

## 142 Recommended Demos

### Electrostatics, Gauss's Law, Conductors

***Rods and furs*** - Good "Day 1" demo. Rub acrylic and polyethylene rods with various materials to demonstrate electrostatic attractions and repulsions. A rotating platform makes this easy to control and show on an overhead projector, even on a moderately humid day. (*Shelf D5-2*)

***Grass seeds and electric fields*** - An impressive visualization of electric fields. Sprinkle grass seeds on the top of a glass plate, and use the Van de Graff generator to charge up various metal configurations glued to the underside of the glass plate: 2 point charges (dipole field), parallel plate capacitor, and concentric circular capacitor. Watch the induced dipoles within the grass seeds line up with the electric fields. Can be visualized using the overhead projector. (*Shelf D6-2*).

***Faraday Cage*** - Very short and sweet demo that demonstrates electrostatic shielding, a topic associated with Gauss's law. Tune a small hand-held radio to some FM radio station, and then place the radio inside a small aluminum cage. The signal completely disappears. (At this stage in the course, they haven't encountered EM waves, but most are satisfied with a simple explanation, such as "associated with radio waves are electric fields that cannot penetrate the conducting shell".) Should make clear why a radio antenna must be placed *outside* of the frame of a car (*Shelf D5-4*).

### Electrostatic potential

***Van de Graff generator and fluorescent bulb*** - Using the new Van de Graff generator and a small fluorescent tube, you can qualitatively demonstrate both the effects of a potential difference and the  $1/r$  dependence of voltage from a point source. If you make the room dark, turn on the VDG, hold the fluorescent tube close to the VDG and orient it radially, you can see the tube glow. It even glows more brightly at the nearer end, due to the  $1/r$  dependence. Students should be impressed, as there are no wires attached to the tube! If you then turn the tube azimuthally so it is perpendicular to the VDG's field lines, the bulb goes dark, since the tube is now approximately oriented along an equipotential surface. (Many other VDG demos are available as well, such as the Electric Plume and the Electric whirl, *Shelf D5-2*)

### Capacitors and Dielectrics

***Wimshurst machine*** - Classic demo that separates charge. The hand crank spins two disks in opposite direction and charges two beakers, each with a unique charge. In essence, this creates a large capacitor. The capacitance of the machine can be controlled by two knobs in the front of the machine. When they are in contact, the capacitance is large. It then takes longer to charge giving a more powerful discharge. See <http://www.youtube.com/watch?v=KidNSdGqaFE> for a good visual explanation.

Understanding this demo is an achievement! Students can take a lot away from it. (*Shelf D6-3*)

### **EMF and DC Circuits**

***Series/Parallel circuit*** - Series/Parallel circuit is designed for use with a 10 Volt power supply or the Hand-Crank Generator. The two light bulbs can be wired in series or in parallel. The two knife switches enable students to switch on one bulb or both bulbs. Use with overhead document camera. (*Shelf C1-4*)

### **RC Circuits**

***Short time constant RC Circuit*** - An RC series circuit with a 0.3 millisecond time constant. By applying a square wave voltage across the circuit using a function generator and attaching an oscilloscope across the capacitor, you can clearly see the capacitor rapidly charging and discharging on a short timescale. By adjusting the frequency of the square wave input, students can see some interesting transient patterns. (*Shelf C4-2*)

### **Magnetic Fields and Magnetic Forces**

***Current carrying wire in a magnetic field*** - Using a power supply (*Shelf C1-1*), apply a current through a wire suspended between two poles of a magnet. Magnet poles are labeled, so students should predict which way the wire will deflect (up or down) with the current is increased from zero. Switch the polarity to watch the wire deflect the other way. (*Shelf D1-4*)

***Currents producing magnetic fields*** - Use with an overhead transparency projector, iron filings and power supply (*Shelf C1-1*). By driving a current through a wire, the magnetic field can be observed using iron filings. Different wire configurations are available - perpendicular to the plane (resulting B field is circumferential), suspended above and parallel to the plane (field points either left or right depending on direction of current), solenoidal (field is vertical inside the coil), toroidal (field is circular inside the coils). An alternative to this demo can be used well with the document camera - involves a perpendicular wire, and several strategically placed compasses to show the field circling the wire (*shelf D3-4*).

### **Induction**

***Coil, magnet and demo galvanometer*** - Simple, but effective. Two ends of a coil are connected to a demo galvanometer (*Shelf C3-3*), and a bar magnet is moved in and out of the coil, and varying speeds. One can pass a wooden ruler through the coil in the same way to show that there is no deflection with non-magnetic materials. (*Shelf C1-4*)

***Hand Crank generator*** - This generator produces up to 12 Volts with a sturdy handle, designed to be cranked by hand. When used to power light bulbs, you can feel the difference in effort required for lighting one bulb, two bulbs (series or parallel), or no

load. (*Shelf C1-3*).

