Predict the spring scale reading for springs A (and B) in each of the following situations in which the system is at rest. Then test your predictions by setting up a model of the situation using the equipment provided for you. **Draw your model set-up next to the each picture.** Find the answers to the unknown forces and write the information down next to your model.

1) 

![Diagram of a system with forces labeled.](image)

Model for testing prediction:

2) 

![Diagram of a system with forces labeled.](image)

3) 

![Diagram of a system with forces labeled.](image)

4) 

![Diagram of a system with forces labeled.](image)
5) Short rope and long bungee cord

Conclusions for Situations 1-5: When you have finished the tests, make a few general statements as to how forces and tension are transferred between objects. What is the relationship? What is the reason for the relationship? Statements should be supported with your data.

Tension force is equal at all locations within the tension system

6.

A? 100 N

200 N

B? 100 N

7)

C? 400 N

A? 200 N

400 N

B? 200 N

Test your predictions for situations #6 and #7 using the same guidelines listed above. When you are finished, make a few general statements as to how forces and tension are transferred between objects in these two situations. Compare and contrast situations #6 and #7 with situations #1-5. Statements should be supported with your data.

- When a new tension system is added, the forces are divided.
- A tension force supporting 200 N of weight each had 100 N of force.
Elicitation Question – Identifying Forces on a Book on a Table

A book is at rest on a table. Sketch all the forces acting on the book.

- Use an arrow to represent the size and direction of each force. If one force is bigger than another, draw its arrow longer.
- Label each force by describing the type of force and the object exerting the force.

![Diagram of a book on a table with forces labeled: F by Earth (gravity) and F by Table.](image-url)
Mass and Weight

**Mass** is the amount of matter in something. It will not change, no matter what the location of the object is.

Units: The base unit for measuring mass in the metric system is **grams (g)**. In physics, we usually use the unit of **kilogram (kg)**.

**Conversion:** \(1,000 \text{ g} = 1 \text{ kg}\)

**Weight** is the force of the pull by the planet (earth) on an object. It is related to that object’s mass and the mass of the planet (or moon or star…) producing the gravitational pull.

**Weight is a Force** and is measured in **Newtons (N)** or **pounds (lb)**.

**Weight** = \(F_g = mg\)  (mass in kg \* gravity of the planet, moon, etc., that the object is near)

A 1 kg mass is pulled downward by the earth’s gravity with a force of about 10 newtons which is equivalent to about 2.2 lbs.

This is because Earth’s **gravity** = 9.8 m/s\(^2\). For simplicity, we round it to **10 m/s\(^2\)**.

**Note:** gravity is an **acceleration**, not a force.

**Conversions:** 1kg ~ 10 Newtons ~ 2.2 lb on Earth

1a. How much does a 1 kg mass weigh on Earth in Newtons?

\[
\text{Weight} = mg = 1 \text{ kg} \times 10\text{m/s}^2 = \underline{10 N}
\]

1b. How much does a 1 kg mass weigh on Earth in pounds?

\[
\text{Weight in pounds} = 1 \text{ kg} \times 2.2\text{ pounds} = \underline{2.2 \text{ pounds}}
\]

1c. What is the mass (in kilograms) of a 150 pound person?

\[
\text{Mass} = 150 \text{ pounds} \times \frac{1 \text{ kg}}{2.2 \text{ pounds}} = \underline{68.18 \text{ kg}}
\]

1d. How much will a 150 pound person weigh in Newtons?

\[
\text{Weight} = mg = 68.18 \text{ kg} \times 10\text{m/s}^2 = \underline{681.8 N}
\]

2a. How much will an 80 kg person weigh on Earth (in Newtons)?

\[
\text{Weight} = mg = 80 \text{ kg} \times 10\text{m/s}^2 = \underline{800 N}
\]

2b. How much will an 80 kg person weigh on Earth (in pounds)?

\[
\text{Define a "Newton" using what you know.} \quad \frac{800 \text{ N}}{10 \text{ N}} = \frac{176 \text{ lbs}}{1 \text{ lb}}
\]

- The force needed to accelerate 1 kg by \(10 \text{ m/s}^2\)
Weight on other Planets or Moons

For any planet (moon, etc...) besides Earth, just multiply the object's mass by the gravity of the planet, moon, etc to find the weight at that location \( F_g = mg \). Alternatively, if the gravity of the other planet is given as a fraction or percentage of Earth’s gravity, multiply the fraction by Earth’s gravity to estimate the gravity of the other planet.

