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EDEXCEL INTERNATIONAL A LEVEL MATHS: QUESTIONS BY TOPIC

Momentum & Impulse (M1.5)

International A Level Mathematics · M1: Mechanics 1 (WME01)

16 questions · 114 marks · Mark schemes included

Past papers January 2020 - June 2025 · 1 sub-topic

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HOW TO USE THIS BOOKLET

Questions are grouped by sub-topic and run from the lowest to the highest mark tariff, then oldest paper first.

Click any row below to jump straight to that sub-topic or question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme; < QUESTION brings you back.

A gold bar in the left margin marks exactly where the question sits on the original page.

Diagrams, graphs, grids and tables are printed exactly as they appear in the original papers.

Each question is filed under its main topic; longer questions may also test skills from other topics.

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QUESTIONS

16 questions · 114 marks · 1 sub-topic

SUB-TOPIC M1.5a

MOMENTUM, IMPULSE & COLLISIONS

Sub-topic M1.5a · 16 questions · 114 marks · lowest tariff first



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- Two particles, P and Q , are moving towards each other in opposite directions along the same straight line when they collide directly. Immediately before the collision the speed of Q is $2u$. The mass of Q is $3m$ and the magnitude of the impulse exerted by P on Q in the collision is $4mu$.

Find

- (a) the speed of Q immediately after the collision,

- (b) the direction of motion of Q immediately after the collision.

Question 1 continued

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Lined area for writing the answer to Question 1.

(Total 4 marks)

Q1



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1. A railway truck S of mass 20 tonnes is moving along a straight horizontal track when it collides with another railway truck T of mass 30 tonnes which is at rest. Immediately before the collision the speed of S is 4 ms^{-1}

As a result of the collision, the two railway trucks join together.

Find

- (a) the common speed of the railway trucks immediately after the collision, (2)

- (b) the magnitude of the impulse exerted on S in the collision, stating the units of your answer.
- (3)**

Question 1 continued

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(Total 5 marks)

Q1



Question 1 continued

Lined area for writing the answer to Question 1.

(Total for Question 1 is 5 marks)



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2. Two particles, P and Q , have masses $2m$ and m respectively. The particles are moving towards each other in opposite directions along the same straight line on a smooth horizontal plane. The particles collide directly.

Immediately before the collision, the speed of P is $3u$ and the speed of Q is $2u$.

The magnitude of the impulse exerted on Q by P in the collision is $5mu$.

Find

- (a) the speed of P immediately after the collision, (3)
- (b) the speed of Q immediately after the collision. (3)

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Q2

(Total for Question 2 is 6 marks)



Question 1 continued

Lined area for writing the answer to Question 1.

(Total for Question 1 is 6 marks)



Question 1 continued

Lined area for writing the answer to Question 1.

(Total for Question 1 is 6 marks)



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- Two particles, P and Q , with masses m and $2m$ respectively, are moving in the same direction along the same straight line when they collide directly. Immediately before they collide, P is moving with speed $4u$ and Q is moving with speed u . Immediately after they collide, both particles are moving in the same direction and the speed of Q is four times the speed of P .

- (a) Find the speed of Q immediately after the collision.

(3)

- (b) Find the magnitude of the impulse exerted by Q on P in the collision.

(3)

- (c) State clearly the direction of this impulse.

(1)

Question 1 continued

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Handwriting practice area with 30 horizontal lines.

(Total 7 marks)

Q1



Question 1 continued

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Handwriting practice area with horizontal lines.

(Total 7 marks)

Q1



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2. A particle P has mass km and a particle Q has mass m . The particles are moving towards each other in opposite directions along the same straight line when they collide directly.

Immediately before the collision, P has speed $3u$ and Q has speed u .

As a result of the collision, the direction of motion of each particle is reversed and the speed of each particle is halved.

- (a) Find the value of k .

(4)

- (b) Find, in terms of m and u , the magnitude of the impulse exerted on Q in the collision.

(3)

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Q2

Question 1 continued

Lined area for writing the answer to Question 1.

(Total for Question 1 is 7 marks)



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Q1

2. Two particles, A and B , are moving in a straight line in opposite directions towards each other on a smooth horizontal surface when they collide directly.

