PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



MARK SCHEME

TOPIC 2: MECHANICS

NEWTON'S LAWS AND MOMENTUM

SCORE	PERCENTAGE
/426	%

STEMUP

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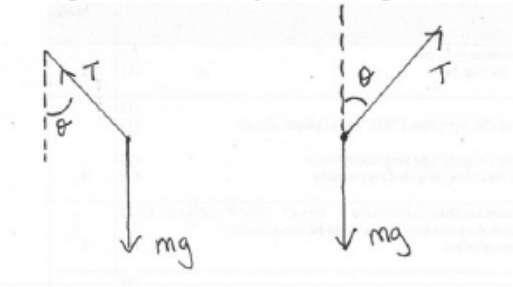
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Mark Scheme

Q1.

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 $\tan\theta = T_{horzt}/mg$ and then $\tan\theta = r\omega^2/g$ **and** observation)	**5**
	Total for question	**5**

Q2.

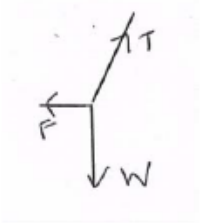
Question Number	Acceptable Answer	Additional Guidance	Mark
*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The table shows how the marks should be awarded for indicative content and structure and lines of reasoning. **Indicative content:** IC1 The rider experiences a resultant force acting towards the centre (of the circular path) IC2 This (resultant) force is constant, as the rider has a constant (angular) velocity **Or** the weight W is constant IC3 At the bottom of the circle P and W act in opposite directions, so P must be greater than W IC4 At the top of the circle P and W act in the same direction, and so P must be less (than at the bottom of the circle) IC5 P is the weight the rider appears to have IC6 The rider would feel heavier at the bottom of the circle **Or** the rider would feel lighter at the top of the circle	Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning Accept "the rider experiences a centripetal force"	6

Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points
6	4
5–4	3
3–2	2
1	1
0	0

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

IC points	IC mark	Max linkage mark	Max final mark
6	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

Q3.

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 $115\ \text{N} \times 20^2\ \text{m}^2 = 46000$ $51\ \text{N} \times 30^2\ \text{m}^2 = 45900$	(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 $F = kQ_1Q_2/r^2$ with 1.6×10^{-19} C $Q = 7.2 \times 10^{-9}$ C Example of answer $100\ Q^2 = 46000 \times 10^{-9}\ \text{N m}^2 / 8.99 \times 10^9\ \text{N m}^2\ \text{C}^{-2}$ $Q^2 = 5.12 \times 10^{-17}\ \text{C}^2$ $Q = 7.2 \times 10^{-9}$ C	(1) (1) (1)	3
	Total for question		11

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	B The two forces acting on the mass are its weight (vertically down) and a tension in the thread.		1
	A assumes there is a centripetal force only C assumes there is an additional centripetal force D assumes the additional centripetal force acts away from the centre of the circle		

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
	• The forces are different types **(1)** • The forces act on the same object **(1)**		2

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	• no net force on bridge (1) • no net moment of force about any point (1)	Alternative wording that implies these 2 points will be accepted	**(2)**
(a)(ii)	• use of $W = mg$ to find the weight of the bridge (1) • use of moment = $F x$ (1) • applies principle of moments (1) • F_A = 43610 N (1) • applies equilibrium of forces or applies principle of moments about a different point to obtain F_B = 45990 N (1)	<u>Example of calculation:</u> W = mg = 8500 kg × 9.8 N kg^{-1}= 83300 N Taking moments about A, Clockwise moments = (1500 N × 4 m) + (4800 N × 6.5 m) + (83300 N × 9.5 m) Anticlockwise moments = F_A × 19 m 19 N × F_A = 828550 Nm F_A = 828550 Nm/19 m = 43610 N $F_A + F_B$ = 1500 N + 4800 N + 83300 N F_B = 89600 N – 43610 N = 45990 N	**(5)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	• resonance occurs when the bridge is forced into oscillation at its natural frequency (1) • this results in an increasing amplitude of oscillation of the bridge, which may damage the bridge (1)		**(2)**
(b)(ii)	• energy was transferred from the oscillating bridge to the dampers (1) • this energy was dissipated in the dampers (and not returned to the bridge) (1) • hence the <u>amplitude</u> of oscillation was kept small (1)		**(3)**

(b)(iii)	• as the viscosity of the fluid increased the fluid would offer greater resistance to movement [accept reverse argument] (1) • a greater resistance to movement would result in a greater energy dissipation (1)		**(2)**

Q8.

Question Number	Acceptable answers	Additional guidance	Mark
	• Opposite horizontal force, labelled friction/resistance/drag **(1)** • Vertically downward force labelled *W*/weight/*mg* **(1)** • Vertically upwards force labelled *R*/Reaction/*N*/Normal (contact force) **(1)**	ignore extra words such as ..of bicycle	**3**

Mark Scheme

Q1.

Question number	Acceptable answers	Additional guidance	Mark
(i)	• Recognise that for passenger to remain in their seat normal reaction $R \geq 0$ **(1)** **or** centripetal force >= weight **(1)** • Equate centripetal force and weight (for R=0) **(1)** • $v = 9.1$ m s^{-1} **(1)**	Example of calculation: $\frac{mv^2}{r} = mg$ $v = \sqrt{rg} = \sqrt{8.5\,\text{m} \times 9.81\,\text{m s}^{-2}} = 9.13\,\text{m s}^{-1}$	**3**
(ii)	• Equate decrease in gravitational potential energy to increase in kinetic energy at top of loop **(1)** • Adds this to 17.0 **(1)** • $\Delta h = 21.3$ m **(1)**	Example of calculation: $mgh = \frac{1}{2}mv^2$ $h = \frac{v^2}{2g} = \frac{(9.13\,\text{m s}^{-1})^2}{2 \times 9.81\,\text{m s}^{-2}} = 4.25\,\text{m}$ $\Delta h = 17 + 4.3 = 21.3$ m	**3**

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• use of $\rho = m/V$ **and** $W = mg$ to calculate upthrust **(1)** • use of downward force of lid = upthrust – weight of diver **(1)** • downward force of lid = 0.021 (N) **(1)**	Example of calculation $m_{displaced} = 1.0 \times 10^3$ kg m^{-3} × 8.0×10^{-6} m^{-3} $= 8.0 \times 10^{-3}$ kg $U = 8.0 \times 10^{-3}$ kg × 9.81 N kg^{-1} = 0.0785 N $W = 0.0059$ kg × 9.81 N kg^{-1} = 0.0579 N Lid force = 0.0785 N - 0.0579 N = 0.0206 N	**3**

