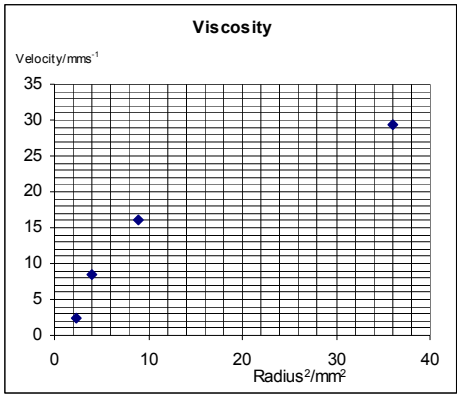
2	
(a)	D
(b)	B
(c)	A
3	C
4	B
5	C
6	D

Question Number	Answer **The question must be marked holistically within the context of the candidate's experimental method.**	Mark
7	*(a) labels on diagram plus additional apparatus required which is not on diagram* markers or reference to light gates **(1)** rule, timing device, micrometer **(1)**	**2**
	(b) state the quantities to be measured diameter, distance, time **(1)** **Or** diameter, velocity **(1)**	**1**
	*(c) for **two** of these quantities explain your choice of measuring instrument,* **Max 2 per quantity** e.g. diameter – micrometer **(1)** reading to 0.01 mm (0.001 mm) **(1)** length – metre rule **(1)** reading to 1 mm **(1)** time – stopwatch **(1)** reading to 0.1 s (0.01 s) **(1)**	**4**
	(d) *state which is the independent and which is the dependent variable*: diameter/radius, (terminal) velocity or time **(1)**	**1**
	(e) explain how the data will be used **Max 2** e.g. radius determination from measured diameter **Or** velocity from distance and time **(1)** graph of v against r^2 and reference to gradient (**1)**	**2**
	(f) identify the main source of uncertainty and/or systematic error: **Max 2** terminal velocity not reached **(1)** reaction time **(1)** temperature not constant **(1)** measurement of diameter **(1)** micrometer zero error **(1)** measurement of distance fallen **(1)** parallax error **(1)**	**2**
	(g) *appropriate comment on safety* **Max 1 Answer should have some explanation/justification** e.g. mop up spills **(1)** wear goggles to avoid splashes in eye **(1)** use gloves (if allergic to oil) **(1)** normal laboratory rules should be followed **(1)** low risk experiment **(1)**	**1**
	Total for question 7	**13**

Question Number	Answer	Mark
8(a)	$9\ mm^2$ **Or** $9 \times 10^{-6}\ m^2$ (1) r / mm | r^2 / mm^2 | v / ms^{-1} 1 | 1 | 0.0098 2 | 4 | 0.034 3 | 9 | 0.0781 4 | 16 | 0.15	**1**
8(b)	**Max 2** Too few results (1) Small range (1) No repeats/means (1) Lack of precision in radius (1) Inconsistent sig figs in v (1)	**2**
8(c)	$v = (2g(\rho_s - \rho_g) / (9\eta) \times r^2$ Explicit or implicit comparison to $y = mx$ or $y = mx + c$ (1) $(2g(\rho_s - \rho_g)/9\eta)$ is constant (dependent mark) **Or** g, ρ_s, ρ_g, and η are constant (dependent mark) **Or** m from $y = mx$ is constant (dependent mark) **Or** velocity directly proportional to radius squared (dependent mark) (1)	**2**
8(d)	Axes labelled with quantities (1) Axes labelled with units (1) Sensible scales (1) Correct plotting of candidate's data from table (1) Line of best fit (1)	**5**
8(e)	Gradient from triangle using more than half the drawn line in either direction (1) Points read correctly from line on graph (1) Correct calculation of gradient to at least 2 s.f. (1)	**3**
8(f)	Substitution into equation for gradient (1) Value for η in range 1.45-1.70 (1) 2 or 3 sig fig and appropriate unit (Pa s or N m^{-2} s or kg m^{-1} s^{-1}) (1) <u>Example of calculation</u> $\eta = 2 \times 9.8 \times (7800 - 1200) \times 10^{-6} / (9 \times 0.0090) = 1.6$ Pa s	**3**
8(g)	**Max 2** Terminal velocity not reached (1) Temperature (not constant) (1) Spheres are thrown not dropped (1) Accuracy of manufacturer's value for radius/diameter (1) Allow any sensible physics alternatives – must be relevant to this experiment	**2**
	Total for Question 8	**18**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>9(a)</td><td>Max 2
Too few (1)
Inconsistent precision/significant figures (1)
No repeats/average for diameter (1)
Inconsistent intervals for diameter (1)</td><td>Max 2</td></tr>
<tr><td>(b)</td><td>
<table>
<tr><td>Diameter /mm</td><td>Radius/mm</td><td>Radius^2/mm^2</td><td>Average time/s</td><td>Velocity /mm s^{-1}</td></tr>
<tr><td>3</td><td>1.5</td><td>2.3</td><td>28</td><td>2.4</td></tr>
<tr><td>4</td><td>2.0</td><td>4.0</td><td>8.08</td><td>8.4</td></tr>
<tr><td>6.01</td><td>3.0</td><td>9.0</td><td>4.25</td><td>16.0</td></tr>
<tr><td>12.03</td><td>6.0</td><td>36.0</td><td>2.32</td><td>29.3</td></tr>
</table>
Correct radius and radius squared values (1)
Velocity value of 16.0 or 16 (1)
Correct unit for velocity (1)
Radius given to 2 sig figs (1)
Note
Accept correct r and r^2 to any sf for first mark</td><td>4</td></tr>
<tr><td>(c)</td><td>Axes labelled with quantity and unit (ecf for unit of velocity) (1)
Suitable scales (1)
Correct plotting (1)
Curved line (1)
Smooth curve of best fit (do not credit if forced through origin) (1)
Example below would gain first 3 marks
 