Particle A has mass $3m$ kg and particle B has mass m kg.

Immediately before the collision, both particles have a speed of 1.5 m s^{-1}

Immediately after the collision, the direction of motion of A is unchanged and the difference between the speed of A and speed of B is 1 m s^{-1}

- (a) Find
- (i) the speed of A immediately after the collision,
 - (ii) the speed of B immediately after the collision.

(5)

- (b) Find, in terms of m , the magnitude of the impulse exerted on B in the collision.

(3)

Question 2 continued

(Total for Question 2 is 8 marks)



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Question 2 continued

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Lined area for writing the answer to Question 2 continued.



Question 2 continued

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Lined area for writing the answer to Question 2.

(Total 10 marks)

Q2



3. A hammer is used to hit a tent peg into soft ground.

The hammer has mass 1.8 kg and the tent peg has mass 0.2 kg .

The hammer and tent peg are both modelled as particles and the impact is modelled as a direct collision.

Immediately before the impact, the tent peg is stationary and the hammer is moving vertically downwards with speed 10 ms^{-1}

Immediately after the impact, the hammer and tent peg move together, vertically downwards, with the **same** speed $v \text{ m s}^{-1}$

- (a) Find the value of v (2)

- (b) Find the magnitude of the impulse exerted on the tent peg by the hammer, stating the units of your answer. (3)

The ground exerts a constant vertical resistive force of magnitude R newtons, bringing the hammer and tent peg to rest after they travel a distance of 12 cm.

- (c) Find the value of R . (5)

Question 3 continued

Lined area for writing the answer to Question 3 continued.



Question 3 continued

Lined area for writing the answer to Question 3 continued.



(Total for Question 3 is 10 marks)

Question 3 continued

Lined area for writing the answer to Question 3 continued.



Question 3 continued

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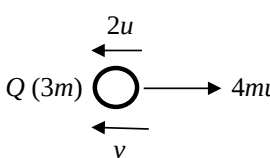


(Total for Question 3 is 12 marks)

MARK SCHEMES

official mark schemes, in the same order as the questions



Question Number	Scheme	Marks
1.		
1(a)	$-4mu = 3m(v - 2u)$ or $4mu = 3m(-v + 2u)$ or $-4mu = 3m(-v - 2u)$ or $4mu = 3m(v + 2u)$	M1A1
	speed is $\frac{2}{3}u$, $0.67u$ or better	A1
		(3)
1(b)	Same as its original direction or direction is unchanged or just 'unchanged' or 'same direction' or 'it is the same'. Allow 'opposite to P's original direction' or 'towards P' Apply isw if they add 'east' or 'to the left' etc ('motion of Q is unchanged' is B0)	DB1
		(1)
		(4)
	Notes for question 1	
1(a)	M1 impulse-momentum equation, dimensionally correct, correct no. of terms, condone sign errors but must be attempting a difference of momenta. Allow if they use m instead of $3m$.	
	A1 Correct equation (v may be replaced by $-v$)	
	A1 cao (must be positive)	
1(b)	DB1 Dependent on obtaining either $\frac{2}{3}u$ or $-\frac{2}{3}u$ for v in (a).	

Question Number	Scheme	Marks
1.		
1(a)	$20000 \times 4 = 50000v$ $v = 1.6(\text{m s}^{-1})$	M1 A1
	OR $20(-v - (-4)) = 30(v - 0)$	(2)
1(b)	$\pm 20000(1.6 - 4)$ OR $\pm 30000 \times 1.6$	M1A1ft
	48000 N s or 48 kN s	A1
	.	(3)
		(5)
	Notes for question 1	
1(a)	M1 for a CLM equation, condone sign errors and extra g 's and any equivalent equation (e.g. $2 \times 4 = 5v$, $20 \times 4 = 50v$, $200 \times 4 = 500v$,... etc) OR : for equating impulses	
	A1 oe Units not needed but must be positive .	
1(b)	M1 impulse-momentum equation, dimensionally correct, correct no. of terms, condone sign errors but must be attempting a difference of momenta (allow 20 or 30 for the mass, M0 if g included or mass omitted)	
	A1ft a correct equation, follow through on their v (allow 20 or 30 for the mass) N.B. If using S to find the impulse, 4 and their v must have opposite signs when awarding the A1ft.	
	A1 cao units needed (allow kg m s^{-1}) and must be positive.	

