Papercrafts In Motion

Grade/Experience: 4th and up/ Novice

Duration: 30-40 minutes

Objectives: Students will…

- observe and test the effect of voltage polarity on motor motion.
- observe and test the effect of changes in mass distribution on motion.
- observe and test the capacity of a given motor to move an object of a given mass.
- understand the difference between rotational motion and linear motion.
- investigate the effect of surface area/friction on motion.

Vocabulary:
Motor, Polarity, Rotational Motion, Linear Motion, Mass, Center of Mass, Motion, Relative Position, Force, Torque, Surface Area, Circuit

Materials:
Self-sticking motor, CR2032 Battery, Maker Tape, Scissors, Printable Visualizer Discs template/Data Sheets, Digital Scale(s), Writing Utensils, Masking or Invisible Tape, Pennies.

Educator Background:

***Note:** The understandings gained by completing this exploration are just the tip of the iceberg relative to using motors to move objects. The same basic materials and our "Test-A-Rossa" template (found in the Origami Circuits portion of the Papercraft Guides located at BrownDogGadgets.com) can be used after this to extend these basic understandings while utilizing relevant mathematics concepts.

This mini investigation uses small paper discs with markings on them to help your students visualize the effects of a small handful of variable changes relative to how motors work and how the forces created by them can act on other objects to produce motion.

Forces & Motion:

According to *Newton's First Law of Motion*, an object has two different states that it can be found in: at rest and in motion. Any object AT rest tends to remain at rest unless it is acted upon by a force greater than the sum of the forces keeping it in place. Speaking of forces, science calls *any pull or push* a **force** and one of the most elemental forces on our planet is the pulling force of gravity. **Gravity** is acting on literally anything on our planet with mass, pulling all mass toward the center of the Earth. This creates the maintained contact between objects of mass and the surface they are held in contact with. *This contact pressure* created by gravity acting on things with mass is referred to as the object's **inertia** and it's what needs to be overcome if the object is to go from the resting state to being in motion. So what is motion? Motion is a word used to describe the act of changing what is called **relative position:** *where something is located in space*. When an object is located in one place and, by comparison, that changes through time, we say that the object was/is in motion. If its' relative position is NOT changing, it is not in the state of motion…it is in the opposite state: rest. Today you and your students will be able to observe, through tinkering, some basic realities of a common technology often used to create the forces necessary to move our built world: the electric motor.

Motors:

There are many technologies that humans have developed to assist in providing the forces needed to make motion happen. Although you and your students will only be working with a small motor with an unevenly weighted mass on its' rotating spindle, it's worth knowing a bit more about what is out there for engineers to choose from when selecting the components needed to complete a circuit project. We can categorize them in a number of ways; one of which being by the TYPE of motion they create. Some create circular, **rotational motion** and others create **linear** or back and forth motion. Another important distinction among these components is what powers them (which energy source gets converted into kinetic/mechanical energy). Some use electrical energy and others make use of compressed fluids like air, steam or incompressible liquids trapped in and released from closed cylinders. Some, like the engines in our cars, rely on controlled explosions from stored fuel to get moving!

Components that create rotational motion include:

- Motors
- Engines (both steam and internal combustion)
- Servos
- Rotary Actuators

Components that create linear motion include:

- Pneumatic or Hydraulic Pistons

- Pneumatic Muscles

Components that create motion and are powered by electricity include:

- Motors
- Servos

Components that create motion and are powered by pressurized fluids (gas or liquid) include:

- Pneumatic or Hydraulic Pistons
- Rotary Actuators
- Pneumatic Muscles
- Engines

Although the rotating spindle and weight attached to your motors aren't visible, your first investigation will be centered on deciding whether those motors create linear motion or rotational motion. Your second short investigation will take that understanding one step further by investigating, through simple adjustments in wiring, how something called **polarity** can alter that rotational motion's direction.

More about motors:

Motor's, like all the components listed above, can be found in a variety of sizes and strengths. Motors are not only trying to act upon an object's MASS but also the forces that are already acting on it such as the *rubbing/pulling force* of **friction**. Motors also all have a maximum twisting force that, in turn, limits how much mass they can effectively carry along with them & how much momentum they can give that mass. This *maximum twisting force* is called **torque**. Your third short investigation with these materials will involve testing the limits of what your students' tiny vibrating motors can actually move and how varying masses can impact the degree/rate of motion created in an object. They will also test and observe those differences while changing how much surface area/friction are in play.

