PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



MARK SCHEME

TOPIC 2: MECHANICS

MOTION AND KINEMATIC QUANTITIES

SCORE	PERCENTAGE
/336	%

STEMUP

These questions belong to Pearson Edexcel, not to us.

The examination questions and mark schemes in this pack were written and published by Pearson Edexcel. They are past assessment materials, reproduced here so that students can revise from them.

What we do not own

STEMUP is not affiliated with Pearson Edexcel and does not own, and makes no claim to own, any of the question or mark scheme material in this pack. Pearson has not endorsed, approved or been involved in the production of it. Pearson, Edexcel and the qualification titles used here belong to their respective owners and appear for identification only.

Where to find the originals

Pearson publishes its past papers and mark schemes free of charge. Always check the current specification at qualifications.pearson.com before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

Mark Scheme

Q1.

Question Number	Acceptable Answer		Additional Guidance	
	• Use of $s = \frac{(u+v)}{2}.t$	(1)	Example of calculation: $32.5\text{ m} = \frac{(u+0)}{2} \times 17.5\text{ s}$ $\therefore u = \frac{32.5\text{ m} \times 2}{17.5\text{ s}} = 3.71\text{ m s}^{-1}$ $P = \frac{\Delta E_k}{\Delta t} = \frac{\frac{1}{2} \times 19.6\text{ kg} \times (3.7\text{ m s}^{-2})^2}{1.25\text{ s}} = 107\text{ W}$	4
	• Use of $E_k = \frac{1}{2}mv^2$	(1)		
	• Use of $P = \frac{\Delta W}{\Delta t}$	(1)		
	• $P = 110\text{ W}$	(1)		

Q2.

Question number	Acceptable answers	Additional guidance	Mark
	Either • Calculate acceleration **(1)** • Use of $F = ma$ **(1)** • $F = 38$ N **(1)** **OR** • Calculate change in momentum **(1)** • Use of $F = \frac{\Delta mv}{\Delta t}$ **(1)** • $F = 38$ N **(1)**	Example of calculation: $F = \frac{0.06\ x\ 25}{0.04} = 37.5$ N	**3**

Q3.

Question Number	Acceptable Answer	Additional guidance	Mark
(a)	• attempts to find area under second peak OR use of a suitable equation of motion OR equate $E = \frac{1}{2}mv^2$ and $\Delta E = mg\Delta h$ (1) • height = 0.9 - 1.0 m (1)	Example of calculation: $h = \frac{1}{2} \times 4.2\ \text{m s}^{-1} \times (1.2-0.70)\ \text{s} = 1.0$ m	**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)	• use of $\Delta E = mg\Delta h$ (1) OR use of $E = \frac{1}{2}mv^2$ (1) • $\Delta E = 0.59$ J	Example of calculation: $E = 0.060\ \text{kg} \times 9.81\text{m s}^{-2} \times (2.0 - 1.0)\text{m}$ $E = 0.59$ J	**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(c)	EITHER • finds gradient of middle section (1) • use of $F = ma$ (1) • $F = 64$ N (1) OR • reads two corresponding pairs of v and t from middle section of graph (1) • use of $F = \frac{m(v-u)}{\Delta t}$ (1) • $F = 64$ N (1)	Example of calculation: $F = \frac{(6.3+4.2)\ \text{m s}^{-1}}{(0.74-0.64)\ \text{s}} \times 0.060\ \text{kg} = 64\ \text{N}$	**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(d)	Initial free-fall • gradient of both graphs is the same (1) Bounce section • the gradient of the soft ball graph is less (1) Second free-fall • gradient of the soft ball graph is the same as the first graph OR the gradient is the same as in the initial free-fall (1)	Accept the first line is the same Accept time for the bounce is longer	**(3)**

Q4.

Question Number	Answer	Additional guidance	Mark
(a)(i)	thermionic emission		**(1)**

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(ii)	• equate $\frac{1}{2}mv^2$ and VQ (1) • $v = 2.3 \times 10^7$ m s^{-1} (1)	Example of calculation: $E = 1500\text{ V} \times 1.6 \times 10^{-19}\text{ C} = 2.4 \times 10^{-16}\text{ J}$ $v = \sqrt{\frac{2 \times 2.4 \times 10^{-16}\text{ J}}{9.11 \times 10^{-31}\text{ kg}}} = 2.3 \times 10^7\text{ m s}^{-1}$	**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(i)	• use of $F = EQ$ and $E = \frac{V}{d}$ (1) OR see $F = \frac{VQ}{d}$ • equate $F = ma$ and $F = EQ$ (1)		**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(ii)	• use of speed = distance/time (1) • $t = 8.7 \times 10^{-10}$ (s) (1) • use of a = $\frac{VQ}{dm}$ (1) • use of $s = ut + \frac{1}{2}at^2$ (1) with $u = 0$ and vertical acceleration to find s • $s = 3.3 \times 10^{-4}$ m (1)	Example of calculation: $t = \frac{0.02\text{ m}}{2.3 \times 10^7\text{ m s}^{-1}} = 8.7 \times 10^{-10}\text{ s}$ $s = \frac{1}{2} \times \left(\frac{50\text{ V} \times 1.6 \times 10^{-19}\text{ C}}{0.01\text{ m} \times 9.11 \times 10^{-31}\text{ kg}} \right) \times (8.7 \times 10^{-10}\text{ s})^2$ $s = 3.3 \times 10^{-4}\text{ m}$	**(6)**

Question Number	Acceptable Answer	Additional guidance	Mark
(c)	• use of $V = V_0/\sqrt{2}$ (1) • vertical line (1) • positive and negative deflection shown (1) • maximum deflection 75 V (1)	Example of calculation: $V_0 = 53\text{ V} \times \sqrt{2} = 75\text{ V}$	**(4)**

Q5.

Question Number	Acceptable answers		Additional guidance	Mark
i	• use of $s = \frac{(u+v)}{2} \times t$	(1)		
	• $v = 3.1$ (m s^{-1})	(1)	Example of calculation: 1.1 m $= \frac{(0+v)}{2} \times 0.77$ s $v = 3.1$ m s^{-1}	2
ii	• use of F = mv^2/r	(1)		
	• $F = 11$ N (allow ecf from (i))	(1)	Example of calculation: $F = \frac{0.050 \text{ kg} \times 3.1^2 \text{ (m s}^{-1})^2}{0.042 \text{ m}}$ $F = 11.4$ N "show that value" gives $F = 10.7$ N	2