</td><td>5</td></tr>
<tr><td>(d)</td><td>One mark for valid reason
Examples
Didn’t reach terminal velocity/is not falling at constant velocity (1)
Distance between markers is too small (1)
Tube too narrow (1)
Misreading of stop-watch or micrometer (1)
Allow temperature changes in context (1)
(Ignore parallax and reaction time alone)</td><td>max 1</td></tr>
<tr><td></td><td>Total for question 9</td><td>12</td></tr>
</table>

(iii) Gradient
The hypotenuse of the triangle must be at least half the length of the drawn line. [1]
Both read-offs must be accurate to half a small square.
If incorrect, write in correct value.
Check for $\Delta y/\Delta x$ (i.e. do not allow $\Delta x/\Delta y$).

y-intercept from graph or substitute correct read-offs into $y = mx + c$ [1]
Label FO.

(e) a = gradient value and b = y–intercept value. [1]
If inverted axes not corrected for –1
Range of values ($0.1AV^{10} \leqslant a \leqslant 0.9AV^{10}$, $b = 0 \pm 0.01A$) and appropriate units [1]

[Total: 20]

2 **(a)** Raw value(s) of x: 25.0 cm $\leqslant x \leqslant$ 35.0 cm with unit to nearest mm. [1]

(b) **(i)** Evidence of repeated measurements of d in **(b)(i)** or **(e)** [1]
Value of d = 3.0 mm ± 1.0 mm or SV ± 1.0 mm [1]
Raw values of d to at least 0.1 mm

(ii) Value of t in range 1 s to 10 s unless SV indicates otherwise. Allow SV ± 5 s [1]

(c) Absolute uncertainty in t_1 in the range 0.1 to 0.6 s [1]
If repeated readings have been taken, then the uncertainty could be half the range.
Correct calculation to get % uncertainty.

(d) v calculated correctly with consistent units. [1]

(e) Second value for d. [1]
Second value for t. [1]
Quality: t_2 less than t_1. (d increases, t decreases) [1]

(f) **(i)** Calculation of two values of k. [1]

(ii) Valid conclusion based on the calculated values. [1]
Candidate must test against a specified criterion.

(iii) Relate raw values of x, t and d. Any decimal place arguments score zero. [1]

	Limitations (4)	Improvements (4)	Ignore
A	**A_p** Two readings not enough (to support conclusion)/too few readings.	**A_s** Take more (sets of) readings and plot a graph/compare values of k.	Repeat readings.
B	**B_p** Time too short/reaction time large compared to measured time/parallax error in judging start/stop.	**B_s** Increase x/lengthen tube/smaller balls/video with timer (playback) in slow motion.	Light gates, motion sensors, data loggers, computers, helpers, solution for parallax error. Set squares, rulers, etc.
C	**C_p** Difficult to see glass balls.	**C_s** Use coloured balls/shine light through.	Use ball bearings (type of ball and oil stays fixed).
D	**D_p** Terminal velocity not reached (by the first marker).	**D_s** A valid method to check reached TV, e.g. time constant over three markers/video with timer (playback) in slow motion, multi-flash photography/stroboscope.	References to starting point. Do not accept 'move *x* down' on its own. Change viscosity of oil (oil and glass must remain fixed).
E	**E_p** Balls not all the same diameter/size/shape/mass	**E_s** Use micrometer screwgauge/top pan balance	
X	**X_p** Balls had a hole in/air bubbles on ball or oil.	**X_s** Clean balls/immerse in oil	

[Total: 20]