Student Investigation 1: *Rotational or Linear Motion* (5 minutes)

For this simple investigation, the question you and your students should seek to answer is *whether the type of motion that is being produced is rotational or linear*. To be able to see and verify that it is, in fact, a rotational motion, your students should cut out the 3.0" visualizer disc. Once outfitted with a vibrating motor/battery combo by sticking it to the center circle, students should be able to view the disc rotating. Even though

- the motor spindle is not directly connected to the paper
- the disc is being moved by motor vibrations

the disc will still move in that same rotational manner because of the vibrations' rotational origin. Your students should follow any of the two assembly instructions depicted on the visualizer print out. Ask them to tell you how the two assembly diagrams differ. They should notice that the two wires from the motor are connected to the battery in opposite ways. Reassure them that both will allow them to make THIS observation but they will revisit the one they haven't tried yet afterward while making some more observations. Your students should use the accompanying data sheet to keep track of their data/observations.

Student Investigation 2: *What is Polarity and how does it affect motor behavior?* (5 minutes)

Just like our planet has a north pole and a south pole, other things also have a *"one side and an opposite side"*. We often use the word **polarity** when discussing this concept in relation to electricity and magnetism. As this relates to components within electric circuits and the energy sources that power them up, it is true to say that:

- Every voltage source has a polarity; these poles are labeled as either + or – . The voltage source is where electricity with the potential to move originates. These poles serve as the start and end of a pathway system that includes components which use the travelling energy along the way. These *systems of voltage/pathways/components* are called **circuits**.
- Some but not all components in circuits ALSO have a polarity and their orientation when "patched into" the pathway system often changes the way they work (sometimes causing them to not work at all).
- Wire coating color, symbols & wire length are often used to indicate polarity.

Using questions 2 and 3 on their data sheets to focus investigation, instruct your students to try each of the two different ways to connect the wires coming from the motor to the sides of the battery. They should follow the assembly illustrations and use the 3.0" disc with the arrows. They should see that polarity changes do not cause the motor to stop working…but they do cause the direction of rotational motion observed in investigation 1 to be reversed.

Student Investigation 3: *How much mass can our motor move?* (10 minutes)

Mass is a measure of *how much stuff (matter) there is in something*. Gravity pulls on that mass to produce what we call weight on a scale. The more mass there is in a given object to pull on top of the scale…the more weight. In this investigation, your students will be testing the effects of increased mass of object on motion. Students may need to make a new tape loop (switching around the wires may have already made the connection less sticky and therefore less reliable) for each of the trials. Instruct your students to cut and weigh out the remainder of the visualizer discs. If each student doesn't have a means of weighing the discs, you can measure them for the group and simple share the data. The discs will undoubtedly have slightly increasing weight and the motor battery combo will have a constant weight. Have your students predict which of these discs will rotate the fastest and then try each out paired with the battery/ motor combo and rate each for speed of rotation. You could have students let each trial run for a single minute and count the number of completed rotations within that minute OR just qualitatively judge it via observation. Afterward, students can use their data sheets to record the weight of each disc as well as its' rank relative to rotation speed. Lastly, they can use more tape loops to stick an increasing number of pennies atop the motor in the center until the disc no longer rotates, effectively finding what might be the maximum mass that the motor's vibrations can act on. Before moving on to the next investigation, ask your students if they think there might be any other reasons for variation in how the same motor/same location moved each different disc. Ask them to imagine two bikes rolling down the same hill one ridden by a man and the other by his clone. They are exactly the same weight… the hill/path down it are exactly the same… there is no wind and there are no brakes on the bikes. The only difference in the two bikes is the thickness of the tires. One has super thin, road racing tires and the other has tires that are twice as thick. Which will roll to a stop at the bottom of the hill first? The thick tired bike will! Why? Those wider tires have more of their surface area in contact with the ground and they produce more of a rubbing force called friction that must be overcome in order to move. Could this be responsible for some of the differences in how these discs of different mass move differently when being moved by the same force? Ask students how they would test such a thing. Take their suggestions in brief discussion but then instruct them to see if they can adjust two of their five discs so that they have **the same mass** but **different amounts of paper in contact with the table surface (surface area)**. Since the paper difference between two discs is not very big, you might achieve this by taping a single penny or something even lighter atop the smaller disc/battery/motor combo. Once they've recorded which discs they used and details about what they added to the smaller one (to bring it up to the mass of the larger one while maintaining a smaller surface area), your students should run the same timed test and speed rank trials that they had before. Along the way, students should be recording their results on the printable data sheet.

Student Investigation 4: *Penny location and pattern finding* (10 minutes)

In addition to mass, polarity and friction (driven by material type/surface area), the way mass is **distributed** in an object will almost always affects how it moves when a force is applied. Allow your students some time to try out a variety of different penny placements using the 2.5" disc. Have them record how they distributed the pennies and any changes in HOW the disc moved in comparison to their first trial. Challenge them to see if they can come up with ways to redistribute the weight via penny placement to create SPECIFIC, less "random" movements including:

- an arc to the right or left
- a straight line