

Safety in the Physics Lab

Abstract

This handout is designed to outline some of the hazards you may encounter in the physics laboratory. It will also acquaint you with some of the state and federal regulations regarding the handling and disposal of substances deemed to be hazardous by our government. The purpose is to give you enough information so that you can take preventive measures when handling these materials.

Rule 0: Never work alone in lab.

In the physics laboratory you may encounter many types of hazards: chemicals, compressed gases, radioactive substances, lasers, electrical hazards, blood-borne pathogens, or mechanical hazards. We wish to consider not only those things that are hazardous to humans, but to the environment as well. It is our social responsibility to reduce as much as possible our detrimental impact on the environment. This means following all government guidelines for the disposal of waste products in order to insure a clean environment.

Chemical Hazards

Many chemicals used in the physics department present a personal hazard when not handled properly. If not disposed of properly, many will “harm the environment,” i.e., directly harm life downstream (e.g., poisons) or indirectly harm life downstream (e.g., the ozone layer protects us from harmful sunlight—harm the ozone layer and you enable sunlight to harm life). The most common hazardous chemicals that you will come across are: acids/bases, solvents, oils, photographic chemicals, and metals. These chemicals come with information regarding their toxicities in the form of Material Safety Data Sheets (MSDSs). We are required by law to have quickly available the MSDS for every chemical used in our lab. Hence, whenever ordering a chemical, *always request a MSDS from the company!* A folder containing our MSDSs is located in the Chemical Prep room (118 SC). After receiving the MSDS, read it and put it in this folder so that others may refer to it when necessary. If you are using a chemical that is in stock in the physics department, make sure you read the MSDS before handling that chemical. The MSDS will clue you in to special handling procedures, if any. It is an unhappy fact that our folder of MSDSs may be missing a stock chemical you are considering using. If you find such a missing MSDS inform Lynn Schultz or the chemical safety officer so we can obtain their MSDS from the manufacturer. If you need immediate access to the chemical you may seek the MSDS on the web: <http://siri.org/msds/> is a good place to start.

How to Read a Material Safety Data Sheet¹

Figures 1 and 2 show a typical Material Safety Data Sheet (MSDS) that is endorsed by the U.S. Department of Labor. While not all MSDSs will have this same format, they will all present the same basic information. Section I lists the manufacturer's name and address as well as telephone numbers to be called for additional information. There is also an emergency telephone number to be called for information in case of overexposure to the chemical.

Section II lists the hazardous ingredients that are in the chemical along with the "Permissible Exposure Limits" (PELs) and/or "Threshold Limit Values" (TLVs). Other exposure guidelines that may be listed are the LDLO (Lethal Dose, Lower limit) or the LD50 (Lethal Dose for which 50% of test subjects died). These limit values have units of milligrams of substance per kilogram of body weight (mg/kg) for solids and liquids or milligrams of substance per cubic meter of air space (mg/m³) for vapors and gases. These values are not to be used as a single indication of hazard potential, but may be used as one factor in comparing toxicity, remembering to consider the length of time the chemical is used and the amount of chemical used.

Section III lists the physical and chemical characteristics of the chemical. These data are of limited use to the non-chemist because they depend on many variables. As a rule-of-thumb, the higher the vapor pressure the more readily a substance will enter the air. Odor should not always be used as a gauge of toxicity levels since exposure to the odor for long periods of time may initiate "olfactory fatigue" (the person gets used to the odor and can no longer smell it).

Section IV lists the fire/explosion hazard data. The flash point is defined as the lowest temperature at which a liquid will give off enough vapor to ignite in air. Liquids with a flash point of less than 140°F (60°C) should be handled with extreme caution to avoid sources of ignition. The special fire fighting procedures should state the possibility for the generation of toxic air contaminants as a result of fire. The possibility for the creation of contaminants may require that even small fires be put out quickly.

Reactivity data is shown in Section V. This section lists the relative stability or instability of the chemical and the conditions to avoid in order to keep it in its most stable state. Also listed is whether the chemical has the potential for forming hazardous polymers or not. You can also find incompatibility and decomposition/byproduct data here.