Question Number	Scheme	Marks
1.		
(a)	CLM: oe $mU = mS + 3mS$ OR $A: -I = m(S - U)$ and $B: I = 3mS$ <u>AND</u> eliminate I to give $-3mS = m(S - U)$ oe	M1
	$S = \frac{1}{4}U$ or $0.25 U$	A1 (2)
(b)	For A: $\pm m(\frac{1}{4}U - U)$	M1A1ft
	$\frac{3}{4}mU$	A1 (3)
Alternative	For B: $\pm 3m\frac{1}{4}U$	M1A1ft
	$\frac{3}{4}mU$	A1 (3)
		(5)
	Notes	
1(a)	M1: CLM equation with correct terms, condone sign errors and cancelled m 's or consistent extra g 's N.B. If they use 2 impulse-momentum equations, each equation must have the correct terms but condone sign errors. They must then eliminate the impulse to produce an equation in m , U and S only. N.B. Allow the use of v or similar for S in the working but must use S for their answer.	
	A1: cao (A0 if m 's not cancelled)	
1(b)	M1: Impulse-momentum for A or B, with correct terms, condone sign errors and allow S for final speed but M0 if m omitted or extra g	
	A1ft: Correct expression in terms of m and U , ft on the magnitude of their S .	
	A1 cao (must be positive and a multiple of mU)	

QUESTION NUMBER	SCHEME	MARKS
2	Before $\xrightarrow{3}$ $\xleftarrow{x}$  After $\xrightarrow{1}$ $\xrightarrow{1.5}$	
2(a)	CLM $(5 \times 3) - x^2 = (5 \times 1) + (x \times 1.5)$ OR: $5(-1 - -3) = x(1.5 - -x)$	M1A1
	$x = 2.5$	A1
		(3)
2(b)	$I = \pm 5(1 - 3)$ or $I = \pm 2.5(1.5 - -2.5)$ ($I = \pm x(1.5 - -x)$)	M1A1
	$ I = 10$ (Ns)	A1
		(3)
		(6)
	Notes for question 2	
(a) M1	Forms CLM equation OR equates impulses, condone sign errors and extra g 's and any correct cancellation, to give an equation in x only.	
A1	Correct unsimplified equation	
A1	Correct answer. If -4 is seen, it must be rejected. (ignore units)	
(b) M1	Impulse-momentum equation, dimensionally correct, correct no. of terms for A or B . Condone sign errors but must be <i>attempting</i> a difference of momenta e.g. allow if they first state $I = \pm m(v - u)$ but then make a sign error and end up with a sum. If they clearly add the momenta, and there is no formula stated, M0. x does not need to be substituted. M0 if g is included.	
A1	Correct numerical expression.	
A1	cao must be positive. Ignore missing or wrong units. A0 if both 10 and another answer are given.	

Q	Scheme	Marks	Notes
1			
(a)	Use of CLM Or equating impulses	M1	Dimensionally correct. Condone sign errors and allow missing m 's and extra g 's.
	$(4m \times 2x) - 3mx = (3m \times 5y) - 4my$ Or: $3m(5y - x) = 4m(y - 2x)$	A1	Correct unsimplified equation and must see all 4 terms but allow missing m 's.
	$y = \frac{5}{11}x$ *	A1*	Obtain given answer from correct working with m 's seen. Allow $y = \frac{5x}{11}$ but A0 if x is <i>clearly</i> in the denominator of the fraction.
		[3]	
(b)	Use of $I = mv - mu$	M1	Dimensionally correct. Condone sign errors and y not substituted but mass and velocities must match. M0 if m is used for mass or g is included or m is missing.
	$\pm 3m \left(\frac{25}{11}x + x \right)$ or $\left(\pm 4m \left(\frac{5}{11}x + 2x \right) \right)$	A1	Correct unsimplified expression
	$\frac{108}{11}mx$ oe	A1	$9.8mx$ or better ($9.8181..mx$), must be positive.
		[3]	
		(6)	

