9/21 In Class–Third Law, Weight, Normal, Tension
edited after section 1 to add part 3c)

Review: Force and Newton's Laws so Far...

Force, $\vec{F}$: A force is a push or a pull.

- it is a vector
- it has units of Newtons, N = kg/m^2

First Law: An object at rest, or in uniform motion, remains at rest or in uniform motion unless acted upon by a net, external force.
Second Law:

$$\Sigma\vec{F} = m\vec{a}$$

Steps to solve Newton's Laws Problems:

For these problems, please begin each problem with these steps:

1. Draw a free body diagram
2. Choose an axis (an origin, depending on problem.) If it's different than usual, label it near (or on if it's legible) the free body diagram.
3. Write
$$\sum\vec{F} = m\vec{a}$$
4. Write the version of
$$\vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \cdots = m\vec{a}$$
appropriate for the problem. (You should have meaningful symbols like $\vec{F}_g$ if there's a gravitational force (rather than $\vec{F}_1$).) Remember also that you should have an $\vec{F}$ for every force arrow in your free body diagram.
5. Replace each $\vec{F}$ with its corresponding column vector. For example, $\vec{F}_g$ is usually $\vec{F}_g = \begin{bmatrix} 0 \\ -mg \end{bmatrix}$ So your fifth step (third line of algebra) should look something like:

$$\begin{bmatrix} F_{1x} \\ F_{1y} \end{bmatrix} + \begin{bmatrix} F_{2x} \\ F_{2y} \end{bmatrix} + \begin{bmatrix} F_{3x} \\ F_{3y} \end{bmatrix} + \cdots = m \begin{bmatrix} a_x \\ a_y \end{bmatrix}$$

Again with meaningful symbols and zeros plugged in.

1. Three forces act on an object of mass 1.5 kg. The three forces are: 10N to the right, 15N up, and 20 N at an angle of 45° down and to the left. (Standard angle would be 225°.)
   (a) Draw a free body diagram
   (b) What is the net force (sum of the forces) on the object? (Use the steps outlined above to solve.)
   (c) What is the acceleration of the object? (Don't forget acceleration is a vector).

2. A cart of mass 0.5kg is pulled with a force of 0.445 N horizontally to the right. (Assume no friction acts on the cart.) What is the acceleration of the cart?
   (a) Draw a free body diagram of the cart.
   (b) What is the acceleration of the cart? (Don't forget acceleration is a vector).

3. A cart of mass 0.5kg is pulled along a horizontal track with a force of 3N at an angle of 30°.
   (a) Draw a free body diagram
   (b) What is the acceleration of the cart?
   (c) What is the Normal Force on the cart?

4. A 1.5 kg mass hangs from a string. What is the tension in the string?

5. A 1.5 kg mass hangs from a string. The mass is in an elevator that is accelerating upwards at a rate of 2 m/s^2. Now what is the tension in the string?

6. A 1.5 kg mass hangs from a string. The mass is in an elevator that is accelerating downwards at a rate of 2 m/s^2. Now what is the tension in the string?

7. What would the tension be if the elevator accelerated down at 9.8m/s^2?

NEW: Newton's Third Law

Third Law: Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first object.

$$\vec{F}_{2on1} = -\vec{F}_{1on2}$$

- This law requires two separate objects!

8. A ping pong ball of mass 3g is thrown to the right, so that it hits a bowling ball of mass 7kg. During the collision, the bowling ball exerts a force of 0.3N to the left on the ping pong ball. (You can imagine this experiment takes place in deep space, where there are no gravitational forces–so that it is a 1D problem.)

   (a) What force does the ping pong ball exert on the bowling ball?

   (b) What is the acceleration of the ping pong ball (during the moments the force acts)?

   (c) What is the acceleration of the bowling ball (during the moments the force acts)?

   (d) What do you think is the point of this example?

9. A book rests on a table.

   (a) Draw a free body diagram for the book.

   (b) Nothing else is on top of the table. The table rests on the floor. The book and the floor are the only things touching the table. Draw a free body diagram for the table. You will need to label things like "Force of the book on the table," which I would call $\vec{F}_{BonT}$.

   (c) Write down (in words) the third law pair of forces in this scenario. Circle the forces on your diagrams.

10. A person of mass 75kg stands (at rest) on their bathroom scale.

   (a) Draw a free body diagram for the person.

(b) Nothing else is on top of the scale. The scale rests on the floor. Draw a free body diagram for the scale.

(c) Write down (in words) the third law pair of forces in this scenario. Circle the forces on your diagramS.

(d) What force does the scale actually measure directly? (See the next problem to understand the distinction.)

11. A person of mass 75kg stands on their bathroom scale in an elevator. The elevator accelerates upward at a rate of 2m/s^2.

    (a) Draw a free body diagram for the person.

    (b) What is the force of gravity on the person?

    (c) What is the normal force on the person?

    (d) What would the scale read in this scenario? (It should be different from the last problem!) Why?

12. A person of mass 75kg stands on their bathroom scale in an elevator. The elevator accelerates downward at a rate of 2m/s^2.

    (a) Draw a free body diagram for the person.

    (b) What is the force of gravity on the person?

    (c) What is the normal force on the person?

    (d) What would the scale read in this scenario? (It should be different from the last problem!) Why?

13. What would the person's weight appear to be if the elevator were accelerating downward at exactly g? This is called *apparent* weightlessness. It is not true weightlessness!