The Video Encyclopedia *of* Physics Demonstrations™

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ATOMIC PHYSICS

Demo 25-01 Emission Spectra

When an electric discharge is passed through a gas, changes of energy level within the atoms and the molecules, including the ionization and recombination of electrons into the atoms and molecules of gas create spectra that are characteristic of the particular gas.† *Figure 1* shows the experimental setup, which uses a replica grating held in front of the video camera to view the spectra directly and obtain very bright results. Several spectra are displayed in the video, including the continuous spectrum of an incandescent lamp and the spectra of three discharge tubes.

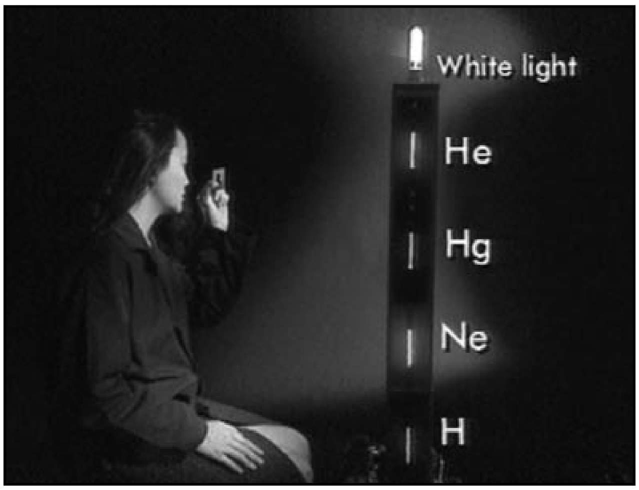

Figure 1

† Sutton, *Demonstration Experiments in Physics,* Demonstration L-104, Bright Light Spectrum..

Some light sources emit all different colors of light and produce white light, others emit only certain colors. We'll use this diffraction grating to separate the colors and the light from various sources to show the types of light emitted by each source.

Here is an incandescent lamp, which increases in brightness as we turn up the voltage. Notice how the spectrum begins with only red light, then spreads out to include other colors as the temperature of the filament increases.

Here are four different gas discharge lamps and their spectra. This time only certain specific colors are present in the light from each lamp.

Equipment

1. Straight filament display lamp.
2. Variac.
3. Four spectra tubes, racked and wired in series, and the transformer: hydrogen, neon, mercury, and helium.
4. Diffraction grating.
5. AC power.

Demo 25-02 Spectral Absorption by Sodium Vapor

Very hot vapors of various elements are often ionized, as occurs in a discharge tube. Somewhat cooler vapor will absorb the same radiation that it emits at higher temperatures. This demonstration shows the absorption of the light from a sodium source by the cooler vapor from a sodium flame. A salt of sodium is burned in front of a large sodium lamp, creating the dark absorption region seen in the video and *Figure 1*.

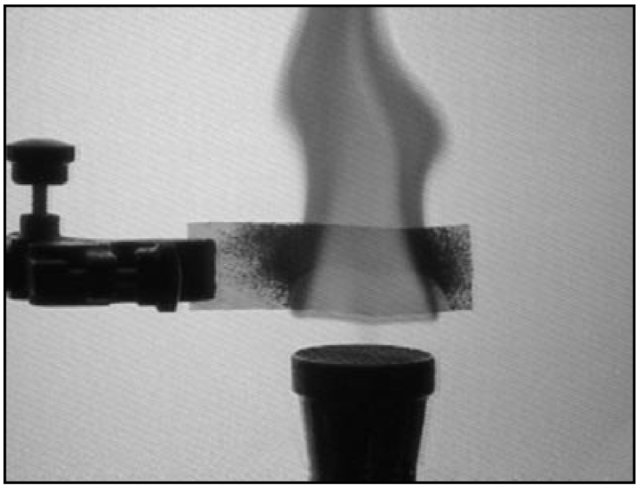

Figure 1

When this sodium chloride is held in a flame, it emits yellow light.

If we put this sodium flame in front of a screen back lit with white light, we can clearly see the white light through the transparent yellow flame.