1a	Impulse on Q or equivalent complete method to obtain v in terms of u :	M1	Complete method to form an equation in (m) , v and u only. N.B. allow consistent missing m 's. Include all relevant terms. Dimensionally correct. Condone sign errors. Need to have correct masses and speeds and pairings.
	$4.5mu = 3mv - 3m \times 2u$	A1	Correct unsimplified equation
	$v = 3.5u$ oe	A1	Correct answer only. A0 for $10.5u/3$.
		(3)	
1b	Impulse on P or CLM OR Impulse on Q AND CLM	M1	Complete method to form an equation in (m) , k and (u) only. N.B. allow consistent missing m 's and/or u 's. Include all relevant terms. Dimensionally correct Condone sign errors. If using CLM only, must have found and be using a v in terms of u .
	$-4.5mu = km \times 2u - km \times 5u$ OR $km \times 5u + 3m \times 2u = km \times 2u + 3m \times 3.5u$	A1	Correct unsimplified equation
	$k = 1.5$ oe	A1	Correct answer only
	N.B. They may do (b) first, using the impulse on P , then use their k value in CLM to answer (a). All marks available.		
		(3)	
		(6)	

Q	Scheme	Marks	Notes
	Allow column vectors throughout apart from in the answers to (a) and (b).		
2a	Use of $\frac{1}{3}(10\mathbf{i} + 4\mathbf{j} - (-5\mathbf{i} + 16\mathbf{j}))$	M1	Condone subtraction in the wrong order and missing brackets
	$= (5\mathbf{i} - 4\mathbf{j})(\text{ms}^{-1})$	A1	Correct only
		(2)	
2b	$\{-5\mathbf{i} + 16\mathbf{j} - 2(5\mathbf{i} - 4\mathbf{j})\} + t(5\mathbf{i} - 4\mathbf{j})$ OR $\{10\mathbf{i} + 4\mathbf{j} - 5(5\mathbf{i} - 4\mathbf{j})\} + t(5\mathbf{i} - 4\mathbf{j})$	M1	Any equivalent unsimplified form using their v , with correct structure.
	$= (-15 + 5t)\mathbf{i} + (24 - 4t)\mathbf{j}$	A1	Correct simplified form
		(2)	
2c	Finding AB (or BA) at $t = 5$ (AB = $-5\mathbf{i} - 12\mathbf{j}$) Must use given r at $t = 5$.	M1	Seen or implied, allow slips.
	e.g. $\theta = \tan^{-1}(\pm \frac{5}{12})$ or $\tan^{-1}(\pm \frac{12}{5})$ or $\sin^{-1}(\pm \frac{5}{13})$ or $\sin^{-1}(\pm \frac{12}{13})$ etc etc	M1	Correct use of trig to find a relevant angle, using their AB or BA , seen or implied
	Bearing $203(^{\circ})$	A1	Correct only, to nearest degree.
		(3)	
		(7)	

Question Number	Scheme	Marks
1(a)	$P(m)$ $Q(2m)$ $\xrightarrow{4u}$ $\xrightarrow{u}$ $\xleftarrow{v}$ $\xrightarrow{4v}$	
	CLM: $4mu + 2mu = mv + 2m \times 4v$	M1 A1
	$4v = \frac{8u}{3}$ ($2.7u$ or better)	A1
		(3)
(b)	$\pm m(v - 4u)$ OR $\pm 2m(4v - u)$	M1 A1ft
	$\frac{10mu}{3}$ ($3.3mu$ or better)	A1
		(3)
(c)	Opposite to the direction of motion	B1
		(1)
		(7)
Notes for Question 1		
1(a)	M1 Correct number of terms, dimensionally correct, condone sign errors Allow even if they assume that both are moving with the same speed after the collision.	
	A1 Correct equation, allow cancelled m 's or consistent extra g 's	
	A1 Correct answer (must be positive as it's a speed) and a single term.	
1(b)	M1 Dimensionally correct imp-momentum equation (M0 if g is included), with correct terms, condone sign errors, but must be a difference of momenta and must be using EITHER m and $4u$ and their v_P OR $2m$ and u and their v_Q	
	A1ft Correct expression, in terms of m and u , follow their v_P or v_Q A0ft if they assume that both move with the same speed after the collision	
	A1 cao Must be positive as it's a magnitude	
1(c)	B1 Any clear equivalent	

