Laboratory Safety and Regulations in Junior Lab

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Your safety in Junior Lab is the staff's top priority. It should be your top priority, too. We are fortunate that there has never been a serious injury in Junior Lab. Prevention of injury is a matter of being aware of and having respect for pieces of equipment that are potentially dangerous. Nevertheless, setting up a reasonably comprehensive and interesting set of experiments in modern physics without using potentially hazardous equipment is virtually impossible. Therefore, being aware of the hazards and exercising appropriate cautions is essential for all students and staff.

Beyond the specific safety procedures listed below, you must also obey the following general rules in Junior Lab:

- **No eating, drinking, or other hand-to-mouth action in the lab.** Leave all food items outside the lab or in a closed container like a backpack.
- **No working without properly trained lab staff present.** Do not work alone. No unauthorized access, after hours or otherwise.
- No bare feet. No pets.

All students will be instructed on lab-specific safety — including the location of the emergency eye wash station and safety showers — during the first lab session of 8.13.

I. CHEMICAL HYGIENE AND ENVIRONMENTAL SAFETY

You will *not* prepare chemical samples or generate hazardous chemical waste in Junior Lab. You may occasionally use closed samples prepared by the lab staff which — in the highly unlikely event of a spill — could constitute hazardous waste. **Do not attempt to clean up or dispose of chemical spills in Junior Lab.** Ask for help from the lab staff, all of whom have the required training for dealing with this situation. Improper disposal of hazardous material in the trash or lab sink could result in environmental contamination and unnecessary exposure of other people to chemical hazards.

The lab staff are responsible for maintenance and awareness of all hazardous substances in the lab. **Do not bring any bring potentially hazardous substances into lab without first consulting the staff.** Hazardous substances are those which are flammable, reactive, toxic, radioactive, or environmental pollutants. **Do not generate unlabeled containers of any substance — hazardous or not — in any lab space.** Unlabeled containers must be treated as containing unknown substances, This triggers worst-case assumptions and expensive disposal protocols.

II. ELECTRICAL SAFETY

The first rule of electrical safety is to never work alone. Some years ago, a student was electrocuted in Building 4 by a laboratory power supply. Had he not been by himself, someone might have saved him.

All high voltage supplies are clearly marked as dangerous. Do not poke or probe into them. Turn off the supply if you need to change cable connections. The supply may be dangerous even when turned off if the capacitors have not discharged; always keep one hand in your pocket when testing any circuit in which there may be high voltages present so that if you get a shock, it will not be across your chest. Never go barefoot in the lab. Remember that it is current that kills. A good (*e.g.* sweaty) connection of 6 volts across your body can kill as well as a poor connection of 600 or 6000 volts if the power supply can generate sufficient current.

The ampere is a large unit of current. The details of an injury will depend not only on the current value, however, but also on its frequency and the path of the current through the body. Currents below 1 mA are generally safe, while painful injuries will generally result from currents as low as 10 mA. Common lore holds that 100 mA is the lower threshold for "deadly current", but ventricular fibrillation can begin as low as 30 mA. Circuit breakers on electrical wall sockets are typically 15 A or 20 A, and will therefore not protect a person from injury.

III. RADIATION SAFETY

Radiation safety at MIT is under the authority of the Radiation Protection Program (N52-496). Junior Lab is accountable to that office for the safe handling and accountability of the sources used in the experiments. **Meticulous care must be taken by all students and staff to insure that every source signed out from the locked repository in 4-361 is returned immediately after its use and signed in.** (See Table I.)

By authority of the Massachusetts Department of Health and the terms of MIT's license to posses radioactive materials, all Junior Lab students are instructed in the safe use and handling of sealed sources of radioactivity during the first class session of 8.13 by a member of the Radiation Protection Program. This constitutes EHS Course 306c (Radiation Safety: Sealed Sources). Attendance at this session is mandated by Massachusetts state law. Junior Lab students do *not* require additional levels of radiation safety training which would qualify them as radiation workers. Students who perform the 'Neutron

TABLE I. A table showing the radioactive sources used in Junior Lab and their approximate activities.