3. Fill in the chart for a 60 kg person at the following locations:

<table>
<thead>
<tr>
<th>Location</th>
<th>Mass (kg)</th>
<th>Weight (N)</th>
<th>Weight (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth</td>
<td>60 kg</td>
<td>( W = mg = 60 \text{kg} \times 9.8 \text{m/s}^2 )</td>
<td>( 60 \text{kg} \times \frac{221 \text{lbs}}{1 \text{kg}} = 1326 \text{lb} )</td>
</tr>
<tr>
<td>Moon (~1/6 Gravity of Earth)</td>
<td>60 kg</td>
<td>( 600 \text{N} \times \frac{1}{6} = 100 \text{N} )</td>
<td>( 132 \text{lb} \times \frac{1}{6} = 22 \text{lb} )</td>
</tr>
<tr>
<td>Mars (~1/3 Gravity of Earth)</td>
<td>60 kg</td>
<td>( 600 \text{N} \times \frac{1}{3} = 200 \text{N} )</td>
<td>( 132 \text{lb} \times \frac{1}{3} = 44 \text{lb} )</td>
</tr>
<tr>
<td>Deep Space (0 gravity)</td>
<td>60 kg</td>
<td>0 N</td>
<td>0 lb</td>
</tr>
</tbody>
</table>

4. Jayden has a mass of 40 kg.

4a. What is Jayden’s weight on Earth (in Newtons)?

\[ W = mg = 40 \text{kg} \times 9.8 \text{m/s}^2 = 392 \text{N} \]

4b. Jayden travels to Venus, which has a gravitational acceleration of 8.87 m/s². What will Jayden’s mass be on Venus?

*Mass does not change*

4c. What will Jayden’s weight be on Venus (in Newtons)?

\[ \text{Weight} = F_g = mg = 40 \text{kg} \times 8.87 \text{m/s}^2 = 354.8 \text{N} \]

4d. Jayden’s space suit weighs 120 N on Earth. What is the mass of the backpack?

\[ 120 \text{N} \times \frac{1 \text{kg}}{10 \text{N}} = 12 \text{kg} \]

4e. What does the backpack weigh (in pounds) on Earth?

\[ 12 \text{kg} \times \frac{221 \text{lbs}}{1 \text{kg}} = 2641 \text{lbs} \]

4f. What will Jayden’s backpack weigh on Venus (in Newtons)?

\[ W = mg = 12 \text{kg} \times 8.87 \text{m/s}^2 = 106.44 \text{N} \]
Drawing Free Body Diagrams

How to diagram the forces on an object:
1. Draw the object all by itself.
2. Draw arrows to represent each force being exerted on the object in the direction the force is being applied. The sizes of the arrows should indicate the relative sizes of the forces being represented.
3. Label each arrow “F by whatever the force is.” Example: Force by Earth (F_E)
4. Write the amount of the force.

Kilograms must be converted to Newtons. 1 Kg weighs ~10 Newtons (on Earth)

Pounds do not need to be converted.
5. Objects must be in contact with other objects in order to put a force on them (with a few exceptions, like F_E)
6. Make sure the total forces cancel each other out if the object is not moving. This means that the forces are balanced, or that the Net Force = 0. (F_net = 0)

Examples:
1. Have a volunteer stand on a bathroom-type spring scale.
   Volunteer Weight: _______
   Draw a force diagram of the major forces acting on the person.

2. Use a scale to determine the weight of several books: \( \frac{20}{lbs} \)
   Have the same person get on the scale and put the pile of books in their hands.
   Scale reading of person with books: _______
   Draw a force diagram of the person holding the pile of books and standing on the scale.

3. Hang 0.5 kg on the spring scale and diagram the forces acting on this mass.
   Convert 0.5 kg to Newtons first.
4. The moon's gravity is about 1/6 the gravity of Earth.
Conversion: Moon gravity ~ 1/6 Earth gravity

4a) A toolkit has a mass of 3 kg. What is its weight in Newtons on Earth?

\[ 3 \text{ kg} \times \frac{10 \text{ N}}{1 \text{ kg}} = 30 \text{ N} \]

4b. What would be its weight in Newtons on the Moon?

\[ 30 \text{ N} \times \frac{1}{6} = 5 \text{ N} \]

4c. Draw a picture of the toolkit hanging from a string from the lunar lander on the moon. Label the forces and the amount of the forces on the toolkit.
Sketch the situation:

Draw a free body diagram of the toolkit:

5. The lunar rover has a mass of 90 kg.

5a. What is the weight of the lunar rover on the Moon?

\[ W = mg = (90 \text{ kg}) \times (10 \times \frac{1}{6}) = 150 \text{ N} \]

5b. The rover is sitting on the surface of the moon. Draw a free-body diagram for the rover on the moon.

5c. An astronaut, who weighs 210 pounds on Earth with his space suit on, sits on the rover. What is the mass of the astronaut?

\[ 210 \text{ lbs} \times \frac{1 \text{ kg}}{2.2 \text{ lbs}} = 95.45 \text{ kg} \]

5d. What is the weight of the astronaut on the moon (in Newtons)?

\[ W = m \cdot g = 95 \text{ kg} \cdot (10 \times \frac{1}{6}) = 158.33 \text{ N} \]

5e. Draw a free-body diagram for the astronaut sitting on the rover on the moon.
Newton's Third Law: Action-Reaction Force Pairs

"For every action, there is an equal but opposite reaction." How does this look in free body diagrams?

