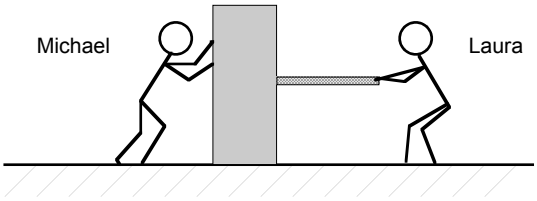
I. Forces, System Schema, & Free-body diagrams

In this tutorial, we will learn a convention for drawing free body diagrams of forces acting on an object. We will also consider the difference between contact and non-contact forces.

Two people are attempting to move a large block. The block, however, does not move. Michael is pushing on the block. Laura is pulling on a rope attached to the block.



A. The large dot at right represents the block. Draw vectors with their *tails* on the dot to show the forces exerted *on* the block. Label each vector and write a brief description of that force next to the vector.

The diagram you have drawn is called a *free-body diagram*. Often a free-body diagram involves a simplified sketch of the object rather than the dot. Regardless of which form is used, a proper free-body diagram should **not** have anything on it except a representation of the object and the (labeled) forces exerted on that object. A free-body diagram **never** includes: 1) forces exerted by the object of interest on other objects, nor 2) sketches of other objects that exert forces on the object of interest.

B. Draw a 2nd diagram where you write down the name of each object in the system and then draw a solid circle drawn around it. Draw two sided arrows like this $\leftrightarrow$ between the object circles of objects that interact (This illustrates all interactions between the objects in this diagram). Draw an additional dotted line around the block to indicate it is the object of interest. This diagram is called a *system schema*.

C. Consider the block in the diagrams above.

Which of the forces exerted on the block arise from *direct contact* between two objects?

Which of the forces exerted on the block **do not** arise from direct contact between two objects?

We will call forces that depend on contact between two objects *contact forces*. Forces that do not arise from contact between two objects we will call *non-contact* forces.

D. There are many different types of forces, including: friction (F_f), tension (F_T), magnetic forces (F_{mag}), normal forces (F_N), and the gravitational force (F_W, for weight). Categorize these forces according to whether they are contact or non-contact forces.

Contact Forces **Non-contact Forces**

All forces arise from an interaction between *two* objects. Forces are specified by identifying the object on which the force is exerted and the agent exerting the force. For example, in the situation above, there is a frictional force exerted *on* the block *by* the floor. There is also a normal force exerted *on* the block *by* the floor.

E. Describe the remaining forces from the diagrams on page 1 in a similar fashion.

Often forces are labeled in a way that makes clear: 1) the type of force, 2) the object on which the force is exerted, and 3) the object exerting the force. For example, a normal force exerted *on* Object A *by* Object B is labeled $\vec{F}_{N,B\to A}$.

F. Redraw the system schema and the the free body diagrams from parts A and B below.
* Label each of the forces on your free-body diagram in the manner described above.
* Label each interaction in your System schema to indentify the type of force.

II. Forces

A. Sketch a free-body diagram and a system shema for a book at rest on a level table. (Remember: A proper free-body diagram should not have anything on it except a representation of the book and the forces exerted *on* the book.)

Label each of the forces exerted on the book by:

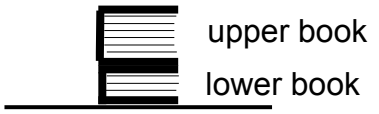
- stating the type of force (e.g., gravitational, frictional, etc.),
- identifying the object on which the force is exerted, and
- identifying the object exerting the force.

1. What evidence do you have for the existence of each of the forces on your diagram?

2. What observation can you make that allows you to determine the *relative magnitudes* of the forces acting on the book?

How did you show the relative magnitudes of the forces on your diagram?

B. A second book of greater mass has been placed on top of the first.



Sketch a system schema for the two books and the table. Then sketch a free-body diagram for the *upper* book. Label the forces as in part A.

Next to the free-body diagram you just drew for the upper book (but separate from it), sketch a free-body diagram for the lower book. Label the forces on both free-body diagrams in the same manner as you did in part A.

1. Examine all the forces on the two free-body diagrams you just drew. Explain why a force that appears on one diagram **should not** appear on the other diagram.

2. What *type* of force does the upper book exert on the lower book? (e.g., frictional, gravitational, etc.)

   Why would it be *incorrect* to say that the weight of the upper book acts on the lower book?

3. Compare the free-body diagram for the lower book to the free-body diagram for the same book in part A (i.e., before the upper book was added).

   Which force(s) have changed?

   Which force(s) have remained the same?

4. What observation can you make that allows you to determine the *relative magnitudes* of the forces on the *upper* book?

5. Are there any forces acting on the *lower* book that have the same magnitude as the forces acting on the *upper* book? Explain your reasoning.

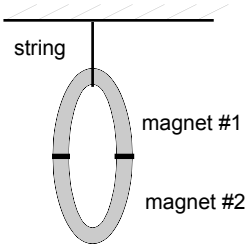
Which, if any, Third Law force pairs are explicitly shown in the diagrams you have drawn? On which object does each of the forces in the pair act?

Identify any third law force pairs on your diagrams by placing "tick marks" through each member of the pair. For example, if you have two third law force pairs shown on your diagram, mark *each* member of the first pair as: —|—, and each member of the second pair as: —||—, etc.

III. Contact and non-contact forces

Two Hanging Magnets

A magnet is supported by another magnet as shown at the right.



1. Draw a system schema for the two magnets and a free-body diagram corresponding to *Magnet #2*.
   Label each of the forces on your diagram by:
   - stating the type of force (e.g., gravitational, normal, etc.),
   - identifying the object on which the force is exerted, and
   - identifying the object exerting the force.

2. Suppose that the magnets were replaced by stronger magnets of the same mass.

   If this changes the free-body diagram for Magnet #2, sketch the new free-body diagram and describe how the diagram changes. (Label the forces as you did in part 1 above.) If the free-body diagram for Magnet #2 does not change, explain why it does not.

3. Can a magnet exert a non-contact force on another object?

   Can a magnet exert a contact force on another object?

   Describe how you can use a magnet to exert *both* a contact force and a non-contact force on another magnet.

4. To ensure you have accounted for all the forces acting on Magnet #2 in parts 1 and 2:

- List all the non-contact forces acting on Magnet #2.

- List all the contact forces acting on Magnet #2.
  (Hint: what objects are in *contact* with Magnet #2?)