If we move the flame in front of this screen back lit with the same yellow light emitted by the sodium, what will we see?

The flame appears very dark in front of the yellow screen. The hot sodium strongly absorbs the same yellow light that it emits.

Equipment

1. Stainless steel wire mesh screen, moistened and dipped in salt.
2. Parallel jaw clamp, right angle clamp, and a ring stand resting on a sliding board along with a Meeker-type burner.
3. Length of rubber tubing and a supply of natural gas.
4. Source of flame.
5. Translucent screen physically divided in half so one side can be illuminated from the rear with white light independently of the other side being flooded with sodium light, also from the rear.
6. Bank of white fluorescent lights.
7. Intense sodium lamp.
8. AC power.

Demo 25-03 Thermionic Emission

Electrons may be emitted from a hot filament through a process known as thermionic emission.† The electrons are "boiled" off the surface and accelerated by a screen that is at a positive potential with respect to the hot filament. They then strike a positively charged anode, on which they are "measured" as an electrical current. The entire system is shown in *Figure 1*, and described in detail in the video using graphics. In this video aspects of thermionic emission are studied, illustrating that electron currents are produced only if the filament is hot and if the hot filament is negatively charged with respect to the anode.

This type of electron discharge is often used in electron tubes, one example is the classical electron e/m apparatus demonstration (Disc 20 Demonstration 4: Fine Beam Tube).

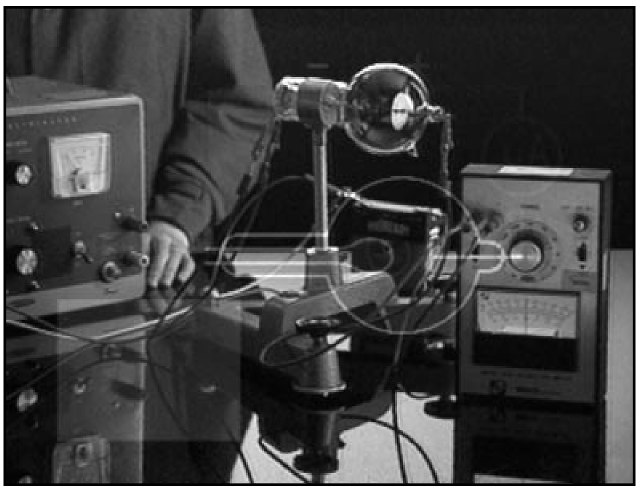

Figure 1

† Sutton, *Demonstration Experiments in Physics,* Demonstration A-16, Hot-cathode Discharges.

When a metal wire becomes hot, electrons in the metal atoms gain kinetic energy and can more easily leave the surface.

We'll use this evacuated glass tube to show the effect.

Two electrodes inside the tube are connected to a 90-volt battery. The negative electrode is a wire which is connected to a power supply that can run a current to heat the wire.

When the wire is cold, no current runs between the electrodes despite the high voltage between them, as shown on this microammeter.

When we heat the wire, current flows between the two electrodes.

If we reverse the battery so that the wire electrode is connected to the positive side of the battery and repeat the demonstration, what will happen?

With the wire electrode positive, current will not flow even when the wire is hot. This is an example of a primitive diode.

Equipment

1. Simple evacuated glass diode tube and a support system.
2. Micrometer.
3. 90-volt dry cell.
4. Power supply.
5. Appropriate electrical leads.
6. AC power.

Demo 25-04 Electron Discharge Tube with Cross

An electron discharge tube is used to show that electrons, like light waves, move in straight lines. Electrons from the cathode of the discharge tube move across the tube, where they encounter a Maltese cross, as seen in *Figure 1*. The electrons are made visible by phosphur on the inner surface of the tube at the right, where they clearly show the shadow of the cross.†

