భారతీయ సాంకేతిక విజ్ఞాన సంస్థ హైదరాబాద్
भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad

SAFETY MANUAL

Mechanical and Aerospace Engineering

Preface and Acknowledgments

This manual contains a number of guidelines that can help all of us perform our research tasks more safely and maintain better order and safety in our laboratories. Each student is expected to read this manual thoroughly and act in accordance with the guidelines. This manual should also be kept readily available for reference.

One of the most fundamental aspects of safety in a research laboratory is good housekeeping. This includes the proper storage and handling of chemicals, gas cylinders, electrical equipment, and so on. The appearance and organization of our facilities directly affect their safety and productivity. There are two golden rules for developing a safe and productive environment:

1) Whenever you use a lab, it is your responsibility to see that unsafe conditions are corrected immediately; and

2) Always leave a laboratory in better condition than when you found it. If we all take on this level of personal responsibility, our facilities can only improve.

Rules specific to our IITH Mechanical & Aerospace Laboratory have been prepared with the aim of creating a better and safer work environment by implementing all the standard safety practices, procedures, and guidelines applicable to our kind of laboratory. We hope to periodically update and revise this manual to make it more useful and effective.

Hence, if you have any comments or additional information that should be added to make this manual more comprehensive or user-friendly, please inform your lab safety incharge.

Index:

1. Introduction

The purpose of this manual is to make all users of IIT Hyderabad Mechanical & Aerospace Laboratory facilities aware of safety and emergency protocols (do's and don'ts) that must be followed. The aim is to provide general safety guidelines. While it does cover a wide variety of hazards—mechanical, chemical, electrical, workplace- and laboratory-related, etc., please use your discretion and, more importantly, common sense. Remember that the ultimate responsibility for conducting a safe experiment resides with the experimentalist.

The institute works with several hazardous materials and equipment. The institute and government regulations allow us to operate with considerable autonomy, trusting us to maintain the highest levels of safety. We need to sustain this trust by maintaining a safe working environment. Furthermore, safety is an important part of any research training. This is especially true for leadership positions where project managers are responsible for the safety of their whole group.

1.1 Safety Principles

The five essential principles of safety to be implemented in the laboratory are:

1.1.1: Following rules
1.1.2: Personal responsibility towards safety
1.1.3: Trust system more than people
1.1.4: Hazard Identification and Risk Assessment (HIRA)
1.1.5: Prompt response to non-conformity, incidents and emergencies

They are discussed below:

1.1.1 Follow Rules

Safety may mean different things to different people. Sometimes because of ignorance and sometimes because of a lack of sufficient forethought, many activities are carried out by individual groups, which lead to incidents resulting in bodily damage, material loss, or both. To prevent such incidents due to confusion, this manual clearly defines standards for safe work practices. These rules need to be followed by everyone in IITH Mechanical & Aerospace Laboratory facilities, both in letter and spirit, even if they sometimes appear burdensome and/or pointless (trust us, there is a reason for everything. Wherever needed, we have explained the same in the manual).

Remember, practicing safety means doing things the right way, not the quick way.

1.1.2 Personal Responsibility

The primary responsibility for safety rests with the individual. A responsible, considerate student with an understanding of the workings of the laboratory, basic knowledge about its equipment and processes, basic subject knowledge, common sense, and an instinct for self-preservation will have little trouble while working in the laboratory. The staff cannot oversee or supervise operations all the time. Under these conditions, any inconsiderate user can endanger their own and the safety of others. Most problems, incidents, and violations in the laboratory result from haste. Haste makes waste and causes safety concerns. All hazards should be identified and clearly labeled in a manner that is easily understood by others using appropriate labels and stickers. One should act responsibly in the event of an accident, e.g., pull the alarm to warn others. Finally, unsafe behaviour should be confronted everywhere, e.g., reminding your friend to wear safety glasses.

1.1.3 Trust structures more than people

No matter how careful people are, they often make mistakes. An effective safety policy does not rely on people but relies on systems to reduce the probability of accidents. Before starting any project or process, it is essential to think about all the potential hazards. The focus should be on reducing the probability of all the hazards through intelligently designed safety precautions. Try to seek solutions that are inherently safe. Safety precautions also include learning how to store, handle, and dispose of all hazardous materials. Experiments should only be conducted in a designated area with proper ventilation and lighting. One should also use appropriate personal protective equipment. Equipment should be well maintained with periodic scheduled inspections.

1.1.4 Hazard Identification and Risk Assessment (HIRA)

Identifying, quantifying, and assessing the potential risk in the workplace and controlling the risk through elimination, substitution, reduction, engineering control, and administrative control are very essential for a safer work environment. All activities need to be listed, and risk assessment must be carried out qualitatively and quantitatively. A standard checklist, protocol, and questionnaire are to be used for Hazard Identification and Risk Assessment (HIRA).

1.1.5 Prompt response to Non-conformity, Incidents and emergencies

Everyone must be prepared to respond quickly and effectively to any non-conformity, incident, or emergency. Become familiar with the work area, available exits, and safety equipment such as eyewash stations, fire extinguishers, sinks, spill kits, and first aid boxes. Timely Identifying non-conformity and acting on the corrective and preventive actions (CAPAs), reporting and investigating incidents, and few moments spent in training could save a life during an emergency.

1.2 Laboratory Safety Committee (LSC)

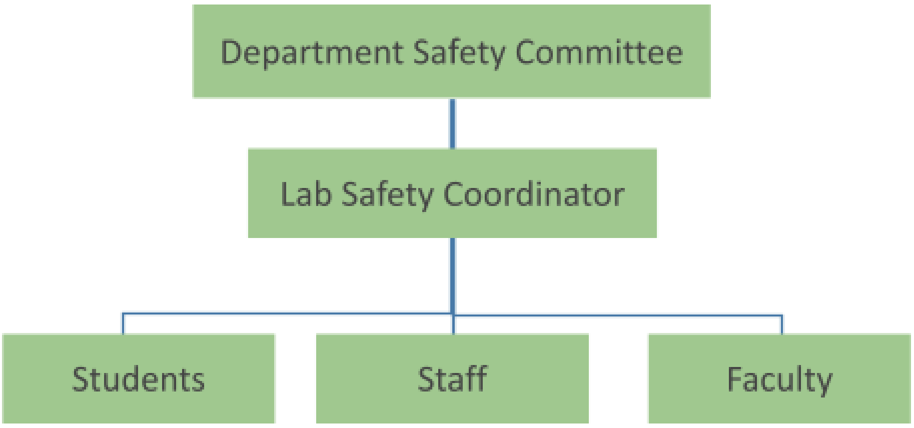
LSC is the committee that is the forum to discuss all safety aspects at IITH Mechanical and Aerospace Laboratory facilities. LSC has representatives from students, staff, and faculty members, comprising a team of experienced and trained personnel who are available to discuss and consult on a safety issue. If you are unsure of something, contact them. If you have a safety issue that does not have an obvious solution, it needs to be discussed in LSC.

The Committee has the right to conduct spot audits, seek information, regulate procedures and policies, and, in extreme cases, recommend disciplinary action.

1.3 The Safety Network

All departments and centres have a designated Department Safety Champion or Safety Coordinator. The safety champion or coordinator is the primary contact point for any safety-related issue or concern in a departmental laboratory. Safety Committee, which is the apex body on all laboratory safety matters. If the champion or coordinator is unable to resolve the safety issue, they need to put the matter before the safety committee through office@mae.iith.ac.in. In case of any major or serious safety-related issues, the chairman of the safety committee, if needed, may seek support or escalate matters as deemed necessary.

Safety Committee Organogram



2. General Safety

Laboratory safety is a very important aspect of scientific education. Without following its rules, experimentation could result in incidents or accidents. In order to reduce the risks involved with experimentation, there are certain procedures that should be followed by individuals and by members of a group. It is important that the correct procedures are used in various situations, such as when handling hazardous materials or preparing, executing, or cleaning up an experiment. It is also essential to understand how to identify and use emergency equipment and protective gear.
This lab manual is provided to guide its reader through and develop an understanding of laboratory safety. It is very important to take time to understand the procedures, concepts, and reasons to make the laboratory as safe as possible.

2.1 Definitions

"Safety" is the state of being "safe," the condition of being protected from harm or other non-desirable outcomes. Safety can also refer to the control of recognized hazards in order to achieve an acceptable level of risk.

