Physics Laboratory Safety Manual

Georgia Gwinnett College

Introduction

Balancing Creativity and Safety: Experimental physics motivates teachers and students to create new techniqu

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Mechanical Hazards

A. Exposed Belts: Exposed belts and pulleys must be covered with a shield. This prevents the hazard of broken belts, and of fingers or clothing being caught between belts and pulleys.

B. Falling Masses: Heavy masses may be used in experiments involving Atwood's machine, free fall, Newton's laws, and momentum. Warning should be given to students to prevent hands and feet from being caught between a moving heavy mass and floor or table surfaces. Students may not beTticipabr

Electrical Hazards

A. Physiological Effects

1. Body Resistance: Students must be warned of the high death potential present even when the voltage is low. The severity of an electrical shock depends primarily on the amount of current to which a person is exposed. Since the current is related to the resistance and voltage, these two factors, as well as the part of the body involved and the duration of the contact, determine the extent of injuries to the victim. If the skin is wet or the surface broken, the resistance drops off rapidly, permitting the current to flow readily through the bloodstream and body tissues. *See chart below for relative hazards of electric shock.*

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
electrode	40,000	2.8	one wet finger on each
each electrode	16,000	6.8	one salt/wet finger on e
rode	1,200	92.0	tight grip on each elect

2. Current-Resistance Relationship: Ohm's law indicates that the amount of current in *amperes* flowing in a circuit varies directly with the electrical potential applied in *volts* (V) and varies inversely with the resistance (R) in *ohms*:

$$\mathbf{I = \frac{V}{R}}$$

Thus, one can calculate the expected current in a given situation. Example: Let R for a damp hand = 1,000 ohms. If an electrical potential of 110 volts is applied across the hand, the current would be:

$$\mathbf{I = \frac{110\ V}{1000\ \Omega} = 0.11\ A = 110\ mA}$$

The table below illustrates how the various current values affect human beings. The readings are approximate and vary among individuals. In view of the information below, it would be sound practice never to receive an electrical shock under any circumstances if it can be avoided.

[illegible]

3. Burns: Many electrical devices become quite hot while in use. In addition, “shorted” dry cells and batteries can produce very high temperatures. Students should never grasp a recently operated device or wiring without first checking for excess heat.

B. Electrical Apparatus

1. Batteries: A battery is an unregulated source of current capable of producing large currents when resistance is low. When short-circuited, connecting wires can become very hot, raising the risk of burns. Short-circuited mercury batteries may even explode. Chemical leakage from batteries is a potential hazard, especially in the case of wet cells that contain caustic chemicals such as sulfuric acid. Certain types of batteries are rechargeable while others are not. Carbon-zinc and nickel-cadmium type batteries can be recharged. Do not, however, attempt to recharge a completely dead carbon-zinc battery, a leaking or corroded battery, or any battery that carries a warning against recharging. Such batteries can cause damage to the charger and may explode, causing personal injury. Lead-acid batteries can be recharged but produce explosive hydrogen gas during the process. They should only be recharged in a well-ventilated area with an appropriate charger.

2. Capacitors: Capacitors are used to store electric charge. They may remain charged for long periods after power is turned off, and they therefore pose a serious shock/burn hazard. Before working on any circuit containing a capacitor, make sure that it is discharged by shorting its terminals with an insulated wire or screwdriver. Oil-filled capacitors may sometimes recharge themselves and should be kept shorted when not in use. Oil from older capacitors may be contaminated with dangerous PCBs. When installing electrolytic-type capacitors in a circuit, proper polarity rules must be followed (negative to negative and positive to positive). Improper connection can result in an explosion. Be on the lookout for capacitors in any apparatus with high voltage components such as oscilloscopes, TV sets, lasers, computers, and power supplies. Electrostatic generators and Leyden Jars are also capacitors and can be a source of unexpected shock.

3. Circuit Loads: Most laboratory electrical circuits have a maximum power rating of 1,500 watts (if fuses are 15 amp) or 2,000 watts (if fuses are 20 amp). The total power load on a circuit should not exceed these values. The total load is the sum of the power ratings of all apparatus plugged into that circuit. The individual power rating is usually found printed on a plate somewhere on the apparatus.

4. Electrostatic Generators: Electrostatic generators used in demonstrations of static electricity produce high voltages (about 105 volts) with very low currents. The danger of these generators depends on their size and capacity to produce enough current to be dangerous. In many cases the shock from such devices is very quick and not harmful. The startling effect, however, can be detrimental to persons with heart conditions. In general, experiments that use human subjects to demonstrate the effect of electrical shock should not be attempted due to the large variation in physical and physiological factors. Leyden jars -- which can be charged with electrostatic generators -- are especially dangerous because of their capacity to store a charge for long periods of time. An accidental discharge through a person can be avoided by properly shorting the devices after use.

