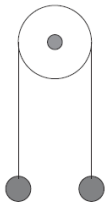
Practice examination questions for connected particles

1. Jan 2005

4 Two particles are connected by a string, which passes over a pulley. Model the string as light and inextensible. The particles have masses of 2 kg and 5 kg. The particles are released from rest.



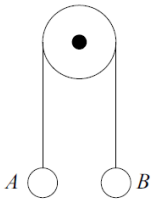
(a) State one modelling assumption that you should make about the pulley in order to determine the acceleration of the particles. *(1 mark)*

(b) By forming an equation of motion for each particle, show that the magnitude of the acceleration of each particle is $4.2\,\mathrm{m\,s^{-2}}$. *(5 marks)*

(c) Find the tension in the string. *(2 marks)*

2. June 2005

4 Two particles, A of mass 5 kg and B of mass 9 kg, are attached to the ends of a light inextensible string. The string passes over a light smooth pulley as shown in the diagram. The particles are released from rest at the same height.



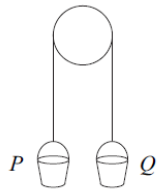
(a) By forming an equation of motion for each particle, show that the magnitude of the acceleration of each particle is $2.8\,\mathrm{m\,s^{-2}}$. *(5 marks)*

(b) Find the tension in the string. *(2 marks)*

(c) When B has been moving for 0.5 seconds it hits the floor. Find the height of A, above the floor, at this time. Assume that A is still below the pulley when B hits the floor. *(4 marks)*

3. Jan 2006

7 A builder ties two identical buckets, P and Q, to the ends of a light inextensible rope. He hangs the rope over a smooth beam so that the buckets hang in equilibrium, as shown in the diagram.



The buckets are each of mass 0.6 kg.

(a) (i) State the magnitude of the tension in the rope. *(1 mark)*

(ii) State the magnitude and direction of the force exerted on the beam by the rope. *(2 marks)*

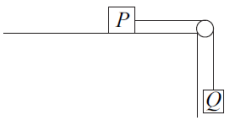
(b) The bucket Q is held at rest while a stone, of mass 0.2 kg, is placed inside it. The system is then released from rest and, in the subsequent motion, bucket Q moves vertically downwards with the stone inside.

(i) By forming an equation of motion for each bucket, show that the magnitude of the tension in the rope during the motion is 6.72 newtons, correct to three significant figures. *(6 marks)*

(ii) State the magnitude of the force exerted on the beam by the rope while the

4. June 2006

5 A small block P is attached to another small block Q by a light inextensible string. The block P rests on a rough horizontal surface and the string hangs over a smooth peg so that Q hangs freely, as shown in the diagram.



The block P has mass 0.4 kg and the coefficient of friction between P and the surface is 0.5.

The block Q has mass 0.3 kg.

The system is released from rest and Q moves vertically downwards.

(a) (i) Draw a diagram to show the forces acting on P. *(1 mark)*

(ii) Show that the frictional force between P and the surface has magnitude 1.96 newtons. *(2 marks)*

(ii) Show that the frictional force between P and the surface has magnitude 1.96 newtons. *(2 marks)*

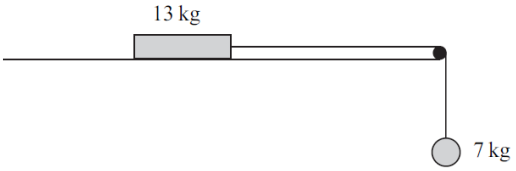
(b) By forming an equation of motion for each block, show that the magnitude of the acceleration of each block is $1.4\,\mathrm{m\,s^{-2}}$. *(5 marks)*

(c) Find the speed of the blocks after 3 seconds of motion. *(2 marks)*

(d) After 3 seconds of motion, the string breaks. The blocks continue to move. Comment on how the speed of each block will change in the subsequent motion. For each block, give a reason for your answer. *(4 marks)*

5. Jan 2007

4 The diagram shows a block, of mass 13 kg, on a rough horizontal surface. It is attached by a string that passes over a smooth peg to a sphere of mass 7 kg, as shown in the diagram.



The system is released from rest, and after 4 seconds the block and the sphere both have speed $6\,\mathrm{m\,s^{-1}}$, and the block has **not** reached the peg.

