

## KS5 "Full Coverage": Connected Particles (Yr2)

This worksheet is designed to cover one question of each type seen in past papers, for each A Level topic. This worksheet was automatically generated by the DrFrostMaths Homework Platform: students can practice this set of questions interactively by going to [www.drfrostmaths.com](http://www.drfrostmaths.com), logging on, *Practise* → *Past Papers* (or *Library* → *Past Papers* for teachers), and using the 'Revision' tab.

### Question 1

**Categorisation:** Determine and use equations of motion for connected particles, where one is vertical and the other is horizontal.

*[Edexcel M1 Jan 2008 Q7a]*

**Figure 3**



Two particles A and B, of mass  $m$  and  $2m$  respectively, are attached to the ends of a light inextensible string. The particle A lies on a rough horizontal table. The string passes over a small smooth pulley P fixed on the edge of the table. The particle B hangs freely below the pulley, as shown in Figure 3. The coefficient of friction between A and the table is  $\mu$ . The particles are released from rest with the string taut. Immediately after release, the magnitude of the acceleration of A and B is  $\frac{4}{9}g$ .

By writing down separate equations of motion for A and B, find the tension in the string immediately after the particles begin to move.

*Input note: give your answer in terms of  $m$  and  $g$ .*

$T = \dots\dots\dots$  N

## Question 2

**Categorisation:** As above, but to determine an unknown mass.

[Edexcel AS Specimen Papers P2 Q7a<sub>ii</sub>]

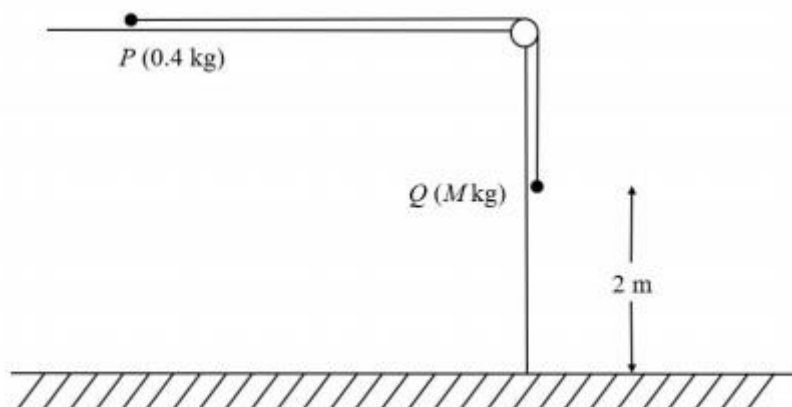


Figure 1

A ball,  $P$ , of mass  $0.4\text{ kg}$  rests on a rough horizontal table and is attached to one end of a thin rope. The rope passes over a pulley which is fixed at the edge of the table. The other end of the rope is attached to another ball,  $Q$ , of mass  $M\text{ kg}$ , which hangs freely below the pulley, as shown in Figure 1.

The system is released from rest with the rope taut and with  $Q$  at a height of  $2\text{ m}$  above the ground and  $Q$  moves downwards with acceleration  $2.5\text{ m s}^{-2}$

In the subsequent motion,  $P$  does not reach the pulley before  $Q$  reaches the ground.

The balls are modelled as particles, the rope as a light and inextensible string and the pulley as being small and smooth. The total resistance to the motion of  $P$  is modelled as having constant magnitude  $1.5\text{ N}$ .

The acceleration due to gravity is modelled as being  $10\text{ m s}^{-2}$

Using this model, find, to 2 significant figures, the value of  $M$ .

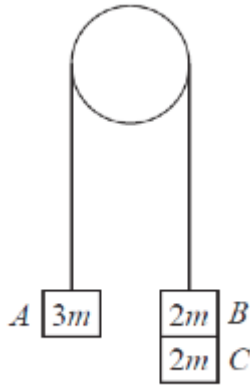
$M = \dots\dots\dots\text{ kg}$

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### Question 3

**Categorisation: Vertically hanging particles on a pulley.**

*[Edexcel M1 June 2014 Q7a(ii) Edited]*



**Figure 5**

Three particles  $A$ ,  $B$  and  $C$  have masses  $3m$ ,  $2m$  and  $2m$  respectively. Particle  $C$  is attached to particle  $B$ . Particles  $A$  and  $B$  are connected by a light inextensible string which passes over a smooth light fixed pulley. The system is held at rest with the string taut and the hanging parts of the string vertical, as shown in Figure 5. The system is released from rest and  $A$  moves upwards.

