Breaking Strain

The maximum tension that a ¼ inch thick steel wire rope can withstand before breaking is 24.4kN.

A Land Rover Discovery II weighs around 2150kg.

Off-road enthusiasts frequently rely on a built-in winch to pull their vehicle out of a hole or over a particularly steep bit of ground.

A pair of Land Rovers are positioned on either side of a steep rise. The angle to the horizontal on one side is 20°, and on the other it's 45°. Each vehicle is 10 metres down the slope from the top, and they are attached via a smooth pulley at the top of the slope using ¼ inch steel cable.

Usually a winch would be attached to a fixed point like a tree, and a high-torque motor in the winch would slowly take in the cable. In this case, however, the car on the 20° slope is driving downhill, attempting to pull the car on the 45° slope uphill. At the low speeds they are travelling, the force exerted by each vehicle is 30kN. Assuming friction is negligible, draw a force diagram to illustrate this situation.

Calculate the tension in the cable.

If the car on the steeper hill cuts out and no longer produces any forwards force, what would the new tension in the cable be? Is this a problem, and if so, what course of action would you suggest to the drivers?

Breaking Strain SOLUTIONS

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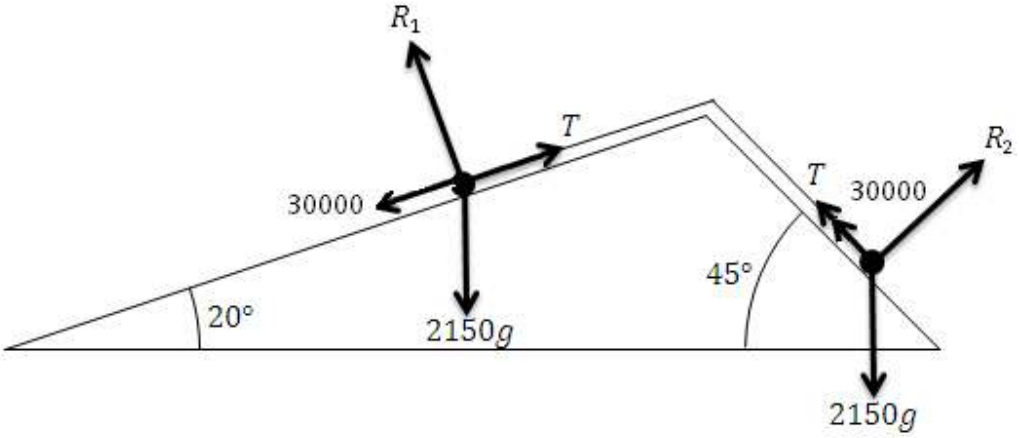
Usually a winch would be attached to a fixed point like a tree, and a high-torque motor in the winch would slowly take in the cable. In this case, however, the car on the 20° slope is driving downhill, attempting to pull the car on the 45° slope uphill. The force exerted by each vehicle is 12kN. Assuming friction is negligible, draw a force diagram to illustrate this situation.



Calculate the tension in the cable.

$Resolving\ down\ the\ slope\ (left-hand\ vehicle)$:
$30000 + 2150g \sin 20 - T = 2150a$

$Resolving\ up\ the\ slope\ (right-hand\ vehicle)$:
$30000 + T - 2150g \sin 45 = 2150a$

$Solving\ simultaneously$: $60000 + 2150g \sin 20 - 2150g \sin 45 = 4300a \implies a = 12.2ms^{-2}\ to\ 3\ s.f.$

$Substituting\ for\ T$: $T = 30000 + 2150g \sin 20 - 2150a = \mathbf{11100N\ to\ 3\ s.f.}$

If the car on the steeper hill cuts out and no longer produces any forwards force, what would the new tension in the cable be? Is this a problem, and if so, what course of action would you suggest to the drivers?

$(Left-hand\ vehicle\ equation\ stays\ the\ same)$

$Resolving\ up\ the\ slope\ (right-hand\ vehicle)$:
$T - 2150g \sin 45 = 2150a$

$Solving\ simultaneously$: $30000 + 2150g \sin 20 - 2150g \sin 45 = 4300a \implies a = 5.19ms^{-2}\ to\ 3\ s.f.$

$Substituting\ for\ T$: $T = 30000 + 2150g \sin 20 - 2150a = \mathbf{26100N\ to\ 3\ s.f.}$

Since this is greater than the breaking strain of the cable, a reduction in the force exerted by the functioning vehicle would be advisable. This would lower the acceleration, but would also decrease the tension in the cable to a safe level.