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INTERNATIONAL A LEVEL MATHEMATICS • MECHANICS 1

Mechanics 1

Exam Questions by Topic: Mark Scheme

Pearson Edexcel International Advanced Level (WME01/01) • Calculator allowed • Take $g = 9.8 \text{ ms}^{-2}$

Every question in the booklet, marked line by line the way an examiner marks it

Chapters (tap a chapter to jump to it)	Qs	Marks	Page	My score
1 Mathematical Models in Mechanics Not examined on its own: modelling ideas are tested within Chapters 2 to 8	—	—	Not applicable	
2 Constant Acceleration Motion graphs, the suvat formulae, vertical motion under gravity	10	82	3	
3 Vectors in Mechanics Resultants, velocity and position vectors, $\mathbf{r} = \mathbf{r}_0 + \mathbf{v}t$	10	81	10	
4 Dynamics of a Particle Moving in a Straight Line $F = ma$, connected particles, pulleys, lifts	10	82	17	
5 Forces and Friction Resolving forces, friction, inclined planes	10	86	25	
6 Momentum and Impulse Conservation of momentum, impulse	10	81	33	
7 Statics of a Particle Equilibrium, limiting friction	10	82	40	
8 Moments Beams and rods, tilting, non-uniform rods	10	82	47	

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How to use this mark scheme

The same marking rules Pearson examiners use for WME01.

Mark every line, not just the answer. Method marks are given for a correct method even when the final answer is wrong. If you lost marks, find the *first* line where your working differs from the scheme. That is the thing to fix.

Code	Meaning
M1	Method mark: for knowing a correct method and attempting to apply it. Small slips in the working do not lose this mark.
dM1	Dependent method mark: can only be given if the method mark before it has been given.
A1	Accuracy mark: for a correct answer or line of working. It can only be given if the method mark it depends on has been given.
B1	Independent mark: for a correct result or statement, whatever method was used.
*	The answer is given in the question. Every step must be shown, and the answer must follow from correct working (cso).
cao	Correct answer only.
cso	Correct solution only: no errors anywhere in the working.
ft	Follow through: the mark can be given for correct work using your own earlier (wrong) answer.
oe	Or equivalent: any correct equivalent form is accepted.

Accuracy after using $g = 9.8$. When $g = 9.8 \text{ ms}^{-2}$ has been substituted, the final answer must be given to 2 or 3 significant figures: more accurate answers (and fractions) lose the final A mark. Exact multiples of g are usually accepted. Using $g = 9.81$ loses accuracy marks.

Marking a sketch. Graph marks are given for the correct shape (straight lines for constant acceleration, no solid vertical lines) and for the key values marked on the axes. An equation of motion or a suvat equation must have the correct number of terms and be dimensionally correct to earn its method mark.



2

Chapter 2: Constant Acceleration

Mark scheme. Marks are shown on the right of each line.

Question 1

6 marks

Part	Scheme	Marks
(a)	Uses $s = \frac{1}{2}(u + v)t$: $84 = \frac{1}{2}(u + 2.5u) \times 6$ $10.5u = 84$ $u = 8$	M1 A1 A1 (3)
(b)	$a = \frac{20 - 8}{6} = 2 \text{ ms}^{-2}$	B1 (1)
(c)	$v^2 = u^2 + 2as$: $14^2 = 8^2 + 2 \times 2 \times s$ 33 m	M1 A1 (2)
Total for Question 1: 6 marks		

Question 2

6 marks

Part	Scheme	Marks
(a)	$v^2 = u^2 + 2as$ with $u = 14.7$, $a = -9.8$ and $s = -19.6$ (signs consistent) $v^2 = 14.7^2 + 2 \times 9.8 \times 19.6 = 600.25$ 24.5 ms^{-1} <i>Using $s = 0$ or the height of the top only is M0. Jan 2021 report: the value of s was misread; $g = 9.81$ loses the A marks.</i>	M1 A1 A1 (3)
(b)	A complete method: $-19.6 = 14.7t - 4.9t^2$ (or $v = u + at$ with $v = -24.5$) $4.9t^2 - 14.7t - 19.6 = 0$, i.e. $t^2 - 3t - 4 = 0$ $t = 4 \text{ s}$ <i>Splitting into up (1.5 s) and down (2.5 s) is equally valid; finding one part only scores M0.</i>	M1 A1 A1 (3)
Total for Question 2: 6 marks		



Question 3

7 marks

Part	Scheme	Marks
(a)	Trapezium shape starting at the origin and ending on the t -axis, with no solid vertical lines	B1
	20 marked on the speed axis; 40, $T + 40$ (or T shown as a length) and $T + 65$ on the time axis	B1
		(2)
(b)	Time to reach 20 ms^{-1} : $\frac{20}{0.5} = 40 \text{ s}$; area = $\frac{1}{2} \times 40 \times 20 + 20T + \frac{1}{2} \times 25 \times 20$	M1
	$400 + 20T + 250 = 3650$ (the distance in metres)	A1
	$T = 150$	A1
		(3)
(c)	$\frac{3650}{40 + 150 + 25}$	M1
	17.0 ms^{-1} (17)	A1
		(2)
Total for Question 3: 7 marks		

Question 4

6 marks

Part	Scheme	Marks
(a)	$\frac{240}{60} = 4 \text{ ms}^{-1}$	B1
	$\frac{0-240}{80} = -3 \text{ ms}^{-1}$ (3 ms^{-1} back towards O)	B1
		(2)
(b)	Average speed = $\frac{480}{180} = 2.67 \text{ ms}^{-1}$ ($\frac{8}{3}$)	B1
	Average velocity 0 ms^{-1} , as the displacement after 180 s is 0	B1
		(2)
(c)	Three horizontal segments: $v = 4$ for $0 < t < 60$, $v = 0$ for $60 < t < 100$, $v = -3$ for $100 < t < 180$	B1
	Values 4 and -3 and times 60, 100, 180 marked; no solid vertical lines	B1
		(2)
Total for Question 4: 6 marks		



Question 5

6 marks

Part	Scheme	Marks
(a)	$0 = 24.5^2 - 2 \times 9.8 \times s$ 30.6 m (or 31 m)	M1 A1 (2)
(b)	$19.6 = 24.5t - 4.9t^2$ $t^2 - 5t + 4 = 0$ $(t - 1)(t - 4) = 0: t = 1 \text{ and } t = 4$ 3 s <i>The ball passes 19.6 m twice (going up and coming down): the time between the two roots is required.</i>	M1 A1 M1 A1 (4)
Total for Question 5: 6 marks		

Question 6

10 marks

Part	Scheme	Marks
(a)	Two straight lines: up from 3 to V , then down to 2 (not to 0); no solid vertical lines 3, V and 2 marked on the speed axis and the total time 20 marked <i>Jan 2025 report: the total time for both stages must not be labelled T_2.</i>	B1 B1 (2)
(b)	$A \text{ to } B: 108 = \frac{1}{2}(3 + V)T_1, \text{ so } T_1 = \frac{216}{V + 3}$ $B \text{ to } C: 68 = \frac{1}{2}(V + 2)T_2, \text{ so } T_2 = \frac{136}{V + 2}$ $T_1 + T_2 = 20: 216(V + 2) + 136(V + 3) = 20(V + 3)(V + 2)$ $352V + 840 = 20V^2 + 100V + 120 \Rightarrow 5V^2 - 63V - 180 = 0 \quad *$	M1 M1 M1 A1* (4)
(c)	$(V - 15)(5V + 12) = 0$ $V = 15$; $V = -2.4$ is rejected since a speed cannot be negative (and $V > 3$) <i>Failing to reject the other root loses the A mark (Jan 2025 report).</i>	M1 A1 (2)
(d)	$T_2 = \frac{136}{17} = 8 \text{ s}; a = \frac{2 - 15}{8}$ Deceleration 1.625 ms^{-2} <i>A deceleration is a positive quantity: an answer of -1.625 loses the A mark.</i>	M1 A1 (2)
Total for Question 6: 10 marks		



