Question	Scheme	Marks	AOs
1(a)	For trailer: Equation of motion	M1	3.4
	$200-120=500a$	A1	1.1b
	For system or lorry: Equation of motion	M1	3.4
	$F-300-120=3000\times0.16$ or $F-200-300=2500\times0.16$	A1	1.1b
	Power = 900 $\times$ 20	M1	3.3
	P = 18	A1	1.1b
		(6)	
(b)	Inextensibility of tow bar => acceleration of trailer = acceleration of car	B1	2.4
		(1)	
		(7 marks)	

Notes:

(a)
M1: Use the model to form equation of motion.
A1: Correct equation
M1: Use the model to form another equation of motion
A1: Correct equation
M1: Use of $P = Fv$
A1: Correct answer

(b)
B1: Clear explanation

Question	Scheme	Marks	AOs
2	Conservation of momentum	M1	3.1b
	$2mu - 3mu = 2mv_P + 3mv_Q$	A1	1.1b
	Newton's Impact Law	M1	3.4
	$2ue = -v_P + v_Q$	A1	1.1b
	Solve for v_Q :complete strategy (set up 2 equations and solve) to find v_Q	M1	3.1b
	$v_Q = \frac{u}{5}(4e-1)$	A1	1.1b
	$e > \frac{1}{4} \Rightarrow v_Q > 0$	M1	1.1b
	Q reverses its direction *	A1*	2.1
	(8 marks)		

Notes:

M1: All terms needed but condone sign errors
A1: A correct unsimplified equation
M1: Use NIL as a model for the motion with e on the correct side of the equation
A1: A correct equation in any form
M1: Solve for v_Q
A1: A correct expression in v_Q and e only
M1: Appropriate statement and inequality **(M0** for converse**)**
A1*: Correct conclusion, fully justified (given answer)

Question	Scheme	Marks	AOs
3	Use work-energy principle to solve the problem	M1	3.4
	$F\times 0.025=\frac{1}{2}\times 0.6\times 22.4^2+0.6g(1.5+0.025)$	A1	1.1b
		A1	1.1b
	$F=6400$ or 6380	A1	1.1b
		(4)	
			(4 marks)

Notes:

M1: All terms needed (M0 if anything other than work-energy used)
A1: All correct, condone one error
A1: All correct
A1: 2SF or 3SF following use of g = 9.8

Question	Scheme	Marks	AOs
4(a)	Conservation of momentum	M1	3.1a
	$mu = mv_A + mv_B$	A1	1.1b
	Newton's Impact Law	M1	3.4
	$ue = -v_A + v_B$	A1	1.1b
	Overall strategy for solving for either velocity	M1	3.1a
	$v_A = \frac{u}{2}(1-e)$	A1	1.1b
	$v_B = \frac{u}{2}(1+e)$	A1	1.1b
	$\frac{1}{2}m(v_A{}^2 + v_B{}^2) = 0.58\frac{1}{2}mu^2$ oe	M1	3.1a
	$\frac{u^2}{4}\left[(1+e)^2 + (1-e)^2\right] = 0.58u^2$	A1	1.1b
	$e = 0.4$	A1	1.1b
		(10)	
(b)	Particles move with same speed in same direction as *A* oe	B1	2.2a
	speed = $\frac{1}{2}u$	B1	2.2a
		(2)	
		(12 marks)	

Notes:

(a)
M1: Correct strategy with use of CLM, with all terms but condone sign errors
A1: Correct equation
M1: Correct use of NIL model with *e* on correct side of equation
A1: Correct equation
M1: Solving for either velocity
A1: Correct expressions for v_A
A1: Correct expressions for v_B
M1: Using a correct strategy to set up an energy equation
A1: Correct equation
A1: cao

(b)
B1: Clear explanation
B1: Correct speed

Question	Scheme	Marks	AOs
5(a)	Use of Impulse-momentum principle	M1	3.1b
	$\mathbf{I} = 0.5\{(2\mathbf{i}+3\mathbf{j})-(4\mathbf{i}-\mathbf{j})\} = (-\mathbf{i}+2\mathbf{j})$	A1	1.1b
	$\lvert\mathbf{I}\rvert = \sqrt{(-1)^2+2^2}$	M1	1.1b
	$\sqrt{5}$ (N s)	A1	1.1b
		(4)	
(b)	KE Loss = Initial KE − Final KE	M1	3.4
	$= \frac{1}{2}\times 0.5\{(4^2+(-1)^2)-(2^2+3^2)\}$	A1	1.1b
	= 1 (J)	A1	1.1b
		(3)	
(c)	Resolve velocities along the normal (impulse)	M1	3.1b
	Separation speed = $(2\mathbf{i}+3\mathbf{j}).\frac{1}{\sqrt{5}}(-\mathbf{i}+2\mathbf{j}) = \frac{4}{\sqrt{5}}$	A1	1.1b
	Approach speed $= (4\mathbf{i}-\mathbf{j}).\frac{1}{\sqrt{5}}(\mathbf{i}-2\mathbf{j}) = \frac{6}{\sqrt{5}}$	A1	1.1b
	Use of Newton's Impact Law along normal: $e = \dfrac{\frac{4}{\sqrt{5}}}{\frac{6}{\sqrt{5}}}$	M1	3.4
	$e = \frac{2}{3}$	A1	1.1b
		(5)	
(d)	Find vector along the wall $\pm(2\mathbf{i}+\mathbf{j})$ and resolve	M1	3.1a
	$0.5\times(2\mathbf{i}+3\mathbf{j}).\frac{1}{\sqrt{5}}(2\mathbf{i}+\mathbf{j}) = \frac{7}{2\sqrt{5}}$; $0.5\times(4\mathbf{i}-\mathbf{j}).\frac{1}{\sqrt{5}}(2\mathbf{i}+\mathbf{j}) = \frac{7}{2\sqrt{5}}$ Hence momentum conserved 'along the wall' *	A1*	2.4
		(2)	
(e)	Wall is modelled as being smooth	B1	3.5b
		(1)	
		(15 marks)	