(a) State **two** assumptions that you should make about the string in order to model the motion of the sphere and the block. *(2 marks)*

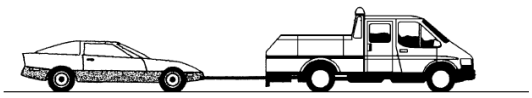
(b) Show that the acceleration of the sphere is $1.5\,\mathrm{m\,s^{-2}}$. *(2 marks)*

(c) Find the tension in the string. *(3 marks)*

(d) Find the coefficient of friction between the block and the surface. *(6 marks)*

6. June 2007

4 A car, of mass 1200 kg, is connected by a tow rope to a truck, of mass 2800 kg. The truck tows the car in a straight line along a horizontal road. Assume that the tow rope is horizontal. A horizontal driving force of magnitude 3000 N acts on the truck. A horizontal resistance force of magnitude 800 N acts on the car. The car and truck accelerate at $0.4\,\mathrm{m\,s^{-2}}$.



(a) Find the tension in the tow rope. *(3 marks)*

(a) Find the tension in the tow rope. *(3 marks)*

(b) Show that the magnitude of the horizontal resistance force acting on the truck is 600 N. *(4 marks)*

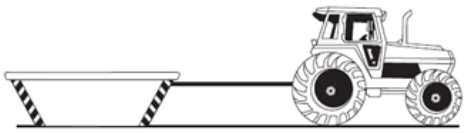
(c) In fact, the tow rope is **not** horizontal. Assume that the resistance forces and the driving force are unchanged.

Is the tension in the tow rope greater or less than in part (a)?

Explain why. *(2 marks)*

7. Jan 2008

6 A tractor, of mass 4000 kg, is used to pull a skip, of mass 1000 kg, over a rough horizontal surface. The tractor is connected to the skip by a rope, which remains taut and horizontal throughout the motion, as shown in the diagram.



Assume that only **two** horizontal forces act on the tractor. One is a driving force, which has magnitude P newtons and acts in the direction of motion. The other is the tension in the rope.

The coefficient of friction between the skip and the ground is 0.4 .

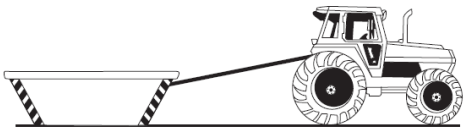
The tractor and the skip accelerate at $0.8\,\mathrm{m\,s^{-2}}$.

(a) Show that the magnitude of the friction force acting on the skip is 3920 N. *(2 marks)*

(b) Show that $P = 7920$. *(3 marks)*

(c) Find the tension in the rope. *(3 marks)*

(d) Suppose that, during the motion, the rope is **not** horizontal, but inclined at a small angle to the horizontal, with the higher end of the rope attached to the tractor, as shown in the diagram.

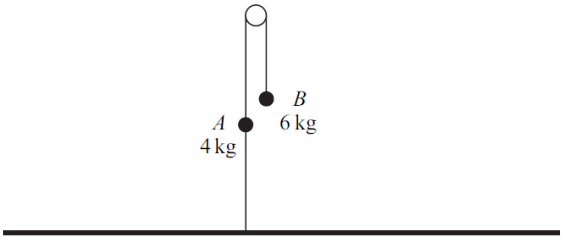


How would the magnitude of the friction force acting on the skip differ from that found in part (a)?

Explain why. *(2 marks)*

8. June 2008

3 Two particles, A and B, have masses 4 kg and 6 kg respectively. They are connected by a light inextensible string that passes over a smooth fixed peg. A second light inextensible string is attached to A. The other end of this string is attached to the ground directly below A. The system remains at rest, as shown in the diagram.



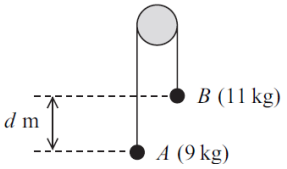
(a) (i) Write down the tension in the string connecting A and B. *(1 mark)*

(ii) Find the tension in the string connecting A to the ground. *(3 marks)*

(b) The string connecting particle A to the ground is cut. Find the acceleration of A after the string has been cut. *(5 marks)*

9. Jan 2009

4 Two particles, A and B, are connected by a string that passes over a fixed peg, as shown in the diagram. The mass of A is 9 kg and the mass of B is 11 kg.



The particles are released from rest in the position shown, where B is d metres higher than A. The motion of the particles is to be modelled using simple assumptions.

(a) State one assumption that should be made about the peg. *(1 mark)*

(b) State two assumptions that should be made about the string. *(2 marks)*

(c) By forming an equation of motion for each of the particles A and B, show that the acceleration of each particle has magnitude $0.98\,\text{m}\,\text{s}^{-2}$. *(5 marks)*

(d) When the particles have been moving for 0.5 seconds, they are at the same level.

(i) Find the speed of the particles at this time. *(2 marks)*

(ii) Find d. *(4 marks)*

10. June 2009

5 A block, of mass 14 kg, is held at rest on a rough horizontal surface. The coefficient of friction between the block and the surface is 0.25. A light inextensible string, which passes over a fixed smooth peg, is attached to the block. The other end of the string is attached to a particle, of mass 6 kg, which is hanging at rest.