Question 7

10 marks

Part	Scheme	Marks
(a)	$v^2 = 0 + 2 \times 9.8 \times 10$ 14 ms^{-1}	M1 A1 (2)
(b)	Rebound speed 7 ms^{-1} : $0 = 7^2 - 2 \times 9.8 \times h$ 2.5 m	M1 A1 (2)
(c)	Height = $\frac{v^2}{2g}$ and the rebound speed halves each time, so each greatest height is $\frac{1}{4}$ of the one before: 2.5, 0.625, ... Total = $10 + 2 \times \frac{2.5}{1 - \frac{1}{4}}$ (each rebound height is travelled up and down) 16.7 m ($\frac{50}{3}$) <i>Counting each rebound height once (giving 13.3 m) is the Oct 2019 "miscounting" error.</i>	M1 M1 A1 (3)
(d)	Straight line from (0, 0) to $v = 14$ at $t = \frac{10}{7} \approx 1.43$, then a parallel line from $v = -7$ up to $v = 0$ at $t \approx 2.14$ Values 14 and -7 shown; no solid vertical line at the bounce; lines parallel	B1 B1 (2)
(e)	e.g. the model predicts infinitely many bounces; air resistance is ignored; the ball will not rebound with exactly half its speed each time	B1 (1)
Total for Question 7: 10 marks		



Question 8

10 marks

Part	Scheme	Marks
(a)	$v = 0 + 9.8 \times 3 = 29.4 \text{ ms}^{-1}$	B1 (1)
(b)	Straight line from the origin to (3, 29.4), a less steep line down to V, then horizontal to $t = 20$; no vertical lines 29.4, 3 and $3 + T$ marked	B1 B1 (2)
(c)	$100.8 = 29.4T - \frac{1}{2} \times 4.2T^2$ $2.1T^2 - 29.4T + 100.8 = 0$, i.e. $T^2 - 14T + 48 = 0$ $(T - 6)(T - 8) = 0$ $T = 6$: $T = 8$ is rejected because her speed would be $29.4 - 4.2 \times 8 < 0$ (she would stop after 7 s) <i>Jan 2021 report: using +4.2 instead of -4.2 for the acceleration was the main error.</i>	M1 A1 M1 A1 (4)
(d)	$V = 29.4 - 4.2 \times 6 = 4.2 \text{ ms}^{-1}$ Distance = $\frac{1}{2} \times 3 \times 29.4 + 100.8 + 4.2 \times (20 - 3 - 6)$ $44.1 + 100.8 + 46.2 = 191.1$: 191 m <i>Using $20 - T$ (not $20 - 3 - T$) for the last stage is the common error.</i>	M1 M1 A1 (3)
Total for Question 8: 10 marks		



Question 9

10 marks

Part	Scheme	Marks
(a)	Height of A: $19.6t - 4.9t^2$ Height of B: $29.4 - 4.9t^2$, and equates $19.6t = 29.4$, so $t = 1.5$ *	M1 M1 A1* (3)
(b)	$19.6 \times 1.5 - 4.9 \times 1.5^2$ 18.4 m (or 18 m)	M1 A1 (2)
(c)	A: $19.6 - 9.8 \times 1.5 = $ 4.9 ms^{-1} , still moving upwards B: 14.7 ms^{-1} downwards (-14.7)	B1 B1 (2)
(d)	Two straight lines: A from 19.6 down to 4.9; B from 0 down to -14.7 Lines parallel, ending at $t = 1.5$, with the values marked	B1 B1 (2)
(e)	The gradient is the acceleration, and both balls have the same acceleration -9.8 ms^{-2}	B1 (1)
Total for Question 9: 10 marks		



Question 10

11 marks

Part	Scheme	Marks
(a)	$Q: 16 \times 12 = 192; P: \frac{1}{2} \times 12 \times 24 = 144$ $192 - 144 = 48 \text{ m}^*$	M1 A1* (2)
(b)	The gap increases while Q is faster: greatest when both speeds are 16, at $t = 8$ (P accelerates at 2 ms^{-2}) Gap = $16 \times 8 - \frac{1}{2} \times 8 \times 16$ (or $16t - t^2$ maximised) 64 m	M1 M1 A1 (3)
(c)	For $t > 12$: P has travelled $144 + 24(t - 12)$ $24t - 144 = 16t$ $t = 18 \text{ s}$ <i>$t^2 = 16t$ gives $t = 16$, but that formula for P only holds for $t \leq 12$: M1 M0 A0.</i>	M1 M1 A1 (3)
(d)	$a = 2$ (horizontal line) for $0 < t < 12$ $a = 0$ for $12 < t < 24$, with no solid vertical line	B1 B1 (2)
(e)	e.g. the acceleration of P changes suddenly from 2 to 0 at $t = 12$, which is unrealistic; the acceleration of a car is unlikely to be constant	B1 (1)
Total for Question 10: 11 marks		



3

Chapter 3: Vectors in Mechanics

Mark scheme. Marks are shown on the right of each line.

Question 1

6 marks

Part	Scheme	Marks
(a)	$\tan \theta = \frac{3}{4}$ (angle below east) or $\frac{4}{3}$; uses a diagram to place the direction $90^\circ + 36.9^\circ = 127^\circ$ <i>Summer 2019 and Jan 2015 reports: stopping at the acute angle 36.9° or 53.1° scores M1 A0.</i>	M1 A1 (2)
(b)	$\mathbf{r} = (-10 + 4t)\mathbf{i} + (18 - 3t)\mathbf{j}$	B1 (1)
(c)	Due east: $\mathbf{j}$ component = 0, $18 - 3t = 0$ $t = 6$ $\mathbf{r} = 14\mathbf{i}$: 14 m from O	M1 A1 A1 (3)
Total for Question 1: 6 marks		

Question 2

6 marks

Part	Scheme	Marks
(a)	Angle $STF = 180^\circ - (150^\circ - 60^\circ) = 90^\circ$ (turning from 060° to 150°) $SF^2 = 6^2 + 8^2$ 10 km Or components: $\vec{SF} = (6 \sin 60^\circ + 8 \sin 150^\circ)\mathbf{i} + (6 \cos 60^\circ + 8 \cos 150^\circ)\mathbf{j} = 9.196\mathbf{i} - 3.928\mathbf{j}$	M1 M1 A1 (3)
(b)	Angle TSF : $\tan^{-1} \frac{8}{6} = 53.1^\circ$ Bearing = $60^\circ + 53.1^\circ$ 113°	M1 M1 A1 (3)
Total for Question 2: 6 marks		



Question 3

6 marks

Part	Scheme	Marks
(a)	$\tan \theta = \frac{4}{3}$ 53.1°	M1 A1 (2)
(b)	$\mathbf{a} + \mathbf{b} = (3 + p)\mathbf{i} - 2\mathbf{j}$ Parallel: $\frac{3+p}{2} = \frac{-2}{-1}$ (or $= \lambda(2\mathbf{i} - \mathbf{j})$) $p = 1$ <i>Equating the resultant to $2\mathbf{i} - \mathbf{j}$ itself (so $-2 = -1$) is the Summer 2019 error: M0.</i>	B1 M1 A1 (3)
(c)	$ 4\mathbf{i} - 2\mathbf{j} = \sqrt{20} = 4.47 \text{ m}$ ($2\sqrt{5}$)	B1 (1)
Total for Question 3: 6 marks		

Question 4

6 marks

Part	Scheme	Marks
(a)	$ 5\mathbf{i} - 12\mathbf{j} = 13$, so $\mathbf{v} = \frac{26}{13}(5\mathbf{i} - 12\mathbf{j})$ $(10\mathbf{i} - 24\mathbf{j}) \text{ km h}^{-1}$	M1 A1 (2)
(b)	$\mathbf{r} = (-20 + 10t)\mathbf{i} + (60 - 24t)\mathbf{j}$	B1ft (1)
(c)	$60 - 24t = 0$, so $t = 2.5$ $11:30$ $\mathbf{r} = 5\mathbf{i}$: 5 km from O <i>Oct 2019 report: a value of t must be turned into the time of day when the question asks for it.</i>	M1 A1 A1 (3)
Total for Question 4: 6 marks		



