THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

The Wizard's Lab - Exhibits on **Mechanics**

Air Cannon:
There is air inside the chamber of the cannon. When the large-area rubber membrane is pushed in, some of the air inside the chamber is displaced. The volume of air under this large area needs to come out through a hole of smaller area, so it does it at a faster speed.

Balance Beam:
Some mechanical balance scales work by comparing the effect of weights on a pivoting bar. For this we use the concept of *torque* (which can be thought of as the power of a force to turn a lever): torque equals the force (like a weight) multiplied by the distance from the force to the pivot point (T = F•d). In this exhibit one can set one heavy weight on one side of the beam and try to balance it by placing one or more smaller weights on the other side of the beam. Each weight supplies its own torque T1, T2, T3, etc. Balance is achieved when the torque on one side of the beam equals the total torque on the other (T1 = T2 + T3) or W1•d1 = W2•d2 + W3•d3.
Example: A 6-ounce weight at 4 inches creates a torque of 24. It can be balanced by 2-oz. at 6 inches plus a 1-oz. weight at 12 inches (6•4 = 2•6 + 1•12 = 24)

Bernoulli Levitator:
The ball in the air stream is surrounded by fast-moving air. Bernoulli's principle says that slower moving air exerts greater pressure than faster moving air. If the ball moves to one side, off the air stream, it would encounter slow air on that side while still having fast-moving air on the other side. Since slower air pushes harder (greater pressure) the ball gets pushed back to the center.

Cartesian Diver:
When the bottle is squeezed, the water gets pushed into the diver making it heavier. The air bubble in the diver gets compressed (gets *denser*). When the diver gets heavier/*denser* than the surrounding water it sinks. Objects denser than water sink.
See *Oil 'n' Water* for similar concepts.

Oil 'n' Water:
No matter how hard you shake the bottle, the oil and water will not stay mixed together. They don't mix because oil molecules and water molecules repel each other. Water will settle to the bottom and the oil will float to the top because the oil is less dense than water.
See the *Cartesian Diver* for similar concepts.

Resonant Pendula:
As one pendulum swings, it pulls with it the cross bar above. This back-and-forth pull (twist) on the cross bar gives tiny pushes to each of the other pendula attached to the bar. You will notice that only one other pendulum begins to swing (*resonates*), and it's the one that has the same length as the pendulum first set in motion. This is because a pendulum can only move at one rate (*frequency*), and that rate depends on its length. The first pendulum gives pulls to the equal-length pendulum at just the right rate to get it swinging higher and higher with each swing, whereas the others get the pulls at the wrong rate.

Rolling Ramp:
The main factor that determines how quickly an object can roll down a ramp is how fast it can develop spin, and this depends on its *moment of inertia*, or mass distribution. The further away the mass is from its center of rotation, the harder it is to get it spinning.
See *Revolving Platform* for similar concepts.

Revolving Platform:
Physics Law: The product of the rotational speed and the mass distribution must remain constant (Conservation of Angular Momentum). When a person spinning changes her/his mass distribution (like ice-skaters do), the rotational speed increases or decreases to compensate for that change.
See *Rolling Ramp* for similar concepts.

Tornado Bottle:
The two bottles connected by their spouts are filled with water and air. When the top bottle has the water, gravity tries to pull the water into the lower bottle. But the lower bottle is already full (of air!) The air in the lower bottle needs to move into the upper bottle so that the water can enter the lower bottle. Yet, the air and the water push against each other and neither can get through the spouts. Sometimes a little of each passes through by taking turns (that's what's happen ing when we see intermittent bubbles.) The most effective way for the air to get to the top and the liquid to get to the bottom is by creating a vortex. The air gets to the top though the center of the vortex, and the water can flow down the walls to the lower bottle.

