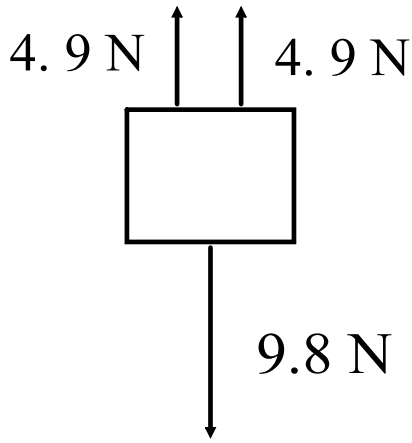
Demonstration

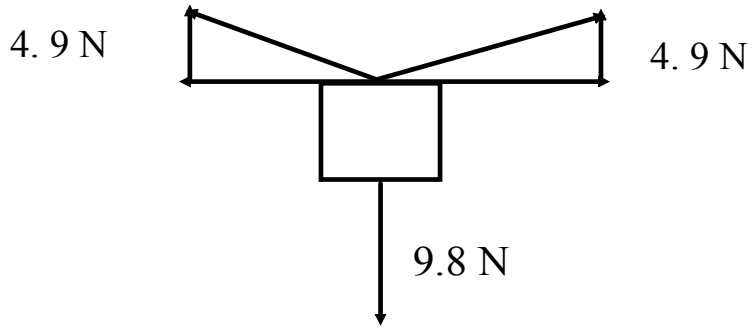
- Tie two loops in the ends of a rope that is about 1 m long.
- Hold a loop in each hand as a classmate carefully hangs a 1 kg mass in the middle of the rope.
- Start with your hands together and slowly move your hands apart.
- Is it possible to hold the rope such that it will lie in straight line parallel to the floor?

The weight of the mass is 9.8 N.

When the hands are together each hand exerts an upward force of 4.9 N. There are no horizontal components of force.



As the hands are moved apart, the horizontal components of force increase. The forces acting along the rope also increase. Each hand must still exert an upward force of 4.9 N to balance the downward force of 9.8 N.



It is not possible to pull hard enough to make the rope perfectly straight.

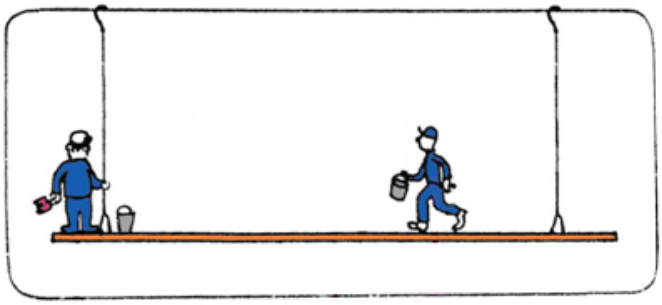
The First Law of Motion

"An object at rest or in uniform motion will remain at rest or in uniform motion unless acted upon by an unbalance/external force."

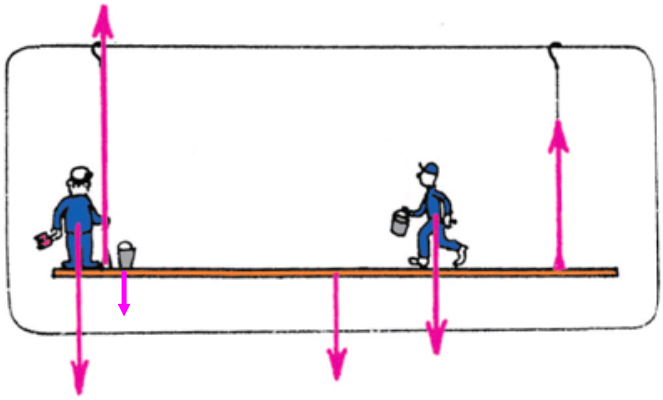
The resultant force (or net force) must equal zero in order for the first law of motion to apply.

Static Equilibrium

If an object is at ***rest***, then we say that it is in a state of "***static equilibrium***."



The sum of the upward vectors equals the sum of the downward vectors. *Fnet* = 0, and the scaffold is in static equilibrium.