Question 5

6 marks

Part	Scheme	Marks
(a)	$\mathbf{r}_A = (1 + 2t)\mathbf{i} + (2 + t)\mathbf{j}$ $\mathbf{r}_B = (7 - t)\mathbf{i} + (-4 + 4t)\mathbf{j}$	B1 B1 (2)
(b)	i: $1 + 2t = 7 - t$, so $t = 2$ j: $2 + t = -4 + 4t$, so $t = 2$ Both components are equal at the same time $t = 2$, so they collide $(5\mathbf{i} + 4\mathbf{j}) \text{ m}$ <i>Jan 2021 report: both the i and the j components must be checked.</i>	M1 M1 A1 A1 (4)
Total for Question 5: 6 marks		

Question 6

10 marks

Part	Scheme	Marks
(a)	$\sqrt{4^2 + 3^2} = 5 \text{ km h}^{-1}$	B1 (1)
(b)	$\mathbf{r}_A = (2 + 4t)\mathbf{i} + (-3 + 3t)\mathbf{j}$, $\mathbf{r}_B = (12 + pt)\mathbf{i} + (7 + qt)\mathbf{j}$ $\vec{AB} = \mathbf{r}_B - \mathbf{r}_A = (10 + (p - 4)t)\mathbf{i} + (10 + (q - 3)t)\mathbf{j}$ Compares with the given $\vec{AB}$: $p - 4 = -6$, $q - 3 = -8$ $p = -2$, $q = -5$	M1 M1 M1 A1 (4)
(c)	$(10 - 6t)^2 + (10 - 8t)^2 = 40$ $100t^2 - 280t + 160 = 0$, $(5t - 4)(t - 2) = 0$: $t = 0.8$ or $t = 2$ $14:48$ and $16:00$	M1 A1 A1 (3)
(d)	$t = 2$: $\vec{AB} = -2\mathbf{i} - 6\mathbf{j}$; angle $\tan^{-1} \frac{2}{6} = 18.4^\circ$ west of south 198°	M1 A1 (2)
Total for Question 6: 10 marks		



Question 7

10 marks

Part	Scheme	Marks
(a)	10 km h^{-1}	B1 (1)
(b)	$1.5(6\mathbf{i} + 8\mathbf{j})$ $(9\mathbf{i} + 12\mathbf{j}) \text{ km}$	M1 A1 (2)
(c)	$\mathbf{r} = (9\mathbf{i} + 12\mathbf{j}) + s(-4\mathbf{i} + 3\mathbf{j})$ $(9 - 4s)\mathbf{i} + (12 + 3s)\mathbf{j}$ <i>Using t hours after 12:00 with $s = t - 1.5$ is equally valid.</i>	M1 A1 (2)
(d)	Due west of L : $\mathbf{j}$ components equal, $12 + 3s = 18$, $s = 2$ $15:30$ Boat at $(\mathbf{i} + 18\mathbf{j})$: 4 km west of L	M1 A1 A1 (3)
(e)	$\overrightarrow{BL} = (5\mathbf{i} + 18\mathbf{j}) - (9\mathbf{i} + 12\mathbf{j}) = -4\mathbf{i} + 6\mathbf{j}$; $\tan^{-1} \frac{4}{6} = 33.7^\circ$ west of north 326°	M1 A1 (2)
Total for Question 7: 10 marks		



Question 8

10 marks

Part	Scheme	Marks
(a)	$\mathbf{v} = \frac{(12\mathbf{i} + 11\mathbf{j}) - (-3\mathbf{i} + 5\mathbf{j})}{5 - 2}$ $(5\mathbf{i} + 2\mathbf{j}) \text{ ms}^{-1}$ <i>Dividing by 5 (the time, not the time interval) is the Jan 2025 error: M0.</i>	M1 A1 (2)
(b)	Speed $\sqrt{29} = 5.39 \text{ ms}^{-1}$ $\tan^{-1} \frac{5}{2}$ from north 068°	B1 M1 A1 (3)
(c)	$\mathbf{r}_0 = (-3\mathbf{i} + 5\mathbf{j}) - 2(5\mathbf{i} + 2\mathbf{j}) = -13\mathbf{i} + \mathbf{j}$ $\mathbf{r} = (-13 + 5t)\mathbf{i} + (1 + 2t)\mathbf{j}$	M1 A1 (2)
(d)	North-east of O: $-13 + 5t = 1 + 2t$ (both positive) $t = \frac{14}{3}$ (4.67 s)	M1 A1 (2)
(e)	$\mathbf{r} = \frac{31}{3}\mathbf{i} + \frac{31}{3}\mathbf{j}$: $\frac{31}{3}\sqrt{2} = 14.6 \text{ m}$	B1 (1)
Total for Question 8: 10 marks		



Question 9

10 marks

Part	Scheme	Marks
(a)	Angle between the two velocities in the triangle: $180^\circ - (150^\circ - 30^\circ) = 60^\circ$ $v^2 = 200^2 + 60^2 - 2 \times 200 \times 60 \cos 60^\circ$ 178 km h^{-1} (177.8) <i>Oct 2019 report: using 120° (vectors not top to tail) is M0. Components give $130\mathbf{i} + 121.2\mathbf{j}$.</i>	B1 M1 A1 (3)
(b)	$\frac{\sin \alpha}{60} = \frac{\sin 60^\circ}{177.8}$ (or $\tan^{-1} \frac{130}{121.2}$ from north) $\alpha = 17.0^\circ$, bearing $30^\circ + 17.0^\circ$ 047°	M1 M1 A1 (3)
(c)	Heading θ: north components cancel, $200 \cos \theta + 60 \cos 150^\circ = 0$ $\cos \theta = \frac{60 \cos 30^\circ}{200}$, $\theta = 74.9^\circ$: heading 075° Speed = $200 \sin \theta + 60 \sin 150^\circ$ 223 km h^{-1}	M1 A1 M1 A1 (4)
Total for Question 9: 10 marks		



Question 10

11 marks

Part	Scheme	Marks
(a)	$A: (5\mathbf{i} + 2\mathbf{j}) + 2(\mathbf{i} + 3\mathbf{j}) = 7\mathbf{i} + 8\mathbf{j}$ at $t = 2$ $B: (-13\mathbf{i} + 23\mathbf{j}) + 5(4\mathbf{i} - 3\mathbf{j}) = 7\mathbf{i} + 8\mathbf{j}$ at $t = 5$ They are at X at different times (14:00 and 17:00), so they do not collide	M1 A1 A1 (3)
(b)	$\vec{AB} = (-18 + 3t)\mathbf{i} + (21 - 6t)\mathbf{j}$ $AB^2 = (3t - 18)^2 + (21 - 6t)^2 = 45t^2 - 360t + 765$ $= 45(t^2 - 8t + 17)$ *	M1 A1 A1* (3)
(c)	$45((t - 4)^2 + 1)$: least when $t = 4$ (or $\frac{d}{dt}(AB^2) = 0$) $\sqrt{45} = 6.71 \text{ km}$ ($3\sqrt{5}$) at 16:00 <i>Jan 2022 report: substitute t into $\vec{AB}$, not into $\mathbf{r}_A$ and $\mathbf{r}_B$ separately.</i>	M1 A1 A1 (3)
(d)	$t = 4: \vec{AB} = -6\mathbf{i} - 3\mathbf{j}; \tan^{-1} \frac{6}{3} = 63.4^\circ$ west of south 243°	M1 A1 (2)
Total for Question 10: 11 marks		



4

Chapter 4: Dynamics of a Particle Moving in a Straight Line

Mark scheme. Marks are shown on the right of each line.

