The Video Encyclopedia *of* Physics Demonstrations™

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DISC TWENTY-ONE

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Chapter 54

Inductance and LR Circuits

Demo 21-01 Inductance Spark

A coil is connected to a 6 VDC power source. When it is disconnected, the collapsing magnetic field induces a large voltage that creates a spark as the connector is removed.† When an iron core is inserted into the coil, the effect is enhanced, leading to a bigger spark, as seen in the video and in *Figure 1*.

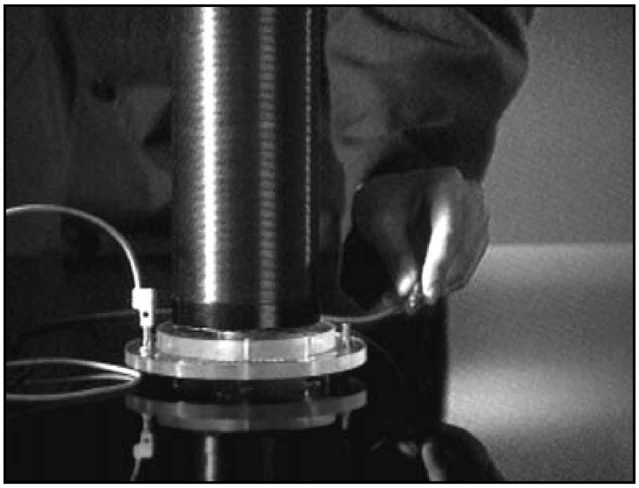

Figure 1

† Sutton, *Demonstration Experiments in Physics*, Demonstrations E-252, Self-inductance, and E-253.

This power supply puts out about 6 volts. When we touch the output leads together and separate them, no spark is seen.

If we hook the leads to this solenoid coil with 2000 turns of wire and disconnect one wire, a small spark is seen.

When an iron core is inserted into the coil and the sequence is repeated, a larger spark is seen.

Equipment

1. Power supply.
2. Appropriate electrical leads.
3. Large induction coil.
4. Iron core for induction coil.
5. AC power.

Demo 21-02 Inductor with Lamp on AC

A large coil is wired in series with a light bulb. When this circuit is placed across a 110-VAC source, the bulb glows brightly. When an iron core is inserted into the coil, the reactance of the coil increases and the voltage across the bulb decreases significantly, so it dims, as shown in *Figure 1* and in the video.†

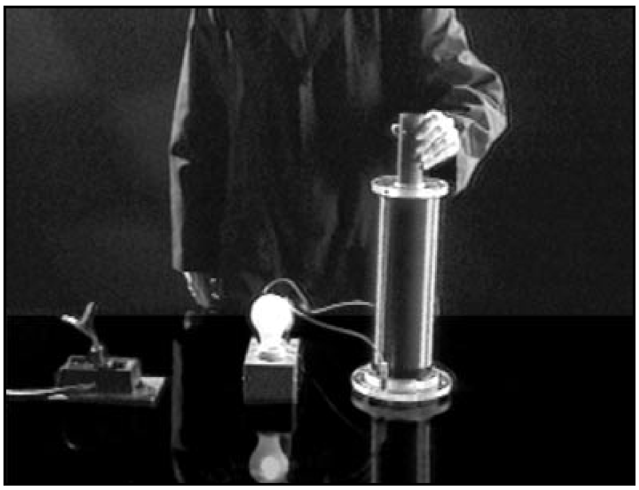

Figure 1

† Sutton, *Demonstration Experiments in Physics*, Demonstration E-258, Inductive Reactance.

We'll use this inductor coil and a light bulb to show the effect of inductance on an alternating current.

When the lamp and inductor are hooked in series to 110 volts AC, the lamp lights normally at first.

If we increase the inductance of the coil by inserting an iron core, the lamp dims as the core is inserted into the coil. The current flowing through the circuit has decreased.

Equipment

1. Same setup as Demonstration 21-01 without the power supply.
2. Light bulb and a socket base.
3. Switched AC power.

Demo 21-03 Lamps in Parallel with Solenoid

A large solenoid coil is wired in parallel with a neon bulb and an incandescent bulb, and a large DC voltage is applied to this circuit, as shown in *Figure 1*.† When the voltage is either switched on or off, a large potential is created across the lights, as indicated by a bright flash of the bulbs. The higher voltage at the start is caused by a ballast resistor in series with the solenoid, which has a small voltage drop at first. That voltage drop increases as the coil draws more current and the bulbs dim. The effect is greater when the coil has an iron core, as shown in the video. The direction of the EMF, indicated by the neon bulb, is opposite for the cases of turning the power on and off.

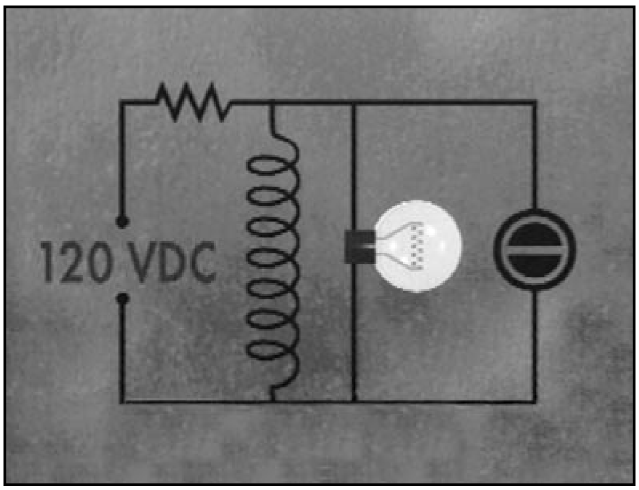

Figure 1

† Sutton, *Demonstration Experiments in Physics*, demonstration E-254, High Voltage from Low by Self-induction.

