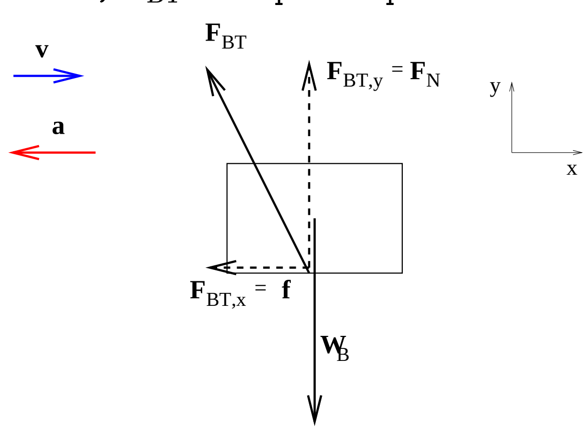
In the previous lecture we learned that there are two kinds of forces, GRAVITY and CONTACT FORCES. Today we will begin to give names to various types of contact forces.

Let us first think about the contact force between unattached surfaces. If you give your book (B) an small initial velocity and let it slide across a table (T), the moving book will quickly come to rest. Consider the forces that act on the book as it is coming to rest. The action is taking place at the surface of the Earth, so of course one of the forces is the force of gravity on the book by the Earth, $\mathbf{F}_{G,BE}$, which is the same thing as the weight of the book, $\mathbf{W}_B$. The only other force on the book is the contact force on the book by the table, $\mathbf{F}_{BT}$. Roughly speaking, what is the direction of $\mathbf{F}_{BT}$? We can answer this question by using Newton's Second Law and our understanding of kinematics. By observing the action, we know that the acceleration of the sliding book was opposite to its velocity. If the book was sliding to the right, as drawn below, then the acceleration was to the left. By the 2nd Law, the net force, $\Sigma\mathbf{F}$, has the same direction as the acceleration. So therefore, when I do the vector force addition $\mathbf{F}_{BT}$ + $\mathbf{W}_B$, the resultant vector must point to the left, the direction of $\Sigma\mathbf{F}$. I am able then to conclude that $\mathbf{F}_{BT}$ must have an upward component to cancel out the weight, and a leftward component which does not get canceled out. Therefore, $\mathbf{F}_{BT}$ must point up and to the left, as drawn below.



The velocity vector is in blue. The acceleration vector is in red.

This sliding-book example helps us to understand the definitions of the NORMAL FORCE and FRICTION, which follow below:

Let B and T represent two unattached surfaces which are in contact.

DEF The NORMAL FORCE ($\mathbf{F}_N$) is the component of $\mathbf{F}_{BT}$ which is perperdicular ($\perp$) to the surfaces at the point of contact. Since the surfaces are not attached, the normal force can only push, it can never pull.

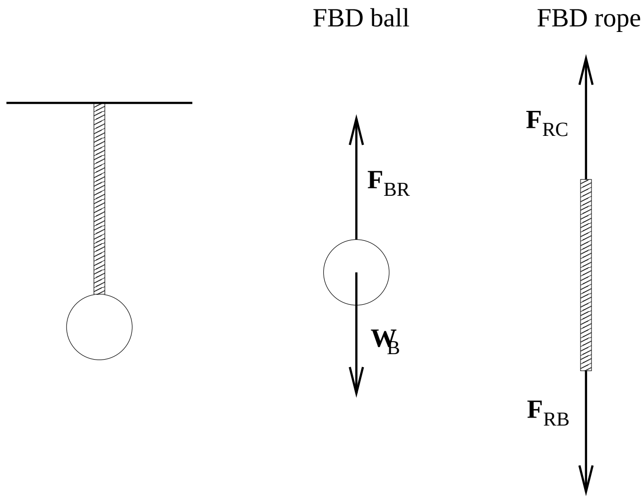
DEF The force of FRICTION ($\mathbf{f}$) is the component of $\mathbf{F}_{BT}$ which is parallel($\|$) to the surfaces at the point of contact.

We can add more subscripts to either of these symbols if necessary. For example, $\mathbf{F}_{N,BT}$ would indicate the normal force on the book by the table. But usually this is not necessary, since we are usually only concerned with the forces on one object. However, it may be necessary if there are multiple objects in our problem.

So we learn that the normal force and friction are NOT two separate forces; instead, they are two components of a single contact force between surfaces. In my drawing, $\mathbf{F}_N = \mathbf{F}_{BT,y}$ and $\mathbf{f} = \mathbf{F}_{BT,x}$. However, if someone asks you, "How many forces are acting on the block?", no one will argue with you if you answer, "Three, gravity, the normal force, and friction," even though technically the correct answer is, "Two, gravity and the contact force by the table".

Next we want to think about the PULLING contact force between an object and an ATTACHED rope, rod, chain, hook, etc.

Consider a ball (B) which is at rest and hanging by a rope (R) which is in turn attached to the ceiling (C). The drawing below shows a FBD for the ball and a FBD for the rope.



Note that the FBD for the rope does not include the weight of the rope! Why is this? In 111, we make our lives easy by using "massless" ropes. Since the rope has essentially no mass, it therefore has no weight. Also, since the acceleration of the rope is zero, the sum of forces acting on the rope is zero. Therefore, for the massless rope, the forces at the two ends of the rope, $\mathbf{F}_{RC}$ and $\mathbf{F}_{RB}$, are equal in magnitude. We use this fact to define tension.

DEF The TENSION (T) in a massless rope (or chain, rod, string, etc.) is the magnitude of the pulling force on the rope at either end of the rope. These are the forces that tend to pull the rope apart.

We can make this definition so simple because the magnitudes of the forces at either end of the massless rope are always equal to one another. (For a vertical rope that has mass, the tension in the rope will increase with height -- meaning that the question, "What is the tension in the rope?", could not have a simple answer because the tension would be different at different points in the rope.)

While "tension" formally refers to the magnitude of the pulling force ON the rope, by the 3rd Law the magnitude of the pulling force OF the rope must have the same value. For example, in my drawing, the 3rd-Law pairs $\mathbf{F}_{RB}$ and $\mathbf{F}_{BR}$ have the same magnitude, as they must; $\mathbf{F}_{BR}$ is the pulling force OF the rope, i.e. the pulling force ON the ball BY the rope. It is thus also acceptable to use the word "tension" to refer to the pulling force of the rope. You must determine the appropriate meaning of "tension" by the context in which the word is used. For example, in the sentence "The forces on the ball are the weight and the tension", the word "tension" refers to $\mathbf{F}_{BR}$. In such a case, the symbol $\mathbf{T}$ must be written as a vector.

Another imaginary device we use in PHY 111 is a "massless and frictionless" pulley. A massless and frictionless pulley, or a perfectly smooth peg, can change the direction of a rope without having any effect on the tension in the rope. The use of massless ropes and massless and frictionless pulleys in our calculations is reasonable as long as the ropes and pulleys that we actually use in an experiment are small in mass compared to the objects of interest, and as long as the pulleys don't have significant friction. The answers that we calculate will then be good predictions of reality to two or three significant figures.

In lecture, we will do examples using the normal force and tension, and we will do a demonstration which will test your understanding of tension.