Hazard: A hazard is a substance, object, or situation that may result in an accident (injury or damage). For example: an airplane collision in air

Risk: A risk is the likelihood that an accident of a specific type and **severity** will occur as a result of a specific event. It is expressed as a ***frequency*** (number of occurrences per year).

Incident: Any unplanned event or series of events that causes or has the potential to cause bodily injuries, fire, damage to the environment, equipment, or property.

Accident: A workplace incident that has caused bodily injuries to human beings and damage to the environment, property, and equipment.

Effects of accidents:

- Injury to Person
- Equipment Damage
- Material Loss
- Financial Loss
- Loss of Business

2.2 Hazard identification

Hazards are identified by applying the following methods:

Comparative methods, e.g., checklists and audits.
Fundamental Methods, e.g., Failure Modes and Effects Analysis.
Failure logic, e.g., fault trees, event trees, and cause-and-consequence diagrams.

2.3 Types of Hazards

2.3.1 Mechanical Hazards:

- Blades
- Moving or rotating belts or chains
- Gears
- Shafts
- Pinch points
- Other

2.3.2 Physical Hazards:

- Noise
- Radiation
- Temperature
- Pressures
- Vibration

2.3.3 Thermal Hazards:

- Hot objects/Material
- High and Low Temperatures
- Flame
- Fire
- Explosion

2.3.4 Chemical Hazards:

- Gases
- Vapors
- Fumes
- Liquids
- Solids

2.3.5 Ergonomic Hazards:

- Unnatural posture
- Extreme force
- Repetition

2.4 Risk Assessments' Types:

- **Qualitative:** very straightforward process based on judgement requiring no specialist skills or complicated techniques, as we apply it in the present study.
- **Quantitative:** tends to deal with the avoidance of low-probability events with serious consequences for the plant and the surrounding environment.

2.4.1 Qualitative risk assessment:

Qualitative risk assessment involves making a formal judgement on the consequences and probability using:

Risk = Severity x Likelihood

Table (1.1) Risk Level Assessment

		Consequences				
		Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Catastrophic (5)
	Almost Certain (5)	Moderate (5)	High (10)	High (15)	Catastrophic (20)	Catastrophic (25)
Likelihood	Likely (4)	Moderate (4)	Moderate (8)	High (12)	Catastrophic (18)	Catastrophic (20)
	Possible (3)	Low (3)	Moderate (6)	Moderate (9)	High (12)	High (15)
	Unlikely (2)	Low (2)	Moderate (4)	Moderate (6)	Moderate (8)	High (10)
	Rare (1)	Low (1)	Low (2)	Low (3)	Moderate (4)	Moderate (5)

Table (1.2): Risk Severity

Severity	Description
1. Insignificant	No Treatment required
2. Minor	Minor injury requiring First Aid Treatment
3. Moderate	Injury requiring Medical Treatment or lost time
4. Major	Serious injury (injuries) requiring special Medical Treatment and/or Hospitalization
5. Severe	Loss of life, permanent disability or multiple serious injuries

Table (1.3) Risk Probability

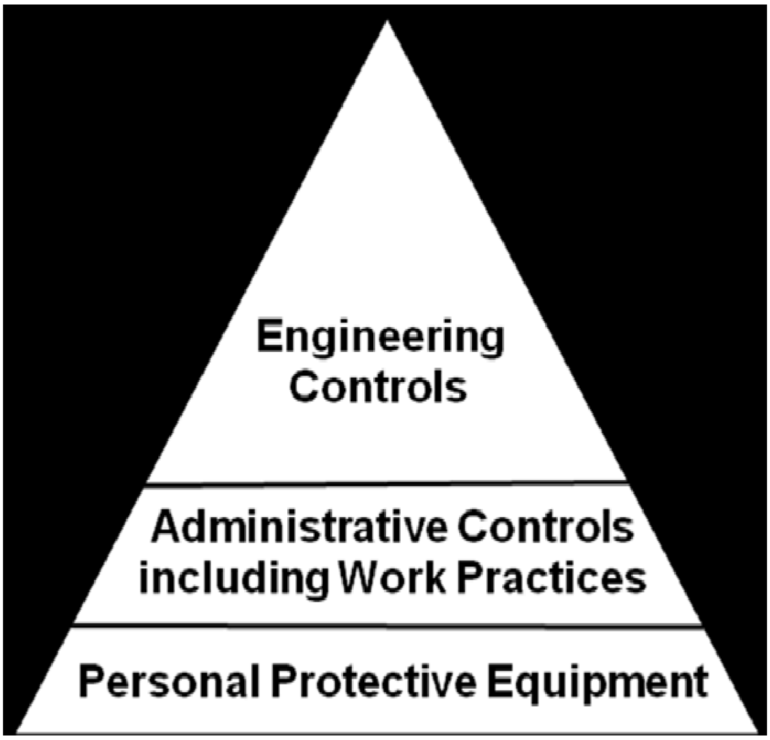
Probability	Description
E. Rare	Will only occur in exceptional circumstances
D. Unlikely	Not likely to occur within the foreseeable future, or within the project lifecycle
C. Possible	May occur within the foreseeable future, or within the project lifecycle
B. Likely	Likely to occur within the foreseeable future, or within the project lifecycle
A. Almost Certain	Likely to occur within the foreseeable future, or within the project lifecycle

Table (1.4) Response to the levels of risk

Assessed Risk Level	Description	Actions
Low	If an incident were to occur, there would be little probability that an injury would result	- Undertake the activity with the existing controls in place - Monitor and Report from Management
Moderate	If an incident were to occur, there would be some chance	-Additional controls may be needed - Investigate cause, mitigation

	that an injury requiring First Aid would result	measures and mixing zone considerations
High	If an incident were to occur, it would be likely that an injury requiring medical treatment would result	-Controls will need to be in place before the activity is undertaken - Senior Management attention needed
Extreme	If an incident were to occur, it would be likely that a permanent, debilitating injury or death would result	-Consider alternatives to doing the activity. - Significant control measures will need to be implemented to ensure safety - Immediate action required by Management

Risks are systematically reduced through control measures, according to the hierarchy of risk control shown in table 1.6, as the Risk elements which include: "Source, Pathway and Receiver". The hierarchy control, is represented in figure (1.1)



Figure(1.1) Hierarchy Control

Table (1.6) Risk control Elements

Elimination: remove the hazard completely from the workplace or activity
Reduction: reduce a hazard with a less dangerous one by many means, as substitution (e.g. a less hazardous chemical)
Engineering Controls: reduce the hazard by many means, as redesign: making a machine or work process safer (e.g. raise a bench to reduce bending), or Isolation: separate people from the hazard (e.g. safety barrier)
Administration Controls: putting rules. signage or training in place to make a workplace safer (e.g. induceson tang, highlighting trip hazards)
Personal Protective Equipment(PPE): Protective Clothing and equipment(e.g. gloves and hats)

2.4.2: Hazard Identification and Risk Assessment (HIRA):

Hazard Identification and Risk Assessment of Thermos Acoustic Instability Laboratory Setup.

2.5. Risk Control

2.5.1 Risk Elimination

The best method of dealing with a hazard is to eliminate it. Once the hazard has been eliminated, the potential for harm has gone.

2.5.2 Risk Substitution

This involves substituting a dangerous process or substance with one that is not as dangerous. This may not be as satisfactory as elimination since there may still be a risk (even if it is reduced).

2.5.3 Risk Engineering Control

- Guarding
- Enclosures
- Substitution
- Process modification
- Equipment modification
- Ventilation
- Lighting engineering controls eliminate the “human factor” in preventing injuries.

2.5.4 Administrative Elements

Administrative solutions usually involve modifications.

This can be done by:

- Reducing the number of people exposed to the danger
- Reducing the amount of time exposed

2.5.5 Personal Protective Equipment (PPE)

The provision of PPE should only be considered when all other control methods are impractical.

- Eyes (example: safety glasses)
- Face (example: face shield)
- Head (example: hard hat)
- Ear (example: ear plugs)
- Hand (example: rubber gloves)
- Foot (example: safety shoes)
- Body (example: rubber apron)
- Respiratory (example: respirator)

2.6 Laboratory Personnel Duties and Responsibilities In General

- Complete all required health, safety, and environmental training.
- Review and follow relevant laboratory authorizations and safety manuals.
- Follow oral and written laboratory safety rules, regulations, and standard operating procedures (SOP) required for assigned tasks.
- Keep your work areas safe and uncluttered.
- Review and understand the hazards of materials and processes in your laboratory prior to conducting work.
- Take appropriate measures to control identified hazards, including consistent and proper use of engineering controls, personal protective equipment (PPE), and administrative controls.
- Understand the capabilities and limitations of PPE issued to you.
- Get prior approval from your PI or laboratory supervisor for the use of restricted chemicals and other materials.
- Consult with PI/laboratory supervisors before using highly hazardous materials or conducting certain higher-risk experimental procedures.
- Report accidents and unsafe conditions immediately to the PI or laboratory supervisor.
- Participate in the medical surveillance program when required.