This incandescent lamp and this neon lamp are wired in parallel with a large solenoid coil.

When we apply a DC voltage to the coil, the lamps flash brightly first, then dim to a steady level.

What will happen to the brightness of the lamps if we open the switch?

Both lamps flash brightly when the switch is opened. The neon lamp flashes on the side opposite its first flash.

If we remove this iron core and repeat the demonstration, how will the brightness of the lamps change?

Without the iron core the effect is reduced.

Equipment

1. Large solenoid with a removable heavy iron core that has two lamp sockets wired in parallel with it, one for a neon lamp and one for an incandescent lamp.
2. Appropriate electrical leads.
3. DC power.

Chapter 55

LRC Circuits

Demo 21-04 Driven LRC Circuit

A series LRC circuit is driven by a sine wave oscillator at its resonant frequency. Using an oscilloscope with isolated inputs, the amplitudes and the phases of the voltage and current across each of the circuit elements can be observed.† The setup used in this demonstration is shown in *Figure 1*.

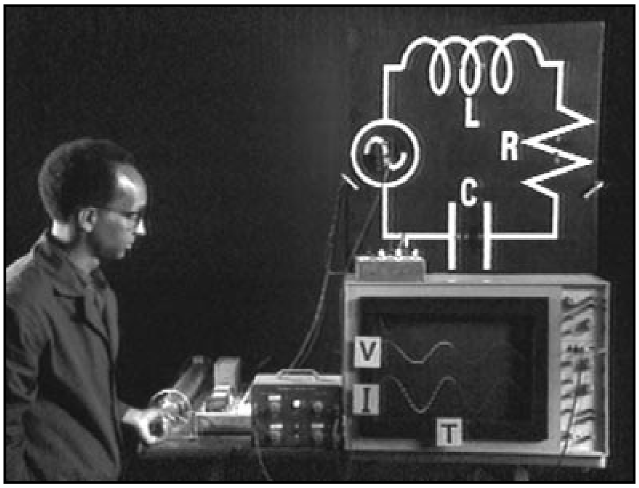

Figure 1

† Freier and Anderson, *A Demonstration Handbook for Physics*, Demonstration En-12, L-C-R Series Circuit.

We'll use this LRC circuit board to demonstrate electrical resonance.

An inductor, resistor, capacitor bank, and AC power source are hooked together in the configuration shown on the front of the board.

The voltage and current for each component can be displayed on an oscilloscope using this probe.

The value of the inductor can be changed to bring the circuit's natural frequency close to the driving frequency.

This causes the circuit to resonate, and a strong current flows.

Here are the voltage and current across the capacitor bank as the circuit passes through resonance.

Here are the voltage and current across the resistor.

Here are the voltage and current across the inductor.

Here are the voltage and current at the power supply as the circuit passes through resonance.

Equipment

1. LRC circuit board with vertical support.
2. Solenoid with removable iron core.
3. Bank of capacitors.
4. Series of small lamps.
5. Transformer.
6. Electronic switch.
7. Oscilloscope.
8. Appropriate electrical leads.
9. AC power.

Demo 21-05 Damped LRC Oscillation

A capacitor is charged and then discharged through a series LRC circuit. When the capacitor discharges into the circuit the system oscillates at its resonant frequency, and damps with a time characteristic for the particular values of the circuit elements.† The system used for this demonstration is shown in *Figure 1*.

In the video the voltage across the capacitor is plotted vs. time to show the resonant frequency and the decay time for damping of the oscillation. Several values of capacitance and resistance are used to study a variety of characteristic times. A time clock and a voltage scale are provided on the video screen for making measurements. Critical damping is also shown in the video.

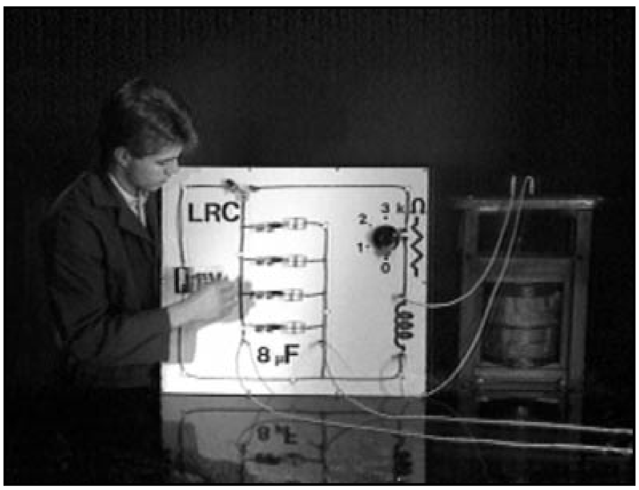

Figure 1

† Freier and Anderson, *A Demonstration Handbook for Physics*, Demonstrations En-9, Ringing Circuit, and Eo-13, Characteristic Times in a Series L-R-C Circuit.

This series circuit of a capacitor bank, a resistor, and an inductor will be used to demonstrate damped oscillations in an LRC circuit.

