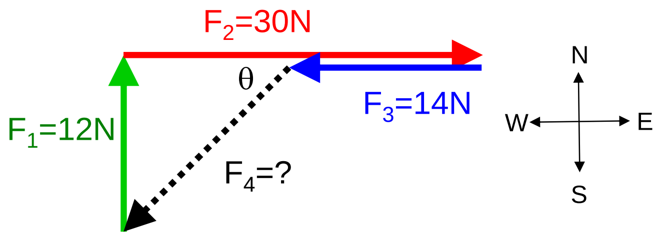
Name______________________________ Pd_____

Forces and Laws of Motion
Worksheet 4.4 – Equilibrium Applications of Newton's Laws

Solve the following problems on another sheet of paper. Include the steps outlined in class as part of your solution (large, clear Free Body Diagram, resolve forces into components, use hatch marks to indicate equal forces, apply Newtons 2nd Law to each direction).

1. Exactly three forces act on an object: 12.0 Newtons to the North, 30.0 Newtons to the East, and 14.0 Newtons to the West. What is the magnitude and direction of the single force that could be added to the object to put it into equilibrium?

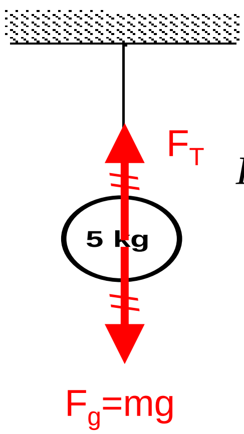


$$F_4^2 = 12^2 + 16^2 = 400 \qquad \tan\theta = 12/16$$
$$F_4 = 20N \qquad \theta = 37o$$

F4 = 20N, 37° SofW

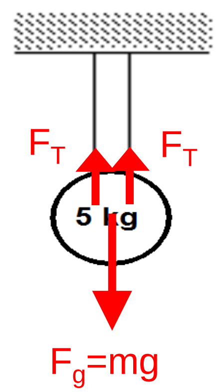
2. Determine the tension in each cable in each of the following cases.

Case A



$$\Sigma F_y = 0$$
$$F_T - F_g = 0$$
$$F_T = F_g$$
$$= mg = 5(9.8)$$
$$F_T = 49N$$

Case B



$$\Sigma F_y = 0$$
$$2F_T - F_g = 0$$
$$2F_T = F_g = mg = 5(9.8)$$
$$2F_T = 49N$$
$$F_T = 24.5N$$

Case C

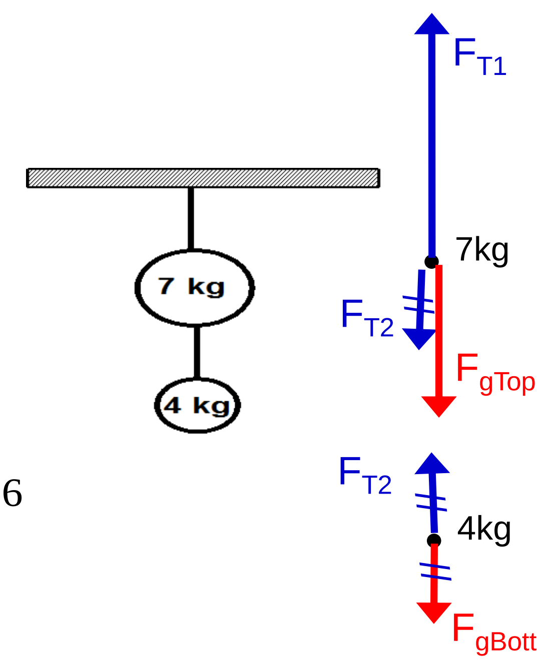
Look at each hanging ball separately

4kg mass

$$\Sigma F_y = 0$$
$$F_{T2} = F_g = 39.2N$$

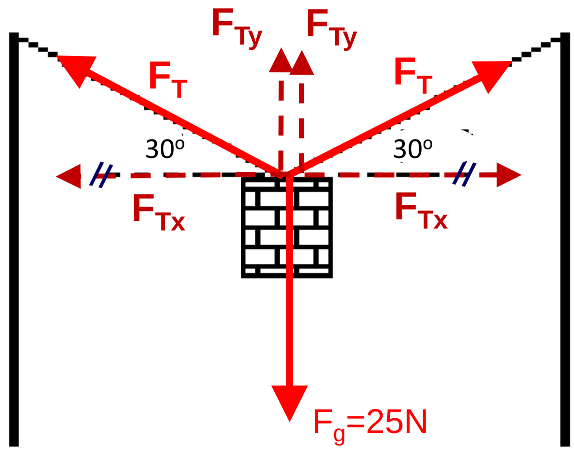
7kg mass

$$\Sigma F_y = 0$$
$$F_{T1} - F_{T2} - F_g = 0$$
$$F_{T1} = F_{T2} + F_g = 39.2 + 68.6$$
$$F_{T1} = 107.8N$$



3. The object hung from the cable has a weight of 25 N

a. What is the tension in the cable? Object is hanging at rest so it is in equilibrium. The horizontal components of the tension are the only two forces in the x-direction so they must be equal and opposite. Because both the horizontal components and the angle of the tension is the same, the tensions in each rope must be the same.