- Inform the PI/laboratory supervisor of any work modifications ordered by a physician as a result of medical surveillance, occupational injury, or exposure.
- Follow basic laboratory security requirements for hazardous or controlled materials.
- If you discover a "**fire**," you have to know the elements of Fire Safety Resources, Procedures of Building Evacuation , Corridor Safety Requirements, Eye Wash and Emergency Shower Guidelines. How to Use a Fire Extinguisher, Flammable and Combustible Liquids Laboratory Fire Safety, Special Laboratories Fire Safety, and Refrigeration Processes for Flammable Liquid Storage.

2.7: Good Safety Practices

2.7.1: General Laboratory Safety Practices:

- Each lab should have a designated lab-in-charge who is responsible for day-to-day enforcement of safety protocols. Each lab will also have a faculty member associated with it who is ultimately responsible for safety in the lab.
- Known and anticipated hazards are considered for all materials or equipment being used. Before using unfamiliar chemicals, equipment, or new products, please read the labels, material safety data sheets (MSDS), and/or user manuals. If in doubt, do some research on the issue and/or discuss it with an authority.
- Training should be provided for all new lab users. Training for existing users must also be provided when new hazards are introduced into a lab, e.g., during introduction of new substances, processes, or equipment.
- Only proper equipment, in good condition, should be used. Before trying something very different from the equipment's intended use, please talk to the lab-in-charge.
- Boxes, chairs, cartons, shelves, chairs with wheels, or anything else that is not a ladder should not be used as a ladder.
- Emergency equipment (e.g., fire extinguishers, emergency eyewash/shower units, etc.) should be unobstructed, clearly visible, and in good working condition.
- First aid kits are available in quickly accessible, visible, and designated places. Ensure that first-aid kits have not expired.
- Eating, drinking, or applying cosmetics near hazardous materials (radioactive, bio-hazardous, or chemical) is not permitted. Since all labs in the department of mechanical and aerospace count as hazardous, ***NO FOOD/DRINK SHOULD BE ALLOWED INSIDE THE LAB.***

- Food and drinks should not be stored in the refrigerator or freezer used to store hazardous materials. Refrigerators storing hazardous materials should have a clearly visible label saying, “No food or drinks” (see appendix for a sample).

Figure 1: No eating, drinking, or munching in the lab. Food should not be stored in lab refrigerator

- No experiments should be carried out after hours or without the presence of a safety champion or the safety incharge; anyone working alone late at night should notify the lab safety incharge.

- All labs need to fill out, update, and periodically review the “Laboratory Hazard Sheet” (see appendix) and post it on the laboratory door. To confirm that the sheet is current, the lab in charge must sign and date the sheet.
- All labs must maintain a working landline that is kept near the door.
- All labs must maintain a list of emergency contact numbers posted very near the phone at eye level. The emergency list should include cell phone numbers of the faculty in charge, the lab in charge, and other regular lab users. The emergency list should also include the numbers for the IITH health centre, campus security, the local police, and the fire station.
- Follow the buddy system. Never work alone in a lab, especially at night and during weekends. Buddy is a fellow lab user who is working close enough to notice if you are in any distress. Friends on cell phones, in offices, or in hostels don’t count.

2.7.2 Good Housekeeping Practices

- Work areas are kept uncluttered and are cleaned upon completion of operations or at the end of each workday. This is particularly important for areas with hazardous materials and equipment.

- Floors are maintained free from tripping, slipping, and falling hazards (e.g., cords, cables, wires, equipment, and tools).
- Spills are attended to immediately and thoroughly.
- Emergency equipment and controls are not blocked
- Hallways and stairways are not used as storage areas.
- Workbenches and shelves are not overloaded with unused equipment, chemicals, or other materials.

2.7.3 Personal Care

- Maintain personal cleanliness so that hazards don't affect you after you leave the lab.
- Confine long hair and loose clothing when in the laboratory to keep them from catching fire.
- dipping into chemicals or becoming entangled in moving machinery.
- Avoid wearing dangling jewelry. These can reflect light from lasers or get caught in moving parts.
- Avoid wristbands, rakhi's, rings, wristwatches, and other wrist ornaments. These may become contaminated with chemicals, react with chemicals, or be caught in the moving parts.
- Remove laboratory coats and gloves before you leave the laboratory to prevent spreading contamination to other areas.

Figure 2: Personal Care cautions

2.7.4 Personal Protective Equipment (PPE)

Protective clothing and equipment safeguard against harmful chemical spills on the body, inhalation, projectiles, etc. You are responsible for wearing the proper protective gear according to the activity you are doing in your lab.

2.7.4.1 Eyes

- Understand the difference between safety glasses, chemical splash goggles, and face shields. The first is for mechanical hazards, the second for liquid hazards, and the third for extra safety when handling bigger hazards.
- Eyes are the most easily injured external organ, so whenever in the vicinity of sharp objects, rapidly moving machines, hot material, or flying particles, safety glasses with side shields must be worn. In fact, it is strongly advisable that safety glasses be worn in the lab at all times.
- Eyes are also covered with blood capillaries, so they can quickly absorb many harmful chemicals. Splash goggles must be worn when there is danger of splashing chemicals.
- When working with large amounts of chemicals (e.g., 4-liter bottles) or in the vicinity of explosive or explosive hazards (e.g., vacuum systems with glass jars), a face shield with safety goggles offers maximum protection.
- Prescription lenses in spectacles do not provide enough protection. In fact, unless they are shatter-resistant, they are hazardous on their own. People who need to wear prescription glasses must wear safety glasses or splash-goggles over their prescription glasses.

Figure 3: Difference between safety glasses and chemical splash safety glasses. From Air Clean Systems

Feature	Safety Glasses 	Face Shield 	Splash Goggles 
Coverage area	Eyes	Eyes, face, nose, and mouth	Eyes, orbital bones
Protection against:	Flying debris, dust, and sparks	Flying debris, splashes, chemicals, and molten metal	Splashes, chemicals, dust, and airborne droplets
Seal around eyes	No	No	Yes
Comfort	Lightweight, comfortable for long wear	Bulky can restrict peripheral vision	It can fog up and may be uncomfortable for extended use
Use cases	Light-duty tasks, woodworking, metalworking	High-impact environments, chemical handling, healthcare	Chemical labs, painting, cleaning, pressurized fluids

Table 1: The difference in the use case between safety glasses , face shield and splash goggles

2.7.4.2 Hands

- Gloves need to be worn anytime you are handling something in the lab.
- Ensure that there is no gap between the end of the lab coat sleeve and the glove wrist.
- Gloves are worn to prevent contact with toxic or biological agents, burns from hot or extremely cold surfaces or corrosives, or cuts from sharp objects. Several types of

safety gloves are available, each for specific hazards. For adequate protection, select the correct glove for the hazard in question

- Chemicals will eventually penetrate all glove materials. Change gloves periodically to minimize penetration.

Glove Type	Use Case	Thickness
Thin Nitrile Gloves 	Laboratory work, medical examinations, and light-duty tasks	<2 mil
ThickNitrile Gloves 	Mechanics, chemical handling, and heavy-duty tasks	2-4 mil
Heat-Resistant Silicon 	High-temperature handling, cooking, and industrial ovens	Varies
Cryogenic Gloves 	Handling extremely cold materials and cryogenic substances	Varies

Table 2: Different types of gloves and their usage

Figure 4: Gloves that are not allowed

- Wash hands after leaving the lab even if you were wearing gloves. Long term exposure to even minuscule amounts of toxin can have very adverse effects on your health. Such chronic exposures are very hard to diagnose or detect. Prevention is the only option.

Figure 5: Always wash hands after lab work.

2.7.4.3 Body and Feet

- Clothing can prevent small chemicals from damaging skin. Cover unprotected skin whenever possible. No shorts. Only wear full-length trousers, salwar, etc.
- Aprons or laboratory coats must be worn especially when handling chemicals.
- Wear stable hard-toe shoes in the lab area to protect feet from chemical splashes and sharp objects on the floor. No slippers, sandals, or high heels. No bare feet.