Health hazard data are presented in Section VI. This includes the routes of entry into the body (inhalation, skin absorption, ingestion, and skin/eye contact), acute

¹*Employer's Implementation Guide for Minnesota Employee Right-to-Know Standards*, Minnesota Department of Health On-Site Consultation Unit, MN OSHA Program, Appendix II.

Figure 1: Example of a Material Safety Data Sheet (page 1)

Figure 2: Example of a Material Safety Data Sheet (page 2)

and chronic health hazards, carcinogenicity, signs and symptoms of exposure, and emergency/first aid procedures. The effects of overexposure would normally be seen only when a person is exposed in excess of PELs or suggested exposure guidelines, and therefore should not be relied on to evaluate hazard potential (or else the damage will already be done). Emergency and first aid procedures are crucial for assisting persons in the event of an accident or injury.

Section VII presents the precautions to be taken for safe handling and use. This section will give you information on how to clean up spills or leaks, how to properly dispose of the chemical, how to handle and store the chemical, and any other special precautions that need to be followed. Note that clean-up steps should be taken only with the proper personal protective equipment. Section VIII lists the proper control measures to be taken when handling the chemical. These may include the use of gloves, protective eyewear, and the use of ventilation to reduce air levels of a substance.

While it may seem that a voluminous amount of data is presented in these Material Safety Data Sheets, you will quickly become familiar with much of the information presented. The safety guidelines mostly follow common sense procedures. Many of the chemicals you work with will only present one health hazard that is easily recognizable (e.g., acids burn!). However, this information is being presented to you because you may encounter more serious hazards when you leave St. John's/St. Ben's and go out into the workplace.

Hazardous Waste Disposal Methods

Hazardous waste disposal is quickly becoming a "hot" topic in our society as we learn about the environmental effects of poor waste disposal practices. Groundwater contamination, ozone depletion, and greenhouse effect are all catchwords used by the media to alert the public to the possible consequences of environmental pollution. There are steps that we can take in the Physics Department to reduce our deleterious impact on the environment. Presently, the waste we generate falls into four categories: 1) oils, 2) solvents, 3) corrosives, and 4) photographic chemicals.

Oils. Used oil should never be dumped down the drain. St. John's garage has a service to pick up and recycle engine oil; our oil should be saved to be combined with that oil. In the Intermediate Laboratory (room 142) you will find a container marked *Used Oil*. If you need to dispose of oil, it can be dumped out into this container. At a later date it will be taken to Br. Damian's used oil barrel in the garage.

Solvents. Solvents are substances such as toluene, acetone, paint thinner, etc. They are usually organic compounds. Solvents come in two varieties: chlorinated (e.g., trichloroethane) and unchlorinated. Chlorinated solvents can **not** be burned in our incinerator (chlorine is a greenhouse gas). If you have a used chlorinated solvent, obtain a glass container from Lynn and pour the solvent into it (observing safety precautions). Label the container clearly, stating what it is and what was cleaned with it. Also give warning information (e.g., flammable). Store the container in the flammables cabinet in the Chemical Prep Room (room 118).

If the solvent is not of the chlorinated type, carefully note how it was used (this is to determine if any hazardous chemicals were dissolved in it as a result of use). There is a container in the hood that has used solvent in it. Also in the hood is a logbook listing what has been put into that container. Check the logbook to see if your used solvent is incompatible with others that have already been added to the container (if unsure, *see Lynn Schultz*). If your used solvent is compatible, add it to the container and *make an entry in the logbook* stating the solvent's name and how it was used. If your used solvent is not compatible, obtain a new, clean container from Lynn. He will then label the container and start a new logbook entry for that container.

Corrosives Corrosives are acids and bases. They can be dumped into the sewer as long as their pH falls in the range of 6–8. In the Chemical Prep Room (room 118) you will find baking soda for neutralizing acids and vinegar for neutralizing bases. Simply add some of the neutralizing agent and test with the pH paper provided. When the pH falls in the range of 6–8, pour the neutralized corrosive down the drain while flushing with copious amounts of water.

