Question number	Answer	Notes	Marks
1 (a) (i)	force = mass x acceleration;	in words or in accepted symbols e.g. F=ma	1
(ii)	substitution; evaluation; e. 38 x 1.5 57 (N)	 57000 (N) scores 1 mark	2
(iii)	any suitable suggestion; e.g. friction between snow/ground and sledge ground is not level towing rope/direction at an angle to the ground/direction of movement	allow air resistance/drag	1
(b) (i)	acceleration = change in velocity; time (taken)	in words or in accepted symbols e.g. $a=\frac{\Delta v}{t}$ $a=\frac{v-u}{t}$ not 's' for 'v'	1
(ii)	*working must be shown* rearrangement of equation OR substitution; evaluation to at least 2SF; e. $t=\frac{2.8}{1.5}$ = 1.9 (s)	Calculation of velocity or acceleration scores 1 mark max. allow 1.87 no unit required	2

(c) (i)	MP1. statement of total distance = area under graph; MP2. any 1 correct distance for a segment of journey; e.g. calculation of distance during acceleration (½ x 3.25x 2.5 = 4.1 m) calculation of distance during constant speed (3.25x 8 = 26 m) calculation of distance during deceleration (½ x 3.25x 4 = 6.5 m) MP3. correct total distance 36.6 (m);	may be assumed by an attempt at sum of the areas allow range of 36-37 (m)	3
(ii)	(average) speed = $\frac{\text{distance (moved)}}{\text{time (taken)}}$;	in words or in accepted symbols e.g. v=s/t condone s=d/t	1
(iii)	substitution; evaluation; e.g. 36.6/14.5 2.52 (m/s)	allow ecf from (c)(i) for distance ignore s.f. allow answers that round to 2.5 or 2.6 (m/s)	2

Total 13 marks

Question number	Answer	Notes	Marks
2 a	any FIVE from: MP1. Object has weight or there is a downward force (due to gravity on the object); MP2. So it accelerates (downwards); MP3. there is (a force of) drag (upwards or to oppose movement); MP4. drag increases as speed increases; MP5. eventually drag = weight ; MP6. (hence) resultant force is zero; MP7. (hence) object travels at constant speed;	allow: gravity pulls it down the speed/velocity increases oil resistance / water resistance / air resistance for drag oil friction / water friction / air friction for drag 'drag increases as it accelerates' forces are equal / forces are balanced accept 'no acceleration' DO NOT ALLOW • (The drag) slows it down MP2 • upthrust for drag MP3 • resistance = acceleration for MP5 • terminal velocity for constant speed for MP7	5

b	<u>Measuring instruments</u> MP1. Timer / stop-clock/ light gate (and data logger); MP2. Ruler / scale; <u>Measurements made</u> MP3. Take time for ball to pass between two points; MP4. determine the distance apart; MP5. Repeat readings lower down; **OR** MP6. For a set time (e.g. for 1 s); MP7. measure distance travelled (in this time); MP8. Repeat readings lower down; **OR** MP9. measure velocity using light gate with data logger; MP10. at two different places; <u>Using measurements</u> MP11. Use speed = distance / time; MP12. How results indicate terminal velocity achieved;	Ignore ticker-timer measurement of mass condone tape measure if the measurements are from top to bottom then only give MP3 or MP4 not both allow velocity for speed	5

(Total for Question 2 = 10 marks)

Question number	Answer	Notes	Marks
3 (a)	any two from : a balance/scales; metre rule or measuring tape; stopwatch or stop-clock;	 allow newtonmeter	2
(b)	dependent = time (taken for fall);	accept speed (of cupcake cases)	2
	independent = mass (of cupcake cases);	accept number/weight (of cupcake cases)	
(c)	Any ONE of • (constant) height; • still air/no (cross) wind; • from rest/zero force at launch; • identical (cupcake) cases;		1
(d)	time in s; mass in g;	accept in either order accept mass in kg weight in N number of cupcake cases in numbers/no units	2

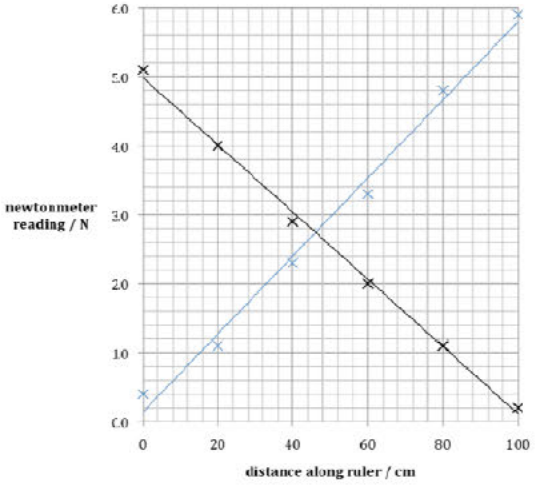
(e)	Any one of • detail of any sensible and valid procedure; e.g. repeat readings for time and then average readings • detail of more suitable conditions e.g. measure over a larger fall work indoors/reduce draughts ;	allow more accurate timing methods;	1

Question number	Answer	Notes	Marks
3(f)	down arrow labelled weight;	allow gravitational force/pull ignore 'gravity'	2
(i)	up arrow labelled drag;	allow air resistance accept friction, upthrust ignore lift	
(ii)	any three from MP1. idea of **unbalanced** force; e.g. at the start, the only force is weight part way down, the weight is greater than the drag MP2. (this unbalanced) force causes acceleration; MP3. idea of balanced forces near the bottom; e.g. near the bottom the forces are equal MP4. therefore no acceleration; e.g. it reaches terminal velocity	do not credit repeat of the diagram above there is no upward force at the start weight equals drag	3