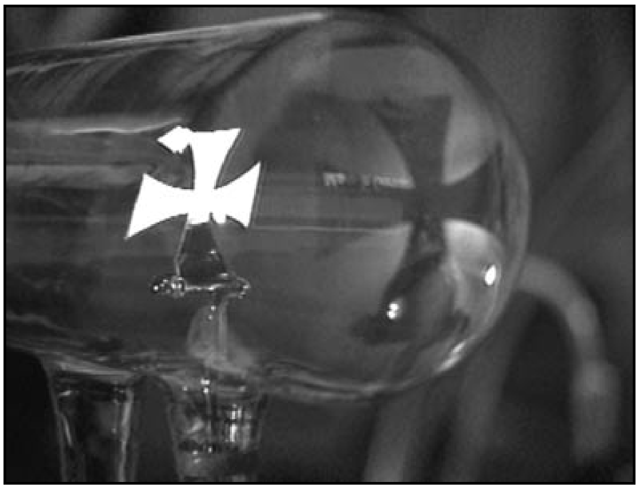

Figure 1

† Sutton, *Demonstration Experiments in Physics,* Demonstration A-13, Special-purpose Discharge Tubes.

We'll use this electron discharge tube to demonstrate that electrons can cast shadows just as light does.

Electrons are emitted by this electrode, and fly toward the side of the tube, where they make the glass glow faintly.

If this maltese cross is inserted in the path of the electrons,

a clear shadow of the cross is seen on the side of the tube.

Equipment

1. Maltese cross discharge tube.
2. Induction coil.
3. Battery eliminator.
4. Appropriate electrical leads.
5. AC power.

Demo 25-05 Discharge Tube and Vacuum Pump

A high DC electric potential is applied to the ends of a glass tube containing air at atmospheric pressure. As the air is pumped out of the tube, a variety of different discharge phenomena can be seen, including the Crookes and Faraday dark spaces, which are shown in *Figure 1*.† As the pressure is decreased by pumping on the tube, a glow discharge begins at the negative end of the tube, then encompasses the entire tube, as the mean free path of the electrons in the low-pressure air becomes longer. At a few millimeters of pressure the dark spaces make their appearance.

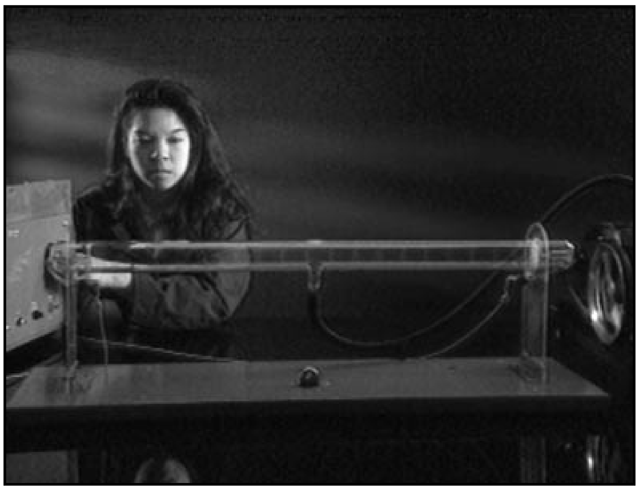

Figure 1

† Sutton, *Demonstration Experiments in Physics,* Demonstration A-12, Glow Discharge.

This long glass tube has electrodes at each end, which are hooked to a high voltage power supply.

A vacuum pump will be used to evacuate the air from the tube, and the high voltage will cause a discharge through the tube which will change with changing pressure.

When the pressure is low enough the discharge begins.

When the pressure is less than one-thousandth of an atmosphere a series of glowing discs forms in the discharge.

Equipment

1. Long glass tube with electrodes at both ends and evacuation port near its center.
2. 7-kilovolt power supply.
3. Appropriate electrical leads.
4. Length of vacuum hose.
5. Vacuum pump.
6. AC power.

Demo 25-06 Plasma Tube

A commercial "plasma tube" is used to illustrate a type of discharge phenomenon. A high-voltage, high-frequency AC potential between the center electrode and the inner coated surface of a partially evacuated glass sphere creates a spark, as shown in *Figure 1*. As the demonstrator moves her hand around the sphere, the spark follows her hand, as shown in the video. Because the discharge is of a very high frequency and ends at the inside surface of the sphere, the demonstrator feels no electric shock!

