Conceptual Physics I
Classical Mechanics

Lesson 3B – Net Force

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Newton's First Law (Law of Inertia)

Objects at rest and objects moving with a constant velocity tend to maintain their state of motion unless acted upon by a force

Clarification: Not just a force, but a *net* force.

Example: If you push with equal and opposite forces on opposite sides of an object at rest, it will remain at rest. The forces cancel and the object stays at rest.

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But if you push with opposite yet *unequal* forces on an object at rest, the object will move in the direction of the largest of the two forces.

Net force is defined as the combination of all forces acting on an object, and it is the net force that causes a change in an object's state of motion.

Do Net Force Worksheet #1

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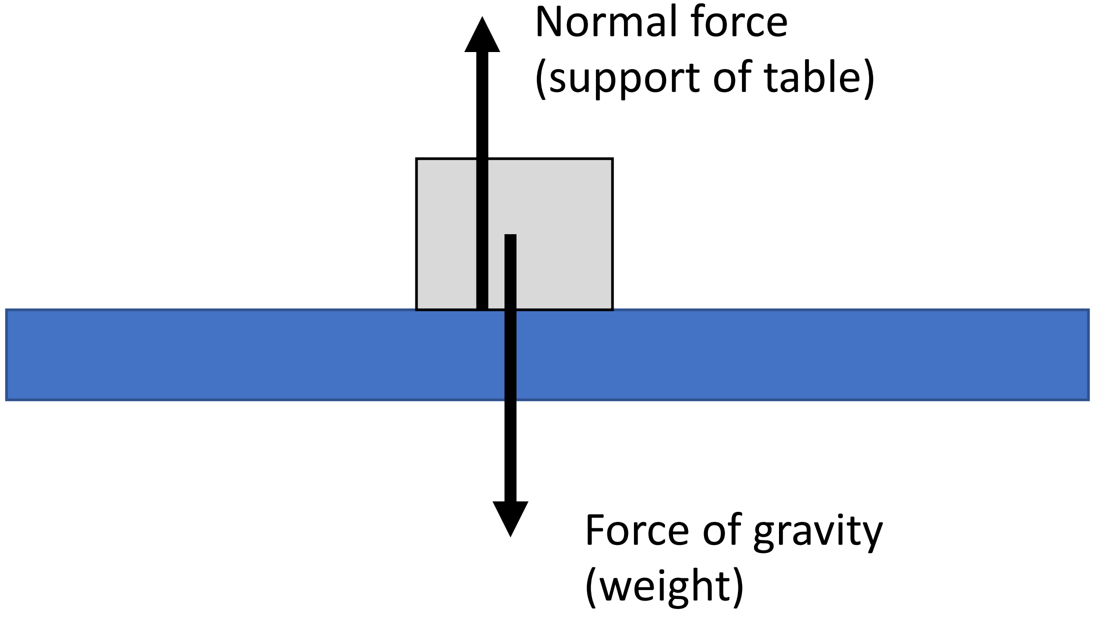
When the *net force* on an object is *zero*, we say the object is at *equilibrium.* An object at equilibrium maintains a constant velocity or is at rest (a special case of constant velocity being zero).

Consider an object at rest on a table.



The fact that the object is at rest means there is zero net force acting on it. There must be a force upward to balance the pull of gravity downward. The upward force is called the *normal force* and is, in this case, exactly equal and opposite to the weight force.

