1)

a	'heavy' and 'light' objects / different weights / different masses dropped (from leaning tower of Pisa) / rolled down incline plane Objects have the same acceleration (of free fall) Objects hit ground at same time	B1 B1 B1	**Must use ticks on Scoris to show where the marks are awarded** **Not**: 'dropping feather' / 'vacuum' / 'experiment on the Moon' for this first B1 mark but can score subsequent B1 marks **Not**: 'fall at the same rate / accelerates at the same rate / same speed'
b(i)	$s = ut + \frac{1}{2}at^2$ and $u = 0$ / $0.600 = \frac{1}{2} \times a \times (0.356)^2$ $a = \frac{2 \times 0.600}{0.356^2}$ $a = 9.47$ (m s^{-2})	C1 C1 A0	**Note**: There are no marks for just an answer, since this is a **'show'** question **Allow**: 2 marks for correct substitution with 'a' the subject or $0.600 = \frac{1}{2} \times a \times (0.356)^2$ followed by $a = 9.469$ (more than 3 sf) **Note:** Using 'v =.600/0.356' followed by $a = \Delta v / \Delta t = 4.73$ scores zero. (Watch out for $4.734 \times 2 = 9.47$)
b(ii)	Air resistance or drag / residual magnetism or 'sticky' electromagnet / trapdoor takes time to open	B1	**Not**: 'Experiment is not done in a vacuum' / 'friction/resistance'
b(iii)	A 'parabola shape' / graph of increasing positive gradient starting from origin and going through 0.356,0.6	B1	Judge the shape of the graph by eye. A horizontal line from 0.6 must cut the graph within the 'vertical zone provided by 0.356 s ' on the time axis
	Total	**7**	

2)

a		Any two from: • area • speed / velocity • viscosity (of air) / temperature / density • (surface) texture / 'aerodynamic' (shape)	B1×2	**Not**: shape / size **Allow**: 'streamlining'
b	**i**	Correct directions of arrows W and D	B1	Award the mark for two arrows in opposite directions as long as one of them is labelled
	ii	weight = 75 × 9.81 weight = 736 (N) or 740 (N)	 B1	**Reminder**: weight can be quoted to more than 2 sf (e.g: 735.75) **Not**: '75 × 10 = 750 N'
	iii	$D = 0.30 \times 20^2$ (= 120 N) $736 - 120 = 75a$ $a = 8.2$ (m s^{-2})	C1 C1 A1	 **Allow**: Answer to 2sf or more **Bald** answer of 8.2 or 8.21 scores 3 marks **Note**: Using 740 (N) gives an answer 8.3 (m s^{-2})
	iv	(D and W are) equal	B1	**Not**: D and W are 'balanced/equilibrium'
	v	drag = weight $736 = 0.30 \times v^2$ $v = 49.5$ (m s^{-1}) or 50 (m s^{-1})	 C1 A1	 **Bald** answer of 49.5 (m s^{-1}) or 50 (m s^{-1}) scores 2 marks
		Total	**10**	

3)

a		**Measurements**: height (of wall) time (of fall) **Instruments**: ruler / tape (measure) stopwatch / timer / clock /video $g = \frac{2s}{t^2}$ / $g = 2 \times$ gradient of s-t^2 graph **Note**: Allow full credit if candidate has used alternative approaches using $v^2 = u^2 + 2as$ or $v = u + at$. Any <u>two</u> from: g is an estimate because • air resistance / drag ignored • parallax problems with 'landing time' • starting / stopping the clock	 B1 B1 B1 B1 B1 B1×2	**Must use tick or cross on Scoris to show if the mark is awarded** **Allow:** 'distance (of fall)' instead of 'height' ✎ **The 4th B1 can only be scored if *stopwatch* / *timer* / *clock* / *video* (camera) is spelled correctly** **Allow:** Use of 'a' instead of 'g' **Note**: a must be the subject **Allow:** 'wind resistance'/'resistive force' for first bullet point **Allow**: 'reaction time' but **not** 'human error' for the third bullet point

4)