Figure 6: Only closed-toed shoes allowed in labs.

2.7.4.4 Breathing Apparatus

- Proper respirators (self-contained breathing apparatus) must be used whenever there is a chance to inhale hazardous chemicals, gases or nano-particles.
- Proper respirators (self-contained breathing apparatus) must be used whenever hazardous gas cylinders are being installed/changed.

2.7.5 Glassware safety

Accidents involving glassware are a leading cause of laboratory injuries. These can be avoided by following a few simple procedures. In general, be certain that you have received proper instructions before you use glass equipment designed for specialized tasks that involve unusual risks or potential injury.

- Handle and store glassware carefully so as not to damage it or yourself.
- When inserting glass tubing into rubber stoppers, corks, or when placing rubber tubing on glass hose connections, protect hands with a heavy glove or towel.
- Substitute plastic connections for glass whenever possible to decrease the risk of injury. Use glassware for vacuum work that is designed for that purpose.
- When dealing with broken glass, wear hand protection when picking up the pieces. Use a broom to sweep small pieces into a dustpan, and store glass pieces in a designated bin for broken glass.

3 Chemical Safety

A wide variety of hazardous chemical and biological agents are used in IITH laboratories. Therefore, it is required to undergo proper orientation to be aware of possible hazards/accidents.

3.1 Basics

- Before a researcher begins to work in a laboratory, he/she must be made aware of potential hazards (chemicals, lasers, autoclaves, etc.) associated with the laboratory by the lab in-charge.
- All researchers are responsible for teaching themselves about the hazards posed by the chemicals in their vicinity. If using a material, the researcher should also know the safe way to store, handle, and dispose-off the hazardous chemical. If you do not know, ask someone who does or reads the MSDS. All labs are expected to maintain a clearly labelled folder with hard copies of MSDSs of all the chemicals in the lab. The folder must be stored in a visible location, preferably near the door. This serves as the inventory of chemicals stored in labs.
- Material Safety Data Sheets (MSDSs) must be reviewed for product specific handling, storage, and disposal information.
- Become familiar with the location of fire extinguishers, spill kits, and first-aid boxes in your area. Familiarize yourself with their use. All laboratories with heavy, hazardous chemical use must have access to a spill kit.
- Before finishing, ensure that the work bench and work areas are clean and that all waste chemicals are properly removed and disposed of. Any chemicals that are to be left over must be clearly labelled. There should also be a note with the user name, phone number, and expected time of return.
- All chemical bottles must be properly labeled. The manufacturer's label is best, as it usually contains a great deal of information about health and physical hazards. If the contents are being stored in another container, the contents need to have the IITH chemical label
- All chemical work must be done inside fume hoods. Do not open chemical bottles outside fume hoods.
- Chemical and biological waste should be segregated, labelled, and appropriately disposed-off.
- It must be reemphasized that no set of rules can substitute for common sense and a professional attitude toward laboratory safety.
- As much as possible, limit the number of chemicals in the lab. Buy a moderate amount of chemicals that can be consumed in the near future. Don't let chemical waste pile-up.

- Don’t mix incompatible chemicals. Certain compositions, like organic solvents and acids, are explosive.
- Date chemicals when received and opened. Unstable chemicals, like ethers, are unstable. Over time, they tend to form explosive peroxides.
- Never add water to acid. Always add acid to water.

Figure 7: Chemical Safety precautions.

3.2.Inhalation hazards

Inhalation hazards are often not obvious and, hence, overlooked, even though the consequences of inhalation can be quite serious.

- Toxic or flammable substances that can be airborne (e.g., gases, vapours, dust, fumes, or mists) should not be used in unventilated areas. In the absence of adequate ventilation, air contaminants can build up to levels that pose health or flammability hazards. As much as possible, use such materials in fume hoods.
- Some specialized equipment is capable of producing airborne hazards such as fumes, dust, or mist. For example, physical vapor deposition systems (sputtering, evaporation, etc.); sand-blasters; grinders, low-melting-point metals; solids that sublime at low-temperature; etc. This hazard is compounded if the same equipment is used to handle materials that are toxic. Care must be taken to reduce exposure while using this equipment or toxic materials. Consider using gas masks, respirators, etc.
- Gases are another common source of inhalation hazards. There are gases, like H2S, that occur naturally and can be tolerated in small amounts. Hence, there is a

tendency to discount their severity. This is a mistake. Always refer to the MSDS to know the exact amount of allowed exposure, whether instantaneous or chronic. When such information is not available, err on the side of caution.

3.3 Fume Hood Usage

- Hoods use air-flow to reduce exposure to fumes. Check the anemometer to ensure good air flow before using a hood.
- Don't do anything that obstructs air-flow in the fume hood. E.g., don't store chemicals or cover vents.
- Keep the sash of the hood as low as possible. This prevents the vapors from back-flowing.
- Chemicals must be placed at least 6 inches inside the face of the hood.
- The user should always remain outside the hood. Never peer inside.

3.4 Chemical Transport, Storage, and Usage.

- As much as possible, limit the storage of flammable and corrosive chemicals in the lab.
- Some chemicals, such as ethers, have recommended storage time limits. Chemicals stored beyond their limit date may form explosive peroxides, which can detonate when removing a cap, agitating, dropping, scraping, etc. Upon arrival, these containers should be marked with the date placed in storage and an expiration date based on the manufacturer's recommendations. Many manufacturers include an expiration date on the product label.
- Flammable materials should be stored in flammable material storage cabinets. Storage outside of the cabinet should be limited to materials used in the current process and must be returned after use to the appropriate storage cabinets. Leaving chemicals on benches or working areas is hazardous and not acceptable. Plastic cabinets are designed for corrosion resistance and are used for storing acid and other corrosive materials. Acids and other corrosive chemicals in the chemistry laboratory may be stored under the fume hoods.
- All cabinets must be labelled by chemical class (e.g., flammable liquids, acids, oxidizers) to ensure chemicals are suitably segregated.
- Store the four classes of chemicals, acids, bases, solvents, and oxidizers, separately. If there is an issue of space, solvents and bases can be stored together, and acids and peroxides can be stored together. However, chemicals, which can react violently or emit hazardous fumes when mixed, should not be stored near each other. E.g., oxidizers and flammables must never be stored together.

- Acids, bases, and oxidizers must be stored with secondary containment (to contain the spill in case the first container ruptures). Corrosion-resistant plastic trays are a low-cost option for secondary containment.
- Large bottles and bottles containing toxic, flammable, or corrosive liquids should be stored on shelves below eye level (maximum 5 feet). Corrosive materials can cause severe tissue damage and are particularly injurious to the eye.
- Volatile or unstable materials may be stored in a flammable-rated refrigerator only in properly sealed containers. Never store flammable solvents (ether or benzene) in the refrigerator in open containers (beakers).
- Food or drink should never be stored in a laboratory refrigerator or freezer. "**No food or drink**"..
- Some chemicals may degrade certain container materials. Always check for compatibility. For example, hydrofluoric is incompatible with glass. Inorganic hydroxides are best stored in polyethylene containers. Some organic solvents will soften cheap plastic, so they should be stored in fluorocarbon or glass bottles.
- Don't carry chemicals in your hands. Transport chemicals in bottle carriers, carts, buckets, etc.
- These are available in stockrooms.
- Label all open chemical bottle samples with the contents, owner's name, and date of preparation. Commercially obtained samples should be dated on the day they were opened.
- Be careful with materials that may form peroxides (diethyl ether, tetrahydrofuran, dioxane). Opened containers of these materials should be discarded within one year of opening. All such containers should be dated upon receipt and upon opening.
- Never leave an unlabeled bottle of "something" behind when you depart. Everything should be labelled with a chemical label.

3.5 Waste Segregation and Disposal

- By law, we are required to dispose of waste as per pollution board rules. We also have a moral obligation to maintain the environment. All lab waste is prima facie hazardous waste that must be segregated and disposed of appropriately. To avoid difficult and potentially costly waste disposal problems, a procedure should be in place to assure all materials are labelled and unneeded chemicals are disposed of properly.
- Material should be placed into compatible storage containers with secure screw-on tops and labelled with the "IITH Waste Label.".

- In general, waste must be stored in the type of container in which the component materials were purchased (glass, plastic, or metal). However, metal cans should not be used for acidic and corrosive solutions (alkali, acid, etc.). Also, as much as possible, avoid glass containers for storage, as they can shatter easily.