The block is released and begins to accelerate.

(a) Find the magnitude of the friction force acting on the block. *(3 marks)*

(b) By forming two equations of motion, one for the block and one for the particle, show that the magnitude of the acceleration of the block and the particle is $1.225\,\text{m}\,\text{s}^{-2}$. *(5 marks)*

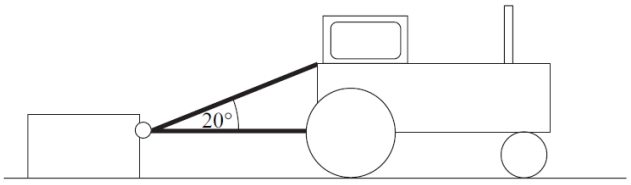
(c) Find the tension in the string. *(2 marks)*

(d) When the block is released, it is 0.8 metres from the peg. Find the speed of the block when it hits the peg. *(3 marks)*

(e) When the block reaches the peg, the string breaks and the particle falls a further 0.5 metres to the ground. Find the speed of the particle when it hits the ground. *(3 marks)*

11. Jan 2010

8 A crate, of mass 200 kg, is initially at rest on a rough horizontal surface. A smooth ring is attached to the crate. A light inextensible rope is passed through the ring, and each end of the rope is attached to a tractor. The lower part of the rope is horizontal and the upper part is at an angle of 20° to the horizontal, as shown in the diagram.



When the tractor moves forward, the crate accelerates at $0.3\,\mathrm{m\,s^{-2}}$. The coefficient of friction between the crate and the surface is 0.4.

Assume that the tension, T newtons, is the same in both parts of the rope.

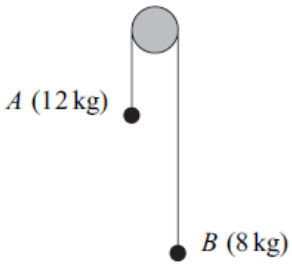
(a) Draw and label a diagram to show the forces acting on the crate. *(2 marks)*

(b) Express the normal reaction between the surface and the crate in terms of T. *(3 marks)*

(c) Find T. *(5 marks)*

12. June 2010

6 Two particles, A and B, have masses 12 kg and 8 kg respectively. They are connected by a light inextensible string that passes over a smooth fixed peg, as shown in the diagram.



The particles are released from rest and move vertically. Assume that there is no air resistance.

(a) By forming two equations of motion, show that the magnitude of the acceleration of each particle is $1.96\,\mathrm{m\,s^{-2}}$. *(5 marks)*

(b) Find the tension in the string. *(2 marks)*

(c) After the particles have been moving for 2 seconds, both particles are at a height of 4 metres above a horizontal surface. When the particles are in this position, the string breaks.

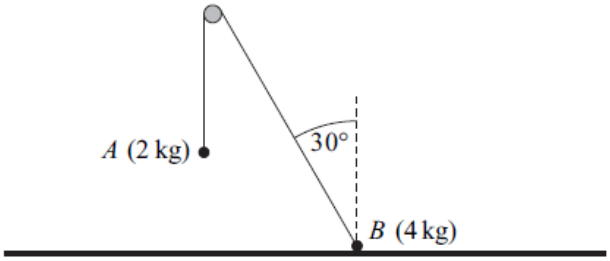
(i) Find the speed of particle A when the string breaks. *(2 marks)*

(ii) Find the speed of particle A when it hits the surface. *(3 marks)*

(iii) Find the time that it takes for particle B to reach the surface after the string breaks. Assume that particle B does not hit the peg. *(5 marks)*

13. Jan 2011

6 Two particles, A and B, are connected by a light inextensible string which passes over a smooth peg. Particle A has mass 2 kg and particle B has mass 4 kg. Particle A hangs freely with the string vertical. Particle B is at rest in equilibrium on a rough horizontal surface with the string at an angle of 30° to the vertical. The particles, peg and string are shown in the diagram.



(a) By considering particle A, find the tension in the string. *(2 marks)*

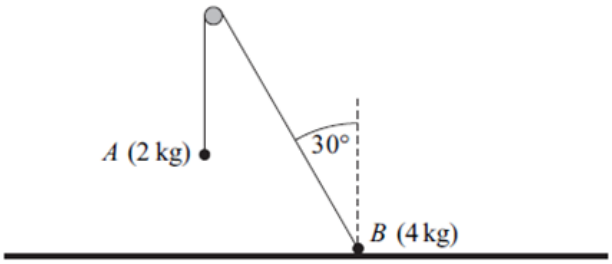
(b) Draw a diagram to show the forces acting on particle B. *(2 marks)*

(c) Show that the magnitude of the normal reaction force acting on particle B is 22.2 newtons, correct to three significant figures. *(3 marks)*

(d) Find the least possible value of the coefficient of friction between particle B and the surface. *(4 marks)*

14. June 2011

6 Two particles, A and B, are connected by a light inextensible string which passes over a smooth peg. Particle A has mass 2 kg and particle B has mass 4 kg. Particle A hangs freely with the string vertical. Particle B is at rest in equilibrium on a rough horizontal surface with the string at an angle of 30° to the vertical. The particles, peg and string are shown in the diagram.