The acceleration of  $A$  is  $\frac{g}{7}$ .

Find the tension in the string as  $A$  ascends.

$T = \dots\dots\dots$

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## Question 4

**Categorisation: Tow bars connecting two horizontally aligned vehicles.**

*[Edexcel M1 June 2001 Q6b Edited]*

A breakdown van of mass 2000 kg is towing a car of mass 1200 kg along a straight horizontal road. The two vehicles are joined by a tow bar which remains parallel to the road. The van and the car experience constant resistances to motion of magnitudes 800 N and 240 N respectively. There is a constant driving force acting on the van of 2320 N.

The magnitude of the acceleration of the van and the car is  $0.4 \text{ m s}^{-2}$ .

Find the tension in the tow bar.

$T = \dots\dots\dots \text{ N}$

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## Question 5

**Categorisation: Connected vehicles on a slope.**

*[Edexcel M1 June 2001 Q6c]*

A breakdown van of mass 2000 kg is towing a car of mass 1200 kg along a straight horizontal road. The two vehicles are joined by a tow bar which remains parallel to the road. The van and the car experience constant resistances to motion of magnitudes 800 N and 240 N respectively. There is a constant driving force acting on the van of 2320 N.

The two vehicles come to a hill inclined at an angle  $\alpha$  to the horizontal, where  $\sin \alpha = \frac{1}{20}$ .

The driving force and the resistances to the motion are unchanged.

Find the magnitude of the acceleration of the van and the car as they move up the hill and state whether their speed increases or decreases.

$\dots\dots\dots$

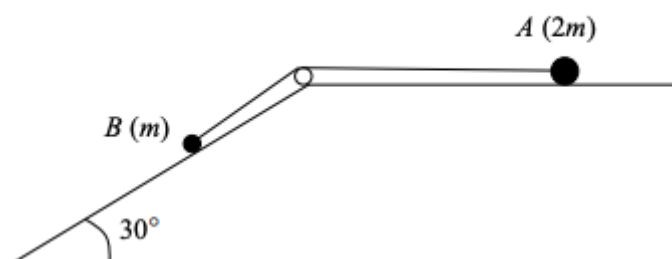
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## Question 6

**Categorisation: Connected particles with one horizontal, one inclined.**

*[Edexcel M1 June 2002 Q7a Edited]*

**Figure 3**



Particles  $A$  and  $B$ , of mass  $2m$  and  $m$  respectively, are attached to the ends of a light inextensible string. The string passes over a small smooth pulley fixed at the edge of a rough horizontal table. Particle  $A$  is held on the table, while  $BA$  and the table is  $\mu$ . The particle  $A$  is released from rest and begins to move.

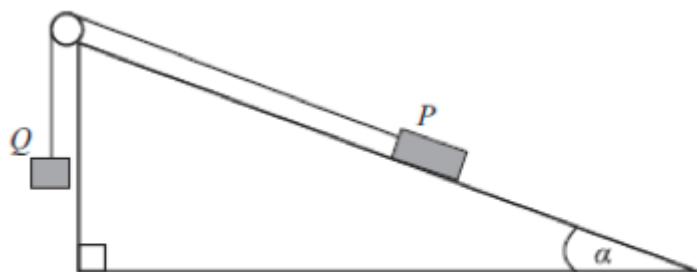
By writing down an equation of motion for each particle, show that, while both particles move with the string taut, each particle has an acceleration of magnitude  $\frac{1}{6}(1 - a\mu)g$ , where  $a$  is a constant to be found.

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## Question 7

**Categorisation: Connected particles where one is vertical, one inclined.**

[Edexcel M1 May 2011 Q6b]



**Figure 2**

Two particles  $P$  and  $Q$  have masses  $0.3$  kg and  $m$  kg respectively. The particles are attached to the ends of a light inextensible string. The string passes over a small smooth pulley which is fixed at the top of a fixed rough plane. The plane is inclined to the horizontal at an angle  $\alpha$ , where  $\tan \alpha = \frac{3}{4}$ . The coefficient of friction between  $P$  and the plane is  $\frac{1}{2}$ .