- A small amount of waste can be collected in the labs. Once a month, lab in-charges are required to collect all the waste and bring it to the waste collection point. Only labelled and segregated waste will be collected, so please make sure all the rules of segregation and labelling are followed.
- Hazardous waste needs to be segregated and disposed of in an appropriate manner to comply with the institute's waste management policy.

4. Fire and Electrical Safety

The best defense against fire is to prevent the fire from starting. Everyone is responsible for fire prevention and knowing how to handle a fire emergency.

4.1 Precautionary procedures

- Be aware of ignition sources in the laboratory and service areas (open flames, heat, and electrical equipment).
- Always store flammable liquids in appropriate cabinets.
- Do not store incompatible reagents together. Some combinations, e.g., acids and organic solvents, are explosive.
- Do not store unstable chemicals, like ethers, for extended periods of time. They tend to form explosive peroxides. If you have an old, sealed bottle, don't open it. Date chemicals when received and opened. This allows tracking.
- Make sure that all electrical cords are in good condition and all electrical outlets are earthed. Remain out of the area of a fire or incident if you are not in position to help.
- Locate the fire exits, fire alarms, and extinguishers in your laboratory. Each laboratory should be equipped with extinguishers. See the following section to learn about different types of fire extinguishers.
- Maintain adequate walking space in the laboratory, minimum of 2 feet, and unobstructed access to exits.
- Ensure adequate ventilation around objects that heat up (e.g., lamps, CPUs, etc.).
- Avoid long-term storage of carton boxes, thermocole, and other plastic or packaging materials. These are major causes of fire incidents.
- Papers, binders, and manuals must be stored in enclosed containers or cups, away from hot objects.
- Do not block access to fire escape routes, even outside of the laboratory. For example, the stairs should be free of debris, nothing should be stored in front of fire hoses, etc.

- Keep your workspace neat and tidy. Oily rags, carton boxes, waste, or papers improperly stored are common causes of spontaneous combustion. Store these materials in covered, metal containers.
- Ensure that fire extinguishers are serviced and inspected regularly.
- Keep a small, handy fire extinguisher near flammable chemicals and organics.

4.2 Electrical Safety

- Access to electrical equipment (e.g., plugs and switches) should be maintained free from obstruction.
- Electrical apparatus is equipped with ground plugs or is properly grounded.
- Make sure that live terminals are not exposed to direct or indirect touching at all switches and outlets.
- Ground-fault circuit breakers are used as needed.
- Two-pin appliances (un-grounded) are not within a 5-foot radius of flammable materials.
- All current-transmitting parts of electrical devices are enclosed.
- Electrical connections are not handled with wet hands or when standing in or near water.
- Safety devices (e.g. fuses) on electrical equipment are not bypassed
- Electrical equipment is disconnected from electrical outlets or circuits when being adjusted, lubricated, moved, or cleaned.
- Do not disconnect power supply by pulling or jerking the cord from the outlet. Pulling the cord causes wear and may cause a shock
- Electrical plugs, cords, and extension cords are maintained in good condition.
- Power strips and extension cords are kept to a minimum, and cords are as short as possible. Daisy chains of surge protectors are not a replacement for permanent plug points. If additional plug points are required, ask BMS. Overloaded power boards can not only damage the devices that are plugged in; they can cause electric shocks and even start fires.
- Cords are placed in areas where they are not exposed to physical damage. They are not run through doorways or ceilings or placed under carpets.
- Don’t splice extension cords or electrical cords without properly insulating the junction with insulation tapes.
- Always make sure that you don’t overload an electrical outlet (e.g., don’t connect a 15A device to a 5A socket). If an outlet is overloaded, it may lead to fire in that circuit.
- Never try to extinguish an electrical fire with water (this can result in electric shock if the burning wires are still alive); use only the proper fire extinguisher.

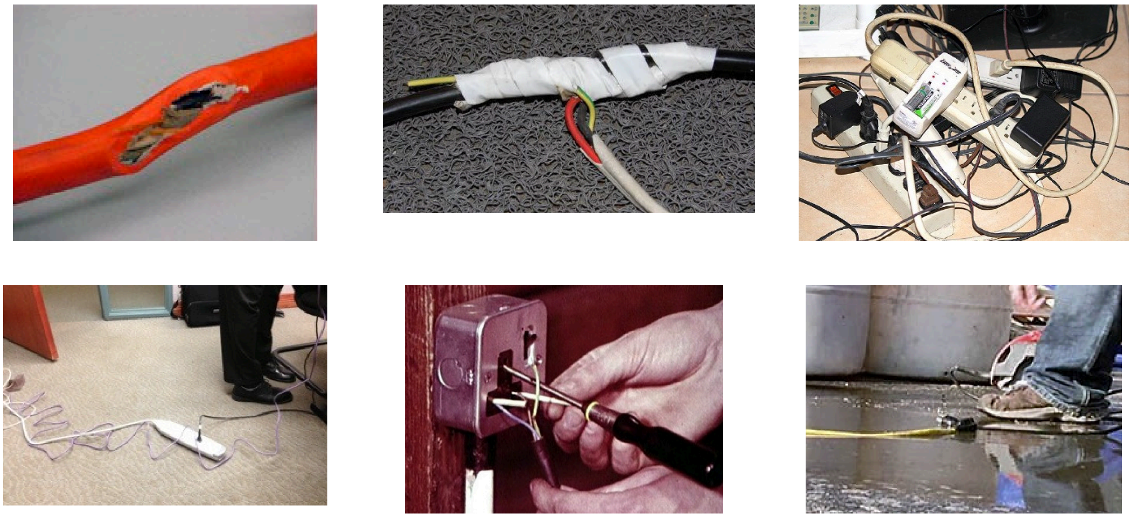


Figure 8: Things to avoid for electrical safety

4.3 Heated Devices

Electrical devices that supply heat in laboratories include: Hotplates Tube and Box Furnaces Heating Mantles Hot-Air Guns Oil Baths Improper use of any one of these could result in fire or burns to the user.

- Check to see if the unit has an automatic safety shutoff in case of overheating.
- Note the condition of electrical cords and have them replaced as required.
- Make sure the apparatus has been maintained as required by the manufacturer.
- Check to see that all heating units in use without automatic shut-off have been turned off before leaving an area for any extended period of time.
- Flammable or combustible solvents should not be used in a heated bath or placed near the bath. Oil baths must always be housed in a chemical fume hood.
- Make sure there is adequate ventilation around the heated equipment.

4.4 Fire Extinguisher

- All must learn how to operate a fire-extinguisher. Mnemonic PASS is often used to describe
  Here is a description of fire extinguisher usage.

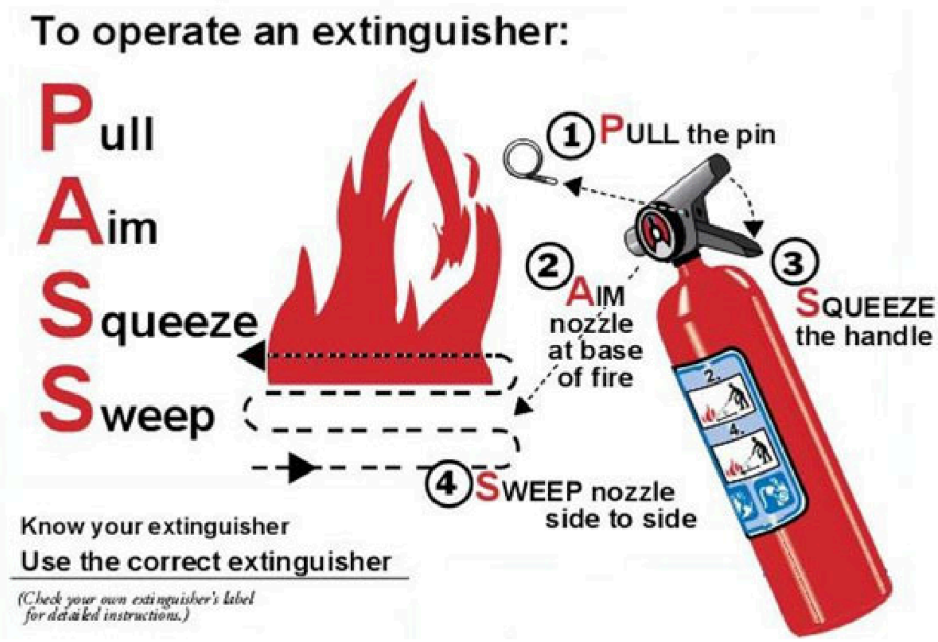


Figure 9: How to Operate a Fire Extinguisher

- Use the correct type of extinguisher. The lab must have extinguishers for all types of hazards present inside it.