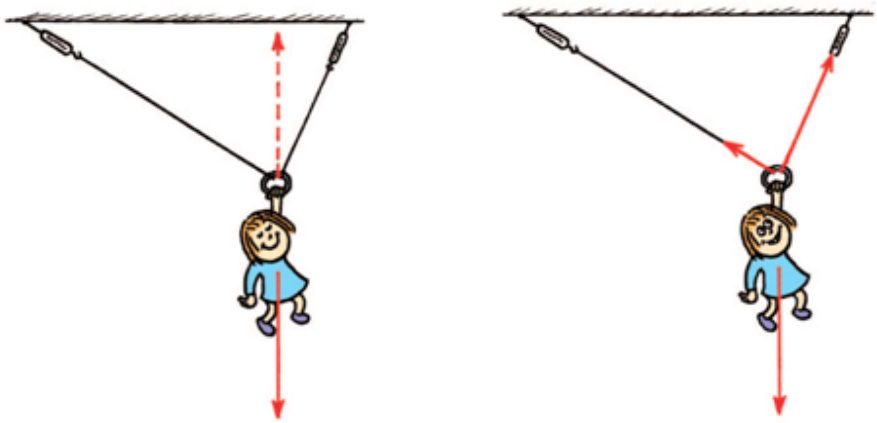


Two sets of swings are shown below. If the children on the swings have equal weights, the ropes of which swing are more likely to break?

Answer: The tension is greater in the ropes hanging at an angle. The angled ropes are more likely to break than the vertical ropes.

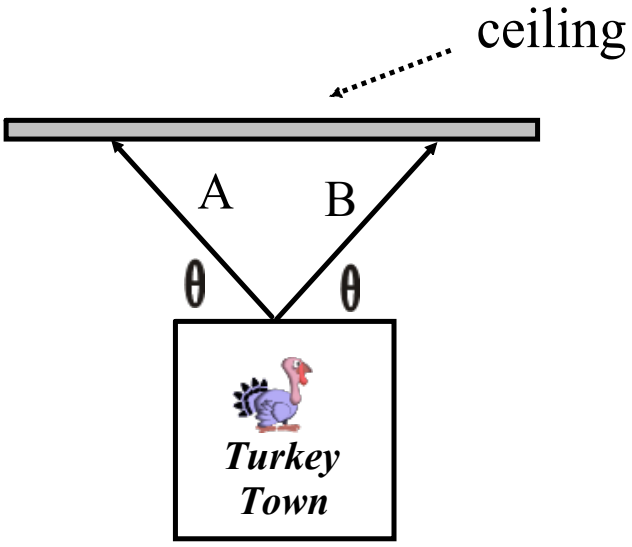
Note

When the ropes supporting Nellie are at different angles to the vertical, the tensions in the two ropes are unequal.



Example

In order for the sign to be in static equilibrium, the sum of the forces acting on the sign must be zero.