Figure 1

This glass globe contains inert gases at low pressure. If it is excited by a high-voltage, high-frequency discharge, the atoms of the gas break down and form filaments of plasma which we can see because of the light they emit. A hand brought near the globe attracts the filaments of plasma.

Equipment

1. Commercially available plasma tube.
2. AC power.

Demo 25-07 Flame Salts

Various salts are held in a flame to produce the flame colors typical of those materials. The materials shown in the video are ferric chloride, cupric chloride, and lithium sulfate. The different colors, created by the ionization and recombination of electrons with the atoms in the flame, can be readily seen.

Many salts generate different colors when put in a flame. We'll use these three salts to show some examples of these colors.

Here is a sample of ferric chloride, an iron salt, put in a flame.

Here is a sample of a cupric chloride, a copper salt.

Here is a sample of lithium sulfate.

Equipment

1. Three pieces of stainless steel wire screen mesh.
2. Forceps.
3. Three salts: ferric chloride, cupric chloride, lithium sulfate.
4. Supply of water.
5. Meeker-type burner.
6. Length of rubber tubing.
7. Supply of natural gas.
8. Source of flame.

Demo 25-08 Jacob's Ladder

A Jacob's ladder consists of a pair of high voltage electrode wires that are close together at the bottom and get further apart at their top. When a high voltage is applied, a spark is created at the bottom of the ladder, where the wires are close together, and rapidly rises to the top. As the spark tries to rise further it becomes extended over too long a distance, goes out, and starts again at the bottom, repeating the above procedure, as shown in the video and seen in *Figure 1*.

The region in which the discharge occurs constitutes a plasma that contains a hot mixture of the gases in the air, ionized gases, and electrons. Because it is hot, the discharge region rises, as seen in the video. The spark continues to follow the path along the discharge because of the low resistance, or higher conductivity, of that path.

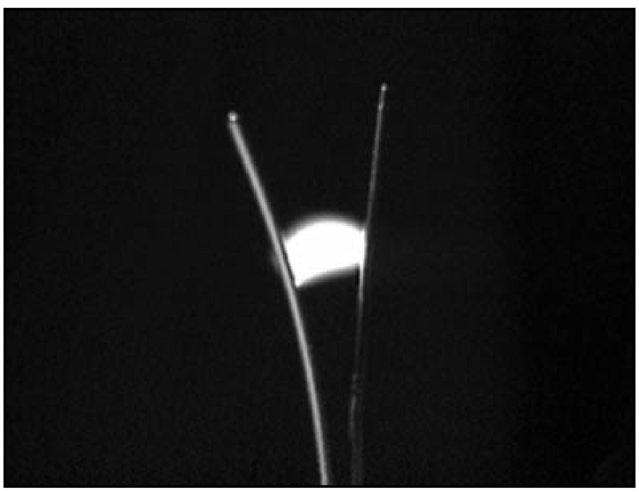

Figure 1

This device is known as a Jacob ladder.

Two wires are supported so that they are close together at the bottom but spread apart as they go up.

When we apply a high AC voltage to the wires, an arc starts at the bottom, then rises to the top.

The arc breaks at the top and reforms at the bottom, and the cycle repeats.

Equipment

1. Jacob's ladder coil attachment.
2. Transformer.
3. Appropriate electrical leads.
4. Variac.
5. AC power.

Demo 25-09 Triboluminescence

Triboluminescence occurs when certain types of materials undergo separation of charge upon splitting, which then discharges as a visible spark. Unrolling certain types of cellophane tape can create triboluminescence. A triboluminescent effect can be seen as sparks that occur when Wintergreen candy is broken, as shown in the video.

Triboluminescence / Script

When some materials are fractured, they give off faint flashes of light—a property known as triboluminescence.

This wintergreen candy shows triboluminescence when it is crushed beneath a piece of glass.

Equipment

1. Very dark room.
2. Supply of wintergreen Lifesavers.
3. Two pieces of very thick glass.

Demo 25-10 Luminescence

Certain materials glow in the dark after being illuminated by ultraviolet radiation, a phenomenon called luminescence. This video presents several examples of such objects, and illustrates the effect of shielding the ultraviolet to prevent luminescence.