The string lies in a vertical plane through a line of greatest slope of the inclined plane. The particle  $P$  is held at rest on the inclined plane and the particle  $Q$  hangs freely below the pulley with the string taut, as shown in Figure 2.

The system is released from rest and  $Q$  accelerates vertically downwards at  $1.4 \text{ m s}^{-2}$ .

Find the value of  $m$ .

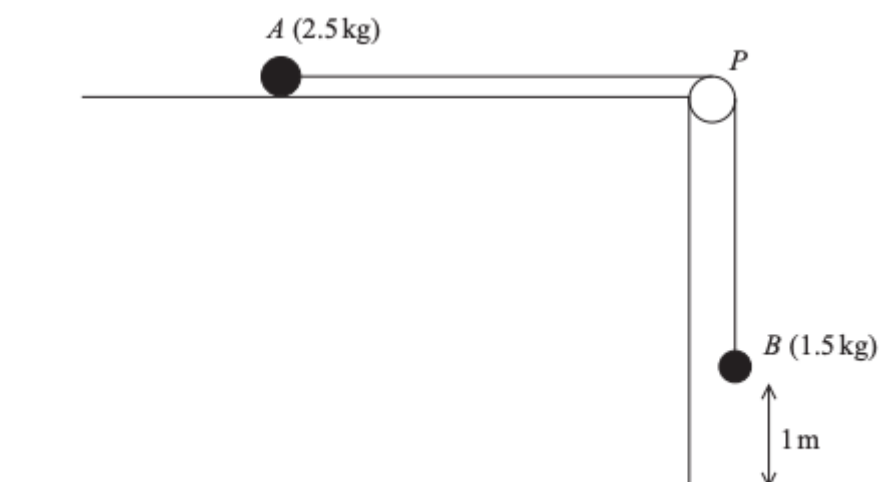
$m = \dots\dots\dots$

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## Question 8

**Categorisation:** Use the acceleration from connected particles to determine a distance subsequently covered or time taken.

[Edexcel AS SAM P2 Q9c Edited]



**Figure 2**

A small ball  $A$  of mass  $2.5 \text{ kg}$  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  $1.5 \text{ kg}$  hanging freely, vertically below  $P$  and with  $B$  at a height of  $1 \text{ m}$  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  $12.7 \text{ N}$ . 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, the pulley is modelled as being small and smooth and the acceleration due to gravity,  $g$ , is modelled as being  $9.8 \text{ m s}^{-2}$ .

It can be shown that the acceleration of  $B$  is  $0.5 \text{ m s}^{-2}$ .

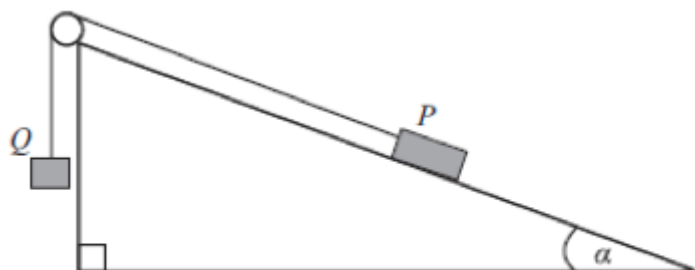
Using the model, find the time it takes, from release, for  $B$  to reach the floor.

$t = \dots\dots\dots \text{ s}$

## Question 9

**Categorisation:** Consider subsequent motion after a rope/string/cable breaks.

[Edexcel M1 May 2011 Q6c]



**Figure 2**

Two particles  $P$  and  $Q$  have masses  $0.3 \text{ kg}$  and  $m \text{ kg}$  respectively. The particles are attached to the ends of a light inextensible string. The string passes over a small smooth pulley which is fixed at the top of a fixed rough plane. The plane is inclined to the horizontal at an angle  $\alpha$ , where  $\tan \alpha = \frac{3}{4}$ . The coefficient of friction between  $P$  and the plane is  $\frac{1}{2}$ .

The string lies in a vertical plane through a line of greatest slope of the inclined plane. The particle  $P$  is held at rest on the inclined plane and the particle  $Q$  hangs freely below the pulley with the string taut, as shown in Figure 2.

The system is released from rest and  $Q$  accelerates vertically downwards at  $1.4 \text{ m s}^{-2}$ .