Notes:
(a) **M1:** Difference of momenta and dimensionally correct **A1:** Correct unsimplified expression **M1:** Must be a sum of squares and dimensionally correct **A1:** Correct answer
(b) **M1:** Using the model: must be a difference and dimensionally correct **A1:** Correct unsimplified expression **A1:** cao
(c) **M1:** Clear attempt to resolve but condone sin/cos confusion **A1:** Allow +/- **A1:** Allow +/- **M1:** Use of Newton's Impact Law to model impact **A1:** cao
(d) **M1:** Clear attempt to resolve but condone sin/cos confusion **A1*:** Correct justification of given answer
(e) **B1:** Correct answer

Question	Scheme	Marks	AOs
6(a)	Using work-energy principle to solve the problem	M1	3.1a
	$R = mg$ and *use* of $F = \mu R$	M1	3.4
	$\frac{1}{4}mg(l-x) = \frac{mg}{2l}(l^2 - x^2)$	A1	1.1b
		A1	1.1b
	Finding the *total* distance moved	M1	1.1b
	Distance = $\frac{3l}{2}$	A1	1.1b
		(6)	
(b)	Thrust = $\frac{mg\frac{1}{2}l}{l} = \frac{1}{2}mg$	B1	1.2
	Overall strategy to solve problem by comparing thrust with max friction ($\frac{1}{4}mg$)	M1	3.1a
	P comes to instantaneous rest and then immediately slides back since $\frac{1}{4}mg < \frac{1}{2}mg$	A1*	2.4
		(3)	
(c)	Using work-energy principle to solve the problem	M1	3.1a
	Use of EPE formula	M1	1.2
	$\frac{1}{4}mgy = \frac{mg}{2l}((\frac{1}{2}l)^2 - (\frac{1}{2}l - y)^2)$	A1ft	1.1b
		A1ft	1.1b
	$y = \frac{1}{2}l$; comes to rest at unstretched length position	A1	2.4
		(5)	
(d)	No tension/thrust in spring => no friction	B1	2.4
	P comes to permanent rest at unstretched length position	B1	2.4
		(2)	
			(16 marks)

Notes:
(a) **M1:** Must include all terms **M1:** Use of μR **A1:** Condone 1 error **A1:** All correct **M1:** Complete method to find the *total* distance moved **A1:** cao
(b) **B1:** Use of Hookes' law to obtain force in spring **M1:** Compare max friction with thrust **A1*:** Correct justification of given answer
(c) **M1:** Must include all terms **M1:** Use of EPE at least once **A1ft:** Condone 1 error, follow through on their answer from (a) **A1ft:** All correct, follow through on their answer from (a) **A1:** Correct y value and statement
(d) **B1:** Clear explanation **B1:** Clear explanation

Question	Scheme	Marks	AOs
7(a)	At D, use CLM along wall	M1	3.1a
	$(m)u\cos\theta = (m)v\cos\alpha$	A1	1.1b
	At D, use NIL along normal	M1	3.4
	$eu\sin\theta = v\sin\alpha$	A1	1.1b
	Overall strategy to obtain connection between angles: $e\tan\theta = \tan\alpha$	M1	3.1a
	Use this result at E (second impact on AB)	M1	3.4
	$e\tan(\theta+\alpha) = \tan(90^\circ - \theta)$	A1	1.1b
		A1	1.1b
	Expand and sub for $\tan\alpha$	M1	1.1b
	$1 = e(e+2)\tan^2\theta$	A1*	2.1
		(10)	
(b)	$0 < e \leq 1 \Rightarrow \tan^2\theta \geq \frac{1}{3}$	M1	2.1
	$\tan\theta \geq \frac{1}{\sqrt{3}}$	A1	1.1b
	$\theta \geq 30^\circ$ i.e. angle between walls must be at least 30° *	A1*	2.2a
		(3)	
			(13 marks)

Notes:

(a) M1: Condone sin/cos confusion
A1: Correct unsimplified
M1: Correct use of NIL with e on correct side of equation but condone sin/cos confusion
A1: Correct equation
M1: Correct strategy to set up two equations to obtain connection between angles
M1: Correct use of NIL with e on correct side
A1: Condone 1 error
A1: All correct
M1: For producing equation in $\tan\theta$ and e only
A1*: Correct justification of given answer

(b) M1: Use of $0 < e \leq 1$ to give inequality
A1: Correct inequality
A1*: Correct justification of given answer