You've probably seen materials which glow in the dark after exposure to light. This property is known as luminescence.

Ultraviolet light is the strongest means of exciting luminescence, as shown by this black light and glow-in-the-dark sword.

A hand held around the sword blocks the ultraviolet light and the portion of the sword that was covered does not glow as brightly as the rest of the sword.

Equipment

1. Ultraviolet light source.
2. Collection of luminescent items.
3. Dark room.
4. AC power.

Demo 25-11 Fluorescence

Objects that glow brightly when they are illuminated by ultraviolet light are said to be fluorescent. This video shows several types of materials that exhibit fluorescence, including certain laundry detergents, some rocks, and some chemicals found in chalk and glass.

Fluorescence / Script

Many chemicals exhibit fluorescence in ultraviolet light. Here are samples of various materials, and the colors that they emit.

Fluorescence is used in this laundry detergent to make clothes “whiter than white.”

Here are some other examples of fluorescent materials.

Equipment

1. Ultraviolet light source.
2. Collection of fluorescent materials.
3. Dark room.
4. AC power.

Demo 25-12 Franck-Hertz Effect

The Franck-Hertz effect is the classic demonstration illustrating that electrons are bound to atoms in specific energy levels. As a beam of electrons is passed through a tube containing mercury vapor at low pressure, little current is seen until the kinetic energy of the electrons is large enough to eject electrons from their orbital states. Greater current is produced, as shown in the video, when the electron beam has sufficient energy to knock out two orbital electrons, then three, and so forth. This is observed as a series of current peaks in the graph of current versus electron accelerating voltage displayed on an oscilloscope in the video, and seen in *Figure 1*. The energy (or voltage) between peaks is the same, and is equal to the energy required to remove one electron from a mercury atom. A graphics section is presented illustrating the mechanism for this phenomenon.

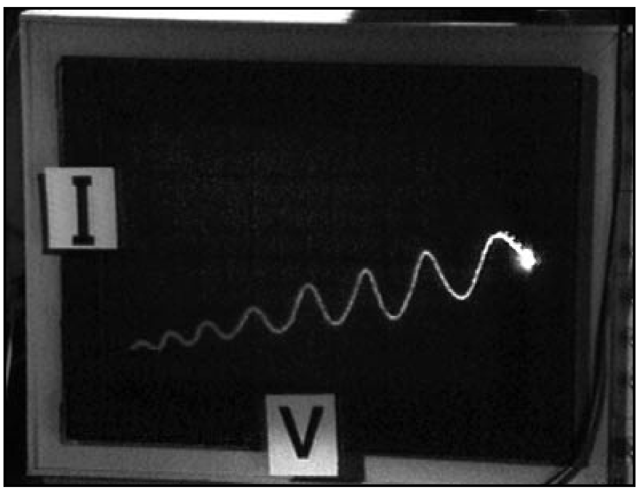

Figure 1

The Franck-Hertz effect shows that atomic energy levels are quantized.

A glass tube filled with neon gas and a small amount of mercury has three electrodes inside as shown on this diagram. This heated electrode emits electrons, which are accelerated toward this wire mesh electrode by a positive voltage applied to it. A third electrode behind the wire mesh is always 1.5 volts lower than the voltage we put on the wire-mesh electrode.

We'll gradually increase the voltage on the wire-mesh electrode from zero to 30 volts. The increasing voltage will also drive the horizontal sweep of this oscilloscope.

Some of the current from the first electrode will pass through the wire-mesh electrode and strike the third electrode. We'll amplify that current and use it to drive the vertical scan of the oscilloscope.

Here is the curve generated as the voltage is increased. Notice the regular peaks and dips in the current which provide evidence of the quantization of the energy levels in the mercury atoms.

Equipment

1. Commercially available Franck-Hertz apparatus.
2. Thermometer.
3. Appropriate electrical leads.
4. Oscilloscope.
5. AC power.