When the particles have been moving for  $0.5 \text{ s}$ , the string breaks. Assuming that  $P$  does not reach the pulley, find the further time that elapses until  $P$  comes to instantaneous rest.

$t = \dots\dots\dots \text{ s}$

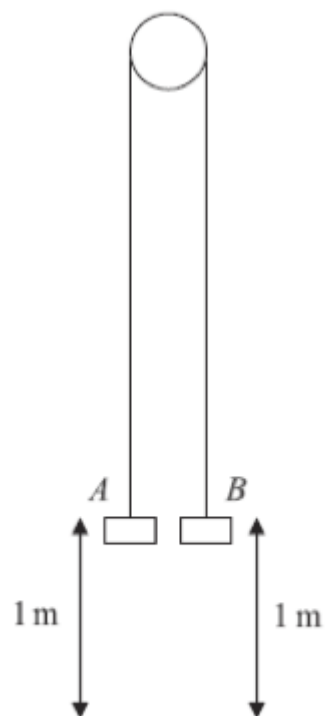
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### Question 10

**Categorisation:** As per Q8-9, but with particles vertically hanging from a pulley.

[Edexcel M1 May 2010 Q8c]



**Figure 3**

Two particles  $A$  and  $B$  have mass  $0.4\text{ kg}$  and  $0.3\text{ kg}$  respectively. The particles are attached to the ends of a light inextensible string. The string passes over a small smooth pulley which is fixed above a horizontal floor. Both particles are held, with the string taut, at a height of  $1\text{ m}$  above the floor, as shown in Figure 3. The particles are released from rest and in the subsequent motion  $B$  does not reach the pulley.

When the particles have been moving for  $0.5\text{ s}$ , the string breaks.

Given that the acceleration of  $A$  immediately after the particles are released is  $1.4\text{ ms}^{-2}$ , find the further time that elapses until  $B$  hits the floor.

..... S

## Question 11

**Categorisation: As per Q8-10, but for a towed vehicle.**

*[Edexcel M1 June 2006 Q6c]*

A car is towing a trailer along a straight horizontal road by means of a horizontal tow-rope. The mass of the car is 1400 kg. The mass of the trailer is 700 kg. The car and the trailer are modelled as particles and the tow-rope as a light inextensible string. The resistances to motion of the car and the trailer are assumed to be constant and of magnitude 630 N and 280 N respectively. The driving force on the car, due to its engine, is 2380 N.

When the car and trailer are moving at  $12 \text{ m s}^{-1}$ , the tow-rope breaks. Assuming that the driving force on the car and the resistances to motion are unchanged, find the distance moved by the car in the first 4 s after the tow-rope breaks.

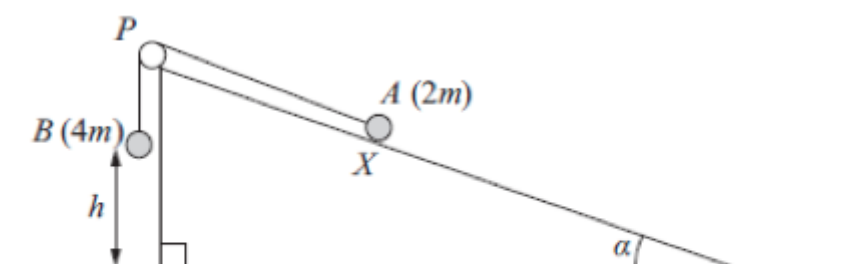
..... m

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## Question 12

**Categorisation: Further practice of subsequent motion after a break.**

[Edexcel M1 Jan 2013 Q7d]



**Figure 5**

Figure 5 shows two particles  $A$  and  $B$ , of mass  $2m$  and  $4m$  respectively, connected by a light inextensible string. Initially  $A$  is held at rest on a rough inclined plane which is fixed to horizontal ground. The plane is inclined to the horizontal at an angle  $\alpha$ , where  $\tan \alpha = \frac{3}{4}$ . The coefficient of friction between  $A$  and the plane is  $\frac{1}{4}$ . The string passes over a small smooth pulley  $P$  which is fixed at the top of the plane. The part of the string from  $A$  to  $P$  is parallel to a line of greatest slope of the plane and  $B$  hangs vertically below  $P$ . The system is released from rest with the string taut, with  $A$  at the point  $X$  and with  $B$  at a height  $h$  above the ground.