Question 1

6 marks

Part	Scheme	Marks
(a)	Resultant = $(2 + p)\mathbf{i} + (3 + q)\mathbf{j}$ and $\mathbf{F} = m\mathbf{a} = 0.5(8\mathbf{i} - 6\mathbf{j})$ $2 + p = 4, 3 + q = -3$ $p = 2, q = -6$	M1 A1 A1 (3)
(b)	$\sqrt{8^2 + 6^2} = 10\text{ms}^{-2}$ Jan 2025 report: leaving the acceleration as a vector loses this mark.	B1 (1)
(c)	$\tan^{-1} \frac{6}{8}$ 36.9° (below $\mathbf{i}$)	M1 A1 (2)
Total for Question 1: 6 marks		

Question 2

6 marks

Part	Scheme	Marks
(a)	$25^2 = 10^2 + 2a \times 150$ 1.75ms^{-2}	M1 A1 (2)
(b)	$D - 450 = 900 \times 1.75$ 2025 N (2030 N)	M1 A1 (2)
(c)	Deceleration $\frac{450}{900} = 0.5\text{ms}^{-2}$ and $0 = 25 - 0.5t$ 50 s	M1 A1 (2)
Total for Question 2: 6 marks		



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Question 3

6 marks

Part	Scheme	Marks
(a)	Whole system: $3000 + 300 + 100 = 1600a$ 2.125 ms^{-2} (2.13)	M1 A1 (2)
(b)	Trailer only: $100 + F = 400 \times 2.125$ (towbar force F acting backwards on the trailer) $F = 750$ 750 N, a thrust <i>Summer 2019 report: assuming the coupling is in tension. A negative tension (-750) must be interpreted as a thrust for the last mark.</i>	M1 A1 A1 (3)
(c)	$0 = 20^2 - 2 \times 2.125s$: 94.1 m	B1 (1)
Total for Question 3: 6 marks		

Question 4

6 marks

Part	Scheme	Marks
(a)	Whole system: $2800 - 250g = 250a$ 1.4 ms^{-2}	M1 A1 (2)
(b)	B only: $T - 50g = 50 \times 1.4$ 560 N <i>Oct 2019 report: forces acting on the wrong part of the system. The rope tension acts on B; the cable tension does not.</i>	M1 A1 (2)
(c)	$a = 0$: $250g = 2450 \text{ N}$	B1 (1)
(d)	Moving down and slowing: acceleration 0.6 ms^{-2} upwards; $T - 50g = 50 \times 0.6$: 520 N	B1 (1)
Total for Question 4: 6 marks		



Question 5

6 marks

Part	Scheme	Marks
(a)	Upwards motion: $-(0.5g + 1.1) = 0.5a$ Deceleration 12ms^{-2}	M1 A1 (2)
(b)	$0 = 18^2 - 2 \times 12 \times h$ 13.5m	M1 A1 (2)
(c)	Downwards: $0.5g - 1.1 = 0.5a$, $a = 7.6\text{ms}^{-2}$ (resistance now acts upwards) $v^2 = 2 \times 7.6 \times 13.5$: 14.3ms^{-1} <i>Using the same acceleration for both directions gives 18ms^{-1}: M0. The resistance opposes the motion, so it changes direction.</i>	M1 A1 (2)
Total for Question 5: 6 marks		



Question 6

10 marks

Part	Scheme	Marks
(a)	$B: 3g - T = 3a$ Correct $A: T - 2g = 2a$ $a = \frac{g}{5} = 1.96 \text{ ms}^{-2}$ $T = 2(g + 1.96) = 23.5 \text{ N} \left(\frac{12g}{5} \right)$ <i>Jan 2025 report: m instead of 2m or 3m; g omitted from a weight or included in ma; $T - 2mg = 3mg - T$.</i>	M1 A1 M1 A1 A1 (5)
(b)	$v^2 = 2 \times 1.96 \times 1.5$ 2.42 ms^{-1} <i>Using $a = g$ (as if B falls freely) is M0.</i>	M1 A1 (2)
(c)	After B lands, A moves freely under gravity: $0 = 5.88 - 2 \times 9.8 \times h$, $h = 0.3$ Greatest height $1.5 + 0.3 = 1.8 \text{ m}$	M1 A1 (2)
(d)	The accelerations of A and B have the same magnitude (and A rises 1.5 m while B falls 1.5 m)	B1 (1)
Total for Question 6: 10 marks		



Question 7

10 marks

Part	Scheme	Marks
(a)	Whole system: $3850 - 350g = 350a$ $3850 - 3430 = 350a$ $a = 1.2 \text{ ms}^{-2}$ *	M1 A1 A1* (3)
(b)	$B: R_B - 10g = 10 \times 1.2$ 110 N	M1 A1 (2)
(c)	$A: R - 40g - 110 = 40 \times 1.2$ (the 110 N of B on A acts downwards, Newton's third law) or A and B together: $R - 50g = 50 \times 1.2$ 550 N	M1 A1 (2)
(d)	A and B together: $50g - 440 = 50d$ Deceleration 1 ms^{-2} $350g - T = 350 \times 1$: 3080 N	M1 A1 A1 (3)
Total for Question 7: 10 marks		



Question 8

10 marks

Part	Scheme	Marks
(a)	$30\,000 - 5000 - 2500 = 30\,000a$ 0.75 ms^{-2}	M1 A1 (2)
(b)	Carriage: $T - 2500 = 10\,000 \times 0.75$ $10\,000\text{ N}$	M1 A1 (2)
(c)	$0.75 \times 40 = 30\text{ ms}^{-1}$	B1 (1)
(d)	Carriage: $2500 = 10\,000a$, deceleration 0.25 ms^{-2} $0 = 30^2 - 2 \times 0.25 \times s$ 1800 m	M1 M1 A1 (3)
(e)	Carriage stops after 120 s; engine: $a = \frac{25\,000}{20\,000} = 1.25$, $s = 30 \times 120 + \frac{1}{2} \times 1.25 \times 120^2 = 12\,600$ $12\,600 - 1800 = 10\,800\text{ m}$ <i>Using the old acceleration 0.75 for the engine is the Summer 2019 error: the acceleration changes when the coupling breaks.</i>	M1 A1 (2)
Total for Question 8: 10 marks		



Question 9

10 marks

Part	Scheme	Marks
(a)	Resultant $(4 + p)\mathbf{i} + 4\mathbf{j}$ Parallel to $\mathbf{i} + 2\mathbf{j}$: $\frac{4+p}{1} = \frac{4}{2}$ $p = -2$	B1 M1 A1 (3)
(b)	$(2\mathbf{i} + 4\mathbf{j}) = 2\mathbf{a}$, $\mathbf{a} = \mathbf{i} + 2\mathbf{j}$ 2.24 ms^{-2} ($\sqrt{5}$)	M1 A1 (2)
(c)	$\mathbf{v} = (3\mathbf{i} - 4\mathbf{j}) + t(\mathbf{i} + 2\mathbf{j})$ Due east: $-4 + 2t = 0$, $t = 2$ $\mathbf{v} = 5\mathbf{i}$: speed 5 ms^{-1}	M1 A1 A1 (3)
(d)	$\mathbf{s} = \mathbf{u}t + \frac{1}{2}\mathbf{a}t^2 = (6\mathbf{i} - 8\mathbf{j}) + (2\mathbf{i} + 4\mathbf{j}) = 8\mathbf{i} - 4\mathbf{j}$ 8.94 m ($\sqrt{80}$) <i>The path is a straight line only if $\mathbf{u}$ is parallel to $\mathbf{a}$; here the magnitude of the displacement is what is asked for.</i>	M1 A1 (2)
Total for Question 9: 10 marks		



Question 10

12 marks

Part	Scheme	Marks
(a)	$P: T_1 = 5a$; Q and R together: $5g - T_1 = 5a$ Both correct $a = 4.9 \text{ ms}^{-2}$ $T_1 = 24.5 \text{ N}$	M1 A1 A1 A1 (4)
(b)	$R: 3g - T_2 = 3 \times 4.9$ 14.7 N	M1 A1 (2)
(c)	$T_1 \sqrt{2}$ (the two parts of the string are perpendicular) 34.6 N	M1 A1 (2)
(d)	P and Q only: $2g = 7a$ 2.8 ms^{-2} <i>Summer 2019 report: continuing with the old acceleration after a particle separates is M0.</i>	M1 A1 (2)
(e)	Speed at the break $4.9 \times 0.5 = 2.45 \text{ ms}^{-1}$; $s = 2.45 \times 0.5 + \frac{1}{2} \times 2.8 \times 0.5^2$ 1.58 m	M1 A1 (2)
Total for Question 10: 12 marks		



5

Chapter 5: Forces and Friction

Mark scheme. Marks are shown on the right of each line.