CHAPTER 68

NUCLEAR PHYSICS

Demo 25-13 Rutherford Scattering

This graphics demonstration illustrates Rutherford scattering, the scattering of alpha particles by heavy nuclei. This experiment established the atomic model of a very small, dense, positively charged nucleus surrounded by a very spread-out cloud of electrons. The scattering of incoming alpha particles is shown in animation for a variety of impact parameters, and the curve of the average number of scattered alphas as a function of scattering angle is presented in the video.

This animation shows how alpha particles are scattered by the electric field from the positive charges in an atomic nucleus.

If the alpha particle passes by the nucleus at a distance, it is only slightly deflected.

A closer pass by the nucleus produces a stronger deflection. If the alpha particle is aimed directly at the nucleus, it can be scattered directly backwards by the intense electric field close to the nucleus.

The fact that such scattering occurs was the first direct evidence that the positively charged particles in an atom are concentrated in a very small space, the nucleus of the atom.

Equipment

This demonstration is an animation.

Demo 25-14 Nuclear Shielding

With the apparatus as shown in *Figure 1*, a Geiger tube is used to observe beta particles and gamma rays from radioactive sources and to study the effect of shielding in attenuating the beams.† Five aluminum sheets are shown in the video to significantly attenuate the electrons, or beta particles, which is shown to be roughly equivalent to a single lead sheet of about the same thickness. On the other hand, the five aluminum sheets have a negligible effect on the gamma rays, and a single lead sheet attenuates the beam only slightly.

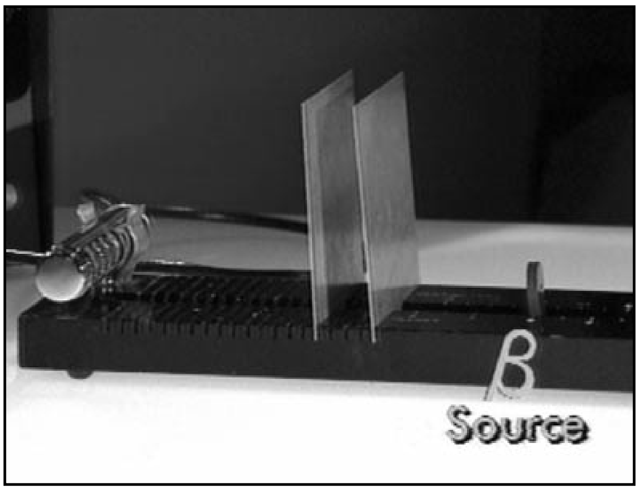

Figure 1

† Freier and Anderson, *A Demonstration Handbook for Physics,* Demonstration MPa-2, Geiger Counter.

Radioactive decay particles, such as beta, or gamma radiation, can be blocked by certain materials.

We'll use this Geiger counter to demonstrate how such shielding varies from one material to another.

When a beta source is put down 20 centimeters away from the tube of the Geiger counter, the Geiger counter begins to click at a rate proportional to the number of beta particles passing through the tube.

If we insert aluminum shields one at a time between the Geiger counter and the source, the count rate is reduced with each additional sheet.

Now we remove the aluminum and insert a single lead sheet.

This one sheet is more effective at blocking the particles than were multiple aluminum sheets.

Here are the actions repeated using a gamma source instead of the beta source.

First with aluminum shields.

Notice that the aluminum does not block the gamma particles as effectively as it blocked the beta particles.

Here is the effect on the gamma particles when lead sheets are used.

Equipment

1. Geiger counter.
2. Differing radioactive sources.
3. Stack of cardboard squares.
4. Stack of aluminum squares.
5. Stack of lead squares.
6. Rack for the above with slots for the absorbers.

Demo 25-15 Mousetrap Chain Reaction

An array of mousetraps, each loaded with two Ping-Pong balls, is used as the classic model of an uncontrolled nuclear chain reaction, as seen in *Figure 1* just as the device is fired.† The Ping-Pong balls represent neutrons in the uranium nuclei, which are exemplified by the mousetraps. Under normal circumstances this system is stable. However, when another ball, representing a fast neutron from another source, is thrown into the array, the ball will strike one of the mousetraps, causing it to release its energy and send its two Ping-Pong balls flying rapidly off. These balls strike other mousetraps, which release their energy to their Ping-Pong balls, resulting in a multiplicative effect, as the entire system goes off.