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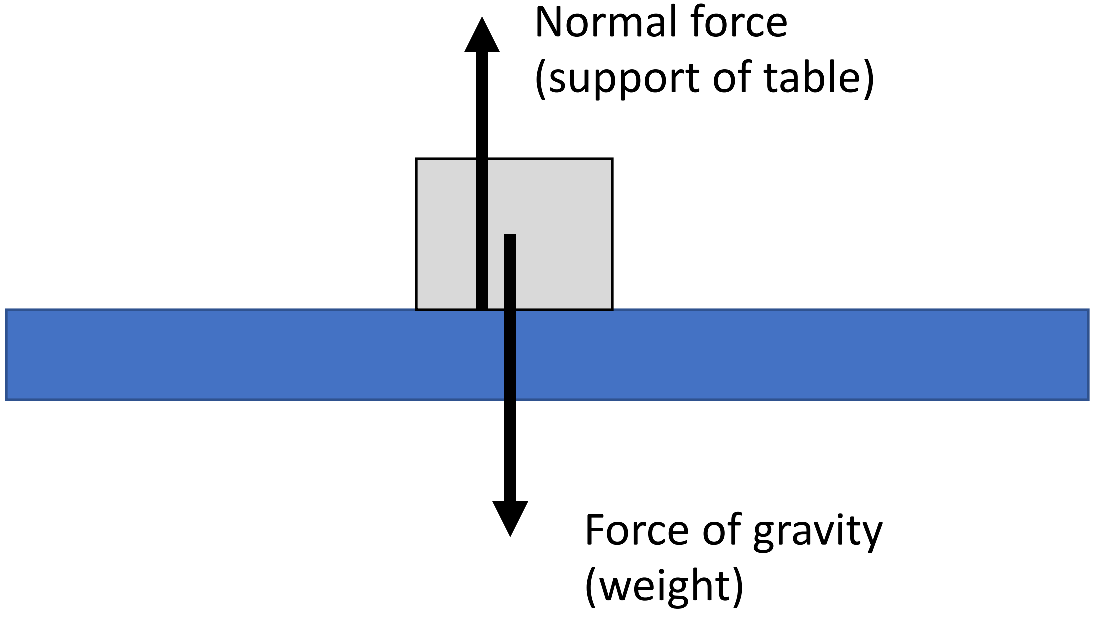
If you were to double the weight of the object, the normal force would double as well to keep the object at rest. If you were to sit on top of the object (and not break the table!), the normal force would increase to equal the sum of the object's weight and your weight.



Does the table really push up on the object? Yes, just as a spring pushes up on your hand when you compress it. The atoms in the table behave like springs and produce the normal force.

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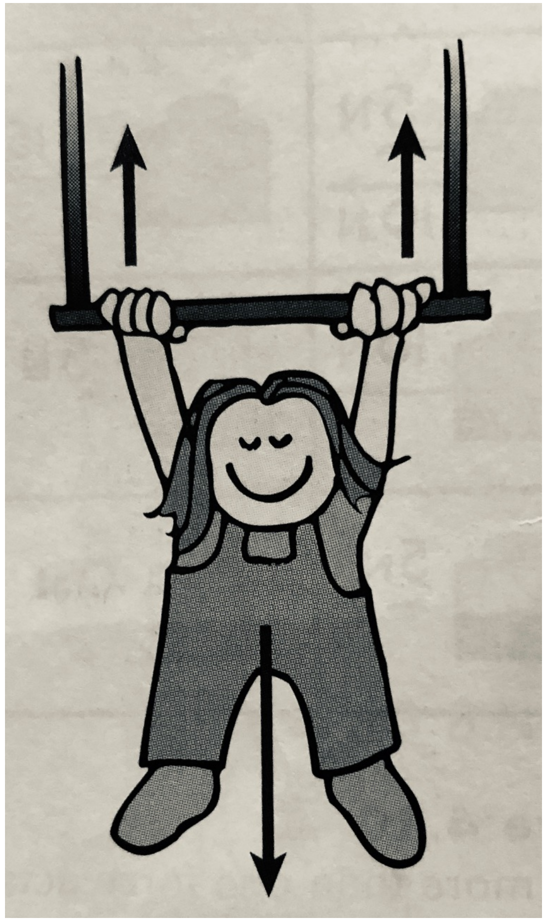
Another force to consider is *tension*.

When you hang from a rope, the atoms in the rope are stretched apart and a *tension force* is established.

If you are at equilibrium, then the total tension found in the ropes must equal your weight force. Therefore each rope will have a tension of *half your weight.*



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Question: When you step on a bathroom scale, the downward force supplied by your feet and the upward force supplied by the floor compress a calibrated spring. The compression of the spring gives your weight. In effect, the scale measures the normal force provided by the floor.