5. Extension Cords: Use extension cords only when there is no convenient way to connect

Vacuum and Pressure Hazards

A. Vacuums

1. Suitable Containers: Many popular physics demonstrations utilize a small vacuum pump to evacuate a chamber such as a bell jar, a coin-feather tube, or a collapsing metal can. Under no circumstances should a standard thin-walled, flat-bottom jar be evacuated because of the likelihood of implosion. If students are to be allowed to pump out a well-designed chamber, make sure it is firmly mounted so it cannot tip over and implode when under vacuum. Any large evacuated chamber should be equipped with a screen shield to help provide protection following an implosion. Such implosions can result from long-term stresses in glass or may result from thermal effects if heating occurs without opportunity to expand. On small chambers where a screen is inconvenient or undesirable, the walls should be wrapped with tape to reduce the flying glass following an implosion. When bell jars are used in demonstrations, remind students that they are specifically designed to withstand atmospheric pressure, and that one should never pump on a conventional container. Full face shields should be worn whenever working with a system which could conceivably implode or explode.

2. Tubes and Implosions: Vacuum tubes, especially large ones, present a safety hazard if the tube breaks. Flying glass and electrodes can travel great distances when a tube implodes. This is a particular danger when tubes such as a cathode ray tube, a TV picture tube, or a Crookes tube are used in a demonstration or experiment that removes them from a protective housing. Under these conditions, safety goggles or shields should be worn by all observers. When an inoperable tube is to be discarded, it should be covered with a heavy canvas cloth and broken by striking the rear of the tube with a hammer. The broken tube should then be carefully disposed of.

3. Vacuum Pumps: Vacuum pumps equipped with belts and pulleys must have the belt and pulley system shielded to prevent clothing and hands from getting caught. This shield should also prevent injury from broken belts striking nearby observers. Students should be warned to be careful of the hot motor and other parts after operation.

B. Pressures

1. Compressed Air: Students in laboratories equipped with compressed air at lab stations or lecture tables should be warned of the danger of blowing dust or other debris into the eyes accidentally with compressed air. High pressure air directed at glassware for drying purposes can provide enough force to knock containers from the hands. The flow of air should be adjusted first to prevent this hazard.

2. Gas Bottles: One of the most common items to be found in any science laboratory is a container of compressed gas. The pressures in gas containers may vary from atmospheric pressure to 10,000 psi, with most tanks essentially designed as shipping containers (with a minimum weight and wall thickness). A container of gas should not be kept around if the gas and its characteristics are unknown. Any gas cylinder icontaiipeuld no-.0002 Twɧc

Heat and Cryogenic Hazards

A. Heat

1. Heating Procedures: Often it is necessary to heat liquids and solids in physics experiments and demonstrations. It is safer to use water baths and hot plates than to heat directly with open flames such as with Bunsen burners. Below are guidelines for heating and handling hot objects.

   - Any glass apparatus that is to be heated should be made of Pyrex® brand or Kimax® brand. It must be free of chips and cracks.
   - Gas burners should be kept away from the body at all times. The pressure of the gas should be adjusted to allow proper ignition. Too high a pressure tends to blow the flame out. Do not allow gas to accumulate if ignition is delayed for any reason.
   - Never heat a closed container if there is no means of pressure relief.
   - Many substances, especially glass, remain hot for a long time after they are removed from the heat source. Always check objects by bringing the back of the hand near them before attempting to pick them up without tongs, hot pads, or gloves.
   - Never set hot glassware on cold surfaces or in any other way change its temperature

4. Burns: A common cause of student injury is a burn from recently heated glassware. To avoid such burns, check the glassware by bringing the back of the hand close before attempting to pick it up. In case of an accidental burn, administer first aid and then seek additional health care if needed.

5. Asbestos: Many older hot plates, hair dryers and other heating elements contain wires or parts insulated with asbestos. Since the dangers of asbestos are well documented, all efforts should be made to replace this equipment with non-asbestos-insulated apparatus.

B. Cryogenics: Dry ice (solid carbon dioxide) is used in some low-friction pucks, as a source of carbon dioxide gas, and as a cooling agent. A mixture of dry ice and alcohol or liquid nitrogen might also be used as low-temperature baths. The temperatures of these materials are low enough to cause tissue damage from a cryogenic “burn.” This is not likely to occur if contact is brief, because the vapor layer formed between the cryogen and the tissue is not a good conductor of heat. Follow the guidelines below to avoid a dry ice “burn.”

