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8.13-14 Experimental Physics I & II "Junior Lab"
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Safety

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, since it is virtually impossible to set up a reasonably comprehensive and interesting set of experiments in modern physics without using equipment which has potential hazards, it is essential that staff and students be aware of the hazards, and exercise appropriate cautions.

Electrical Safety

The first rule is never to work alone. Some years ago a student was electrocuted in another area 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.

Laser Safety

A laser beam may not seem very bright, but if it enters your eye it will be focused by your eye lens 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 reflector so that the beam doesn't shine around the room. Never examine the performance of an optical system with a laser by viewing the beam directly with your eye.

Cryogenic Safety

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. Then pressure will build up until something explodes. During the 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 a professor or TA.

Liquid nitrogen is chemically inert, but it can cause severe frostbite. Wear gloves and protective glasses when transferring or transporting liquid nitrogen.

Radiation Safety

Radiation safety at MIT is under the authority of the Radiation Protection Office. Junior Lab is accountable to that office for the safe handling and accountability of the sources used in the experiments. During the first class session, a member of the Radiation Protection Office will instruct you in the safe use and handling of radioactive material.

Meticulous care must be taken by all students and staff to insure that every source signed out from the repository be returned immediately after its use and signed in.

Ionizing radiation damages tissue; any exposure should therefore be minimized. The unit of radiation exposure is the rem (roentgen equivalent man). A new unit, called the Sievert (= 100 rem) is recommended by the [International Commission on Radiation Units and Measurements](#) (ICRU). Your inescapable dosage from cosmic rays and other background sources is 360 mrem yr⁻¹, which works out to 4.2 x 10⁻² mrem hr⁻¹. The recommended limit to exposure for a member of the general public is 100 mrem yr⁻¹, averaged over any consecutive five years. If you follow the Junior Lab guidelines, your exposure will be only a small fraction of the dose you receive from the natural background. A meter is available for you to check the 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 ⁹⁰Sr source in the e/m experiment and the ²⁴¹Am 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 dangerous dosages to the skin.

The strength of a radioactive source is measured in curies (Ci). A one-curie source has an activity of 3.7 x 10¹⁰ disintegrations s⁻¹. 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⁻¹. 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 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 hr⁻¹, 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 fullbody 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 "soft" (i.e. < 1 KeV) can be reduced by many orders of magnitude with a millimeter of aluminum while 1.2 MeV gamma rays from ⁶⁰Co are attenuated by only a factor of 2 by a lead sheet one-half of an 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.

List of Precautions for Working with Radioactive Materials

1. Don't handle radioactive sources any more than you have to.
2. Work quickly when transferring or positioning radioactive sources.
3. 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.
4. Replace sources in the lead storage cabinet when they are not in use and ensure that the cabinet is locked at all times.
5. Keep sources away from your body.
6. Never bring a radioactive source near your eyes because they are particularly sensitive to radiation.
7. Be aware of the sources being used in neighboring experiments.

A table showing the radioactive sources used in Junior Lab and their approximate activities is given below.

EXPERIMENTS	ISOTOPES	~ ACTIVITIES (MCI)
Compton Scattering	¹³⁷ Cs	0.4
Mössbauer Spectroscopy	⁵⁷ Co	7
Rutherford Scattering	²⁴¹ Am	0.2
Alpha Decay	Uranium Ore	5×10^{-6}
Relativistic	⁹⁰ Sr	8

EXPERIMENTS	ISOTOPES	~ ACTIVITIES (MCI)
Dynamics	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	0.0005
	⁵⁴ Mn	0.0002
	²² Na	0.002