Experiment	Isotope	~ Activity (mCi)
Compton Scattering	^{137}Cs	0.4
Mössbauer Spectroscopy	^{57}Co	4
Rutherford Scattering	^{241}Am	0.2
Alpha Decay	Uranium Ore	5×10^{-6}
	^{226}Rd	0.013
Relativistic Dynamics	^{90}Sr	8
	^{133}Ba	0.08
X-Ray Physics	^{241}Am	10
	^{55}Fe	0.7
	^{90}Sr	0.6
	^{57}Co	0.02
Calibration Sources	^{133}Ba	0.005
	^{109}Cd	0.008
	^{137}Cs	0.007
	^{57}Co	0.0001
	^{60}Co	0.01
	^{54}Mn	0.0002
	^{22}Na	0.01

Physics' experiment at the MIT Nuclear Reactor Laboratory will be notified of additional required training specific to that facility.

As discussed in your training, there are a few simple precautions to be taken for safely working with sealed sources of radioaction:

- Do not handle radioactive sources any more than you need to.
- Work quickly when transferring or positioning radioactive sources.
- Never take a source away from the Junior Lab, even temporarily. The senior staff are legally responsible for the sources and must periodically account for their presence and condition.
- Replace sources in the lead storage cabinet when they are not in use and ensure that the cabinet is locked at all times.
- Keep sources away from your body.
- Never bring a radioactive source near your eyes because they are particularly sensitive to radiation.
- Be aware of the sources being used in neighboring experiments. Be aware of neighboring experimenters when using sources.
- Remember ALARA — *As Low As Reasonably Achievable*!

Ionizing radiation damages tissue; any exposure should therefore be minimized. The unit of radiation exposure is the rem (roentgen equivalent man). For an average individual, the background dosage from cosmic rays and other environmental sources is about 360 mrem/year, which works out to 4.2×10^{-2} mrem/hour. The recommended limit to controllable exposure for a member of the general public is 100 mrem/year, averaged over any consecutive five years. If you follow the Junior Lab guidelines, your exposure will be only a fraction of the dose you receive from the natural background. A survey meter is available in 4-361 for you to check radiation levels yourself.

Radioactive sources emit three types of radiation: high energy helium nuclei (alpha rays), electrons (beta rays), or photons (gamma rays). Most of the sources in Junior Lab emit only gamma radiation. Of the sources which do emit alpha or beta particles, most are enclosed in plastic or metals, which prevent particulate radiation from escaping. The exceptions are the ^{90}Sr source in the 'Relativistic Dynamics' experiment and the ^{241}Am source in the 'Rutherford Scattering' experiment; both sources are in an enclosed apparatus. These sources should never be handled. Handling of open alpha- or beta-emitters can result in contamination or dangerous dosages to the skin.

Radiation is quantified is several different ways:

- The quantity of a radioactive material in a source — called its "activity" — is measured in curies (Ci). A one-curie source has an activity of 3.7×10^{10} disintegrations per second. The curie is an extraordinarily large unit: millicuries and microcuries are more common in laboratory usage.
- The "absorbed dose" is a quantity that measures the total energy absorbed per unit mass; it is measured in rads, where 1 rad = 100 erg/g.
- The "equivalent dose" is measured in the units discussed above, the rem. The equivalent dose is derived from the absorbed dose by multiplying by a "radiation weighting factor" which is a measure of how damaging a particular type of radiation is to biological tissue. For photons (gamma rays) and electrons and positrons (beta particles), the radiation weighting factor is unity; for helium nuclei (alpha particles), it is 20; for protons with energy greater than 2 MeV it is 5; and for neutrons it ranges from 5 to 20, depending on the energy.

When you use the survey meter in the lab, the readings are in rads, and you must consider the type of particle when you work out the equivalent dose.