Example 1: Pushes from the side. Jack pushes on the box with 300N, but it doesn't move. Jack weighs 500N. The box weighs 1000N. Draw the forces on Jack and the box.

Jack pushes on the box towards the right. Based on Newton's Third Law (Action-Reaction), which way will the box push back on Jack? **left**

This is called an Action-Reaction pair. One object pushes on another, and the second object pushes back with an equal but opposite force. Place these action-reaction pairs on your force diagrams. Also label the force by Earth ($F_E$) your diagrams. Note that the action and reaction forces are on separate objects.

To complete your force diagrams, you need to decide what force is keeping the objects from moving in opposite directions, and what force is keeping your objects from falling.

What force keeps the box from sliding across the floor when Jack pushes on it? **friction**

What force keeps Jack from sliding backwards (away from the box—to the left) when he pushes on the box? **friction**

This force resists motion, and should be equal but opposite in size, as long as the situation is static.

What keeps both Jack and the Box from falling vertically downwards? **floor**

Fill in the blanks below with the missing forces.

**Action-Reaction Pair**

- $F_{by \text{ friction}} = 300N$
- $F_{by \text{ Box}} = 300N$
- $F_{by \text{ Jack}} = 300N$
- $F_{by \text{ friction}} = 300N$
- $F_{g \text{ floor}} = 500N$
- $F_{g \text{ ground}} = 1000N$
- $F_{g \text{ Box}} = 1000N$
Example 2: Stacked Boxes. Box A sits on Box B. Draw the forces on each box.

Box A pushes on Box B with \(10\) N. So, Box B pushes back on Box A with \(10\) N of force.

\[
\begin{align*}
A &= 10 \text{ N} \\
B &= 20 \text{ N}
\end{align*}
\]

**Action-Reaction Pair**

- \(F_{by \text{ Box B}} = 10\) N
- \(F_{by \text{ Box A}} = 10\) N

Why doesn’t Box B push back on A with 20 N?

Because it pushes back with equal force as the weight of box A (10N)

Why doesn’t the table push back on Box B with 20N (the weight of Box B)?

Because the force of weight by box A (10N) is adding to the push by weight of box B (20N)

What is the force of Box B on the table? **30 N**

Why?

10 N by weight of A plus 20 N of weight from box B = 30 N

Example 3. Draw your own force diagrams with Action-Reaction pairs. Jill pushes on a 1500N boulder with 600N, but it doesn’t move. Mia sits on top of the boulder. She weighs 300N. Jill weighs 400N. Draw the forces on the boulder, Jane, and Mia.

There are two Action-Reaction Force Pairs. Label them. Be sure your arrows are equal in magnitude (size) but facing in opposite directions for each of your force pairs.
Forces on Static Objects

Diagram and label each major force on the indicated object. Give the magnitude (size) of each of the forces.

Since these are static objects, the Net Force on each object = \( \text{ON} \)

1. A stationary block with a mass of 3 kg is hung from a string.

\[ W = mg = 3 \text{ kg} \times 10 \text{ m/s}^2 = 30 \text{ N} \]

2. A stationary block with a mass of 1 kg is resting on a spring.


4. Michelle is pulling on a spring scale attached to a rope which is attached to the cart. The spring scale reads 32 N. Diagram the forces acting on the cart.

(frictionless wheels) Julie
5. Sara puts a bathroom-type scale on the back of her 5450 N car in order to learn how hard she must push to get it moving. With the brakes off and out of gear, the car does not begin to move until the force scale reads \(270\) N. Draw the forces on the car when the scale reads \(220\) N and the car has not yet started to move.

6. Janine is pushing on a 3,000 N cart with a force of 200 N, but the cart is not moving. Kent, who weighs 600 N is sitting on top of the cart. Janine weighs 500 N. Draw the forces on the cart, on Janine, and on Kent.

7. Label or list 2 different action-reaction pairs in problem 6.
Statics Practice Problems

Make sure that forces and weights are given in Newtons or pounds. Mass is in grams or kg.

Conversions: 1 kg ~ 10 N ~ 2.2 pounds on Earth

1. Mrs. Leigh is trying to move her piano. She pushes the 200 kg piano with a force of 100 N, but it won't budge. Mrs. Leigh weighs 500 N

   1a. Draw the forces on the piano.  
   1b. Draw the forces on Mrs. Leigh.

2. Andy is holding his dog and sitting on a hover craft, which is not moving but is hovering 5 cm above the ground. Andy's mass is 50 kg, his dog's mass is 15 kg, and the hovercraft's mass is 7 kg.

   2a. Draw the forces on Andy.  
   2b. Draw the forces on the hovercraft.

3. Kayla and Jason are trying to move a jukebox across the floor. Kayla uses a force of 80 N and Jason uses a force of 100 N. They are both pushing on the left side of the jukebox, but it is not moving. The jukebox weighs 600 N, Kayla weighs 400 N, and Jason weighs 500 N. Draw the forces on the jukebox.