Chapter 7: Physical Hazards

Overview

Physical hazards include mechanical, electrical, heat, sound, and radiation hazards that may occur in physics laboratory activities, as well as a variety of other science activities. Hazards in each of these categories have the potential to cause injuries (or, in some extreme cases, even death), but by taking general precautions, such as using appropriate protective equipment and emphasizing routine safety, physical hazards can be easily minimized.

Mechanical Hazards

- In general, safety can be increased by ensuring that equipment is well maintained.
- Turn off all equipment before leaving the area.
- Students must only use equipment with teacher supervision.

Rotating Machinery

Machinery with rotating parts can catch loose clothing, hands, or hair, potentially causing serious injuries. Uncovered parts may also fly off, thereby creating additional risk, especially for eye injuries.

To minimize risks, do the following wherever possible:

- Ensure rotating shafts, belts, and pulleys are covered by guards, lids, or covers.
- Check devices attached to a rotor before use to ensure that they are tightly fastened.
- Wear (and have students wear) eye protection when using uncovered, rapidly rotating parts, as in the demonstration of centripetal force and circular motion.
- Have students stand back as much as possible.
- Have a safety shield available in the science area.

Tools

Careless use of tools or use of tools in poor condition can cause injuries to the hands, eyes, head, and limbs.

To minimize risks:

- Regularly check tools for defects or damage.
- Damaged tools should be immediately removed from student use.
- Provide students with clear instructions on safe use before they have access to tools.

Cutting Tools (Scalpels, Razor Blades)

By design, these instruments are very sharp. Careless use can quickly result in deep cuts.

To minimize risks:

- Use extreme caution in handling cutting tools, and ensure that students do the same.
- Replacement of blades is best done by teachers or technicians.
- Wear eye protection when using cutting tools in case a blade breaks.

Magnets

Large, powerful magnets or electromagnets can attract other magnets or iron/nickel objects with surprising force, which can cause painful pinching of fingers or hands.

To minimize risks:

- Inform students of this hazard before such magnets are used.

Glassware

Any kind of glassware has the potential to break, creating the risk for cuts or spilled materials.

To minimize risks:

- Wear goggles for eye protection.
- Use heat-resistant glassware, which is less likely to crack when heated.
- Avoid using glass containers that are cracked or chipped, since they may crack further during the experiment.
- Clean up any broken glass immediately and dispose of in a special waste bin dedicated to broken glass.
- Do not pick up glass with your hands—use a dustpan and brush or broom.

Projectile Launchers

Projectile launchers are often used in the study of motion—sometimes as demonstration devices and sometimes as equipment for student laboratories. Equipment used includes such devices as ballistic pendulums, commercially available devices that launch plastic and steel balls, and classroom-constructed devices that launch a variety of materials. When decisions are made regarding the use of such equipment—such as which devices are to be used, who will use them, and how to use them—it is important to recognize factors that can introduce potential risk. These factors include the power of the launcher, the nature of the projectile, and the maturity, skill, and safety awareness of the user. The location and orientation of the launcher when the device is operated relative to the location of students is also a concern. These devices should never be oriented in a way that puts students in the line of fire.

To minimize risks:

- Wear goggles for eye protection.
- Participants and spectators should be behind the line of fire.
- Avoid using projectiles with sharp points.
- Ensure that misfiring does not place participants or spectators at risk.

Testing Structural Design to Failure

The Early and Middle Years science curricula contain many activities where students are required to make fair tests on various structures for design, stability, strength, and efficiency of performance. Such testing, particularly for strength, often requires stress-to-failure determination, which may require some precautions.

To minimize risks:

- Assess all inherent risks of testing to determine necessary precautionary measures.
- Wear goggles for eye protection.
- Minimize height at which testing is done on collapsing structures.
- Use of heavy weights should be closely supervised.
- Testing should be only attempted during teacher supervision.
- Testing should be done in a clearly marked area a safe distance from students.

Electrical Hazards

The two major risks related to electricity are electrical shock and fire. Some specific hazards and precautions are described below. An emergency power switch must be installed in every classroom or laboratory in which there is electrical equipment. A placard must also be visible to clearly label the emergency switch.

Faulty Wiring

Frayed cords and loose or broken connections will eventually create a short circuit. Fire, electrical shock, or equipment damage may result.

To minimize risks:

- Check external wiring of equipment before use.
- Verify normal function before making equipment available for student use.
- Ensure that the third ground prong on an extension cord or plug is still attached. Never cut the ground prong off of a device or extension cord.
- Do not disconnect power cords by tugging on the wire—always grab the plug end when disconnecting.

Heavy-duty Usage of Lightweight Equipment

Equipment damage and overheating, and therefore fire, are always possible if equipment is in prolonged use at power ratings greater than for which the item was designed.