What will each scale read if you stand on two scales with your weight divided equally between them? Each scale will read half your weight.

What happens if you stand with more of your weight on one foot than the other? One scale will read more than the other, but the sum is still your total weight.

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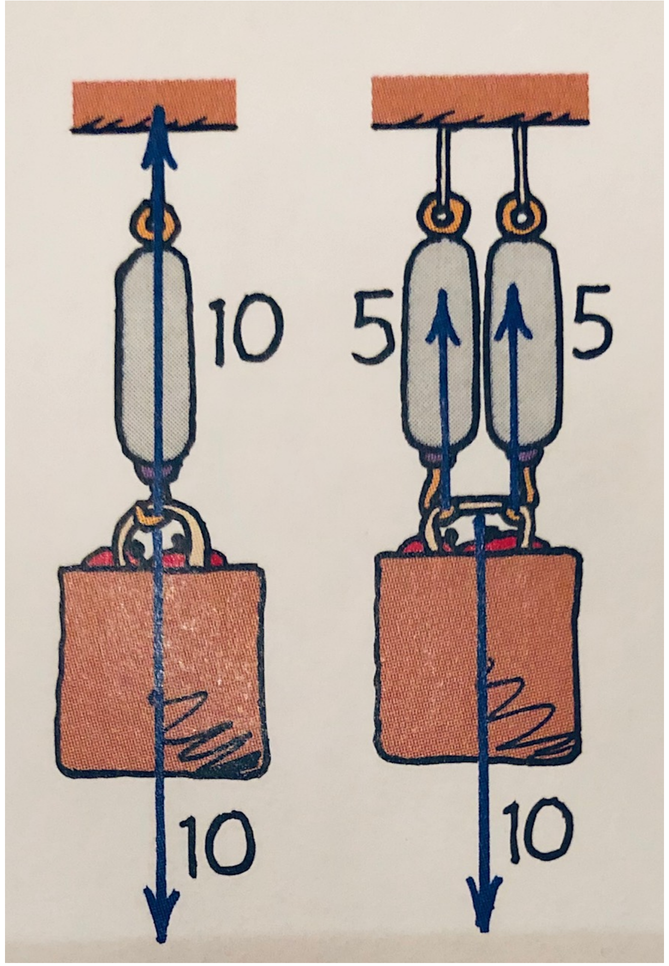
Consider the scales at the right.

In the first picture, there is only one scale, and the reading must equal the weight of the bag (10 N).

In the second picture, there are two scales, and the sum of the readings must equal 10 N; thus they read 5 N and 5 N.



