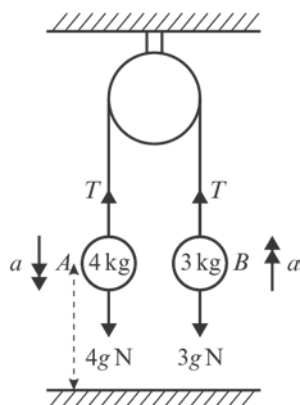


Forces and motion 10F

1 a



$$\text{For A: } R(\downarrow), \quad 4g - T = 4a \quad (1)$$

$$\text{For B: } R(\uparrow), \quad T - 3g = 3a \quad (2)$$

$$(1) + (2): 4g - 3g = 7a$$

$$\Rightarrow a = \frac{g}{7}$$

Substituting into equation (2):

$$\begin{aligned} T &= 3a + 3g = \frac{3g}{7} + 3g = \frac{24g}{7} \\ &= 33.6 \text{ N (3 s.f.)} \end{aligned}$$

$$\mathbf{b} \quad u = 0, a = \frac{g}{7}, s = 2, m, v = ?$$

$$v^2 = u^2 + 2as$$

$$v^2 = 0^2 + 2 \times \frac{g}{7} \times 2 = \frac{4g}{7} = 5.6$$

$$v = \sqrt{5.6} = 2.366\dots$$

 When A hits the ground it is travelling at 2.37 m s^{-1} (3 s.f.).

$$\mathbf{c} \quad \text{For A: } (\downarrow)$$

$$\text{From part b, } v^2 = \frac{4g}{7}$$

This represents the initial velocity of B when A hits the ground.

$$\text{For B: } (\uparrow)$$

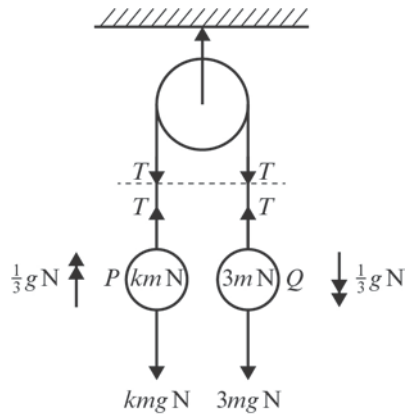
$$u^2 = \frac{4g}{7}, v = 0, a = -g, s = ?$$

$$v^2 = u^2 + 2as$$

$$0 = \frac{4g}{7} - 2gs \Rightarrow s = \frac{2}{7}$$

 The height above the initial position is $2\frac{2}{7} \text{ m}$.

2



a For $Q, R(\downarrow)$: $3mg - T = 3m \times \frac{1}{3}g = mg$
 $2mg = T$

The tension in the string is $2mg$ N.

b For $P, R(\uparrow)$: $T - kmg = km \times \frac{1}{3}g$
 $3T - 3kmg = kmg$
 $3T = 4kmg$

Substituting for T : $6mg = 4kmg$

$$k = \frac{6mg}{4mg}$$

The value of k is 1.5.

c Because the pulley is smooth, there is no friction, so the magnitude of acceleration of P = the magnitude of acceleration of Q .

d Up is positive.

While Q is descending, the distance travelled by $P = s_1$

$$u = 0, a = \frac{1}{3}g, t = 1.8, s = s_1$$

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

$$s_1 = (0 \times 1.8) + \left(\frac{1}{2} \times \frac{g}{3} \times 1.8^2 \right) = \frac{3.24g}{6} = 0.54g \quad (1)$$

Speed of P at this time = v_1

$$\text{Using } v^2 = u^2 + 2as$$

After Q hits the ground, P travels freely under gravity and rises by a further distance s_2

$$v = 0, u = v_1, a = -g, s = s_2$$

$$v^2 = u^2 + 2as$$

$$0^2 = 0.36g^2 - 2gs_2$$

$$s_2 = \frac{0.36g^2}{2g} = 0.18g \quad (2)$$

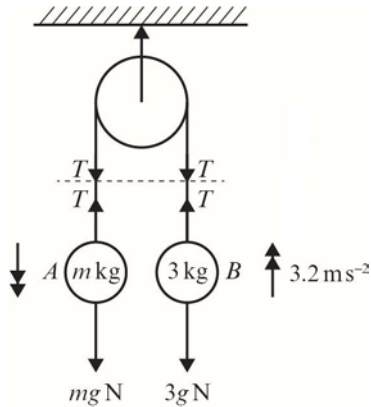
(1) + (2): Total distance travelled by P from its initial position = $s_1 + s_2$

- 2 d P and Q are at the same height initially, so P starts at height s_1 above the plane.
 Its final position = initial position + total distance travelled

$$= s_1 + (s_1 + s_2) = 2s_1 + s_2 = 2 \times 0.54g + 0.18g = 1.26g$$

P reaches a maximum height of 1.26g m above the plane, as required.