(a)		… ***immediately*** *after jumping* Only force is the weight/drag = 0/net force = weight acceleration = g/9.8(1 m s^{-2}) (Allow 'mg' for weight. Do not allow 'gravity' for weight.) … ***before*** *terminal velocity is reached* Any <u>two</u> from: Drag increases (with speed) /drag $\propto$ speed^2 Net or resultant or total force decreases / weight > drag Acceleration is less than g … ***at*** *terminal velocity* weight = drag / net force = 0 acceleration = 0 /<u>constant</u> speed or velocity (AW)	 B1 B1 B1 B1 B1 B1 B1	**Alternatives** accepted for *drag* are: friction/air resistance **Allow**: 'Has acceleration of free-fall/due to gravity' as alternative for second B1 mark **Allow**: velocity instead of speed. **Allow**: 'drag $\propto$ speed' as BOD. **Allow**: Acceleration decreases **Allow**: upward force(s) = downward force/'forces balanced'
(b)		(Transformed to) heat/thermal (energy)	B1	**Not**: 'Friction'/sound
(c)		Any <u>two</u> from: 1. The terminal velocity increases 2. Initial gradient/slope is the same/equal to g 3. Time taken to reach terminal velocity is longer	B1 × 2	 **Allow**: Initial acceleration is the same/g/9.8(1 m s^{-2})
		Total	**9**	

5)

(a)		$(s = \frac{1}{2}at^2)$; 0.700 = ½ × 9.81 × t^2 $t^2 = \frac{2 \times 0.700}{9.81} (= 0.1427)$ t = 0.378 (s) or 0.38 (s)	C1 C1 A1	**Allow**: a = 9.8 (m s^{-2}) **Note**: Using a = 10 (m s^{-2}) gives 0.374 (s) or 0.37 (s); this scores 2 marks **Allow** full credit for correct use of $v^2 = 2as$ and $v = at$
(b)	**(i)**	acceleration or deceleration displacement or distance	B1	
	(ii)	A tangent drawn on Fig. 4.2 at point **A** Determine the gradient of the tangent Deceleration value in the range 13.0 to 17.0 (m s^{-2})	B1 M1 A1	**Note**: This is an independent mark **Note**: Ignore sign **Special case**: Allow 1 mark for using a chord about t = 0.05 seconds to determine the deceleration and the value lies in the range 13.0 to 17.0 (m s^{-2})
	(iii)	At **A:** Drag > weight The ball is decelerating/'slowing down' At **B**: Drag = weight The ball has zero acceleration/has reached terminal velocity/has reached constant velocity	 B1 B1 B1 B1	 **Allow**: 'friction'/'resistive force' for drag **Allow**: upward/negative acceleration **Note:** Allow full credit if *upthrust* and *drag* are both mentioned and applied correctly at points **A** and/or **B**
	(iv)	The (gravitational) potential energy/(G)PE (of the ball) is converted into heat/thermal (energy)	B1	
		Total	**12**	

6)

a		$F \rightarrow$ kg m s^{-2} **or** $A \rightarrow$ m^2 and $v \rightarrow$ m s^{-1} Manipulation leading to $k \rightarrow$ kg m^{-3} $k \rightarrow$ kg m^{-3}	M1 M1 A0	**Alternative**: (units on rhs:) kg m^{-3} × m^2 × m^2 s^{-2} **or** (unit for lhs:) = kg m s^{-2} M1 Manipulation leading to same units on both sides M1 **Allow** other correct methods
b	**i**	Arrow directly opposite to D on Fig. 6.1	B1	**Ignore** position and length of arrow
	ii	The ball is not at terminal velocity, since D and W are not (directly) opposite / The ball is not at terminal velocity because there is a net force	B1	**Not** D and W are at 90°
	iii	It is travelling (vertically) upwards It will slow down / It decelerates / It accelerates (vertically) downwards / There is a net downward force / drag opposes motion	M1 A1	
c		At the start, acceleration = g (because there is no drag) Drag increases (as its speed increases / accelerates) net force decreases or net force < weight (As it falls) acceleration decreases / (As it falls) acceleration < g	B1 B1 B1 B1	**Allow** 9.8(1) m s^{-2} / acceleration of free fall / acceleration due to gravity (**Not** 'gravity' on its own) **Not** rate of acceleration is g **Not** 'rate of acceleration decreases' unless it is qualified or 'acceleration slows down'
		Total	**10**	

7)

(a)		Drag increases with speed (ORA) / drag $\propto$ speed^2	B1	
(b)		Galileo dropped different mass balls / rolled different mass balls (down a ramp) Balls hit the ground / reached the bottom (of ramp) at the same time (Galileo -) All objects fall with the same acceleration and (Aristotle -) Heavy / massive objects fall faster / quicker (than light objects)	B1 B1 B1	**Allow** object / trolley instead of ball
(c)	**(i)**	(The two forces are weight and drag) weight = drag	B1	**Not** 'gravity' for weight **Allow**: weight = drag + upthrust
	(ii)	When the parachute is opened, drag increases / drag is greater than the weight Drag decreases as the speed decreases / net force decreases The (magnitude of the) deceleration decreases (between 50 m s^{-1} and 4 m s^{-1}) (At 4 m s^{-1}) deceleration or acceleration = 0	B1 B1 B1 B1	
		Total	**9**	