Types of Fire	Material	Class	Method to Extinguish
Ordinary Combustible Material	Wood, paper, textiles, etc.	A	Water, Foam spray, ABC powder, Wet Chemical
Flammable Liquids	Oils, solvents, grease, paint, etc.	B	Foam spray, ABC powder, and carbon dioxide
Flammable Gases	SiH_4, GeH_4, organic vapors, etc.	C	ABC powder
Metal	Magnesium, Aluminum, Sodium, Potassium, Zirconium, Titanium, etc.	D	Special metal extinguishers. Do not use ordinary extinguishers found in the building, or else a violent reaction may result.

Electrical	Short circuit, hot electrical components, lightning discharge, etc.	E	Powder type: Carbon dioxide

Table 3: Type of Fire Material Class Method to Extinguish

Symbol found on Fire Extinguishers and what they mean	Water	Foam Spray	ABC Powder	Carbon dioxide	Wet Chemical
A Wood, Paper & Textiles	✓	✓	✓	X	✓
B Flammable Liquids	X	✓	✓	✓	X
C Flammable Gases	X	X	✓	X	X
Electrical Contact	X	X	✓	✓	X
F Cooking Oils & Fats	X	X	X	X	✓

Figure 10: Symbols Found on Extinguishers and Their Meaning.

4.5 Fire Safety infrastructure

All departments are required to periodically evaluate fire preparedness. Depending on the hazards, the department may be required to invest in layers of Fire-alarms, sprinklers, fire-detectors, etc. General guidelines are:

- All multi-story buildings must have an operational fire hydrant loop. The primary responsibility for maintaining the hydrant loop rests with the departments.
- All buildings with significant gas, electrical, or chemical hazards must have a sprinkler system. The maintenance and testing of the system are the responsibility of the departments.
- All departments must have an evacuation plan and emergency response team (ERT). Details are in the Section on Emergency Response.

5. Laser and Radiation Safety

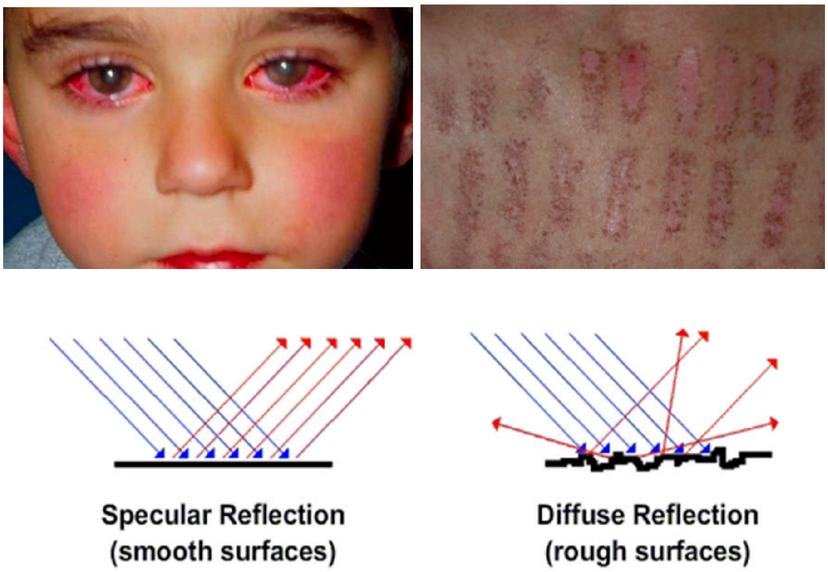


Figure 11: Radiation by Laser

5.1 Laser Safety

LASER is an acronym for Light Amplification by Stimulated Emission of Radiation. A laser produces an intense, highly directional beam of light. High-power lasers can cause damage to the eyes and skin, and in extreme cases, they can cause blindness and burns

5.1.1 Exposure to Laser

1. **Primary beam:** direct hit or exposure from primary beam. This is the most hazardous.
2. **Specular reflection:** exposure from laser hitting a shiny or smooth surface. This can be as hazardous as the primary beam.
3. **Diffuse reflection:** exposure from a rough object. Typically, this is less serious but also hard to detect and hence dangerous.

5.1.2 Laser Classification

Lasers can be classified based on power and wavelength. For details, please see below

5.1.3 Visible lasers (400–700 nm)

Based on their hazards, laser sources are categorized into classes. The modern ANSI/IEC classification is preferred (see table below) over the older FDA Roman numeral classification. (Class I-IV). Class 1 lasers have the lowest hazard, while Class 4 lasers create the greatest hazard. Exposure is typically expected to be <0.25 s. It is expected that the user will have an aversion response, which will prevent longer exposures.

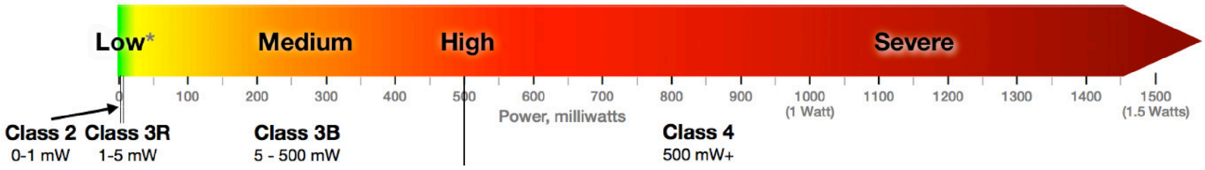


Figure 12: Different classes of laser

Class	Procedure	Training	Eye Exam	Energy	Hazard
1	Not Required	Not Required	Not Required		Typically, when the laser is not accessible,. It is non-hazardous to the eye.
1M	Not Required*	Not Required*	Not Required		Hazardous with collecting optics, e.g., with microscopes.
2	Not Required	Not Required	Not Required	0-1mW	Hazardous only when person overcomes aversion response
2M	Not Required	Not Required	Not Required		Hazardous with collecting optics and class 2 hazard
3R	Not Required	Not Required	Not Required	1-5 mW	Hazardous only when person overcomes aversion response or uses optics
3B	Required	Required	Suggested	5-500 mW	direct-beam eye hazard. No serious injury from diffuse reflection to the eye or to the skin.
4	Required	5-500mW	Suggested	> 500 mW	Hazard to the eye and skin from direct, specular, or diffuse reflection. Fire hazard.

Table 4: classification of different lasers and their hazards

In general, we should never come in the way of laser light. Calculations have been done to estimate the distance at which lasers with a typical beam spread are very dangerous. Calculations for some typical lasers are given in the table below. However, please remember that lasers are still dangerous beyond these distances. Do not stare at a laser, ever.

Laser Class	Fire Hazard Distance (m)	Skin Burn Distance (m)	Flash Blindness Distance (<100 μW/cm²)	Eye Hazard Distance (NOHD) (<2.5 mW/cm²)
Class 2 0.99 mW, 532 nm	0.6	0.9	67 m	14 m
Class 3R 4.99 mW, 532 nm	1.4	2.1	149 m	32 m
Class 3B 499 mW, 532m	7.0	10.5	747 m	158 m
Class 4 5W, 532mn	11.0	16.6	1182 m	250 m

Table 5: Classification of Laser Class along with hazard distance

5.1.4 Non-Visible lasers (>700 nm)

- Non-visible lasers don't trigger the aversion reflex, increasing the potential for longer exposure, which can be highly dangerous. Even at lower powers, there's a significant risk of causing vision loss.
- Eye damage from lasers depends on their wavelengths. Wavelengths between **380-1400 nm** pass through the cornea and get absorbed by the retina. Conversely, wavelengths longer than 1400 nm are absorbed strongly in the cornea and typically don't reach the retina at low exposures. While absorption in the cornea causes damage, since retinal damage is often irreversible, lasers between **380-1400 nm** are deemed more hazardous.
- Non-visible lasers, specifically those between **700-1400 nm**, are even more dangerous due to the absence of an aversion response. This absence increases the

risk of extended exposure and subsequent damage without the protective reflex to limit exposure time.