To minimize risks:

- Always use equipment in the way its manufacturer intended.

Electrical Equipment Near Water

Use of electrical equipment near water creates the potential for a shock hazard if water gets into the electrical system. In addition, there is the potential for malfunction or failure of the equipment.

To minimize risks:

- Ensure equipment used near sinks or other water sources is properly insulated and grounded.
- Use ground-fault interrupter (GFI) plugs where available.
- Switch current off at the wall outlet or unplug immediately if water gets into the electrical equipment, and do not use again until completely dry.

Electrical Equipment Near Flammable Liquids or Their Vapours

The brushes of an electric motor will generate sparks, which can ignite flammable vapours under poorly ventilated conditions.

To minimize risks:

- Ensure that electrical equipment is used only in properly ventilated areas, away from flammable liquids.
- In the case of fume hoods, it is mandatory that the fume hood exhaust fan motor be explosion proof. This means that if there is a spark produced by the motor, the spark is completely encased and, due to the structure of the motor, is not allowed to make contact with the flammable vapours that may be outside the motor.

Shorting Dry Cell Circuits

Short circuits in devices not protected by a fuse can lead to overheating and to the risk of fire or injury. Such risks occur when a circuit is completed between terminals of a dry cell or dry cells without adding any resistance in the form of a bulb or other electrical device. Contact with overheated wires can lead to skin burns or a fire if the wires are near flammable materials. Severe short circuits can also cause dry cells to melt, give off toxic fumes, and possibly explode.

To minimize risks:

- Ensure a circuit has at least one source of resistance (e.g., bulb, electric motor).
- Whenever possible, all circuits should contain a mechanical switch.
- If an open switch is not included, connect the battery/batteries last into a circuit.

High Voltage Equipment

Some student-wired laboratory set-ups or teacher-made demonstration equipment may have the potential to deliver a high voltage discharge.

Common risks include the following:

- Capacitors that build up and store current can discharge on contact, generating a powerful shock.
- Polarized capacitors can explode if incorrectly connected into a circuit.
- Tesla coils can cause severe skin burns.
- Electrostatic generators, particularly the Van de Graaf, can cause serious shocks if students join hands.

- Isolation transformers that use 120V AC current can be fatal since only one wire needs to be attached.

To minimize risks:

- Ensure high voltage equipment is handled with extreme care.
- Ensure any use of such equipment is under the direct supervision and guidance of a qualified person.
- Ensure the equipment is in good working order before using it in the classroom.

Heat Hazards

Heating devices create fire and injury hazards. The potential risks posed by these devices vary with the heating device used and the way in which it is used.

To minimize risks:

- Provide test tube holders or tongs to handle hot equipment and containers.
- Provide heat-resistant gloves for handling heated objects or containers.
- Warn students about the dangers of reaching over an exposed flame or heat source.
- Provide heat-resistance glassware to prevent cracking and spilling of hot contents.
- Ensure students allow ample time for heated objects to cool before touching them.

Additional precautions for specific heat sources are described below.

Bunsen Burners

Figure 14 **Bunsen Burner**

Bunsen burners provide a direct and very efficient source of heat for laboratory purposes: however, there is a risk of burns, particularly to student fingers and hands. If the burner is used to heat water or a solution, the rapid heating can cause hot liquid to bubble out as it reaches its boiling point. In general, Bunsen burners would not be the preferred source of heat in Early Years settings and might also be avoided in Middle Years.

To minimize risks:

- Use Bunsen burners only if the activity requires high heat and if the maturity of the students is sufficient.
- Provide students with training on the use of Bunsen burners, particularly the routine of lighting and regulating flame intensity and air flow to produce a smokeless flame.
- To reduce the chance of ″bumping,″ which is the superheating of some of the liquid being heated, boiling chips or glass beads should be used.
- Heating liquids in test tubes can be the most dangerous. First, the flame should be as low as possible and the test tube must be held firmly with a test tube clamp. For gentle heating, the test tube should be quickly rotated in and out of the flame and the contents swirled for even heating. If the liquid is not evenly heated, it may super-heat and bump out of the test tube.
- Point the test tube mouth away from anyone nearby when using Bunsen burners to heat a solution or water in a test tube.
- Never heat a stoppered test tube.
- Use hot plates when flammable liquids are being used anywhere in the laboratory.

Hot Plates

Figure 15 **Hot Plate**

Electric hot plates with thermostatic controls provide a safer, controllable, and reliable source of heat that meets the needs of science courses; however, they can still cause burns to skin. In addition, coiled hot plates, which might still be in use in some schools, have greater potential to cause burns because of the exposed coils. Hot plates require a long time to completely cool before they can be handled safely.