The voltage across the capacitors is shown by the vertical position of the trace on this oscilloscope. When the switch is thrown to the left, a battery charges the capacitor bank.

Throwing the switch to the right connects the charged capacitor in series with the resistor and inductor, with the resulting oscillations in capacitor voltage shown on the oscilloscope.

If we increase the capacitance, the period of the oscillations increases.

What will happen to the oscillations if we increase the resistance in the circuit?

The oscillations die away more quickly as the resistance is increased.

Equipment

1. Damped LRC board and vertical support.
2. Large solenoid.
3. Oscilloscope.
4. Appropriate electrical leads.
5. AC power.

Demo 21-06 Tesla Coil

Tesla coils produce very large AC voltages at very high frequencies using a typical circuit shown in *Figure 1*.† Some of the effects of this high voltage discharge are shown in the video, including inductive lighting of a fluorescent bulb. Because of the skin effect at high frequencies, this discharge can be safely passed through a person, as shown in the video.

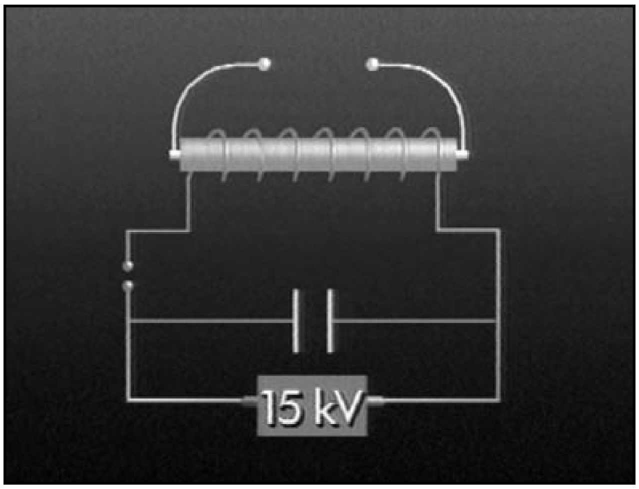

Figure 1

† Freier and Anderson, *A Demonstration Handbook for Physics*, Demonstration Ep-2, Tesla Coil.

This Tesla coil produces a very high-voltage discharge.

A 15,000-volt transformer provides the initial input. That is applied to a capacitor in series with a narrow spark gap, which breaks down under the high voltage thousands of times a second. The pulsed voltage produced by the breakdown feeds into this 8-turn primary coil. A secondary coil consisting of thousands of turns of fine wire amplifies that to a very high voltage at high frequency.

The electromagnetic radiation emitted can light a fluorescent tube at a distance.

Because of the high frequency and low current, the discharge can pass through a metal rod into the body with no harm.

Equipment

1. Tesla coil.
2. Large capacitor equipped with an adjustable spark gap.
3. Transformer.
4. Appropriate electrical leads.
5. AC power.
6. Fluorescent tube.
7. Aluminum rod.

CHAPTER 56

ELECTROMAGNETIC WAVES

Demo 21-07 Light in a Vacuum

A beeper and a light operate within a bell jar. As the air is pumped out of the jar, the sound disappears but the light can still be readily seen, illustrating that light does not require a medium in which to propagate, and passes readily through a vacuum.

We are able to see the stars through the vacuum of interstellar space, so light must be able to travel in a vacuum.

To verify that fact and contrast it with the behavior of sound, we'll remove the air from a jar containing this electronic siren and flashing light.

After most of the air is removed, the flashing light can still be seen. The sound can no longer be heard.

If we return the air to the jar, the sound becomes audible.

Equipment

1. Electronic siren, suspended inside a bell jar, is wired in series with an LED.
2. Pump plate.
3. Length of vacuum hose.
4. Vacuum pump.
5. DC power for the LED and siren.
6. AC power for the vacuum pump.

Demo 21-08 Straight Line Propagation

Light waves travel in straight lines, so we can speak of light traveling as "rays."†
Because light rays travel in straight lines, small or distant sources of light produce shadows. This demonstration shows that the shadows produced by various objects have the same shape as the objects, thus verifying that light does indeed travel in straight lines.

† Sutton, *Demonstration Experiments in Physics*, Demonstration L-15, Rectilinear Propagation of Light.
Freier and Anderson, *A Demonstration Handbook for Physics*, Demonstration Oa-1, Straight Line Propagation of Light.

A light bulb with a very small filament will be used to show that light travels in straight lines.

Shadows cast by these objects have the same shape as the outline of the objects themselves.

Equipment

1. Carbon arc lamp with the lenses removed.
2. DC power.
3. Cardboard shapes with differing geometries.

Demo 21-09 Pinhole Camera

A pinhole camera uses a small "pinhole" to define the rays of light from a bright source, thus creating an "image" on a screen on the opposite side of the pinhole.† This demonstration uses an iris as a pinhole and a light bulb filament as the object, as shown in *Figure 1*, to investigate the effect on the image of changing the size of the pinhole and changing the position of the object. An animation illustrates how the light rays create the "image."

