

Curriculum topics:

- Static Electricity
- Experimental Variables
- Momentum
- Electrically Charged vs. Uncharged

Subject:

Physical Science

Grade range: 4 – 12

Who we are:

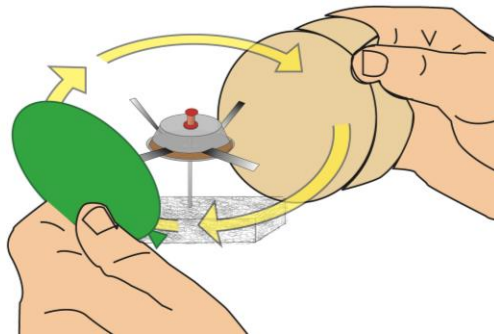
Resource Area for Teaching (RAFT) helps educators transform the learning experience through affordable “hands-on” activities that engage students and inspire the joy and discovery of learning.

For more ideas and to see RAFT Locations

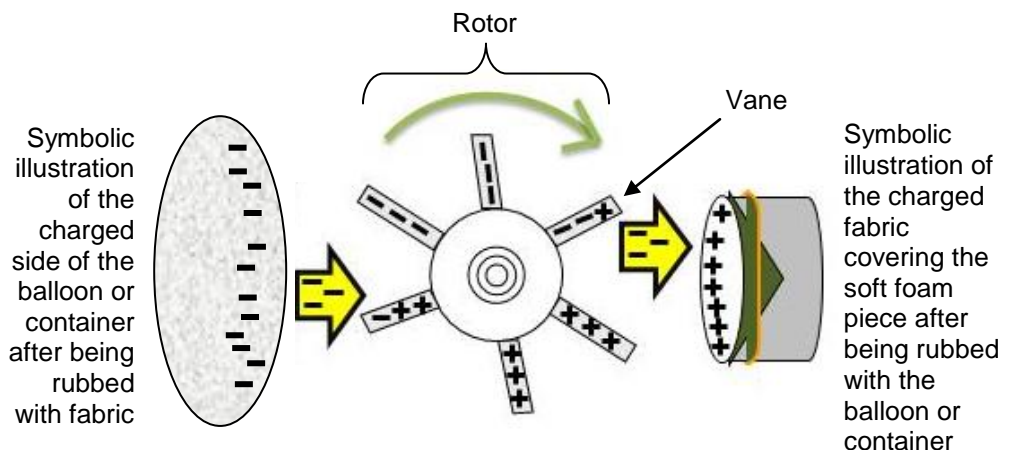
www.raft.net/visit-raft-locations

STATIC MERRY-GO-ROUND

Make and power a version of the first electric motor!



This unique adaptation of the world’s first electric motor lets students create spinning motion using only hand-generated static electric charges.



Symbolic illustration of the directions the electrons travel as the vanes spin

Teaching tip: The ability to produce a sustainable static charge varies with temperature and (especially) humidity! To double check: 1) Rub inflated balloon on clean fabric or hair; 2) Place rubbed side of balloon against a wall; 3) Let go! 4) If the balloon stays in place – then the static motor should rotate.

Materials required (per unit)

- Thin straw half section, 9 cm (3½") long
- Wood screw, Phillips head, size #4, 1.9 cm (¾") long or equal
- Stiff foam base
- Pushpin
- Sports bottle cap
- Reflective Mylar®
- Rubber band that fits tightly around cap rim
- Fabric square (silk, wool, acetate, or other suitable fabric), 10 cm x 10 cm (4" x 4")
- Soft foam piece (to hold fabric)
- Rubber band that fits around soft foam piece
- Container, polystyrene
- Balloon, inflated

Caution: Rubber bands and balloons contain natural rubber latex which may cause allergic reactions.



WARNING:

CHOKING HAZARD—Children under 8 yrs. can choke or suffocate on uninflated or broken balloons. Adult supervision required.

Tools required

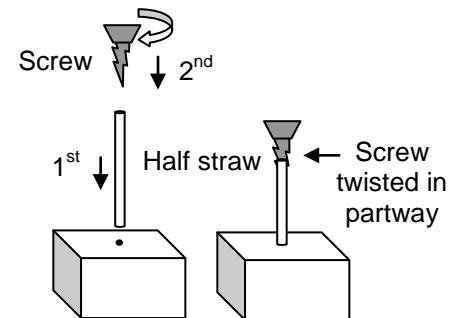
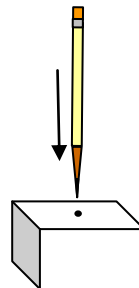
- Scissors
- Ruler
- Pencil or other sharp object to make a hole in the foam block

Materials preparation

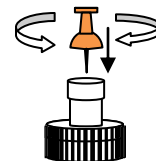
- 1 Cut 5 straws in half to make 10 half straws.
- 2 Cut 10 Mylar® sheets in half to make 20 pieces 3.25 cm x 4 cm (1¼" x 1½"). Set aside 10 pieces for later use.

