Questions

Q1.

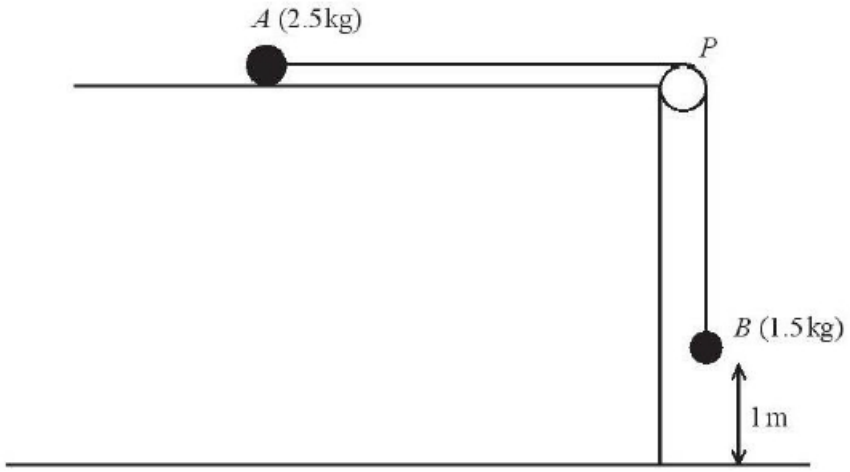

Figure 2

A small ball *A* of mass 2.5 kg is held at rest on a rough horizontal table.

The ball is attached to one end of a string.

The string passes over a pulley *P* which is fixed at the edge of the table. The other end of the string is attached to a small ball *B* of mass 1.5 kg hanging freely, vertically below *P* and with *B* at a height of 1 *m* above the horizontal floor.

The system is released from rest, with the string taut, as shown in Figure 2.

The resistance to the motion of *A* from the rough table is modelled as having constant magnitude 12.7 N. Ball *B* reaches the floor before ball *A* reaches the pulley.

The balls are modelled as particles, the string is modelled as being light and inextensible and the pulley is modelled as being small and smooth.

(a) (i) Write down an equation of motion for *A*.

(ii) Write down an equation of motion for *B*.

(4)

(b) Hence find the acceleration of *B*.

(2)

(c) Using the model, find the time it takes, from release, for *B* to reach the floor.

(2)

It was found that it actually took 2.3 seconds for ball *B* to reach the floor.

(d) Using this information

(i) comment on the appropriateness of using the model to find the time it takes ball *B* to reach the floor, justifying your answer.

(ii) suggest one improvement that could be made in the model.

(2)

(Total for question = 10 marks)

Q2.

Unless otherwise indicated, wherever a numerical value of g is required, take $g = 9.8$ m s^{-2} and give your answer to either 2 significant figures or 3 significant figures.

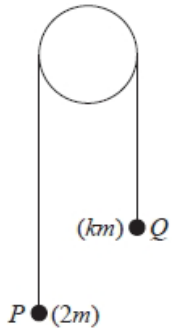

Figure 1

Two small balls, P and Q, have masses $2m$ and km respectively, where $k < 2$.
The balls are attached to the ends of a string that passes over a fixed pulley.
The system is held at rest with the string taut and the hanging parts of the string vertical, as shown in Figure 1.

The system is released from rest and, in the subsequent motion, P moves downwards with an acceleration of magnitude $\frac{5g}{7}$

The balls are modelled as particles moving freely.
The string is modelled as being light and inextensible.
The pulley is modelled as being small and smooth.

Using the model,

(a) find, in terms of m and g, the tension in the string,

(3)

(b) explain why the acceleration of Q also has magnitude $\frac{5g}{7}$

(1)

(c) find the value of k.

(4)

(d) Identify one limitation of the model that will affect the accuracy of your answer to part (c).

(1)

(Total for question = 9 marks)

Q3.