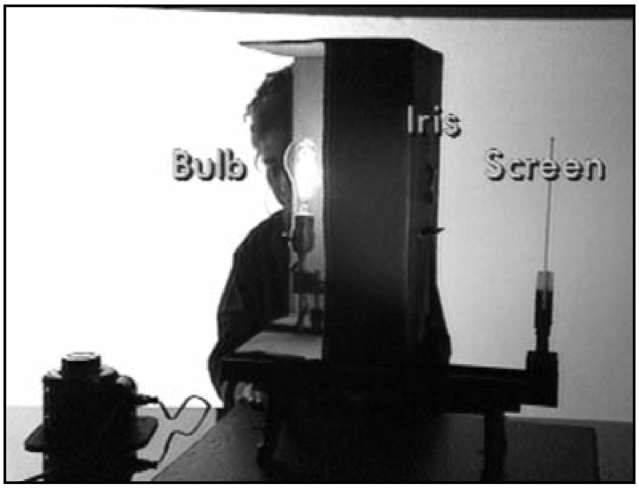

Figure 1

† Sutton, *Demonstration Experiments in Physics*, Demonstration L-16, Pinhole Camera.
Freier and Anderson, *A Demonstration Handbook for Physics*, Demonstrations Oa-2, Pinhole Projection, and Oa-3, Pinhole Camera.

We'll use this expandable iris to show how a small hole can be used to form an image of an object.

If we place the iris between the bulb and the screen, light passing through the hole in the iris forms an image of the filament on the screen. If we move the lamp farther away from the pinhole, the image becomes smaller.

This animation shows how the light from different parts of the filament reaches the screen and forms an image.

When the iris is widened, the brightness of the image increases but the shape of the image becomes indistinct.

Equipment

1. Pinhole camera arrangement made up of an expandable iris, a lamp whose filament enables one to easily determine orientation, and a box enclosure.
2. Translucent screen.
3. AC power.

Demo 21-10 Inverse Square Law

A general law of wave propagation that applies to all types of waves is the "inverse square law," which states that the intensity of a wave decreases inversely as the square of the distance from the source.† This demonstration uses a light photometer to measure the intensity of a small light source at various distances from the source, as seen in *Figure 1*. The resultant intensities follow the inverse square law, as shown by a graph of intensity vs. distance from the source presented in the video.

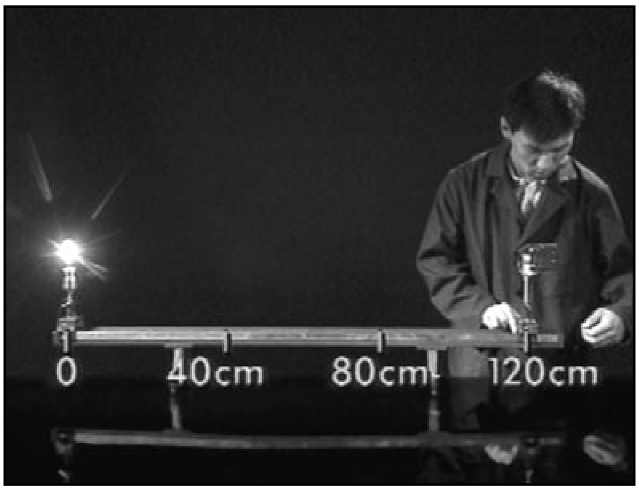

Figure 1

† Sutton, *Demonstration Experiments in Physics*, Demonstration L-11, Inverse Square Law of Intensity of Illumination.
Freier and Anderson, *A Demonstration Handbook for Physics*, Demonstration Oi-1, Inverse Square Law.

Light from a distant source appears much dimmer than light from the same source seen up close. We'll use this small filament light source and a photometer to demonstrate how the intensity of a light varies with distance.

The photometer measures the intensity of light falling on its sensor. When the photometer is 40 centimeters from the light, the light intensity reading is 0.41 lumens.

If we double the distance, the intensity is 0.10 lumens, or about one-quarter of the original reading. What will the intensity be at three times the original distance?

At three times the distance, the light intensity is 0.04 lumens, or about one-ninth of the original reading. This graph plots the intensity of the light measured at the three distances.

Equipment

1. Optics bench.
2. Two bench mounts.
3. Two parallel jaw clamps.
4. Photometer.
5. Small filament lamp.
6. AC power for lamp.

Demo 21-11 Radio Waves

A radio wave system with a wavelength of about 3 meters is used to illustrate the existence and transmission of radio waves.† A dipole transmitting antenna is oriented horizontally. A dipole receiving antenna indicates the reception of radio waves by an incandescent lamp whose intensity increases with the strength of the wave. When the receiving antenna is held close to and parallel to the transmitting antenna, the light glows brightly, as shown in *Figure 1*. As the receiver is moved further from the transmitter, the light becomes dimmer. When the two antennas are oriented perpendicular to each other, the light goes out, indicating the polarization of the radio waves.

Figure 1

† Sutton, *Demonstration Experiments in Physics*, Demonstration A-36, Ultra High-frequency Apparatus.

This radio transmitter and a metal pickup antenna will be used to show some of the properties of electromagnetic waves.

When the transmitter is turned on, an alternating current runs back and forth on these antenna rods at approximately 100 million cycles per second. The resulting electromagnetic wave is picked up on this antenna, and lights the light bulb connecting the two halves.

As the antenna moves further from the transmitter, the light bulb dims.

When the antenna is turned at right angles to the transmission antenna, the light bulb goes out.

Equipment

1. Basic radio wave transmitting demonstrator.
2. AC power.

Demo 21-12 Impossible Triangle

Three connected square aluminum bars, one of which has a cutout, are viewed by a video camera at a position from which the bars appear to be assembled into an impossible triangle, as shown in *Figure 1*. A pendulum is swung through the open end of the triangle so that it looks as though it were moving through solid material. Finally, the video shows how the illusion is accomplished by rotating the triangle on camera so that the opening is visible.

