V g - \rho_l V g}{6\pi r\eta}$ $v = \frac{Vg(\rho_s - \rho_l)}{6\pi r\eta}$	3

Q9.

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)	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

Q10.

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 digital 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**

Q11.

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

Q12.

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

Q13.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• Weight and drag force are equal for terminal velocity stated or implied (1) • Quotes $F = 6\pi\eta r v$ 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) • $v = 760\ (\text{m s}^{-1})$ (1)	Example of calculation $v = 2 \times 9.81\ \text{N kg}^{-1} \times 1.0 \times 10^3\ \text{kg m}^{-3} \times (2.5 \times 10^{-3}\ \text{m})^2 / 9 \times 1.8 \times 10^{-5}\ \text{Pa s}$ $v = 757\ \text{m s}^{-1}$	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

Q14.

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) 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}	3
(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) (The 3 marking points can be awarded if seen anywhere within part (c))	3
	Total for question	**9**

Q15.

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} $\times 8.0 \times 10^{-6}$ 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

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**

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)** <u>Example of calculation</u> $\eta = \dfrac{\text{N}}{\text{m} \times \text{m s}^{-1}} = \text{N m}^{-2}\text{ s} = \text{Pa s}$	**2**

Question Number	Acceptable Answers	Mark
(b)(ii)	Reading from graph of viscosity: 1.09 to 1.13 (× 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)** <u>Example of calculation</u> $v = \dfrac{4.0 \times 10^{-6}\text{ kg} \times 9.81\text{ N kg}^{-1}}{6 \times \pi \times 5.0 \times 10^{-4}\text{ m} \times 1.11 \times 10^{-3}\text{ Pa s}}$ 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

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th></th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>(b)</td><td>• Axes labelled with quantities and units
• Suitable scale
• Correct plotting
• Line of best fit (judged by eye)</td><td>(1)
(1)
(1)
(1)</td><td>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</td><td>4</td></tr>
</table>

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

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th></th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>(c)</td><td>• 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</td><td>(1)
(1)
(1)
(1)</td><td>MP4 to be consistent with calculated value for η

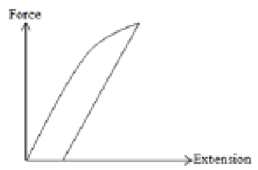
<u>Example of calculation</u>
$\eta = \frac{9.81 \text{ N kg}^{-1} \times (8000 \text{ kg m}^{-3} - 1260 \text{ kg m}^{-3})}{18 \times 2.52 \times 10^{3} \text{ m}^{-1} \text{ s}^{-1}}$
$\eta = 1.46$ Pa s</td><td>4</td></tr>
</table>

Q18.

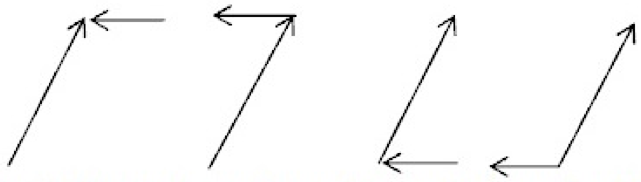
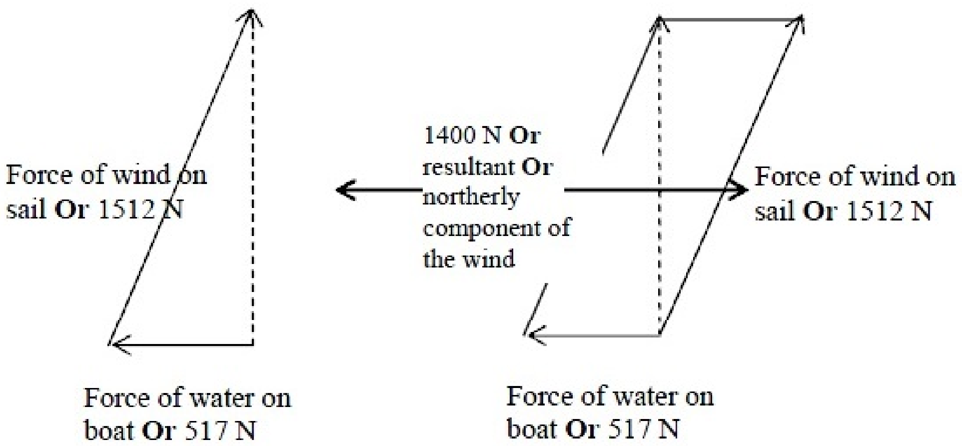
Question Number		Mark
(a) (i)	Use of equation of motion suitable for a, e.g. $v = u + at$ (1) $a = 16.3\ \text{m s}^{-2}$ ($2.1 \times 10^5\ \text{km h}^{-2}$ or $58.7\ \text{km h}^{-1}\ \text{s}^{-1}$) (1) Example of calculation $a = \frac{37.5\ \text{m s}^{-1} - 0}{2.3\ \text{s}}$ $a = 16.3\ \text{m s}^{-2}$	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 (1) (distance = 43 m) Examples of calculations $E_k = ½ \times 10\,000\ \text{kg} \times (37.5\ \text{m s}^{-1})^2 = 7.03 \times10^6$ J Power = 7.03×10^6 J / 2.3 s = 3.1×10^6 W	3
(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) (do not accept 'lost' but accept air resistance as an alternative to friction)	1
*(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 (1) (accept a reverse argument e.g. when cold oil is more viscous) Lower frictional/resistive force **Or** less viscous drag (1)	2
	Total for question	**11**