This system models nuclear fission. When neutrons strike uranium nuclei, the struck nuclei divide into two smaller nuclei, each of which releases energy and several fast neutrons. These neutrons in turn strike other uranium nuclei, causing them to fission, releasing more energy and fast neutrons. If the amount of uranium available is limited, the device can be used as a fission reactor to produce heat for an electric generator. If the amount of uranium exceeds the critical mass, the fission reaction proceeds in a rapid and uncontrolled manner, creating a uranium, or atomic, bomb.

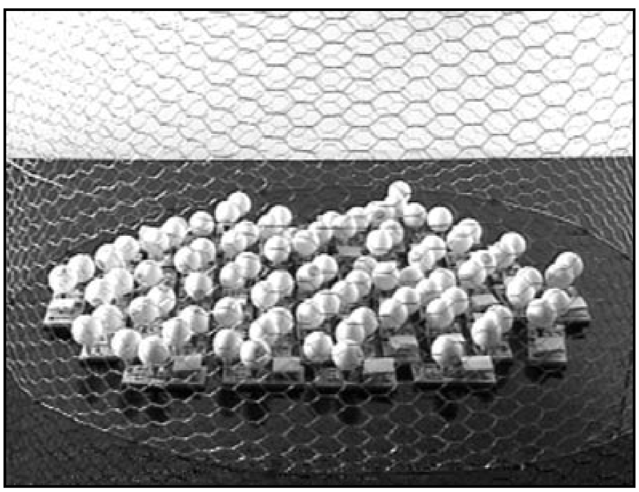

Figure 1

† Freier and Anderson, *A Demonstration Handbook for Physics,* Demonstration MPa-1, Mousetrap Chain Reaction.

Nuclear chain reactions are the basis of nuclear power and nuclear weapons.

We'll use this set of mousetraps to demonstrate how a chain reaction works. Each mousetrap has been set, then loaded with two Ping-Pong balls. Each mousetrap represents an atomic nucleus, while the Ping-Pong balls represent neutrons inside the atomic nuclei.

When a single Ping-Pong ball is dropped inside, a chain reaction begins.

Here it is again in slow motion.

Equipment

1. Series of mousetraps equipped with two golf tees and enlarged triggers.
2. Supply of Ping-Pong balls.
3. Chicken wire enclosure with a hole in the top to drop the trigger ball through.

Demo 25-16 Half-Life

The half-life of a radioactive material is the statistical average time during which one-half of that material will decay. The half-life is illustrated in this demonstration for an isomer of Barium 137 with a half-life of about 170 seconds. The Barium 137 radioisotope is the daughter from the beta decay of Cesium 137, an isotope with a thirty-year half-life which is readily available commercially. Barium 137 decays by an isomeric transition, emitting a 662-keV gamma ray, which is observed using a Geiger counter attached to a computer.

In the video, the Barium sample is prepared by chemically separating it from the Cesium. Gamma rays from the Barium are counted and the number of counts per ten-second interval displayed by the computer. The number of counts per ten-second interval decreases, as shown in the video and in *Figure 1*, such that after one half-life of about 160 seconds the count rate is about one-half of its original value.

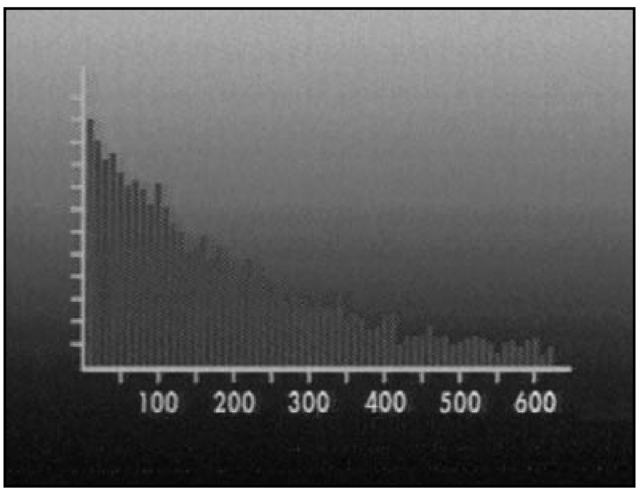

Figure 1

Radioactive decay is characterized by a time span known as the half-life of the radioactive material. We'll use this Geiger counter connected to a computer to demonstrate the concept of half-life.

