Walk-in Lab 4
Acceleration in an elevator

Physics 121

CID(s): ______________________

Description

Do you know that weird feeling you get in your stomach when you ride in an elevator? You feel this way whenever your body is accelerated. Today you get to use a scale on an accelerating elevator to connect this feeling to Newton's Second Law, $\mathbf{F} = m\mathbf{a}$.

Objectives: There are three parts to this lab:

1. Understand exactly what a spring scale and a balance beam scale measure.
2. Use your understanding of how spring scales work and Newton's Second Law to measure your acceleration in a moving elevator.
3. Understand why the spring scale and the balance beam scale in the accelerating elevator behave so differently.

Equipment: One bathroom spring scale and one medical beam scale in the south elevator near S415 ESC.

Remember, you can work in groups of up to three people. The scales are in the south ESC elevator, the one nearest S415 ESC. Have fun figuring out how you can use what you have learned about physics to understand why these scales behave the way they do in the elevator.

Part A – How do spring scales and balance beam scales work?

Let's think about the spring scale first. Draw a picture of yourself standing on the spring scale in the elevator and draw the little dashed line around yourself that we call a free-body diagram.

What forces act on you across the dashed line (there are only 2)? ______________________

When you are standing still on the elevator, what is your acceleration? (It is not 9.8 m/s^2.) __________

Use your answer to these two questions and Newton's Second Law, $\mathbf{F} = m\mathbf{a}$, to show that when you are standing still the force the scale exerts on you is equal to the downward force of gravity on you (your weight). Sketch your argument in the space below by writing a few sentences and/or a simple equation which you solve to find the answer.

The force you just found is the force the scale exerts on you, but the scale actually reads the force you exert on it. Which law of physics guarantees that these two forces have the same magnitude?

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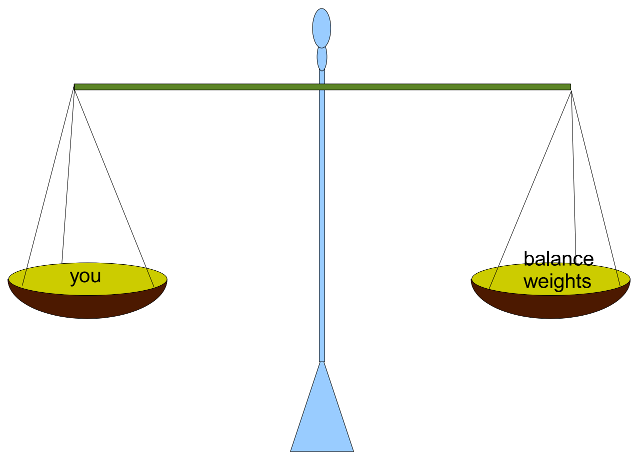
Balance scales, like the one in the elevator that looks like it came out of a doctor's office, work completely differently. Their important parts are not easy to see, but they work like the ancient scales of justice shown in the diagram.



Scales like this don't read out the force of gravity on you; they just tell you when one mass is the same as another. When you adjust the moving weights on the medical scale until the beam balances, you have done the equivalent of putting a mass in the right pan of the scale of justice that is the same as your mass sitting in the left pan. Notice, for instance, that if both masses were doubled, the scales would still be balanced.

When you use these two different scales on the elevator it will be important to understand that these two scales don't work in the same way.

Part B – What happens to my spring-scale weight when I ride the elevator?

Go back to the free-body diagram of you and the spring scale, but this time suppose that you have moved the scale into the elevator, have just pushed the "up" button, and that the elevator has started to move.

Is your acceleration positive or negative (let the positive direction be up)? ____________

Use Newton's Second Law to figure out whether the force exerted on you by the scale as you start up is greater than or less than its value when the elevator is stopped. Write your one-word answer here. ____________

Use Newton's Second Law again to figure out whether the force exerted on you by the scale as you are coming to a stop after having traveled upward is greater than or less than its value when the elevator is stopped. Write your answer here. ____________

Is your acceleration positive or negative as you are coming to a stop? ____________

Now go do the experiment on the elevator and see if you got it right. As you ride on the elevator, write down the largest and smallest scale readings during your trip up. Note the readings when you start moving, while you are moving at constant speed between floors, and when you are slowing down as you arrive at the upper floor. It will be easier to do this if you go up 2 or 3 floors instead of just one. Write your scale readings below and convert them from pounds to Newtons. (1 pound = 4.45 Newtons)

1. When the elevator is at rest: ____________ pounds = ____________ Newtons
2. When the elevator is starting upwards:____________ pounds = ____________ Newtons
3. When the elevator at constant speed between floors: ____________ pounds = ____________ Newtons
4. When the elevator is slowing down: _________ pounds = _________ Newtons

Analysis: Use the acceleration of gravity, $g = 9.8$ m/s^2, and the scale reading when you were at rest to calculate your mass in kg. Write it here: ____________ kg

Use the diagram, Newton's Second Law, your mass, and the scale reading when the elevator started upward to calculate the maximum value of your upward acceleration. Write it here: ____________ m/s^2.

Use the diagram, Newton's Second Law, your mass, and the scale reading when the elevator was slowing down to calculate the maximum magnitude of your downward acceleration. Write it here: ____________ m/s^2.

You will have noticed that your answers above to items 1 and 3 are nearly equal. Use Newton's Second Law to argue that they should be exactly equal by writing a few sentences and/or equations below.

Part C – Your weight on a medical beam scale

Now go back into the elevator and repeat your four "weight" measurements using the big medical scale. When the elevator is not moving, step onto the scale and slide the little weights until the beam is exactly horizontal and balanced. If the balance beam is tipped down, the weights on the slide are too far to the right. For example, this would happen if the weights were set to 185 pounds and your weight were 150 pounds. On the other hand, if the balance beam is tipped up the weights are too far to the left. This could happen if the weights were set to 120 pounds and your weight were 150 pounds. With the elevator at rest, measure your weight and record it below. Then start the elevator and while it is accelerating watch the balance beam to see if it tips up (you "weigh" more) or down (you "weigh" less) or if it stays balanced. Write what you see here:

1. When the elevator is at rest: ____________ pounds
2. When the elevator is accelerating downwards (tipped up, down, or balanced?): ____________
3. When the elevator is moving at constant speed between floors (up, down, or balanced?): ____________
4. When the elevator is accelerating upwards (up, down, or balanced?): ____________

Use the "scales of justice" model of this scale and Newton's Second Law to explain what you observed. This is actually not so easy, so be careful and discuss the question with your partners. Think about what happens to the apparent weight of the two masses while the elevator is accelerating.