Falling Problem

Pete, who weighs 60kg, is suspended 15m above the ground by a rope which passes over a smooth pulley. The other end is held by Brian, weighing 70kg, who is standing on the ground.

Adam steps off a nearby building and grabs the end of the rope held by Pete. Adam weighs 80kg.

Modelling Adam, Brian and Pete as particles, and assuming none of them let go of the rope, calculate the speed at which Adam and Pete will hit the ground.

Instead of falling the full 15 metres in this fashion, Adam catches hold of Brian's rope when they draw level, and succeeds in stopping all vertical motion long enough to transfer himself to Brian's rope. Pete's rope is then released and Brian now descends with Adam. Calculate the speed at which they will hit the ground in this situation.

Calculate the speed Adam would have hit the ground had he simply dropped the 15m.

Finally, calculate the time taken to complete the drop, assuming the change-over takes 2 seconds.

Falling Problem Solutions

Pete, who weighs 60kg, is suspended 15m above the ground by a rope which passes over a smooth pulley. The other end is held by Brian, weighing 70kg, who is standing on the ground.

Adam steps off a nearby building and grabs the end of the rope held by Pete. Adam weighs 80kg.

Modelling Adam, Brian and Pete as particles, and assuming Brian doesn't let go of the rope, calculate the speed at which Adam and Pete will hit the ground.

$$140g - T = 140a$$

$$T - 70g = 70a$$

$$140g - 70g = 140a + 70a \quad \Rightarrow \quad 70g = 210a \quad \Rightarrow \quad a = 3.27ms^{-2} \text{ to } 3 \text{ s.f.}$$

$$v^2 = u^2 + 2as \quad \Rightarrow \quad v = \sqrt{2 \times 3.27 \times 15} = \mathbf{9.90ms^{-1} \text{ to } 3 \text{ s.f.}}$$

Instead of falling the full 15 metres in this fashion, Adam catches hold of Brian's rope when they draw level, and succeeds in stopping all vertical motion long enough to transfer himself to Brian's rope. Pete's rope is then released and Brian now descends with Adam. Calculate the speed at which they will hit the ground in this situation.

$$150g - T = 150a$$

$$T - 60g = 60a$$

$$150g - 60g = 150a + 60a \quad \Rightarrow \quad 90g = 210a \quad \Rightarrow \quad a = 4{,}2ms^{-2}$$

$$v^2 = u^2 + 2as \quad \Rightarrow \quad v = \sqrt{2 \times 4.2 \times 7.5} = \mathbf{7.94ms^{-1} \text{ to } 3 \text{ s.f.}}$$

Calculate the speed Adam would have hit the ground had he simply dropped the 15m.

$$v^2 = u^2 + 2as \quad \Rightarrow \quad v = \sqrt{2 \times 9.8 \times 15} = \mathbf{17.1ms^{-1} \text{ to } 3 \text{ s.f.}}$$

Finally, calculate the time taken to complete the drop, assuming the change-over takes 2 seconds.

$$\textit{First stage of motion}: \quad s = 7.5 \quad a = 3.27 \quad u = 0 \quad t = ?$$

$$s = ut + \frac{1}{2}at^2 \quad \Rightarrow \quad 7.5 = \frac{3.27}{2}t^2 \quad \Rightarrow \quad t = 2.14s \text{ to } 3 \text{ s.f.}$$

$$\textit{Second stage of motion}: \quad s = 7.5 \quad a = 4.2 \quad u = 0 \quad t = ?$$

$$s = ut + \frac{1}{2}at^2 \quad \Rightarrow \quad 7.5 = \frac{4.2}{2}t^2 \quad \Rightarrow \quad t = 1.89s \text{ to } 3 \text{ s.f.}$$

$$\textit{Changeover}: t = 2s \quad \textit{so} \quad \textit{Total time} = 2.14 + 2 + 1.89 = \mathbf{6.03s \text{ to } 3 \text{ s.f.}}$$