Q6.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• distance between at least two pairs of images	(1)	MP1 and 2 could come from marks on the diagram	
	• distances between images are the same in x direction	(1)		
	• distance between images varies in y direction showing a changing velocity	(1)		
	• velocity in the x direction is constant so x direction is independent of y direction	(1)		4
(ii)	• use of $v^2 = u^2 + 2as$ or $s = ut + \frac{1}{2}at^2$	(1)	alt to MP2 : 0.5 m s^{-1} (allow 0.4 to 0.6) if using distance taken from first two images and $v_H = d/t$	
	• initial vertical component velocity = 0.47 m s^{-1}	(1)	Example of calculation: $0 = u^2 - 2 \times 9.81 \text{ m s}^{-2} \times 0.011$ m $u_V = 0.465$ m s^{-1}	
	• use of $v_H = d/t$ in the horizontal	(1)	$v_H = \frac{0.08 \text{ m}}{0.08 \text{ s}}$	
	• Use of Pythagorus with v_H and u_V	(1)	$v_H = 1.0$ m s^{-1} $v = \sqrt{(0.47^2 + 1.0^2)}$	
	• Resultant velocity = 1.1 m s^{-1}	(1)	Resultant velocity = 1.1 m s^{-1}	5

(iii)	• Use of $\Delta W = F\ \Delta s$ (1) • Use of $E_k = ½\ mv^2$ (1) • $F = 0.015$ N (1) Alternative • Use of $v^2 = u^2 + 2as$ (1) • Use of $F = ma$ (dependent on MP1) (1) • $F = 0.015$ N (1)	Allow ECF from (a)(ii) Example of calculation: $2 \times F \times 0.003\text{m}$ $= \frac{1}{2} \times 150 \times 10^{-6}\text{kg} \times 1.1^2\ (\text{m s}^{-1})^2$ $F = 0.015$ N "show that" value gives $F = 0.013$ N Alternative $1.1^2\ (\text{ms}^{-1})^2 = 2 \times a \times 0.003$ m $a = 202\ \text{m s}^{-2}$ $2 \times F = 150 \times 10^{-6}\ \text{kg} \times 202\ \text{ms}^{-2}$ $F = 0.015$ N	3

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• use of density = mass / volume (1) • use of $V = 4/3\ \pi r^3$ (1) • $r =$ 1720 m (1)	Example of calculation: $V = 1.0 \times 10^{13}\ \text{kg} \div 470\ \text{kg m}^{-3}$ $= 2.13 \times 10^{10}\ \text{m}^3$ $= 4/3\ \pi r^3$ $r = \sqrt[3]{(2.13 \times 10^{10}\ \text{m}^3 \times 3) \div 4\pi}$ $= 1720$ m	**(3)**

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• use of $g = GM/r^2$ (1) • $g = 2.3 \times 10^{-4}\ \text{N kg}^{-1}$ (1)	Example of calculation: $g = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 1.0 \times 10^{13}\ \text{kg} / (1720\ \text{m})^2$ $g = 2.25 \times 10^{-4}\ \text{N kg}^{-1}$	**(2)**

Question Number	Acceptable answers	Additional guidance	Mark
(c)	• use of $s = ½\ gt^2$ (1) • $s = 1.2 \times 10^3$ m (1)	Example of calculation: $s = 0.5 \times 2.25 \times 10^{-4}\ \text{m s}^{-2} \times (3300\ \text{s})^2$ $= 1.2 \times 10^3$ m	**(2)**

Question Number	Acceptable answers	Additional guidance	Mark
(d)	An explanation that makes reference to the following: • the calculated height is comparable with the radius (of asteroid) (1) • the field should be considered as radial rather than parallel, so the gravitational field strength is decreasing significantly for the probe (1) OR $g = GM/r^2$ the change in r is comparable with the radius, so there will be a significant change in g (1) • acceleration is less, so the actual height would be less (1)		**(3)**

Q8.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $s = ut + \frac{1}{2}at^2$ **(1)** • Recognise $u = 0$ **(1)** • Use of $v = d/t$ in horizontal direction **(1)** • Displacement = 1.1 m **(1)**	Example of calculation: $0.65\,\text{m} = \frac{1}{2}9.81\,\text{m s}^{-2}t^2$ $t = 0.364\,\text{s}$ $s = 3.0\,\text{m s}^{-1} \times 0.364\,\text{s}$ $s = 1.09\,\text{m}$	**(4)**

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	• inner lane covers a smaller distance (1) • inner lane has a smaller radius of curvature (1) • (maximum horizontal force is the same for both cars) therefore maximum speed is greater for the car on the outside lane (so outcome unclear) (1)		3

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• calculates mean value of time (1) • use of $s = ut + \frac{1}{2}at^2$ (1) • a = 9.5 m s^{-2} to 2/3 sf (1)	Example of calculation: Average time, t_{av} = (0.45 s +0.51 s + 0.43 s)/3 = 0.46 s $s = ut + \frac{1}{2}at^2 \quad \therefore a = \frac{2 \times 1.00\,\text{m}}{(0.46\,\text{s})^2} = 9.45\,\text{m s}^{-2}$	**(3)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	• calculates % uncertainty in t using range / half-range **Or** calculates uncertainty in s using precision of instrument (1) • doubles uncertainty in t (1) • uncertainty in a = 18 % (1)	Example of calculation: Uncertainty in t = (0.04/0.46) × 100% = 8.7 % Uncertainty in t^2 = 2 × 8.7 % = 17.4 % Uncertainty in s = (0.01/1.00)× 100 % = 1 % Uncertainty in g = 18.4 %	**(3)**

Question Number	Acceptable Answer		Additional Guidance	Mark
(c)	• % uncertainty in t would decrease	(1)		
	• longer times identified as key factor in reducing uncertainty in value obtained for *g*	(1)		**(2)**

Q11.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of $v^2=u^2+2as$	(1)		
	• $v = 0$ so $u = \sqrt{-2as}$	(1)	ignore whether minus sign included or not	
	• a is a deceleration caused by friction (with surface)	(1)	Alternative:	
	• States $F = ma$ where F is friction	(1)	• Work done by friction (with surface)	
	• As $F = km = ma$ so a must be constant **Or** $F=ma$ if F proportional to m then a must be constant	(1)	• States $W= Fs$	
	• so acceleration a the same (as 1 p coin) so statement correct	(1)	• States $E_k = ½ mu^2$	(6)
			• So $Fs = ½ mu^2$	
			• As $F = km$	
			• m's cancel so statement correct	

Q12.

Question Number	Acceptable Answer	Additional Guidance	Mark
	The acceleration (of the platform) is: • (directly) proportional to displacement from equilibrium position **(1)** • (always) acting towards the equilibrium position **Or** the idea that acceleration is in the opposite direction to displacement **(1)** [An equation with symbols defined correctly is a valid response for both marks. e.g $a \propto -x$ or $F \propto -x$]	Accept towards undisplaced point/fixed point/central point for equilibrium position. Accept a definition in terms of the force i.e. the (resultant) force (on the platform) is: • (directly) proportional to displacement from equilibrium position • (always) acting towards the equilibrium position **Or** the idea that force is in the opposite direction to displacement	**2**

Q13.

Question number	Acceptable answers	Additional guidance	Mark
	• Use of $s = ut + \frac{1}{2}at^2$ **(1)** • Use of $s = \frac{1}{2}at^2$ with vertical components to find t **(1)** • Use of $s = ut$ with horizontal components to find s **(1)** • Subtract 12 from their answer for horizontal distance **(1)** • Distance from net = 6 m **(1)** • Makes conclusion whether the ball is within the required range of the net **(1)**	Answer consistent with calculated value. Example of calculation: $t = \sqrt{\frac{2 \times 2.5}{9.81}} = 0.714$ s $s = 25 \times 0.714 = 17.85$ m Distance from net = 17.85 – 12 = 5.9 m	**6**

Q14.

