

So why doesn't it just sit in one place and buzz? Why does it move forward? Most toothbrush bristles are angled just like the hairs on a gecko's foot, meaning they'll slide smoothly in one direction, but not so easily in any other. The brushbot is thrown forward by the swinging weight and the bristles slide along the surface a short distance. When the weight swings back again, the bristles catch and resist moving. This way the brushbot creeps along the surface using friction, pushing along with its bristly feet.

In some ways, your brushbot works a little like how a snake eats. Snakes have teeth which are angled backwards, just like the bristles on the toothbrush. Any prey they consume can move in easily.

The surface **friction** on which a brushbot moves will affect the behavior of the brushbot. Practice on the surface that the brushbot will be competing on.

Friction is actually a force that appears whenever two things rub against each other. Friction is a 'catch all' phrase for any force opposing the relative motion of objects in contact. Friction releases some of the energy. This release can be in the form of noise, vibration, and energy transfer. Friction can also transfer energy into heat energy. If you rub your hands together you will notice that the skin on your hands warms up. Some of the energy of motion in your hands is transferred to heat energy through the friction process.

Brushbots fall over easily: consider where your motor and other items added are attached in order to create a balanced system. **Center of gravity** is the exact spot on an object where there is the same amount of weight on one side of the spot as there is on the opposite side. Once you change the weight anywhere on the object, the center of gravity changes too. The ease with which an object can be balanced depends greatly on the location of its center of gravity.


### Some ideas for your consideration....

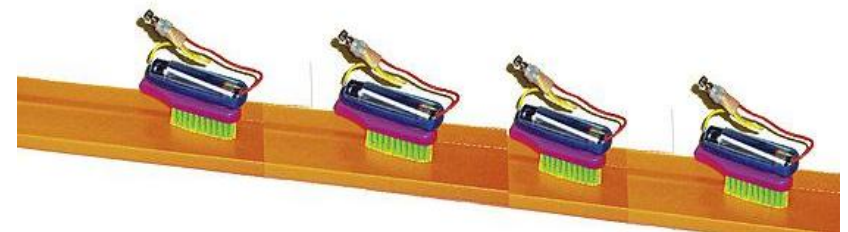
- \*Mount the motor on the end. This will convert as much vibration as possible into axial motion.
- \*Mount the motor on the rear end. This tends to lift the device off the front bristles and reduce friction.
- \*Mount the battery on the handle end. (Similar principle as above)
- \*Remove the middle bristles. This eliminates friction from unneeded center bristles.
- \*Split the bristles. (Similar principle as above)
- \*Cut a slot in the plastic. The lightest, longest tends to move faster. (Notice how ships are designed)
- \*Cut the sides of the plastic. (Similar principle as above)
- \*Use a tail. This will tend to convert unwanted sideways movement into axial motion along the track.
- \*Change the vibration pattern by modifying the motor shaft by an unbalanced weight which may create more vibration, and/or slow the motor.



## Global BrushBot Olympics

### Olympic summer event: 750 Millimeter Relay Race

- a. The competition track consists of a wooden/painted track: 80 cm long, with 1 cm high and 2 cm wide rails (conduit molding, painted white); there is, in addition, a 4.5 cm X 2 cm starter box. 
- b. Robots will be made of no more than one toothbrush head and one micro motor. Additional weights or other items may be added. The bot must fit within the starter box with only the bristles touching the surface or the rails of the track throughout the race.
- c. There will be 3 members on the relay team. If a bot falls on or off the track, turns in the wrong direction, or stops moving, a team member may pick up the bot and re-start at the starting line. The winner is the last of the 3 bots that falls off the far end of the track first. Winners of each round will play off against other round winners until an overall Gold Medal winner is determined.



## Olympic new event: Sumo (2 entries per country)

- The sumo ring (dohyo) will consist of the bottom of a 32 cm diameter round metal pan (playing surface is 27 cm in diameter). An 8 cm square is marked on the middle of the pan, with each corner identified with a mark that denotes a starting point (shikiri-sen).
- Robots will be made of 1 toothbrush head, 1 micro motor, 1 battery. Additional weights and/or other items including decorative items to create a sumo wrestler-appearing brushbot may be added. Robots must fit within a 9 cm diameter plastic pipe to be considered qualified to play; no part of the robot can extend beyond the vertical plane of the pipe or can be touching the interior of the pipe surface. Only the brush bristles may touch the playing surface (other features must not touch the surface during the match).
- Each sumo brushbot, facing each other, will be touching one of the marks on the ring at the start. The referee (gyoji) will announce the start of the match. A bot must be in motion at the start and throughout the match, or the bot is disqualified. The match ends when there is only one bot remaining standing on its bristles, moving on the playing surface. If no bot leaves the arena or falls in 30 seconds, the winner is the bot that is closest to the center of the field (as measured from the end of the motor shaft).
- The winner of each match will advance to determine the Yokuzuna (highest rank).



## Olympic winter event: Pairs Figure Skating (2pair entries per country)

- The ice skating arena consist of the bottom of a 32 cm diameter round metal pan (playing surface is 27 cm in diameter).
- Robots will be made of 1 or 2 toothbrush heads, 1 micro motor, 1 battery. Additional weights and/or other items including decorative items to create a figure skating-appearing brushbot may be added. Only the brush bristles may be touching the surface. Pairs may touch/hold “hands.”
- The figure skater must move on the arena surface for at least 15 seconds during which judging will be based on: appearance, performance, dramatic presentation. Music may be played to accompany the figure skating performance.



## To make your brushbot:

- Place toothbrush head on a table top and vibrate table by striking it with your hand; see the natural movement of the brush. You can “train” the bristles by rubbing the bristles against the table top or hand.
- Use the double stick glue (UGlu) strips to attach the straw (battery holder) to the brush head; the straw can be attached in line or perpendicular to the brush length.
- Place the AAA battery in the straw, and put the yellow rubber band around the battery.
- Test the micro motor by placing the stripped end of the wire at each end of the battery (use rubber band to hold the wire to contact the battery). The motor should vibrate.
- The motor can be attached using UGlu strips to the straw or to the brush head or left freely dangling.
- Use origami or other materials to create costumes for sumo and figure skating brushbots. Other materials including plastic straws, paper clips, small photos, stickers, cardboard, etc. may be used.



## What's happening? ...the science behind the brushbot.....it is all about scientific inquiry and friction, center of gravity, inertia

Your brushbot should crawl erratically over any smooth, flat surface and maybe even fall over occasionally – if you're getting no movement try bending the bristles a bit or trying a different surface. To understand how it works, imagine holding a heavy bowling ball and taking a run-up as if to throw it, only to have your fingers stick in the holes at the last second. You'd probably be thrown off balance and fall flat on your face. This is called 'inertia'. An object in motion will stay in motion and an object at rest will stay at rest unless acted on by an unbalanced force

The unbalanced motor works in a similar way. Unbalanced by the weight, the motor's spinning shaft makes it vibrate rapidly, in turn making the toothbrush head shake in one direction and then back again very quickly.

Cell phone motors used to create vibration alerts in consumer electronics use this technique. As the motor shaft spins, the weight on the shaft, being off-kilter, makes the motor, and therefore the entire pager, vibrate. A tiny motor thinner than a pencil with an unbalanced weight is whizzing around each time the phone rings. This vibration is transferred to the whole phone making it all vibrate and alerting you to the call.