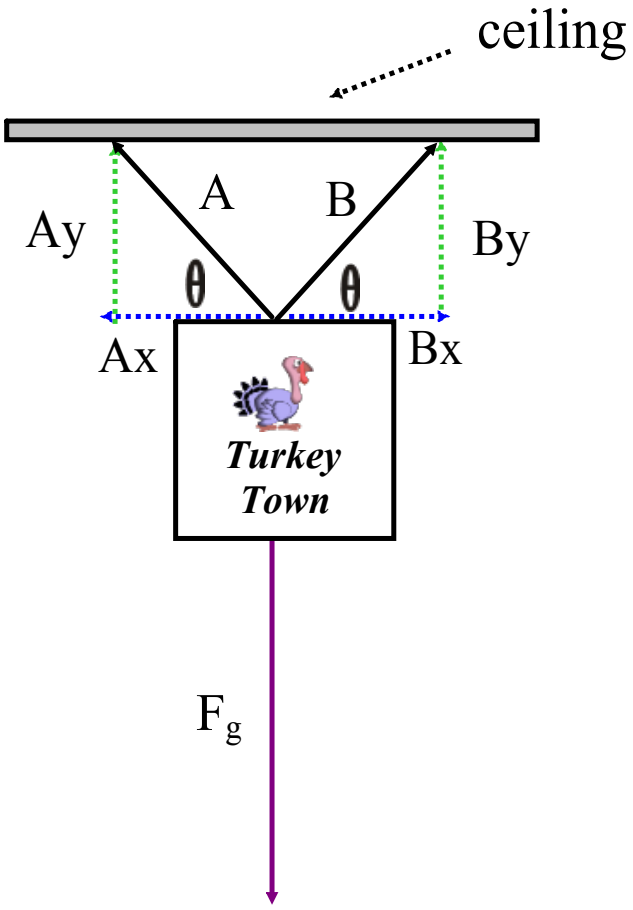


The sum of the horizontal components is 0 N.

$$A_x + B_x = 0$$

The sum of the vertical components is 0 N.

$$A_y + B_y + (-F_g) = 0$$


ceiling
A
B
Ay
By
θ
θ
Ax
Bx
Turkey
Town
F_g

Static Equilibrium equal angles two cables

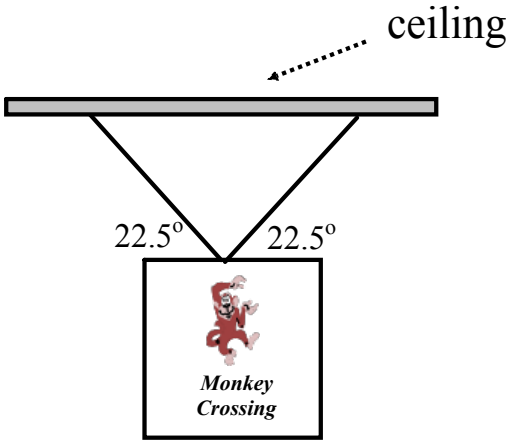
Static Equilibrium

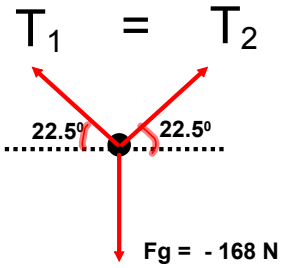
Static Equilibrium two cables one is horizontal

static equilibrium 2 cables different angles

Sample Problems

1. A sign that weighs 168 N is supported by two ropes, A and B, that make 22.5° angles with the horizontal. Determine the tension along the ropes.



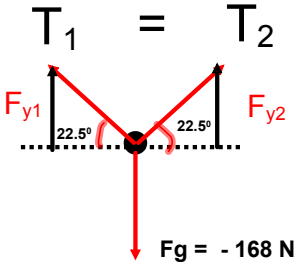


The sum of the horizontal components is 0 N.

$A_x + B_x = 0$

The sum of the vertical components is 0 N.

$A_y + B_y + (-F_g) = 0$

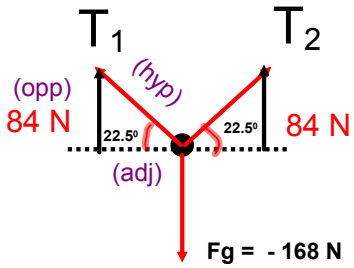


$F_{y1} = F_{y2}$

Static equilibrium means that all vertical forces must balance out.

So $F_{y1} + F_{y2} = 168$ N

F_{y1} must equal half of 168 N = 84 N



Sin 22.5° = $\frac{\text{opp}}{\text{hyp}} = \frac{84\text{N}}{\text{hyp}}$

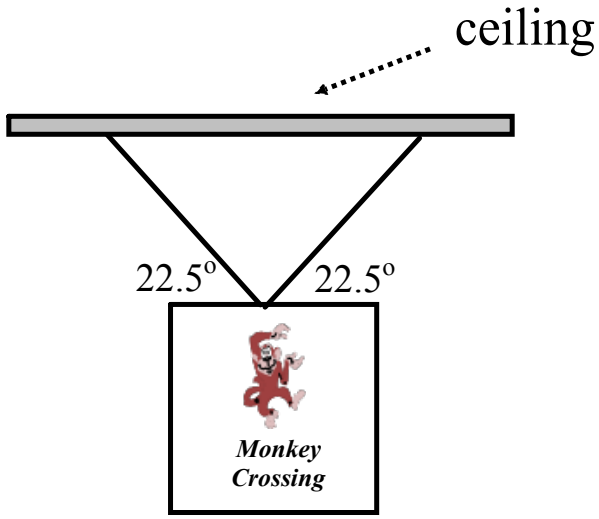
hyp = $\frac{\text{opp}}{\text{Sin } 22.5^0} = \frac{84\text{ N}}{0.38}$