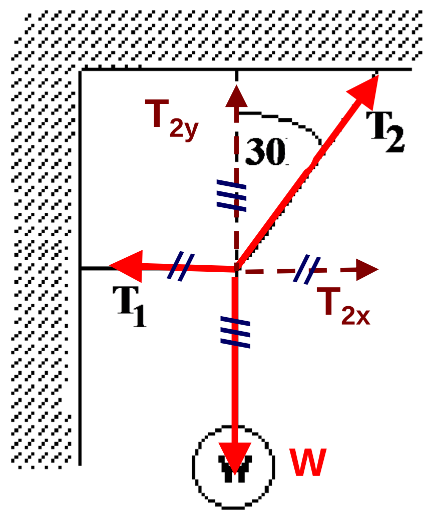


$$\begin{aligned} \Sigma F_y &= 0 \\ 2F_{Ty} - F_g &= 0 \\ 2F_T \sin 30 &= 25 \\ F_T &= 25N \end{aligned}$$

b. Repeat the problem above with a 5° angle. How does the tension compare? The vertical components of the tension support the weight. At a shallower angle, less of the tension force will be directed vertically so the tension in the ropes will have to increase to still support the weight.

$$\begin{aligned} \Sigma F_y &= 0 \\ 2F_{Ty} - F_g &= 0 \\ 2F_T \sin 5 &= 25 \\ F_T &= 143N \end{aligned}$$

4. The cable to the left exerts a 30 N force. The cables transfer the forces to the meeting point so that is where the FBD should be drawn. This is an equilibrium situation so there are no net forces in any direction.



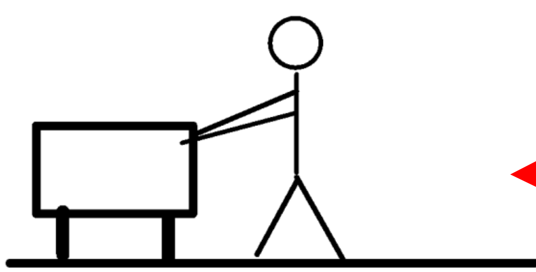
a. What is the value of T_2?

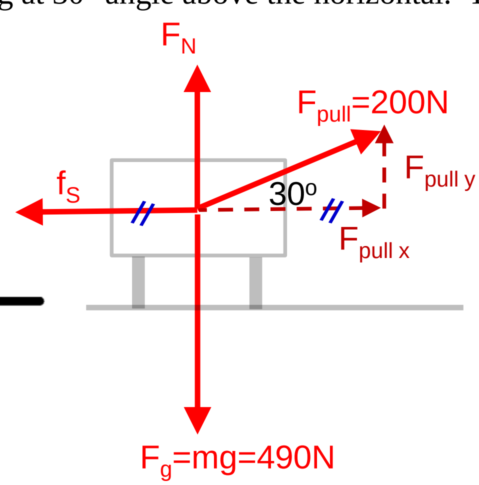
$$\begin{aligned} \Sigma F_x &= 0 \\ T_1 &= T_{2x} \\ 30 &= T_2 \cos 60 \\ T_2 &= 60N \end{aligned}$$

b. What is the force of gravity acting on the ball?

$$\begin{aligned} \Sigma F_y &= 0 \\ W &= T_{2y} \\ W &= T_2 \sin 60 = 60 \sin 60 \\ W &= 52N \end{aligned}$$

