Lesson 22: Net Force

The **net force** is the vector sum of all the forces acting on an object.

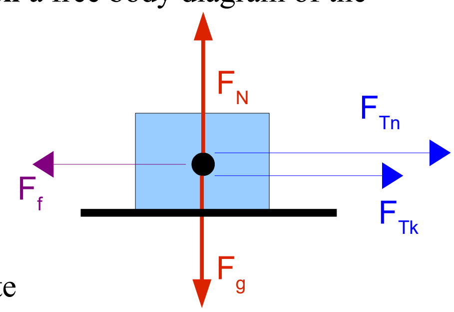
- If the forces are parallel we can just add them together as positive and negative forces.
- If the forces are at an angle we have to add them as components of vectors.

When someone talks about his gross pay and net pay, what do they mean? Gross pay is how much you are paid before any deductions. Net pay is how much you actually get on your paycheck after all the deductions.
It's the same sort of thing when we examine net force. After you have added and subtracted all the forces you are left with the net force acting on the object.

Example 1: A car is stuck in a snow drift. Niels and Kal attach two ropes to the vehicle and try to pull it out by pulling in the same direction. Niels pulls with a force of 75N while Kal pulls with a force of 68N. There is a force due to friction of 40N acting on the car. **Sketch** a free body diagram of the situation and **determine** the net force acting on the car.

Sketch a free body diagram, remembering to show the friction acting against the two people pulling.

- Notice how Niels and Kal and both pulling in the same direction, parallel to each other. Since we've shown it to the right, we will call these two forces positive.
- Friction is acting against them, in exactly the opposite direction. We will call this force negative.



Niels and Kal pulling the car against friction.

To determine the net force, we will need to write out a formula.

- We won't find this on the data sheet, since every net force question can be based on different forces.
- Net force will be equal to all the forces from the free body diagram added together.

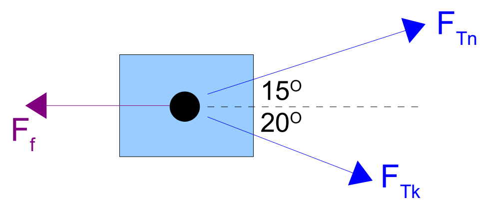
$$F_{NET} = F_{Tn} + F_{Tk} + F_f$$
$$= 75 + 68 + -40$$
$$F_{NET} = 103 \text{ N}$$

Warning!
Do not subtract any forces. We always add to find the net force. The direction of a vector determines its sign, and that's the only way minuses should appear in the formula.

The net force is 103 N acting to the right.

Example 2: As Niels and Kal pull the car, they notice a patch of ice on the road directly in front of them. To keep on pulling without slipping on the ice, they must begin to pull at an angle as they walk around the ice. Niels still pulls with a 75N at [E15^{O}N] and Kal pulls with 68N at [E20^{O}S]. Friction is still 40N. **Sketch** a new free body diagram and **determine** the new net force.

Be careful with the new sketch, since you'll need to use it to figure out the components of the vectors to be able to add everything. We're going to draw a ***top-down view***, which is not the regular thing to do, and kind of *bends* the rules of free body diagram drawings. We are not able to directly show F_N and F_g... instead, we will just make a note they point out and into the page.

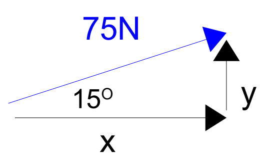


Note: F_g and F_N are not shown in this diagram, but do point into and out of the page.

We need to figure out each of the applied forces' components.

Note: In all of the calculations that follow I will not be using sig digs. Rounding off in the middle could screw up the final answer. Only the final answer will be rounded for sig digs.

Niels' Components

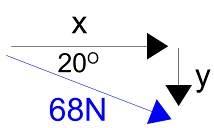


Niels' vector broken into components.

$$\cos\theta = \frac{adj}{hyp}$$
$$adj = \cos\theta(hyp)$$
$$adj = \cos 15^{o}(75)$$
$$x = adj = 72.444\text{N}$$

$$\sin\theta = \frac{opp}{hyp}$$
$$opp = \sin\theta(hyp)$$
$$opp = \sin 15^{o}(75)$$
$$y = opp = 19.411N$$

Kal's Components



Drawing 1: Katrien's vector broken into components.

$$\cos\theta = \frac{adj}{hyp}$$
$$adj = \cos\theta(hyp)$$
$$adj = \cos 20^{o}(68)$$
$$x = adj = 63.899\text{N}$$

$$\sin\theta = \frac{opp}{hyp}$$
$$opp = \sin\theta(hyp)$$
$$opp = \sin 20^{o}(68)$$
$$y = opp = 23.257\text{N}$$

Now we figure out what all of our x-components added together give us It's sort of like doing a special "x-component only" net force. Don't forget that friction is an x-component.

x-components

$F_x = F_{an} + F_{ak} + F_f$

$= 72.444 + 63.899 + -40$

$F_x = 96.343$ N

Now figure out the total of the y-components. Be careful that you show Kal's y-component as negative, since it is pointing down. Friction does not have a y-component since it was totally pointing in the x direction.