To minimize risks:

- Ensure hot plates, as well as the heated materials and containers, are handled with care using proper techniques.
- Avoid coiled hot plates, if possible, and take extra care if they must be used.

Candles

Candles provide low intensity heat and thus are limited in their usefulness. However, they can be a good source of heat for activities where low intensity is required. The main problem with candles is their instability, which can cause fires or spill hot wax when they tip over.

To minimize risks:

- Secure the candle firmly to a base to prevent tipping. Impaling the bottom of the candle onto a nail protruding from a board base is effective. Setting the candle into a small pool of hot molten wax is generally not adequate to prevent tipping over.

NOT RECOMMENDED: Alcohol Burners

Figure 16 **Alcohol Burner**

These burners must not be used in any classroom or science laboratory at any grade level. There have been countless accidents from this type of burner. Alcohol is both odourless and invisible when burning. Teachers and students have been seriously burned by filling alcohol burners that have hot wicks.

NOT RECOMMENDED: Primus Cartridge Burners

It is NOT recommended that these burners be used at any grade level.

This type of burner, which is often used for camp cooking, presents a significant burn hazard associated with its use. One major drawback of this heat source is the inability to control the air supply to the flame. Thus, the heat intensity of the flame is always high (blue in colour), regardless of the size of the flame. Butane cartridges tend to be narrow and thus must be stabilized when in use. They cannot be refilled or recycled, and therefore present a concern to the environment.

NOT RECOMMENDED: Butane Burners

Figure 17 **Butane Burner**

While these burners are relatively easy to use and function much like a Bunsen burner, they are not recommended. They do have separate adjustments for gas and for air; however, the cartridges are not rechargeable and must be replaced once the gas is used up, making them more expensive to use than Bunsen burners and a concern to the environment.

Rocketry Hazards

Rockets are devices containing combustible propellants that produce thrust by expelling hot gases. Depending on their physical size and the size of the motor(s), rockets are classified as model rockets or high-powered (model) rockets. The guidelines and regulatory requirements that must be met for each of these are quite different.

Model Rockets

No special training or certification is required for building, installing, and firing model rockets made of lightweight materials weighing 1.5 kg or less. Rockets in this category are restricted to types A to G motors, producing up to a maximum of 160 Newton-seconds impulse, which in combination cannot exceed 320 Newton-seconds (N-s) total impulse. For less powerful A to F motors, the person must be over the age of 12 years and be supervised by an adult. To purchase “G” level motors, a person must be 18 years old or older. Model rockets use pre-manufactured solid propellant rocket motors with black powder or composites as propellants.

Flying of model rockets should be done in accordance with the *Canadian Rocketry Association Safety Code*. This can be found at <www.canadianrocketry.org>. Also, check with local authorities for bylaws regulating the firing of such rockets.

High-Powered (Model) Rockets

Rockets in this category have motors with an impulse over 160 Newton-seconds but not exceeding 40 960 N-s. Installing and firing such rockets is restricted to individuals over the age of 18, requires Canadian Association of Rocketry High Power certification, and is restricted to approved launches. Transport Canada has set out requirements for launching high-powered model rockets in Canada. These can be found at the Canadian Association of Rocketry website at <www.canadianrocketry.org/>. The major inherent risks associated with firing rockets include possible burns and the potentially lethal impact of misguided rockets.

Sound Hazards

Prolonged exposure to sound in excess of 85 decibels (dB) contributes to cumulative damage to inner ear hair cells, which may result in permanent loss of hearing at the specific frequencies to which the lost hair cells were sensitive. Such volumes might be created, for example, by loud music at school dances or by large generators in mechanical rooms. By contrast, high-impact noise causes eardrum perforation. Such noise is generated by pneumatic tools such as jackhammers. The eardrum perforations will heal, but each time this happens, scar tissue builds up on the eardrum and makes it less sensitive to sound waves. Any equipment or instruments generating significant sound should be monitored for loudness to ensure they do not exceed allowable occupational exposure limits set out in the *Workplace Safety and Health Act*.

Radiation Hazards

Radiation is not usually a hazard encountered in classrooms or the topic of discussions about safety in science. It is an invisible, often insidious hazard associated with the decay of radioactive materials such as isotopes of uranium and thorium, as well as emissions from electronic equipment or other sources. Radiation is the emission of energy in either particulate or electromagnetic form and is generally classified into two distinct categories: ionizing and non-ionizing.

Non-ionizing Radiation

Non-ionizing radiation increases the kinetic energy of molecules in body tissue, leading to heat production. This heat production is not enough to change the tissues chemically. Examples of this kind of radiation are sound waves, visible light rays, lower frequency ultraviolet rays, and microwaves.