Question Marks	Acceptable Answers		Additional guidance	Mark
i	• Use of $W = \frac{1}{2}CV^2$ • $W =$ 45 μJ	(1) (1)	Example of calculation $W = \frac{1}{2} 40\mu F \times (1.5\ V)^2$ $W =$ 45 μJ Alt: Use $Q = CV$ then $E = QV/2$ for MP1	2
ii	• Use of $V = V_o e^{-t/RC}$ • Time = 0.14 (s)	(1) (1)	Example of calculation $0.5 = e^{-t/5000\times40\times10^{-6}}$ $\ln 0.5 = -t/0.2$ $t = 0.14$s	2
iii	• Use of speed = d/t • Speed = 3.6 ms^{-1} Allow ecf from ii	(1) (1)	Show that value gives 5.0 ms^{-1} Example of calculation $v = 0.5\text{m}/0.14\text{s}$ $= 3.6$ ms^{-1}	2
iv	• use of $s = \frac{at^2}{2}$ • s = 9 cm + comment that foil is not broken at its centre (comment consistent with calculation) Allow ecf from ii	(1) (1)	Show that value gives 0.049 m Example of calculation $s = \frac{9.81\ ms^{-2} \times 0.14^2\ s}{2} = 0.094$ m	2

Q15.

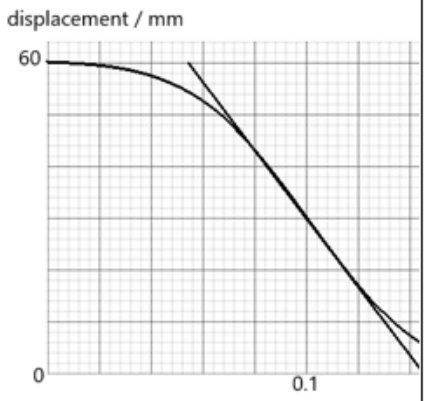
Question Number	Acceptable answers		Additional guidance	Mark
(a)	• Use of $v\cos\theta$ where θ is angle between v and vertical or sin equivalent • Component = 8.55 (m s^{-1})	(1) (1)	Example of calculation Component = 14.2 cos53° Component = 8.546 m s^{-1}	2

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• Use of $s = ut + ½\ at^2$ (ecf value from (a) • Using a = -9.81 m s^{-2} • h = 2.3 m above ground	(1) (1) (1)	If show that value used h = 2.2 m Example of calculation $s = 8.55$ m s$^{-1} \times 1.98$ s + ½ $\times(-9.81\text{ m s}^{-2}) \times 1.98^2\text{s}^2$ $s =$ 16.93 m - 19.23 m s = -2.3 m	3

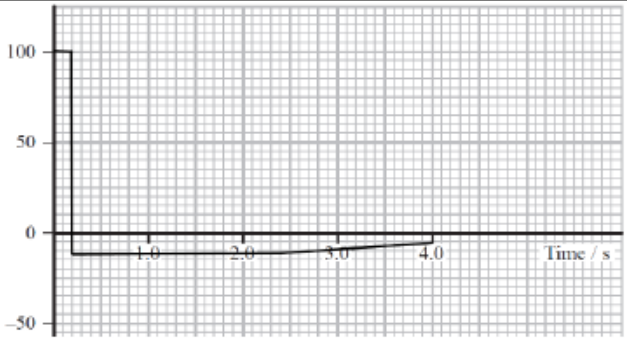
Question Number	Acceptable answers	Additional guidance	Mark
(c)	• Horizontal component velocity = $v\cos37°$ **(1)** • R = horizontal component x time **(1)** • R = 22.5 m **(1)**	Example of calculation $R = 14.2\cos 37° \times 1.98$ R = 22.5 m	**3**

Mark Scheme

Q1.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• uses ratio of lengths to determine p.d. across potentiometer • V = 9.6 (V)	(1) (1)	Example of calculation: p.d. across potentiometer = $\frac{115\text{ mm}}{60\text{ mm}} \times 5\text{ V} = 9.6\text{ V}$	2
(ii)	• determines p.d. across R • apply $V = IR$ to potentiometer to determine current **Or** uses ratio of resistances = ratio of p.d.s • $R = 3000\ \Omega$	(1) (1) (1)	Example of calculation: current in circuit = $\frac{9.6\text{ V}}{12000\ \Omega} = 8.0 \times 10^{-4}$ A p.d. across $R = 12 - 9.6 = 2.4$ V $R = {}^{2.4\text{ V}}/_{8.0 \times 10^{-4}\text{A}}$ R = 3000 Ω (show that value gives 2400 Ω)	3
(iii)	• A battery has internal resistance • There is a p.d. across the internal resistance • Terminal p.d. less (than e.m.f.) **Or** refers to $V = E - Ir$	(1) (1) (1)	Accept "lost volts" for MP2 V must be the subject	3
(iv)	• tangent drawn on the curve • uses a triangle base of at least 0.06 s • attempt to find a gradient • velocity = 0.68 m s^{-1} so velocity not exceeded allow range from to 0.60 m s^{-1} to 0.80 m s^{-1}	(1) (1) (1) (1)	MP2 dependent on MP1  v = gradient = $\frac{60\text{ mm}}{0.144 - 0.056}$ v = 682 mm s^{-1}	4

Q2.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• Positive value of acceleration for first 0.2 s **(1)** • Constant at 100 m s^{-2} **(1)** • Negative value of acceleration up to 4 s **(1)**		**5**
	• Initially at -12 m s^{-2} (value between -10 and -15 on graph) **(1)** • Negative value reducing in magnitude in last 1.0 s to 2.0 s (can be a step change) **(1)**		

Q3.

Question number	Acceptable answers	Additional guidance	Mark
	• Uses weight of displaced air = ρVg **(1)** • Finds resultant force = upthrust − weight **(1)** • Uses F = ma to find acceleration **(1)** • Acceleration = 0.161 m s^{-2} **(1)**	Example of calculation: Weight of air displaced = ρVg = 1.20 kg m^{-3}×2880 m^3× 9.81m s^{-2} = 33 903N Resultant upward force = 33 903 N − (3400 kg × 9.81m s^{-2}) = 549 N Acceleration = 549 N/3400 kg = 0.161 m s^{-2}	**4**

Q4.