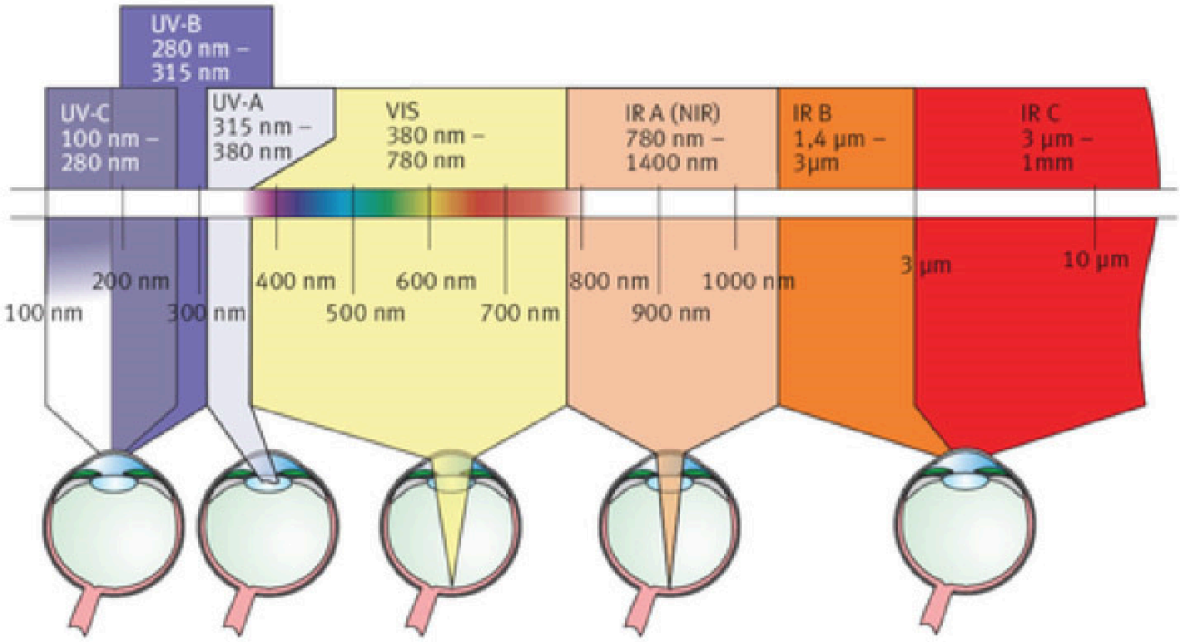


Figure 13: Effect of laser wavelength on various parts of the eyes. Retina damage is irreparable. Cornea and lens damage are extremely painful.

5.1.5 Laser Protection

- Essential Eye Protection: Class III and IV lasers necessitate the use of suitable laser safety glasses and protective gear.
- Purposeful Safety Glasses: Laser safety glasses reduce laser beam intensity, meeting ANSI Z136 standards, with protection linked to higher optical density (OD).
- OD Selection Importance: Transmittance is specified in terms of optical density (OD) Choosing appropriate OD levels aligns with the laser

OD	Transmittance	OD	Transmittance
0.0	100%	5.0	0.001%
1.0	10%	6.0	0.0001%
2.0	1%	7.0	0.00001%
3.0	0.1%	8.0	0.000001%
4.0	0.01%	9.0	0.0000001%

$$OD = \log_{10}\frac{1}{T}$$

$$\Rightarrow 10^{-OD}$$

OD = Optical Density
T = Transmittance (decimal)

As per ANSI Z136

Figure 14: Different types of OD selection Criteria

Unfortunately, the correct choice of laser safety eyewear depends upon many local factors other than power that cannot be evaluated remotely, including the beam path, laser parameters, and lab environment. We can't recommend specific eyewear for your application. Always discuss your needs with your supervisor. EN 207 is a more recent and complete standard that accounts for some of these effects. We highly recommend that it be used instead of ANSI Z136.

Laser Mode	Engraved Symbol	Pulse Duration
Continuous Wave (CW)	D	>0.25 s
Pulsed Mode	I	>1 µs - 0.25 s
Giant Pulsed Mode	R	1 ns - 1 µs
Mode Locked	M	< 1ns

Wavelength	Laser Mode	Maximum Power Density (P) or Maximum Energy Density (E)	Minimum Scale Number (LBn)
180 - 315 nm	D	$1x10^{n-3}$ W/m^2 ($1x10^{n-7}$ W/cm^2)	$log_{10}(P)+3$
	I and R	$3x10^{n+1}$ J/m^2 ($3x10^{n-3}$ J/cm^2)	$log_{10}(E/3)-1$
	M	$3x10^{n+10}$ W/m^2 ($3x10^{n+6}$ W/cm^2)	$log_{10}(P)-10$
>315 - 1400 nm	D	$1x10^{n+1}$ W/m^2 ($1x10^{n-3}$ W/cm^2)	$log_{10}(P)-1$
	I and R	$5x10^{n-3}$ J/m^2 ($5x10^{n-7}$ J/cm^2)	$log_{10}(E/5)+3$
	M	$1.5x10^{n-4}$ J/m^2 ($1.5x10^{n-8}$ J/cm^2)	$log_{10}(E/1.5)+4$
>1400 - 1000000 nm	D	$1x10^{n+3}$ W/m^2 ($1x10^{n-1}$ W/cm^2)	$log_{10}(P)-3$
	I and R	$1x10^{n+2}$ J/m^2 ($1x10^{n-2}$ J/cm^2)	$log_{10}(E)-2$
	M	$1x10^{n+11}$ W/m^2 ($1x10^{n+7}$ W/cm^2)	$log_{10}(P)-11$

Figure 15: EN207 standard For laser safety Glasses

5.1.6 Best Practices

- Never look directly at the laser beam or light-pump source.
- Do not allow any object that could cause reflections in or along the beam, such as spherical buttons, screw heads, or jewellery, in the working area.
- Keep a high general illumination level where lasers are in operation to cause contraction of pupils and reduce hazards.
- Post warning signs on laser equipment and on the doors of labs and rooms that have laser equipment.
- Always wear personal protective glasses whenever lasers are in the same room, irrespective of whether you are using that laser or not.
- High-power lasers must be partitioned into separate work spaces with wall-to-floor partitions. No safety eyewear works for all wavelengths, so simultaneously using lasers with different wavelengths in the same work area is dangerous.

- Good-quality laser protection Goggles often have relevant protection levels listed on them. Before using laser equipment, always check if the protection is adequate.

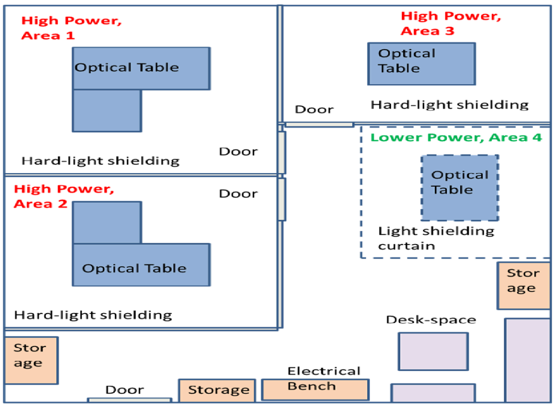


Figure 16: Layout of the high-power laser lab at CeNSE, showing separate workspaces for reference

Figure 17: Safety goggles with safety rating

5.2 Ultraviolet safety

- All radiation with wavelengths shorter than 350 nanometers should be considered dangerous.
- Protective safety glasses with UV-absorbing lenses should be worn when there is even a chance of accidental eye exposure.
- Skin exposed to strong UV radiation can receive painful burns, analogous to sunburns. So be completely clothed while working with UV radiation.
- UV lights are often used to sterilize the room or area. In such cases, please make sure the room has tinted or plastic windows so that UV light does not escape.

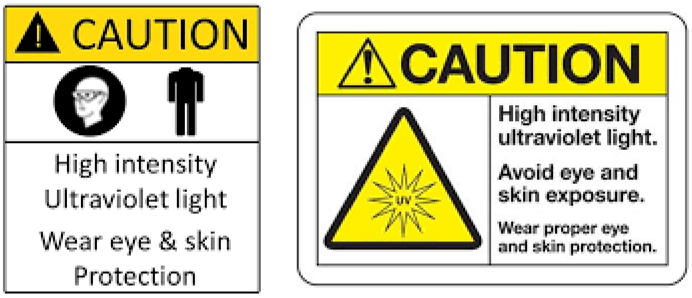


Figure18: Caution for UV Safety

6. High-Pressure Safety

If pressure equipment fails to be used, it can seriously injure or kill people nearby and cause serious damage to property. In addition, sometimes the gases are chemically active. The addition of chemical energy makes the tank ticking time bombs that must be safely handled. Please treat gas with due respect.