How to build it

- 1 Make a small starter hole by inserting the point of a pencil into the center of the stiff foam block. Insert the half straw into the starter hole as shown. Push the straw far enough into the block so that the straw stays upright.
- 2 Twist the pointed end of the screw **part way** into the end of the straw as shown.



- 3 Carefully position the tip of the pushpin over the exact center of the sports cap. Slowly push the pushpin straight down. Twisting will help the tip penetrate the cap.

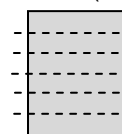


- 4 Place the rubber band around the cap as shown.

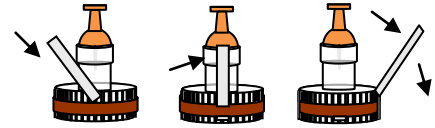


- 5 Cut across the narrow width of the Mylar® rectangle as shown. Make 6 vanes, each 6 mm (1/4") wide by 3.25 cm long (1¼").

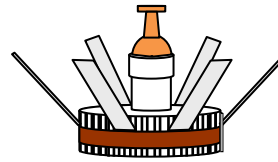
3.25 cm (1¼")



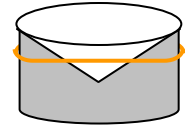
- 6** Position one vane at a 45° angle (as shown at right) Once inserted, tip the strip upright and then bend it at the rubber band to create a crease. Evenly insert the remaining vanes under the rubber band. Bend each vane down in turn.



The completed cap (**rotor**) will look like this:



- 7** Drape the fabric square over the soft foam piece, letting the corners hang over the sides. Place a rubber band over the corners to secure the fabric to the foam.

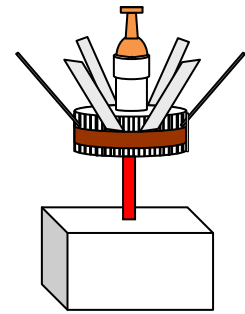


Construction tip: For best results, keep the fabric dry and clean. Handle it by the corners only.

To do and notice

- 1** To assemble the motor, insert the point of the pushpin (now hidden inside the sports cap) into the cross on the head of the screw. To do this, tip the cap so the point of the pushpin can be seen and then line up the head of the screw with the end of the pin. Hold the pieces together to retain the alignment while placing the base onto a flat surface.

If the pushpin is correctly positioned, the cap will wobble back and forth similar to the head on a bobble-head toy. Give the cap a gentle spin. The cap should spin freely; if not, reposition the pushpin on the screw.



- 2** In one hand, hold the foam piece covered with fabric so that the fabric faces outward. In the other hand hold the balloon or container. Briskly rub the fabric and the balloon/container together. Note: The rubbing process will need to be repeated frequently while doing the following activities.

Teaching tip: The ability to produce a static charge varies with temperature and (especially) humidity! Cool, dry days are best for static activities. Avoid doing static activities after students exercise or have recess.

- 3** Touch each vane with your finger to neutralize any charge imbalance. Bring the freshly-charged balloon/container very near to one of the vanes. What happens?

Teaching tip: When only one charged item is used, the vane will quickly take on the same charge and then it will be repelled. Some of the charge may be lost into the air as the vane moves away. The motor may stop or change direction when the vane comes back around to the charged item.

- 4** Rub the balloon/container with the fabric again, and place the **balloon/container on one side** of the motor and the **fabric on the other** (as shown in the illustrations on page 1). Vary the position of the fabric and balloon/container for best effect. Repeat the rubbing as needed. With practice, the motor will rotate continuously!

Teaching tip: After the fabric and balloon/container are positioned around the motor, move them up or down slightly. The motor will spin faster as the vanes come close to new areas of the fabric and balloon/container that have not yet lost their charge imbalance.

Curriculum Standards:

Energy can be transferred from place to place and converted from one form to another
(Next Generation Science Standards: Grade 4, Physical Science, 3-2 & 3-4; High School, Physical Science, 3-3)

Electric or magnetic interactions between objects not in contact with each other
(Next Generation Science Standards: Middle School, Physical Science, 2-5; High School, Physical Science, 3-2 & 3-5)

Motion changes and energy transfer
(Next Generation Science Standards: Middle School, Physical Science 3-5)

Compare Multiple solutions & Test variables
(Next Generation Science Standards: Engineering Design, Grades 3-5, 1-2 & 1-3; Middle School, 1-2 & 1-4)

Science & Engineering Practices
(Next Generation Science Standards: Grades 4-12)

Additional standards at: <http://www.raft.net/raft-idea?isid=408>

Learn more

- As an introductory activity, have students first build a motor with only 1 vane and use the single vane rotor to do the activities in **To do and notice**.
- Turn this activity into a Design Challenge by creating one version of the motor ahead of time, and then inviting students to create a vane shape and/or arrangement that spins faster than the first model.
- Explore other materials that can be rubbed together to generate a charge imbalance.
- Use extra vanes (set aside earlier) to create new versions of the rotor.
- Instead of placing both the fabric and balloon/container near the motor, substitute a finger for one item. What happens differently?
- Research why static motors are easier to fabricate on a miniature scale.