(Total for Question 3 = 13 marks)

Question number	Answer	Notes	Marks
4 (a) (i)	work done = force x distance moved ;	Accept W = F x d Allow rearrangements do not accept eqn in units only	1
(ii)	Substitution into correct equation; Calculation; 170 x 110 19 000 (J)	Accept **18 700** (J)	2
(iii)	exactly same as their answer to (ii);		1

Question number	Answer	Notes	Marks
4 (b) (i)	KE = ½mv^2	Accept word equation	1
(ii)	addition of masses before OR addition of energies after; Substitution into correct equation; Calculation; 1650 + 950 = 2600 (OR 436 425 + 251 275 = 687 700) ½ x 2600 x 23^2 688 000	Accept for 1 mark - either 436 000 or 251 000 accept for 2 marks - both 436 000 and 251 000 Accept for 3 marks- 687 700	3
(c)	Any **three** of 1. idea that mass and acceleration are inversely related; 2. Idea that (total) mass is less; 3. Idea of less (air) resistance / friction; 4. Idea of less work done/less energy used; 5. Idea of amount work related to amount of (chemical) energy from fuel;	allow F = m x a mentioned weight for mass drag doesn't have to use energy to pull the caravan	3
		Total	**11**

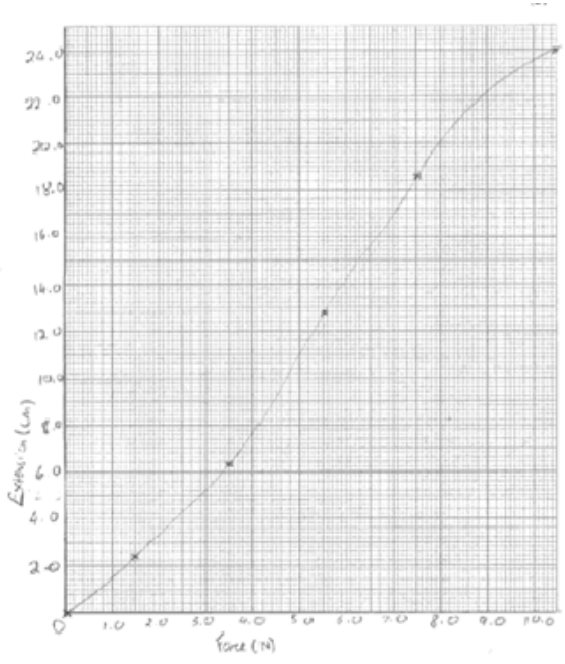
Question number	Answer	Notes	Marks
5 (a) (i)	A – distance A		1
(ii)	D – force D		1
(b) (i)	Force (C) in N; or Force in newtons;	Allow: Reading from newton-meter in N	1
(ii)	Plotting ;; Line of best fit;  0 5.1 20 4.0 40 2.9 60 2.0 80 1.1 100 0.2	To nearest ½ square, penalise errors up to two marks Suited to candidate's plotting (allow a smooth curve) no double lines judge LoBF by balance of points about the line	3
(iii)	Reading from graph to ± 1 cm; e.g.	To nearest ½ small square	1

Question number	Answer	Notes	Marks
5 (c)	weight of ruler;	Accept other valid reasons allow force for weight ignore 'it's got a force acting' 'because of gravity'	1
		Total	**8**

<table>
<tr><th>Question number</th><th>Answer</th><th>Notes</th><th>Marks</th></tr>
<tr><td>6 (a)</td><td>all 3 for both marks;;

any two for 1 mark ;

<table>
<tr><th>item</th><th>Tick if needed</th></tr>
<tr><td>ammeter</td><td></td></tr>
<tr><td>steel spring</td><td></td></tr>
<tr><td>retort stand and clamp</td><td>✓</td></tr>
<tr><td>rubber band</td><td>given ✓</td></tr>
<tr><td>ruler</td><td>✓</td></tr>
<tr><td>thermometer</td><td></td></tr>
<tr><td>mass hanger</td><td>✓</td></tr>
<tr><td>mass</td><td>given ✓</td></tr>
</table>
</td><td>each incorrect tick = -1</td><td>2</td></tr>
</table>

<table>
<tr><td>(b) i</td><td>5.5 (in the table)</td><td></td><td>1</td></tr>
<tr><td>ii</td><td>suitable scale for axes;
axes labelled with units;
points plotted to nearest mm square (minus one for each plotting, up to max 2 marks);;
Line (curve) of best fit acceptable;
</td><td>-1 for each incorrect plot
Allow (ecf) a balanced straight line of best fit that takes account of any plotting errors and indicated anomalies
<table><tr><th>Mass in g</th><th>Force in N</th><th>Extension in cm</th></tr><tr><td>0</td><td>0</td><td>0.0</td></tr><tr><td>150</td><td>1.5</td><td>2.4</td></tr><tr><td>350</td><td>3.5</td><td>6.3</td></tr><tr><td>550</td><td></td><td>12.8</td></tr><tr><td>750</td><td>7.5</td><td>18.6</td></tr><tr><td>1050</td><td>10.5</td><td>24.0</td></tr></table></td><td>5</td></tr>
<tr><td>iii</td><td>No / yes (no mark)

Idea that Hooke’s law should show (direct) proportionality;

Use of data (from the table or graph) to explain that the results do not show this;
e.g. ‘line is a curve’, ‘(table shows) rubber band extends unevenly’</td><td>Allow (ecf) - converse from <u>straight</u> drawn line, using data from their graph (not the table)
e.g. ‘Yes’ AND ‘line is a straigh</td><td>2</td></tr>
<tr><td></td><td></td><td>Total</td><td>10</td></tr>
</table>