(a) By considering particle A, find the tension in the string. *(2 marks)*

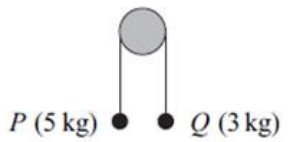
(b) Draw a diagram to show the forces acting on particle B. *(2 marks)*

(c) Show that the magnitude of the normal reaction force acting on particle B is 22.2 newtons, correct to three significant figures. *(3 marks)*

(d) Find the least possible value of the coefficient of friction between particle B and the surface. *(4 marks)*

15. Jan 2012

5 Two particles, P and Q, are connected by a string that passes over a fixed smooth peg, as shown in the diagram. The mass of P is 5 kg and the mass of Q is 3 kg.



The particles are released from rest in the position shown.

(a) By forming an equation of motion for each particle, show that the magnitude of the acceleration of each particle is $2.45\,\mathrm{m\,s^{-2}}$. *(5 marks)*

(b) Find the tension in the string. *(2 marks)*

(c) State **two** modelling assumptions that you have made about the string. *(2 marks)*

(d) Particle P hits the floor when it has moved 0.196 metres and Q has not reached the peg.

(i) Find the time that it takes P to reach the floor. *(3 marks)*

(ii) Find the speed of P when it hits the floor. *(2 marks)*

Answers

1. Jan 2005

4(a)	Light or smooth	B1	1	Acceptable assumption
(b)	$5g - T = 5a$	M1		Three term equation of motion for one particle
		A1		Correct equation
	$T - 2g = 2a$	M1		Three term equation of motion for other particle
	$3g = 7a$	A1		Correct equation
	$a = \frac{3g}{7} = 4.2 \text{ ms}^{-2}$	A1	5	AG; correct acceleration from correct working
(c)	$T = 2\times4.2 + 2\times9.8 = 28 \text{ N}$	M1		Substitute $a = 4.2$ into one equation of motion
		A1	2	Correct tension
	Total		**8**	

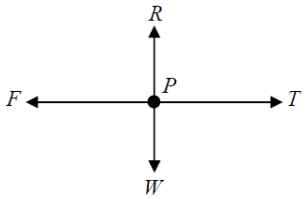
2. June 2005

4(a)	$9g - T = 9a$	M1		M1: Equation for one particle
	$T - 5g = 5a$	A1		A1: Correct equation
	$4g = 14a$	M1		M1: Equation for other particle
		A1		A1: Correct equation
	$a = \frac{4g}{14} = 2.8 \text{ ms}^{-2}$ **AG**	A1	5	A1: Correct a from correct working
(b)	$T - 5g = 5\times2.8$	M1		M1: Substituting acceleration to find T
	$T = 63 \text{ N}$	A1	2	A1:Correct tension
(c)	$s = \frac{1}{2}\times2.8\times0.5^2$	M1A1		M1: Constant acceleration equation with $u = 0$ and $a \neq g$ to find s. Allow $\pm$ answers
	$= 0.35 \text{ m}$			
	$\text{Total} = 2\times0.35 = 0.7 \text{ m}$	A1		A1: Correct equation
		A1ft	4	A1: Correct distance A1: Doubling their distance to get total distance apart
	Total		**11**	

3. Jan 2006

7(a)(i)	$T = 0.6\times9.8 = 5.88N$ Or $0.6g$	B1	1	
(ii)	Force $= 2T = \downarrow 11.76N$ Or 11.8 N	B1		Magnitude
	Or $1.2g$	B1	2	Direction
(b)(i)	$Q: 0.8g - T = 0.8a$	M1		Either equation
		A1		
	$T - 0.6g = 0.6a$	A1		
	$0.2g = 1.4a$	m1		Alternative for m1 A1 if solving for T
	$a = 1.4$	A1		m1 method for solving, A1 accurate attempt
	$T = 6.72\text{N}$	A1	6	cao | SC whole string to find a :$0.2g = 1.4a$ M1 $a = 1.4$ A1
(ii)	Force $= 2T = 13.44\text{N}$	B1	1	cao | to find T :M1 A1
	Total		**10**	