Question Number	Acceptable answers	Additional guidance	Mark
(b)	**Either** • use of force of lid = $V\rho g$ **(1)** • volume of air = 8.0×10^{-6} m^{-3} - their value **(1)** • volume of air = 5.9×10^{-6} (m^3) **(1)** **Or** • use of upthrust on diver = weight of diver **(1)** • use of upthrust = $V\rho g$ **(1)** • volume of air = 5.9×10^{-6} (m^3) **(1)**	Example of calculation volume = 0.0206 N ÷ 9.81 N kg^{-1} ÷ 1.0×10^3 kg m^{-3} $= 2.1 \times 10^{-6}$ m^{-3} new volume of air = 8.0×10^{-6} m^{-3} - 2.1×10^{-6} m^{-3} $= 5.9 \times 10^{-6}$ m^3	**3**

Question Number	Acceptable answers	Additional guidance	Mark
(c)	• use of pV = constant (1) • $p = 1.4 \times 10^5$ Pa (1)	Example of calculation $p_1 \times V_1 = p_2 \times V_2$ $p_2 = 1.01 \times 10^5$ N m^{-2} × 8.0×10^{-6} m^{-3} / 5.9×10^{-6} m^3 $p = 1.37 \times 10^5$ Pa	2

Q3.

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) • 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)	**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 (1) • 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}	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 $v = u + at$ (1) • 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)	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

Q4.

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Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points
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4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of $v = u + at$ (1) • $a = 0.81$ m s^{-2} (1)	Example of calculation $a = \frac{v-u}{t} = \frac{97 \text{ m s}^{-1}}{120 \text{ s}} = 0.808 \text{ m s}^{-2}$	2
(ii)	• Use of $s = ut + \frac{1}{2}at^2$ **Or** $v^2 = u^2 + 2as$ **Or** $s = \left(\frac{(v+u)}{2}\right)t$ (1) • Use of $v_{av} = \frac{s}{t}$ with $t = 320$ s (1) • $v_{av} = 75$ m s^{-1} (1)	Ecf acceleration from (a)(i) Example of calculation $s = ut + \frac{1}{2}at^2 = 0.5 \times 0.808 \text{ m s}^{-2} \times (120 \text{ s})^2 = 5820$ m $s_2 = 29900 \text{ m} - 5820 \text{ m} = 24\,080$ m $t = 440\text{s} - 120 \text{ s} = 320$ s $v_{av} = \frac{24\,080 \text{ m}}{320 \text{ s}} = 75.3 \text{ m s}^{-1}$	3

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of $\Delta W = F\Delta s$ and $P = W/t$ (1) • Use of $F = ma$ (1) • $a = 0.31$ m s^{-2} (1)	Example of calculation: In 1 second $W = F\Delta s$ $4500 \text{ W} = F \times 34 \text{ m s}^{-1}$ Force applied by motor = 132 N $F = ma$ $132 \text{ N} = 420 \text{ kg} \times a$ $a = 0.31$ m s^{-2}	3
(ii)	• Neglect friction forces when it starts from rest (1) **Or** Motor/Driving force independent of speed	Do not accept "force" without a description	1

Q7.

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: $F = \frac{0.06 \times 25}{0.04} = 37.5$ N	**3**

Q8.

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 $\Delta E = mg\Delta h$ OR use of $E = \frac{1}{2}mv^2$ (1) • $\Delta E = 0.59$ J (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)**

Q9.

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)**

Q10.

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
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<td>This question assesses a student's ability to show a coherent and logical structured answer with linkage 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.
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<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
Indicative content:

Newton's 3rd law pair of forces must be of the same type
Or Newton's 3rd law pair of forces must act on different bodies
The two forces mentioned are not a 3rd Law pair
Or gravity is not a good description of force
The lift on the plane should be paired with the push of the plane on the air
Or the gravitational force of Earth on plane should be paired with the gravitational force of plane on Earth.
If the vertical resultant force is zero the plane will not accelerate vertically
So the plane could be 'at rest' or moving with uniform velocity in the vertical direction
There must be some horizontal motion so plane can't be in same place

</td>
<td>The following table shows how the marks should be awarded for structure and lines of reasoning
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<tr><td></td><td></td></tr>
</table>
Linkage Marks

IC points 1 – 3
Two of these points could score one linkage mark

IC points 4 – 6
Two of these points could score one linkage mark</td>
<td>6</td>
</tr>
</table>

Q11.

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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.

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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></td></tr>
</table>

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Question number	Acceptable answers	Additional guidance	Mark
* (continued)	**Indicative content** • At terminal velocity the forces on the drop are balanced **OR** weight = drag • The p.d. creates an electrostatic force acting upwards on the drop • The electrostatic force increases as p.d. increases • The net upward force causes the drop to have a negative acceleration • As speed decreases the drag decreases • The drop remains stationary when the forces are balanced **OR** until the drop remains stationary when weight = electrostatic force		**6**

Q12.

Question number	Acceptable answers	Additional guidance	Mark
(b)	• Equate the electric force and the gravitational force **(1)** • Use of E=V/d to obtain $q = mgd/V$ **(1)**	$qE = mg$ $q(V/d) = mg$ $q = mgd/V$	**2**
(c)	An explanation that makes reference to: • Electrostatic/upward force (on drop) would be greater than the weight/downward force **(1)** • So drop would <u>accelerate</u> upwards **(1)**	Indication of which force is greater, unbalanced is insufficient.	**2**

Q13.

Question Number	Acceptable Answer	Additional guidance	Mark
(a)	An explanation that makes reference to the following: • due to the large mass and speed <u>OR</u> large momentum <u>OR</u> large energy (1) • the alpha particle would have a large <u>change</u> in momentum when deflected through large angles which requires a large force (1)		**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)	• use of $F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$ (1) • charge of alpha $= 2 \times 1.6 \times 10^{-19}$ (C) (1) • r = 1.3×10^{-13} (m) (1) • comparison of the two distances (1) • conclusion that the alpha particle must reach a closer distance to give a larger force and relates this to the model (1)	Accept calculating a force for $r = 1.4 \times 10^{-10}$ and comparing forces <u>Example of calculation:</u> $r = \sqrt{8.99 \times 10^9 \text{ N m}^2\text{C}^{-2} \times \frac{(79 \times 2)(1.6 \times 10^{-19} \text{ C})^2}{2}}$ $r = 1.3 \times 10^{-13}$ m	**(5)**

Q14.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • Sweeping the ice smooths out the surface (1) **Or** Sweeping the ice melts the suraface of the ice. (1) • So frictional forces are reduced (and the deceleration of the stone is reduced	For MP2 accept references to a lower rate of working against friction **Or** less work done against friction for a given displacement	**2**

Q15.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $p = F/A$ (1) • Cylinder pressure = calculated pressure + atmospheric pressure (1) • $p = 2.0 \times 10^5$ Pa (1)	Example of calculation $p = 8.8\ \text{N} / 9.2 \times 10^{-5}\ \text{m}^2$ $= 9.57 \times 10^4$ Pa Total $p = 9.57 \times 10^4$ Pa + 1.0×10^5 Pa $= 1.957 \times 10^5$ Pa	**3**

Q16.

