Introduction to Mechanics
Applying Newton's Laws
Statics
Pulleys

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Last time

- types of forces: normal force
  - elevators and acceleration
  - inclines
- tension

Overview

- static equilibrium
- tension and statics
- elevators again
- pulleys

Static Equilibrium

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"at rest and remains at rest" $\Rightarrow$ $\vec{\mathbf{a}} = 0$

$\vec{\mathbf{a}} = 0 \Rightarrow \vec{\mathbf{F}}_{net} = 0$ for the object.

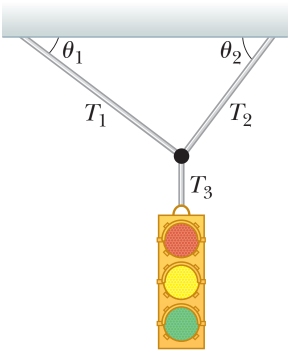
For Static Equilibrium:

- $\vec{\mathbf{v}} = 0$
- $\vec{\mathbf{a}} = 0$
- $\vec{\mathbf{F}}_{net} = 0$

Statics with Tensions

These type of problems are equilibrium problems. The idea is to **equate forces in perpendicular directions**.

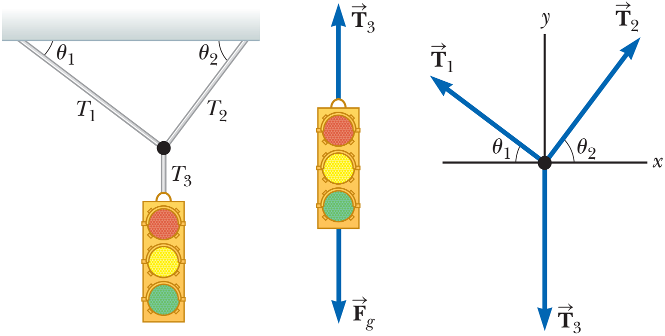
Consider a hanging traffic light:



Static $\Rightarrow$ $\vec{\mathbf{F}}_{\text{net}} = 0$ for the traffic light and cables.

Statics with Tensions

Example: A traffic light weighing 200 N is suspended by two light cables, as shown in the diagram, so that $\theta_1 = 30°$ and $\theta_2 = 45°$.



Find the tensions T_1 and T_2.

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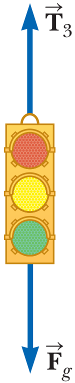

Static $\Rightarrow$ $\vec{\mathbf{F}}_{\text{net}} = 0$ for the traffic light.

<u>traffic light, y-direction:</u>

$$F_{\text{net},y} = m a_y \quad (a_y \to 0) \tag{1}$$

$$T_3 - F_g = 0$$

$$T_3 = F_g = 200N \tag{2}$$

Statics with Tensions

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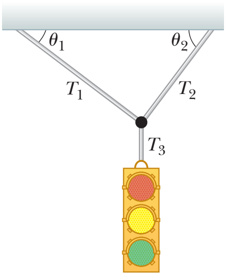

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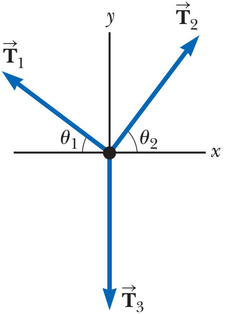

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junction, x-direction:

$$\begin{aligned} F_{\text{net},x} &= \cancelto{0}{m}\ \cancelto{0}{a_x} \\ T_1 \cos\theta_1 - T_2 \cos\theta_2 &= 0 \\ T_1 \cos\theta_1 &= T_2 \cos\theta_2 \quad (3) \end{aligned}$$

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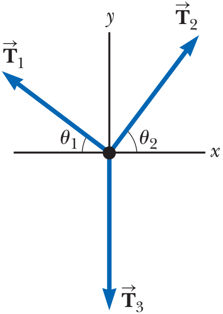

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junction, y-direction:

$$\begin{aligned} F_{\text{net},y} &= \cancelto{0}{m}\cancelto{0}{a_y} \\ T_1 \sin\theta_1 + T_2 \sin\theta_2 - T_3 &= 0 \\ T_1 \sin\theta_1 + T_2 \sin\theta_2 &= T_3 \quad (4) \end{aligned}$$

Statics with Tensions

$$T_1 \cos\theta_1 = T_2 \cos\theta_2 \tag{3}$$

And using eq (2), equation (4) becomes:

$$T_1 \sin\theta_1 + T_2 \sin\theta_2 = F_g \tag{5}$$

We have two independent equations, and just the two unknowns T_1 and T_2. ($\theta_1 = 30^\circ$ and $\theta_2 = 45^\circ$.) Solve as you like!

