SPH4U: Newton's Third Law

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A: Forces as Interactions

Throughout our unit on forces, we have been making use of the term *interaction*. When two objects affect one another, we say that they *interact*. We have also noticed that these interactions come in the form of a push or a pull on the objects which we call *forces*. This brings us to a very important idea.

Whenever two objects interact, they each exert a force on the other.These two forces are really just two parts of a **single interaction**. We will call the two forcesa *3rd law force pair*. The forces in a 3rd law force pair share some important characteristics:

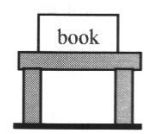
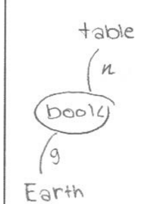
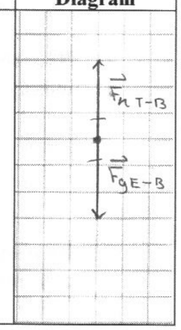
- they have the same magnitude
- they are the same type (gravitational, normal, etc.)
- they involve the same pair of objects
- they point in opposite directions
- they arise and act simultaneously

This understanding of interactions is known as *Newton's 3rd Law*. Please never use the words *action* or *reaction* when describing forces. To do so is simply wrong.

B: BookLearnin'

One of the exciting things about studying physics is that as your understanding grows, the physics of very simple situations becomes much more nuanced and subtle. Let's think about your physics book at rest upon a table.

1. **Represent**. Draw an ID and FD for the system of the book.

Sketch	Interaction Diagram	Force Diagram
		

To show better the details of an interaction, we can use a more specific force notation which we will call *3rd law notation*. For example the earth interacts with the textbook gravitationally and we can symbolize this as: $\vec{F}_{g\ E-B}$, which reads: "the force of gravity of the **earth** acting on the **book**".Using this notation we can write Newton's 3rd Law as: $\vec{F}_{A-B} = -\vec{F}_{B-A}$ with the understandingof the characteristics of a force-pair.

2. **Represent**. Label the forces in your force diagram using this new notation.

Note that if you have done this correctly, all the subscripts for the forces on one objectwill end with the same letter. Double check this every time you use this notation.

3. **Reason.** Isaac says, "I think gravity and the normal force make up a third-law pair in this situation. Just look at the size and direction of the forces." Do you agree or disagree with Isaac? Explain.

We disagree with Isaac because in order for this situation to be a third-law pair, the forces must be the same type. However, in this situation, there are 2 forces, gravity and normal force. Therefore, this situation is not a third-law pair.

4. **Reason**. Emmy says, "Do gravity and the normal force always have the same size? Why do they here?" Explain to Emmy.

Gravity and normal force do not necessarily need to be the same size. The sizes can be different if there is acceleration in the y-direction. In this situation, they have the same size since there is no acceleration and the net force is 0.

5. **Reason.** Albert says, "So if gravity and the normal force are not members of the same 3rd-law pair, is there a 3rd-law partner for $\vec{F}_{g\ E-B}$?" Explain what it is and why it doesn't appear on this force diagram.

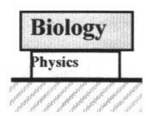
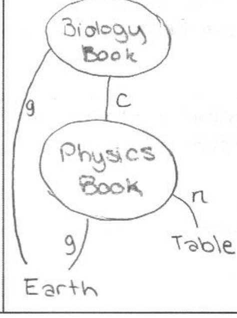
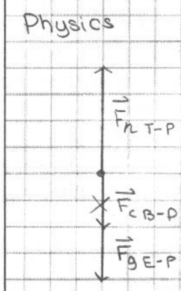
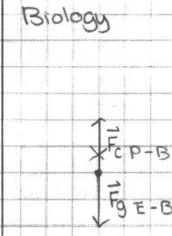
A 3rd-law partner does exist for $\vec{F}_{g\ E-B}$. It is $F_{g\ B-E}$ and it is the force that the book exerts on the Earth. It doesn't appear on this force diagram because the diagram represents the forces acting on the book only.

C: The Stack O' Books

Your homework is piling up – your slender physics text is sitting on the table and your massive biology text is on top.

1. **Represent.** Draw a single interaction diagram for this situation. We will consider the bio book and physics book as two separate systems: circle each.

2. **Represent**. Draw a force diagram for each text. (Hint: you should draw five forces in total!) Whenever we study the forces of more than one object, use the 3rd law notation introduced above.

Sketch	Interaction Diagram	Force Diagram	Force Diagram
			

A *contact force* is one that is evident only when two objects are in contact. A *non-contact* force is evident even when the two objects are not in physical contact.

3. **Reason**. Which forces are contact and non-contact forces?
$\vec{F}_n$ and $\vec{F}_c$ are contact forces. $\vec{F}_g$ is a non-contact force

4. **Reason**. Are there any 3rd-law force pairs appearing in the two diagrams? If so, indicate these with a small "×" on each member. If there is a second pair use a "××" on each member, and so on.

5. **Reason**. Rank the magnitude of the forces appearing in the two force diagrams from smallest to largest. Explain your ranking.
The rank is $\vec{F}_{g\ E-P}$, $\vec{F}_{g\ E-B}$, $\vec{F}_{cP-B}$, $\vec{F}_{cB-P}$, $\vec{F}_{n\ T-P}$. We decided that $\vec{F}_{g\ E-P}$ was the smallest since the force of gravity on the physics book is smaller due to the smaller mass. $\vec{F}_{g\ E-B}$ was next b/c the biology book has a greater mass, so will have a greater force of gravity. $\vec{F}_{g\ E-B}$ will be the same as $\vec{F}_{cP-B}$ and $\vec{F}_{cB-P}$. $\vec{F}_{nT-B}$ will be the greatest.