Question 1

6 marks

Part	Scheme	Marks
(a)	Resolving vertically: $R + P \sin 30^\circ = 20g$ $R = 196 - 0.5P$ <i>Jan 2021 report: adding the vertical component of the pull to the weight is M0.</i>	M1 A1 (2)
(b)	Horizontally: $P \cos 30^\circ - F = 20 \times 0.5$ $F = 0.4R = 0.4(196 - 0.5P)$ $P \cos 30^\circ - 78.4 + 0.2P = 10$ $P = 82.9$ (83)	M1 M1 A1 A1 (4)
Total for Question 1: 6 marks		

Question 2

6 marks

Part	Scheme	Marks
(a)	Parallel to the plane: $P \cos 20^\circ - 2g \sin 20^\circ = 2 \times 1.5$ Correct equation $P = 10.3$	M1 A1 A1 (3)
(b)	Perpendicular: $R = 2g \cos 20^\circ + P \sin 20^\circ$ Correct with their P 21.9 N (22) <i>The horizontal force has a component into the plane, so $R \neq mg \cos 20^\circ$.</i>	M1 A1 A1 (3)
Total for Question 2: 6 marks		



Question 3

6 marks

Part	Scheme	Marks
(a)	$0 = 8^2 - 2a \times 10$	M1
	3.2 ms^{-2}	A1
		(2)
(b)	$\mu mg = m \times 3.2$	M1
	$\mu = 0.33$ (0.327)	A1
		(2)
(c)	$\frac{8}{3.2} = 2.5 \text{ s}$	B1
		(1)
(d)	Friction μmg and ma are both proportional to m , so m cancels	B1
		(1)
Total for Question 3: 6 marks		

Question 4

6 marks

Part	Scheme	Marks
(a)	$R = 15g + 60 \sin 25^\circ$	M1
	172 N (172.4)	A1
		(2)
(b)	Constant speed: $F = 60 \cos 25^\circ$ and $F = \mu R$	M1
	$\mu = 0.32$ (0.315)	A1
		(2)
(c)	$R = 15g$ now: $60 - \mu \times 15g = 15a$	M1
	0.91 ms^{-2} (0.908)	A1
		(2)
Total for Question 4: 6 marks		



Question 5

6 marks

Part	Scheme	Marks
(a)	$R = mg \cos \alpha = \frac{12}{13}mg$ and the greatest friction is $0.3 \times \frac{12}{13}mg = 0.277mg$ Component of weight down the plane $mg \sin \alpha = \frac{5}{13}mg = 0.385mg$ $0.385mg > 0.277mg$, so friction cannot hold it: it slides * <i>Jan 2025 report: a comparison with a conclusion is needed; friction cannot move a particle up the plane.</i>	M1 A1 A1* (3)
(b)	$mg \sin \alpha - 0.3mg \cos \alpha = ma$ 1.06 ms^{-2} (1.055)	M1 A1 (2)
(c)	$\mu = \tan \alpha = \frac{5}{12}$	B1 (1)
Total for Question 5: 6 marks		



Question 6

12 marks

Part	Scheme	Marks
(a)	Perpendicular: $R + 30 \sin 20^\circ = 3g \cos 25^\circ$ $R = 16.38$ Parallel: $30 \cos 20^\circ - 3g \sin 25^\circ - 0.4R = 3a$ Correct equation 3.07 ms^{-2} <i>Jan 2023 Q8 was worth 8 marks on this structure. $R = 3g \cos 25^\circ$ (ignoring the pull) loses the first A mark and the final A mark.</i>	M1 A1 M1 A1 A1 (5)
(b)	$v^2 = 2^2 + 2 \times 3.07 \times 5$ 5.89 ms^{-1}	M1 A1 (2)
(c)	Force removed: $R = 3g \cos 25^\circ$, friction $0.4R$ now acts down the plane with the weight component Deceleration $g \sin 25^\circ + 0.4g \cos 25^\circ = 7.69$ $BC = \frac{5.89^2}{2 \times 7.69} = 2.26 \text{ m}$ (2.3)	M1 A1 A1 (3)
(d)	Compares $3g \sin 25^\circ = 12.4$ with the greatest friction $0.4 \times 3g \cos 25^\circ = 10.7$ (or $\tan 25^\circ = 0.466 > 0.4$) Weight component is larger, so the parcel does not remain at rest : it slides down	M1 A1 (2)
Total for Question 6: 12 marks		



Question 7

11 marks

Part	Scheme	Marks
(a)	$R = 4g \cos \alpha = 3.2g$ and $F = 0.25R$ $0.8g = 7.84 \text{ N}$	M1 A1 (2)
(b)	$A: T - 4g \sin \alpha - 0.8g = 4a$ $B: 5g - T = 5a$ Adding: $5g - 2.4g - 0.8g = 9a$, so $a = 0.2g$ * $T = 5(g - 0.2g) = 4g = 39.2 \text{ N}$	M1 M1 A1* A1 (4)
(c)	Angle between the two parts of the string $= 90^\circ - \alpha = 53.1^\circ$; force $= 2T \cos 26.6^\circ$ 70.1 N <i>Jan 2022 report: the angle between the string on the plane and the vertical string causes difficulty. The cosine rule on a triangle with sides T, T is equally valid.</i>	M1 A1 (2)
(d)	Speed when B lands: $v^2 = 2 \times 0.2g \times 1 = 3.92$ A now decelerates at $g \sin \alpha + 0.25g \cos \alpha = 0.8g$ $s = \frac{3.92}{2 \times 7.84} = 0.25 \text{ m}$	M1 M1 A1 (3)
Total for Question 7: 11 marks		



Question 8

11 marks

Part	Scheme	Marks
(a)	$A: T - 0.3 \times 2g = 2a; B: 3g - T = 3a$ Both correct ($R = 2g$ for A) $a = 4.7 \text{ ms}^{-2}$ (4.704) $T = 15 \text{ N}$ (15.3)	M1 A1 A1 A1 (4)
(b)	$v^2 = 2 \times 4.704 \times 1$ 3.07 ms^{-1}	M1 A1 (2)
(c)	After B lands the string is slack; friction alone decelerates A : $0.3 \times 2g = 2a, a = 2.94$ $0 = 9.408 - 2 \times 2.94s$ $s = 1.6 \text{ m}$ A travels $1 + 1.6 = 2.6 \text{ m} < 3 \text{ m}$, so it does not reach the pulley * <i>Jan 2021 report: the final inequality (the correct way round) with a conclusion is needed; using the old acceleration after B lands is M0.</i>	M1 M1 A1 A1* (4)
(d)	e.g. friction at the pulley; the mass of the string; the size of A (not a particle); the string stretching	B1 (1)
Total for Question 8: 11 marks		



Question 9

10 marks

Part	Scheme	Marks
(a)	Whole system: $2500 - 400 - 150 - 1300g \sin \alpha = 1300a$ $1300a = 1313$ 1.01 ms^{-2} <i>Oct 2019 report: omitting the weight components is M0 even if it happens to give a correct later value.</i>	M1 A1 A1 (3)
(b)	Trailer: $T - 150 - 300g \sin \alpha = 300 \times 1.01$ Correct equation 600 N	M1 A1 A1 (3)
(c)	Trailer: $150 + 300g \times \frac{1}{20} = 300d, d = 0.99 \text{ ms}^{-2}$ $0 = 20^2 - 2 \times 0.99 \times s$ 202 m (200)	M1 M1 A1 (3)
(d)	e.g. resistances such as air resistance increase with speed, so they are unlikely to be constant	B1 (1)
Total for Question 9: 10 marks		



