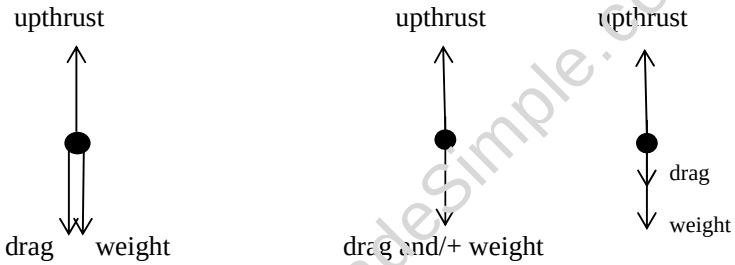
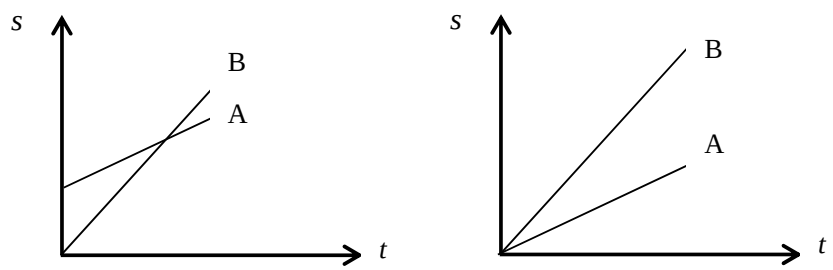
Question Number	Answer	Mark
1(a)(i)	No abrupt change in direction/speed of flow **Or** no eddies **Or** fluid flows in layers/flow lines/streamlines **Or** no mixing of layers **Or** layers remain parallel **Or** velocity at a (particular) point remains constant **(1)** (smooth and streamlined are not sufficient)	**1**
1(a)(ii)	**Any 2 from:** Small object **(1)** Smooth surface **(1)** Low/small velocity **(1)**	**2**
1(b)(i)	Distance between markers **(1)** Diameter of the ball bearing **(1)**	**2**
1(b)(ii)	Weight of the ball bearing **(1)**	**1**
1(b)(iii)	Upthrust **Or** weight of glycerol/fluid displaced (by the ball bearing) **(1)**	**1**
1(b)(iv)	Calculate the velocity (of the ball bearing) (for each drop) **Or** use $v=h/t$ **(1)** Plot v against r^2 (or t against $1/d^2$ etc.) **(1)** Determines/calculates/measures the gradient **(1)** $\eta = \frac{2g(\rho_b - \rho_g)}{9 \times \text{gradient}}$ **Or** gradient $= \frac{2g(\rho_b - \rho_g)}{9 \times \eta}$ Or correct alternative **(1)** (only allow MP2, MP3 & MP4 if a straight line would be produced) (do not allow MP2 if graph axes are complex, e.g. $W_b - W_g$ against $6\pi rv$) (Allow converse answer for a graph of r^2 against v)	**4**
1(c)	At a low temperature: the flow rate (of the glycerol) is reduced/slower **Or** speed (of the glycerol) decreases **Or** (the glycerol) moves slowly **(1)** (Do not credit ref to nitrogen removal or flow of waste water) the viscosity is high/large/increased **(1)** (do not accept "thicker") (marks not awarded for answer is in terms of increasing temperature and decreasing viscosity as it is not in the context of the question)	**2**
	Total for Question	**13**

Question Number	Answer	Mark
2	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**
	Total for question	**2**

Question Number	**Answer**	**Mark**
3(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**
***3(a)(ii)**	(QWC – work must be clear and organised in a logical manner using technical terminology where appropriate) Upthrust 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**
3(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**

3(b)(ii)	Measurement from photographs 0.5 - 0.7 (cm) Use of distance = measurement × 12 Use of speed = distance/time speed = 0.18 – 0.25 m s^{-1} Example of calculation 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}	**(1)** **(1)** **(1)** **(1)**	**4**
3(c)(i)	(Stokes' law is only for) small (solid) spheres **Or**(Stokes' law is only for) laminar flow **Or** there is turbulent flow 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)** **(1)**	**2**
***3(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) Use of $4\pi r^3/3$ to find the volume of the sphere Use $V\rho g$ to find the upthrust / weight of the bubble Drag = upthrust – weight **Or: Stokes' law method 2 marks** Measure the diameter/radius of the sphere (from the photograph) Calculate the (terminal) velocity using $v = s/t$ **and** substitute into $F = 6\pi r\eta v$	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**4**
	Total for question		**18**

Question Number	Answer		Mark
4(a)	X is Upthrust **Or** weight of oil/fluid displaced Y is Drag **Or** friction **Or** fluid resistance **Or** viscous/resistive force Z is Weight **Or** gravitational pull/force	**(1)** **(1)** **(1)**	**3**
4(b)	Diameter of the ball Distance and time (to travel measured distance) (1 mark max for radius **and** (terminal) velocity if neither mark awarded)	**(1)** **(1)**	**2**
	Total for Question		**5**