4. June 2006

5(a)(i)		B1	1	Accept mg, $0.4g$ or 3.92 for weight Arrows and labels needed
(ii)	$F = 0.5 \times (0.4 \times 9.8)$ $F = 1.96\text{N}$	M1 A1	2	Need to see 0.4×9.8 or 3.92 used
(b)	$T - 1.96 = 0.4a$ $0.3g - T = 0.3a$ $a = 1.4\text{ms}^{-2}$	M1A1 M1A1 A1	5	Consistent reversal of signs in both equations 4 marks; reversal of signs in one equation, M1 A1 M1 A0 Sign change needs justification (whole string: equation, $0.3g - 1.96 = 0.7a$ M1A1 $a = 1.4$ A1) max 3/5
(c)	$v = 1.4 \times 3$ $v = 4.2\text{ms}^{-2}$	M1 A1	2	Full method CAO
(d)	P : Friction will cause speed to decrease Q : Gravity will cause speed to increase	M1 A1 M1 A1	4	Accept decelerate or comes to rest Accept accelerate
	Total		**14**	

5. Jan 2007

4(a)	The string is light and inextensible or inelastic or taut	B1 B1	2	First assumption Second assumption
(b)	$6 = 0 + 4a$ $a = \frac{6}{4} = 1.5$	M1 A1	2	Finding a using a CA equation Correct a from correct working
(c)	$7 \times 9.8 - T = 7 \times 1.5$ $T = 68.6 - 10.5 = 58.1$	M1A1 A1	3	Three term equation of motion with F for the 7 kg particle. Correct equation Correct tension
(d)	$58.1 - F = 13 \times 1.5$ $F = 58.1 - 19.5 = 38.6$ $R = 13.98 = 127.4$ $38.6 = \mu \times 127.4$ $\mu = \frac{38.6}{127.4} = 0.303$	M1A1 A1 B1 dM1 A1	6	Three term equation of motion with F for the 13 kg particle. Correct equation Correct F Correct R Use of $F = \mu R$ Correct coefficient of friction
			13	

6. June 2007

4(a)	$T - 800 = 1200 \times 0.4$ $T = 800 + 480$ $= 1280$ N	M1 A1 A1	3	Three term equation of motion for the car Correct equation Correct tension Treat calculation of two tensions as two methods unless one selected Treat sum or difference of two tensions as an incorrect method

(b)	$3000-800-F=4000\times0.4$ $F=3000-800-1600$ $F=600$ N **OR** $3000-1280-F=2800\times0.4$ $F=3000-1280-1120$ $F=600$ N	M1 A1 A1 A1	 4	Four term equation of motion (truck or both) Correct terms Correct signs AG Correct resistance force from correct working
(c)	Increase, because a greater tension would be needed so that the horizontal component would be the same as the tension above.	B1 B1	 2	Greater Reason Second B1 dependent on the first B1 mark
	Total		**9**	

7. Jan 2008

6(a)	$F=0.4\times1000\times9.8$ **AG** $=3920$	M1 A1	 2	Use of $F=\mu R$ Correct friction from correct working. Allow $F=0.4\times9800$ Allow verification
(b)	$P-3920=5000\times0.8$ **AG** $P=7920$ N	M1 A1 A1	 3	Three term equation of motion including an explicit 0.8 Correct equation Correct force from correct working. Allow $P=5000\times0.8+3920$
(c)	$T-3920=1000\times0.8$ $T=4720$ N or $7920-T=4000\times0.8$ $T=4720$ N	M1 A1 A1	 3	Three term equation of motion Correct equation Correct tension
(d)	Friction is reduced because the normal reaction is reduced.	B1 E1	 2	Friction reduced Acceptable explanation
	Total		**10**	

8. June 2008

3(a)(i)	$T=6\times9.8=58.8$ N	B1	1	Use of tension being equal to the weight Accept $6g$
(a)(ii)	$58.8=T+4\times9.8$ $T=58.8-39.2$ $=19.6$ N	M1 A1 A1	 3	Three term equation for equilibrium containing 58.8, T and 4×9.8 or equivalent terms. For M1, 58.8 can be replaced by candidates answer to part (a)(i) provided it is not zero. Correct equation Correct tension Accept $2g$

(b)	$6g - T = 6a$	M1 A1		Three term equation of motion for 6 kg particle containing 58.8 or $6g$, T and $6a$. Correct equation
	$T - 4g = 4a$	M1 A1		Three term equation of motion for 4 kg particle containing 39.2 or $4g$, T and $4a$. Correct equation
	$2g = 10a$ $a = 1.96 \text{ ms}^{-2}$	A1	5	Correct acceleration Candidates who work consistently to obtain $a = -1.96$ gain full marks.
	Special Case for whole system $6g - 4g = 10a$ $a = 1.96$	(M1) (A1) (A1)	(3)	Difference in weights equal to $10a$ A1: Correct equation A1: Correct acceleration
	Total		**9**	

