Trajectory Kit

In this kit you will have the following experiments:

1. A Wrinkle in Space time
2. Oh-k facemasks

Designed by Lily Nestor, Cecilia Dean, and Dan Reiter.

These kits are designed to explore the properties of objects traveling through space and time. A Wrinkle in Space time explores how gravity bends the fabric of spacetime by looking at stretching some fabric you have around the house. Oh-K Facemask explores how we can use our facemasks to launch things. Make sure that you do this one in a socially distant way!

This kit contains some of the materials needed, but we highly encourage you to explore how you can use the stuff around your house. Be creative, be curious, and have fun!

Kit Includes.

- 1 Golf ball (sun)
- 3-4 smaller metal balls as planets and to launch.

ACE Project:
Modelling General Relativity

For a younger audience

About Us:

This was made by Dan Reiter, Lily Nestor, and Cecilia Dean. We are three enthusiastic Physics majors from St. Olaf College (Um Yah Yah!)

Dan aspires to one day win a Nobel Prize in Physics, or an Oscar, which ever comes first!

Lily wants to enter the Space Industry to send humans to the stars!

Cecilia looks forward to use Physics in Renewable Energy Engineering to help the planet!

We hope you have fun with these projects!

A Wrinkle in Space-Time

Explanation for Participants:

Why do you stay on the Earth? Because of the force of gravity! It keeps you on the ground and stops you from floating off. But there's another way to think about gravity, and it has to do with the gravity between planets and suns.

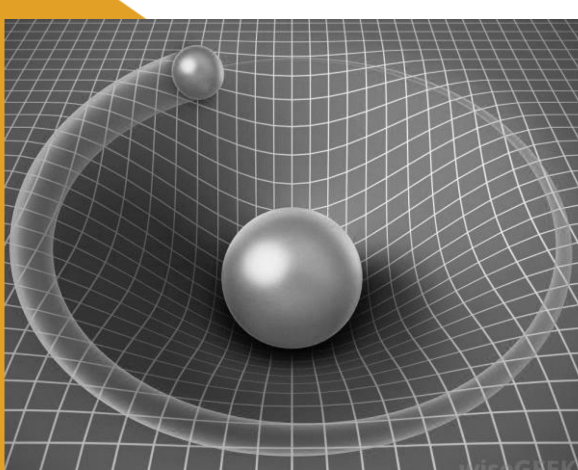
Think of space as a GIANT bedsheet, and our Sun as a ball on top of it. The Sun is HEAVY and pulls the sheet down. The planets aren't as heavy as the sun, so they pull the sheet down less. We call the sheet we are working with a General Relativity sheet because it relates to Einstein's theory of General Relativity. You'll see us call it the GR Sheet later in the experiment.

Just like the Earth pulls you down on it, the Sun pulls the planets towards it! The Sun is heavier and goes down farther in the sheet, so the planets will go around it, just like the moon goes around the Earth.

But what about a bigger ball? Won't that stretch the sheet more? Not necessarily! There's a difference between the idea of *mass* and *size.* Mass involves the weight of an object, and the object that is heavier will stretch the sheet more than an object that is lighter, no matter the size difference. For example, a golf ball will stretch the sheet more than a ping pong ball.

It's this stretching that creates the orbits of planets, and that's what we're exploring today!

You might notice that the planets in our experiment all end up crashing into the Sun, but don't worry about that! Our model has Earth pulling down on it, making it look like the planets are going into the Sun, but in space, the pull of the Sun makes it so that the planets orbit around it!



A Wrinkle in Space-Time Cont.

Materials:

- Small Sheet
- Balls (we'll call them "masses" later on)
- Clips or Tape to Fasten
- Other Balls
- Video Recording Device

Instructions:

Find a small sheet, pillow case, or blanket and stretch it out the corners as tight as you can. You will want to use clips, tape, clamps, or heavy objects to secure each corner. You can tie the corners to doorknobs, furniture, or anything secure.

First, place the heaviest ball in the middle of the stretchy sheet. Then, take one marble and let it go at the edge. Did it go straight towards the Sun? That's right!

Now try rolling it to the side and see what happens! Change how fast you roll it! Add more balls to see what happens!