Figure 1

Here is an interesting triangle.

We can swing a pendulum through the triangle.

Here is how it works.

Equipment

A “triangular” shape on a support rod that can be viewed from different angles to present differing perspectives.

Demo 21-13 Lecher Wires

A long antenna consisting of two parallel wires is connected to the radio transmitter of Demonstration 11, as shown in *Figure 1*. This system, called "Lecher Wires," is used to show the standing electromagnetic waves in the antenna.† The contacts of a small incandescent bulb are connected to two heavy rods so this probe can be slid along the antenna with one rod contacting each of the two antenna wires. The small light glows brightly at the voltage antinodes along the antenna and does not glow at all at the voltage nodes. A graphics section illustrates the complete standing wave pattern.

Figure 1

† Sutton, *Demonstration Experiments in Physics*, Demonstration A-37, Lecher Wires.
Freier and Anderson, *A Demonstration Handbook for Physics*, Demonstration Ep-13, Lecher Wires.

These two wires hooked to a radio transmitter will be used to show standing electromagnetic waves.

This probe consists of an incandescent bulb wired between two conducting rods. When we touch the rods to the wires carrying the radio energy, the bulb will light when there is a sufficient difference in voltage between the two wires.

Here is the standing wave pattern of voltage differences between the two wires as the probe is run along their length.

Equipment

1. Two long, bare parallel wires.
2. Radio wave transmitter from Demonstration 21-11.
3. Probe made up from two conducting rods attached to either side of a small lamp and mounted on a non-conductive handle.
4. AC power.

Demo 21-14 Microwave Unit

A microwave emitter "E" that produces 3-cm microwaves is fixed in space, and a receiver "R" is mounted on a rotating platform, as shown in *Figure 1*. A bar graph of red light-emitting diodes located in front of the receiver provides a graph of length proportional to the intensity of the signal picked up by the receiver. When the receiver is directly in front of the emitter, the bar graph indicates a strong signal; as the receiver is rotated away from a line directly in front of the emitter the signal decreases, as indicated in the video by the length of the bar graph. The microwave beam can be blocked by a metal sheet, as shown in the video.

Figure 1

This microwave board consists of a microwave emitter mounted above a circular board so that it cannot move, a microwave receiver fastened to the edge of the board so that it rotates with the board, and a bar-graph display under the board. The length of the bar of lights indicates the amount of microwave radiation the receiver is picking up.

As this metal sheet blocks the beam, the bar shrinks. The bar returns to its former length when the sheet is removed.

Equipment

1. The Brett Carroll microwave board.
2. AC power.
3. Metal sheet.

Demo 21-15 Microwave Standing Waves

A metal sheet placed in front of the microwave transmitter of Demonstration 14 reflects the microwaves backward at an angle of 180° to form standing waves. A diode is used as the receiver probe. When the probe is moved along the line between the transmitter and the metal plate, it indicates the standing waves by responding to the intensity of the microwave signal at each point, as shown on the bar graph and in *Figure 1*. The bar graph indicates its maximum at voltage antinodes and virtually zero at voltage nodes in the standing wave. Using a graphic distance scale overlay on the video, the loop length of the microwave standing wave can be determined, from which the wavelength can be calculated as twice the loop length.

Figure 1

This setup consists of a microwave emitter, a diode which picks up the microwaves, and a bar-graph display whose length indicates the intensity of the microwaves picked up by the diode. This metal sheet reflects the microwave beam back upon itself.

If we place the diode close to the metal sheet and move it toward the emitter, we observe a standing wave pattern formed by the interference of the incoming and reflected beams.

Equipment

1. Same setup as the previous demonstration with the metal sheet held in place with magnetic bar.
2. Remote diode detector.

Demo 21-16 Microwave Absorption

Microwaves travel from the transmitter to the receiver as shown in Demonstration 14. If a dry paper towel is placed directly between the transmitter and the receiver the microwaves readily pass through the dry paper, as shown in *Figure 1*. When the paper is wetted, the water absorbs the microwaves and the receiver sees no transmitted signal, as shown in the video.

Figure 1

Microwave Absorption / Script

This device consists of a microwave emitter, a microwave receiver, and a bar-graph display whose length indicates the intensity of the microwaves picked up by the receiver.

If a dry cloth is placed in the microwave beam, the beam passes straight through the cloth without diminishing.

If we wet the cloth by dipping it in a beaker of water, the water absorbs the microwaves and the beam no longer passes through.

Equipment

1. Same setup as Demonstration 21-14.
2. Piece of cloth.
3. Supply of water.

Demo 21-17 Radio in Faraday Cage

Disc 17 Demonstration 14 showed that electric charge resides on the outside of a conductor because electric fields cannot penetrate the conductor. This is also true for changing electric fields such as those of FM radio waves, as shown in this video using the apparatus of *Figure 1*. When a metal screen "cage" is positioned over the radio, as shown in *Figure 1*, the sound of the radio is attenuated. A cage made of finer mesh screen blocks the signal entirely.