5. A person pulls on a 50 kg desk with a 200N force acting at 30° angle above the horizontal. The desk does not budge.





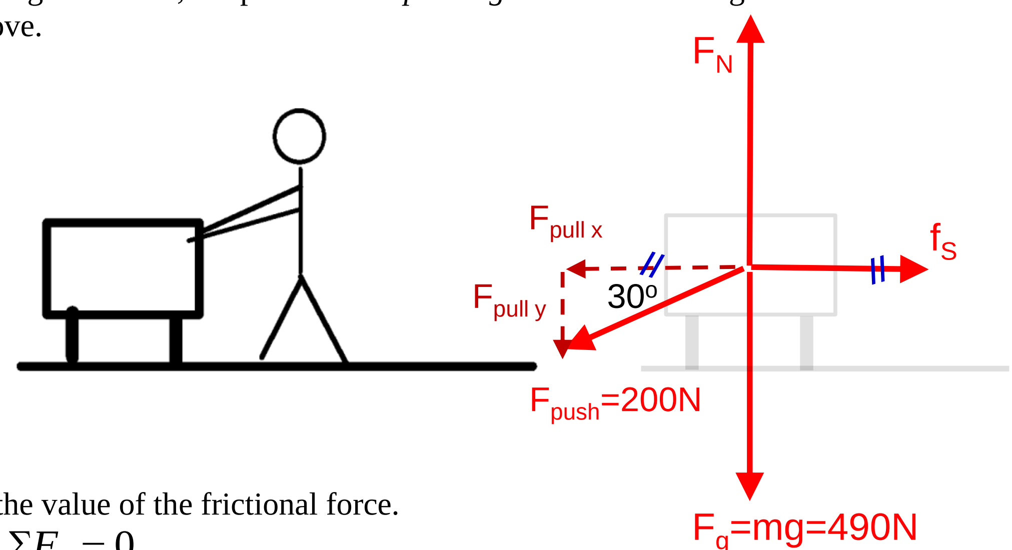
a. Determine the value of the frictional force.

$$\Sigma F_x = 0$$
$$-f_S + F_{Pullx} = 0$$
$$f_S = F_{Pullx} = F_{Pull}\cos 30 = 200\cos 30$$
$$f_S = 173.2N$$

b. Determine the normal force.

$$\Sigma F_y = 0$$
$$F_N + F_{Pully} - F_g = 0$$
$$F_N + F_{Pull}\sin 30 - 490 = 0$$
$$F_N = 490 - 100 = 390N$$

6. Suppose in the diagram above, the person were *pushing* down at a 30° angle with 200 N of force. The desk still does not move.



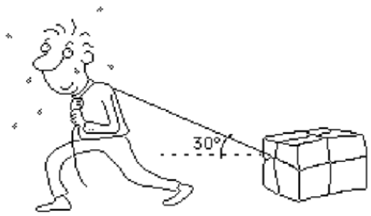
a. Determine the value of the frictional force.

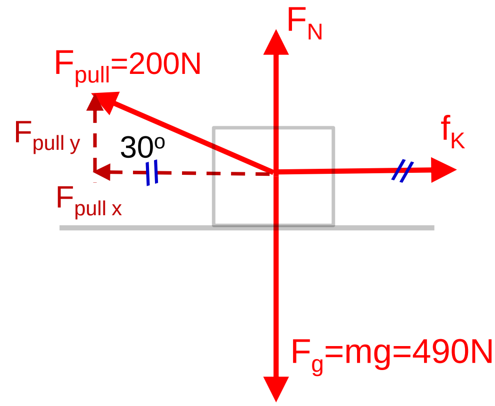
$$\Sigma F_x = 0$$
$$f_S - F_{Pushx} = 0$$
$$f_S = F_{Pushx} = F_{Push}\cos 30 = 200\cos 30 = F_{Push}\cos 30 = 200\cos 30$$
$$f_S = 173.2N$$

b. Determine the normal force.

$$\Sigma F_y = 0$$
$$F_N - F_{Pushy} - F_g = 0$$
$$F_N - F_{Push}\sin 30 - 490 = 0$$
$$F_N = 490 + 100 = 590N$$

7. A man pulls a 50 kg box *at constant speed* across the floor. He applies a 200 N force at an angle of 30°.





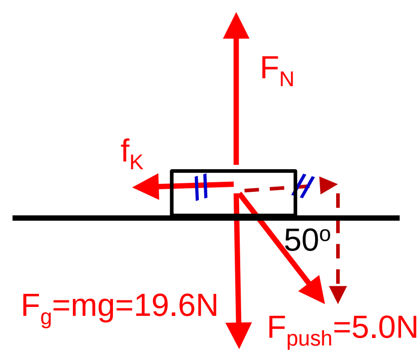
a. What is the value of the frictional force opposing the motion?
Since the box is being pulled at a <u>constant velocity</u> across the floor, there is no acceleration and therefore no net force on the box

$$\Sigma F_x = 0$$
$$f_K - F_{Pullx} = 0$$
$$f_K = F_{Pullx} = F_{Pull}\cos 30 = 200\cos 30$$
$$f_K = 173.2N$$

b. What is the value of the normal force?

$$\Sigma F_y = 0$$
$$F_N + F_{Pully} - F_g = 0$$
$$F_N + F_{Pull}\sin 30 - 490 = 0$$
$$F_N = 490 - 100 = 390N$$