For gamma rays with energy greater than 1 MeV, a useful approximation is that the equivalent dose due to a source with an activity of C microcuries is $5.2 \times 10^{-4} C E_\gamma R^{-2}$ mrem/hour, where R is the distance from the source in meters and E_γ is the energy of the gamma ray in MeV. For gamma rays with energy less than 1 MeV, this formula is still approximately true for a full-body dose. However, low-energy gamma rays deposit their energy in a smaller mass of tissue than high-energy gamma rays and can cause high local doses. For example, the local dose to the hands from handling a 10 keV source can be up to 25 times the value given by the above formula; hands, however, have a higher tolerance to radiation than inner organs or eyes.

The protective value of shielding varies drastically with the energy of the photons. The intensity of a "soft" x-ray beam of less than 1 keV can be reduced by many orders of magnitude with a millimeter of aluminum while 1.2 MeV gamma rays from ^{60}Co are attenuated by only a factor of two by a lead sheet 0.5 inch thick. The best way to keep your dosage down is to put distance between you and the source. If you stay a meter away from most sources in Junior Lab, you will be receiving, even without any lead shielding, a dose which is much less than your allowable background dose. If, however, you sit reading the write-up with a box of sources a few inches away, you may momentarily be receiving ten to a hundred times the background level.

IV. CRYOGENIC SAFETY

Liquid nitrogen, boiling at 77 K, is chemically inert, but it can cause severe frostbite. Wear gloves and protective glasses when transferring or transporting liquid nitrogen. Splashing against the skin should be avoided as much as possible, but it is generally not dangerous because the liquid will boil away rapidly, leaving only cold gas which will not transfer heat to the skin efficiently enough to cause injury. However, pooling of the liquid against the skin for even a short time will cause injury, and care must be taken to avoid this situation. Ultimately, the most ready source of injury when working with liquid nitrogen or other cryogens is not the liquid itself, but rather touching the cold metal surfaces of uninsulated valves and transfer vessels.

Liquid helium, boiling at 4.2 K, requires significantly more careful handling than liquid nitrogen, and should not be manipulated by Junior Lab students. When the cap on a liquid helium Dewar is left off, air flows in and freezes in the neck, forming a strong cement. When a probe is inserted, it may be frozen in solid. Pressure will then build up until something explodes. During the 8.14 'Superconductivity' experiment, never leave the Dewar cap off for more than a few seconds. Always ream out the Dewar before you use it. Check periodically to see that the probe is free. If the probe should freeze in the Dewar, get help immediately from any of the Junior Lab staff or instructors.

V. LASER SAFETY

A laser beam may not seem very bright, but if it enters your eye it will be focused by the lens of your eye to a pinpoint spot on the retina where the intensity is sufficient to destroy retinal cells. It is wise to terminate a laser beam with a diffuse absorber so that the beam does not shine around the room. Never examine the performance of an optical system with a laser by viewing the beam directly with your eye or reflector.

Students who perform the 'Doppler-Free Saturated Absorption Spectroscopy' or 'Raman Spectroscopy' experiments in 8.14 require additional laser safety training from MIT EHS, which must be completed prior to performing the experiment: EHS Course 371c (Laser Safety), about 1.5 hours in length, offered by EHS every two weeks. The 'Doppler-Free' experiment utilizes a near-IR laser operating at 40 mW of output power. As such, it is classified as a Class 3b laser. The 'Raman Spectroscopy' experiment utilizes a 532 nm (green) laser operating at 2 W, placing it in the highest laser safety category, Class 4. Class 3b and Class 4 lasers require special safety training to operate. All students should download the MIT Laser Safety manual and read, at a minimum, Section Two.XVI.D dealing with Class 3b laser controls.

VI. BIOLOGICAL SAFETY

Junior Lab is classified as a BL1 (Biohazard Safety Level 1) laboratory space, meaning that specific areas of the laboratory are authorized under the MIT Biosafety Program for use of specific minimally infectious pathogens. (No human tissues are allowed.) Students who perform the 'Optical Trapping' biophysics experiment are required to complete EHS Course 260c (General Biosafety for Researchers) or 262c (Undergraduate Teaching Lab Biosafety) before beginning work on the experiment. A 262c training session with a member of the Biosafety Program will be organized early in the semester by the Junior Lab staff for all students who require it.