Slippery Slope

The film *Touching the Void* tells the true story of Joe Simpson and Simon Yates and their 1985 attempt to scale Siula Grande. While successful with the ascent, the steep descent they attempted got them in serious trouble.

Simpson falls and breaks his leg part-way down the mountain, and Yates attempts to lower him down a particularly dangerous slope by means of a rope since he cannot walk. The slope is inclined at 60° to the horizontal, and the coefficient of friction between Joe Simpson and the snowfield is 0.7. Joe is being held in equilibrium by a rope at an angle of 5° from the slope. Draw a force diagram to show all forces acting on Joe.

Assuming Joe (and his kit) weighs $100kg$, find the minimum tension in the rope.

What is the largest tension that could be applied to the rope?

Slippery Slope Solutions

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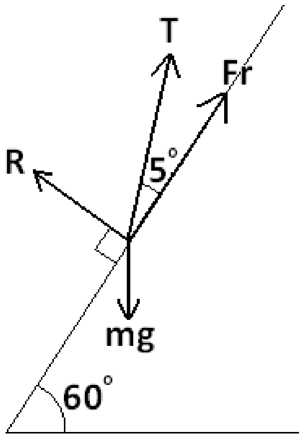


Assuming Joe (and his kit) weighs $100kg$, find the minimum tension in the rope.

Minimum tension occurs when friction is at maximum: $F_r = 0.7R$

Resolving parallel to the slope: $F_r + T\cos 5 = 100g\sin 60 = 50g\sqrt{3} \quad \Rightarrow \quad 0.7R + T\cos 5 = 50g\sqrt{3}$

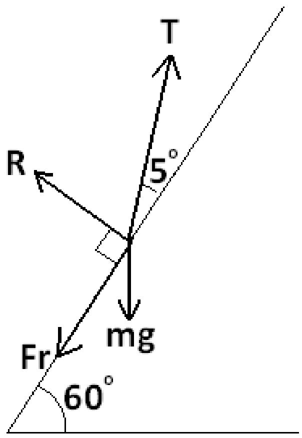
Resolving perpendicular to the slope: $R + T\sin 5 = 100g\cos 60 = 50g$

Solving simultaneously: $R = 50g - T\sin 5 \quad and \quad R = \frac{50g\sqrt{3} - T\cos 5}{0.7}$

$$0.7(50g - T\sin 5) = 50g\sqrt{3} - T\cos 5 \quad \Rightarrow \quad 35g - 0.7T\sin 5 = 50g\sqrt{3} - T\cos 5$$

$$T(\cos 5 - 0.7\sin 5) = \left(50\sqrt{3} - 35\right)g \quad \Rightarrow \quad T = \frac{\left(50\sqrt{3} - 35\right)g}{\cos 5 - 0.7\sin 5} = \boldsymbol{541N\ to\ 3\ s.f.}$$

What is the largest tension that could be applied to the rope?



At maximum tension, friction will be maximum, but acting down the slope: $F_r = 0.7R$

Resolving parallel to the slope: $T\cos 5 = 100g\sin 60 + F_r = 50\sqrt{3}g + 0.7R$

Resolving perpendicular to the slope: $R + T\sin 5 = 100g\cos 60 = 50g$

Solving simultaneously: $R = 50g - T\sin 5 \quad and \quad R = \frac{T\cos 5 - 50\sqrt{3}g}{0.7}$

$$50g - T\sin 5 = \frac{T\cos 5 - 50\sqrt{3}g}{0.7} \quad \Rightarrow \quad 0.7(50g - T\sin 5) = T\cos 5 - 50\sqrt{3}g$$

$$35g - 0.7T\sin 5 = T\cos 5 - 50\sqrt{3}g$$

$$T(\cos 5 + 0.7\sin 5) = \left(50\sqrt{3} + 35\right)g \quad \Rightarrow \quad T = \frac{\left(50\sqrt{3} + 35\right)g}{\cos 5 + 0.7\sin 5} = \boldsymbol{1130N\ to\ 3\ s.f.}$$