Q	Solution	Mark	Notes
1.	either $\rightarrow u$ $\rightarrow 3u$ or $\leftarrow u$ $\rightarrow 3u$		
(a)	$\pm 5m(3u - (-2u))$	M1	Use of $I = m(v - u)$ seen or implied, with correct terms. Condone sign errors. M0 if g included
	$25mu$	A1	Must be positive
		(2)	
(b)	Use of CLM	M1	Or equal and opposite impulses. Requires all terms dimensionally correct. Condone sign errors.
	$3mku - 10mu = 3mu + 15mu$ or $3mku - 10mu = -3mu + 15mu$	A1	Correct unsimplified equation for either case.
	$\Rightarrow k = \frac{28}{3}$ or $k = \frac{22}{3}$	A1	One correct value. Any equivalent form. Accept decimal to 1dp or better.
	Equation for second value	M1	Their equation from M1 above with the final direction of P reversed.
	Second value correct.	A1	Any equivalent form. Accept decimal to 1dp or better.
		(5)	
		[7]	

Question Number	Scheme	Marks
2(a)		
	CLM: $km \times 3u - mu = -km \times \frac{3}{2}u + m \times \frac{1}{2}u$	M1 A1 A1
	$k = \frac{1}{3}$	A1
		(4)
2(b)	$I = m \left(\frac{1}{2}u - -u \right)$ OR $I = \frac{1}{3}m \left(\frac{3}{2}u - -3u \right)$	M1 A1
	$I = \frac{3}{2}mu$ must be positive	A1
		(3)
		(7)
	Notes for question 2	
2(a)	M1 Correct no. of terms, dim correct, condone sign errors but structure must be correct – allow consistently cancelled m 's or extra g 's	
	A1 Correct equation with one error	
	A1 Correct equation	
	A1 Allow 0.33 or better	
2(b)	M1 Condone sign errors but must have masses and speeds paired correctly and must be attempting a difference of momenta. Allow M1 if k is not substituted. M0 if g included	
	A1 Allow $\pm m \left(\frac{1}{2}u - -u \right)$ OR $\pm \frac{1}{3}m \left(\frac{3}{2}u - -3u \right)$ (no ft on k)	
	A1 cao Allow them to change a negative expression into a positive one	
	N.B. If they do (b) first, and obtain an impulse of magnitude I , then they do (a) : $I = km \left(\frac{3u}{2} - -3u \right)$, apply CLM scheme to their equation.	



Question Number	Scheme	Marks
1(a)	$\xrightarrow{\quad} 2u \quad 3u \xleftarrow{\quad}$ $A (4 \text{ kg}) \quad B (2 \text{ kg})$ $\xrightarrow{\quad} v \quad \xrightarrow{\quad} 2u$ CLM: $(4 \times 2u) + (-3u \times 2) = 4v + (2 \times 2u)$ OR Equating impulses: $2(2u - 3u) = 4(-v - 2u)$	M1 A1
	$\frac{1}{2}u \text{ (m s}^{-1}\text{)}$	A1
		(3)
1(b)	The direction of motion is reversed.	B1
		(1)
1(c)	OR For B: $I = \pm 2(2u - 3u)$ For A: $I = \pm 4\left(\frac{u}{2} - 2u\right)$	M1 A1
	$I = 10u \text{ N s or } 10u \text{ kgms}^{-1}$	A1
		(3)
		(7)
Notes		
(a)		
M1	Dimensionally correct CLM equation or equating of impulses equation. Allow consistent extra g's. Ignore sign errors. May be +v or -v	
A1	Correct unsimplified equation	
A1	Cao. Must be positive .	
(b)		
B1	Accept <i>opposite direction</i> . Do not accept <i>changed</i> or <i>to the left</i> or <i>backwards</i> , away from B N.B. This mark is dependent on correctly obtaining $\frac{1}{2}u$ or $-\frac{1}{2}u$ in (a)	
(c)		
M1	Dimensionally correct impulse-momentum equation using A or B. Condone sign errors with appropriate velocities. M0 if g is included	
A1	Correct unsimplified equation	
A1	Cao with units. Accept kg m/s	

