Question Number	Answer	Mark
1(a)(i)	3 correct labelled arrows: Upthrust, *U* (1) weight, *W*, *mg* (1) (viscous) drag, water resistance, viscous force, V, F, D [upwards] (1) ('resistance' not sufficient) Each incorrect force decreases the maximum possible mark by one U and D can share an arrow. Arrows need not touch particle. Ignore unlabelled arrows.	**3**
1(a)(ii)	upthrust + drag = weight or with unambiguous symbols (allow ecf from diagram) (1) forces in equilibrium / balanced forces / no resultant force / no acceleration / constant velocity (1)	**2**
1(b) (i)	Down and along (1) (shape of trajectory not important)	**1**
1(b)(ii)	Lines crossing, eddies, sudden changes in direction, change in direction > 90°, lines disappearing and appearing (1) Turbulent flow can be seen at any position	**1**
1(b)(iii)	Laminar const vel at a point/no eddies/lines don't cross, but turbulent keeps changing direction/eddies/lines cross (1) Some comparison required. Smooth/streamlined/chaotic not sufficient descriptors	**1**
1(b) (iv)	Turbulent flow → eddies/continual changes will disturb particle back into the flow / stop particle from continuing downwards / lifts particle (1) Answer should imply some upwards force/motion imposed on the particle	**1**
	Total for question	**9**

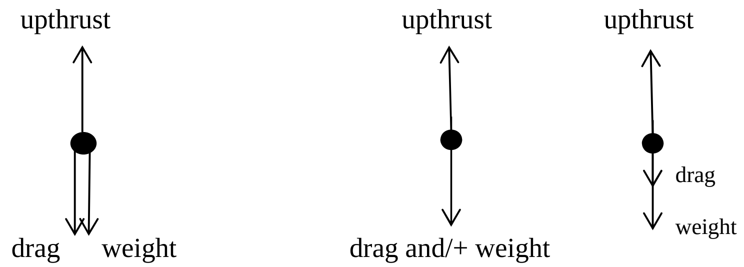
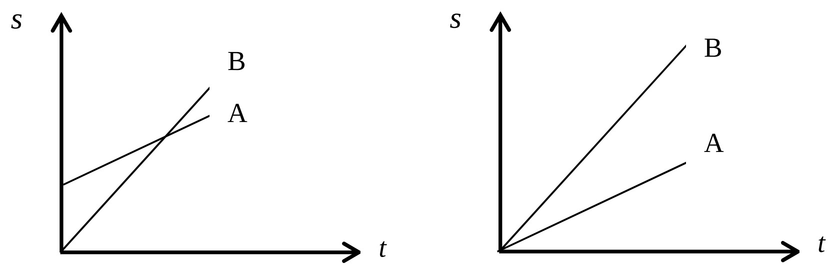
Question Number	Answer	Mark
2	Label the fluid flow below and above A and describe each of them. (Accept names on text lines instead of labels on diagram) Below A = laminar or streamline **(1)** Above A = turbulent **(1)** Below A - no abrupt change in direction or speed of flow / no mixing of layers / lines of flow don't cross velocity/speed/direction at a point is constant / layers parallel / (no eddies is not sufficient) (smooth not sufficient) (ignore references to particles not mixing) **(1)** Above A – mixing of layers / lines of flow cross / contains eddies/whirlpools/vortices / sudden changes in speed or direction / velocity at a point is not constant **(1)** Allow the mark for the description if the name label is incorrect but the description matches the name. Allow the mark for the description if it is in the correct place but the label is incorrect.	**(4)**
	Total for question	**4**