After exploring these, try starting the balls from different points in the sheet. Try racing the balls around the Sun!

If you want to become the *Orbital Champion,* try and make the most amount of orbits around the Sun. The person who gets the most can add their name to the *Orbital Champion* list!

Parents/Teachers

Explanation:

General relativity proposed the idea of gravity wells in the space time fabric. The way to visualize this is by placing a mass on an elastic sheet and see how the sheet dips down based on the mass. This is a gravity well! The greater the mass, the more it stretches space time and pulls things towards it. Objects such as black holes rip through this fabric and change the perception of space and time around them. It's this warping of space time that creates the orbits.

This demonstration is showing it using the effects of Earth's gravity to pull the mass down into the fabric on the General Relativity (GR) sheet, but in space the gravity wells would be such that it creates the steady orbits instead of everything going straight into the sun like this demonstration may insinuate. The fabric of the sheet acts as a damping force on the oscillation of the masses that planets wouldn't necessarily experience in space but does affect our experiment by slowing the oscillations and causing them to go towards the middle instead of steady orbits.

The velocity and masses of the planets come into play in how they orbit around the Sun, and that is part of what this experiment is seeking to show. Some further explorations are these: With the Sun at the center, we can look at the circular/elliptical orbits of the planets, but what about if the Sun isn't at the center? This is a problem that the old astronomers had to deal with, because they weren't able to model the orbits well without the sun at the center. How does that show up on our GR sheet? Another is that if masses/velocities are balanced well, sometimes they can end up in binary systems (two stars - sometimes galaxies - circling each other). Try seeing what would happen if you paired up multiple masses around the sheet!

Parents/Teachers

Instructions:

For the set up of this, take the sheet provided in the pack and fasten at least the four corners of the sheet. Make sure it is tight. Clamps and duct tape have been provided. Objects to fasten the sheet which could include counters, chairs, or even people holding the sheet if there are enough participants. Feel free to try it out with an even larger sheet (if you have one) after working with the sheet provided to increase the fun.

Once the sheet is attached, place the heaviest ball in the middle of the sheet and see how it dips down. This will be our sun! Take one of the balls and let it go (with no starting velocity) at the edge of the sheet and see what happens. After remarking on those observations, try rolling a ball perpendicular instead of towards the sun and see the difference.

Change the starting velocities or add more masses to see what happens. Examine the effects of velocity in the amount of orbits or susceptibility to the gravity well. Try starting the masses from different points on the sheet as well.

One further piece of fun would be to race the masses around the sheet or see how many orbits can be made. Whoever can make the most orbits wins! Record the most amount of orbits and determine who will be the *Orbital Champion!*

Further Exploration

Our exploration of the GR sheet thus far has *revolved* around the idea of how to manipulate the orbit of planets in more of a qualitative way. An extension of this experiment would be to use a sheet with a grid pattern on it and explore how much each mass stretched the fabric in a numerical fashion and compare that stretching/curvature with its effects on the orbits. This is important because it would help to explore the concepts or gravity wells and the compensations that must be made depending on what sort of mass is being examined, a calculation that may impact future space travel. For example, looking at the gravity wells of different planets helps to show what is needed to escape the planet. This also has implications with black holes. The stretching of space time as an object approaches the event horizon greatly impacts how the perception of space and time change, and such quantitative explorations could help to examine that.

ACE Project:
Facemask springs

For a younger audience

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Oh-k Facemasks

Explanation for Participants:

I'm sure you've noticed that these masks are elastic and springy. We can use that property to launch things. In this experiment, we are going to use facemask catapults to examine what we call “k values” (does the title make sense now?) and find out what happens when we link catapults in “series” and in “parallel”. Let's get started!!

Materials:
- Clips or Tape to Fasten
- Balls (we’ll call them “masses” later on)

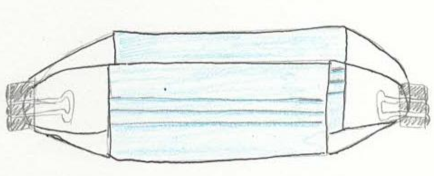
Not Provided:
- 2+ Spare facemasks (keep yours on your face!)

Instructions:

First, secure two ends of a single mask to a desk or chair with the clips provided in the kit. Now put one of the masses into the mask and launch it towards the sheet. Try pulling back more and less and watch what happens.