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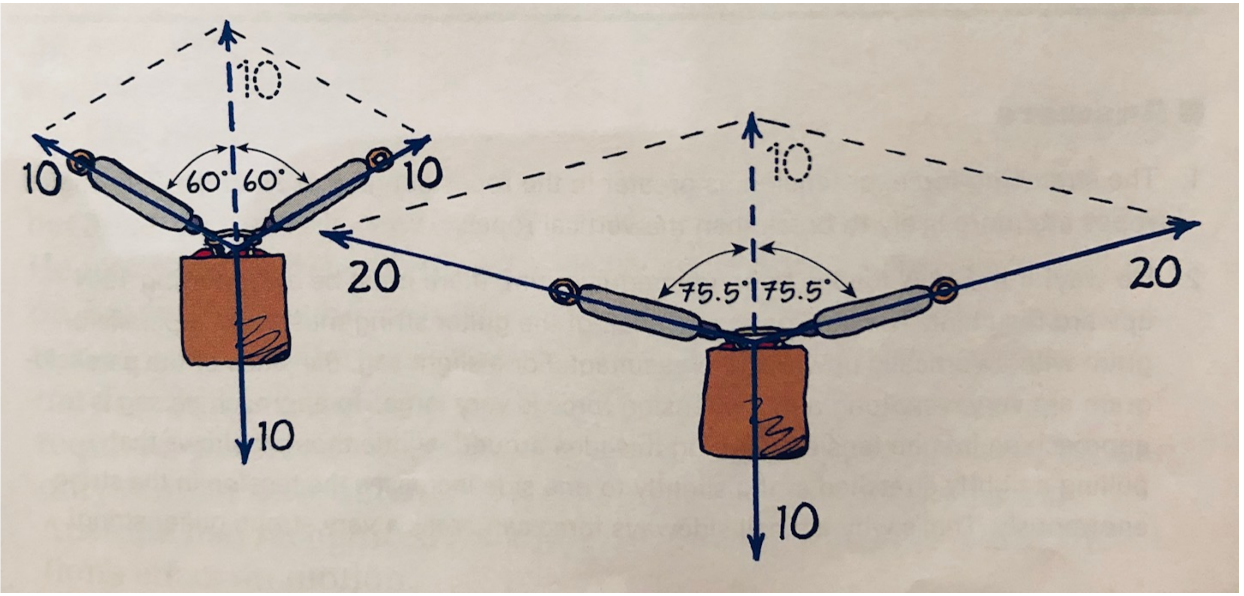
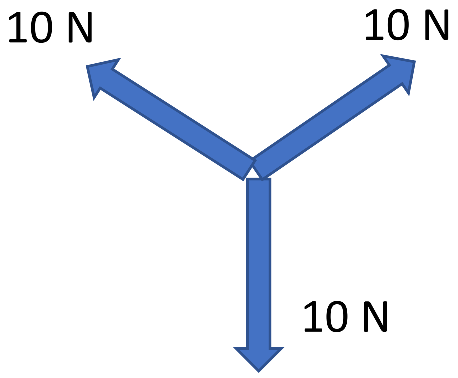
Now let's consider spring scales that are not vertical. The tension in the springs will depend on the angle from the vertical direction.

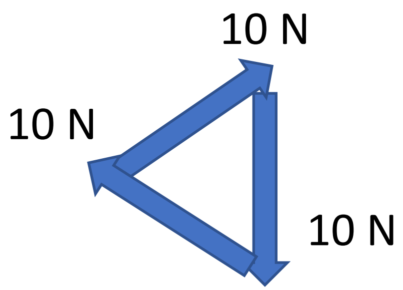
If the object is at equilibrium then the forces have to balance each other out.



The forces on the bag in the left diagram must balance (vector sum = 0).

Vectors are added graphically by placing them tail-to-head consecutively. If the head of the last vector touches the tail of the first vector, the vector sum is zero.





