Introduction to Forces

Jeremy Du, Arnold Mong

October 13, 2015

Finally, after six weeks of physics, we are done learning about motion! It was getting pretty hard to come up with 2D motion physics problems that only used motion equations, since you have like five formulas that you use over and over again. Now, we can talk about the next big thing: forces.

1 Vectors

Before we can get to forces, we should talk about vectors. In physics, motion is usually described in two quantities: scalars and vectors. A *scalar* is a quantity that has only magnitude. Some examples of scalars are the mass of Arnold, Arnold's body temperature, and Arnold's density. In math terms, we can think of scalars as just numbers - values we can freely add, subtract, etc. A *vector*, like a scalar, also has magnitude, but it also has direction. Some examples of vectors are Arnold's velocity, Arnold's displacement, and Arnold's force. You may have seen "vector notation" before, where you had something like $< 1, 2, 3 >$. While a scalar only has one value, a set of numbers is required to represent a vector.

Hold up hold up. Ever since this school year started, we've been doing physics, but we never used vectors yet. One possible reaction to this is: ???. Another possible reaction is: "Why do we need vectors at all if we can solve all those motion problems without using them?" For basic physics, it may be true that vectors aren't necessary. However, just the concept of vectors has greatly furthered the advancement of mechanics and physics as a whole. As my textbook puts it, "Vectors provide a compact and elegant way of describing the behavior of even the most complicated physical systems." In specific terms for us, with vectors, we now can specify direction for displacement, velocity, and acceleration for systems that have even more than two dimensions. Further, if you remember the 'dot product' of vectors, dotting vectors also provides us with physical applications. If vectors are confusing, don't worry about it. Just know that it's a concept that lets us easily describe what is going on in some system, which is what physics is all about.

Now that we've gone over a very brief intro about vectors, we can redefine all the terms from motion with vectors. Position is a vector that represents, well, the position of our object that we are interested in. Usually, we denote this as $\mathbf{r}(t)$. (Note: if the function is bolded, it means the output is a vector) **Displacement** is then the change in position, which is $\mathbf{r}(t) - \mathbf{r}(0)$. **Velocity** and **acceleration** are denoted as $\mathbf{v}(t)$ and $\mathbf{a}(t)$, respectively.

With this, we can't forget about our scalar functions. The speed of our object is simply the magnitude of velocity, or $s(t) = \mathbf{v}(t)$. Distance is also a scalar, and it's the absolute value of the displacement function.

2 Forces

Cool cool cool, cool to be in school. Let's talk about forces. In Sir Isaac Newton's *Principia*, published in 1687, Newton published three fundamental laws of motion. These three laws are pretty famous, and have altered how we view the world.

Newton's first law of motion states: Every body in a state of motion continues in that state unless an external force acts on it. Newton's third law states: For every action there is an equal and opposite reaction. That is, if Jeremy pushes on Arnold, there is an equal force (in magnitude) that Arnold is imparting on Jeremy. In symbols, this is: $\mathbf{F}_{JA} = -\mathbf{F}_{AJ}$. (Note how we can use vectors now!)

These two laws are super important, but they're kind of descriptions/definitions. Newton's second law, which states $\mathbf{F} = m\mathbf{a}$, is the one we can do some stuff on. Note: in the second law, we frequently say $\mathbf{F} = m\mathbf{a}$. However, it is extremely important to understand that $\mathbf{F}$ denotes the sum of *all* the forces acting on our object.

Quick check: Newton's third law states that if Jeremy pushes Arnold, there's an equal and opposite force. That is, the two forces cancel out. If these two forces sum to zero, then by Newton's second law, shouldn't acceleration be zero as well?

2.1 Example Forces

1. Something falling: If an object has mass m, and from 1D motion, we know that it has acceleration of g. From Newton's second law, we can say this force is a constant mg. This is called the force of gravity. In an equation, this is: $F_g = mg$.

2. Normal forces: If an object is on the floor (say the chair you're sitting on right now), it is clearly not accelerating. Then, by Newton's second law, $\mathbf{F}_{net} = 0$. Since we know gravity is still pulling down on the object, the ground must also be exerting a force on the object. This force is *perpendicular* to the surface of contact (for our object, the normal force points up to the ceiling), so it is called the *normal* force (normal as in orthogonal).

3. There are a bunch of other forces. Some examples are frictional forces and tensile forces, which you guys will probably cover later in class. Today, we may go over them if we have time at the end.

2.2 Free Body Diagrams

Drawing diagrams on the computer is hard, so we're going to go to the board for this one.

3 Problems

1. Arnold is chillin' like a villain on top of a spaceship, when suddenly, the spaceship begins to accelerate up at 10 times the acceleration of gravity. What is the force that Arnold is imparting on the spaceship?

2. Arnold is again chillin' like a villain when he suddenly (no external force) blows up into four pieces of equal mass. One piece goes flying towards the ceiling, another shoots off to the left, and the third piece goes forward. What is the speed of Arnold's fourth piece? Assume Arnold is a particle, and that the first three pieces are all traveling at the same speed v.