3



- a Since the pulley is smooth, |acceleration of A| = |acceleration of B|

For A: $s = 2.5$, $u = 0$, $t = 1.25$, $a = ?$ (down is positive)

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

$$2.5 = (0 \times 1.25) + \frac{1}{2}a \times 1.25^2$$

$$a = \frac{2.5 \times 2}{1.25^2} = 3.2$$

The initial acceleration of B is 3.2 m s^{-2} as required.

- b For B , $R(\uparrow)$: $T - 3g = 3a$

$$T = 3(a + g) = 3(3.2 + 9.8) = 39$$

The tension in the string is 39 N.

- c For A , $R(\downarrow)$: $mg - T = ma$

$$T = m(g - a) = m(9.8 - 3.2) = 6.6m$$

Substituting for T :

$$39 = 6.6m$$

$$m = \frac{39}{6.6} = \frac{390}{66} = \frac{65}{11} \text{ as required}$$

- d Because the string is inextensible, the tension on both sides of the pulley is the same.

- e The string will become taut again when B has risen to its maximum height and then descended to the point where A is just beginning to rise again.

If B reaches the maximum height t seconds after A hits the ground, it will also take t seconds to return to the same position as it is moving under gravity alone throughout this period. The total time of travel will be $2t$.

For B , taking up as positive, while the string is taut:

$$u = 0, a = 1.4, s = 2.5, m, v = v_1$$

$$v^2 = u^2 + 2as$$

$$v_1^2 = 0^2 + 2 \times 3.2 \times 2.5 = 16$$

Once the string is slack: $u = v_1 = 4$, $v = 0$, $a = -9.8$, $t = ?$

$$v = u + at$$

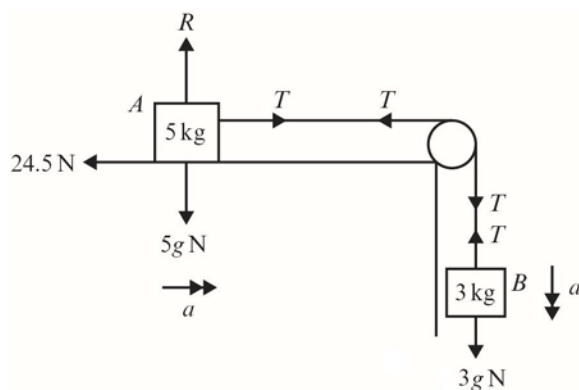
$$0 = 4 - 9.8t$$

$$3 \text{ e } t = \frac{4}{9.8} = \frac{40}{98} = \frac{20}{49}$$

At this point B descends under gravity. After a further t seconds the string once again becomes taut.

The string becomes taut again $2t = \frac{40}{49}$ s after A hits the ground.

4



a For A : $R(\rightarrow)$, $T - 24.5 = 5a$ (1)

For B : $R(\downarrow)$, $3g - T = 3a$
 $29.4 - T = 3a$ (2)

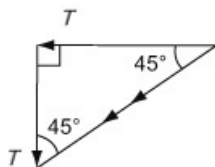
(1) + (2): $29.4 - 24.5 = 8a$
 $4.9 = 8a$
 $0.6125 = a$

The acceleration of the system is 0.613 ms^{-2} (3 s.f.)

b $T - 24.5 = 5 \times 0.6125$
 $T = 27.5625$

The tension in the string is 27.6 N (3 s.f.)

c



By Pythagoras,

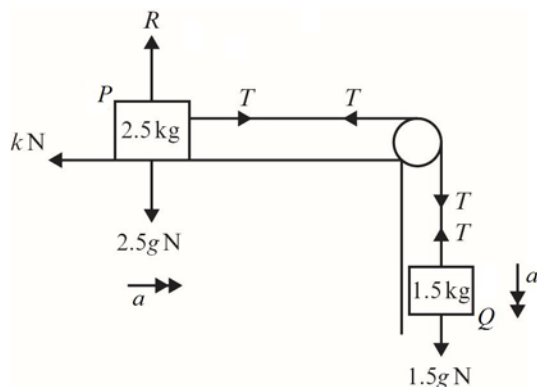
$$F^2 = T^2 + T^2 = 2T^2$$

$$F = T\sqrt{2} = 27.5625 \times \sqrt{2}$$

$$= 38.979\dots$$

The magnitude of the force exerted on the pulley is 39 N (2 s.f.)

5



- a i** For Q : $s = 0.8$, $u = 0$, $t = 0.75$, $a = ?$ (down is positive)

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

$$0.8 = (0 \times 0.75) + \frac{1}{2}a \times 0.75^2$$

$$a = \frac{0.8 \times 2}{0.75^2} = 2.844\dots$$

The acceleration of Q is 2.84 m s^{-2} (3 s.f.)

- ii** For Q , $R(\downarrow)$: $1.5g - T = 1.5a$

$$T = 1.5(g - a) = 1.5(9.8 - 2.84) = 10.44$$

The tension in the string is 10.4 N (to 3 s.f.), as required.

- iii** For P , $R(\rightarrow)$: $T - k = 2.5a$

Substituting:

$$10.4 - k = 2.5 \times 2.84$$

$$k = 10.4 - 7.1$$

The value of k is 3.3 N

- b** Because the string is inextensible, the tension in all parts of it is the same.