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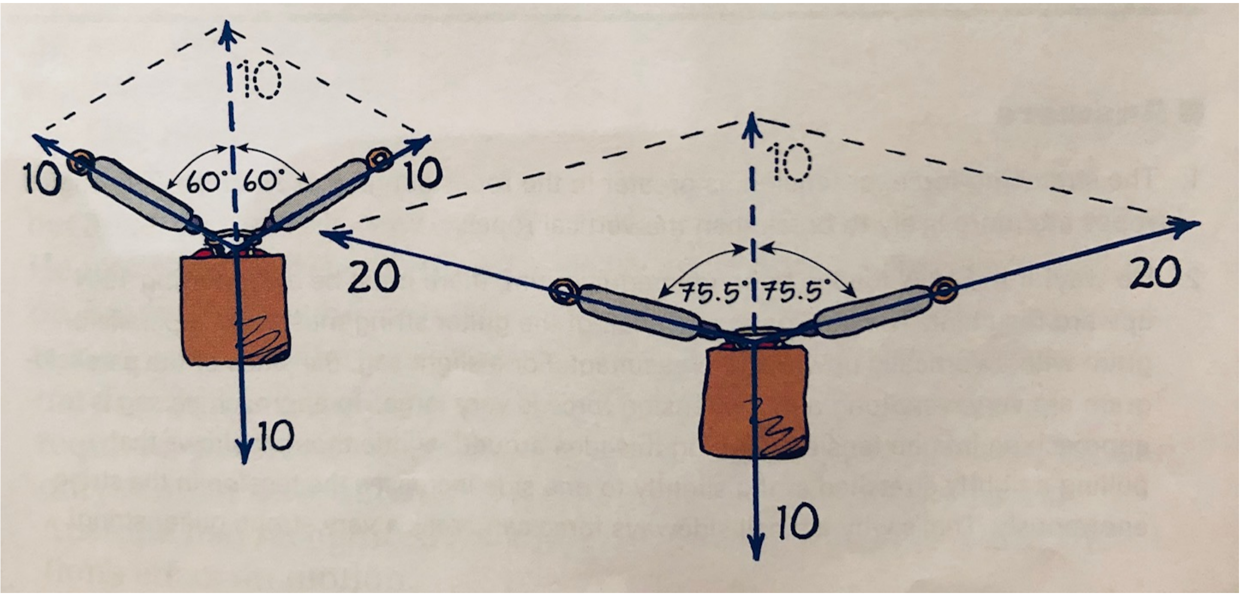
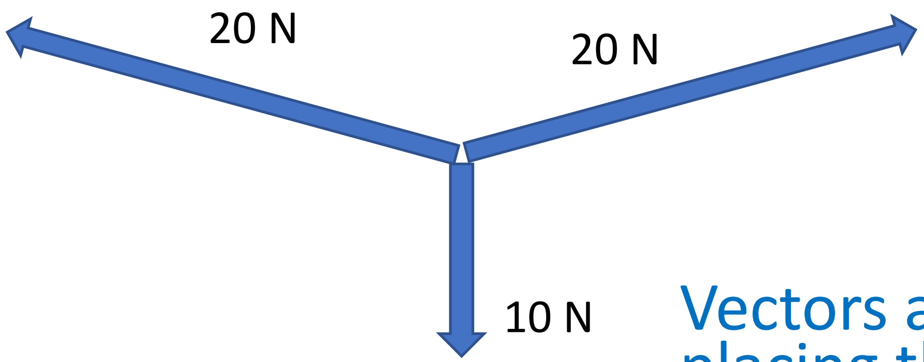
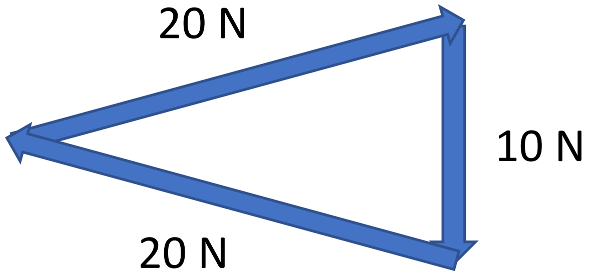
The forces on the bag in the right diagram must also balance (vector sum = 0) if the bag is at equilibrium.





Vectors are added graphically by placing them tail-to-head consecutively. If the head of the last vector touches the tail of the first vector, the vector sum is zero.



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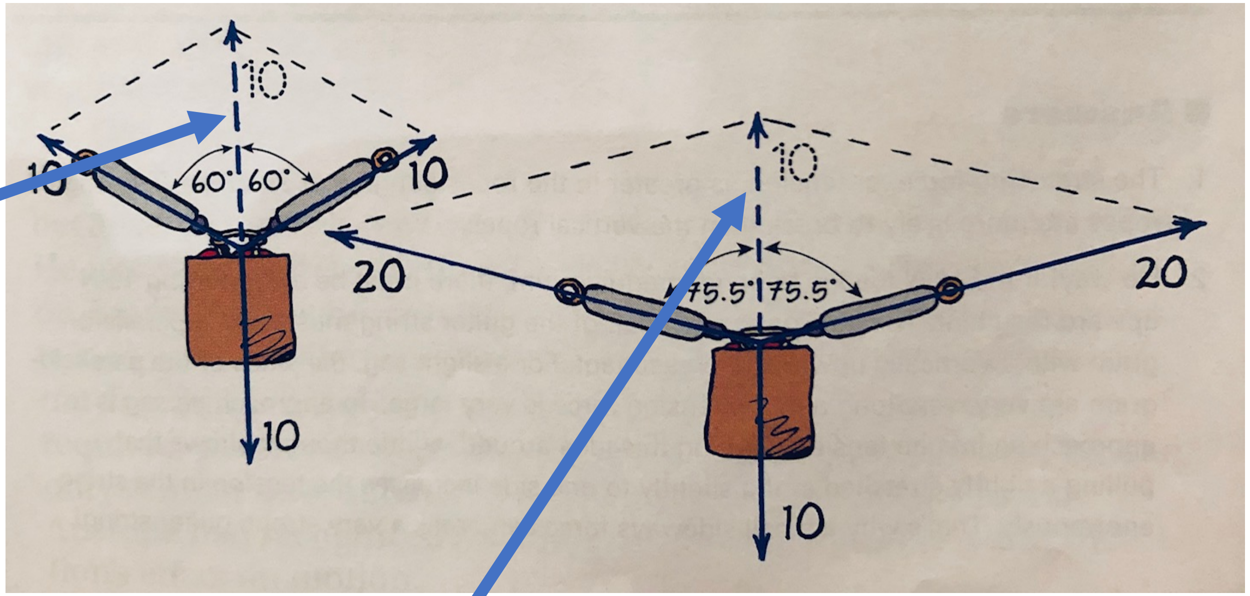
The vector sum of the two forces represented by the spring scales must be 10 N upward. Thus the bag remains at equilibrium.