Particle  $B$  does not rebound when it hits the ground and  $A$  continues moving up the plane towards  $P$ .

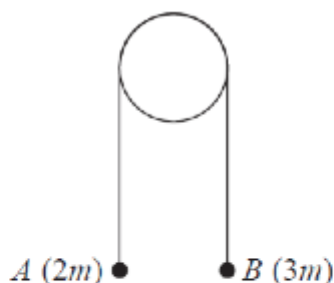
Given that  $A$  comes to rest at the point  $Y$ , without reaching  $P$ , find the distance  $XY$  in terms of  $h$ .

$XY = \dots\dots\dots$

### Question 13

Categorisation: As above.

[Edexcel M1 June 2014(R) Q5b]



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**Figure 2**

Two particles  $A$  and  $B$  have masses  $2m$  and  $3m$  respectively. The particles are connected by a light inextensible string which passes over a smooth light fixed pulley. The system is held at rest with the string taut. The hanging parts of the string are vertical and  $A$  and  $B$  are above a horizontal plane, as shown in Figure 2. The system is released from rest.

After descending  $1.5\text{ m}$ ,  $B$  strikes the plane and is immediately brought to rest. In the subsequent motion,  $A$  does not reach the pulley.

Find the distance travelled by  $A$  between the instant when  $B$  strikes the plane and the instant when the string next becomes taut.

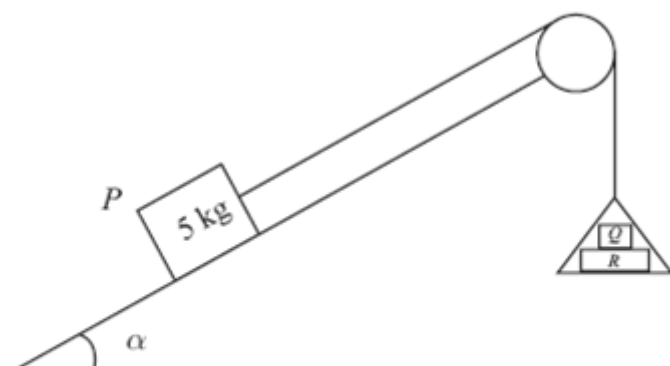
$s = \dots\dots\dots\text{ m}$

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## Question 14

**Categorisation: Multiple particles on a pan.**

[Edexcel M1 Jan 2009 Q7b Edited]



**Figure 3**

One end of a light inextensible string is attached to a block  $P$  of mass 5 kg. The block  $P$  is held at rest on a smooth fixed plane which is inclined to the horizontal at an angle  $\alpha$ , where  $\sin \alpha = \frac{3}{5}$ . The string lies along a line of greatest slope of the plane and passes over a smooth light pulley which is fixed at the top of the plane. The other end of the string is attached to a light scale pan which carries two blocks  $Q$  and  $R$ , with block  $Q$  on top of block  $R$ , as shown in Figure 3. The mass of block  $Q$  is 5 kg and the mass of block  $R$  is 10 kg. The scale pan hangs at rest and the system is released from rest.

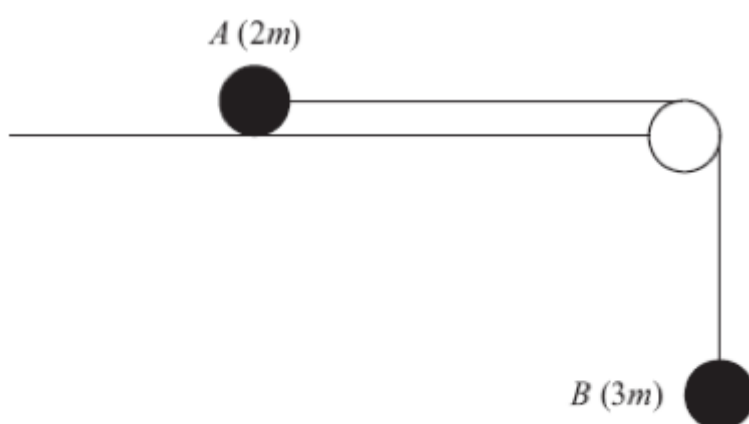
By modelling the blocks as particles, ignoring air resistance and assuming the motion is uninterrupted, find the magnitude of the force exerted on block  $Q$  by block  $R$ .