Photographic Chemicals Photographic chemicals are considered hazardous to the environment because of their silver content. Not only does the fixer solution fall into this category, but also the film, negatives, and paper. The developer solution is an acid and can be neutralized and sewered. The fixer, film, negatives, and paper should be stored in the Dark Room (room 150B) in the properly labeled containers to await disposal.

Compressed Gases

The compressed gases used in this Physics Department do not, under present government definitions, present a hazard to the environment. However, the mishandling of compressed gases can result in serious personal injury. A compressed gas is “any material or mixture having in the container an absolute pressure exceeding 40 psi at

70°F or, regardless of the pressure at 70°F, having an absolute pressure exceeding 104 psi at 130°F; or any liquid flammable material having a vapor pressure exceeding 40 psi absolute at 100°F as determined by ASTM Test D-323.”²

The unique properties of compressed gases (e.g., pressure, diffusivity, low flash points for flammable gases, low boiling points, and no visual and/or odor detection) frequently make the handling of these materials more hazardous than the handling of liquids and solids. Hazards that you may encounter in this Physics Department are: 1) anesthetic effects and asphyxiation caused by the diffusion of leaking gases; 2) the rapid formation of explosive concentrations of flammable gases (also caused by the diffusion of leaking gases); and 3) frostbite caused by cryogenic liquids such as helium and nitrogen. *These hazards can all be prevented by following the guidelines for safe handling outlined by the Occupational Safety and Health Administration (OSHA).* These guidelines center on containment of the material, preventing its escape to the environment, and proper control of pressure and flow.

General Precautions³

1. Never drop cylinders or allow them to strike each other violently. Also avoid dragging, rolling, or sliding cylinders, even for a short distance. They should be moved by using a suitable hand truck. If a cylinder becomes punctured or if the regulator breaks off, it can become a lethal projectile. (There are reports of punctured cylinders punching holes through concrete walls.)
2. The valve-protection cap should be on each cylinder until it has been secured against a wall, bench, or placed in a cylinder stand, and is ready to be used.
3. Never tamper with safety devices in valves or cylinders.
4. Do not store full and empty cylinders together. Serious suck-back can occur when an empty cylinder is attached to a pressurized system.
5. No part of a cylinder should be subjected to a temperature higher than 125°F. A flame should never be permitted to come in contact with any part of a compressed gas cylinder.
6. Cylinders should not be subjected to artificially created low temperatures (–20°F or lower), since many types of steel lose their ductility and impact strength at low temperatures. Special stainless steel cylinders are available for low temperature use.

²Hazardous Materials Regulations of the Department of Transportation, R.M. Graziano Tariff No. 31, issued by R.M. Graziano, Agent, 1920 “L” St. N.W., Washington, D.C. 20036.

³*Safe Handling of Compressed Gases in Laboratory and Plant*, Matheson Gas Products, pp. 2–3

Figure 3: Cylinder parts and markings.

7. Do not place cylinders where they may become part of an electrical circuit.
8. Bond and ground all cylinders, lines, and equipment used with flammable compressed gases.
9. Use compressed gases only in a well ventilated area.
10. When discharging gas into a liquid, a trap or suitable check valve should be used to prevent liquid from getting back into the cylinder or regulator.
11. When returning empty cylinders, close the valve before shipment, leaving some positive pressure in the cylinder. Replace any valve outlet and protective caps originally shipped with the cylinder. Mark or label the cylinder “empty” (or utilize standard DOT “empty” labels) and store in a designated area for return to the supplier.
12. Before using cylinders, read all label information and data sheets associated with the gas being used. Observe all applicable safety practices.

Cylinders⁴

Figure 3 shows the important cylinder parts and markings. The cylinder cap ① is used to protect the cylinder valve. The cap should remain on the cylinder whenever