For any pair of scales, ropes, or wires supporting a load, the greater their angle from the vertical, the larger the tension force in them.

Same situation. The vector sum of the two forces represented by the spring scales must be 10 N upward. Thus the bag remains at equilibrium.

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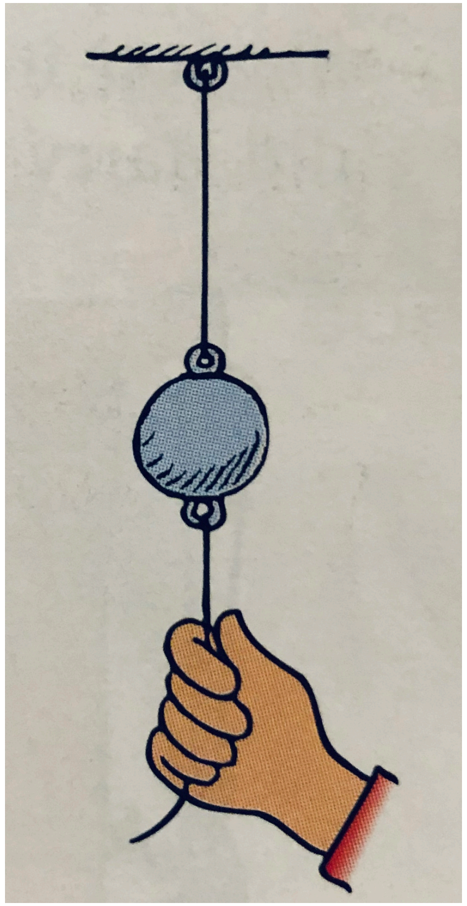
- Question: A massive ball is suspended on a string and slowly pulled by another string attached to it from below.

a) Is the string tension greater in the upper or the lower string? Upper tension is greater because it has to balance both the weight and the tension created by the hand pulling on the lower string. Which string is more likely to break? Upper string because it has more tension. Which property, mass or weight, is important here? Weight (the force).

b) If the string is instead snapped downward, which string is more likely to break? Lower string because the ball has a large amount of inertia which resists motion. Is mass or weight important this time? Mass, because it is a measure of inertia.



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- Question: If the children on the swings are of equal weight, which swing is more likely to break?

  The tension is greater in the ropes hanging at an angle.

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- Question: Harry's weight is 500 N and the rope, unknown to him, has a breaking point of 300 N. Why doesn't the rope break when he is supported as shown on the left?

  Each rope has a tension of half his weight (250 N) and is below its breaking point.

  One day Harry is painting near a flagpole, and for a change, he ties the free end of the rope to the flagpole instead of to his chair (picture on right). Why did Harry end up taking his vacation early?

  The rope is now bearing all his weight (500 N) and breaks.