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The Wizard's Lab - Exhibits on Electricity

Big Capacitor:
A capacitor stores electricity temporarily, akin to a bucket holding water. As a current from the battery charges up a capacitor, the intensity of the current diminishes until the capacitor's charge has reached the full potential —this can be seen by the gradual dimming of the bulb until it's off. Through another circuit, the capacitor's charge can drain out. We can observe the second bulb's brightness go through a similar pattern: gradual reduction of intensity to off as the capacitor's charge reaches zero. Now, the capacitor is ready to accept charge from the battery again.

Electricity Makers:
Moving a magnet inside a coil of wire causes an electric current in a circuit. The amount of current depends on the number of turns in the coil of wire and the strength of the magnet. The current also depends on how fast the magnet is moving in the coil. The electric meter measures the amount of current created by moving the magnets in the coils of wire (as long as the coil is in a circuit with the electric meter.)

Human Battery:
Batteries work by chemical reactions. Touching metals creates chemical reactions on them. Some metals react more than others. Touching two different metals creates an unbalance of reactions that is capable of pushing electrons along a circuit (an electric current.) Your body, made of salty water among other things, is conductive enough to allow a measurable current flow through it.
See *Resistors* for similar concepts.

Resistors:
Resistors are conductors that limit the amount of current that can pass through a circuit. They come in many values (of resistance). A true conductor is a resistor with value 0 Ω (ohms), while a true insulator would have a very big (infinite) resistance. In this exhibit we can measure how effective different resistors are at liming the current coming form a battery.
See *Human Battery* for similar concepts.

Solar Cells:
Solar cells are made of materials called *semiconductors*. By their construction, the semiconductor in a solar cell allows the energy of light to knock electrons free and push them to flow in a certain direction. One cell produces about half-volt of electricity (a fairly weak push on electrons.) To get more voltage one can connect two or more cells *in series*. The higher voltage can bring more power to the motor turning the propeller.

Transformer-Shocker
Voltage can be thought of as 'electrical force.' A transformer can be used to raise the voltage, but only if the current is changing. When you hold down the button while touching the contacts, a steady current flows through the transformer and no voltage-raising can occur. When you let go of the button the current abruptly changes to zero, the transformer raises the voltage for this quickly-changing current and you feel a short but powerful shock.

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The Wizard's Lab - Exhibits on Optics

Benham's Disk:
The illusion of seeing colors in this rotating black-and-white pattern is not completely understood. One theory is based on the different response rates of color-detecting cells in your eyes called *cones*. Three different types of cones perceive red, green, and blue. White parts on the disk trigger all three of types of cones, but because some cells respond quicker than other cells, we see colors.

Bird in a Cage:
A bird is painted on one side of a board, a cage on the other. When the board spins fast, the bird appears in the cage. This is due to a phenomenon called *persistence of vision*: as the board spins, our eyes process the images a fraction of a second longer than the image is actually in front of the eyes. The brain then "slurs" the images together and creates a single image of the bird in the cage.
See *Praxinoscope* for similar concept.

Black Box:
In the absence of light we cannot see color. When you look into the box, your eye covers the hole. When the hole is covered the light cannot enter the box.

Concave Mirror:
A concave mirror has a curvature towards the observer. A curved mirror reflects the light coming from an object in different directions, depending on what part of the mirror the ray of light hits. This creates a distortion of the image. If the object is closer to the concave mirror than some prescribed distance, the image will appear larger and closer. If the object is at that prescribed distance (called *focal distance*), there will be no image. If the object is beyond the focal distance, the image will appear smaller, up-side-down and in front of the mirror. This is how you can "shake hands" with yourself —with the image of your own hand!
See *Mirage Maker* for a similar concept.

Convex Mirror:
A convex mirror has a curvature away from the observer. It reflects the light coming from an object in different, divergent directions. This distorts of the image. The images from a convex mirror will always appear smaller, closer, right-side-up and "behind" the mirror.