Question Number	Answer	Mark
3(a) (i)	Show that the resultant upward force at the moment it is released is about 200 N Use of density x volume **(1)** Use of mass x g **(1)** Correct answer [215 (N) to at least 2 sf] **(1)** **[no ue]** <u>Example of calculation</u> Mass of displaced air = density x volume $= 1.2\ \text{kg m}^{-3} \times 2830\ \text{m}^3 = 3396\ \text{kg}$ upthrust = weight of displaced air = $3396\ \text{kg} \times 9.81\ \text{N kg}^{-1} = 33\,315\ \text{N}$ resultant force = 33 315 N – 33 100 N = 215 N [If candidate starts from difference in densities, apply mark scheme in the same way.]	**(3)**
3(a) (ii)	Find the initial upward acceleration Use of $F = ma$ **(1)** Correct answer [$0.06\ \text{m s}^{-2}$] **(1)** <u>Example of calculation</u> $F = ma$ $a = 215\ \text{N} / 3370\ \text{kg}$ $= 0.064\ \text{m s}^{-2}$ [Use of 200 N gives $0.059\ \text{m s}^{-2}$]	**(2)**
3(a) (iii)	Justify that effect of air resistance is negligible Use of Stokes' law equation, $F = 6\pi\eta rv$ **(1)** Find viscous drag (6.0×10^{-3} (N)) **(1)** **(no ue)** Relevant comment, e.g. **very** small **in comparison** to other forces (not just "small")/ **much** small**er** than other forces (not just smaller) **(1)** <u>Example of calculation</u> $F = 6\pi\eta rv$ $F = 6 \times \pi \times 1.8 \times 10^{-5}\ \text{kg m}^{-1}\ \text{s}^{-1} \times 8.8\ \text{m} \times 2\ \text{m s}^{-1}$ $= 6.0 \times 10^{-3}\ \text{N}$ This is very much less than upthrust and so is negligible	**(3)**
3(b)	Add labelled arrows Correctly show weight (W, mg), upthrust (U), and viscous drag /drag/friction/air resistance (V, F, D) 3 correct = 2, 2 correct = 1 [4 labels, max 1 for 3 correct forces, zero for 2 correct forces, 5 labels or more = zero] [Forces do not need to be co-linear. Accept two correct labels on the same arrow. Accept buoyancy force for upthrust]	**max (2)**

	[Do not accept 'gravity']	
3(c)	Explain why this density change limits the height to which the balloon will rise. Mass/weight of displaced air decreases / upthrust decreases / density of air in balloon eventually equals density of surrounding air [accept density greater than surrounding air] **(1)** Net upward force would decrease / no resultant upward force / no more upwards acceleration **(1)**	**(2)**
	Total for question	**12**

Question Number	Answer	Mark
4(a)	Describe what is meant by: laminar flow – no abrupt change in direction or speed of flow /air flows in layers/flowlines/streamlines with no mixing (1) turbulent flow – mixing of layers / contains eddies / abrupt changes in speed or direction (1)	**2**
4(b)	Add to the diagram laminar flow shown - at least 3 continuous lines (1) turbulent flow shown – eddies / layers crossing over (1)	**2**
4(c)	Explain how this would increase the range of the ball. (smaller area of turbulent flow →) less resistive force (1) Less kinetic energy dissipated / kinetic energy dissipated at lower rate / less work done against air resistance / less deceleration (1)	**2**
	Total for question	**6**

Question Number		Mark
5	Pa = N m^{-2} (1) N = kg m s^{-2} (1) (Pa = kg m s^{-2} m^{-2} scores both marks) (The use of fractions rather than indices can still score both marking points)	**2**
	Total for question	**2**

Question Number	Answer	Mark
6(a)(i)	Weight/W/mg **(1)** Upthrust/U **(1)** Drag/Friction/Fluid resistance/F/D/V **(1)** (all lines must touch the black dot and should be approximately vertical by eye) (−1 for each additional force) 	3
*6(a)(ii	(QWC – work must be clear and organised in a logical manner using technical terminology where appropriate) <u>Upthrust</u> is greater for the larger bubble **(1)** Drag/friction increases **(1)** Upthrust increases more than drag **Or** greater (initial) resultant force on bubble **Or** higher terminal velocity **Or** upthrust is related to volume/radius^3 **and** drag related to area/radius$^{(2)}$ **(1)**	3
6(b)(i)	Both graphs straight from t = 0 (labels not required) **(1)** Initial gradient of A less than gradient of B (minimum of 1 label required) **(1)** (The lines do not have to meet i.e. the lines could stop before the meeting point The lines can start anywhere on the displacement axes) 	2