Question Number	Acceptable Answer	Additional guidance	Mark
(a)	• attempts to find area under second peak (1) OR use of a suitable equation of motion OR equate $E = \frac{1}{2}mv^2$ and $\Delta E = mg\Delta h$ • height = 0.9 - 1.0 m (1)	Example of calculation: $h = \frac{1}{2} \times 4.2\ \text{m s}^{-1} \times (1.2-0.70)\ \text{s} = 1.0\ \text{m}$	**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)	• use of $\Delta E = mg\Delta h$ (1) OR use of $E = \frac{1}{2}mv^2$ (1) • ΔE =0.59 J	Example of calculation: $E = 0.060\ \text{kg} \times 9.81\text{m s}^{-2} \times (2.0 - 1.0)\text{m}$ $E = 0.59\ \text{J}$	**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(c)	EITHER • finds gradient of middle section (1) • use of $F = ma$ (1) • F = 64 N (1) OR • reads two corresponding pairs of v and t from middle section of graph (1) • use of $F = \frac{m(v-u)}{\Delta t}$ (1) • F = 64 N (1)	Example of calculation: $F = \frac{(6.3+4.2)\ \text{m s}^{-1}}{(0.74-0.64)\ \text{s}} \times 0.060\ \text{kg} = 64\ \text{N}$	**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(d)	Initial free-fall • gradient of both graphs is the same (1) Bounce section • the gradient of the soft ball graph is less (1) Second free-fall • gradient of the soft ball graph is the same as the first graph OR the gradient is the same as in the initial free-fall (1)	Accept the first line is the same Accept time for the bounce is longer	**(3)**

Q5.

Question number	Acceptable answers	Additional guidance	Mark
	A description that makes reference to the following points: • Refer to $v^2 = u^2 + 2as$ **(1)** • Where s is height reached, v is zero, $a = -g$ **(1)** • So $u = \sqrt{2gs}$ **(1)**	Allow argument $\frac{1}{2} mv^2 = mgh$ to get the same results.	**3**
(ii)	• Air resistance will act on the popper… **(1)** • …As a decelerating force **(1)** **OR**… dissipating energy **(1)** • So the initial speed will be lower than in the absence of air resistance, so the suggestion is not correct **(1)**		**3**

Q6.

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>*</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
</td><td>Guidance on how the mark scheme should be applied:

The mark for indicative content should be added to the mark for lines of reasoning. For example an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td>6</td></tr>
</table>

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>* (continued)</td><td>The following table shows how the marks should be awarded for structure and lines of reasoning.
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td><td></td><td></td></tr>
</table>

Question number	Acceptable answers	Additional guidance	Mark
* (continued)	**Indicative content** • As parachute opens (at B) the upwards force increases • Along BC the velocity is decreasing at a non-constant rate • The drag is greater than weight (negative gradient) • The drag is decreasing (curved line) • Eventually the drag force balances the weight • No acceleration so line is horizontal		

Q7.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• straight line starting on v axis with negative gradient • intercept on t axis marked 5.2 with unit s	(1) (1)		2
(ii)	• Use of $s = \frac{(u+v)t}{2}$ with $v = 0$ • Use of another SUVAT equation to determine a • Use of $F = ma$ • Resistance = 16 N **Or** • Use of area = base × height / 2 • Use of acceleration is gradient of line • Use of $F = ma$ • Resistance = 16 N **Or** • Use of $s = (u + v)t/2$ with $v = 0$	(1) (1) (1) (1) (1) (1) (1) (1)	<u>Example of calculation</u> Using SUVAT eg $7.8\text{ m} = (u + 0)5.2\text{ s}/2$ $u = 3.0\text{ m s}^{-1}$ $7.8\text{ m} = 3.0\text{m s}^{-1} \times 5.2\text{ s} + \frac{1}{2}\, a\, 5.2^2\text{ s}^2$ $a = (-)0.58\text{ m s}^{-2}$ Using area under graph $\text{Area} = 7.8\text{ m} = v \times \frac{5.2\text{ s}}{2}$ $v = 3.0\text{ m s}^{-1}$ $a = \text{gradient} = \frac{3.0\text{ m s}^{-1}}{5.2\text{ s}}$ $a = (-)0.58\text{ m s}^{-2}$ $F = 28\text{ kg} \times 0.58\text{ m s}^{-2}$ $F = 16.2\text{ N}$	4

	• Use $E_k = ½ mv^2$ • Use of $W = F\Delta s$ • Resistance = 16 N		

Q8.

Question number	Acceptable answers	Additional guidance	Mark
	D		1

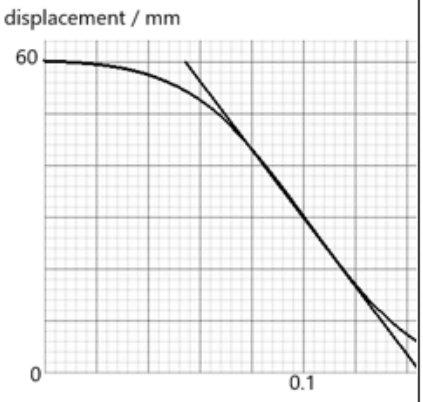
Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is A B is not correct as the rebound velocity wil be about $0.7 \times v_{\text{initial}}$ C is not correct as the velocity must switch sign on rebound D is not correct as the velocity must switch sign on rebound		1

Mark Scheme

Q1.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• uses ratio of lengths to determine p.d. across potentiometer • V = 9.6 (V)	(1) (1)	Example of calculation: p.d. across potentiometer = $\frac{115\text{ mm}}{60\text{ mm}} \times 5\text{ V} = 9.6\text{ V}$	2
(ii)	• determines p.d. across R • apply $V = IR$ to potentiometer to determine current **Or** uses ratio of resistances = ratio of p.d.s • R = 3000 Ω	(1) (1) (1)	Example of calculation: current in circuit = $\frac{9.6\text{ V}}{12000\ \Omega} = 8.0 \times 10^{-4}$ A p.d. across R = 12 – 9.6 = 2.4 V $R = {}^{2.4\text{ V}}/_{8.0 \times 10^{-4}\text{A}}$ R = 3000 Ω (show that value gives 2400 Ω)	3
(iii)	• A battery has internal resistance • There is a p.d. across the internal resistance • Terminal p.d. less (than e.m.f.) **Or** refers to $V = E - Ir$	(1) (1) (1)	Accept "lost volts" for MP2 V must be the subject	3

(iv)	• tangent drawn on the curve • uses a triangle base of at least 0.06 s • attempt to find a gradient • velocity = 0.68 m s^{-1} so velocity not exceeded allow range from to 0.60 m s^{-1} to 0.80 m s^{-1}	(1) (1) (1) (1)	MP2 dependent on MP1  $v = \text{gradient} = \frac{60\text{ mm}}{0.144 - 0.056}$ $v = 682$ mm s^{-1}	4

Q2.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• V at top/start = 0V **Or** recognition "potential divider" **Or** V increases (by implication) **Or** V at bottom = 1.5V • Two sections of wire act as series resistors **Or** $R=\rho l/A$ **Or** comment about R proportional to length **Or** $\frac{V}{1.5} = \frac{R}{R_T}$ • potential difference proportional to length of wire	(1) (1) (1)	**Alternative MS** Constant Current (I) in wire (1) p.d. across section of wire $=Ir$ between A and loop (1) Increases from 0V to 1.5V linearly (1)	3