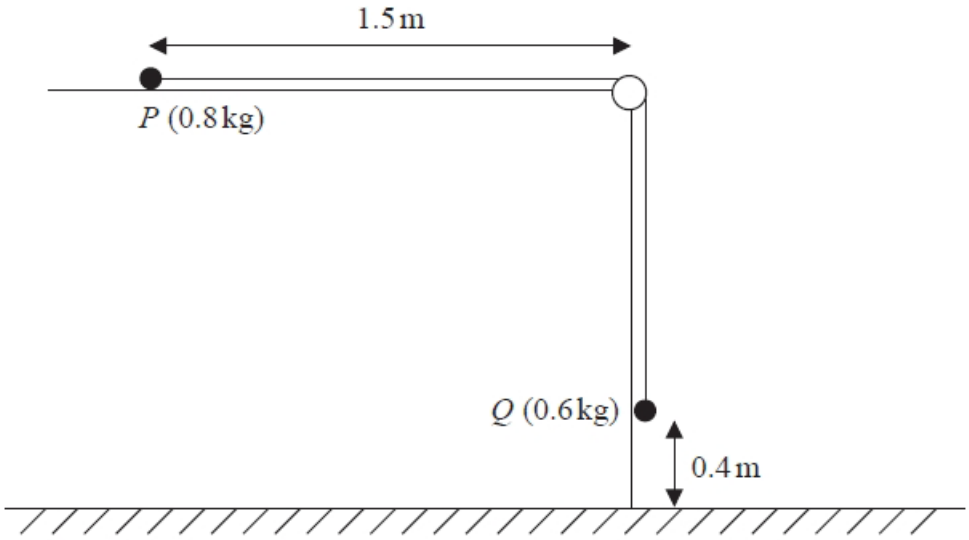

Figure 1

A small ball, *P*, of mass 0.8 kg, is held at rest on a smooth horizontal table and is attached to one end of a thin rope.

The rope passes over a pulley that is fixed at the edge of the table.

The other end of the rope is attached to another small ball, *Q*, of mass 0.6 kg, that hangs freely below the pulley.

Ball *P* is released from rest, with the rope taut, with *P* at a distance of 1.5 m from the pulley and with *Q* at a height of 0.4 m above the horizontal floor, as shown in Figure 1.

Ball *Q* descends, hits the floor and does not rebound.

The balls are modelled as particles, the rope as a light and inextensible string and the pulley as small and smooth.

Using this model,

(a) show that the acceleration of *Q*, as it falls, is 4.2 m s^{-2}

(5)

(b) find the time taken by *P* to hit the pulley from the instant when *P* is released.

(6)

(c) State one limitation of the model that will affect the accuracy of your answer to part (a).

(1)

(Total for question = 12 marks)

Q4.

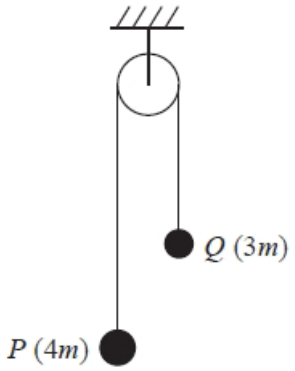

Figure 1

One end of a string is attached to a small ball *P* of mass 4m.

The other end of the string is attached to another small ball *Q* of mass 3m.

The string passes over a fixed pulley.

Ball *P* is held at rest with the string taut and the hanging parts of the string vertical, as shown in Figure 1.

Ball *P* is released.

The string is modelled as being light and inextensible, the balls are modelled as particles, the pulley is modelled as being smooth and air resistance is ignored.

(a) Using the model, find, in terms of *m* and *g*, the magnitude of the force exerted on the pulley by the string while *P* is falling and before *Q* hits the pulley.

(8)

(b) State one limitation of the model, apart from ignoring air resistance, that will affect the accuracy of your answer to part (a).

(1)

(Total for question = 9 marks)

Q5.