6(b)(ii)	Measurement from photographs 0.5 **-** 0.7 (cm) **(1)** Use of distance = measurement × 12 **(1)** Use of speed = distance/time **(1)** speed = 0.18 – 0.25 m s $^{-1}$ **(1)** <u>Example of calculation</u> Measurement = 0.55 cm Distance = 0.55×10^{-2} m× 12 = 6.6×10^{-2} m speed = $\frac{6.6 \times 10^{-2}\ \text{m}}{0.33\ \text{s}}$ speed = 0.20 m s^{-1}		4
6(c)(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
***6(c)(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
	Total for question		**18**

Question Number		Mark
7(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) <u>Example of calculation</u> $a = \dfrac{37.5\ \text{m s}^{-1} - 0}{2.3\ \text{s}}$ $a = 16.3\ \text{m s}^{-2}$	**2**
7(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) <u>Examples of calculations</u> $E_k = ½ \times 10\,000\ \text{kg} \times (37.5\ \text{m s}^{-1})^2 = 7.03 \times 10^6\ \text{J}$ Power = $7.03 \times 10^6\ \text{J} / 2.3\ \text{s} = 3.1 \times 10^6\ \text{W}$	**3**
7(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**
***7(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**
7 (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**

Question Number		Mark
7(a)	Graph does not have a zero gradient **Or** Graph does not shows constant velocity **Or** the velocity is constantly changing **Or** Graph always shows an acceleration (or deceleration) **Or** Graph not horizontal/ flat **Or** Graph not parallel to the time/x-axis **(1)** (Accept 'line/gradient/tangent' in place of 'graph')	**1**
7(b) (i)	Use of gradient of tangent **(1)** a = 6.5 to 7.4 (m s^{-2}) (conditional mark) **(1)** (Check graph to make sure that the values have been read accurately from the graph, misreading from the graph will only score 1 mark even if the answer falls in the above range) <u>Example of calculation</u> Acceleration = $\frac{8.0\text{ m} - 1.2\text{ m}}{1.0\text{ s}}$ Acceleration = 6.8 m s^{-2}	**2**
7(b)(ii)	Use of $F = ma$ **(1)** F = 0.016 to 0.018(N) (ecf acceleration from (b)(i)) **(1)** <u>Example of calculation</u> F = 6.9 m s^{-2} × 0.0024 kg = 0.017 N	**2**
7 (b) (iii)	Use of W = mg **(1)** Drag = 0.006 to 0.008(N) (ecf) **(1)** <u>Example of calculation</u> W = 0.0024 kg ×9.81 N kg^{-1} = 0.0235 N 0.017 = 0.0235 – drag Drag = 0.0065 N	**2**
7 (b) (iv)	Use of Stokes' law equation with velocity either 5.2 m s^{-1} or 6.6 m s^{-1} **(1)** $F = 3.5 \times 10^{-5}$ (N) or 4.5×10^{-5} (N) (no unit error) **(1)** <u>Example of calculation</u> $F = 6\pi\eta rv$ $= 6\pi \times 1.8 \times 10^{-5} \times 2 \times 10^{-2} \times 5.2$ m s^{-1} $= 3.5 \times 10^{-5}$ N	**2**

7 (c)(i)	Correctly identifies a region of laminar flow and region of turbulent flow **(1)**	
7 (c)(ii)	the idea that there is turbulent flow **Or** ball is moving fast **Or** this is a large sphere **Or** Statement about Stokes law force for laminar flow only **Or** Stoke's law assumes that the ball is moving slowly (which this is not) **Or** Stoke's law is for a small sphere (and the hollow ball is large) **(1)** **Or** A large amount of eddies increases the drag	**1**
7 (d)	**Max 3** Falls with constant acceleration **(1)** At about 0.8 s: the ball bounces **Or** the ball changes direction **(1)** Speed of ball after the bounce is less than the speed before the bounce **(1)** Max height reached at about 1.3 s. **(1)** Accelerations are the same before and after the bounce **(1)**	**3**
	Total for question	**14**