**Lenz's law tube** - Drop a mass through the 1.5 meter tube. It takes about half a second to drop. Then drop a magnet with an identical mass. It takes over 10 times as long to fall. (*Shelf C1-3*)

**Ring Launcher** - In this classic demonstration of electromagnetic induction, an aluminum ring is propelled straight up a maximum distance of 2 meters. The changing magnetic field from the AC powered coil causes a changing magnetic flux through the aluminum ring. The induced EMF in the ring sets up a current which produces a magnetic field. The induced magnetic field opposes the field of the coil, pushing the ring up. Accessories include a coil with a bulb that lights by induction when the coil is placed over the launcher core. Also includes three additional rings: one split aluminum ring that will not launch, one copper ring to show the effect of changing materials and one shorter aluminum ring with higher resistance to show that it will not go as high because of decreased induced current. (*Shelf C1-3*)

### **Inductance, Alternating Current, Transformers and RLC Circuits**

**RLC Circuit board** - Use with signal generator and oscilloscope (*shelves C1-1 and C1-2*). This circuit board offers components for demonstrating: Voltage/Current Phase Relationships, RLC Resonance, and Non-ohmic Characteristics. Include resistors, capacitors and an inductor coil. Recommended application - Use with laptop and datastudio file "RLC\_demo.ds". With this file and the PASCO 750 Interface, you can input a sinusoidal signal of any frequency, and visualize the voltage across R, L and C simultaneously (different colors on the digital oscilloscope). Investigate phase relationships and resonance. (*Shelf C4-2*)

**Primary and secondary coils** - The secondary coil slides over the primary coil, and the soft iron core slides into either or both, providing a look at magnetic induction and transformer theory. This rugged device is sensitive enough to be used with voltmeters instead of galvanometers. The coils are wound around hollow wooden cores, with a turns ratio of approximately 12 to 1. The primary coil is mounted on a wooden stand (*Shelf C5-3*).

### **EM Waves, Polarization**

**Microwave Polarization:** In this demo, you send a modulated linearly polarized microwave signal (3 cm wavelength) to a receiver horn, which is connected to an audio speaker. The loudness of the speaker signal depends on the amplitude of the microwave radiation. As you rotate the receiver horn up to 90 degrees, you can hear the signal strength drop to zero (vertically polarized radiation and horizontally oriented antenna in this configuration).

Another interesting thing to do is obstruct the signal with a grill, which contains a set of metal bars all oriented in the same direction. By orienting the bars parallel to the

polarization axis, the received signal is very low (bars absorb the signal). By orienting the bars perpendicular to the polarization axis, you get nearly 100% transmission. This is often very surprising to students, because it goes against their intuition that EM waves propagate through space like waves on a string (which would produce the opposite effect). Even more surprising is to rotate the horn to 90 degrees, such that there is no reception, and place the grill in between at 0, 45 and 90 degree angles - no signal at 0 and 90, as expected, but at 45 degrees, the signal reappears! (*Shelf B6-3*)

***Optical polarization*** - This demo complements the Microwave demo well when showed right afterwards. The demo consists of 3 polaroid filters, and should be used with either a document camera or an overhead transparency projector. Place one filter, and watch the intensity drop by ~half. Place a second filter on top of the first, and vary the angle to demonstrate Malus's law. Finally, with the two filters oriented at 90 degrees (no throughput), place a third filter *in between* the two at 45 degrees, and watch the light come back (More "stuff" in the way, yet more light!). Show them that if you place the filter at 45 degrees either in front of or behind the other two, there is still no light - the third filter must be placed in between. (*Shelf B2-3*)

### **EM Waves, Optics - Refraction, Dispersion and Interference**

***Big spring*** - Useful for making an analogy with thin films. Have a student hold one end of the spring, and you send a pulse down to the student. The pulse will bounce back inverted (180 degree phase shift), since the student acts like a fixed end. A similar effect occurs when light reflects off of a material with higher index of refraction - behaves more like a fixed end than a free end, so the wave is inverted. (*Shelf F1-2*)

***Interference demo*** - 2 possibilities here. One easy option is to set up a bright light bulb and pass out slit plates (contain single/double slits and various gratings) for students to look through individually. The interference patterns are strongly visible. A second option, (a bit more time consuming) is to set up a slit plate on the front desk, and shine red and green laser light through assorted slits (single and double) and diffraction gratings to see the effect of slit size/spacing as well as frequency on the patterns. (*Both experiments in kits on shelf A6-3*)