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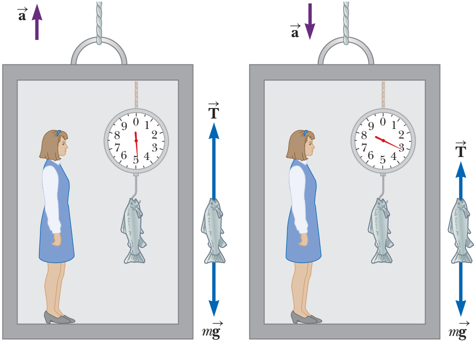
Answer:

$$T_1 = 146 \text{ N}, T_2 = 179 \text{ N}$$

Elevator Problems

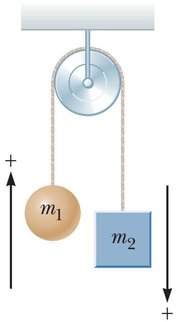
In an accelerating elevator, the tension in a support cable may be greater or less than the weight of an object suspended from the cable.



In these pictures there is a non-zero net force on the fish. That means $T \neq mg$.

Pulleys

Pulleys “turn tensions around a corner”.



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Pulleys

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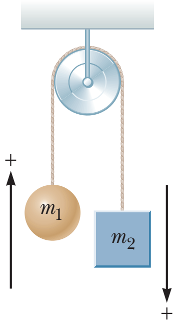
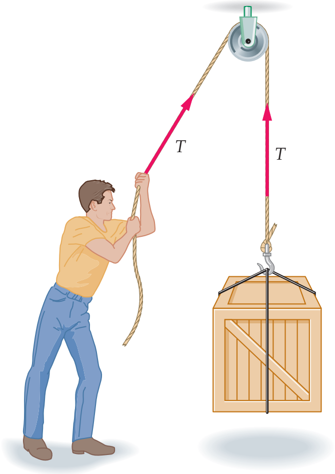


For the moment, we are just considering *massless, frictionless* pulleys. What does that mean?

- Massless: we do not have to worry about force needed to accelerate each atom in the pulley
- Frictionless: the *axle* of the pulley has no friction to resist the wheel turning

Pulleys and Tension

If the rope is light (massless) and the pulley is massless and frictionless, the tension in the rope on both sides of the pulley is the same.



[1]Figure from Walker, "Physics".

Pulleys and Tension

A pulley is suspended over a well, and a light rope is run over the pulley which is used to lift a bucket of water with a constant velocity. If the mass of water is 5 kg, what is the tension in the chain supporting the pulley?

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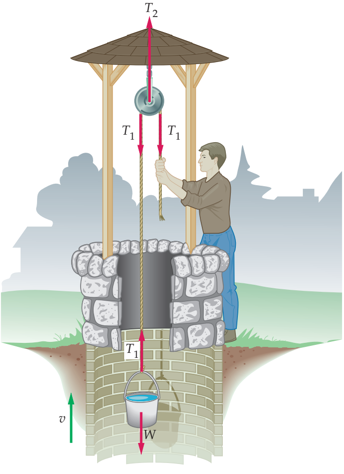
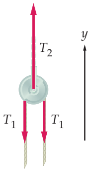
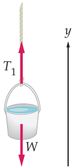


Physical picture



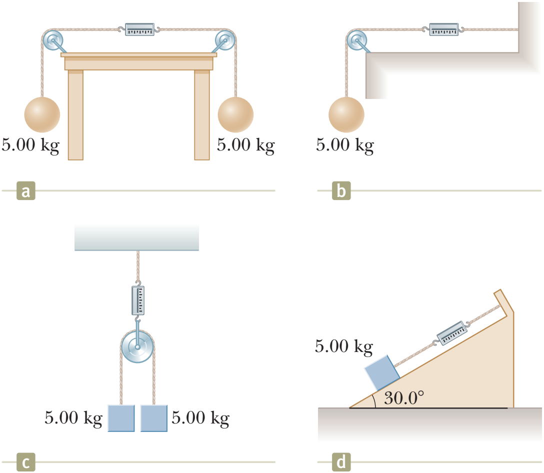
Forces acting on the pulley



Forces acting on the bucket

Tension and Force Meters

28. The systems shown in Figure P5.28 are in equilibrium. **W** If the spring scales are calibrated in newtons, what do they read? Ignore the masses of the pulleys and strings and assume the pulleys and the incline in Figure P5.28d are frictionless.



Summary

- tension and statics
- more accelerating elevators
- pulleys

Homework

Walker Physics:

- Ch 6, onward from page 177. Questions: 1; Problems: 31, 35, 99 (statics)
- Ch 6, Problems: 32 & 33, 37 (pulleys)