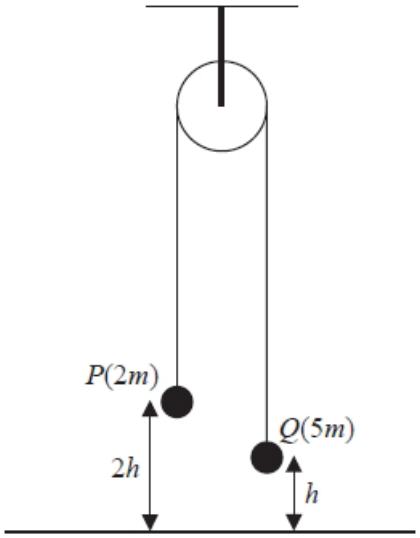

Figure 1

A ball *P* of mass 2*m* is attached to one end of a string.

The other end of the string is attached to a ball *Q* of mass 5*m*.

The string passes over a fixed pulley.

The system is held at rest with the balls hanging freely and the string taut.

The hanging parts of the string are vertical with *P* at a height 2*h* above horizontal ground and with *Q* at a height *h* above the ground, as shown in Figure 1.

The system is released from rest.

In the subsequent motion, *Q* does not rebound when it hits the ground and *P* does not hit the pulley.

The balls are modelled as particles.

The string is modelled as being light and inextensible.

The pulley is modelled as being small and smooth.

Air resistance is modelled as being negligible.

Using this model,

(a) (i) write down an equation of motion for *P*,

(ii) write down an equation of motion for *Q*,

(4)

(b) find, in terms of *h* only, the height above the ground at which *P* first comes to instantaneous rest.

(7)

(c) State one limitation of modelling the balls as particles that could affect your answer to part (b).

(1)

In reality, the string will not be inextensible.

(d) State how this would affect the accelerations of the particles.

(1)

(Total for question = 13 marks)

Mark Scheme

Q1.

Question	Scheme	Marks	AOs
(a) (i)	Equation of motion for A	M1	3.3
	$T - 12.7 = 2.5a$	A1	1.1b
(ii)	Equation of motion for B	M1	3.3
	$1.5g - T = 1.5a$	A1	1.1b
		(4)	
(b)	Solving two equations for a	M1	1.1b
	$a = 0.5$	A1	1.1b
		(2)	
(c)	$1 = \frac{1}{2} \leftarrow 0.5\, t^2$	M1	3.4
	$t = 2$ seconds	A1ft	1.1b
		(2)	
(d)	(i) Not very appropriate for valid reason, see below in notes	**B1**	3.5a
	(ii) Valid improvement in model, see below in notes.	**B1**	3.5c
		(2)	
			(10 marks)

Notes

(a) (i) 1st M1 for resolving horizontally for A
1st A1 for a correct equation
(ii) 2nd M1 for resolving vertically for B
2nd A1 for a correct equation

(b) M1 for complete correct strategy for solving the problem, setting up **two** equations in a, and then solving them for a
A1 for $a = 0.5$

(c) M1 for a complete method (which could involve use of more than one *suvat* formula) to give an equation in t only
A1ft from their a to get time in seconds

(d) (i) B1 for model is inappropriate, with valid reason
e.g. the ball has taken longer to reach the floor because the model
- does not include air resistance
- does not include the roughness of the pulley

or any other appropriate comment

(ii) B1 for e.g. Do not model ball B as a particle but give its dimensions so distance it falls changes
e.g. Do not model pulley as being small so string not parallel to table
e.g. Do not model resistance as being constant

Q2.

Question	Scheme	Marks	AOs
(a)	Equation of motion for P	M1	3.3
	$2mg - T = 2m \leftrightarrow \frac{5g}{7}$	A1	1.1b
	$T = \frac{4mg}{7}$	A1	1.1b
		(3)	
(b)	Since the string is modelled as being inextensible	B1	3.4
		(1)	
(c)	Equation of motion for Q **OR** for whole system	M1	3.3
	$T - kmg = km \leftrightarrow \frac{5g}{7}$ **OR** $2mg - kmg = (km + 2m)\frac{5g}{7}$	A1	1.1b
	$\frac{4mg}{7} - kmg = km \leftrightarrow \frac{5g}{7}$ oe and solve for k	DM1	1.1b
	$k = \frac{1}{3}$ or 0.333 or better	A1	1.1b
		(4)	
(d)	e.g The model does not take account of the mass of the string (see notes below for alternatives)	B1	3.5b
		(1)	
			(9 marks)

