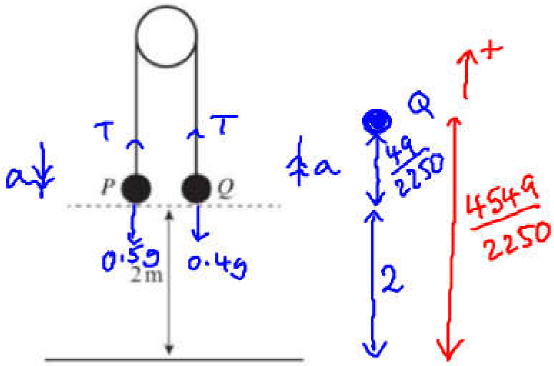
15 Two particles P and Q have masses 0.5 kg and 0.4 kg respectively. The particles are attached to the ends of a light inextensible string. The string passes over a small smooth pulley which is fixed above a horizontal floor. Both particles are held, with the string taut, at a height of 2 m above the floor, as shown. The particles are released from rest and in the subsequent motion Q does not reach the pulley.



a **i** Write down an equation of motion for P. ✓ **(2 marks)**

ii Write down an equation of motion for Q. ✓ **(2 marks)**

b Find the tension in the string immediately after the particles are released. ✓ **(2 marks)**

c Find the acceleration of A immediately after the particles are released. ✓ **(2 marks)**

When the particles have been moving for 0.2 s, the string breaks. $T = 0$

d Find the further time that elapses until Q hits the floor. **(9 marks)**

a i) P, R↓, $F = ma$

$0.5g - T = 0.5a$ ①

ii) Q, R↑, $F = ma$

$\boxed{T - 0.4g = 0.4a}$ ②

b) and c)

① + ②

$0.5g - 0.4g = 0.9a$

$\frac{0.1g}{0.9} = a$

$a = \frac{1}{9}g = \frac{49}{45} = 1.09\ \text{ms}^{-2}$ (3sf)

② $T = 0.4a + 0.4g$

$= 0.4 \times \frac{49}{45} + 0.4 \times 9.8 = 4.3555$

$= 4.36\ \text{N}$ (3sf)

d) First 0.2 seconds of motion

$a = \frac{49}{45}$

$u = 0$

$t = 0.2$

$v = ?$

$v = u + at$

$= 0 + 0.2 \times \frac{49}{45} = \frac{49}{225}$

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

$s = \frac{1}{2} \times \frac{49}{45} \times 0.2^2 = \frac{49}{2250}$

New acceleration for Q

string breaks → $T = 0$

$-0.4g = 0.4a$

$-g = a$

$a = -9.8$

After string breaks ↑+

$a = -9.8$

$u = \frac{49}{225}$

$s = -\frac{4549}{2250}$

$t = ?$

$-\frac{4549}{2250} = \frac{49}{225}t - 4.9t^2$

$4.9t^2 - \frac{49}{225}t - \frac{4549}{2250} = 0$

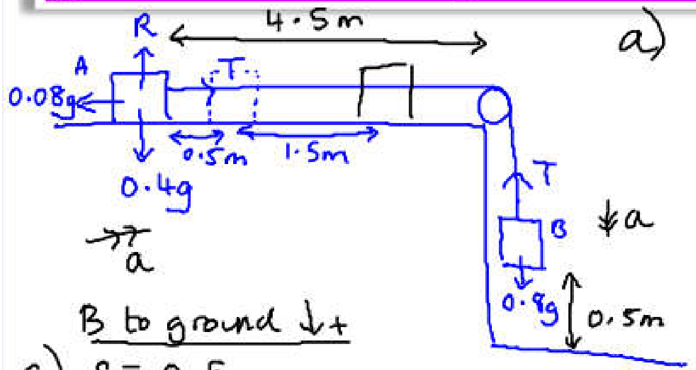
$t = 0.665$ secs (3sf)

or $t = \cancel{-0.621}$

Connected Particles - pulleys on tables

Two particles A and B of masses 0.4kg and 0.8kg respectively are connected by a light inextensible string. Particle A lies on a rough horizontal table 4.5m from a small smooth pulley which is fixed at the edge of the table. The string passes over the pulley and B hangs freely, with the string taut, 0.5m above horizontal ground. A frictional force of magnitude 0.08g opposes the motion of particle A. The system is released from rest. Find:

(a) The acceleration of the system
(b) The tension in the string
(c) The time taken for B to reach the ground
(d) The total distance travelled by A before it first comes to rest.