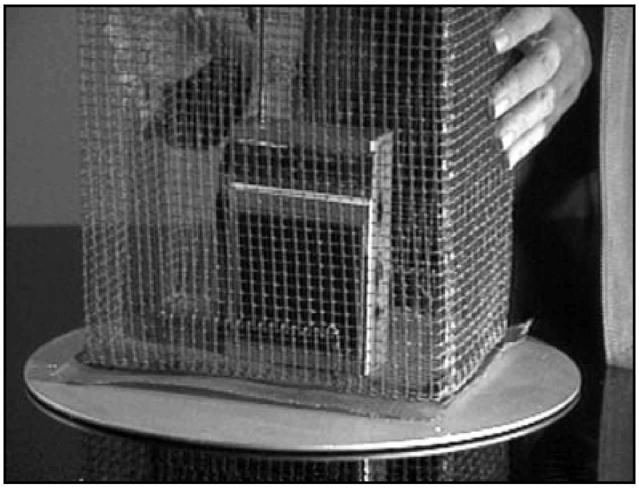

Figure 1

These metal cages are called Faraday cages. When an operating radio is placed inside the metal cage with the large mesh, the intensity of the signal is reduced due to the partial blocking of the electromagnetic radiation by the cage.

When the cage of fine mesh is placed over the radio, the signal intensity is reduced even more.

Equipment

1. Aluminum disc.
2. Square of fine copper screening.
3. Portable radio.
4. Hailstone screen enclosure.
5. Fine copper screen enclosure.

Chapter 57

Plane Mirrors

Demo 21-18 Microwave Reflection

A microwave beam is reflected obliquely from a smooth metallic surface. The video illustrates that the angle of incidence is equal to the angle of reflection for the microwave beam, as shown in *Figure 1*.

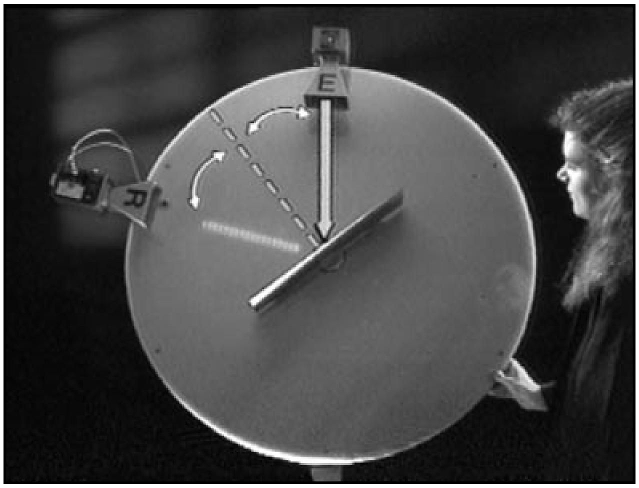

Figure 1

This device consists of a microwave emitter, a microwave receiver, and a bar-graph display whose length is proportional to the intensity of the microwaves picked up by the receiver. We'll use it to show how microwave radiation is reflected when it strikes a metal plate.

If we attach this aluminum plate to the center of the board, the display shows that the beam no longer passes through to the receiver.

Rotating the receiver around to the other side of the plate shows that the microwave beam is reflected by the metal plate.

The beam is reflected from the metal plate at the same angle at which it struck the plate.

Equipment

Same setup as Demonstration 21-14 with the metal plate held at a 45° angle by the magnetic bar.

Demo 21-19 Diffuse/Specular Reflection

Light beams reflected off a mirror surface produce reflected light beams, as shown in *Figure 1*. This is called specular reflection. When the same light beams strike a diffuse surface such as a piece of white paper, the light reflects off the paper in all directions, so that a reflected light beam cannot be seen. This is called diffuse reflection.† Both diffuse and specular reflection are illustrated in the video.

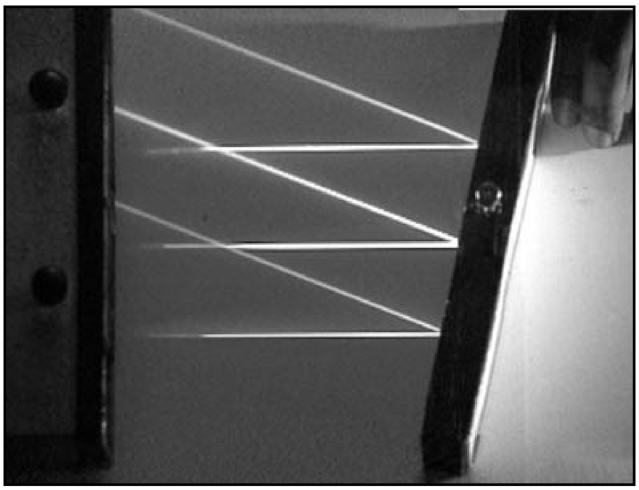

Figure 1

† Freier and Anderson, *A Demonstration Handbook for Physics*, Demonstration Ob-1, Reflection from Smooth and Rough Surfaces.

We'll use these light beams, and a mirror, to show two different types of reflection.

This side of the mirror reflects all parts of the beams at the same angle and we still have a beam. This is known as specular reflection.

The other side of the mirror is covered with a sheet of white paper. If we put that side in the light beams, the light is reflected in many directions and we no longer have a beam. This is known as diffuse reflection.

This animation shows how different parts of the beams are reflected from the two surfaces.

Equipment

1. Optics board.
2. Multiple-beam light source.
3. Transformer.
4. AC power.
5. Straight mirror with a piece of paper mounted on its backside.
6. Support bracket for mirror.