Notes: Condone both equations of motion appearing in (a) if used in (c)

(a)

M1: Resolving vertically for P with usual rules, correct no. of terms but condone sign errors and a does not need to be substituted (N.B. inconsistent omission of m is M0). Allow ma on RHS for M1

A1: A correct equation (allow if they use 7 instead of $\frac{5g}{7}$)

A1: A correct answer of form cmg, where $c = \frac{4}{7}$ oe or 0.57 or better

(b)

B1: String is inextensible. N.B. B0 if any extras (wrong or irrelevant) given

(c)

M1: Resolving vertically for Q or for a whole system equation, with usual rules, correct no. of terms but condone sign errors and neither T nor a does need to be substituted
(N.B. inconsistent omission of m is M0 and M0 if k is omitted from LHS or RHS or both.)

A1: A correct equation (allow if they use 7 instead of $\frac{5g}{7}$)

DM1: Sub for T using their answer from (a), if necessary, and solve to give a numerical value of k (i.e. m's must cancel)

A1: $k = \frac{1}{3}$ or 0.333 or better.

(d)

B1: e.g. Pulley may not be smooth
Pulley may not be light
Particles may not be moving freely e.g. air resistance
Balls may not be particles
String may not be light
String may not be inextensible
(but allow converses in all cases e.g. 'pulley smooth')

N.B. B0 if any extra incorrect answer is given BUT ignore incorrect consequence of a correct answer.

Also note: B0 : Use of a more accurate value of g

Q3.

Question	Scheme	Marks	AOs	Notes
(a)	Equation of motion for Q	M1	3.3	Equation of motion for Q with correct no. of terms, condone sign errors.
	$0.6g - T = 0.6a$	A1	1.1 b	A correct equation
	Equation of motion for P	M1	3.3	Equation of motion for Q with correct no. of terms, condone sign errors.
	$T = 0.8a$	A1	1.1 b	A correct equation
	$a = 4.2$ (m s^{-2}) *	A1*	2.2 a	Given acceleration obtained correctly. **You must see an equation in a only before reaching $a = 4.2$**
		(5)		**N.B.** if they just use the whole system equation: $0.6g = 1.4a$, can only score max M1A1M0A0A0 **N.B.** Use of $g = 9.81$ or 10 loses final A mark only. **N.B.** Complete verification, using both equations, can score full marks.

(b)	$0.4=\frac{1}{2}\times 4.2\times t_1^2$ or e.g. they may find v first and then use $v=4.2t_1$	M1	2.1	Complete method (they may use more than one *suvat* equation) to find time for Q to hit the floor (M0 if 0.4 **not** used as distance moved and/or if 4.2 is **not** used as acceleration and this applies to finding v as well if they use v to find t_1)
	$t_1=0.436(4357\ldots..)$ Allow 0.43, 0.44, 0.436, or better, or any surd form e.g. $\frac{2}{\sqrt{21}}$	A1	1.1 b	See alternatives
	$v=4.2\times t_1$ or $v=\sqrt{2\times 4.2\times 0.4}$ or $0.4=\frac{(0+v)}{2}\times t_1$ $(v=1.8330\ldots)$	M1	3.4	Complete method to find speed of Q as it hits the floor (M0 if 0.4 **not** used as distance moved and/or if 4.2 is **not** used as acceleration and this applies to finding t_1 as well if they use t_1 to find v)
	$t_2=\frac{1.5-0.4}{v}$	M1	1.1 b	Uses distance/speed to find time for P to hit the pulley after Q has hit the floor. N.B. This is independent of previous M mark.
	Complete strategy to solve the problem by finding the sum of the two times t_1+t_2	**DM 1**	3.1 b	Complete method to solve the problem by finding and adding the two required times, dependent on previous three M marks
	1.0 (s) or 1.04 (s)	A1	1.1 b	
		(6)		

(c)	e.g. rope being light; rope being inextensible; pulley being smooth; pulley being small; balls being particles	B1	3.5 b	Clear statement. Allow negatives of these i.e. the rope may not be light, the rope may not be inextensible etc Must be a limitation of the model stated in the question Penalise incorrect or irrelevant extras
		(1)		B0 for: Air resistance, table being smooth
		(12 marks)		

Q4.