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

Q17.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	• no net force on bridge (1) • no net moment of force about any point (1)	Alternative wording that implies these 2 points will be accepted	**(2)**
(a)(ii)	• use of $W = mg$ to find the weight of the bridge (1) • use of moment = $F x$ (1) • applies principle of moments (1) • F_A = 43610 N (1) • applies equilibrium of forces or applies principle of moments about a different point to obtain F_B = 45990 N (1)	<u>Example of calculation:</u> W = mg = 8500 kg × 9.8 N kg^{-1}= 83300 N Taking moments about A, Clockwise moments = (1500 N × 4 m) + (4800 N × 6.5 m) + (83300 N × 9.5 m) Anticlockwise moments = F_A × 19 m 19 N × F_A = 828550 Nm F_A = 828550 Nm/19 m = 43610 N $F_A + F_B$ = 1500 N + 4800 N + 83300 N F_B = 89600 N – 43610 N = 45990 N	**(5)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	• resonance occurs when the bridge is forced into oscillation at its natural frequency (1) • this results in an increasing amplitude of oscillation of the bridge, which may damage the bridge (1)		**(2)**
(b)(ii)	• energy was transferred from the oscillating bridge to the dampers (1) • this energy was dissipated in the dampers (and not returned to the bridge) (1) • hence the <u>amplitude</u> of oscillation was kept small (1)		**(3)**

(b)(iii)	• as the viscosity of the fluid increased the fluid would offer greater resistance to movement (1) [accept reverse argument] (1) • a greater resistance to movement would result in a greater energy dissipation		**(2)**

Q18.

Question Number	Acceptable answers	Additional guidance	Mark
	• the tension will equal the mass (of spider) ×acceleration (as the thread brings spider's fall to a stop) **(1)** • plus the weight (of the spider) so is incorrect **(1)**		**2**

Q19.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is C A *is not correct because acceleration is 0* as *v* constant B *is not correct because there is a resistive force opposing weight* D *is not correct because there is a weight*	There is a resultant force acting on the object.	**1**

Q20.

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**

Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	
(i)	• Wear safety glasses (to protect eyes from breaking wire) **Or** wear suitable footwear (to protect feet from falling masses) **Or** place sand tray under masses (to catch them if they fall)		1

Question Number	Acceptable Answer	Additional Guidance	
(ii)	• $\lambda = 2L$ substituted into $v = f\lambda$ (1) • v substituted into $v = \sqrt{\frac{T}{\mu}}$ (1) • Correct re-arrangement into $y = mx + c$ format (1)	$v = f\lambda$ and $\lambda = 2L$ so $v = 2fL$ $v = \sqrt{\frac{T}{\mu}}$, so $4f^2L^2 = \frac{T}{\mu}$ $L^2 = \left(\frac{T}{4\mu}\right).\frac{1}{f^2}$, so gradient is $\frac{T}{4\mu}$	3
(iii)	• Gradient calculated (1) • Use of gradient = $\frac{T}{4\mu}$ (1) • $\mu = 1.8$ (g m^{-1}) (1) • SWG consistent with their calculated value of μ (24 swg) (1)	Example of calculation gradient = $\frac{(0.043-0)\text{m}^2}{(15.0-0.0)\times 10^{-6}\text{s}^2} = 2.87\times10^3\text{m}^2\text{s}^{-2}$ $\mu = \frac{2.1\text{ kg}\times 9.81\text{ m s}^{-2}}{4\times 2.87\times10^3\text{m}^2\text{s}^{-2}} = 1.79\times10^{-3}\text{ kg m}^{-1}$ $\therefore \mu = 1.79$ g m^{-1}	4

Q2.

Question number	Acceptable answers	Additional guidance	Mark
(i)	• Recognise that for passenger to remain in their seat normal reaction $R \geq 0$ **(1)** **or** centripetal force >= weight **(1)** • Equate centripetal force and weight (for R=0) **(1)** • $v = 9.1$ m s^{-1} **(1)**	Example of calculation: $\frac{mv^2}{r} = mg$ $v = \sqrt{rg} = \sqrt{8.5\text{m}\times 9.81\text{m s}^{-2}} = 9.13\text{m s}^{-1}$	3
(ii)	• Equate decrease in gravitational potential energy to increase in kinetic energy at top of loop **(1)** • Adds this to 17.0 **(1)** • $\Delta h = 21.3$ m **(1)**	Example of calculation: $mgh = \frac{1}{2}mv^2$ $h = \frac{v^2}{2g} = \frac{(9.13\text{m s}^{-1})^2}{2\times 9.81\text{m s}^{-2}} = 4.25\text{m}$ $\Delta h = 17 + 4.3 = 21.3$ m	3

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• use of $\rho = m/V$ **and** $W = mg$ to calculate upthrust (1) • use of downward force of lid = upthrust – weight of diver (1) • downward force of lid = 0.021 (N) (1)	Example of calculation $m_{displaced} = 1.0\times10^3$ kg m^{-3} × 8.0×10^{-6} m^{-3} $= 8.0\times10^{-3}$ kg $U = 8.0\times10^{-3}$ kg × 9.81 N kg^{-1} = 0.0785 N $W = 0.0059$ kg × 9.81 N kg^{-1} = 0.0579 N Lid force = 0.0785 N - 0.0579 N = 0.0206 N	3

Question Number	Acceptable answers	Additional guidance	Mark
(b)	**Either** • use of force of lid = $V\rho g$ **(1)** • volume of air = 8.0×10^{-6} m^{-3} - their value **(1)** • volume of air = 5.9×10^{-6} (m^3) **(1)** **Or** • use of upthrust on diver = weight of diver **(1)** • use of upthrust = $V\rho g$ **(1)** • volume of air = 5.9×10^{-6} (m^3) **(1)**	Example of calculation volume = 0.0206 N ÷ 9.81 N kg^{-1} ÷ 1.0×10^3 kg m^{-3} = 2.1×10^{-6} m^{-3} new volume of air = 8.0×10^{-6} m^{-3} - 2.1×10^{-6} m^{-3} = 5.9×10^{-6} m^3	**3**

Question Number	Acceptable answers	Additional guidance	Mark
(c)	• use of pV = constant **(1)** • $p = 1.4 \times 10^5$ Pa **(1)**	Example of calculation $p_1 \times V_1 = p_2 \times V_2$ $p_2 = 1.01 \times 10^5$ N $m^{-2} \times 8.0 \times 10^{-6}$ m^{-3} / 5.9×10^{-6} m^3 $p = 1.37 \times 10^5$ Pa	**2**

Q4.