Folding Mirrors:
Flat mirrors, like the ones in this exhibit, reflect light at an equal but opposite angle as the angle of the light coming onto them. The two mirrors in this exhibit are hinged. Depending on the angle between the two mirrors, the light coming from an object between them can bounce once from either mirror, from both mirrors or several times between the mirrors before the light reaches your eye. The number of images is determined by the number of possible reflections (bounces) between the mirrors. Notice: mirrors at an angle of 1/3 of a circle create 3 images. Mirrors at an angle of 1/4 of a circle create 4 images. …an angle of 1/6 of a circle creates 6 images, etc. Smaller angles create more images.
See *Trick Mirrors* and *Infinity Mirror* for similar concepts.

Infinity Mirror:
When you look through the hole, it looks as if the road never ends. This is because the reflection of the road on one mirror is reflected on the other mirror, which is also reflected on the first mirror, and on and on. So many reflections make the road look endless.
See *Folding Mirrors* and *Trick Mirrors* for a similar concept.

Lenses:
The lenses in this exhibit are convex, of different curvatures. One can feel the difference in curvatures by gauging the thickness of the lenses with our fingers. When a lens is placed in the path of the light from a distant object (in this exhibit, the lightbulb) it will form an image of the object at a distance that is inversely proportional to the curvature of the lens. Note: images made by convex lenses are always inverted (up-side-down.)

Light Polarizers:
Light travels through space as waves, akin to waves traveling down a slack rope. The waves on the rope can be vertical or horizontal or slanted at different angles. In light, the waves have all those directions at the same time. A *polarizer* is a film that lets through (selects) only waves undulating in one of those directions. After light has gone through one polarizer, it may go through another polarizer if the selected directions are the same, but may be blocked by the second polarizer if the selected directions are different.

Mirage Maker:
Concave mirrors have curvatures like shallow bowls and can create images that appear in front of the mirror and inverted. In the mirage maker there are two horizontal concave mirrors facing each other. A little plastic pig sits at the center of the bottom mirror. The top mirror, which has a hole in its center, creates an inverted image of the pig just below it. The bottom mirror creates an inverted image of this image which appears just above the center of the top mirror (through the hole.) As a result, the pig appears to be floating just above the exhibit.
See *Concave Mirror* for a similar concept.

Periscope:
There is a flat mirror at each end of the periscope. Light from the room comes in one of the openings of the periscope, is reflected by the first mirror at a 90° angle towards the second mirror and then reflected again at a 90° angle out the other opening where it gets to the eye. The periscope allows you to see over or under objects, and it can make objects look shorter than they are.
See *Trick Mirrors* for a similar concept.

Praxinoscope:
By spinning the wheel and looking at the mirrors near the center, the wizard appears to be moving continuously. The fast succession of static images (wizards in the mirrors) is interpreted by the brain as continuous motion. The brain fills in the missing information.
See *Bird in a Cage* for a similar concept.

Radiometer:
The radiometer is a four-vane spinner that can rotate with almost no friction, in an environment that is a nearly a vacuum (there are some gas molecules.) The vanes are painted black on one side and white on the other. The black sides absorb radiant light and turn it into heat, which is then transferred to the gas in front of them. The heated gas expands, pushing on the vanes and causing the spinner to rotate. The speed of the spinner indicates the amount of radiation (light).

Spectra of Lights:
White light is a mixture of all the colors of the rainbow. Not all “white” lights are the same. Incandescent bulbs and fluorescent lights are examples of different “white” lights. A *diffraction grating* is a film with microscopic parallel grooves. It separates light into its component colors. In this exhibit, you can view the different colors that make up each kind of light.

Trick Mirrors:
Items A, B, and C have one, two and three flat mirrors respectively. Item A, with one mirror, creates an image where right and left are flipped (like all common mirrors.) Item B, with two mirrors at a 90° angle, creates an image where right and left are flipped back to their original sides (if the seam between the mirrors is vertical): light coming from the right side of your face gets to the mirror on the right, bounces to the mirror on the left, and comes out towards you on the left side. Your image on this mirror is the way people actually see you! Item C, with three mirrors, flips the image completely (up-side down), no matter how you hold it.
See *Folding Mirrors* for a similar concept.