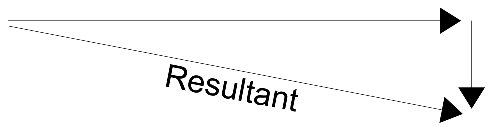
y-components

$F_y = F_{an} + F_{ak}$

$= 19.411 + -23.257$

$F_y = -3.846\ N$

Finally, add your x and y-components as a vector diagram to get the resultant.



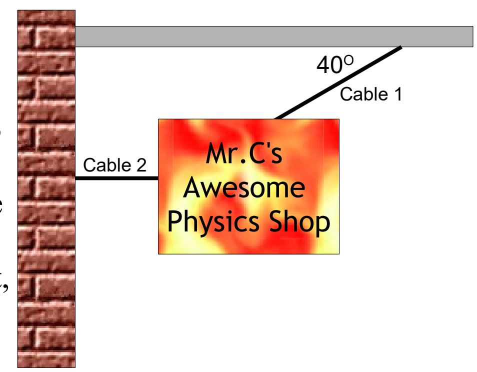
Resultant based on components.

$$c^2 = a^2 + b^2$$
$$c^2 = 96.343^2 + 3.846^2$$
$$c = 96.420N = 96N$$

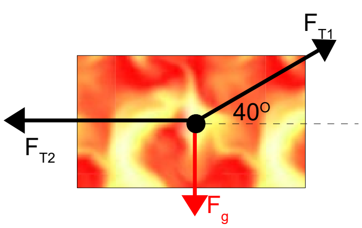
$$\tan\theta = \frac{opp}{adj}$$
$$\tan\theta = \frac{3.846}{96.343}$$
$$\theta = 2.3^o$$

The net force is 96N [E2.3^{o}S].

Example 3: A 20kg sign is supposed to hang from a pair of cables attached to the wall and a support beam as shown in the diagram. The cables that will be used can withstand a force of tension up to 300N each. **Determine** the tension in cable one (F_{T1}) and cable two (F_{T2}), and **explain** any concerns you may have.

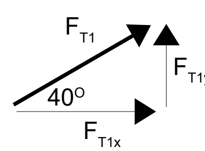


- Start off by drawing a free body diagram of the situation. Be sure to include the force due to gravity.
- In the diagram I've moved the 40^o angle into a different spot, but this is ok. Since I am still measuring the angle from a straight horizontal line in both cases, they are congruent angles.



- The important thing is that for the sign to hang without moving or falling, the net force acting on it must be zero. When several forces acting on each other cancel each other out, resulting in zero net force, we say that the forces are in a state of **equilibrium**.

- F_{T1} is pulling the sign up and to the right, while F_{T2} is pulling it to the left, and F_g is pulling it down.
  - F_{T1} will have to be broken into components (F_{T1x} & F_{T1y}).
  - F_{T1y} is the only force holding the sign up, so it must be equal in magnitude to F_g pulling it down. That way the net force acting vertically will be zero.



F_{T1} broken into components.

$$F_g = mg \qquad F_{NET} = F_g + F_{T1y}$$
$$F_g = 20.0(-9.81) \qquad 0 = -196.2 + F_{T1y}$$
$$F_g = -196.2\,N \qquad F_{T1y} = +196.2\,N$$

- We can use this value of F_{T1y} to calculate F_{T1} based on the triangle shown in Drawing 8.

$$F_{T1}$$
$$\sin\theta = \frac{opp}{hyp}$$
$$hyp = \frac{opp}{\sin\theta} = \frac{196.2}{\sin 40}$$
$$hyp = 305.23\,N$$

- We can also see from the free body diagram that the force of tension in the second cable is exactly opposite to the x-component of the tension in the first cable. The net force is also zero horizontally. If we calculate F_{T1x} (look back at drawing 8), it must be equal but opposite to F_{T2} .

$$F_{T1x}$$
$$\tan\theta = \frac{opp}{adj}$$
$$adj = \frac{opp}{\tan\theta} = \frac{196.2}{\tan 40}$$
$$adj = 233.82\,N$$

$$F_{NET} = F_{T2} + F_{T1x}$$
$$0 = F_{T2} + 233.82\ N$$
$$F_{T2} = -233.82\ N$$

- So the final values for the tensions in the two wires are 3.1e2 N [up] in wire one, and 2.3e2 N [left] in wire two. Since the tension in wire one is greater than the 300 N the wire can withstand, it will have to be replaced with a stronger wire.

Homework

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p.133 #2
p.135 #2
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