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)** • 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)**	**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 (1) • 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) • velocity = 1.0 m s^{-1} – 1.3 m s^{-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 $v = u + at$ (1) • 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)	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

Q5.

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)	Example of calculation: $\text{F} = \frac{11 \times 10^{-3}\ \text{kg} \times 9.81\ \text{N kg}^{-1}}{\sin 30^{\circ}} = 0.22\ \text{N}$	**(3)**

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of $v = \frac{2\pi r}{T}$ **(1)** or $\omega = \frac{2\pi}{T}$ • Use of $a = \frac{v^2}{r}$ **(1)** or $r\omega^2$ • $a = 8.8\ \text{m s}^{-2}$ **(1)**	Example of calculation $v = \frac{2\pi 6800000\text{m}}{92\times 60\text{s}} = 7740\ \text{m s}^{-1}$ $a = \frac{7740^2(\text{m s}^{-1})^2}{6800000\ \text{m}} = 8.81\ \text{m s}^{-2}$ or $\omega = \frac{2\pi}{92\times 60\ \text{s}} = 1.14\times 10^{-3}\ \text{rad s}^{-1}$ $a = 6800000\ \text{m} \times (1.14\times 10^{-3}\ \text{rad s}^{-1})^2$ $a = 8.81\ \text{m s}^{-2}$	3
(ii)	• The astronauts have weight or not weightless **(1)** **Or** Earth's gravitational field = 8.8 N kg^{-1} on ISS (ECF from (b)(i)) • Earth's gravitational field keeps astronauts/ISS in circular motion **(1)** **Or** Weight provides the centripetal force • Our notion of "weight" is reaction force acting on us from the ground/floor **(1)** • There are no reaction forces from the ISS on the astronauts so they "feel" weightless **(1)**		4

Q7.

Question number	Acceptable answers	Additional guidance	Mark
(b)	• Equate the electric force and the gravitational force **(1)** • Use of E=V/d to obtain $q = mgd/V$ **(1)**	$qE = mg$ $q(V/d) = mg$ $q = mgd/V$	2
(c)	An explanation that makes reference to: • Electrostatic/upward force (on drop) would be greater than the weight/downward force **(1)** • So drop would accelerate upwards **(1)**	Indication of which force is greater, unbalanced is insufficient.	2

Q8.

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)**

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $\rho = m/V$ (1) • Use of relationship upthrust = weight of liquid (1) • Use of $F = 6\pi\eta rv$ (1) • $\eta = 3.97 \times 10^{-2}$ (Pa s) so it is sunflower oil (1)	Example of calculation mass of oil displaced $= 9.20 \times 10^{2}$ kg m^{-3} $\times$ 1.41×10^{-8} m^{3} $= 1.30 \times 10^{-5}$ kg upthrust = 1.30×10^{-5} kg $\times$ 9.81 m s^{-2} $= 1.27 \times 10^{-4}$ N weight of sphere = 1.10×10^{-4} kg $\times$ 9.81 m s^{-2} $= 1.08 \times 10^{-3}$ N weight = upthrust + drag 1.08×10^{-3} N = ($6\pi \times \eta \times 1.5 \times 10^{-3}$ m $\times$ 0.849 m s^{-1}) + 1.27×10^{-4} N $\eta = 3.97 \times 10^{-2}$ Pa s	4

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
	• Take a correct moment about pivot P (1) • Converts the mass to weight of beam ie ×9.81 seen (1) • Appreciates centre of mass 0.5 m from P (1) • $T = 25$ kN (1)	eg T.6.cos20 or sin70 If cos20's are absent from both sides of equation then can still credit 4 marks Example of Calculation: $T \times 6(\text{m}) \times \cos 20 = 3.05 \times 10^4(\text{kg}) \times 9.81(\text{ms}^{-2}) \times 0.5(\text{m}) \times \cos 20$ $T = 24.9\text{kN}$	4

Q11.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $F = \frac{mv^2}{r}$ (1) • States that $F = mg$ only as reaction force is zero (1)	Example of derivation: $mg = \frac{mv^2}{r}$ $v = \sqrt{gr}$	(2)

Q12.

Question Number	Answer	Mark
	C	1

Q13.

Question Number	Acceptable Answer	Additional guidance	Mark
	C	$\frac{mgh}{t}$	(1)

Q14.

Question Number	Answer		Mark
(a)(i)	$R = 9.32$ kN Example of answer $R = 950\ \text{kg} \times 9.81\ \text{m s}^{-2}$ $R = 9320$ N	(1)	1
(a)(ii)	Use of $F = mv^2/r$ $R = mg - mv^2/r$ $R = 2480$ N ecf their value of R Example of calculation $R = 9320\ \text{N} - (950\ \text{kg} \times 12.0^2\ \text{m}^2\ \text{s}^{-2} / 20.0\ \text{m})$ $R = 2480$ N	(1) (1) (1)	3
(b)	An answer that either states implicitly or implies that 'The required centripetal force > mg and so cannot be provided'.	(1)	1
	Total for question		5

Q15.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	• no net force on bridge (1) • no net moment of force about any point (1)	Alternative wording that implies these 2 points will be accepted	**(2)**
(a)(ii)	• use of $W = mg$ to find the weight of the bridge (1) • use of moment = $F x$ (1) • applies principle of moments (1) • F_A = 43610 N (1) • applies equilibrium of forces or applies principle of moments about a different point to obtain F_B = 45990 N (1)	<u>Example of calculation:</u> W = mg = 8500 kg × 9.8 N kg^{-1}= 83300 N Taking moments about A, Clockwise moments = (1500 N × 4 m) + (4800 N × 6.5 m) + (83300 N × 9.5 m) Anticlockwise moments = F_A × 19 m 19 N × F_A = 828550 Nm F_A = 828550 Nm/19 m = 43610 N $F_A + F_B$ = 1500 N + 4800 N + 83300 N F_B = 89600 N – 43610 N = 45990 N	**(5)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	• resonance occurs when the bridge is forced into oscillation at its natural frequency (1) • this results in an increasing amplitude of oscillation of the bridge, which may damage the bridge (1)		**(2)**
(b)(ii)	• energy was transferred from the oscillating bridge to the dampers (1) • this energy was dissipated in the dampers (and not returned to the bridge) (1) • hence the <u>amplitude</u> of oscillation was kept small (1)		**(3)**

