Lecture 9 Force and Motion

Newton's Third Law

We can all accept the idea that if I stretch a spring (object A), I pull on it and it pulls on me (object B). This is the essence of Newton's Third Law. The only extra bit of necessary information is that the force of the spring pulling on me is equal and opposite to the force of me pulling on the spring.

$F_{A \text{ on } B} = - F_{B \text{ on } A}$, notice the negative sign – this is the opposite part.

So let's do a free body diagram:

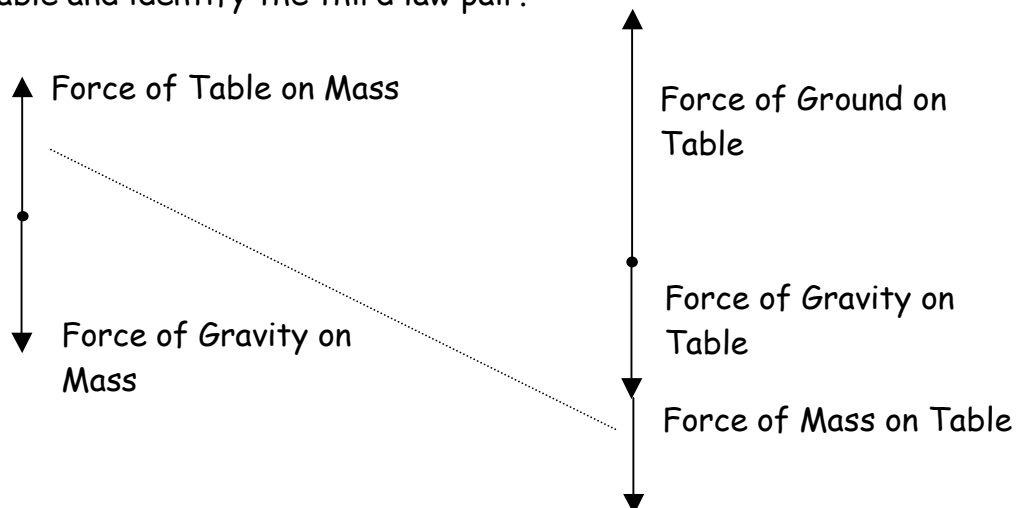$F_{A \text{ on } B}$ $F_{B \text{ on } A}$
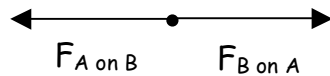
What's wrong with this diagram? Each force acts on a different object so we would need to define two different diagrams. This is how to express these forces properly.

$F_{B \text{ on } A}$

$F_{A \text{ on } B}$
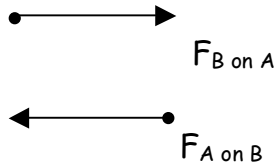
Each acts on a different object, hence, we need two separate diagrams. This is the biggest challenge with Newton's Third Law, identifying these equal and opposite forces and relegating them to separate diagrams. So let's try an example:

For a mass resting on a table, draw a free-body diagram for the mass and the table and identify the third law pair.

Force of Table on Mass

Force of Ground on Table

Force of Gravity on Mass

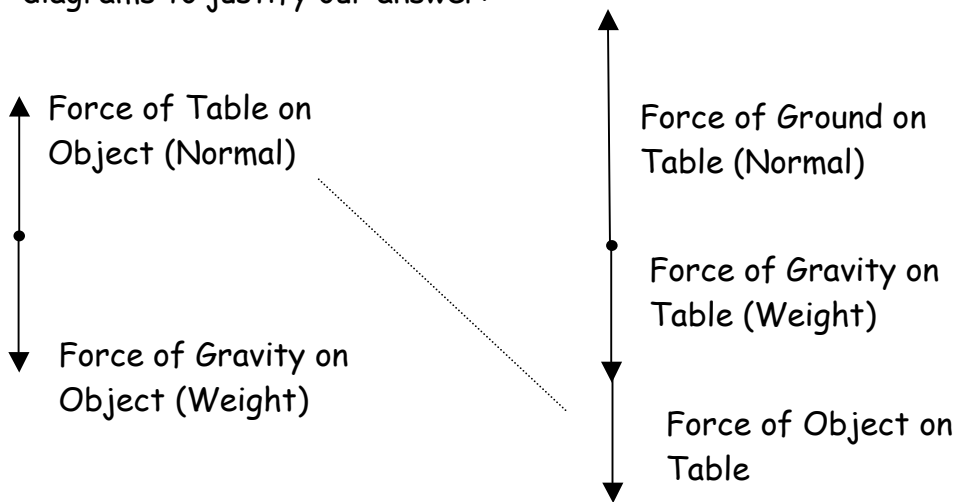Force of Gravity on Table

Force of Mass on Table

Notice that each force in third law pair acts on separate objects and they are equal magnitude and opposite in direction.

Now that you know all about Newton's third law, let's try to answer another question:
True or False: The normal force and weight of an object are a third law pair.

The answer is false! First of all, each force acts on the same object. Third law pairs must act on different objects. We can use the same free-body diagrams to justify our answer:

Force of Table on Object (Normal)

Force of Gravity on Object (Weight)

Force of Ground on Table (Normal)

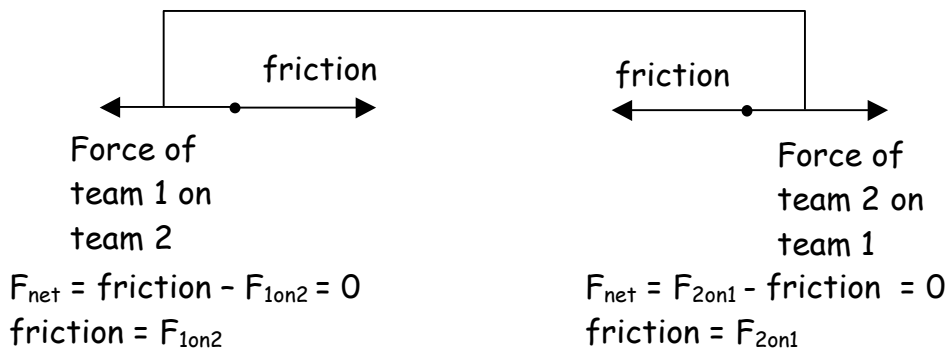Force of Gravity on Table (Weight)

Force of Object on Table

Notice that in this case a Normal force is paired with a non Weight force.

One final example:
Use Newton's Second and Third Laws to prove that in a tug of war, each team pulls with equal and opposite force.

We can draw force diagrams for each team and identify third law pairs.

friction

friction

Force of team 1 on team 2

Force of team 2 on team 1

F_{net} = friction – F_{1on2} = 0
friction = F_{1on2}

F_{net} = F_{2on1} – friction = 0
friction = F_{2on1}

In this first case the two teams would be in equilibrium, i.e. nobody's moving. If team 1 increases their force, then team 2 would also increase its force. But deciding who moves is not about third law pairs, it's about Newton's Second Law. We only look at the forces on one object:

$F_{net} = F_{2on1}$ – friction

This tells us that when friction < F_{2on1}, the team will move into the center and lose. because Fnet ≠ 0, so there would be an acceleration! This is a second law relationship, not third!

Just remember that in a third law pair the forces have to act on different objects. Also, recall $F_{A\ on\ B} = -F_{B\ on\ A}$, the forces are equal and opposite in a third law pair…