Chemical Hazards in Physics

A. Carbon Dioxide: The use of dry ice in cryogenic experiments must be accompanied by precautions against production of an oxygen-deficient atmosphere. Carbon dioxide, which is more dense than air, easily collects in a non-ventilated area. (*See Cryogenics*)

B. Carbon Monoxide: Do not allow carbon monoxide from incomplete combustion to collect in a closed area. Always conduct demonstrations using small internal combustion engines under a vented hood or outdoors.

C. Explosives: Do not attempt to make explosive compounds such as those that might be used in model rocketry. Only factory-made, pre-loaded rocket engines should be used for this purpose.

D. Flammables: Do not use flammable substances near an open flame unless the purpose is to demonstrate flammability. Many flammables produce toxic fumes and should be burned only under a vented hood. Large containers of flammable liquids should be opened, and liquids transferred, in a room free from open flames or electrical arcs and, preferably, under a fume hood.

E. Mercury: Do not use mercury in the classroom. Use alternate equipment not requiring mercury in place of mercury. There are many reasons for this recommendation: The vapors from free mercury are cumulatively toxic. Mercury is absorbed through the skin. The vapors it forms are absorbed by inhalation. Complete clean up of any mercury spill, which is absolutely necessary, is difficult to accomplish. *NOTE:* As stated earlier, each laboratory where mercury is used should be equipped with a mercury-spill kit. Follow the directions that come with these commercially available kits.

F. Other Heavy Metals/Solder: Highly toxic cadmium oxide may be produced when silver solder containing cadmium is overheated. Some solders contain flux, which may produce noxious fumes. Use fume hoods when working with these materials.

Radiation Hazards

A. Infrared Radiation: Caution students that, beyond a limited exposure, infrared waves (heat waves) entering the eye can cause burns to the cells of the retina. Infrared lamps and the sun are concentrated sources of these waves.

- Follow manufacturer's instructions when using any infrared lamp.
- The sun should never be viewed directly, especially at times when its visible light is partially obscured. (The visible light triggers the body's natural defenses of avoidance and pupil constriction.) Lenses and sunglasses do not offer protection from this radiation. Safe viewing of the sun can be done by projecting an image of it through a very small hole onto a white piece of paper about one-half meter behind the hole.

B. Microwaves: A microwave apparatus is often used to demonstrate various wave behaviors of electromagnetic radiation. Microwave devices designed for school use have sufficiently low power to be free of radiation hazards when the manufacturer's instructions are followed. Microwave ovens that are in good working order and used properly do not pose any safety hazard in a classroom. Follow these guidelines:

- Check the apparatus for radiation leakage before use if there are any doubts about its safety.
- Inspect ovens periodically to ensure they are clean and the door, hinges, vision screen, seals, and locks are secure and working properly.
- Do not place metal objects in the heating cavity.
- Do not permit students to stand close to an oven during operation.

C. Radioisotopes: Radioisotopes produce biological injury (cell damage) resulting from their ionizing properties. Gamma rays and beta particles are hazardous both inside and outside the body. Alpha particles cannot penetrate skin and are not hazardous if kept outside the body. The use of license-exempt quantities, especially sealed sources, will create minimum hazard because of the small amount of radiation present. Safe handling requires these protective measures:

- Time - Minimize contact time with samples.
- Distance - Use tongs, forceps, etc., to avoid direct contact.
- Shielding - Use shielding appropriate for the radiations encountered.
- Storage - Store radioactive materials so that people are not in frequent close proximity to them and they are not damaged accidentally.

D. Ultraviolet Radiation: Ultraviolet light can be absorbed in the outer layers of the eye, producing an inflammation known as conjunctivitis. The effect usually appears several hours after exposure and, unless the exposure is severe, will disappear within several days. Sources of harmful ultraviolet light likely to be encountered in physics include mercury vapor lamps, electrical arcs (e.g., the carbon arc lamp), incandescent ultraviolet lamps, and the sun.

- Mercury vapor lamps and electric arcs should not be observed without elimination of their ultraviolet emissions.
- Plastic or glass sheets which transmit poorly in the ultraviolet region offer good protection for the viewer of these sources.