⁴*Safe Handling of Compressed Gases in Laboratory and Plant*, Matheson Gas Products, pp. 4

the cylinder is not connected to a gas line. The cylinder valve is opened and closed by turning the valve handwheel (2). Never open the valve unless a regulator is attached to the valve outlet. Sometimes there is no handwheel and the valve must be opened and closed using a special wrench. The valve packing nut (3) contains a packing gland and packing around the valve stem. It is only adjusted occasionally and is usually tightened if there is leakage around the valve stem. *Never tamper with this nut.* If you do observe leakage around the valve stem, contact a faculty member. The pressure release valve (4) permits gas to escape in the event of unsafe pressure build-up in the cylinder caused by high temperatures. The valve outlet connection (5) connects to a pressure regulator. These connectors have different numbers of threads per inch to prevent the interchange of incompatible equipment. For example, a hydrogen regulator will not fit on an oxygen cylinder. The cylinder collar (6) holds the cylinder cap at all times, except when regulating equipment is attached to the cylinder valve. The valve outlet cap (7) protects the valve threads and keeps the outlet clean. This cap is not used universally.

The specification number (8) signifies that the cylinder conforms to the Department of Transportation specification DOT-3A. This specification governs the materials of construction, capacities, and test procedures. In this example it indicates that the service pressure for which this cylinder is designed is 2265 psi at 70°F. Nonliquified, nonflammable gases may be overfilled by 10%. The cylinder serial number is indicated by (9) and (10) indicates the month and year of initial hydrostatic testing (in this case, June 1975). Thereafter, hydrostatic tests are performed every five years, with the new test date being stamped on the shoulder of the cylinder. The original inspector's insignia for conducting hydrostatic and other tests required for the approval of the cylinder under DOT specifications is shown by (11).

Pressure Regulator Handling and Use⁵

Figure 4 shows a typical pressure regulator used with compressed gas. The purpose of the regulator is to reduce the pressure to a safe value. When attaching a regulator to a cylinder, *never force the threads!* If the inlet of the regulator does not go onto the outlet of the cylinder smoothly it may be an indication that the regulator was not intended for use with the chosen gas. Once the proper regulator has been attached, use the following procedure to obtain the desired delivery pressure:

1. After the regulator is attached, turn the delivery pressure-adjusting screw counterclockwise until it turns freely.
2. Open the cylinder valve until the tank gauge on the regulator registers the

⁵*Safe Handling of Compressed Gases in Laboratory and Plant*, Matheson Gas Products, pp. 7

Figure 4: A typical pressure regulator.

cylinder pressure. At this point the cylinder pressure should be checked to see if it is at the expected value. A large error could indicate that the cylinder valve is leaking or that the tank is partially empty.

3. With the flow-control valve at the regulator outlet closed, turn the delivery pressure-adjusting screw clockwise until the desired delivery pressure is reached. Control of flow is usually accomplished by means of a valve supplied in the regulator outlet or by a supplementary valve put in the pipeline downstream. Do not adjust the flow by adjusting the pressure. This defeats the purpose of the pressure regulator, and higher flows obtained in this manner may be exceeding the design pressure of the system.

Radioactive Substances

The CSB/SJU Physics Department no longer carries a license through the Nuclear Regulatory Commission (NRC). All sources that were “licensable quantities” as defined by the NRC have been properly disposed of. This means that any exposure you get in our labs will be minimal, and not much greater than exposures that occur naturally. However, for your future reference and understanding, we will take a look at radiation in physics labs as a general topic.

Radiation comes in a number of forms: α particles, β particles, γ -rays, x-rays, and fast and slow neutrons. α particles are helium nuclei (2 protons, 2 neutrons) and

move at velocities up to 5% of the speed of light. β particles are electrons and move at velocities up to 99% of the speed of light. γ -rays and x-rays are electromagnetic radiation (i.e., high energy photons).⁶ Neutrons are usually only encountered in radiation therapy medical facilities, in the cores of nuclear reactors, or in the blast zones of atomic weapons. Other types of radiation do exist (e.g., heavy metal ions found in outer space), but you will probably not encounter these types of radiation in your normal life (unless you become an astronaut or do research work in high energy physics). Radiation is emitted when an atom *decays* from a state of higher energy to a state of lower energy.

γ -rays and neutrons are by far the most *penetrating* types of radiation. β particles are somewhat less penetrating than γ -rays and neutrons. α particles are the least penetrating. Thus the target organ of α particles is usually the skin, whereas γ -rays generally have no difficulty hitting the internal organs. The various types of radiation have different biological effects even given identical amounts of energy per unit volume to the absorber. Crudely speaking slow neutrons deliver about five times the biological effect of γ -rays other things being equal. Fast neutrons deliver about ten times the effect and α particles deliver about twenty times.⁷ From this it should be obvious that the effects on humans differs greatly for different types of radiation.