Now try launching some of the heavier masses. What happens now?
What you should find is that the heavier masses will not be launched as far. This is because larger masses have more of a property called inertia. The more inertia something has, the harder it is to move it.

Masks in Parallel



Stack masks and fasten to same binder clips or fasteners

Oh-k Facemasks

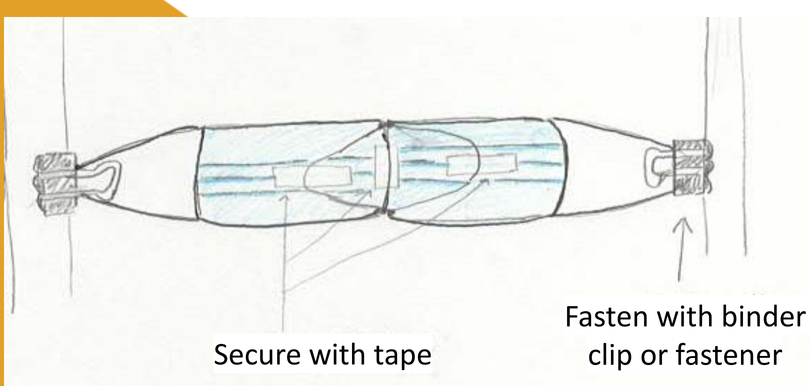
Instructions Continued:

Now let's try something new. Connect one of the ear loops of your mask with the ear loop of another mask with duct tape. This is something called connecting in series. Try to launch another mass and see what happens. Did the mass travel farther or less far than before when it was not connected in series?

After you have made some observations, take these two same masks and connect their remaining ear loops together with duct tape. You have now connected your masks in parallel. Take a few moments to launch some of the masses and see what happens. Were you able to launch the masses farther than before?

Earlier we talked about how each spring has its own "springiness". Some springs are stretchier than others and therefore have different stretchiness values. In Physics, we call this number the “k value”. Springs with low k values are much stretchier than stiff springs with high k values. When masks are connected in series their combined k value is decreased and when they are connected in parallel their k value is increased. Which do you think would be best for a farther launch? A higher or smaller k value??

Masks in Series



Parents/Teachers

Explanation:

As you might have studied in some of your courses, or observed in your everyday lives, some objects have a certain springy-quality which holds potential energy in it. We define the energy of a spring as $E=½*k*A^2$ where A is the maximum amplitude of the spring. Due to the law of conservation of energy, we know that Kinetic energy+Potential Energy=0. So, when the spring is stretched out and waiting to release this kinetic energy, its potential energy is very high. We can use this energy to launch things in a catapult.

A spring, which is a type of harmonic oscillator, wants to return to its equilibrium position when it is stretched out. Nowadays, we're going just about everywhere with a type of spring: our facemasks! While they are essential to keep on your face when in public, and during this demonstration, we will observe the spring-like qualities of the facemasks' elastics and learn how we can better understand its properties.

The "springiness" of a spring is understood through its "k" value. The equation for a force creating by a spring is $F=-k*x$ where x is the distance the spring has moved from its equilibrium point and k is this "springiness factor."

We can change the total springiness of a spring system by making two springs work together. The resulting springiness, we will call "k effective."

Parents/Teachers

Instructions:

First, we will observe the simple catapult with only a mask. Attach one end of the mask to a desk or chair or another upright thing with a clip or with tape (make sure it's firmly attached). Place a mass in the center of the mask and pull the mask back, keeping the ear loop which is not attached to the desk stable. Release and observe how far the projectile goes.

To begin observing how to change the "k effective," let's look at two facemasks in series. Attach two masks by their ear loops with tape. Again, clip one end of the mask to a desk and use your hand to hold the end of the mask steady. Make sure not to pull on the mask elastic, only extend far enough to minimize slack in the mask. Place a projectile in the center of the mask system, pull back the same amount as you did for the single mask and see how far it goes.

Now for two facemasks in parallel, nest one facemask in another and set it up as you did for the single facemask. Place a ball in the center of the mask, pull back the same amount as you have for the other masks, release, and observe the distance travelled.

Which configuration makes the balls launch farther?