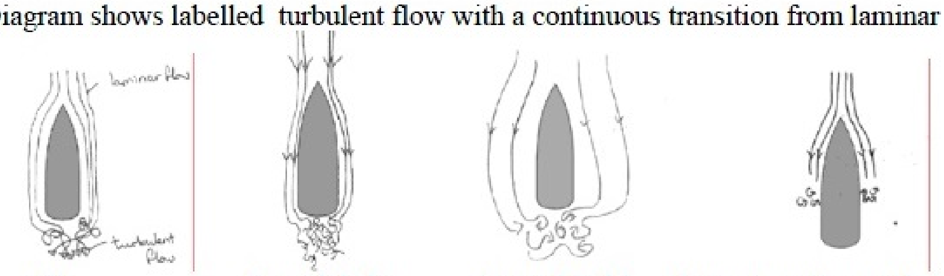
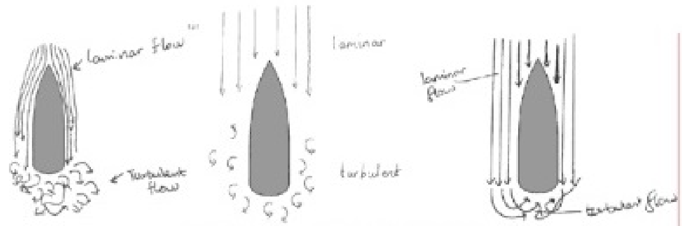
Q19.

(a)(i)	Use of density = $\frac{\text{mass}}{\text{volume}}$ **Or** see upthrust = ρVg Use of upthrust = mass of water displaced x g Upthrust = 0.026 N 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) **Or** Use of density = $\frac{\text{mass}}{\text{volume}}$ Use of weight = mass × g Density $_{\text{copper}}$ = 8625 kg m^{-3} **Or** density $_{\text{nylon}}$ = 1098 kg m^{-3} 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 <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	(1) (1) (1) (1) (1) (1) (1) (1)	4

(a)(ii)	Use of either stress = $\frac{\text{load}}{\text{cross sectional area}}$ **Or** strain = $\frac{\text{extension}}{\text{original length}}$ **Or** see $E = \frac{Fx}{A\Delta x}$ Use of Young modulus = $\frac{\text{stress}}{\text{strain}}$ **Or** use of $E = \frac{Fx}{A\Delta x}$ Extension = 0.0775 m <u>Example of calculation</u> Stress = $\frac{65.0\text{ N}}{1.30 \times 10^{-7}\text{ m}^2}$ = 5.00×10^8 Pa **Or** strain = $\frac{\text{extension}}{20.0\text{ m}}$ 129×10^9 Pa = 5.00×10^8 Pa ÷ $\frac{\text{extension}}{20.0\text{ m}}$ Extension = 0.0775 m	(1) (1) (1)	3
(b)(i)	Loading graph to include elastic(straight) line and some plastic(curved) section Unloading line showing a permanent extension Unloading line to be parallel to the loading line 	(1) (1) (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**

Q20.

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) <u>Example of calculation</u> 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)	<u>Wind/air</u> 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) 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) (1)	 **2**

(a)(iv)	Use of $F = ma$ Acceleration = 3.6 m s^{-2} (allow ecf from (a)(i) if answer rounds to 1400 N) <u>Example of calculation</u> 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} <u>Example of calculation</u> 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**