**Jan 2020 WME01
Final**

Question Number	Scheme	Marks
1(a)		
	$\pm m_2 \left(\frac{1}{3}u - -u \right)$	M1 A1
	$\frac{4m_2 u}{3}$	A1 (3)
(b)	CLM: $m_1 u - m_2 u = -m_1 v + m_2 \frac{1}{3}u$ OR $\frac{4m_2 u}{3} = m_1 (v - -u)$	M1 A1
	$\frac{u(4m_2 - 3m_1)}{3m_1}$ oe	A1
		(3)
(c)	$\frac{u(4m_2 - 3m_1)}{3m_1} > 0$	M1
	$(4m_2 - 3m_1) > 0 \Rightarrow 4m_2 > 3m_1 \Rightarrow m_2 > \frac{3}{4}m_1$ * Given answer	A1*
	N.B. If they use $-v$ in (b), can score M1 for $-v < 0$ and possibly A1.	(2) (8)
Notes for question 1		
1(a)	M1 for impulse-momentum principle applied to Q ; condone sign errors but must be using m_2 for mass and subtracting momenta M0 if it's dimensionally incorrect e.g if g is included.	
	First A1 for $\pm m_2 \left(\frac{1}{3}u - -u \right)$	
	A1 Correct answer, must be positive and a single term (Allow fraction replaced by a decimal to at least 2 SF)	
(b)	M1 CLM, with usual rules (allow consistent extra g 's), or impulse-momentum principle applied to P , using their answer from (a) which must be in terms of m_2 and u (but allow consistent extra g 's)	
	A1 Correct equation (allow consistent use of $-v$ instead of v)	
	A1 Correct answer only. Any equivalent expression with m_2 terms collected (Allow fraction replaced by a decimal to at least 2 SF)	
(c)	M1 Correct inequality for their v , containing u . N.B. Their first statement must include u and > 0 or < 0 as appropriate	
	A1* Correct given answer correctly obtained. N.B. $\frac{3}{4}m_1 < m_2$ is A0	

Question Number	Scheme	Marks
2.		
(a)	$T + (T + 20) = W$ $M(A), 4.5(T + 20) = 2.625W$ <u>Any two of these</u> $M(G), 2.625T = 1.875(T + 20)$ $M(C), 4.5T = 1.875W$ $M(B), 6T + 1.5(T + 20) = 3.375W$ N.B. The A marks and the DM1 can only be scored if the candidate is using T and $T + 20$ or T and $T - 20$ in both equations. N.B. Can score M1A1 for a correct vertical resolution, even if T and $T + 20$ are the wrong way round. N.B. If they just use T_A and T_C , can score max M1A0 M1A0DM0A0 If they assume that $T_A = T_C$, can score max M1A0 M1A0DM0A0 If they assume that the tensions are T and 20 , can score max M1A0 M1A0 DM0A0 If they use T and $20T$, can score max M1A0 M1A0DM0A0 N.B. If it's not clear from their working which way round they have the two tensions, use their diagram to decide.	M1 A1 M1 A1
	Solve for W	DM1
	$W = 120$	A1
		(6)
(b)	The beam remains straight, or rigid, or in a straight line or 1-dimensional or it doesn't bend	B1 (1)
		(7)
	Notes for question 2	
(a)	M1 First equation (vertical resolution or moments) with usual rules	
	A1 Correct equation (T may be replaced by $T - 20$)	
	M1 Second equation (vertical resolution or moments) with usual rules	
	A1 Correct equation (T may be replaced by $T - 20$)	
	DM1 Dependent on previous two M marks, for solving for W	
	A1 cao	
(b)	B1 any appropriate comment. N.B. Penalise incorrect extras.	