6. **Represent**. Based on your ranking of the magnitudes of the forces, do you need to make any modifications to your two force diagrams? Explain why or why not.
Yes, I need to make modifications to my force diagrams, I need to make the $\vec{F}_{g\ E-P}$ slightly smaller b/c right now it's the same as $\vec{F}_{g\ E-B}$. Then I need to make $\vec{F}_{nT-P}$ smaller to accomodate for the change in $\vec{F}_{g\ E-P}$

7. **Reason**. Compare the force diagram for the physics text from parts B and C. Which forces changed when the biology text was added and which remained the same? Explain.
The force of gravity on the book remains the same because the mass doesn't change. A contact force was introduced when the Biology text was added. Because of this, the normal force of changed to balance out the gravity and contact force.

8. **Test**. Marie says, "In this situation, the weight of the biology text acts on the physics text." Test this assertion. Use your hand in the place of the physics text. Lower the biology text (or other, hefty book) onto your hand. Are you feeling a contact force, or a non-contact force?
We are feeling a contact force

9. **Summarize.** Based ontoday's investigation andthe rest of our work in gr. 12 physics, what can we conclude about the size of the normal force compared with the force of gravity? What is the best way to determine the size of the normal force? We can conclude that size of the normal force is not necessarily dependant on the force of gravity. Based on the situation, the normal force may or may not equal the force of gravity. The best way to determine the size of the normal force is to carefully look at the situation.

SPH4U Homework: Magnets and the Third Law! Name:

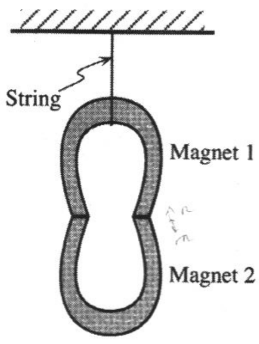
Let's explore our understanding of the third law using a new interaction: magnetism! We can treat magnetic interactions just like we do gravitational interactions.

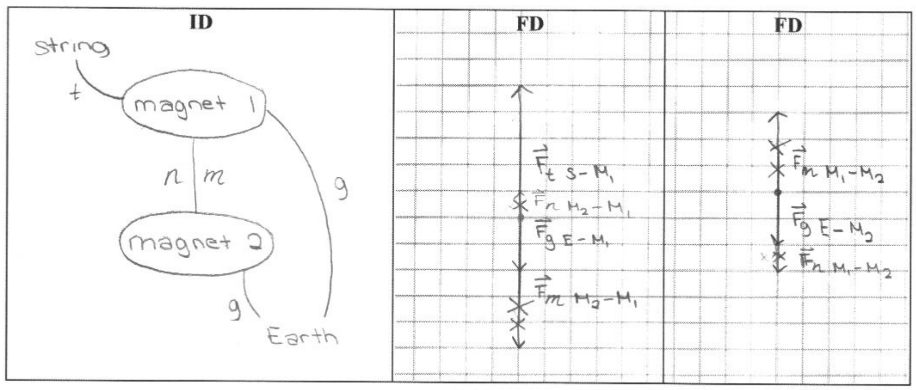
A: Two Horseshoes

One magnet is supported by another magnet that hangs from a string.

1. **Represent.** Draw a single interaction diagram that includes the two magnets. Circle each magnet as a separate system.

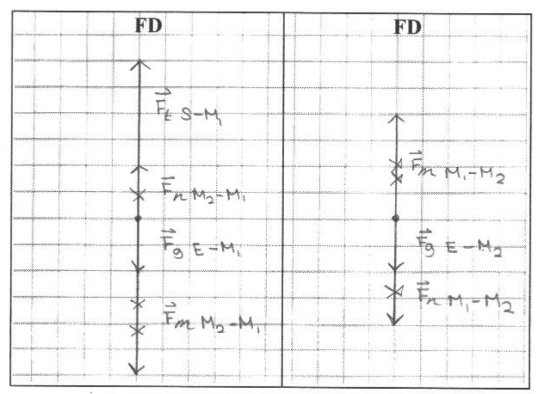
2. **Represent.** Draw a FD for each magnet. Make sure you use the complete 3rd law notation for the forces. Draw an × or×× on any third law pairs of forces.





3. **Reason.** Suppose that the two magnets were preplaced by stronger magnets of the same mass. Describe any changes to the ID. Draw revised FDs for each.

The ID will remain the same



4. **Reason.** Can a magnet exert a non-contact force on an object? Explain.

Yes, it is possible for a magnet to exert a non-contact force on an object. For example, it can repel another magnet and not touch it

5. **Reason.** Can a magnet exert a contact force on an object? Explain.

Yes, if a magnet is touching an object, it is exerting a contact force

6. **Explain.** How could you use a magnet to exert both a contact and a non-contact force on another magnet?

Point the opposite poles of 2 magnets together. They should attract each other and connect. The magnet is now exerting a contact force.

Next, point the same poles of 2 magnets together. They will repel eachother. The magnet is now exerting a non-contact force, since it isn't touching the other magnet, but is still creating a pushing force.

Adapted from McDermott, L. *Tutorials in Introductory Physics.* Prentice Hall, 2002