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• Tangent drawn at 1.5 s • Scales p.d. to give distance • Gradient determined using a base of triangle of at least 1.0 s **Or** use of $s = \frac{(u+v)}{2}t$ **and** correct V read from graph • velocity = 1.0 m s^{-1} – 1.3 m s^{-1}	(1) (1) (1) (1) (1)	Example of calculation Gradient = $\frac{1.1\text{V} - 0.2\text{V}}{1.0\text{s}} = 0.9\text{Vs}^{-1}$ As 1.5 V represents 2.00 m $v = 0.9\ \text{Vs}^{-1} \times \frac{2.00\text{m}}{1.5\text{V}} = 1.2\ \text{ms}^{-1}$	4

Question Number	Acceptable answers		Additional guidance	Mark
(c)	• Use of $v = u + at$ • Use of $a = g\sin\theta$ • Calculates a value for a, θ or v (using a SUVAT AND $a = g\sin\theta$) • Valid comparison of their calculated quantity and the stated quoted uncertainty.	(1) (1) (1) (1)	Example of calculation $1.5\,\text{ms}^{-1} = 1.2\,\text{m s}^{-1} + \text{a} \times 0.5\,\text{s}$ $a = \frac{0.3\,\text{m s}^{-1}}{0.5} = 0.6\,\text{m s}^{-2}$ $0.6\,\text{m s}^{-2} = 9.81\,\text{m s}^{-2}\sin\theta$ $\theta = 3.6°$	4

Q3.

Question Number	Acceptable Answer		Additional guidance	Mark
(a)	• attempts to find area under second peak OR use of a suitable equation of motion OR equate $E = \frac{1}{2}mv^2$ and $\Delta E = mg\Delta h$ • height = 0.9 - 1.0 m	(1) (1)	Example of calculation: $h = \frac{1}{2} \times 4.2\ \text{m s}^{-1} \times (1.2 - 0.70)\ \text{s} = 1.0\ \text{m}$	**(2)**

Question Number	Acceptable Answer		Additional guidance	Mark
(b)	• use of $\Delta E = mg\Delta h$ OR use of $E = \frac{1}{2}mv^2$ • ΔE =0.59 J	(1) (1)	Example of calculation: $E = 0.060\ \text{kg} \times 9.81\text{m s}^{-2} \times (2.0 - 1.0)\text{m}$ $E = 0.59$ J	**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(c)	EITHER • finds gradient of middle section (1) • use of $F = ma$ (1) • $F = 64$ N (1) OR • reads two corresponding pairs of v and t from middle section of graph (1) • use of $F = \frac{m(v-u)}{\Delta t}$ (1) • $F = 64$ N (1)	Example of calculation: $F = \frac{(6.3+4.2)\ \text{m s}^{-1}}{(0.74-0.64)\ \text{s}} \times 0.060\ \text{kg} = 64\ \text{N}$	**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(d)	Initial free-fall • gradient of both graphs is the same (1) Bounce section • the gradient of the soft ball graph is less (1) Second free-fall • gradient of the soft ball graph is the same as the first graph OR the gradient is the same as in the initial free-fall (1)	Accept the first line is the same Accept time for the bounce is longer	**(3)**

Q4.

Question number	Acceptable answers	Additional guidance	Mark
	A description that makes reference to the following points: • g is directly proportional to r up to R_0 **(1)** • and then g decreases with increasing r **(1)** • where g is proportional to the inverse of the square of r **(1)**		**3**

Q5.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• Attempts to find area under graph **(1)** • Height = 19 m **(1)** Alternative: • Use equations of motion to Height = 19 m **(2)**	Range for base of triangle between 1.8 and 2s to recognise area Example of calculation: Area = $\frac{1}{2} \times 1.9\text{s} \times 20\text{ms}^{-1}$ = 19 m	**2**

Q6.

Question number	Acceptable answers	Additional guidance	Mark
	• Force on object = mg (local g) **(1)** • Force is proportional to displacement **(1)** • Force acts in the opposite direction to the displacement **(1)** • Therefore we can say $F = -kx$, so the condition for SHM is met and the prediction is correct **(1)**		**4**

Mark Scheme

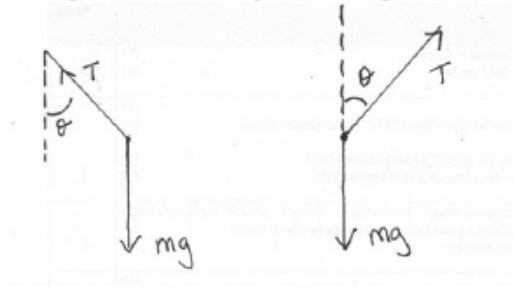
Q1.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• V at top/start = 0V **Or** recognition "potential divider" **Or** V increases (by implication) **Or** V at bottom = 1.5V	(1)	**Alternative MS** Constant Current (I) in wire (1) p.d. across section of wire = Ir between A and loop (1) Increases from 0V to 1.5V linearly (1)	3
	• Two sections of wire act as series resistors **Or** $R=\rho l/A$ **Or** comment about R proportional to length **Or** $\frac{V}{1.5}=\frac{R}{R_T}$	(1)		
	• potential difference proportional to length of wire	(1)		

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• Tangent drawn at 1.5 s	(1)	Example of calculation Gradient = $\frac{1.1\text{V}-0.2\text{V}}{1.0\text{s}}=0.9\text{Vs}^{-1}$ As 1.5 V represents 2.00 m $v=0.9\ \text{Vs}^{-1}\times\frac{2.00\text{m}}{1.5\text{V}}=1.2\ \text{ms}^{-1}$	4
	• Scales p.d. to give distance	(1)		
	• Gradient determined using a base of triangle of at least 1.0 s **Or** use of $s=\frac{(u+v)}{2}t$ **and** correct V read from graph	(1) (1)		
	• velocity = 1.0 m s^{-1} – 1.3 m s^{-1}			

Question Number	Acceptable answers		Additional guidance	Mark
(c)	• Use of $v=u+at$	(1)	Example of calculation $1.5\,\text{ms}^{-1}=1.2\,\text{m s}^{-1}+\text{a}\times 0.5\,\text{s}$ $a=\frac{0.3\,\text{m s}^{-1}}{0.5}=0.6\,\text{m s}^{-2}$ $0.6\,\text{m s}^{-2}=9.81\,\text{m s}^{-2}\sin\theta$ $\theta=3.6°$	4
	• Use of $a=g\sin\theta$	(1)		
	• Calculates a value for a, θ or v (using a SUVAT AND $a=g\sin\theta$)	(1)		
	• Valid comparison of their calculated quantity and the stated quoted uncertainty.	(1)		

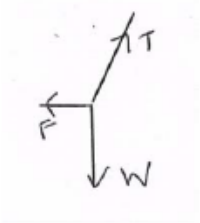
Q2.