..... N

## Question 15

**Categorisation: Determine the force on a pulley.**

[Edexcel M1 May 2013 Q8c]



**Figure 2**

Two particles  $A$  and  $B$  have masses  $2m$  and  $3m$  respectively. The particles are attached to the ends of a light inextensible string. Particle  $A$  is held at rest on a smooth horizontal table. The string passes over a small smooth pulley which is fixed at the edge of the table. Particle  $B$  hangs at rest vertically below the pulley with the string taut, as shown in Figure 2. Particle  $A$  is released from rest.

Assuming that  $A$  has not reached the pulley, find the magnitude and direction of the force exerted on the pulley by the string.

magnitude = .....  $m$

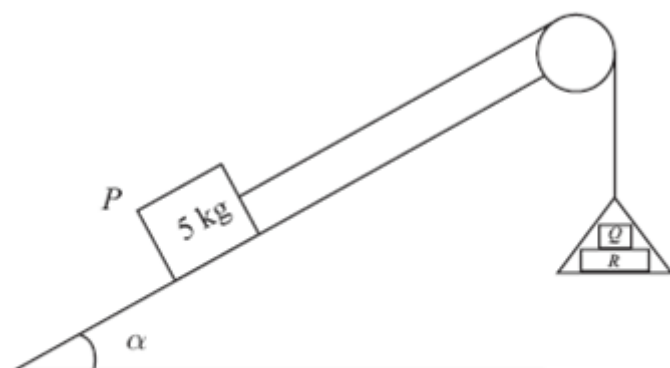
direction = .....  $^{\circ}$  below the horizontal

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## Question 16

**Categorisation:** As above, but for an inclined plane.

[Edexcel M1 Jan 2009 Q7c Edited]



**Figure 3**

One end of a light inextensible string is attached to a block  $P$  of mass 5 kg. The block  $P$  is held at rest on a smooth fixed plane which is inclined to the horizontal at an angle  $\alpha$ , where  $\sin \alpha = \frac{3}{5}$ . The string lies along a line of greatest slope of the plane and passes over a smooth light pulley which is fixed at the top of the plane. The other end of the string is attached to a light scale pan which carries two blocks  $Q$  and  $R$ , with block  $Q$  on top of block  $R$ , as shown in Figure 3. The mass of block  $Q$  is 5 kg and the mass of block  $R$  is 10 kg. The scale pan hangs at rest and the system is released from rest.

By modelling the blocks as particles, ignoring air resistance and assuming the motion is uninterrupted, find the magnitude of the force exerted on the pulley by the string.

Give your answer correct to 3 significant figures.

..... N

# Answers

## Question 1

7.(a)	B: $2mg - T = 2m \times 4g/9$	M1 A1
	$\Rightarrow T = \underline{10mg/9}$	A1 (3)

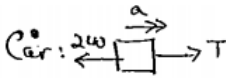
## Question 2

Equation of motion for $Q$ with usual rules	M1
$10M - T = 2.5M$	A1
$M = 0.33$	A1

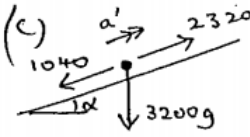
## Question 3

7(a)	$4mg - T = 4ma$	M1A1
	$T - 3mg = 3ma$	M1A1
	Condone the use of $4mg - 3mg = 4ma + 3ma$ in place of one of these equations.	M1A1
	Reach <b>given answer</b> $a = \frac{g}{7}$ correctly ***	A1
	Form an equation in $T$ : $T = 3mg + 3\left(mg - \frac{T}{4}\right)$ , $T = 3mg + 3m\frac{g}{7}$ , or $T = 4mg - 4m\frac{g}{7}$	M1
	$T = \frac{24}{7}mg$ or equivalent, $33.6m$ , $34m$	A1 (7)

## Question 4

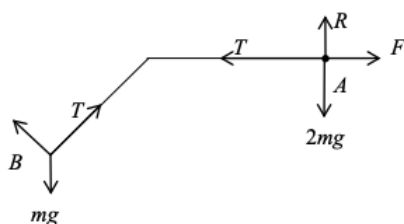
 $1200a = T - 240$ $\rightarrow T = 720 \text{ N}$	M1 A2 ✓ -1 e.e. A1 (4)
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## Question 5

