Flipping Physics Lecture Notes:
Letting Go of Your Numbers Dependency
http://www.flippingphysics.com/numbers-dependency.html

Many of my students have an inability to move forward in a problem without having numbers to plug in for variables. I call this your "Numbers Dependency".[1] Today I am going to show an example of what that is, how to work without numbers, and why I think it is important to let go of your numbers dependency. In order to do so, let's expand on a lesson we already did: Bo in an elevator.[2] Here is a new problem:

Example: Bo is standing on a scale in an elevator. When the elevator is at rest, the reading on the scale is 722 N. When the elevator is accelerating, the reading on the scale is 745 N, what is Bo's acceleration?

The following is a typical, numbers dependent solution:

Knowns: $F_{N_1} = 722N,\ a_{y_1} = 0,\ F_{N_2} = 745N,\ a_{y_2} = ?$

Part 1: $\sum F_y = F_{N_1} - F_g = ma_{y_1} = m(0) = 0 \Rightarrow F_{N_1} = F_g = mg$

$$\Rightarrow 722 = m(9.81) \Rightarrow m = \frac{722}{9.81} = 73.5984kg$$

Part 2: $\sum F_y = F_{N_2} - F_g = F_{N_2} - mg = ma_{y_2} \Rightarrow 745 - (73.5984)(9.81) = 23 = (73.5984)\,a_{y_2}$

$$\Rightarrow a_{y_2} = \frac{23}{73.5984} = 0.312507 \approx 0.313\frac{m}{s^2}$$

This is a typical solution which is not numbers dependent:

Knowns: $F_{N_1} = 722N,\ a_{y_1} = 0,\ F_{N_2} = 745N,\ a_{y_2} = ?$

Part 1: $\sum F_y = F_{N_1} - F_g = ma_{y_1} = m(0) = 0 \Rightarrow F_{N_1} = F_g = mg \Rightarrow m = \frac{F_{N_1}}{g}$

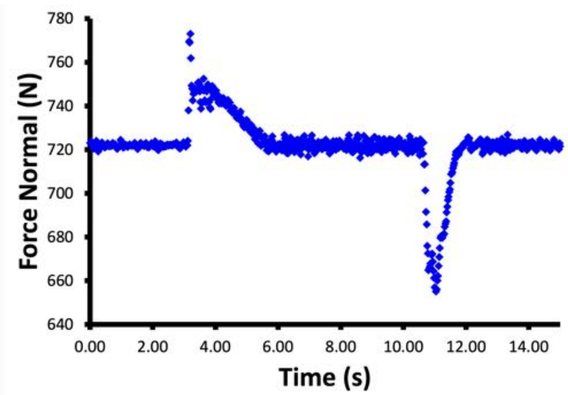
Part 2: $\sum F_y = F_{N_2} - F_g = F_{N_2} - mg = ma_{y_2} \Rightarrow a_{y_2} = \frac{F_{N_2} - mg}{m} = \frac{F_{N_2} - F_{N_1}}{F_{N_1}/g}$

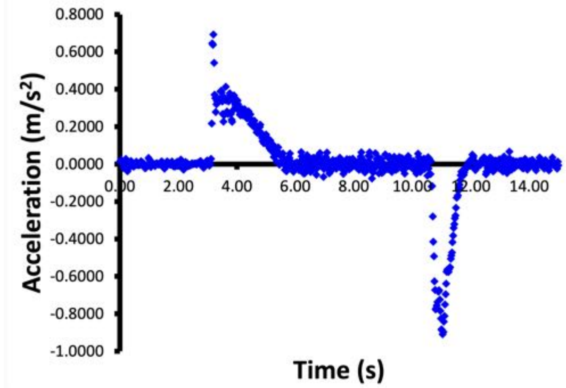
$$\Rightarrow a_{y_2} = g\left(\frac{F_{N_2} - F_{N_1}}{F_{N_1}}\right) = (9.81)\left(\frac{745 - 722}{722}\right) = 0.312507 \approx 0.313\frac{m}{s^2}$$