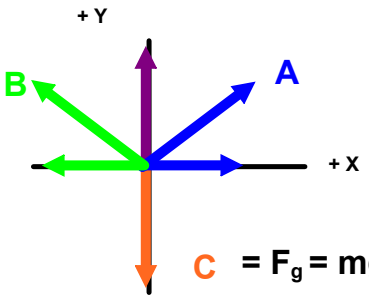
hyp = 220 N

The tension along each rope is 220 N

Sample Problems ~ Method 2

1. A sign that weighs 168 N is supported by two ropes, A and B, that make 22.5° angles with the horizontal. Determine the tension along the ropes.





C = F_g = mg = 168 N

$\Sigma F_x = A \cos 22.5 - B \cos 22.5 + 0 = 0$

$A \cos 22.5 = B \cos 22.5$ $A = B$

$\Sigma F_y = A \sin 22.5 + B \sin 22.5 - mg = 0$

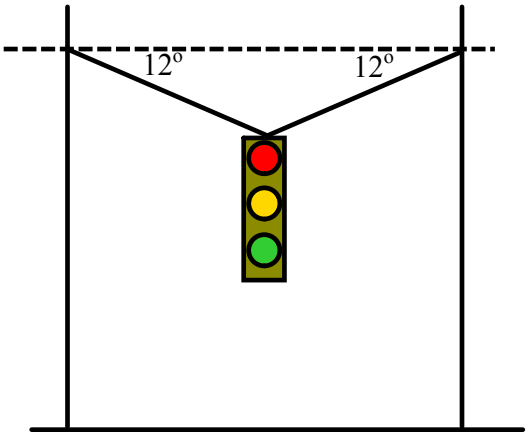
$B \sin 22.5 + B \sin 22.5 = mg$

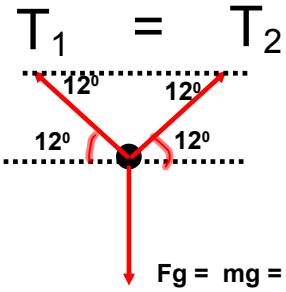
$B (\sin 22.5 + \sin 22.5) = 168\ N$

$B = 220\ N$

The tension along each rope is 220 N

2. A traffic light hangs in the center of the road from cables as shown in the figure. If the mass of the traffic light is 65 kg, what is the magnitude of the force that each cable exerts on the light to prevent it from falling?



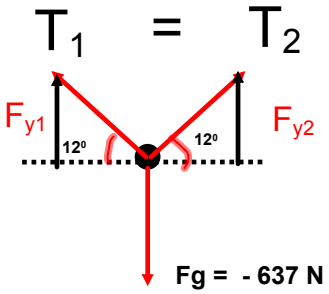


The sum of the horizontal components is 0 N.

$A_x + B_x = 0$

The sum of the vertical components is 0 N.

$A_y + B_y + (-F_g) = 0$

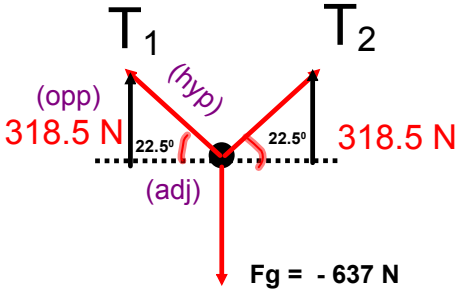


$F_{y1} = F_{y2}$

Static equilibrium means that all vertical forces must balance out.