Demo 21-20 Angle of Incidence and Reflection

This demonstration illustrates that the angle of incidence is equal to the angle of reflection when a light beam reflects off a mirror surface.† An angle scale rotates with the mirror such that the angles of incidence and reflection can be readily observed and their equality verified, as shown in *Figure 1*.

Figure 1

† Sutton, *Demonstration Experiments in Physics*, Demonstration L-22, Laws of Reflection. Freier and Anderson, *A Demonstration Handbook for Physics*, Demonstrations Ob-8, Optical Disc, and Ob-11, Blackboard Optics—Plane Mirror.

Angles of Incidence and Reflection / Script

A narrow beam of light is aimed at a small mirror in the center of this disc.

This is the angle of incidence of the beam, and this is the angle of reflection.

We'll rotate the disc to show how the angle of reflection of the beam varies with the angle of incidence.

The angle of reflection is equal to the angle of incidence.

Equipment

1. Circular disc with protractor markings along its rim and a small mirror mounted at its center. A light beam source is mounted independently of the rotating disc at one side.
2. Transformer.
3. AC power.

Demo 21-21 Location of Image

A piece of plate glass is used as a partially silvered mirror to achieve the optical illusion of a candle burning in a beaker of water. The image of a candle burning in front of the plate glass appears to be in a beaker of water located that same distance behind the plate glass, as shown in *Figure 1*.† As the system is rotated in front of the camera, the candle appears to remain in the beaker of water, showing that the image has a fixed "location" in space. Finally the plate glass is removed, revealing the illusion.

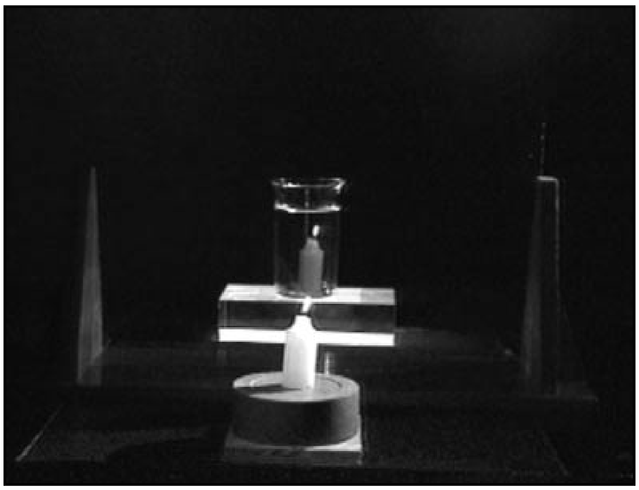

Figure 1

† Sutton, *Demonstration Experiments in Physics*, Demonstration L-18, Plane Mirror.
Freier and Anderson, *A Demonstration Handbook for Physics*, Demonstration Ob-2, Position of Image.

This sheet of glass acts a bit like a mirror, reflecting an image of a candle placed in front of it.

If we put a glass of water behind the glass sheet so that it seems to be in the same position as the candle's image, the candle seems to be burning underwater.

If we rotate the board on which the object sits so that we look at the image from a different angle, the candle's image stays in the glass of water at any viewing angle.

Equipment

1. Rectangular Lazy Susan.
2. Vertical sheet of glass and its support system.
3. Candle.
4. Source of flame.
5. Tall beaker of water.

Demo 21-22 Parity Reversal in a Mirror

A set of cartesian coordinate axes is compared with the reflection of an identical set of axes in a mirror, showing that parity is reversed in the image produced by a plane mirror. Only when two of the coordinates are interchanged in the test system is the image of the original set of axes the same as the test axes, as shown in *Figure 1*.† For this reason a plane mirror is said to produce a "perverted" image, in which there is no inversion top to bottom or left to right, but there is an inversion back to front. That produces a change in parity, or "handedness" in the image.

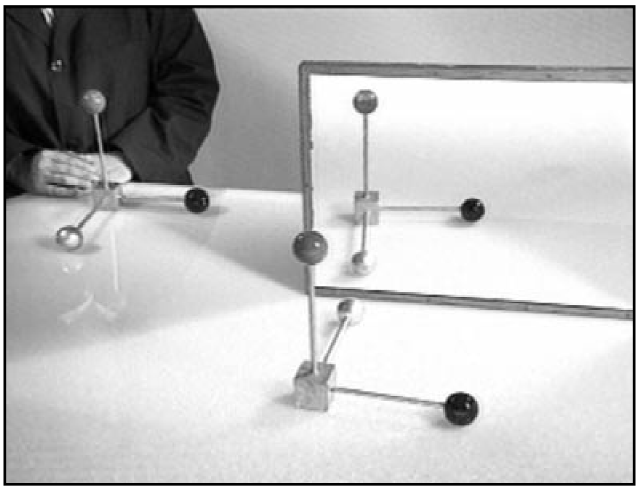

Figure 1

† Sutton, *Demonstration Experiments in Physics*, Demonstration L-18, Plane Mirror.
Freier and Anderson, *A Demonstration Handbook for Physics*, Demonstration Ob-9, Perversion.

We all know that images in a mirror appear reversed, but exactly how does an object differ from its mirror image?

We'll use these two identical ball and stick frames to find out. If they are set side by side, the different colored balls are in the same position on both frames.

Here is the image of one of the frames in a mirror. If we place the second frame the same distance behind the mirror as the image, we can not make the position of the colored balls coincide with those in the image.

When we reverse the position of any two of the balls in the second frame, it can easily be made to coincide with the image in the mirror.