(b)(iii)	• as the viscosity of the fluid increased the fluid would offer greater resistance to movement [accept reverse argument] (1) • a greater resistance to movement would result in a greater energy dissipation (1)			**(2)**

Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of $v = \frac{2\pi r}{T}$ or $\omega = \frac{2\pi}{T}$ (1) • Use of $a = \frac{v^2}{r}$ or $r\omega^2$ (1) • $a = 8.8\ \text{m s}^{-2}$ (1)	Example of calculation $v = \frac{2\pi 6800000\text{m}}{92\times 60\text{s}} = 7740\ \text{m s}^{-1}$ $a = \frac{7740^2(\text{m s}^{-1})^2}{6800000\ \text{m}} = 8.81\ \text{m s}^{-2}$ or $\omega = \frac{2\pi}{92\times 60\ \text{s}} = 1.14\times 10^{-3}\ \text{rad s}^{-1}$ $a = 6800000\ \text{m} \times (1.14\times 10^{-3}\ \text{rad s}^{-1})^2$ $a = 8.81\ \text{m s}^{-2}$	3
(ii)	• The astronauts have weight or not weightless (1) **Or** Earth's gravitational field = 8.8 N kg^{-1} on ISS (ECF from (b)(i)) • Earth's gravitational field keeps astronauts/ISS in circular motion (1) **Or** Weight provides the centripetal force • Our notion of "weight" is reaction force acting on us from the ground/floor (1) • There are no reaction forces from the ISS on the astronauts so they "feel" weightless (1)		4

Q2.

<table>
<tr><th>Question Number</th><th>Acceptable Answer</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 logical structured answer with linkage 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 points seen in answer</th><th>Number of marks awarded for indicative 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>

Indicative content:

Newton's 3rd law pair of forces must be of the same type
Or Newton's 3rd law pair of forces must act on different bodies
The two forces mentioned are not a 3rd Law pair
Or gravity is not a good description of force
The lift on the plane should be paired with the push of the plane on the air
Or the gravitational force of Earth on plane should be paired with the gravitational force of plane on Earth.
If the vertical resultant force is zero the plane will not accelerate vertically
So the plane could be 'at rest' or moving with uniform velocity in the vertical direction
There must be some horizontal motion so plane can't be in same place

</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 and lines of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkage 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 linkage between points and is unstructured</td><td>0</td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
</table>

Linkage Marks

IC points 1 – 3
Two of these points could score one linkage mark

IC points 4 – 6
Two of these points could score one linkage mark
</td>
<td>6</td>
</tr>
</table>

Q3.

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)**

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	D		1

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	B		1

Q6.

Question number	Acceptable answers	Additional guidance	Mark
	• The forces are different types **(1)** • The forces act on the same object **(1)**		**2**

Mark Scheme

Q1.

Question Number	Answer		Mark
*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) **Either** Initial momentum is zero Nucleus and alpha particle have equal momentum (accept $m_n u_n = m_\alpha u_\alpha$ or $p_n = p_\alpha$) alpha particle and nucleus move in opposite directions Mass of alpha particle < mass of nucleus (therefore $v_n < v_\alpha$) **Or** The nucleus and alpha particle exert an equal but opposite force on each other. Mass of alpha particle < mass of nucleus Acceleration of nucleus < acceleration of alpha particle Force/acceleration acts for same time so Δv for nucleus is smaller for nucleus	(1) (1) (1) (1) (1) (1) (1) (1)	**4**
	Total for question		**4**

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: $F = \frac{0.06 \times 25}{0.04} = 37.5$ N	**3**

Q3.

Question Number	Acceptable Answer	Additional Guidance	
	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 table shows how the marks should be awarded for indicative content and lines of reasoning.		

IC points	IC mark	Max linkage mark available	Max final mark
6	4	2	**6**
5	3	2	**5**
4	3	1	**4**
3	2	1	**3**
2	2	0	**2**
1	1	0	**1**
0	0	0	**0**

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between its points and is unstructured	0

	Indicative content: • (Collision takes place on an ice surface so) there is minimal friction **Or** External forces are negligible • Momentum is conserved in the collision • The momentum of stone A before the collision equals the momentum of (A and) B after the collision • Stone A must be at rest after the collision • All of the kinetic energy of stone A must have been transferred to stone B • Kinetic energy is conserved in an elastic collision		6

Q4.

Question number	Acceptable answers	Additional guidance	Mark
(i)	• Use of ½ $mv^2 = mgh$ **(1)** • $v = 2.43$ m s^{-1} **(1)**	Example of calculation: $v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 0.30} = 2.43$ m s^{-1}	**2**
(ii)	• Use of impulse = change in momentum **(1)** • Recognises initial velocity is zero **(1)** • Hence $F = 0.923$ N **(1)** • Use of $l = \pi d$ **(1)** • Equates calculated value of F with BIl **(1)** • Hence I = 191 A **(1)**	Example of calculation: $Ft = mv - mu$ where $u = 0$ So $F = (0.019 \text{ kg} \times 2.43 \text{ m s}^{-1})/0.05 \text{ s} = 0.923$ N $l = \pi \times 0.048 \text{ m} = 0.151$ m $I = 0.923 \text{ N}/(0.032 \text{ T} \times 0.151 \text{ m}) = 191$ A	**6**

Q5.

Question Number	Answer	Mark
	B	**1**

Q6.