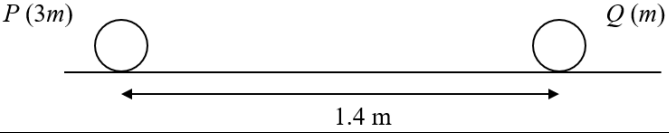


Question Number	Scheme	Marks
2(a)	Correct relationship between the speeds after the collision. v and $v+1$ OR $w-1$ and w	B1
	$(3m \times 1.5) + (m \times -1.5) = 3mv + m(v+1)$ [Or $(3m \times 1.5) + (m \times -1.5) = 3m(w-1) + mw$]	M1 A1
	Speed of A = $\frac{1}{2}$ (m s ⁻¹) Speed of B = $\frac{3}{2}$ (m s ⁻¹)	A1 A1
		(5)
2(b)	For B: $\pm m(1.5 - -1.5)$ OR For A: $\pm 3m(0.5 - 1.5)$	M1 A1ft
	$3m$ (Ns)	A1
		(3)
		(8)
	NOTES	
(a) B1	<i>speed</i> of B = 1 + <i>speed</i> of A . Must be seen before the CLM equation is used i.e. algebraic not numerical quantities	
M1	Dimensionally correct CLM equation with correct number of terms. Allow consistent extra <i>g</i> 's or cancelled <i>m</i> 's. Ignore sign errors. Allow the use of 2 unknowns for speeds after. (M0 if same speeds)	
A1	Correct equation in 1 unknown	
A1	Correct speed of A	
A1	Correct speed of B	
(b) M1	Dimensionally correct impulse-momentum equation using A or B with correct number of appropriate terms. Condone sign errors but must be difference of momenta. M0 if <i>g</i> is included.	
A1ft	Correct unsimplified equation. Follow through their answer in (a),but if using B, terms must have same signs, if using A, terms must have opposite signs.	
A1	Cao (must be positive)	

Question Number	Scheme	Marks
2.		
2(a)	$2m \times 3u = 2mv + 4m \times 2u$ OR $I = 4m \times 2u$ and $-I = 2m(v - 3u)$ AND add to eliminate I $v = -u$ so speed is u	M1A1 A1 (3)
2(b)	Opposite to its original direction, reversed, in opposite direction, direction QP , opposite direction to Q Direction changed is B0	DB1 (1)
2(c)	$R = 4mg$ $F = 4ma$; OR $-Ft = 4m(0 - 2u)$ $4mg\mu = 4ma$ (their <u>calculated</u> a or unknown a) $-\mu 4mgt = 4m(0 - 2u)$	B1 M1 A1
	$0^2 = (2u)^2 - 2a\left(\frac{6u^2}{g}\right)$ (their <u>calculated</u> a or an unknown a) OR $\frac{6u^2}{g} = \frac{(0 + 2u)}{2}t$ (their <u>calculated</u> t or an unknown t)	M1A1
	$\mu = \frac{1}{3}$ correctly obtained	A1 (6) (10)
Notes for question 2		
2(a)	M1 Complete method to give equation in m , u and v only, dimensionally correct, correct no. of terms, condone sign errors and consistent cancelled m 's or extra g 's	
	A1 Correct equation	
	A1 u ; must be positive	
2(b)	DB1 Dependent on an answer of $+u$ or $-u$ in (a)	
2(c)	B1 cao Seen anywhere, e.g. on a diagram	
	M1 Equation of motion (Allow F for friction at this stage) OR Impulse-momentum equation	
	A1 Correct equation with F substituted	
	M1 Use of <i>suvat</i> to obtain an equation in u and a only OR Use of impulse-momentum to obtain an equation in u and t only	
	A1 Correct equation ; equations must be consistent to earn both A marks.	
	A1 Accept 0.33 or better	