A common factor among these different types of radiation is that they are *ionizing* radiation. Ionizing radiation, as the name implies, ionizes the material it hits. This means that it strips off electrons from atoms and molecules; what remains behind now has a positive charge. In humans the ionization of tissues causes a disruption of their chemical structure and thus interferes with their normal metabolic processes. Peroxides are formed causing the death of local tissues. The destruction of lymphoid elements can bring on unfavorable immune responses. Enzymes become deactivated which can result in the loss of the selective permeability of cell membranes. Cells may burst because the reduction in the size of molecules caused by the ionization increases the osmotic pressure of the tissue fluid surrounding the cell.⁸

Lymphoid elements and bone marrow are the types of cell that are most susceptible to the destructive effects of ionizing radiation. The central nervous system and skeletal muscles are the least vulnerable. The skin lies somewhere in between these two extremes, but because of its exposed state, it usually bears the brunt of the radiation damage. The law of Bergonié and Tribodeau states that the vulnerability of a cell to radiation is directly proportional to its reproductive capacity (i.e., the faster a cell grows and divides, the more susceptible it is to radiation damage).⁹

⁶*Introductory Biophysics*, Hallett, Speight, and Stinson, p. 79.

⁷*Physics for the Health Professions*, Jensen, p. 211.

⁸*Ibid.*, p. 209.

⁹*Ibid.*, p. 209.

Radiation Units

There are several units describing radiation. Some relate to the activity of the radioactive substance and others relate to the energy *absorbed* from the radioactive substance (not all the energy emitted from the source is absorbed by the target).

Physicists are usually concerned with the activity of a radioactive substance. The *curie* (Ci) is a unit that corresponds to 3.7×10^{10} disintegrations per second. In the lab you will be dealing with radioactive sources that are in the microcurie (μCi) range. A related unit is the *becquerel* (Bq). One becquerel is equal to one disintegration per second. Therefore, $1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq}$.

Biologists are usually concerned with how much energy is absorbed by tissue (i.e., the dose) when it is exposed to a radioactive substance. The basic unit of γ -ray exposure is defined as the amount of charge dQ generated by ionization formed within a volume element of air of mass dm . Thus the SI unit of exposure given by dQ/dm is in coulombs per kilogram (C/kg). However, the historical unit is the roentgen (R) which is defined as the amount of radiation that produces one electrostatic unit of charge (of either sign) per 0.001293 g (1 cm^3 at STP) of air. The roentgen is related to SI units by: $1 \text{ R} = 2.58 \times 10^{-4} \text{ C/kg}$.¹⁰ An exposure of 1 R is equivalent to the absorption by dry air of 83 ergs/g.¹¹

The energy absorbed from *any* type of radiation per unit mass of the absorber is defined as the *absorbed dose*. The historical unit of absorbed dose is the *rad* (roentgen absorbed dose). One rad is defined to be 100 ergs/g and thus is approximately equal to 1 R. The SI unit is the *gray* (Gy) and is defined as 1 joule/kilogram. Therefore, $1 \text{ Gy} = 100 \text{ rad}$. The absorbed dose depends on the atomic number of the absorbing material.¹² For an exposure of 1 R, air and water will both have an absorbed dose of about 0.83 rad because they have about the same atomic number, but the absorbed dose in lead will be much higher.

In living organisms, the absorption of equal amounts of energy per unit mass by different sources of radiation does not guarantee the same biological effect. Effects depend on whether the energy is deposited in the form of heavy charged particles or electrons. The *linear energy transfer* (L) is the local rate of energy deposition along the particle track. Radiations with higher L values tend to cause more biological damage than radiations with low L values. However, the *penetration depth* is inversely proportional to L . Therefore, radiations with high L values do most of their damage to the outside layers of the absorber while low L value radiations can cause damage deeper in the interior. The *dose equivalent* (H) is the product of the *absorbed dose* (D)

¹⁰ *Radiation Detection and Measurement*, Knoll, p. 74.