Ultraviolet Radiation

When short wavelength radiation, such as ultraviolet rays, is absorbed by the skin or eyes at a high enough intensity or for a long enough time, the result can be sunburn and painful "welder's flash" burns on the eye. Prolonged or chronic exposure to ultraviolet radiation may also lead to premature skin aging. At sufficiently high intensities, non-ionizing radiation can disrupt essential physiological processes. However, in normal school laboratory practices where low-intensity radiation sources are used and exposure is minimized, levels will be well below specified limits and it will generally not be necessary to measure actual field strengths.

To reduce these risks:

- Minimize skin exposure.
- Never look directly at a source of ultraviolet rays without appropriate eye protection.

Potential sources of ultraviolet rays include lasers, stethoscopes, microwave ovens, UV bulbs, welders, fluorescent bulbs, gas discharge tubes, and burning magnesium ribbon.

Visible Light and Lasers

The direct or reflected viewing of any intense visible light source—electric arcs, burning magnesium ribbon, the sun, or even collimated or focused beams from ordinary tungsten lights—can cause retinal damage. For example, looking at the sun requires the use of a solar filter equivalent to that of a welding mask. The visible beam of light from a laser is focused by the lens of the eye and can cause severe retinal damage with very brief exposure if the laser is of sufficient power.

To reduce risks:

- Do not allow students to use lasers without close supervision.
- Use lasers in a well-lit room so that the pupils of the eye are small.
- Position lasers so that the beam cannot enter the eyes directly or by reflection.
- Demonstration lasers must be limited to 1 milliwatt beam of power and be within the wavelength range of visible light (400 to 780 nanometres). The normal blink response time of 0.25 seconds is sufficient to prevent retinal damage.

Stroboscopes

Rhythmical pulses of light, especially in the range of 3 to 7 Hertz, can cause unpleasant or dangerous physiological effects in some people, including nausea and epileptic seizures.

To minimize these risks:

- Avoid the range of 3 to 7 Hertz.
- Warn students of potential effects and monitor them closely for unusual behaviour or onset of nausea during use of stroboscopes.
- Excuse students who know that flashing light has a negative effect on them.

Microwaves

All microwave ovens produced since 1971 are covered by a federal radiation standard that assures such ovens are safe. This standard limits leakage of microwaves to values well below the level at which heating or burning of human tissue would occur, even at distances as close as 5 cm.

Ionizing Radiation

The term *ionizing radiation* refers to radiation in several forms:

- alpha particles
- beta particles
- gamma rays
- ultraviolet radiation, particularly at higher frequencies

The possession and use of materials that emit such radiation is tightly controlled by the Atomic Energy Control Board (AECB). Ionizing radiation has sufficient energy to break chemical bonds and damage human tissue, increasing risk of harmful genetic mutations and cancer. Potential harm is proportional to the energy absorbed, which in turn is affected by the amount of exposure. Although alpha particles can be stopped by a sheet of paper and beta particles by a layer of clothing, both are much more hazardous if ingested or inhaled. Both gamma and X-rays easily pass through the human body. Lead shielding is necessary to protect against such rays. Cathode ray tubes (CRTs) do not normally pose a radiation risk but can emit X-rays under high voltage conditions.

It should be noted that there is no readily applicable standard that specifies what amount of radiation exposure is safe. In general, the level of radioactivity in materials considered acceptable for Senior Years activities is so small that it approaches the level of normal background radiation. Such low levels do not require special licensing from the AECB, since potential health risks are minimal. These low-level sources are readily available through science supply companies. These have radioactivity levels measured in microcuries and can generally be disposed of via the local landfill. Check with your municipal office to ensure this is the case. Furthermore, no elaborate safety equipment or protective measures are necessary.

Radioactive materials available for purchase come in both sealed and unsealed containers. Sealed containers have the radioactive material permanently embedded within a metal, plastic, or other medium. Such sources are easier to handle and are generally safer to use than the unsealed sources of the same material. Sealed sources in license-exempt quantities are also readily disposable.

Protection from Ionizing Radiation

Special handling and shielding of radioactive materials is required in instances where activity levels exceed the exemption quantities set out in Schedule 1 of the *Nuclear Substances and Radiation Devices Regulations*. Materials that have such high levels of radioactivity are not recommended for school use. See <www.nuclearsafety.gc.ca/eng/regulatory_information/Regulations/index.cfm> for more information on these regulations.

To minimize the potential hazards of ionizing radiation:

- Use low-level radioactive material with emissions in millicuries.
- Keep the time for potential exposure to a minimum.
- Stay as far from the radiation source as possible. As a rule, if the distance is doubled, exposure is reduced by a factor of four.
- Monitor radiation levels throughout time of exposure with the use of a Geiger counter.
- Store in a suitably shielded container (e.g., a lead storage pot in a properly marked cabinet not frequently used by people).