Question 10

12 marks

Part	Scheme	Marks
(a)	$\sin \alpha = \frac{3}{5}, \cos \alpha = \frac{4}{5}; R = \frac{4}{5}mg$ Up the plane: $-mg \sin \alpha - 0.5R = ma$ $-\frac{3}{5}mg - \frac{2}{5}mg = ma$ Deceleration $g \text{ ms}^{-2}$ *	B1 M1 A1 A1* (4)
(b)	$\frac{14^2}{2g} = \boxed{10 \text{ m}}$	B1 (1)
(c)	Compares $mg \sin \alpha = 0.6mg$ with the greatest friction $0.5 \times 0.8mg = 0.4mg$ (or $\tan \alpha = 0.75 > 0.5$) $0.6mg > 0.4mg$, so P slides down *	M1 A1* (2)
(d)	Down the plane, friction now acts up: $mg \sin \alpha - 0.4mg = ma$ $a = 0.2g = 1.96$ $v^2 = 2 \times 1.96 \times 10$: $\boxed{6.26 \text{ ms}^{-1}}$	M1 A1 A1 (3)
(e)	Straight line from 14 down to 0 at $t = \frac{10}{7} \approx 1.43$, then a less steep straight line to -6.26 at $t \approx 1.43 + 3.19 = 4.62$ Values marked; the second line is less steep and continues below the axis with no vertical jump	B1 B1 (2)
Total for Question 10: 12 marks		



6

Chapter 6: Momentum and Impulse

Mark scheme. Marks are shown on the right of each line.

Question 1

6 marks

Part	Scheme	Marks
(a)	$25\,000 \times 3 - 15\,000 \times 1 = 40\,000v$ 1.5ms^{-1} in the original direction of A	M1 A1 A1 (3)
(b)	Impulse on B: $15\,000(1.5 - (-1))$ 37 500 $37\,500\text{Ns}$ <i>Oct 2022 report: the units are required. Using $1.5 - 1$ (ignoring the change of direction) is M0.</i>	M1 A1 A1 (3)
Total for Question 1: 6 marks		

Question 2

6 marks

Part	Scheme	Marks
(a)	$I = 0.2(8 - (-12))$ (towards the wall negative) Correct 4Ns <i>0.2(12 - 8) = 0.8 ignores the change of direction: M0.</i>	M1 A1 A1 (3)
(b)	$4 = F \times 0.05$ 80N	M1 A1 (2)
(c)	$4\text{Ns towards the wall}$ (Newton's third law)	B1 (1)
Total for Question 2: 6 marks		



Question 3

6 marks

Part	Scheme	Marks
(a)	$3 \times 5 - 2 \times 2 = 3 \times 1 + 2v$ 4 ms^{-1} Direction reversed (now in the original direction of P) <i>Jan 2021 report: failing to account for the opposite initial directions.</i>	M1 A1 A1 (3)
(b)	$3(5 - 1)$ 12 N s	M1 A1 (2)
(c)	12 N s : equal and opposite to the impulse on P (or $2(4 - (-2)) = 12$)	B1 (1)
Total for Question 3: 6 marks		

Question 4

6 marks

Part	Scheme	Marks
(a)	The string is inextensible, so once taut A and B must move together $2 \times 6 = 5v$ 2.4 ms^{-1} <i>Oct 2019 report: not realising that the particles move with the same speed in the same direction.</i>	B1 M1 A1 (3)
(b)	3×2.4 7.2 N s	M1 A1 (2)
(c)	No friction, so the speed of A is still 6 ms^{-1} when the string becomes taut (no external impulse)	B1 (1)
Total for Question 4: 6 marks		



Question 5

6 marks

Part	Scheme	Marks
(a)	$-\lambda mu = 2m(-u) - 2m(3u)$ $\lambda mu = 8mu$ $\lambda = 8$	M1 A1 A1 (3)
(b)	$-4mu = 2mv - 6mu, v = u$ speed u , in the original direction	M1 A1 (2)
(c)	$2m(3u) - \lambda mu < 0: \lambda > 6$	B1 (1)
Total for Question 5: 6 marks		

Question 6

10 marks

Part	Scheme	Marks
(a)	Friction deceleration $0.25g = 2.45 \text{ ms}^{-2}$ $v^2 = 6^2 - 2 \times 2.45 \times 2$ 5.12 ms^{-1} <i>Jan 2025 report: the initial speed must be used in $v^2 = u^2 + 2as$.</i>	B1 M1 A1 (3)
(b)	$0.4 \times 5.119 = 0.4 \times 0.5 + 0.6v$ 3.08 ms^{-1}	M1 A1 (2)
(c)	0.6×3.079 (or $0.4(5.119 - 0.5)$) 1.85 N s	M1 A1 (2)
(d)	Both decelerate at 2.45 ms^{-2} : A travels $\frac{0.5^2}{4.9} = 0.051 \text{ m}$ B travels $\frac{3.079^2}{4.9} = 1.935 \text{ m}$ Distance apart = 1.88 m	M1 M1 A1 (3)
Total for Question 6: 10 marks		



Question 7

10 marks

Part	Scheme	Marks
(a)	$2m \times 4u = 2m \times u + mv$ $6u$	M1 A1 (2)
(b)	$2m(4u - u)$ $6mu$	M1 A1 (2)
(c)	$m \times 6u = m \times ku + 3mw$ $w = \frac{(6-k)u}{3}$	M1 A1 (2)
(d)	B does not catch C: $ku \leq \frac{(6-k)u}{3}$, so $k \leq \frac{3}{2}$ A does not catch B: $u \leq ku$, so $k \geq 1$ Both conditions, with the correct inequalities $1 \leq k \leq \frac{3}{2}$ Equal speeds give no further collision (the particles stay a fixed distance apart), so the inequalities include equality.	M1 M1 A1 A1 (4)
Total for Question 7: 10 marks		



Question 8

10 marks

Part	Scheme	Marks
(a)	$v^2 = 2 \times 9.8 \times 5$	M1
	9.9 ms^{-1} ($7\sqrt{2}$)	A1
		(2)
(b)	$400 \times 9.9 = 500V$	M1
	7.9 ms^{-1} (7.92)	A1
		(2)
(c)	100×7.92	M1
	792 N s (790)	A1
		(2)
(d)	$0 = 7.92^2 - 2a \times 0.2$, $a = 156.8$ (deceleration)	M1
	Equation of motion for hammer and pile: $R - 500g = 500 \times 156.8$	M1
	Correct equation	A1
	83300 N ($8.33 \times 10^4 \text{ N}$)	A1
	<i>Omitting the weight 500g is the common error; the resistance must stop the weight as well as the motion.</i>	
		(4)
Total for Question 8: 10 marks		



Question 9

10 marks

Part	Scheme	Marks
(a)	$3 \times 4 = 3 \times 2 + 1 \times v$ 6 ms^{-1}	M1 A1 (2)
(b)	$1(3 - (-6))$ 9 N s	M1 A1 (2)
(c)	B reaches the wall after 1.5 s, when A is 3 m from the first collision point (6 m from the wall) After that: $6 = 2t + 3t$, so $t = 1.2 \text{ s}$ Time between collisions $1.5 + 1.2 = 2.7 \text{ s}$ Distance from the wall $3 \times 1.2 = 3.6 \text{ m}$	M1 M1 A1 A1 (4)
(d)	$3 \times 2 + 1 \times (-3) = 4V$ 0.75 ms^{-1} towards the wall	M1 A1 (2)
Total for Question 9: 10 marks		



Question 10

11 marks

Part	Scheme	Marks
(a)	$2m(3u - (-u)) = 8mu$ It depends only on the mass and velocities of P , which are all known	B1 B1 (2)
(b)	$2m(3u) - km(u) = 2m(-u) + kmv$ Correct equation $v = \frac{(8-k)u}{k}$ Or: the impulse on Q is $8mu$ in the positive direction, so $km(v+u) = 8mu$.	M1 A1 A1 (3)
(c)	Reversed means $v > 0$: $8 - k > 0$ $0 < k < 8$	M1 A1 (2)
(d)	$\frac{8-k}{k} = 3$ $k = 2$	M1 A1 (2)
(e)	Deceleration $0.5g$; $0 = (3u)^2 - 2(0.5g)s$ $\frac{9u^2}{g}$	M1 A1 (2)
Total for Question 10: 11 marks		



7

Chapter 7: Statics of a Particle

Mark scheme. Marks are shown on the right of each line.