Equipment

1. Mirror.
2. Two coordinate models with differing colored spheres at the ends of the axis where the rods can be interchanged in one set.

Demo 21-23 Hinged Mirrors

Two mirrors joined by a hinge are separated by a variety of angles to observe the symmetry of the images created.† A single light placed in front of one of the mirrors produces a number of images that depend on the angle between the two mirrors. In general, the number of lights (object plus images) will be equal to 360° divided by the angle between the two mirrors, as shown in the video and in *Figure 1* for the case of the mirrors at 90°.

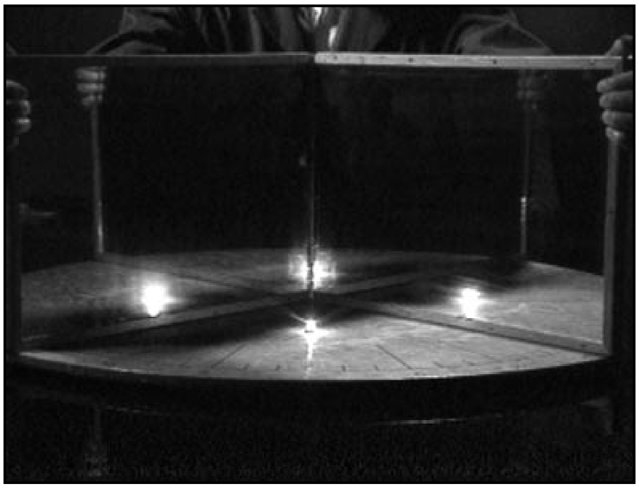

Figure 1

† Sutton, *Demonstration Experiments in Physics*, Demonstration L-20, Multiple Reflections in Plane Mirrors.
Freier and Anderson, *A Demonstration Handbook for Physics*, Demonstration Ob-4, Mirrors at an Angle.

We're used to seeing only one image in a mirror. But if we put two mirrors together at an angle, we can get images of images, producing an interesting pattern.

Here are the two mirrors at 90 degrees to one another.

We see the object and the three images in a regular pattern. If we move the mirrors to 60 degrees, how many images will we see?

There are now five images and one object for a total of six light bulbs arranged in a hexagon.

Equipment

1. Two mirrors hinged together at their edges, sitting on a protractor type base with a small lamp and socket at its center.
2. DC power for the lamp.

Demo 21-24 Corner Reflector

A corner reflector can be formed by three mirrors positioned on the inside surfaces of the corner of a box, at right angles to each other. The fascinating feature of this type of mirror arrangement is that a ray of light striking one of the mirrors will reflect successively off the three mirrors and return antiparallel to its original direction back to its source.† (This can be readily proved using geometry). In the video the corner reflector shows the image of two students beside the video camera taking the picture, as shown in *Figure 1*.

An array of corner reflectors was placed on the moon by the Apollo astronauts in 1969, and has been used regularly since then with a pulsed laser beam in a series of experiments known as lunar ranging.

Figure 1

† Sutton, *Demonstration Experiments in Physics*, Demonstration L-21, Plane Mirrors—Special Combinations.
Freier and Anderson, *A Demonstration Handbook for Physics*, Demonstration Ob-6, Straight Back Reflector.

This corner reflector consists of three mirrors attached at right angles to form the corner of a box.

The two students whose images appear in the mirror are looking into the mirror along the same axis as the camera, which can be seen between their faces. Regardless of the angles to which the third student turns the corner reflector, the two students and the camera always see their own inverted images at the corner point of the reflector.

Equipment

Three flat mirrors mounted together at their edges to form a corner.

Demo 21-25 Barbershop Mirrors

Two mirrors placed parallel to each other a few feet apart can be used to study multiple reflections of the type often found in barber shops.† Tilting one of the mirrors slightly separates the images, allowing us to clearly view more images, as seen in the video and in *Figure 1*.

Figure 1

† Freier and Anderson, *A Demonstration Handbook for Physics*, Demonstration Ob-5, Parallel Mirrors.

When two mirrors are placed opposite one another, multiple reflections result.

An object placed between the mirrors produces many images, identical in orientation but decreasing in size with each reflection.

Tilting one of the mirrors skews the reflections off to the side.

Equipment

1. Two vertical parallel mirrors facing one another, one taller than the other.
2. Objects of interest.

Demo 21-26 Mirror Box

A mirror box consists of a large box with holes in the ends and a half-silvered mirror in the middle, with a light on each side. The lights are wired across a variac such that when one of the lights gets brighter the other gets dimmer. Two people stick their heads into the box to perform the experiment. As the lighting is changed, the brighter face is seen more strongly by both observers. When the lighting on both sides is approximately equal, the images of the two faces are superposed, as shown in the video and in *Figure 1*. An animated graphics section further explains this phenomenon using ray diagrams.

Figure 1

This mirror box consists of a half-silvered mirror in the middle of a large box with light bulbs on each side of the mirror.

The light bulbs are connected to a variac such that when one gets brighter the other gets dimmer.

When two people stick their heads into the ends of the box and the lights are adjusted,

each person observes a metamorphosis of one of the viewers into the other.

Here is a ray diagram showing how light from each person can be seen by either one of them.

Equipment

1. A box enclosure with a half-silvered mirror mounted vertically at its midpoint, with a light bulb mounted in far corners that can be dimmed as required.
2. Two variacs.
3. AC power.