Question Number	Answer		Mark
(a)	Sum of momenta before (collision) = sum of momenta after (collision) **Or** the total momentum before (a collision) = the total momentum after (a collision) **Or** total momentum remains constant **Or** the momentum of a system remains constant	**(1)**	
	Providing no external/unbalanced/resultant force acts **Or** in a closed system	**(1)**	**2**
(b)(i)	Use of equation(s) of motion sufficient to get answer Initial speed = 1.1 (m s^{-1}) Example of calculation $s = (u + v)t/2$ 0.69 m = $(u + 0) \times 1.3$ s /2 u = 1.06 m s^{-1}	**(1)** **(1)**	**2**
(b)(ii)	Constant acceleration/deceleration (accept constant force)	**(1)**	**1**
(b)(iii)	Use of momentum = mv ecf v from (b)(i) Calculates momentum after collision using correct mass Speed of pellet = 117 or 124 or 129 (m s^{-1}) Example of calculation Momentum after = (97.31 + 0.84) g × 1.06 m s^{-1} = 104 g m s^{-1} Momentum before = momentum after Speed of pellet = 104 g m s^{-1} / 0.84 g = 124 m s^{-1}	**(1)** **(1)** **(1)**	**3**
***(c)(i)**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Mention of momentum	**(1)**	
	Pellet (bounces back so) has negative momentum /velocity **Or** momentum after = momentum of car - momentum of pellet	**(1)**	
	Pellet undergoes a bigger momentum/velocity change **Or** mass of car is less	**(1)**	**3**
(c)(ii)	reference to greater horizontal momentum/force	**(1)**	**1**

(d)	[The question says that the calculations are correct, the question is about the assumptions made. Do not credit a statement that the GPE is correct. MP1 is for the assumption that the KE after firing is the same as the max GPE. Do not credit energy loss due to air resistance or sound] $E_k \rightarrow E_{grav}$ of pendulum correct **Or** KE after collision is correct **(1)** E_k in collision not conserved **Or** not an elastic collision **Or** inelastic collision (do not credit just 'KE is lost') **(1)** Some energy becomes heat **(1)** E_k (of pellet before collision)is greater than 0.16J **(1)**	**4**
	Total for question	**16**

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Use of $E_{grav} = mg\Delta h$ **(1)** • Use of $E_K = \frac{1}{2}mv^2$ for block and projectile **(1)** • Use of $p = mv$ **(1)** • Use of conservation of momentum **(1)** • Use of $E_K = \frac{1}{2}mu^2$ for projectile **(1)** • $\Delta E = 490$ J **(1)**	MP1: Use of suvat equation to calculate u MP2: Use of $E_K = \frac{1}{2}mv^2$ for block and projectile **Or** use of $E_{grav} = mg\Delta h$ Example of calculation $E_{grav} = (2.4 + 0.065)\text{kg} \times 9.81\ \text{m s}^{-2} \times 0.55\ \text{m} = 13.3\ \text{J}$ (of block and projectile) $13.3\ \text{J} = \frac{1}{2} \times (2.4 + 0.065)\text{kg} \times v^2$ $\therefore v = \sqrt{\frac{13.3\ \text{J}}{0.5 \times 2.465\ \text{kg}}} = 3.28\ \text{m s}^{-1}$ $0.065\ \text{kg} \times u = 2.465\ \text{kg} \times 3.28\ \text{m s}^{-1}$ $\therefore u = \frac{8.10\ \text{kg m s}^{-1}}{0.065\ \text{kg}} = 124.6\ \text{m s}^{-1}$ $E_K = \frac{1}{2} \times 0.065\ \text{kg} \times (125\ \text{m s}^{-1})^2 = 504\ \text{J}$ $\therefore \Delta E = (504 - 13.3)\ \text{J} = 491\ \text{J}$	6

Q8.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of $E_K = p^2 / 2m$	(1)	MP1 accept use of $p = mv$ **and** Use of $E_k = ½ mv^2$ MP4 accept (n + ½) λ or n λ respectively Example of calculation $p = \sqrt{(2 \times 9.11 \times 10^{-31}\ \text{kg} \times 9.6 \times 10^{-17}\ \text{J})}$ $p = 1.32 \times 10^{-23}\ \text{kg m s}^{-1}$ $\lambda = 6.63 \times 10^{-34}\ \text{Js} / 1.32 \times 10^{-23}\ \text{kg m s}^{-1}$ $\lambda = 5.0 \times 10^{-11}\ \text{m}$	6
	• Use of $\lambda = h/p$	(1)		
	• $\lambda = 5.0 \times 10^{-11}$ (m) calculated from E_K **Or** $E_K = 9.7 \times 10^{-17}$ (J) calculated fro $\lambda = 5.0 \times 10^{-11}$ m **Or** $p = 1.3 \times 10^{-23}$ (kg m s^{-1}) calculated from E_K **and** $p = 1.3 \times 10^{-23}$ (kg m s^{-1}) calculated from $\lambda = 5.0 \times 10^{-11}$ m	(1)		
	• path difference at X is $\lambda/2$ **Or** path difference at Y is λ	(1)		
	• (electron) waves at X are in antiphase **Or** (electron) waves at Y are in phase	(1)		
	• at X destructive interference/superposition takes place **Or** at Y constructive interference/superposition takes place	(1)		

Q9.

Question Number	Acceptable Answer		Additional guidance	Mark
(a)	An explanation that makes reference to the following: • due to the large mass and speed OR large momentum OR large energy	(1)		**(2)**
	• the alpha particle would have a large change in momentum when deflected through large angles which requires a large force	(1)		

Question Number	Acceptable Answer	Additional guidance	Mark
(b)	• use of $F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$ (1) • charge of alpha $= 2 \times 1.6 \times 10^{-19}$ (C) (1) • r = 1.3×10^{-13} (m) (1) • comparison of the two distances (1) • conclusion that the alpha particle must reach a closer distance to give a larger force and relates this to the model (1)	Accept calculating a force for $r = 1.4 \times 10^{-10}$ and comparing forces Example of calculation: $r = \sqrt{8.99 \times 10^9 \text{ N m}^2\text{C}^{-2} \times \frac{(79 \times 2)(1.6 \times 10^{-19} \text{ C})^2}{2}}$ $r = 1.3 \times 10^{-13}$ m	**(5)**

Q10.

Question Marks	Acceptable Answers	Additional guidance	Mark
	• Magnet accelerates ball Or magnet increases ball's KE (1) • Momentum is conserved in the collision(s) (1) • (Since collisions are elastic) KE conserved so third ball moves off with the same velocity/KE as incoming ball hit magnet with (1)	Marks can be gained by discussing either set of balls	3

Q11.

Question Number	Answer	Mark
	A	1

Q12.

Question Number	Acceptable Answer	Additional guidance	Mark
	B	total kinetic energy is mv^2	**(1)**

Q13.

Question Number	Answer	Mark
	A	**1**

Q14.