Question 1

6 marks

Part	Scheme	Marks
	Horizontally: $T_A \cos 30^\circ = T_B \cos 45^\circ$	M1
	Correct	A1
	Vertically: $T_A \sin 30^\circ + T_B \sin 45^\circ = 4g$	M1
	Correct	A1
	Solves: $T_A = 28.7 \text{ N}$	A1
	$T_B = 35.1 \text{ N}$	A1
	<i>Jan 2022 report: the weight is 4g, not 4. The triangle of forces (sine rule with angles 45°, 60°, 75°) is equally valid.</i>	
		(6)
Total for Question 1: 6 marks		

Question 2

6 marks

Part	Scheme	Marks
(a)	$3 + p - 5 = 0$ and $-4 + 2 + q = 0$	M1
	$p = 2, q = 2$	A1
		(2)
(b)	Resultant of the other two forces = $-(-5\mathbf{i} + 2\mathbf{j}) = 5\mathbf{i} - 2\mathbf{j}$	M1
	$\mathbf{a} = \frac{1}{2}(5\mathbf{i} - 2\mathbf{j}) = 2.5\mathbf{i} - \mathbf{j}$	A1
	2.69 ms^{-2}	A1
	21.8° below $\mathbf{i}$ (towards $-\mathbf{j}$)	A1
		(4)
Total for Question 2: 6 marks		



Question 3

6 marks

Part	Scheme	Marks
(a)	$R + 20 \sin \theta = 40$ with $\sin \theta = \frac{3}{5}$ 28 N	M1 A1 (2)
(b)	Horizontally: $F = 20 \cos \theta = 16$ At rest: $F \leq \mu R$, so $16 \leq 28\mu$ $\mu \geq \frac{16}{28} = \frac{4}{7}$ * <i>Using $F = \mu R$ (an equation) instead of the inequality loses the A mark (Jan 2018 scheme).</i>	B1 M1 A1* (3)
(c)	Limiting equilibrium: P is on the point of slipping	B1 (1)
Total for Question 3: 6 marks		

Question 4

6 marks

Part	Scheme	Marks
(a)	East-west: $Q = 12 \sin 120^\circ$ $Q = 6\sqrt{3}$ (10.4)	M1 A1 (2)
(b)	North-south: $P + 12 \cos 120^\circ = 0$, i.e. $P = 12 \cos 60^\circ$ $P = 6$ <i>A diagram with north marked avoids the sign error in the component $12 \cos 120^\circ = -6$.</i>	M1 A1 (2)
(c)	East-west: $12 \sin \phi = 6$ with the bearing ϕ between 090° and 180° bearing 150° , and $P = -12 \cos 150^\circ = 6\sqrt{3}$ (10.4)	M1 A1 (2)
Total for Question 4: 6 marks		



Question 5

6 marks

Part	Scheme	Marks
(a)	Limiting: $2g \sin \alpha = \mu \times 2g \cos \alpha$ $\mu = \tan \alpha = \frac{7}{24}$ *	M1 A1* (2)
(b)	About to move up: $P = 2g \sin \alpha + \mu \times 2g \cos \alpha$ $= 2g \left(\frac{7}{25} + \frac{7}{24} \times \frac{24}{25} \right)$ 11.0N (11)	M1 A1 A1 (3)
(c)	Down the plane, opposing the direction in which the particle is about to move	B1 (1)
Total for Question 5: 6 marks		

Question 6

10 marks

Part	Scheme	Marks
(a)	Perpendicular to the plane: $R + \frac{1}{2}mg \sin 30^\circ = mg \cos \alpha$ $R = \frac{4}{5}mg - \frac{1}{4}mg$ $R = \frac{11}{20}mg$ Jan 2025 report: $R = mg \cos \alpha$, ignoring the effect of the string, is the most common error.	M1 A1 A1 (3)
(b)	Parallel: $F + \frac{1}{2}mg \cos 30^\circ = mg \sin \alpha$, so $F = \frac{3}{5}mg - \frac{\sqrt{3}}{4}mg$ Correct F Limiting: $F = \mu R$, $\mu = \frac{\frac{3}{5} - \frac{\sqrt{3}}{4}}{\frac{11}{20}}$ $= \frac{12 - 5\sqrt{3}}{11}$ *	M1 A1 M1 A1* (4)
(c)	$\mu = 0.304 < \tan \alpha = 0.75$ (or $0.6mg > 0.304 \times 0.8mg$), so it slides $mg \sin \alpha - \mu mg \cos \alpha = ma$ 3.50 ms^{-2}	B1 M1 A1 (3)
Total for Question 6: 10 marks		



Question 7

10 marks

Part	Scheme	Marks
(a)	Tension in the horizontal string = $3g$ (smooth pulley) Horizontally: $T \sin \theta = 3g$; vertically: $T \cos \theta = 4g$ Both correct $\tan \theta = \frac{3}{4}$: $\theta = 36.9^\circ$ $T = 5g = 49 \text{ N}$	B1 M1 A1 A1 A1 (5)
(b)	$\tan 45^\circ = \frac{Mg}{4g}$ $M = 4$	M1 A1 (2)
(c)	The tension is the same on both sides of the pulley, so it equals the weight $3g$ of the hanging particle	B1 (1)
(d)	Two perpendicular tensions of $3g$: $3g\sqrt{2}$ 41.6 N	M1 A1 (2)
Total for Question 7: 10 marks		



Question 8

11 marks

Part	Scheme	Marks
(a)	Least P: on the point of slipping down, friction up the plane Perpendicular: $R = 2g \cos \alpha + P \sin \alpha$ Parallel: $P \cos \alpha + 0.25R = 2g \sin \alpha$ $0.8P + 0.25(15.68 + 0.6P) = 11.76$ $P = 8.25$ (8.3)	B1 M1 M1 A1 A1 (5)
(b)	Greatest P: about to slip up, friction down: $P \cos \alpha = 2g \sin \alpha + 0.25R$ Correct equation with $R = 2g \cos \alpha + P \sin \alpha$ $0.65P = 15.68$ $P = 24.1$ (24)	M1 A1 M1 A1 (4)
(c)	$P \cos \alpha - 2g \sin \alpha = 12 - 11.76$ $0.24 \text{ N, acting down the plane}$ <i>The particle is not in limiting equilibrium here: friction is only as large as it needs to be</i> ($0.24 < 0.25 \times 24.68$).	M1 A1 (2)
Total for Question 8: 11 marks		



Question 9

10 marks

Part	Scheme	Marks
(a)	Vertically: $R + 1.5 \sin 30^\circ = 0.4g$, $R = 3.17$ Friction needed = $1.5 \cos 30^\circ = 1.30 \text{ N}$ Greatest friction $\mu R = 0.5 \times 3.17 = 1.585$ $1.30 < 1.585$ so the ring stays at rest; friction 1.30 N	M1 A1 M1 A1 (4)
(b)	Limiting with R upwards: $P \cos 30^\circ = 0.5(0.4g - P \sin 30^\circ)$ Correct equation $P(\cos 30^\circ + 0.25) = 1.96$ $P = 1.76$	M1 A1 M1 A1 (4)
(c)	When $P \sin 30^\circ > 0.4g$ the pull lifts the ring against the rod, so the rod pushes down: $R = P \sin 30^\circ - 0.4g$ Then limiting needs $P \cos 30^\circ \leq 0.5(0.5P - 3.92)$, i.e. $0.616P \leq -1.96$, which is impossible, so the ring moves	B1 B1 (2)
Total for Question 9: 10 marks		



Question 10

11 marks

Part	Scheme	Marks
(a)	$R = 5g \cos \alpha = \frac{60}{13}g$ and the greatest friction $0.2R = \frac{12}{13}g$ Least M : A about to slip down, friction up the plane: $Mg + \frac{12}{13}g = 5g \sin \alpha$ $Mg + \frac{12}{13}g = \frac{25}{13}g$ $M = 1$ *	B1 M1 A1 A1* (4)
(b)	Greatest M : about to slip up, friction down: $Mg = \frac{25}{13}g + \frac{12}{13}g$ Correct $M = \frac{37}{13}$ (2.85)	M1 A1 A1 (3)
(c)	$Mg = 5g \sin \alpha$: $M = \frac{25}{13}$ (1.92)	B1 (1)
(d)	A : $T - \frac{25}{13}g - \frac{12}{13}g = 5a$; hanging particle: $4g - T = 4a$ $\frac{15}{13}g = 9a$ 1.26 ms^{-2}	M1 A1 A1 (3)
Total for Question 10: 11 marks		



8

Chapter 8: Moments

Mark scheme. Marks are shown on the right of each line.