¹¹ *Physics for the Health Professions*, Jensen, p. 211.

¹² *Radiation Detection and Measurement*, Knoll, p. 76.

L in water (keV/ μm)	Type of Radiation	Q
3.5 or less	x, γ , or β	1
7.0	thermal neutrons	2
23	thermal neutrons	5
53	fast neutrons	10
175	α	20

Table 1: Quality factors for different types of radiation.

Table 2: Average human radiation exposure in millirems per year.

and the *quality factor* (Q). The quality factor is also known as the *relative biological effectiveness* (RBE). See Table 1 for some quality factor values.¹³

Units for the dose equivalent, H , depend on the units used for absorbed dose, D . If D is expressed in the historical unit of the rad, then H is expressed in units of the *rem* (roentgen equivalent in *man*). In the SI system of units absorbed dose is expressed in grays, giving the dose equivalent in the unit of the *sievert* (Sv). Since $1 \text{ Gy} = 100 \text{ rad}$, then $1 \text{ Sv} = 100 \text{ rem}$.¹⁴

¹³*Ibid.*, pp. 76–77.

¹⁴*Ibid.*, pp. 77–78.

Safety Considerations

It is important to remember that the radioactive sources you will be using in the physics lab will subject you to far less radiation than what is present *naturally* in your body (see Table 2). Typically you will be exposed to less than 0.05% of the normal background radiation. However, this does not mean that you should handle radioactive materials in a carefree way. Of greatest importance is to not let any radioactive material enter your body. The effects of radiation are cumulative so if you accidentally ingest some substance with a half life of years, you will be exposing yourself for years. *Therefore, do not bring food or drink into the lab if you are working with radioactive substances.*

Radioactive substances come in three states: gas, liquid, and solid. The gaseous radioactive substance you might encounter is radon. Containers of radon gas are used in research. The amount of radon gas that leaks into a room is not enough to cause damage. Obviously you should not breathe the gas directly.

Liquid radioactive substances can be dangerous if not handled properly. Usually the liquid will be in a sealed container. In this case you can handle the container with your bare hands. If the container breaks, *do not* attempt to clean it up without first contacting a professor or the lab instructor. Spills should be cleaned up only when wearing gloves since a liquid can easily enter the body through a cut. When handling liquid radioactive substances that are not in sealed containers always use gloves. In addition, only handle them in a hood; this will prevent any splashes from entering your body through the eyes, ears, nose, or mouth. Always seal the container before taking it out of the hood.

Solid radioactive substances will come in three forms: sealed in plastic, unsealed, and in natural forms such as rock. When a source is sealed in plastic there is no danger of it entering your body from handling it. However, you do not want to swallow it. Unsealed sources look like a metal disks. Handle them with tweezers. Never poke the tweezers into your skin. If you do touch your body with the tweezers or if you pick up the source with your hands make sure you wash your hands/body before touching your mouth, rubbing your eyes, itching your ear, etc. Rocks that contain radioactive substances are generally of no concern, but as a matter of habit and safety you should wash your hands after handling.

Lasers

During your lab experience at CSB/SJU you will likely have opportunity to work with lasers. Lasers are, generally speaking, devices that generate or amplify light. The hazards in our department are mostly limited to permanent damage of the retina (with one exception... see below). This “light” can be electromagnetic radiation outside the visible spectrum. This means that you may not be able to see the beam (e.g., the diode laser used in the Speed of Light experiment emits in the IR range). Special precautions should be taken when using any laser beam not visible to the naked eye. Make absolutely sure that there are no stray beams, and that all light is aligned along a predictable path. Special cards can be used that fluoresce when exposed to non-visible ranges of em radiation. Use these to check the area for stray light. If a high-powered beam is used (≥ 5 mW) safety goggles should be worn at all times. Check the specifications on the goggles you choose to make certain that they effectively block the wavelength of light you’ll be using in the lab.

