PodCast Episode 1: Physics With Mr. R - The Foundations of Classical Physics

Introduction:

The year:1620. 44 oddly dressed people later known as Pilgrims set foot in the new world. They'd be dead in a year. That is had the Indians not helped them—help now celebrated in that most unique of American holidays, Thanksgiving. But why **did** the Indians cooperate?

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This is "Physics with Mr. R" and today we're going to be talking about the foundations of classical physics.

So, why did the Indians cooperate? Quite simply they thought the pilgrims had superior magic. When Europeans started showing up in America prior to the Pilgrims, they inadvertently brought what seemed like powerful magic—diseases that decimated entire villages. The Indians resisted by invoking their own magic with various ceremonies, but to no avail. The Europeans keep coming. For Indians, the logical conclusion: cooperate or die. The Europeans obviously had superior magic.

In a sense the Indians were right: the Europeans came from a culture armed with more than firearms, it was a culture armed with an early version of the closest thing to real magic in human history: physics.

By 1600, a full 20 years before the pilgrim arrival, William Gilbert, the father of electrical engineering, had already published his celebrated work on magnetism and formulated the term electricity. By the time they landed, Francis Bacon was publishing his thoughts on the scientific method. The scientific revolution was already well under way.

A mere 67 years after the pilgrims landed, Issac Newton published the bible of classical physics: *Philosophiae Naturalis Principia Mathematica*, detailing his famous laws of motion and gravity.

Models:

So, what is classical physics? In a word: models. Mathematical models or in other words sets of equations with the power to predict physical events occurring on a human scale, and by predicting them, control them.

Did you hear those words human scale. Classical physics only works for a certain range of sizes. If we go too small, too big, or too fast, classical physics breaks down, but in between it's remarkably useful. And, it turns out that the in between scale where classical physics works, matches very well with the scale humans experience.

Physics is very powerful but is not reality; it's a simplified version of reality, For example, we can make accurate predictions about falling objects (provided they don't fall too far) with physics equations that assume the Earth is flat and has no atmosphere. Sure we could use more accurate equations that account for the Earth's curvature, air resistance, or even the gravitational attraction force of Jupiter, but when we confirmed the predictions with actual measurements, random measurement errors would be larger than the improvement in accuracy from the more complex model. This ability to simplify is a hallmark of physics and the basis of modern engineering.

Frame of Reference:

Before we can start building models we have to take care of some details. First on the list: frame of reference. The frame of reference is what we assume is not moving.

Let's talk basketball. If we place the frame of reference on the court, the ceiling, the hoop, and so forth everything is normal. Place the FOR on the basketball and the game would be quite different. When a player dribbled the court would move up and down under the stationary basketball. When he shot, the player and floor would suddenly move down and backwards. When in position under the ball, the hoop would move upwards, momentarily encircling the ball as the crowd goes wild.

The conflict between Galileo and the Catholic Church was perhaps the most famous argument in history about where to place the frame of reference. The Church wanted it on Earth and Galileo on the Sun. We now know the best model is the simplest: a frame of reference on the Sun. Still, the Earth centered model was not as useless as it sounds. Ptolemy had devised an Earth centered model in the 1st century, which, for its day, did a splendid job of predicting the position of celestial bodies. Compared to Galileo's model, however, it was not only far more complex but useless for 20th century endeavors like space exploration.

Where we place the frame of reference is a big deal for at least 2 good reasons: First it can greatly simplify our models. Second, until we fix the frame of reference we have no way to state how fast we're going.

Sit in a chair, put the FOR on the floor, and your not moving. Put the FOR at the center of the Earth and you're going about 1000 mph (assuming you're somewhat near the equator) Put the FOR at the center of the Sun and you're going around 60,000 mph, depending on the time of year.

We'll eventually learn some rules for locating the frame of reference but for now, we'll simply place it in the most convenient spot for simplifying our problems. When it comes to FOR the simplest model is often the best.

Quantities

We also need to talk about different types of quantities before we can start model building. Let's start with scalars. These are quantities that can be described merely by stating their magnitude (by the way magnitude is just a fancy way of saying size). These quantities include mass, temperature, volume, distance, speed and so forth.

We can do a lot of modeling with scalars but the real power of physics comes from quantities called vectors. Like a scalar, a vector has a magnitude; however, it also has a direction.

Imagine yourself walking while balancing atop the handrail around the edge of the Grand Canyon. A random force of say 200 lb in magnitude happens along and decides to apply itself to you. Wouldn't it be a big deal to know the force's direction? The result of applying the force is totally different if it's applied in the direction of the canyon rather than the direction of the parking lot. A force is a vector because we have to state not just its magnitude but its direction in order to describe it in a way that enables us to predict its effects.