Question 1

6 marks

Part	Scheme	Marks
(a)	$M(A): R_C \times 3 = 20g \times 2$ Correct equation $131 \text{ N} \left(\frac{40g}{3} \right)$	M1 A1 A1 (3)
(b)	$R_A + R_C = 20g$ (or $M(C): 3R_A = 20g \times 1$) $65.3 \text{ N} \left(\frac{20g}{3} \right)$	M1 A1 (2)
(c)	The weight acts at the midpoint, 2 m from A	B1 (1)
Total for Question 1: 6 marks		

Question 2

6 marks

Part	Scheme	Marks
(a)	$T_A + 1.5T_A = 50g$ $T_A = 20g = 196 \text{ N}$ $T_B = 30g = 294 \text{ N}$	M1 A1 A1 (3)
(b)	$M(A): 30g \times 4 = 30g \times 2 + 20g \times AC$ $AC = 3 \text{ m}$	M1 A1 (2)
(c)	The beam is rigid (it stays straight), so the distances do not change <i>Summer 2019 report: a comment about the beam remaining straight is all that is expected.</i>	B1 (1)
Total for Question 2: 6 marks		



Question 3

6 marks

Part	Scheme	Marks
(a)	Greatest m: on the point of tilting about D, so $R_C = 0$ $M(D): mg \times 1.5 = 20g \times 1$ $m = 13.3 \left(\frac{40}{3}\right)$ <i>Jan 2021 report: some assumed the reaction at the pivot is zero. It is the other support.</i>	B1 M1 A1 (3)
(b)	$M(C): R_D \times 2.5 = 20g \times 1.5 + 10g \times 4$ $R_D = 28g = 274 \text{ N}$ $R_C = 30g - 28g = 19.6 \text{ N}$	M1 A1 A1 (3)
Total for Question 3: 6 marks		

Question 4

6 marks

Part	Scheme	Marks
	Tilting about C means $R_D = 0$; tilting about D means $R_C = 0$ $M(C): 30 \times 1 = W(x - 1)$ $M(D): 50 \times 1 = W(3 - x)$ Adds (or eliminates x): $80 = 2W$ $W = 40$ $x = 1.75$ <i>The weight is W newtons: writing Wg is an accuracy error (Jan 2021 report).</i>	B1 M1 M1 M1 A1 A1 (6)
Total for Question 4: 6 marks		



Question 5

6 marks

Part	Scheme	Marks
(a)	Moments about A: $10\bar{x} = 2 \times 0 + 5 \times 1 + 3 \times 3$ Correct 1.4 m	M1 A1 A1 (3)
(b)	$10g = 98 \text{ N}$	B1 (1)
(c)	New balance point $\frac{14}{11} = 1.27 \text{ m from A}$ $0.127 \text{ m towards A}$	M1 A1 (2)
Total for Question 5: 6 marks		

Question 6

10 marks

Part	Scheme	Marks
(a)	M(A): $T_C \times 2.1 = 60g \times 1.5 + 40g \times 0.9$ $2.1T_C = 126g$ $T_C = 60g = 588 \text{ N}^*$	M1 A1 A1* (3)
(b)	$100g - 60g = 392 \text{ N}$	B1 (1)
(c)	$2.1T_C = 90g + 40gd$ with $T_C \leq 800$ $882 + 392d \leq 1680$ 2.04 m	M1 A1 A1 (3)
(d)	On the point of tilting about C: tension at A is 0 M(C): $Mg \times 0.9 = 60g \times 0.6$ $M = 40$ <i>Jan 2025 report: using the tension from earlier parts instead of zero at A is the common error.</i>	B1 M1 A1 (3)
Total for Question 6: 10 marks		



Question 7

10 marks

Part	Scheme	Marks
(a)	$M(C): R_D \times 3 = 30g \times 2 + 70g \times 1.5$ Correct equation $R_D = 55g = \boxed{539 \text{ N}}$ $R_C = 100g - 55g = \boxed{441 \text{ N}}$	M1 A1 A1 A1 (4)
(b)	Man near A, about to tilt about C ($R_D = 0$): $70g(1 - x) = 30g \times 2$ $x = \frac{1}{7} = 0.143$ Man near B, about to tilt about D ($R_C = 0$): $70g(x - 4) = 30g \times 1$ $x = \frac{31}{7} = 4.43$ $\boxed{0.143 \leq x \leq 4.43}$ (m from A)	M1 A1 M1 A1 A1 (5)
(c)	e.g. his weight is taken to act at one point, but his feet cover a length of the plank, so the limits are approximate	B1 (1)
Total for Question 7: 10 marks		

Question 8

11 marks

Part	Scheme	Marks
(a)	$R_C + R_D = 18g$ and $R_C = 2R_D$ $R_D = 6g, R_C = 12g$ $M(A): 12g \times 1.5 + 6g \times 5 = 18g \times x$ Correct equation $x = \frac{8}{3} = 2.67 \text{ m}$	M1 A1 M1 A1 A1 (5)
(b)	About to tilt about D: $R_C = 0$ $M(D): mg \times 1 = 18g \left(5 - \frac{8}{3}\right)$ $\boxed{42 \text{ kg}}$	B1 M1 A1 (3)
(c)	$R_C = R_E = 11.5g$ $M(A): 11.5g \times 1.5 + 11.5g \times AE = 18g \times \frac{8}{3}$ $\boxed{AE = 2.67 \text{ m}}$	B1 M1 A1 (3)
Total for Question 8: 11 marks		



Question 9

10 marks

Part	Scheme	Marks
(a)	$M(C): 30g \times 2.5 = 20g \times 0.5 + mg \times 3.5$ Correct equation $m = 18.6 \left(\frac{130}{7} \right)$	M1 A1 A1 (3)
(b)	$(30 + 20 + m)g$ $672 \text{ N} \quad (670)$	M1 A1 (2)
(c)	$M(C): 30g \times 2 = 20g \times 0.5 + mg \times y$ $y = \frac{50}{m} = \frac{35}{13} = 2.69 \text{ m from } C$ Moves $3.5 - 2.69 = 0.808 \text{ m}$	M1 A1 A1 (3)
(d)	Any two: the plank is not exactly uniform; the children are not particles; the plank may bend; the pivot has a width	B2 (2)
Total for Question 9: 10 marks		



Question 10

11 marks

Part	Scheme	Marks
(a)	The bolt pulls the board down at A $M(C): F \times 1 = 40g \times 1 + 60g \times 3$ $F = 220g = \boxed{2160 \text{ N}}$ (2156) Vertically: $R_C = F + 100g$ $320g = \boxed{3140 \text{ N}}$ (3136) <i>Taking the bolt force upwards gives a negative answer; it must be interpreted as downwards.</i>	B1 M1 A1 M1 A1 (5)
(b)	$M(C): 40g + 3mg \leq 2500$ $m \leq \frac{2500/9.8 - 40}{3}$ $\boxed{71.7 \text{ kg}}$	M1 A1 A1 (3)
(c)	$M(C): 2000 = 40g(x - 1) + 60g \times 3$ $392(x - 1) = 236$ $\boxed{x = 1.60}$	M1 A1 A1 (3)
Total for Question 10: 11 marks		