When a radioactive sample is held near the Geiger counter, the computer adds up all the counts received in a ten-second span and displays the total in a bar-graph form.

We'll prepare a radioactive sample by washing a small amount of a short-lived isotope, into this vial.

New bars for each ten-second count total will be displayed at one-second intervals on the screen.

After 160 seconds of real time, the total of the counts in each ten-second interval has decreased by about half from the original.

After another 160 seconds, they have decreased by half again. The count totals continues to decrease by half every 160 seconds. The half-life of this isotope is about 160 seconds.

Equipment

1. Miniature radioisotope generator.
2. PC computer.
3. Geiger counter peripheral.
4. AC power.

Demo 25-17 Cosmic Rays

Cosmic rays from outer space interact with the air in the upper atmosphere to produce cosmic ray muons, which shower the earth's surface continually. Because these cosmic ray muons are very energetic, they pass through most objects, including the human body, with virtually no effect, only to be absorbed in the interior of the earth.

This demonstration illustrates the existence of cosmic rays using two cosmic ray detectors in coincidence, that is, two detectors that see the same cosmic ray muon as it proceeds from outer space, through the atmosphere, and into the earth. If the two detectors are vertically aligned, coincident cosmic rays can be observed, because cosmic rays come from almost directly above us. When the two detectors are horizontally displaced, no cosmic ray coincidences are observed, as shown in the video. In the final scene a student is sandwiched between the two cosmic ray detectors, as seen in *Figure 1*, while the system is reading coincident cosmic rays, illustrating that we are indeed being continually bombarded by cosmic rays that we cannot detect by our bodies alone.

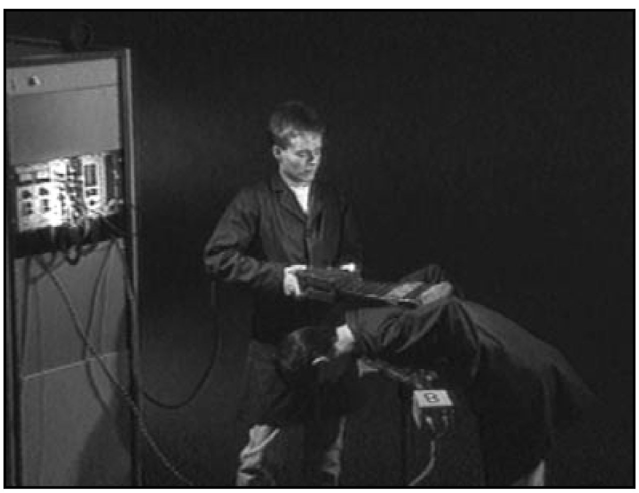

Figure 1

This array of electronic instrumentation is set up to identify cosmic ray muons.

Two paddles of plastic scintillator material, labeled A and B, respond to an energetic cosmic ray muon by producing a click in the loudspeaker, which you can hear.

Here are muons detected by paddle A. Here are muons detected by paddle B. This apparatus is also able to tell us when the same cosmic ray muon is detected by both paddle A and paddle B, called a coincidence.

Because most cosmic ray muons come straight down from directly above, no coincident muons are observed unless one paddle is directly above the other. If the paddles are aligned vertically the same muon can come through both paddles and create a coincidence.

If a person lies between the two paddles, we can see that coincident muons passing through both paddles have to pass through the person. Humans on Earth are subject to continual bombardment by cosmic ray muons.

Equipment

1. Electronic cosmic ray detection assembly.
2. Two plastic scintillator paddles.
3. Loudspeaker.
4. Appropriate electrical leads.
5. AC power.