The advantages of letting go of your numbers dependency are:

- When using primarily numbers there are three times numbers are typed into the calculator. When using primarily variables numbers are typed into the calculator only once. Each time a number is typed into the calculator; it increases the chances of making a mistake.
- Many numbers had to be written and rewritten in the numbers solution. Each time a number has to be written down; it increases the chances of making a mistake.
- The variables solution shows that there is no reason to calculate Bo's mass.
  - If you need the number for Bo's mass, the variables solution has an equation you can use to solve for it.
- The variables solution ends with a general equation for acceleration in terms of variables. This means we can now determine Bo's acceleration given any force normal reading on the scale. This is how labs work. We collect data and perform redundant calculations. For example, now that we have the force normal as a function of time for Bo in the elevator, we can also calculate the acceleration of Bo as a function of time.

[1] "Numbers Dependency" was introduced in "An Introductory Tension Force Problem" http://www.flippingphysics.com/tension-problem.html
[2] "Do You Feel Your Weight? A lesson on Apparent Weight" https://www.flippingphysics.com/apparent-weight.html





- From the variable equation for Bo's acceleration in the y-direction we can deduce a lot of information.
  - If force normal 2 is increased, Bo's acceleration is also increased.
  - If the acceleration due to gravity on the planet increases, and the ratio of F_{N2}/F_{N1} remains the same, Bo's acceleration also increases.
  - if $F_{N_2} = 0$, then $a_{y_2} = g\left(\frac{F_{N_2} - F_{N_1}}{F_{N_1}}\right) = g\left(\frac{0 - F_{N_1}}{F_{N_1}}\right) = -g$ Bo is in free fall.
- Lastly, without a numbers dependency we can solve problems like this:

Example: Bo is in an elevator and feels like he weighs half his weight. What is his acceleration?

To solve this problem, recall that weight is synonymous with force of gravity and what you feel is not your weight, but rather the force normal which acts on your body. In other words, the force normal in part 2 of our solution equals half of the force of gravity and we know the force of gravity equals the force normal in part 1. That means our solution is:

Knowns: $F_{N_2} = \frac{F_g}{2} = \frac{F_{N_1}}{2},\ a_{y_1} = 0,\ a_{y_2} = ?$

Part 1: $\sum F_y = F_{N_1} - F_g = m a_{y_1} = m(0) = 0 \Rightarrow F_{N_1} = F_g = mg \Rightarrow m = \frac{F_{N_0}}{g}$

Part 2: $\sum F_y = F_{N_2} - F_g = F_{N_2} - mg = m a_{y_2} \Rightarrow a_{y_2} = \frac{F_{N_2} - mg}{m} = \frac{F_{N_2} - F_{N_1}}{F_{N_1}/g}$

$$\Rightarrow a_{y_2} = g\left(\frac{F_{N_2} - F_{N_1}}{F_{N_1}}\right) = g\left(\frac{F_{N_1}/2 - F_{N_1}}{F_{N_1}}\right) = g\left(\frac{1/2 - 1}{1}\right) = -\frac{g}{2}$$

Bo is currently accelerating downward with the elevator at half the rate of free fall acceleration. As you get further into your physics learning, problems are going to have fewer and fewer numbers in them.

In summary, letting go of your numbers dependency reduces mistakes, allows you to better understand relationships between variables, allows for easier repeated calculations like we do in labs, and the future of your physics learning includes fewer numbers. A numbers dependent solution is like a dead-end one-way street. In order to solve the problem again with different numbers, you need to get out of your car, go back to the beginning of the street, get in a new car, and drive down the street again. However, a solution that is primarily variables is like a turnabout with many, many exits. You just need to pick a path to extend your physics learning, but you do need practice learning how to drive around a turnabout.