a) A, $R\rightarrow$, $F=ma$

$$\boxed{T-0.08g=0.4a} \quad ①$$

B, $R\downarrow$, $F=ma$

$$0.8g-T=0.8a \quad ②$$

$① + ②$

$$0.8g-0.08g=1.2a$$
$$0.6g=a$$

b) ① $T=0.4a+0.08g$

$$=0.4\times0.6g+0.08g$$
$$=0.24g+0.08g$$
$$=0.32g$$
$$T=3.14\text{N}\ (3sf)$$

Checklist
F=ma ✓
F=ma ✓
Solve ✓

SUVAT: v ⇨ u ✓
New acceleration: T = 0 ✓
SUVAT ✓
Solve problem ✓

B to ground ↓+

c) $s=0.5$
$a=0.6g$ $\quad v=?$
$u=0$
$t=?$

$$s=ut+\tfrac{1}{2}at^2$$
$$0.5=0.3gt^2$$
$$t=\frac{5\sqrt{3}}{21}=0.412\ (3sf)$$

d) $v^2=u^2+2as$
$v^2=2\times0.6g\times0.5$
$v^2=0.6g$
$v=\sqrt{0.6g}$

B hits floor, $T=0$
A has new value for a.

$$-0.08g=0.4a$$
$$-0.2g=a$$

A travelling after B hits floor

$a=-0.2g$
$u=\sqrt{0.6g}$
$v=0$
$s=?$

$$v^2=u^2+2as$$
$$0=0.6g+2\times(-0.2g)\times s$$
$$0=0.6g-0.4gs$$
$$0.4\cancel{g}s=0.6\cancel{g}$$
$$s=\frac{0.6}{0.4}=1.5\text{m}$$

Total distance $=0.5+1.5$
$=2$ m

A box A of mass 0.8 kg rests on a rough horizontal table and is attached to one end of a light inextensible string. The string passes over a smooth pulley fixed at the edge of the table. The other end of the string is attached to a sphere B of mass 1.2 kg, which hangs freely below the pulley. The magnitude of the frictional force between A and the table is F N. The system is released from rest with the string taut. After release, B descends a distance of 0.9 m in 0.8 s.

Modelling A and B as particles, calculate

(a) the acceleration of B,

(2)

(b) the tension in the string,

(3)

(c) the value of F.

(3)

Sphere B is 0.9 m above the ground when the system is released. Given that it does not reach the pulley and the frictional force remains constant throughout,

(d) find the total distance travelled by A.

(7)

(Total 15 marks)

Ex 10F Q4, 5

7a	Correctly uses $s = ut + \frac{1}{2}at^2$ to write $0.9 = (0)t + \frac{1}{2} \times a \times (0.8)^2$	**M1**	3.1b	5th Solve problems of connected particles using pulleys.
	Correctly finds $a = \frac{45}{16}$ (m s^{-2}) or 2.8125 (m s^{-2}). Accept awrt 2.8 (m s^{-2}).	**A1**	1.1b	
		(2)		
7b	Demonstrates an understanding that the resultant force acting on sphere B is $1.2g - T$.	**M1**	3.1b	5th Solve problems of connected particles using pulleys.
	Uses $F = ma$ to write $1.2g - T = 1.2\left(\frac{45}{16}\right)$	**M1**	3.3	
	Correctly solves to find $T = \frac{1677}{200}$ (N) or 8.385 (N). Accept 8.4 (N).	**A1 ft**	1.1b	
		(3)		

7c	Demonstrates an understanding that the resultant force acting on box A is $T - F$.	**M1**	3.1b	5th Solve problems of connected particles using pulleys.
	Uses $F = ma$ to write $\frac{1677}{200} - F = 0.8\left(\frac{45}{16}\right)$	**M1**	3.3	
	Correctly solves to find $F = \frac{1227}{200}$ (N) or 6.135 (N). Accept 6.1 (N).	**A1ft**	1.1b	
		(3)		

7d	Uses $v = u + at$ to write $v = 0 + \frac{45}{16} \times 0.8$	**M1**	3.1b	5th Solve problems of connected particles using pulleys.
	Solves to find $v = \frac{9}{4}$ or 2.25 m s^{-1}.	**A1 ft**	1.1b	
	Uses $F = ma$ to write $-F = 0.8a$ or $-\frac{1227}{200} = 0.8a$	**M1**	3.1b	
	Solves to find $a = -\frac{1227}{160}$ m s^{-2} or 7.66…(m s^{-2}).	**A1 ft**	1.1b	
	Uses $v^2 = u^2 + 2as$ to write $0 = \left(\frac{9}{4}\right)^2 + 2\left(-\frac{1227}{160}\right)s$	**M1**	2.2a	
	Solves to find $s = \frac{135}{409}$ (m) or 0.33… (m). Accept awrt 0.33 (m).	**A1 ft**	1.1b	
	States that the total distance travelled will be 1.23 m (0.9 + 0.33).	**B1 ft**	3.2	
		(7)		

(15 marks)