Question Number	Answer	Mark
	Free body force diagram showing 2 forces only Weight/W/mg **(1)** Tension / T **(1)** (Each additional forces e.g. horizontal component or resultant force, 1 mark penalty) **If θ is angle to the vertical then**: (Resolving vertically): $T\cos\theta = mg$ **(1)** (Resolving horizontally): $T\sin\theta = mv^2/r$ **Or** $T\sin\theta = mr\omega^2$ **(1)** Derives $\tan\theta = v^2/rg$ **and** links to observations **Or** Derives $\tan\theta = r\omega^2/g$ **and** links to observations **(1)** If angle to horizontal is used candidates can score MP3 and 4.[then sin and cos swop over and tan of angle will be reciprocal of above] <u>Examples of free body force diagrams</u>  (full credit for the last 3 marks can be given to candidates who draw a vector triangle and derive $\tan\theta = T_{horz}/mg$ and then $\tan\theta = r\omega^2/g$ **and** observation)	**5**
	Total for question	**5**

Q3.

Question Number	Acceptable Answer	Additional guidance	Mark
	• recognises minimum upward force is mg (1) • resolve force parallel to string (1) • minimum force = 0.22 N (1)	<u>Example of calculation:</u> $F = \frac{11 \times 10^{-3}\ \text{kg} \times 9.81\ \text{N kg}^{-1}}{\sin 30^\circ} = 0.22\ \text{N}$	**(3)**

Q4.

Question Number	Answer		Mark
(a)(i)	*W*/*mg* and *T* correct *F*/*E*/ electric force correct Example of diagram  	(1) (1)	2
(a)(ii)	See $T\cos\theta = W$ See $T\sin\theta = F$ **Or** Draws a correct triangle of forces Correctly labels θ (if a triangle is drawn it must be a closed polygon with correctly orientated direction of arrows)	(1) (1) (1) (1)	2
(b)(i)	Records 1pair of values from graph Records 2nd pair of values from graph Use of $F r^2$ Shows that $F_1r_1^2 = F_2r_2^2$ (accept answers with or without the powers of ten included) Example of answer Ignoring powers of 10 115 N × 20^2 m^2 = 46000 51 N × 30^2 m^2 = 45900	(1) (1) (1) (1)	4
(b)(ii)	Uses constant from (b) ignoring powers of ten errors **Or** uses a pair of values from graph Use of $F = kQ_1 Q_2 / r^2$ with 1.6×10^{-19} C $Q = 7.2 \times 10^{-9}$ C Example of answer $100\ Q^2 = 46000 \times 10^{-9}$ N m^2 / 8.99×10^9 N m^2 C^{-2} $Q^2 = 5.12 \times 10^{-17}$ C^2 $Q = 7.2 \times 10^{-9}$ C	(1) (1) (1)	3
	Total for question		**11**

Q5.

Question Number	Acceptable Answer	Additional guidance	Mark
	An explanation that makes reference to: • correct reference to Newton's 3rd law (1) • balloon moves in opposite direction to the air (1) • applies Newton's 2nd law so that resultant force on balloon causes it to accelerate (1) OR applies Newton's 2nd law so that resultant force on balloon causes its momentum to change		**(3)**

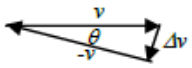
Q6.

Question number	Acceptable answers	Additional guidance	Mark
	A		**1**

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	• Measures angle at 52° +/- 2 ° **(1)** • Uses $F = ma$ horizontally **(1)** • Resolves forces vertically **(1)** • Uses $a = v^2 / r$ **Or** $a = r\omega^2$ **(1)** • Calculates the 51° and reaches a consistent conclusion **(1)**	Accept angle calculate from measured dimensions and trigonometry. Example of calculation $T\sin\theta = \frac{mv^2}{r}$ $T\cos\theta = mg$ $\tan\theta = \frac{v^2}{rg}$ $\tan\theta = (3.8)^2$ (m s^{-1})^2 / 1.2 m ×9.81 m s^{-2} $\theta = 50.8°$	**5**

Q8.

Question mark	Acceptable Answers		Additional Guidance	Mark
	• vector velocities at two positions as part of a triangle and third side identified as Δv	(1)	Example of diagram 	5
	• Acceleration $a = \Delta v/t$ (i)	(1)	Ignore arrow directions	
	• Use of trigonometry: $\Delta v/v \approx \sin\theta \approx \theta$ for small angles (ii)	(1)	Combine (i) and (ii) $a = v\theta/t$	
	• Use of $v = r\theta/t$ (iii)	(1)	Substitute for θ using (iii) a = $\frac{v}{t} \times \frac{vt}{r}$ then "t"s cancel	
	• Combine i, ii, iii to final equation	(1)		
	OR			
	• Diagram shows components of v with angle turned through	(1)	Allow other fully correct methods	
	• Acceleration $= 2v\sin\theta/t$	(1)		
	• Use of trigonometry: $\Delta v/v \approx \sin\theta \approx \theta$ for small angles	(1)		
	• $t = r2\theta/v$ and 2s cancel	(1)		
	• Simplify to final equation	(1)		

Q9.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of momentum = mv	(1)	Example of calculation: $7.1(g)u = 7.1(g) \times 0.9(ms^{-1}) \times cos\,8 + 3.6(g) \times 1.4(ms^{-1}) \times cos\,10$	(4)
	• See component(s) in x direction	(1)	$u = \frac{(6.33 + 4.96)}{7.1}$	
	• Uses momentum conservation	(1)	$u = 1.59ms^{-1}$	
	• $u = 1.6$ (m s^{-1})	(1)		

Question Number	Acceptable answers		Additional guidance	Mark
(ii)	• Use of $E_k = ½\,mv^2$	(1)	Allow ecf from b(i)	(2)
	• Value of Initial $E_k = 9.0\times10^{-3}$ (J) and Final $E_k = 6.4\times10^{-3}$ (J) (Show that value gives Initial $E_k = 1.42\times10^{-2}$ (J) allow ecf from (b)(i))	(1)	Example of calculation: Initial $E_k = ½\times7.1\times10^{-3}(kg)\times1.59^2(ms^{-1})^2 = 9.0\times10^{-3}$ J Final $E_k = ½\times7.1\times10^{-3}\times0.9^2 + ½\times3.6\times10^{-3}\times1.4^2 = 6.4\times10^{-3}$ J	

Q10.