Similar considerations should be given to visible beams, although the task is easier if you can see the hazard. The most powerful beam we can generate in our labs is via the Argon-ion laser in room 137 (up to 8 Watts). At maximum power output, or with a focused beam, the beam can easily burn holes in tissue. Thus we take special precautions to control the path of the beam *before* focusing or increasing the power output. Lasers are classified by the output power vs human reaction times according to the Laser Performance Standard set by the US Dept. of Health and Human Services. Class I is the lowest power and least dangerous (≤ 1 mW). Class IV is the highest class you’ll encounter here.

When performing any laser experiment, seal the area so that you are in a relatively “light-tight” environment. The easiest way to do this is shut the lab door and ask anyone present (not involved in your experiment) to leave. Wear goggles if using a beam power ≥ 5 mW. In any case *Never Look Directly into the Laser Beam!!*. Even low powered HeNe Lasers are capable of damaging your eyes with prolonged exposures. Perform your alignments BEFORE you increase to higher power. After all, you don’t need much power to set up your experiment. While performing alignments you should block stray beams such that they are isolated on the table or bench top.

Even low power beams can be focused to dangerous *irradiance* levels. The irradiance is defined as the power per unit surface area (W/m^2). For example a 1 Watt beam focused to a spot size of .10 mm diameter has an irradiance of $1.3 \times 10^8 W/m^2$. Therefore focusing should be the last step in setting up your experiment. In all cases let common sense be your guide.

Electrical Hazards

In this and other technical fields you will often rely on electronic devices to take your data. In some case these will be potentially hazardous situations. One should always be aware of the possibility of getting shocked by a high voltage power source. Keep track of grounds at all times, and make sure your equipment is properly grounded. Also be aware that polarized plugs are standard for wiring, but not all equipment have the proper polarized plug. An electric (AC) field sensing device can quickly identify such components. If polarization is reversed (i.e. the HOT wire connected where the NEUTRAL wire should be) then cases and outer shells can become potential paths to ground, which could give you quite an unexpected jolt of electricity.

Remember that electricity and water don't mix. Anything in water becomes an active ground, and current will flow freely through it. Remember that the real killer is the flow of electrons through the body; even a fairly low voltage (110 AC) can yield enough current to kill in extreme cases.

Keep in mind that some devices store electrical energy (e.g., capacitors) so that an unplugged device is not guaranteed to be safe from shock hazards. Television and monitors in particular have large capacitors capable of releasing a very large current quickly. Never "open-up" any electronic device; electronics repair must be carried on under a qualified supervisor.

Bloodborne Pathogens

Pathogenic organisms in the blood and other bodily fluids can pose a serious health threat to anyone who comes in contact. These include, but aren't limited to HIV and hepatitis. Thus it is a written policy of the Universities that the following standard be applied:

- All incidents involving human blood and other potentially infectious materials must be treated as if it is known that the blood or bodily fluid is infected with a bloodborne pathogen – this is known as Universal Precautions.
- The college must have a written policy stating how these incidents will be handled, must provide the appropriate clean-up supplies and personal protective equipment and employee training.
- All infectious waste must be disposed of properly.

- If any employee becomes exposed to potentially infectious materials, the college is responsible for any necessary medical attention that employee may require.

In a nutshell, this means that you should treat any bodily fluid other than sweat or saliva as a hazardous substance. If you encounter this situation, try to assist the person in handling their own wound without exposing yourself (give them a bandage, etc). Otherwise stay clear of the fluids, and notify me or a faculty member as soon as possible. I have the clean-up kit for bio-hazardous waste disposal.

Mechanical Hazards

Most of the mechanical hazards in the department can be found in the machine shop. If you would like to use this facility the department offers a special machine-shop safety course. It is designed to give you a brief overview of the potential hazards, and proper use of equipment. Note that those who have not completed the machine-shop safety program ARE NOT AUTHORIZED to use those facilities. Please let me know if you are interested in attending this program.

There are a variety of smaller hazards around the department to beware of. Be cautious in cluttered areas...put things away and clean up if necessary. Others involve common sense (watch your fingers if using a hammer, etc.). I am working to assure that any hazard with serious potential risk is marked with signs to warn you. As a final note, don't try to lift or move very massive objects without consulting me first. We have carts, dollies, and friends to help in these cases.