Question	Scheme	Marks	AOs
(a)	Equation of motion for P with usual rules	M1	3.3
	$4mg - T = 4ma$	A1	1.1b
	Equation of motion for Q with usual rules	M1	3.3
	$T - 3mg = 3ma$	A1	1.1b
	Solve these equations for T (does not need to be in terms of mg)	M1	1.1b
	$T = \frac{24mg}{7}$ in any form (does not need to be a single term)	A1	1.1b
	Force on pulley = $2T$	M1	3.4
	$\frac{48mg}{7}$ Accept $6.9mg$ or better	A1	1.1b
		(8)	
(b)	Weight of the rope or extensibility of rope Or: pulley may not be smooth	B1	3.5b
		(1)	
			(9 marks)

Notes:		
(a)	M1	Translate situation into the model and set up the equation of motion for P M0 if they omit m's i.e. $4g - T = 4a$
	A1	Correct equation
	M1	Translate situation into the model and set up the equation of motion for Q M0 if they omit m's i.e. $T - 3g = 3a$
	A1	Correct equation
		N.B. Condone either of the above equations being replaced by the 'whole system equation': $4mg - 3mg = 7ma$ (N.B. $a = g/7$) **N.B.** a replaced by $-a$ consistently can score all the marks
	M1	Solve equations for T
	A1	$T = \frac{24mg}{7}$ oe
	M1	T does not need to be substituted.
	A1	$\frac{48mg}{7}$ oe Must be in terms of m and g and be a single term
(b)	B1	B0 if any incorrect extras are given

Q5.

Question	Scheme	Marks	AOs
(a)	(i) Equation of motion for P	M1	3.3
	$T-2mg=2ma$	A1	1.1b
	(ii) Equation of motion for Q	M1	3.3
	$5mg-T=5ma$	A1	1.1b
	N.B. (allow $(-a)$ in both equations)	**(4)**	
(b)	Solve equations for a or use whole system equation and solve for a	M1	3.4
	$a=\frac{3g}{7}=4.2$	A1	1.1b
	$v=\sqrt{2\times\frac{3g}{7}\times h}=\sqrt{8.4h}$ or $v^2=2\times\frac{3g}{7}\times h\ (=8.4h)$	M1	1.1b
	$0=\frac{6gh}{7}-2gH$	M1	1.1b
	$H=\frac{3h}{7}$	A1	1.1b
	Total height $=2h+h+H$	M1	2.1
	Total height $=\frac{24h}{7}$	A1	1.1b
		(7)	
(c)	e.g. The distance that Q falls to the ground would not be exactly h oe	B1	3.5b
		(1)	
(d)	e.g. The accelerations of the balls would not have equal magnitude (allow 'wouldn't be the same' oe) B0 if they say 'inextensible => acceleration same'	B1	3.5a
		(1)	
			(13 marks)

Notes:		
a	M1	Translate situation into the model and set up the equation of motion for P (must contain T and a)
	A1	Correct equation
	M1	Translate situation into the model and set up the equation of motion for Q(must contain T and a)
	A1	Correct equation
		N.B. Allow the above 4 marks if the equations appear in (b).
		If m's are omitted consistently, max (a) M1A0M1A0 (b)M1A0M1M1A1M1A0
b	M1	Solve for a
	A1	Allow 4.2 (m s^{-2}) or must be in terms of g only.
		N.B. Allow the above 2 marks if they appear in (a).
	M1	Complete method to produce an expression for v or v^2 in terms h, using their a
	M1	Complete method to produce an expression for H in terms of h ,using $a = -g$ and $v = 0$
	A1	Correct expression for H
	M1	Complete method to find the total distance
	A1	cao but allow $3.4h$ or better
c	B1	B0 if any incorrect extras are given
d	B1	B0 if any incorrect extras are given or for an incorrect statement e.g. tension is not constant so accelerations will be different