8. A man pushes a 2.0 kg broom *at constant speed* across the floor. The broom handle makes a 50° angle with the floor. He pushes the broom with a 5.0 N force.



a. What is the value of the normal force?

$$\Sigma F_y = 0$$
$$F_N - F_{Pushy} - F_g = 0$$
$$F_N - F_{Push}\sin 50 - 19.6 = 0$$
$$F_N = 3.8 + 19.6 = 23.4N$$

b. What is the value of the frictional force opposing the motion?
Since the box is being pulled at a constant velocity across the floor, there is no net force on the box

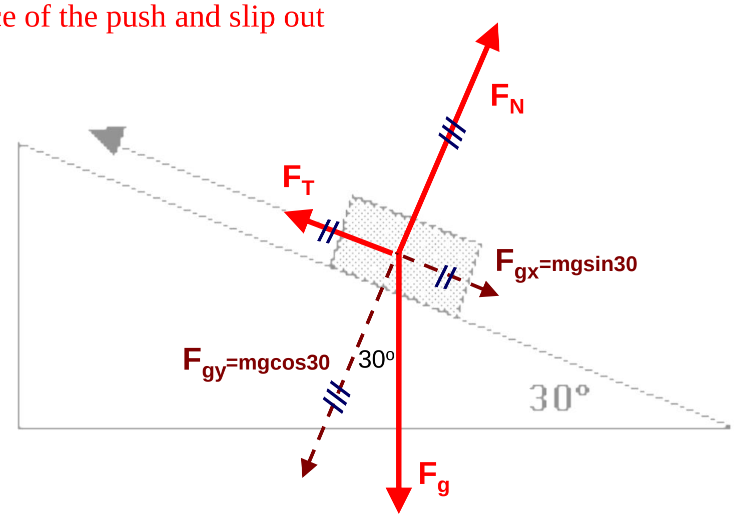
$$\Sigma F_x = 0$$
$$f_K = F_{Pushx}$$
$$= F_{Push}\cos 50 = 5.0\cos 50$$
$$f_K = 3.2N$$

c. If the frictional force were suddenly reduced to zero, what would happen to the broom?

The broom would accelerate forward due to the net force of the push and slip out

9. The box on the *frictionless* ramp is held at rest by the tension force. The mass of the box is 20 kg.

a. What is the value of the tension force?

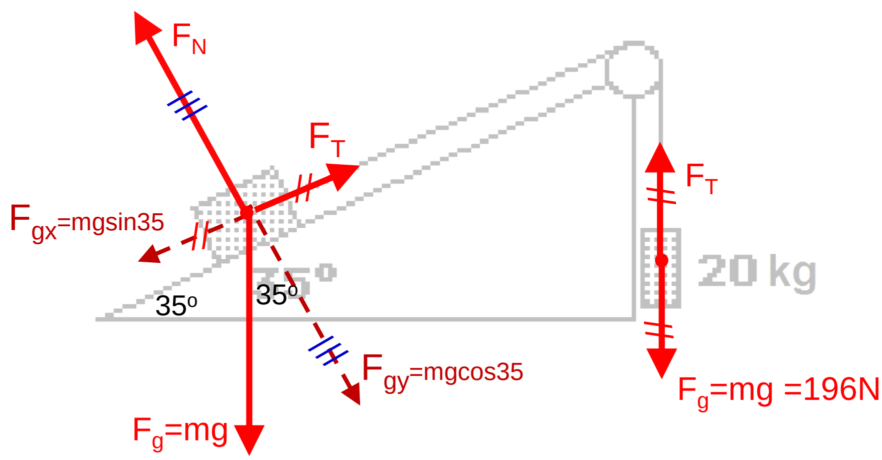


$$\begin{aligned} \Sigma F_x &= 0 \\ F_T &= F_{gx} \\ &= F_g \sin 30 = mg \sin 30 \\ F_T &= 98N \end{aligned}$$

b. What is the value of the normal force?

$$\begin{aligned} \Sigma F_y &= 0 \\ F_N &= F_{gy} \\ &= F_g \cos 30 = mg \cos 30 \\ F_N &= 169.7N \end{aligned}$$

10. In the system below the pulley and ramp are *frictionless* and the block is in static equilibrium. What is the **mass** of the block on the ramp?



Hanging block: *F_T = Fg = 196N*

On Incline:

$$\begin{aligned} \Sigma F_x &= 0 \\ -F_T + F_{gx} &= 0 \\ F_T &= F_{gx} \\ 196 &= F_g \sin 35 = mg \sin 35 \\ m &= 34.9kg \end{aligned}$$