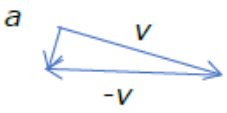
Question Number	Acceptable answers		Additional guidance	Mark
(a)	• Use of $v\cos\theta$ where θ is angle between v and vertical or sin equivalent • Component = 8.55 (m s^{-1})	(1) (1)	Example of calculation Component = 14.2 cos53° Component = 8.546 m s^{-1}	2

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• Use of $s = ut + ½\ at^2$ (ecf value from (a)) • Using a = $-9.81\,\text{m s}^{-2}$ • h = 2.3 m above ground	(1) (1) (1)	If show that value used h = 2.2 m Example of calculation $s = 8.55\ \text{m s}^{-1} \times 1.98\,\text{s} + ½ \times (-9.81\,\text{m s}^{-2}) \times 1.98^2\,\text{s}^2$ s = 16.93 m - 19.23 m s = -2.3 m	3

Question Number	Acceptable answers		Additional guidance	Mark
(c)	• Horizontal component velocity = v cos37° • R = horizontal component x time • R = 22.5 m	(1) (1) (1)	Example of calculation $R = 14.2\cos 37° \times 1.98$ R = 22.5 m	3

Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	• vector velocities of same length with arrows as shown to indicate a difference. The "minus" v line should be approximately horizontal. **(1)** • third side identified as Δv/acceleration in direction approximately towards centre of circle **(1)**	Example of diagram  Accept "$-v$" line as arrow to right and labelled "v"	**2**

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
	• Uses $\tan\theta = B_V \div B_H$ **(1)** **Or** uses $\tan\theta = B_H \div B_V$ • Angle = 69° **(1)**	Example of calculation: $\tan\theta = 49/19$ $\theta = 68.8°$ Accept use of vector triangle as alternative to calculation	**(2)**

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• distance between at least two pairs of images (1) • distances between images are the same in x direction (1) • distance between images varies in y direction showing a changing velocity (1) • velocity in the x direction is constant so x direction is independent of y direction (1)	MP1 and 2 could come from marks on the diagram	4
(ii)	• use of $v^2 = u^2 + 2as$ or $s = ut + \frac{1}{2}at^2$ (1) • initial vertical component velocity = 0.47 m s^{-1} (1) • use of $v_H = d/t$ in the horizontal (1) • Use of Pythagorus with v_H and u_V (1) • Resultant velocity = 1.1 m s^{-1} (1)	alt to MP2 : 0.5 m s^{-1} (allow 0.4 to 0.6) if using distance taken from first two images and $v_H = d/t$ Example of calculation: $0 = u^2 - 2 \times 9.81\ \text{m s}^{-2} \times 0.011\ \text{m}$ $u_V = 0.465\ \text{m s}^{-1}$ $v_H = \frac{0.08\ \text{m}}{0.08\ \text{s}}$ $v_H = 1.0\ \text{m s}^{-1}$ $v = \sqrt{(0.47^2 + 1.0^2)}$ Resultant velocity = 1.1 m s^{-1}	5

(iii)	• Use of $\Delta W = F\ \Delta s$ (1) • Use of $E_k = ½\ mv^2$ (1) • $F = 0.015$ N (1) Alternative • Use of $v^2 = u^2 + 2as$ (1) • Use of $F = ma$ (dependent on MP1) (1) • $F = 0.015$ N (1)	Allow ECF from (a)(ii) Example of calculation: $2 \times F \times 0.003\text{m}$ $= \frac{1}{2} \times 150 \times 10^{-6}\text{kg} \times 1.1^2\ (\text{m s}^{-1})^2$ $F = 0.015$ N "show that" value gives $F = 0.013$ N Alternative $1.1^2\ (\text{ms}^{-1})^2 = 2 \times a \times 0.003\ \text{m}$ $a = 202\ \text{m s}^{-2}$ $2 \times F = 150 \times 10^{-6}\ \text{kg} \times 202\ \text{ms}^{-2}$ $F = 0.015$ N	3

Q4.

Question number	Acceptable answers	Additional guidance	Mark
(i)	• use of $F = Q_1Q_2/4\pi\varepsilon_0r^2$ **(1)** • use of $F = Gm_1m_2/r^2$ **(1)** • Expresses forces as a ratio **(1)** **OR** calculates the individual forces F_e=8.1 x 10^{-8} N F_g = • 3.6 x 10^{-47} N **(1)** • Ratio = 2 x 10^{39} or 5 x 10^{-40} and identifies gravitational force as insignificant **(1)**		**4**
(ii)	• use of $F = mv^2/r$ and $F = Q_1Q_2/4\pi\varepsilon_0r^2$ **(1)** • to derive $v = \sqrt{\frac{Q_1Q_2}{4\pi\epsilon_0 rm}}$ **(1)** • velocity = 2.2× 10^6 m s^{-1} **(1)**	Example of calculation: $v = \sqrt{\frac{Q_1Q_2}{4\pi\epsilon_0 rm}}$ $v = \sqrt{\frac{1.6\times10^{-19}\text{ C}\times1.6\times10^{-19}\text{ C}}{4\pi\times8.85^{-12}\text{ F}m^{-1}\times5.3\times10^{-11}\text{m}\times9.1\times10^{-31}\text{ kg}}}$ $v = 2.185 \times 10^6$ m s^{-1}	**3**

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is A B is not correct as these forces are not in equilibrium C is not correct as these forces are not in equilibrium D is not correct as these forces are not in equilibrium		**1**

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
	• Draws one labelled scaled vector (either pion or muon) **(1)** • start of muon line should begin at start of pion line **Or** end of muon line should coincide with end of pion line **(1)** • angle between them should be approx 30° **(1)** • p of antineutrino = 9.5×10^{-20} N s ± 0.5×10^{-20} N s **(1)** • angle of antineutrino with muon = 150° ± 5° **Or** angle of antineutrino with pion = 120° ± 5° **(1)**	Label can be "pion" or momentum value. The line should be straight and have an arrow. 	**5**

Mark Scheme

Q1.

Question Number	Answer	Additional guidance	Mark
(a)(i)	thermionic emission		**(1)**

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(ii)	• equate $\frac{1}{2}mv^2$ and VQ (1) • $v = 2.3 \times 10^7$ m s^{-1} (1)	Example of calculation: $E = 1500\text{ V} \times 1.6 \times 10^{-19}\text{ C} = 2.4 \times 10^{-16}\text{ J}$ $v = \sqrt{\frac{2 \times 2.4 \times 10^{-16}\text{ J}}{9.11 \times 10^{-31}\text{ kg}}} = 2.3 \times 10^7\text{ m s}^{-1}$	**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(i)	• use of $F = EQ$ and $E = \frac{V}{d}$ (1) OR see $F = \frac{VQ}{d}$ • equate $F = ma$ and $F = EQ$ (1)		**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(ii)	• use of speed = distance/time (1) • $t = 8.7 \times 10^{-10}$ (s) (1) • use of a = $\frac{VQ}{dm}$ (1) • use of $s = ut + \frac{1}{2}at^2$ (1) with $u = 0$ and vertical acceleration to find s • $s = 3.3 \times 10^{-4}$ m (1)	Example of calculation: $t = \frac{0.02\text{ m}}{2.3 \times 10^7\text{ m s}^{-1}} = 8.7 \times 10^{-10}\text{ s}$ $s = \frac{1}{2} \times \left(\frac{50\text{ V} \times 1.6 \times 10^{-19}\text{ C}}{0.01\text{ m} \times 9.11 \times 10^{-31}\text{ kg}} \right) \times (8.7 \times 10^{-10}\text{ s})^2$ $s = 3.3 \times 10^{-4}\text{ m}$	**(6)**

Question Number	Acceptable Answer	Additional guidance	Mark
(c)	• use of $V = V_0/\sqrt{2}$ (1) • vertical line (1) • positive and negative deflection shown (1) • maximum deflection 75 V (1)	Example of calculation: $V_0 = 53\text{ V} \times \sqrt{2} = 75\text{ V}$	**(4)**