9. Jan 2009

4(a)	Peg is smooth	B1	1	B1: Correct assumption
(b)	String is light	B1		B1: First correct assumption
	String is inextensible or inelastic Tension is the same throughout the string	B1	2	B1: Second correct assumption Note: Ignore any additional assumptions.
(c)	$11g - T = 11a$	M1 A1		M1: Equation of motion for A, containing T, 11g or 107.8 and $11a$. A1: Correct equation
	$T - 9g = 9a$	M1 A1		M1: Equation of motion for B containing T, $9g$ or 88.2 and $9a$. A1: Correct equation
	$2g = 20a$ $a = 0.98 \text{ ms}^{-2}$ **AG**	A1	5	A1: Correct acceleration from correct working.
	$2g = 20a$ $a = 0.98 \text{ ms}^{-2}$ **AG**	A1	5	A1: Correct acceleration from correct working. Note: Do not penalise candidates who consistently use signs in the opposite direction throughout, provided they give their final answer as 0.98. If final answer is – 0.98 don't award final A1 mark. **Special Case:** Whole String Method $2g = 20a$ and $a = 2g/20 = 0.98$ OE M1A1A1 Use of $g = 9.81$ gives 0.981. If this is the first time award M1A1M1A1A0, but don't penalise again on the same script.

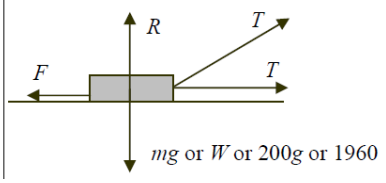
4(d)(i)	$v = 0 + 0.98 \times 0.5 = 0.49 \text{ ms}^{-1}$	M1 A1	2	M1: Use of constant acceleration equation to find v with $u = 0$, $a = 0.98$ and $t = 0.5$. A1: Correct v
(d)(ii)	$s = 0 + \frac{1}{2} \times 0.98 \times 0.5^2 = 0.1225 \text{ m}$ **OR**	M1 A1		M1: Finding distance travelled by each particle with $u = 0$, $a = 0.98$ and $t = 0.5$. A1: Correct distance. Accept 0.122 or 0.123

	OR $0.49^2 = 0^2 + 2\times 0.98s$ $s = \frac{0.49^2}{2\times 0.98} = 0.1225$ $d = 2\times 0.1225$ $= 0.245$ m	 (M1) (A1) M1 A1	 4	0.123 M1: Finding distance travelled by each particle with $u = 0$, $a = 0.98$ and their v. A1: Correct distance. Accept 0.122 or 0.123 M1: Doubling distance or use of $d/2$ in their original equation. A1: Correct final distance. Allow 0.244 or 0.246. (Use of $0.5 \times 0.49 = 0.245$ scores zero unless justified)
				If candidates calculate the distance first award marks as above (see (d)(i)) or: M1: Use of constant acceleration equation to find v with $u = 0$, $a = 0.98$ and $s = 0.1225$. A1: Correct v **Note: If parts (i) and (ii) are not separated or clearly labelled still award marks for both parts if justified.**
	Total		**14**	

10. June 2009

5(a)	$R = 14\times 9.8 = (137.2)$ $F = 0.25\times 137.2$ OR $F = 0.25\times 14\times 9.8$ $F = 34.3$ N	M1 M1 A1	 3	M1: Finding the normal reaction. Accept $14g$. M1: Use of $F = \mu R$ A1: Correct friction Use of $g = 9.81$ gives $R = 137.3$ and $F = 34.3$ so in this case do not penalise use of $g = 9.81$.
(b)	$6g - T = 6a$ $T - 34.3 = 14a$ $6g - 34.3 = 20a$ $a = \frac{6g - 34.3}{20} = 1.225$ ms^{-2}	M1A1 M1A1 A1	 5	M1: Equation of motion for the particle, containing T, $6g$ or 58.8 and $6a$. A1: Correct equation with correct signs. M1: Equation of motion for the block, containing T, 34.3 or their F and $14a$. A1: Correct equation with correct signs. A1: Correct acceleration from correct working. If -1.225 is obtained from consistent
	AG			working award 4 marks and if changed to $+1.225$ with an explanation, award full marks. Special Case: Whole string method $6g - 34.3 = 20a$ OE $a = 1.225$ award M1A1A1 Use of $g = 9.81$ gives $a = 1.228$ penalise use of $g = 9.81$ by deducting 1 mark, but don't penalise again on the same script.