Question Number	**Acceptable answers**	**Additional guidance**	**Mark**
	The only correct answer is B *A is not correct because this is not dimensionally correct* *C is not correct because* $E_k/_{2p} = v/_4$ *D is not correct because this is not dimensionally correct*		**1**

Q15.

Question Number	**Acceptable answers**	**Additional guidance**	**Mark**
	B as equal to total momentum before = 1×2−0.5×2	1.0	**1**
	A is the answer if each trolley had the same momentum C is the momentum of the second trolley only D is the answer if the two trolleys were travelling in the same direction		

Mark Scheme

Q1.

Question Number	Answer		Mark
*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) **Either** Initial momentum is zero Nucleus and alpha particle have equal momentum (accept $m_n u_n = m_\alpha u_\alpha$ or $p_n = p_\alpha$) alpha particle and nucleus move in opposite directions Mass of alpha particle < mass of nucleus (therefore $v_n < v_\alpha$) **Or** The nucleus and alpha particle exert an equal but opposite force on each other. Mass of alpha particle < mass of nucleus Acceleration of nucleus < acceleration of alpha particle Force/acceleration acts for same time so Δv for nucleus is smaller for nucleus	(1) (1) (1) (1) (1) (1) (1) (1)	**4**
	Total for question		**4**

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: $F = \frac{0.06 \times 25}{0.04} = 37.5$ N	**3**

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to the following points: Observation 1 • (the fraction of alpha scattering is less for aluminium) so the force of repulsion is less (at a given distance) **(1)** • therefore the charge on an aluminium nucleus is less than on gold nucleus **(1)** Observation 2 • (the E_k is less for scattered alpha for aluminium) so recoiling nucleus must have some/more kinetic energy **(1)** • The mass of an aluminium nucleus is less than mass of a gold nucleus **(1)**		**4**

Q4.

Question Number	Acceptable Answer	Additional Guidance	
	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 table shows how the marks should be awarded for indicative content and lines of reasoning. **IC points / IC mark / Max linkage mark available / Max final mark** **6** / 4 / 2 / **6** **5** / 3 / 2 / **5** **4** / 3 / 1 / **4** **3** / 2 / 1 / **3** **2** / 2 / 0 / **2** **1** / 1 / 0 / **1** **0** / 0 / 0 / **0**	**Number of marks awarded for structure of answer and sustained line of reasoning** Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout: **2** Answer is partially structured with some linkages and lines of reasoning: **1** Answer has no linkages between its points and is unstructured: **0**	

	Indicative content: • (Collision takes place on an ice surface so) there is minimal friction **Or** External forces are negligible • Momentum is conserved in the collision • The momentum of stone A before the collision equals the momentum of (A and) B after the collision • Stone A must be at rest after the collision • All of the kinetic energy of stone A must have been transferred to stone B • Kinetic energy is conserved in an elastic collision		6

Q5.

Question Number	Answer		Mark
*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) **Max 6** **Fixed target** There is momentum before the collision so there must be momentum after the collision. So particle(s) created must have some kinetic energy So not all KE converted to mass **Colliding beams** (If particles have the same mass and speed), total initial momentum is zero Momentum after collision will be zero If one stationary particle is created All of the kinetic energy of the particle is converted to mass	(1) (1) (1) (1) (1) (1) (1)	6
	Total for question		6

Q6.

Question Number	Answer	Mark
*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) statement that indicates that the conservation of momentum does apply (1) the idea that the probe and tank move in opposite directions [accept move apart] **Or** the idea that the probe and tank experience equal and opposite forces (1) Probe and tank experience equal **changes** in momentum (in opposite directions) (1) Statement that indicates that (total) energy is conserved (1) Kinetic energy of the system increases (so speed increases) (1) (Some) chemical energy converted to KE (1)	6
	Total for question	6

Q7.

Question Number	Answer	Mark
	B	1

Q8.

Question Number	Answer		Mark
(a)	Sum of momenta before (collision) = sum of momenta after (collision) **Or** the total momentum before (a collision) = the total momentum after (a collision) **Or** total momentum remains constant **Or** the momentum of a system remains constant	**(1)**	
	Providing no external/unbalanced/resultant force acts **Or** in a closed system	**(1)**	**2**
(b)(i)	Use of equation(s) of motion sufficient to get answer Initial speed = 1.1 (m s^{-1}) Example of calculation $s = (u + v)t/2$ 0.69 m = $(u + 0) \times 1.3$ s /2 u = 1.06 m s^{-1}	**(1)** **(1)**	**2**
(b)(ii)	Constant acceleration/deceleration (accept constant force)	**(1)**	**1**
(b)(iii)	Use of momentum = mv ecf v from (b)(i) Calculates momentum after collision using correct mass Speed of pellet = 117 or 124 or 129 (m s^{-1}) Example of calculation Momentum after = (97.31 + 0.84) g × 1.06 m s^{-1} = 104 g m s^{-1} Momentum before = momentum after Speed of pellet = 104 g m s^{-1} / 0.84 g = 124 m s^{-1}	**(1)** **(1)** **(1)**	**3**
***(c)(i)**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Mention of momentum	**(1)**	
	Pellet (bounces back so) has negative momentum /velocity **Or** momentum after = momentum of car - momentum of pellet	**(1)**	
	Pellet undergoes a bigger momentum/velocity change **Or** mass of car is less	**(1)**	**3**
(c)(ii)	reference to greater horizontal momentum/force	**(1)**	**1**

(d)	[The question says that the calculations are correct, the question is about the assumptions made. Do not credit a statement that the GPE is correct. MP1 is for the assumption that the KE after firing is the same as the max GPE. Do not credit energy loss due to air resistance or sound] $E_k \rightarrow E_{grav}$ of pendulum correct **Or** KE after collision is correct **(1)** E_k in collision not conserved **Or** not an elastic collision **Or** inelastic collision (do not credit just 'KE is lost') **(1)** Some energy becomes heat **(1)** E_k (of pellet before collision)is greater than 0.16J **(1)**	**4**
	Total for question	**16**

Q9.