QUESTION NUMBER	SCHEME	MARKS
3	Before 10 ↓ 0 After H 1.8 T 0.2 v ↓	
3(a)	$10 \times 1.8 = (0.2 + 1.8)v$	M1
	$v = 9$ (positive)	A1
		(2)
3(b)	For tent peg, $I = \pm 0.2(v - 0)$ or For hammer, $-I = \pm 1.8(v - 10)$	M1 A1
	1.8Ns OR 1.8 kgms^{-1} units needed.	A1
		(3)
3(c)	$0 = 9^2 + 2a(0.12)$ OR $0 = 9^2 - 2a(0.12)$	M1A1
	$2g - R = 2a$ $R - 2g = 2a$	M1 A1
	$R = 690$ or 695	A1
		(5)
	N.B. Using $u = 10$ for 9 can score M0A0M1A1A0 max	
	Using $s = 12$, can score M1A0M1A1A0 max	(10)
ALT 1	$0.12 = \frac{(9+0)}{2}t$	M1A1
	$(R - 2g)t = 2 \times 9$	M1A1
	$R = 690$ or 695	A1
ALT 2	$0.12R = \frac{1}{2} \times 2 \times 9^2 + 2g \times 0.12$	M2A2
	$R = 690$ or 695	A1
	Notes for question 3	
(a)		
M1	Forms CLM equation, condone sign errors and extra g 's and any correct cancellation	
A1	cao	
(b)		
M1	Impulse-momentum equation, dimensionally correct, correct no. of terms. Condone sign errors.	
	N.B. M0 if g is included.	
A1	A1 correct unsimplified equation	
A1	A1 cao must include units.	
(c)		
M1	Equation formed to find the acceleration. Must be dimensionally correct and have the correct no. of terms.	
A1	Correct unsimplified equation. Note $a = -337.5$	

M1	Use of $F=ma$. Must be dimensionally correct and have the correct no. of terms.	
A1	Correct equation, a does not need to be substituted but should be consistent with their a from first equation.	
A1	N.B. Use the equation for a to define the positive direction. cao	
	ALT 1	
M1	Equation(s) formed to find the time	
A1	Correct unsimplified equation. Note $t = \frac{2}{75} = 0.02666\ldots$	
M1	Use of imp-mom equation. Must be dimensionally correct and have the correct no. of terms.	
A1	Correct equation, t does not need to be substituted but should be consistent with their t from first equation.	
A1	cao	
	ALT 2	
M2	Use of work-energy equation. Must be dimensionally correct and have the correct no. of terms.	
A2	Correct unsimplified equation, -1 each error.	
A1	cao	

QUESTION NUMBER	SCHEME	MARKS
3		
3(a)	$\lambda = 3m(5 - 0)$	M1
	$= 15m$	A1
		(2)
3(b)	$2.5^2 = 5^2 + 2a(1.4)$ OR $5^2 = 2.5^2 + 2a(1.4)$	M1 A1
	$R = 3mg$	B1
	Use of $F = \mu R$	M1
	N2L $-\mu(3mg) = 3m \times a$ or just $-\mu g = a$	M1 A1
	$\mu = 0.68$ or 0.683	A1
		(7)
3(c)	$3m(2.5) + m(0) = \pm 3mv + m(2.1)$ OR $3m(\pm v - (-2.5)) = m \times 2.1$ $v = \pm 1.8$ so speed is $1.8 \text{ (m s}^{-1}\text{)}$	M1 A1
		A1
		(3)
		(12)
	Notes for Question 3	
3(a)		
M1	Use of $I = \pm m(v - u)$ with $3m$ and 5 . May not see $u = 0$. M0 if g is included or m missing.	
A1	Correct answer. N.B. $\lambda = \text{NOT NEEDED}$.	
3(b)		
M1	Complete method, using <i>suvat</i> , to find an equation in a only. Ignore sign errors.	
A1	Correct unsimplified equation in a only. (the exact value for a is $\frac{-375}{56} = -6.6964\dots$)	
B1	Correct expression for R seen.	
M1	Use $F = \mu R$ for their R (must have found an R)	
M1	Correct method using N2L to give an equation in (m) , μ and a . Must have correct number of forces and either $3m$ or m on BOTH sides of the equation or on neither side. Allow missing g .	
A1	Correct unsimplified equation in m , μ and a N.B. a does NOT need to be substituted for this mark but it must be consistent (in direction) with the previous <i>suvat</i> equation. i.e. it must lead to a POSITIVE value for μ .	
A1	Correct answer for μ to 2 or 3 sf.	
3(c)		

M1	Dimensionally correct CLM equation in v ONLY with correct number of terms and correct pairings of masses and velocities. Allow consistent extra g 's. Ignore sign errors. OR equate impulses to give a dimensionally correct equation in v ONLY. Allow consistent extra g 's. Ignore sign errors.	
A1	Correct unsimplified equation.	
A1	Correct speed, must be positive.	