Related activities: See RAFT Idea Sheets:

Electrifying - <http://www.raft.net/ideas/Electrifying.pdf>

Electrophorus - <http://www.raft.net/ideas/Electrophorus - a Charge Carrier.pdf>

Neon Bulb - Make it Glow - <http://www.raft.net/ideas/Neon bulb - Make it Glow.pdf>

All Charged Up - <http://www.raft.net/ideas/All Charged Up.pdf>

Sparking CD Capacitor - <http://www.raft.net/ideas/Sparking CD Capacitor.pdf>

Static Spinner - <http://www.raft.net/ideas/Static Spinner.pdf>

Static Tetherball - <http://www.raft.net/ideas/Static Tetherball.pdf>

Static Detector - <http://www.raft.net/ideas/Static Detector.pdf>

Resources

Visit <http://www.raft.net/raft-idea?isid=408> for “how-to” video demos and more ideas!

- **Basic background information on static electricity** – <http://www.sciencemadesimple.com/static.html>
- **Benjamin Franklin and his electric motor** – http://ethw.org/Benjamin_Franklin's_Electric_Motor
- **Videos on Electricity and Magnetism from the Khan Academy** – <https://www.khanacademy.org/science/physics/electricity-and-magnetism>

The science behind the activity

(**Bold** words are scientific terms.)

Touching two items together and then separating them can move **electrons** from one item to the other. The item that gains electrons will have a net negative (-) charge if the item has more electrons than **protons**. The item that loses electrons will have a net positive (+) charge if the item has fewer electrons than protons. Note that electrons are moved, not created, in this process!

Charges will “stay put” unless the item is a conductor (metal, etc.) that lets electrons move about easily. An item with a **net charge** (positive or negative) is said to be **charged** or to have a **charge imbalance**.

Opposite (**unlike**) charges (+/-) are **attracted** to each other. Same (**like**) charges (+/+ or -/-) are **repelled** by each other. The forces of attraction and repulsion become greater when the distance between the charged items becomes smaller.

Different materials vary in how strongly they “hold on” to electrons. For solid materials the positive charges (protons) cannot leave or move about like the electrons.

Touching a charged item can eliminate (**neutralize**) the charge imbalance at the spot touched (or all over if the item is a conductor). The human body can safely give up or take on the electrons needed to neutralize small charge imbalances. Touching the Mylar® strips removes any existing charge imbalance. The electrons can leap across an air gap unseen or cause a spark if the charge imbalance is large enough. Charge imbalances can also be neutralized, over time, by opposite charges on dust and moisture in the air. The charge imbalance will diminish more slowly if the air is cool and/or dry. Generating a large or lasting charge imbalance in a damp or humid environment may be impossible.

An uncharged, **neutral**, item has an equal number of positive and negative charges. Surprisingly, a neutral item will still be mutually attracted to any charged item! The attraction is due to the neutral item’s electrons rearranging their orbits very slightly when near a charged item (becoming **polarized**). The electrons will move slightly closer to a positively charged item or slightly away from a negatively charged item. The result is a net attraction, as the attractive force from the slightly closer opposite charges is greater than the repelling force of the slightly farther apart like charges. This is why a Mylar® strip that is initially neutral will rotate toward a charged item that is being held in place.

When a Mylar® strip moves near enough to a charged item, some electrons can bump over the gap. Some electrons will move toward the Mylar® from a negatively charged item **or** from the Mylar® toward a positively charged item. Either way, the Mylar® will end up with the same charge (+ or -) as the nearby charged item. A Mylar® strip, which can rotate, will be repelled from the charged item, since like (same) charges repel each other. The strip is now strongly attracted to the oppositely charged second item. When a charged strip moves near enough to the second item, some electrons are again transferred. The Mylar® strip now acquires the same type of charge as the second item. The strip is now repelled from this second item, but will be attracted to the first charged item. The Mylar® strip continues rotating due to momentum. When a Mylar® strip rotates near the first charged item, the process repeats. The attractive force changes to a repelling force and the Mylar® strip rotates away, repeating the cycle. See the illustration on page 1.

Reflective Mylar® has a thin coating of aluminum, which is a conductor. Electrons can move easily in a conductor. The electron movement and electron transfer happen so quickly that the strips spin without stopping. Only a relatively small number of electrons are moved to or from a strip each time. The charged item(s), having a much larger net charge, can supply or take on extra electrons for many rotations of the strips.

An expanded **science behind the activity** can be found at <http://www.raft.net/raft-idea?isid=408>.