Question Number	Answer	Mark
*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) No external/unbalanced/resultant force so momentum of system is conserved **(1)** Rocket gains momentum in backward direction **(1)** Module gains equal amount of momentum in forward direction **(1)** Kinetic energy of the system increases **(1)** (Some) chemical energy converted to KE **Alternative mark scheme** if candidate presumes that the initial total momentum is zero (Max 4) **(1)** No external/unbalanced/resultant force so momentum of system is conserved **(1)** Rocket and module have equal amount of momentum and move in opposite directions (after separation) **(1)** Kinetic energy of the system increases **(1)** (Some) chemical energy converted to KE	**5**
	Total for question	**5**

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Use of $E_{grav} = mg\Delta h$ (1) • Use of $E_K = \frac{1}{2}mv^2$ for block and projectile (1) • Use of $p = mv$ (1) • Use of conservation of momentum (1) • Use of $E_K = \frac{1}{2}mu^2$ for projectile (1) • $\Delta E = 490$ J (1)	MP1: Use of suvat equation to calculate u MP2: Use of $E_K = \frac{1}{2}mv^2$ for block and projectile **Or** use of $E_{grav} = mg\Delta h$ Example of calculation $E_{grav} = (2.4 + 0.065)\text{kg} \times 9.81\ \text{m s}^{-2} \times 0.55\ \text{m} = 13.3\ \text{J}$ (of block and projectile) $13.3\ \text{J} = \frac{1}{2} \times (2.4 + 0.065)\text{kg} \times v^2$ $\therefore v = \sqrt{\frac{13.3\ \text{J}}{0.5 \times 2.465\ \text{kg}}} = 3.28\ \text{m s}^{-1}$ $0.065\ \text{kg} \times u = 2.465\ \text{kg} \times 3.28\ \text{m s}^{-1}$ $\therefore u = \frac{8.10\ \text{kg m s}^{-1}}{0.065\ \text{kg}} = 124.6\ \text{m s}^{-1}$ $E_K = \frac{1}{2} \times 0.065\ \text{kg} \times (125\ \text{m s}^{-1})^2 = 504\ \text{J}$ $\therefore \Delta E = (504 - 13.3)\ \text{J} = 491\ \text{J}$	6

Q11.

Question Marks	Acceptable Answers	Additional guidance	Mark
	• Magnet accelerates ball Or magnet increases ball's KE (1) • Momentum is conserved in the collision(s) (1) • (Since collisions are elastic) KE conserved so third ball moves off with the same velocity/KE as incoming ball hit magnet with (1)	Marks can be gained by discussing either set of balls	3

Q12.

Question Number	Acceptable Answer	Additional guidance	Mark
	B	total kinetic energy is mv^2	**(1)**

Q13.

Question Number	Answer	Mark
	B	1

Q14.

Question Number	Acceptable Answers	Additional guidance	Mark
a	• fundamental – quarks and leptons (1) • Baryons made of 3 q (1) • Mesons made of quark and antiquark (1) • 6 quark **Or** 6 leptons (1) • Each particle has an antiparticle (1)	MP2 and 3 could be given for a named particle and its quark composition Can be inferred if either set named	5

Question Number	Acceptable Answers	Additional guidance	Mark
b	• Use of $\Delta E = \Delta mc^2$ (1) • Conversion of J to eV (1) • mass = 120 GeV/c^2 (1)	Example of calculation: $E = 2.2\times10^{-25}\text{kg}\times(3.0\times10^{8})^{2}(\text{ms}^{-1})^{2}$ $E = 1.98\times10^{-8}\text{J}$ $E = 1.98\times10^{-8}\text{J}\div1.6\times10^{-19}\text{JeV}^{-1}$ $E = 124\times10^{9}\text{eV}$	3

Question Number	Acceptable Answers		Additional guidance	Mark
c(i)	• Energy (of protons) converted to mass (of Higgs) **Or** Energy is required to overcome electrostatic repulsion between protons • Reference to $E = mc^2$ (can be written in any form) • Because c^2 is very large (E must be large) **Or** Higgs particle is massive so needs a lot of energy to create it	(1) (1) (1)	Alternative based on numerical values: Observation that Higgs mass is 120 GeV/c^2 This requires an energy of at least 120 GeV Each beam of protons would need an energy of at least 60 GeV	3
c(ii)	• Use of circumference = $2\pi r$ • Use of $p = Bqr$ • $p = 5.7 \times 10^{-15}$ Ns	(1) (1) (1)	Example of calculation: $r = 27000 \div 2\pi$ $r = 4300$ m $p = 8.3\text{T} \times 1.6 \times 10^{-19}\text{C} \times 4300\text{m}$ $p = 5.7 \times 10^{-15}$ Ns	3
ciii	0	(1)	zero	1

Question Number	Acceptable Answers		Additional guidance	Mark
d	• High speeds **Or** relativistic • Mass (of proton) increases • **Or** this equation is only valid at non-relativistic speeds	(1) (1)	Alt: speeds close to speed of light	2

Q15.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	An explanation that makes reference to the following: • air molecules make collisions with the puck and transfer momentum to the puck (1) • according to Newton's 2nd law the change of momentum creates a force on the puck (1) • the rate of change of momentum by air molecules colliding with bottom of puck is greater than that due to the collisions on the top of the puck (1) • the net (upward) force balances the weight of the puck <u>OR</u> the greater air pressure below the puck allows the puck to be supported. (1)		**(4)**

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>* (b)</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></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></td></tr>
</table>

5 - 4	3
3 - 2	2
1	1
0	0

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

Indicative content:

- applying Newton's 3rd law one puck (A) exerts a force on the other puck (B) and vice versa (1)
- forces equal in magnitude and opposite and direction (1)
- forces act for same time (1)
- $F\Delta t_A = -F\Delta t_B$ (1)
- applying Newton's 2nd law $F\Delta t = \Delta p$ since F is a resultant force on each puck (1)
- total change in momentum = zero, so momentum is conserved (1)
  OR Δp for one puck = $-\Delta p$ for the other puck, so momentum is conserved

(6)

Question Number	Acceptable Answer		Additional Guidance	Mark
(c)(i)	• resolve velocities to find forward/sideways component	(1)	Example of calculation: Forwards velocity components: $v\cos 30^\circ = 0.866\,v$; $2\cos 60^\circ = 1\,\text{m s}^{-1}$ $4m = m \times 0.866v + m \times 1$ $\therefore v = \dfrac{(4-1)\,\text{m s}^{-1}}{0.866} = 3.46\,\text{m s}^{-1}$	**(3)**
	• apply principle of conservation of momentum	(1)		
	• v = 3.46 m s^{-1}	(1)		
(c)(ii)	• use $KE = \frac{1}{2}mv^2$	(1)	Example of calculation: $KE_i = \frac{1}{2}m \times 4^2 = 8m$ $KE_f = \frac{1}{2}m \times 3.46^2 + \frac{1}{2}m \times 2^2$ $= 6m + 2m = 8m$	**(3)**
	• show that final KE is equal to initial KE	(1)		
	• elastic collisions conserve KE, so collision is elastic	(1)		