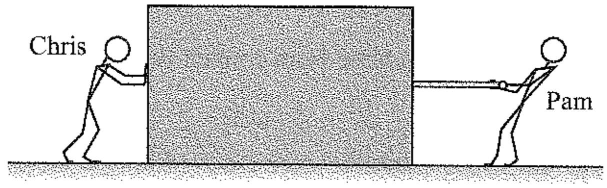
I. Identifying forces

Two people are attempting to move a large block. The block, however, does not move. Chris pushes on the block. Pam pulls on a rope attached to the block.



A. Draw a dot on a large sheet of paper to represent the block. Draw vectors with their "tails" on the dot to show the forces exerted *on* the block. Label each force vector and next to it write a brief description of the force.

In Newtonian physics, all forces are considered as arising from an interaction between *two* objects. Forces are specified by identifying the object *on which* the force is exerted and the object *that is exerting* the force. For example, in the situation above, a gravitational force is exerted *on* the block *by* the Earth.

B. Describe the remaining forces you have indicated above in a similar fashion.

The diagram that you have drawn is called a *free-body diagram.* A free-body diagram should show only the forces exerted *on* the object or system of interest (in this case, forces exerted *on the block*). Check your free-body diagram and, if necessary, modify it accordingly.

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 or (2) sketches of other objects that exert forces on the object of interest.

C. All forces arise from interactions between objects, but the interactions can take different forms.

Which of the forces exerted on the block require *direct contact* between the block and the object exerting the force?

Which of the forces exerted on the block *do not* arise from direct contact between the block and the object exerting the force?

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

D. There are many different types of forces, including: friction ($\vec{f}$), tension ($\vec{T}$), magnetic forces ($\vec{F}^{mag}$), normal forces ($\vec{N}$), and the gravitational force ($\vec{W}$, for weight). Categorize these forces according to whether they are contact or non-contact forces.

Contact forces	Non-contact forces

E. Consider the following discussion between two students.

Student 1: "I think the free-body diagram for the block should have a force by Chris, a force by the rope, and a force by Pam."

Student 2: "I don't think the diagram should show a force by Pam. People can't exert forces on blocks without touching them."

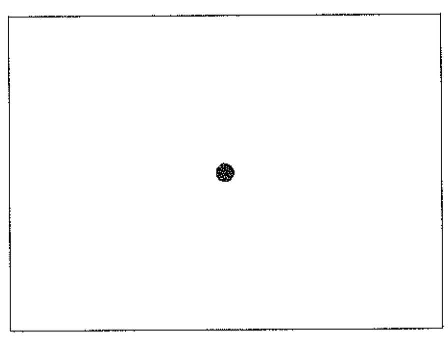
With which student, if either, do you agree? Explain your reasoning.

It is often useful to label forces 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, the gravitational force exerted *on* the block *by* the Earth might be labeled $\vec{W}_{BE}$. Your instructor will indicate the notation that you are to use.

F. Label each of the forces on your free-body diagram in part A in the manner described above.

➪ Do not proceed until a tutorial instructor has checked your group's free-body diagram.

Copy your group's completed free-body diagram in the space at right after it has been checked by a tutorial instructor.



II. Drawing free-body diagrams

A. Draw a free-body diagram 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.)

Make sure the label for each force indicates:

- the type of force (*e.g.*, gravitational, normal),
- the object on which the force is exerted, and
- the object exerting the force.

Free-body diagram for book

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 is placed on top of the first.

1. Draw a free-body diagram for each of the books in the space below. Label all the forces as in part A.

Free-body diagram for upper book	Free-body diagram for lower book

   Specify which of the forces are contact forces and which are non-contact.

2. 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.

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

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

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 a force acting on the *upper* book? Explain.

C. 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 of the forces changed when the upper book was added and which remained the same?

III. Identifying Newton's third-law force pairs

As discussed earlier, in Newtonian physics, all forces are considered as arising from an interaction between *two* objects. In addition, all forces come in pairs; whenever one object exerts a force on a second object, the second object also exerts a force on the first object. For example, if you push on a wall, the wall also pushes back on you. According to Newton's third law, the two forces in such a pair have the same magnitude and point in opposite directions. The two forces together are called an *action-reaction* or *Newton's third-law force pair.*

A. Consider the following *incorrect* statement made by a student:

"I think that the normal force and the weight are a third-law force pair. They're the same size and point in opposite directions, so they must be a third-law pair."

1. The student has incorrectly identified a third-law force pair. What force *does* make a third-law force pair with the normal force on the book by the table?

2. The student is correct that the normal force and the weight are equal in magnitude. Explain how you can tell they are equal.

B. What third-law force pairs are shown in the diagrams that you have drawn? Identify all third-law force pairs on your free-body diagrams by placing one or more small "×" symbols through each member of the pair. For example, if you have two sets of third-law force pairs shown on your diagrams, mark *each* member of the first pair as —×→, and *each* member of the second pair as —××→.

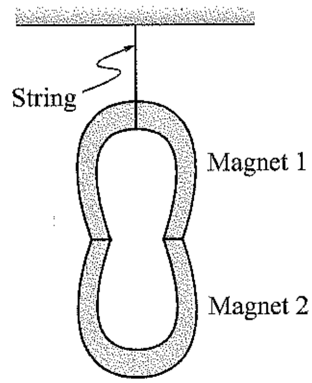
C. Can both members of a third-law force pair appear on the same free-body diagram? Explain why or why not.

D. Can the members of a third-law force pair be different types of forces (*e.g.*, one a gravitational force and one a frictional force)? Explain why or why not.

➪ Discuss your responses to this section with a tutorial instructor.

IV. Supplement: Contact and non-contact forces

A. A magnet is held up by another magnet as shown at right.



1. Draw a free-body diagram for magnet 2. The label for each of the forces on your diagram should indicate:
   - the type of force (*e.g.*, gravitational, normal),
   - the object on which the force is exerted, and
   - 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.

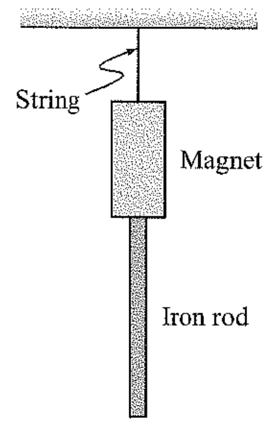
3. Can a magnet exert a non-contact force on another object?

   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 help ensure that 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:* Which objects are in *contact* with magnet 2?)

B. An iron rod is held up by a magnet as shown. The magnet is supported by a string.



1. In the spaces below, sketch a free-body diagram for the iron rod and a separate free-body diagram for the magnet.

   The label for each of the forces on your diagrams should indicate:

   - the type of force (*e.g.*, gravitational, normal),
   - the object on which the force is exerted, and
   - the object exerting the force.

Free-body diagram for iron rod	Free-body diagram for magnet
(*Hint:* There should be three forces.)	(*Hint:* There should be four forces.)

2. For each of the forces shown in your diagram for the iron rod, identify the corresponding force that completes the Newton's third-law (or action-reaction) force pair.

3. How would your diagram for the iron rod change if the magnet were replaced with a stronger magnet? Which forces would change (in type or in magnitude)? Which forces would remain the same?