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Laser Safety

The laser produces an intense, highly directional beam of light that, if directed, reflected, or focused upon an object, is partially absorbed, raising the temperature of the surface and/or the interior of the object. Potentially, this can cause an alteration or deformation of the material. These properties can cause adverse biological effects in tissue. Photochemical effects are also a danger when the wavelength of the laser radiation is sufficiently short (i.e., in the ultraviolet or blue light region of the spectrum). Low-power lasers may emit levels of light that are not a hazard, or are no more hazardous than an electric light bulb. Some lasers concentrate visible light to an extent that retinal damage can occur in a very short time. Fortunately, these lasers are not often found in school science laboratories. Most lasers used in school laboratories are the continuous wave, low power (0.5 - 3.0 mW.), helium-neon lasers. The only optical danger is possible damage to the retina if a subject looks directly into the beam or non-diffused reflection. The diameter of the beam, the time of exposure, blink response time, and retina spot size all can affect the probability of injury. Since some of these lasers in this range are considered Class III lasers (see chart below), certain safety precautions are important to teach and use when working with lasers.

A. Biological Effects: The human body is vulnerable to the outputs of some lasers and can,

C. Laser Guidelines: Lasers can be used safely through the use of suitable facilities, equipment, and well-trained personnel. Class II lasers require no special safety measures. However, as in the case of a movie projector, a person should not stare directly into the projection beam. Safety training is desirable for those working with Class III systems.

- Practice good housekeeping in the lab to ensure that no device, tool, or other reflective material is left in the path of the beam.
- Before a laser operation, prepare a detailed operating procedure outlining operation.
- Whenever a laser is operated outside the visible range (such as a CO_2 laser), a warning device must be installed to indicate its operation.
- A key switch to lock the high voltage supply should be installed.
- Use the laser away from areas where the uninformed and curious might be attracted by its operation.
- Illuminate the area as brightly as possible to constrict the pupils of the observers.
- Set up the laser so that the beam path is not at normal eye level (i.e., so it is below 3 feet or above 6½ feet).
- Use shields to prevent strong reflections and the direct beam from going beyond the area needed for the demonstration or experiments.
- The target of the beam should be a diffuse material capable of absorbing the beam and reflection.
- Cover all exposed wiring and glass on the laser with a shield to prevent shock and

Rocketry

A. Local Regulations: Before beginning a model rocket program, check local regulations on the use of model rockets. Be sure also to check regulations about launch sites and fire codes in your area.

B. Model Rocketry Safety Code: Follow the guidelines for safe launching and recovery of model rockets outlined below.

- Construction - In making model rockets, use only lightweight materials such as paper, wood, plastic, and rubber; use no metal as structural parts.
- Engines - Use only pre-loaded, factory-made model rocket engines in the manner recommended by the manufacturer. Do not alter or attempt to reload the engines.
- Flying Conditions - Do not launch a rocket in high winds or near buildings, power lines, tall trees, low flying aircraft, or under any conditions that might endanger people or property, such as the threat of lightning.
- Jet Deflector - The launcher must have a jet deflector device to prevent the engine exhaust from hitting the ground directly.
- Launch Area - Always launch rockets from a cleared area that is free of any easy-to-burn materials; use non-flammable recovery wadding.
- Launch Rod - To prevent accidental eye injury, always place the launcher so the end of the rod is above eye level, or cap the end of the rod with the hand when approaching it. Never place head or body over the launching rod. When the launcher is not in use, always store it so that the launch rod is not in an upright position.
- Launch Safety - Do not let anyone approach a model rocket on a launcher until making sure that either the safety interlock key has been removed or the battery has been disconnected from the launcher.
- Launch Targets and Angle - Do not launch a rocket so its flight path will carry it against a target on the ground; never use an explosive warhead nor a payload that is intended to be flammable. The launching device must always be pointed within 30 degrees of vertical.
- Launching System - The system used to launch model rockets must be remotely controlled and electrically operated, and must contain a switch that will return to “off” when released. All persons should remain at least 10 feet from any rocket that is being launched.
- Power Lines - Never attempt to recover a rocket from a power line or other dangerous places.
- Pre-Launch Test - When conducting research activities with unproven designs or methods, try to determine their reliability through pre-launch tests. Conduct launching of unproven designs in complete isolation from persons not participating in the actual launching.
- Recovery - Always use a rocket system with model rockets that will return them safely to the ground so that they may be flown again.
- Stability - Check the stability of model rockets before their first flight, except when launching models of proven stability.
- Weight Limits - Model rockets must weigh no more than 453 grams (16 ozs.) at liftoff, and the engine must contain no more than 113 grams (4 ozs.) of propellant.

For further information about model rockets and model rocket safety, contact: Estes Rocket Industries, P.O. Box 227, Penrose, CO 81240