11. Jan 2010

8(a)		B1 B1	 2	B1: F, R and mg (or equivalent) with arrows and labels. B1: Two **equal** tension forces with arrows and labels. Ignore components if shown with a different notation, eg dotted lines.

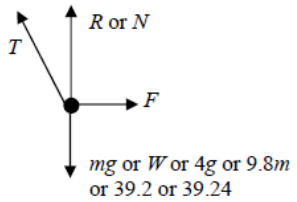
(b)	$R + T\sin 20° = 1960$ **OR** $R + T\sin 20° = 200g$ $(R =)1960 - T\sin 20°$ **OR** $(R =)200g - T\sin 20°$	M1A1 A1	3	M1: Resolving vertically with three terms. Must include sin20° or cos20° or sin 70° or cos70° with T and 200g or 1960. A1: Correct equation. A1: Correct expression for the normal reaction. Note: If g = 9.81 is used for the first time deduct one mark. Should get 1962 instead of 1960.
(c)	$T\cos 20° + T - F = 200 \times 0.3$ $T\cos 20° + T - 0.4(1960 - T\sin 20°) = 200 \times 0.3$	M1A1 M1		M1: Four term equation of motion. Must include sin20° or cos20° or sin 70° or cos70° with T and a second T term with no trig. A1: Correct equation M1: Use of friction law with their expression for R, provided that R has two terms. Note that this mark does not depend on any previous marks.
	$T = \dfrac{60 + 784}{\cos 20° + 1 + 0.4\sin 20°} = 406$	dM1 A1	5	Example If Candidate gives 1960 as answer to part (b), then: $F = 0.4 \times 1960 = 784$ scores M0 here dM1: Solving for T. Note: This mark requires both of the previous M marks. A1: Correct tension. Accept AWFW 406 to 407. Note: If g = 9.81 is used should get 407 instead of 406.
	Total		**10**	

12. June 2010

6(a)	$12g - T = 12a$ $T - 8g = 8a$ $4g = 20a$ $a\left(= \dfrac{4g}{20}\right) = 1.96\ \text{ms}^{-2}$ AG	M1A1 M1A1 A1	5	M1: Three term equation of motion, with 12g (or 117.6), 12a (not 12ga) and T. A1: Correct equation M1: Three term equation of motion, with 8g (or 78.4), 8a (not 8ga) and T. A1: Correct equation A1: Correct acceleration from correct working. Note: Do not penalise candidates who consistently use signs in the opposite direction throughout, provided they give their final answer as 1.96. If final answer is – 1.96 don't award final A1 mark. Special Case: Whole String Method $4g = 20a$ and $a = \dfrac{4g}{20} = 1.96$ OE M1A1A1

				20
(b)	$T = 8g + 8\times1.96 = 94.1\text{ N}$	M1A1	2	M1: Use of three term equation of motion to find T, with $a = 1.96$. A1: Correct tension. Accept 94.08.
(c)(i)	$v = 0 + 1.96\times2 = 3.92\ \text{ms}^{-1}$	M1A1	2	M1: Use of constant acceleration equation to find v, with $a = 1.96$ and $u = 0$. A1: Correct v. Using $s = 4$ scores M0.
(ii)	$v^2 = 3.92^2 + 2\times9.8\times4$	M1 A1F		M1: Use of constant acceleration equation to find v, with $a = \pm9.8$ and $u \neq 0$. A1F: Correct equation. FT initial velocity from (c)(i).
	$v = 9.68\ \text{ms}^{-1}$	A1F	3	A1F: Correct v. FT initial velocity from (c)(i). For example 11.8 from 7.84.

13. Jan 2011

6(a)	$T = 2\times9.8 = 19.6\text{ N}$	M1A1	2	M1: Equating tension and weight. A1: Correct tension CAO Accept $2g$ Accept 19.62 from $g = 9.81$
(b)		B1 B1	2	B1: R, F (not μR) and mg correct B1: T correct, must be in roughly correct direction. If more than four forces shown, do not award more than one mark. Note all forces must be shown as arrows and have labels. Note some candidates may draw the force diagram in the section with the question. Components can be ignored if shown in a different notation eg dashed arrows.
(c)	$T\cos30° + R = 4\times9.8$ $(R =)39.2 - 19.6\cos30°$ $= 39.2 - 16.9741...$ $= 22.2259....$ $= 22.2\text{ N (to 3sf)}$ AG	M1 A1 A1	3	M1: Resolving vertically to form a three term equation. (May be implied) A1 Correct expression for R or equation for R. Must see 19.6cos30 or equivalent (eg $2g\sin60$) A1: Correct force. Must see intermediate working, for example third or fourth line of working in solution opposite. Example: $19.6\sin30° - R = 4\times9.8$ scores M1A0A0. Use of $g = 9.81$ still gives 22.2 N as the final answer.
(d)	$T\cos60° = F$ $F = 19.6\cos60° = 9.8$ $19.6\cos60° \le \mu(39.2 - 19.6\cos30°)$ $\mu \ge \dfrac{19.6\cos60°}{39.2 - 19.6\cos30°}$ $\mu \ge 0.441$	M1 A1 dM1 A1	4	M1: Resolving horizontally A1: Correct expression for friction dM1: Use of $F = \mu R$ or $F \le \mu R$ (do not allow $F \ge \mu R$) A1: Final answer of $\mu = 0.441$ or $\mu \ge 0.441$ from correct working Use of $g = 9.81$ still gives 0.441 as the final answer.
	Total		**11**	