So $F_{y1} + F_{y2} = 637$ N

F_{y1} must equal half of 637 N = 318.5 N



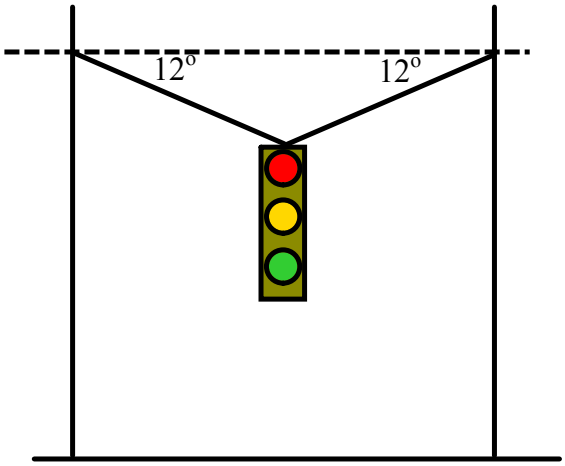
Sin 12° = opp / hyp = 318.5N / hyp

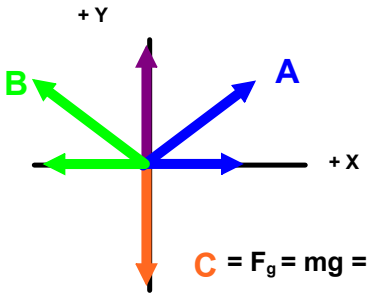
hyp = opp / Sin 12° = 318.5 N / 0.21`

hyp = 1532N

The tension along each rope is 1532 N

2. A traffic light hangs in the center of the road from cables as shown in the figure. If the mass of the traffic light is 65 kg, what is the magnitude of the force that each cable exerts on the light to prevent it from falling?





$\Sigma F_x = A\cos 12 - B\cos 12 + 0 = 0$

$A\cos 12 = B\cos 12 \qquad A = B$

$C = F_g = mg = (65)(9.80)\ N$

$= 637\ N$

$\Sigma F_y = A\sin 12 + B\sin 12 - mg = 0$

$B\sin 12 + B\sin 12 = mg$

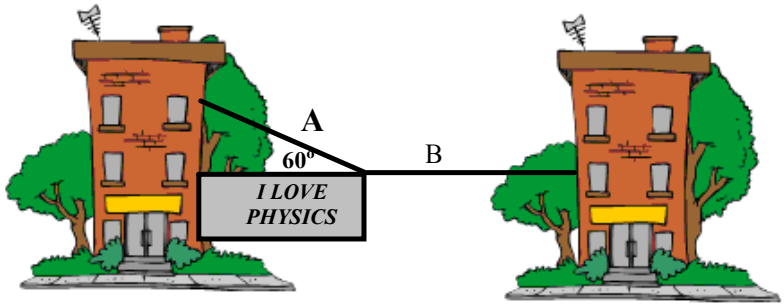
$B(\sin 12 + \sin 12) = 637\ N$

$B = 1532\ N$

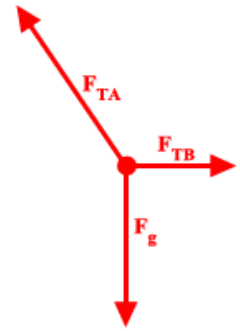
The tension along each rope is 1532 N

TRY

Bubba Newton wants to hang a sign weighing 7.50 x 10^2 N outside his apartment. Calculate the tension in cable B.



Free Body Diagram



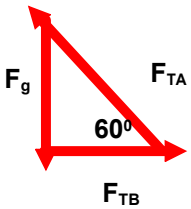
F_g = -750 N

θ = 60°

F_{TB} = ?

Since the sign is in equilibrium, we know that the net force is zero and $\vec{F}_{TA} + \vec{F}_g + \vec{F}_{TB} = 0$

Vector Diagram



$$\tan\theta = \frac{F_g}{F_{TB}}$$

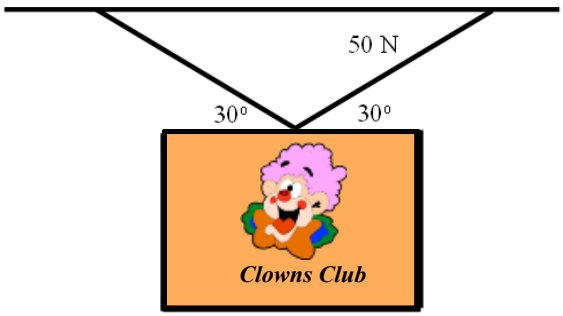
$$\tan 60^\circ = \frac{750\,N}{F_{TB}}$$