Vectors are typically represented by arrows. The length of the arrow represents the magnitude and the way the arrow points, the direction.

We now have scalars which have only magnitude and vectors which have magnitude and direction, so is there a quantity that only has direction? Yes, rays. These are represented as arrows and are used in applications like optics for describing the path that light takes when it is, say, reflected by a mirror. Rays are also useful for mapping things like force fields. We'll say more about that when we talk about gravity fields.

Distance vs. Displacement

Sometimes there's a scalar and a vector quantity that seem alike but are distinctly different, such as the scalar distance and the vector displacement. Distance indicates the length of the path an object travels to reach a destination. Displacement measures only the change in location along a straight line between the starting and ending points. An arrow drawn between the starting and ending points gives the displacement's direction.

To illustrate the difference, let's imagine we have a buzzy bee sitting on the edge of the desk right here. He's a happy buzzy bee because he's in a physics problem. The bee takes off and flies randomly all around the room. Eventually he gets tired and lands on exactly the spot he took off from. What was the distance the bee traveled? Something. We could hire pixies with tape measures to follow the bee around and measure the length of the path he flew if we wanted a more accurate measure, but in this case it doesn't matter.

What was the bee's displacement? Zero. Here we care only about where the bee started and where he ended. Since he did not change position, his displacement is zero. Hopefully, you can see how profoundly different vectors and scalars can be even when they seem to be addressing the same subject.

Speed

We're now ready for our first mathematical model: average speed.

Speed = distance / time

or

$S = D / t$

Note that on the right side of the equal sign we have distance, a scalar divided by another scalar time giving us, on the left side of the equal sign, speed which is also a scalar. This is pretty typical, mathematical expressions with nothing but scalars in them yield nothing but scalars.

If we travel 120 miles in two hours, our average speed will be 120 divided by 2 or 60 mph. If we stop for an hour to eat lunch our average speed for a trip falls. When we're sitting in the restaurant we add an hour to our time but nothing to our distance. Our new average speed is 120 divided by 3 or 40 mph—quite a change.

We could calculate our average speed for a vacation trip by dividing the mileage traveled by the time on vacation. Of course if we stayed for a long time in one place the average speed would be low.

Velocity

By contrast with the scalar speed:

The vector Velocity = displacement divided by time interval

Note that now we have a vector quantity on the right side of the equal sign—displacement--and so the equation yields a vector, velocity.

If we calculated the average velocity of our vacation we'd get zero even if we never stopped the car. Why? Since we end our trip at the same point we started from, the displacement will be zero.

If we limit the motion of an object to a single dimension, we see another property of a vector: it can have a negative or positive sign that indicates its direction. Since we've limited motion to a single dimension, the object can only move back and forth along a straight line. We can arbitrarily define velocity in one direction as positive or moving forward and velocity in the other as negative or moving backwards. In other words, the positive or negative sign on the velocity indicates the direction the object is headed. It has nothing to do with whether the object is slowing down or speeding up.

This is worth repeating: the sign—either positive or negative—on a vector, any vector, even vectors other than velocity, indicates only the vector's direction in a particular dimension (either forward or backwards). The sign does not indicate if the object is speeding up or slowing down.

Scalars typically are never negative. The exception are scalars with arbitrarily defined zero values such as the Celsius temperature scale. Here zero is arbitrarily defined as the freezing point of water for no particular reason other than we drink it. Since temperatures can clearly be less than the freezing point of water, Celsius temperatures can be negative. By contrast, the Kelvin temperature scale has a true zero value, absolute zero.

Even with scalars that can be negative, the negative sign never indicates a direction in space.

We've been talking about average speed and average velocity; could we talk about instantaneous speed and velocity? Yes! All we have to do is reduce the time interval until it is as close to zero as possible. Yes, the distance or displacement would also be very small, but something small divided by something even smaller can still yield a large number. The reading on a car's speedometer is considered instantaneous speed.

Speed, Velocity, So What?

So, what's the big deal about the difference between speed and velocity? While it's useful to have information about speed (especially if driving past a highway patrol car), information about velocity is even more useful particularly if we want to change it. If we know how we want to change the velocity of an object and we know its mass, we can calculate the size of the required force. When do we want to change the velocity of an object? How about launching rockets, racing cars, or even mundane activities like bicycling. Knowing the required forces gives us critical information so that we can successfully and safely design equipment without huge amounts of trial and error experiments.

Conclusion

To recap, we've said that physics is about the closest thing to real magic in human history and yet, so far we haven't done much to demonstrate its power. To be honest, we've barely covered some information about physics' equivalent of the ABC's. It does take a lot of time and effort to learn enough physics to use its power, but be patient and you will be rewarded.

Be sure to check out our web site at intuitor.com. Until next time, I'm Tom Rogers and this is physics with Mr. R.