14. June 2011

6 (a)	$1000 = V \times 4$ $V = 250\ \text{ms}^{-1}$	M1 A1	2	M1: Equation for horizontal motion to find V. Must not contain g. Could contain cos0° or equivalent. A1: Correct V.
(b)	$(h =)\frac{1}{2} \times 9.8 \times 4^2$ $= 78.4$ metres to 3sf	M1 A1	2	M1: Vertical equation to find height with $u = 0$ and $a = \pm 9.8$. A1: Correct height. Accept –78.4
(c)	$(v_y =) 9.8 \times 4 = 39.2\ \text{ms}^{-1}$ or $(v_y =)\sqrt{2 \times 9.8 \times 78.4} = 39.2\ \text{ms}^{-1}$ $(v =)\sqrt{250^2 + 39.2^2} = 253\ \text{ms}^{-1}$	M1A1 dM1A1	4	M1: Calculation of vertical component of velocity with $u = 0$ and $a = \pm 9.8$. A1: Correct vertical component. dM1: Calculation of speed. A1: Correct speed.
(d)	$\tan\alpha = \frac{39.2}{250}\ \left(\text{or } \tan\alpha = \frac{250}{39.2}\right)$ $\alpha = 8.91°$ **OR** $\sin\alpha = \frac{39.2}{253}\ \left(\text{or } \sin\alpha = \frac{250}{253}\right)$ $\alpha = 8.91°$ **OR**	M1A1F A1 (M1A1F) (A1)	3	M1: Using tan to find angle with opposite and adjacent sides. Can be inverted as shown in brackets. A1F: Correct trig expression. A1: Correct angle. M1: Using sin to find angle with hypotenuse and one other side. Can be changed as shown in brackets. A1F: Correct trig expression. A1: Correct angle.
	OR $\cos\alpha = \frac{250}{253(.055)}\ \left(\text{or } \cos\alpha = \frac{39.2}{253}\right)$ $\alpha = 8.91°$	 (M1A1F) (A1)		A1: Correct angle. M1: Using cos to find angle with hypotenuse and one other side. Can be changed as shown in brackets. A1F: Correct trig expression. A1: Correct angle. Accept 8.83° from this method. Note: Accept 8.98° from 253.1 Accept negative angles Note: FT value of V from (a) and speed from (c) if needed. Do not FT 39.2 from (c) in place of 253. Note: Accept energy methods if used correctly in part (c).
	Total		**11**	

15. Jan 2012

5(a)	$4720 - 3R = 2200 \times 1.6$ $R = \frac{4720 - 3520}{3} = 400$ OR	M1A1 A1 A1	4	M1: Three term horizontal equation of motion with mass of 2200 kg and $3R$ (or $2R$ and R). A1: All terms correct (4720, $3R$ and 2200×1.6). A1: Correct signs. A1: Correct value for R.

	$4720 - R - T = 1200 \times 1.6$ $T - 2R = 1000 \times 1.6$ $4720 - 3R = 3520$ $R = 400$	(M1A1) (A1) (A1)		M1: Forming an equation for each body and adding to eliminate T. A1: Two correct equations. A1: Correct equation in R. A1: Correct value for R.
(b)	$T - 2 \times 400 = 1000 \times 1.6$ $T = 800 + 1600 = 2400$ N OR $4720 - T - 400 = 1200 \times 1.6$ $T = 4720 - 400 - 1920 = 2400$ N	M1A1F A1F (M1) (A1F) (A1F)	3	M1: Three term equation of motion for caravan with T, $2R$ and 1000×1.6. A1F: Correct equation, with their value for R from part (a). A1F: Correct tension. Follow through from part (a) using $T = 1600 + 2R$ M1: Four term equation of motion for car with 4720, T, R and 1200×1.6. A1F: Correct equation, with their value for R from part (a) A1F: Correct tension. Follow through from part (a) using $T = 2800 - R$ Note: do not follow through if a negative value is used for R.
	Total		**7**	