$$F_{TB} = \frac{750\,N}{\tan 60^\circ} = 433\,N = 4.33 \times 10^2\,N$$

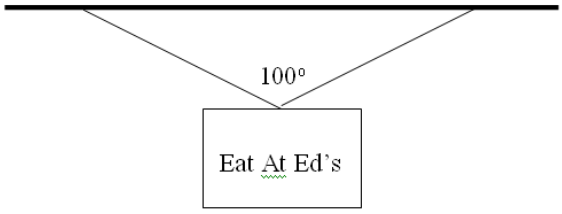
The tension in Cable B is 4.33 x 10^2 N

Worksheet - Static Equlibrium

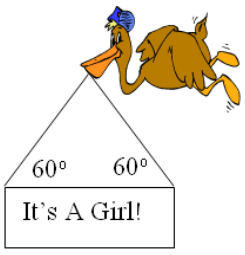
1. Find the magnitude of the weight of the clown's picture. (50 N)



2. If the sign has a mass of 5.00 kg, what is the tension in the cables?



3. After its most recent delivery, the infamous stork announces the good news. If the sign has a mass of 10 kg, then what is the force of tension along the each cable?



Worksheet Static Equilibrium

1. Joe wishes to hang a sign weighing 750 N so that cable A attached to the store makes a 30.0° angle as shown in diagram #1. Cable B is attached to an adjoining building. Calculate the magnitude of the tension in cable B. (433 N)

2. A camper hangs a 26 kg pack between two trees, using two separate pieces of rope of different lengths, as shown in diagram #2. What is the magnitude of the tension in each rope? (2.3×10^2 N in the short rope; 84 N in the long rope)

3. Find the magnitude of the tensions in the two cords shown in diagram #3. Neglect the mass of the cords, and assume that the angle θ is 30° and the mass m is 200 kg. (3.9×10^3 N, 3.4×10^3 N)

4. Find the magnitude of the tensions in the two wires supporting the traffic light as shown in diagram #4. (1.8×10^2 N, 2.4×10^2 N)

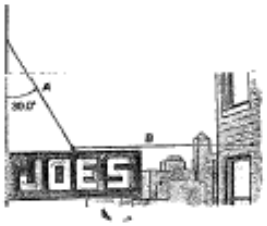


diagram #1

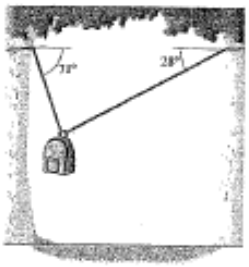


diagram #2

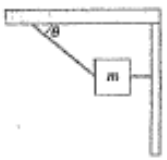


diagram #3

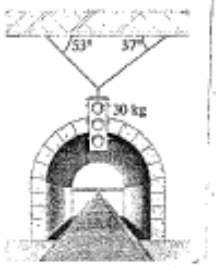
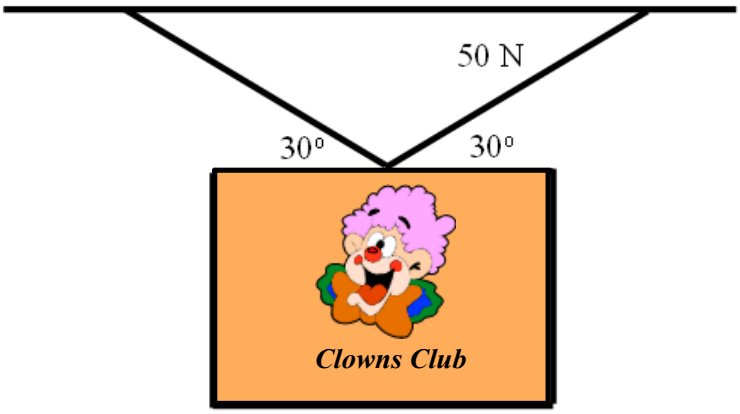