(c)  $3200a' = 2320 - 1040 - 3200g \cdot \frac{1}{20}$ $a' = -0.09 \text{ m s}^{-2}$ $\Rightarrow$ magn. $0.09 \text{ m s}^{-2}$ speed decreasing	(4 terms) M1 A2 -1 e.e. M1 A1 A1 ✓ (6)
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## Question 6



$$R = 2mg \Rightarrow F = 2\mu mg$$

$$A: T - 2\mu mg = 2ma$$

$$B: mg \times \frac{1}{2} - T = ma$$

$$\text{Eliminating } T: 3ma = \frac{1}{2}mg - 2\mu mg$$

$$a = \frac{1}{6}(1 - 4\mu)g (*)$$

B1

M1 A1

M1 A1

M1

A1

## Question 7

$$mg - T = 1.4m$$

$$T - 0.3g \sin \alpha - F = 0.3 \times 1.4$$

$$F = 0.5R$$

$$\text{Eliminating } R \text{ and } T$$

$$m = 0.4$$

M1 A1

M1 A2

M1

DM1

A1

(8)

## Question 8

$$1 = \frac{1}{2} \leftarrow 0.5 t^2$$

M1

$$t = 2 \text{ seconds}$$

A1ft

## Question 9

$$v = 1.4 \times 0.5$$

$$-0.3g \sin \alpha - F = 0.3a$$

$$a = -9.8$$

$$0 = 0.7 - 9.8t$$

$$t = 0.071 \text{ s or } 0.0714 \text{ s (1/14 A0)}$$

B1

M1 A1

A1

M1

A1

(6)

## Question 10

$$(\uparrow) v = u + at$$

$$v = 0.5 \times 1.4$$

$$= 0.7$$

M1

A1 ft on a

$$(\uparrow) s = ut + \frac{1}{2}at^2$$

$$s = 0.5 \times 1.4 \times 0.5^2$$

$$= 0.175$$

M1

A1 ft on a

$$(\downarrow) s = ut + \frac{1}{2}at^2$$

$$1.175 = -0.7t + 4.9t^2$$

$$4.9t^2 - 0.7t - 1.175 = 0$$

$$t = \frac{0.7 \pm \sqrt{0.7^2 + 19.6 \times 1.175}}{9.8}$$

$$= 0.5663 \text{ or } -...$$

DM1 A1 ft

DM1 A1 cao

$$\text{Ans } 0.57 \text{ or } 0.566 \text{ s}$$

A1 cao (9)

## Question 11

(c) Car:	$1400a' = 2380 - 630$	M1 A1
	$\Rightarrow a' = 1.25 \text{ m s}^{-2}$	A1
	distance = $12 \times 4 + \frac{1}{2} \times 1.25 \times 4^2$	M1 A1 ✓
	= <u>58 m</u>	A1 (6)

## Question 12

(d)	$v^2 = 2 \times 0.4gh$ $-2mg \sin \alpha - F = 2ma'$ $a' = -0.8g$ $0^2 = 0.8gh - 2 \times 0.8g \times s$ $s = 0.5h$ $XY = 0.5h + h = 1.5h$	M1 M1 A1  M1 A1 A1
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## Question 13

b	$a = \frac{g}{5}$ At time of impact $v^2 = u^2 + 2as = 2 \times \frac{g}{5} \times 1.5 = 0.6g$ Vertical motion under gravity $0 = 0.6g - 2gs$ $s = 0.3 \text{ (m)}$ Total distance $2 \times 0.3 = 0.6 \text{ (m)}$	B1  M1A1 M1  DM1A1 (6)
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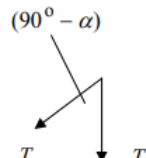
## Question 14

(b)	For Q: $\begin{matrix} 5g - N = 5a \\ N = 2g \end{matrix}$	M1 A1 A1 f.t. (3)
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## Question 15

$F = \sqrt{T^2 + T^2}$	M1 A1 ft
$F = \frac{6mg\sqrt{2}}{5}; 1.7mg \text{ (or better); } 16.6m; 17m$	A1
Direction clearly marked on a diagram, with an arrow, and $45^\circ$ (oe) marked	B1

## Question 16

(c)	 $F = 2T \cos\left(\frac{90^\circ - \alpha}{2}\right)$ $= 12g \cos 26.56^\circ$ $= 105 \text{ N}$	M1 A2  A1 f.t. A1 (5)
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