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• distance between at least two pairs of images (1) • distances between images are the same in x direction (1) • distance between images varies in y direction showing a changing velocity (1) • velocity in the x direction is constant so x direction is independent of y direction (1)	MP1 and 2 could come from marks on the diagram	4
(ii)	• use of $v^2 = u^2 + 2as$ or $s = ut + \frac{1}{2}at^2$ (1) • initial vertical component velocity = 0.47 m s^{-1} (1) • use of $v_H = d/t$ in the horizontal (1) • Use of Pythagorus with v_H and u_V (1) • Resultant velocity = 1.1 m s^{-1} (1)	alt to MP2 : 0.5 m s^{-1} (allow 0.4 to 0.6) if using distance taken from first two images and $v_H = d/t$ Example of calculation: $0 = u^2 - 2 \times 9.81\ \text{m s}^{-2} \times 0.011\ \text{m}$ $u_V = 0.465\ \text{m s}^{-1}$ $v_H = \frac{0.08\ \text{m}}{0.08\ \text{s}}$ $v_H = 1.0\ \text{m s}^{-1}$ $v = \sqrt{(0.47^2 + 1.0^2)}$ Resultant velocity = 1.1 m s^{-1}	5
(iii)	• Use of $\Delta W = F\ \Delta s$ (1) • Use of $E_k = ½\ mv^2$ (1) • $F = 0.015$ N (1) Alternative • Use of $v^2 = u^2 + 2as$ (1) • Use of $F = ma$ (dependent on MP1) (1) • $F = 0.015$ N (1)	Allow ECF from (a)(ii) Example of calculation: $2 \times F \times 0.003\text{m}$ $= \frac{1}{2} \times 150 \times 10^{-6}\text{kg} \times 1.1^2\ (\text{m s}^{-1})^2$ $F = 0.015$ N "show that" value gives $F = 0.013$ N Alternative $1.1^2\ (\text{ms}^{-1})^2 = 2 \times a \times 0.003\ \text{m}$ $a = 202\ \text{m s}^{-2}$ $2 \times F = 150 \times 10^{-6}\ \text{kg} \times 202\ \text{ms}^{-2}$ $F = 0.015$ N	3

Q3.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of $s = ut + \frac{1}{2}at^2$	(1)	Example of calculation: $0.65\,\text{m} = \frac{1}{2} 9.81\,\text{m s}^{-2} t^2$ $t = 0.364\,\text{s}$ $s = 3.0\,\text{m s}^{-1} \times 0.364\,\text{s}$ $s = 1.09\,\text{m}$	(4)
	• Recognise $u = 0$	(1)		
	• Use of $v = d/t$ in horizontal direction	(1)		
	• Displacement = 1.1 m	(1)		

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is D *A is not correct because the acceleration in the vertical plane is g* *B is not correct because the horizontal component of velocity is constant* *C is not correct because of v = 0 – at gives t = v / g*		1

Q5.

Question Marks	Acceptable Answers		Additional guidance	Mark
i	• Use of $W = \frac{1}{2}CV^2$ • $W =$ 45 μJ	(1) (1)	Example of calculation $W = \frac{1}{2} 40\mu F \times (1.5\ V)^2$ $W =$ 45 μJ Alt: Use $Q = CV$ then $E = QV/2$ for MP1	2
ii	• Use of $V = V_o e^{-t/RC}$ • Time = 0.14 (s)	(1) (1)	Example of calculation $0.5 = e^{-t/5000\times40\times10^{-6}}$ $\ln 0.5 = -t/0.2$ $t = 0.14$s	2
iii	• Use of speed = d/t • Speed = 3.6 ms^{-1} Allow ecf from ii	(1) (1)	Show that value gives 5.0 ms^{-1} Example of calculation $v = 0.5\text{m}/0.14\text{s}$ $= 3.6$ ms^{-1}	2
iv	• use of $s = \frac{at^2}{2}$ • s = 9 cm + comment that foil is not broken at its centre (comment consistent with calculation) Allow ecf from ii	(1) (1)	Show that value gives 0.049 m Example of calculation $s = \frac{9.81\ ms^{-2} \times 0.14^2\ s}{2} = 0.094$ m	2

Q6.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• Use of $v\cos\theta$ where θ is angle between v and vertical or sin equivalent • Component = 8.55 (m s^{-1})	(1) (1)	Example of calculation Component = 14.2 cos53° Component = 8.546 m s^{-1}	2

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• Use of $s = ut + ½\ at^2$ (ecf value from (a) • Using a = -9.81 m s^{-2} • h = 2.3 m above ground	(1) (1) (1)	If show that value used h = 2.2 m Example of calculation $s = 8.55$ m s$^{-1} \times 1.98$ s + ½ $\times(-9.81$ m s$^{-2}) \times 1.98^2$ s^2 $s =$ 16.93 m - 19.23 m s = -2.3 m	3

Question Number	Acceptable answers	Additional guidance	Mark
(c)	• Horizontal component velocity = $v\cos37°$ **(1)** • R = horizontal component x time **(1)** • R = 22.5 m **(1)**	Example of calculation $R = 14.2\cos 37° \times 1.98$ R = 22.5 m	**3**

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Attempt to determine an area **(1)** • Uses area = change of momentum **(1)** • velocity in range 28 – 33 ($m\,s^{-1}$) **(1)**	eg markings on the graph Example of calculation: Approximates area = triangle = (0.0005 s × 5500 N) / 2 Area = 1.375 Ns Velocity = 1.375 Ns / 0.046 kg = 29.1 ms^{-1}	**3**
(ii)	• Use of $s = ut + \frac{1}{2}at^2$ in vertical direction **(1)** • if s + then ut + and at^2 negative **(1)** **Or** if s – then ut – and at^2 positive • Use of velocity = distance / time in horizontal direction **(1)** • Correct component of velocity in each direction **(1)** • Distance = 76 m and comment such as yes it reaches the green. (ECF from bi) **(1)** Range of distance 70.5 m for b(i) $v = 28\ m\,s^{-1}$ to 93.6 m for $v = 33\ m\,s^{-1}$	Alt: Use of pythagorus to find resultant velocity Also accept conclusion based on a comparison of velocity values from (i) and (ii) Example of calculation: $7.5m = 29m\,s^{-1}\sin\theta 3.5s - \frac{1}{2} 9.81m\,s^{-2}3.5^2s^2$ $7.5m = 101.5\sin\theta - 60.1$ $\sin\theta = 67.6 / 101.5$ $\theta = 41.8°$ $29\ ms^{-1}\cos 41.8 = x / 3.5\ s$ $x = 75.7\ m$ Using the "show that" value: $7.5m = 30m\,s^{-1}\sin\theta 3.5s - \frac{1}{2}9.81m\,s^{-2}3.5^2s^2$ $7.5m = 105\sin\theta - 60.1$ $\sin\theta = 67.6 / 105$ $\theta = 40.1°$ $30\ ms^{-1}\cos 40.1 = x / 3.5\ s$ $x = 80.3\ m$	**5**