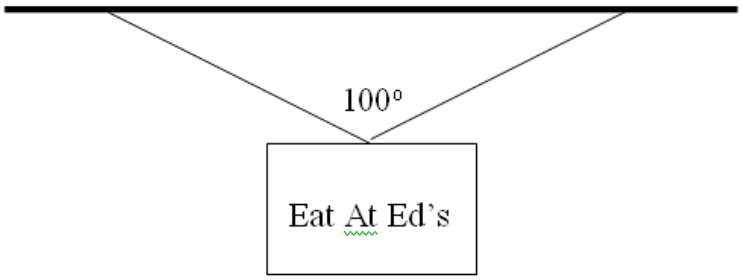
diagram #4

Worksheet - Static Equlibrium

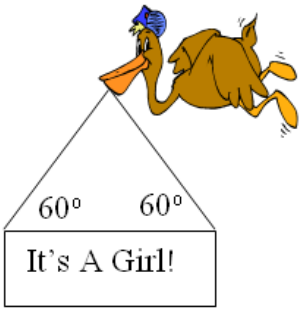
1. Find the magnitude of the weight of the clown's picture. (50 N)



2. If the sign has a mass of 5.00 kg, what is the tension in the cables?

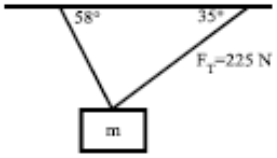


3. After its most recent delivery, the infamous stork announces the good news. If the sign has a mass of 10 kg, then what is the force of tension along the each cable?

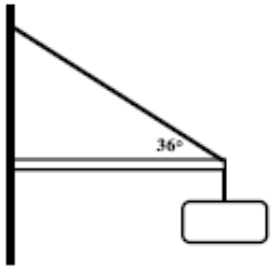


1.3.1 In Class or Homework Exercise

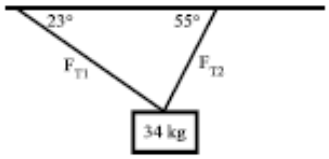
1. Find the unknown mass in the diagram below:



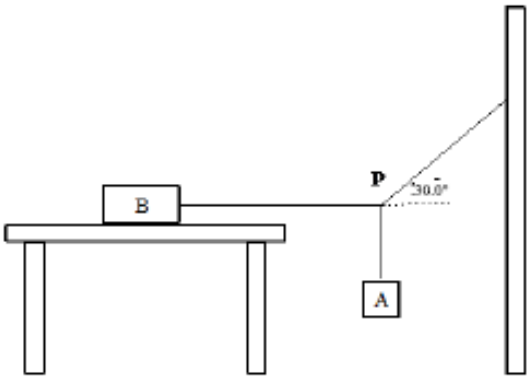
2. A sign with a mass of 165 kg is supported by a boom and a cable, as shown in the diagram below. The cable makes an angle of 36° with the boom. Find the magnitude of the force exerted by the boom and the cable on the sign. Ignore the mass of the boom.



3. Find the tensions F_{T1} and F_{T2} in the two strings indicated:



4. In the diagram shown below, block A has a mass of 10.5 *kg* and block B has a mass of 52.6 *kg*. The string runs from Block B to the wall. The segment of string from block B to point P on the string is horizontal. The friction between block B and the table is unknown. Find the minimum coefficient of friction between block B and the table that would prevent block B from moving.



5. Three students are pulling ropes that are attached to a car. Barney is pulling north with a force of 235 N; Wilma is pulling with a force of 175 N in a direction 23° E of N; Betty is pulling with 205 N east. What equilibrant force must a fourth student, Fred, apply to prevent acceleration?
6. Your mother asks you to hang a heavy painting. The frame has a wire across the back, and you plan to hook this wire over a nail in the wall. The wire will break if the force pulling on it is too great, and you don't want it to break. If the wire must be fastened at the edges of the painting, should you use a short wire or a long wire? Explain.
7. When lifting a barbell, which grip will exert less force on the lifter's arms: one in which the arms are extended straight upward from the body so that are at right angles to the bars, or on in which the arms are spread apart so that the bar is gripped closer to the weights? Explain.

Attachments

- Static Equilibrium
- Static Equilibrium equal angles two cables
- static equilibrium 2 cables different angles
- Static Equilibrium two cables one is horizontal