6.1 Examples of pressure systems and equipment

- Compressed air systems (fixed and portable)
- Pipework and hoses
- Gas cylinders

Figure 19: Gas Cylinder Manifold

6.2 General Rules

- During storage and use, all cylinders need to be clearly labelled. Flammable, toxic, and pyrophoric gases must be distinguished by the colour of the tags and stored in segregated areas. Please see the appendix for examples.
- All gas cylinders need to be chained to the wall. The chain must either be at half height or two chains at 1/3 and 2/3 height. This ensures that the cylinder stays vertical in the event of cylinder valve failure, preventing it from flying through the walls like a missile.
- Please ensure the fittings and regulators being used are rated for the pressure they are subjected to.
- The cylinder must be located away from other hazards. Maintain an exclusion zone around a cylinder as per standard given below.
- The cylinders come with a valve guard. This protects the cylinder valve in case the cylinder falls. Please keep it on if the cylinder is not being used.

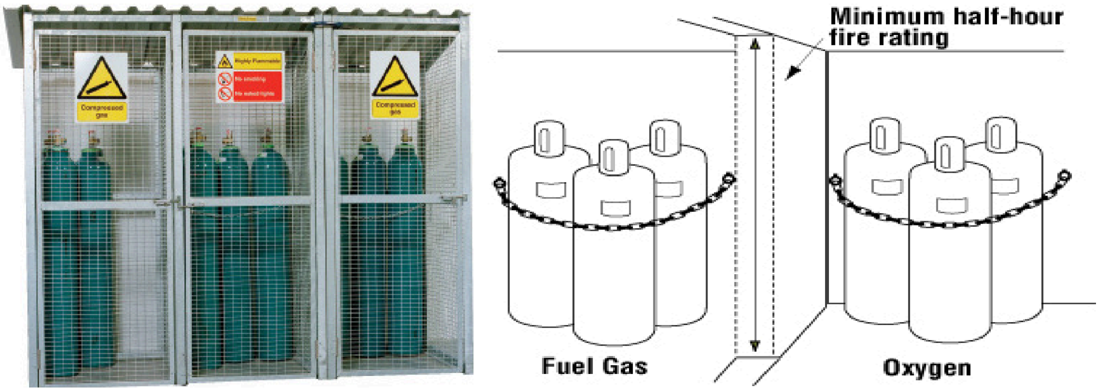


Figure 20: For long-term storage, segregate cylinders, store them in covered but ventilated cages, and keep them chained.

- Always install the cylinder with an output pressure gauge and shut-off valve. The former makes sure an unsafe pressure is not maintained in the line. The latter is useful in an emergency where the gas supply needs to be turned off.
- Cylinders must always be moved on carts. Do not roll them horizontally. If handling a gas cylinder manually, you must have two people holding the cylinder.

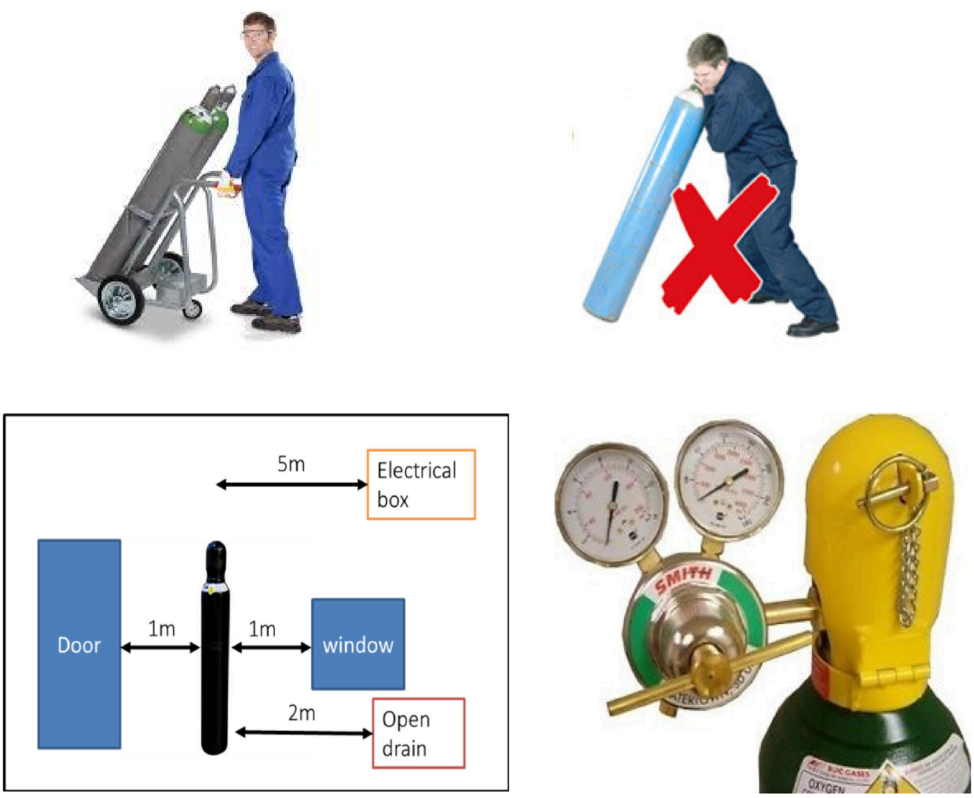


Figure 21: Proper method of cylinder transport. Don't roll the cylinders Regulator and valve guard

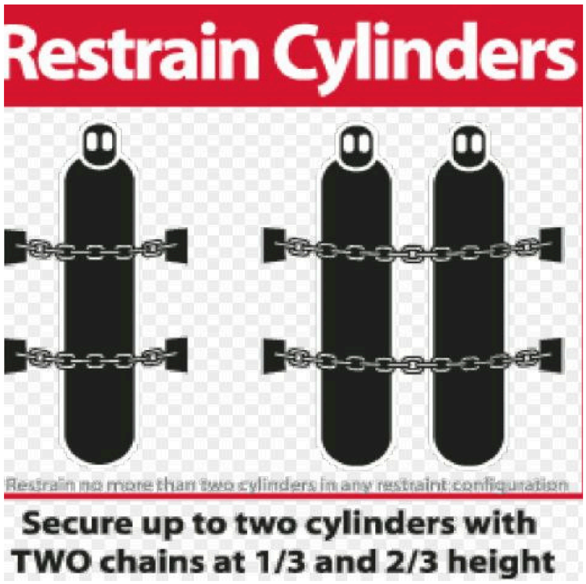


Figure 22: Rules to follow during use. Maintain an exclusion zone around the cylinder. Don't remove valve guards. Use gas regulators. Always restrain cylinders at 1/2 or 1/3+2/3 height. Gas cylinders

- The spindle valves in tanks come in different designs. On the left is an older design, where there is danger of spindle loosening while the valve is being turned on. There are two threads in a series. Opening one can open the other. The probability of this is significantly lower in newer spindle valves (see figure on the right). Request all lab in-charges to do a self-audit on the cylinders in their labs. If they have cylinders with old designs, please get those replaced with the more modern ones. I will add his information to the safety manual as well. The squiggly bracket in the picture can be a guide to telling the difference.

6.3 Hazardous gases

Any gas that is categorized as toxic or pyrophoric is a hazardous gas. These are considered significantly more dangerous than compressed gases and need additional handling.

- Hazardous gases need a gas cabinet to be operated safely. Gas cabinets shut off the gas flow in case of alarms or gas leaks. The gas cabinets may be completely automatic or semiautomatic. The need for a gas cabinet must be decided on a case-by-case basis. In general, highly toxic and/or pyrophoric gases require a gas cabinet.
- Hazardous gases must only be used with welded, face-seal fittings (VCR® or equivalent). No Swagelok® or other compression fittings. No plastic tubing. In extreme cases, coaxial lines are needed. IITH prefers purged coax lines instead of evacuated ones.

- The design of all gas manifolds for hazardous gases must be certified by two faculty members.
- All welded fittings carrying hazardous gases must be leak-checked.
- Lab facilities with hazardous gases are supposed to install automatic sensors for the detection and warning of harmful gas leaks. Hand-held detectors are strongly recommended.
- Proper respirators (self-contained breathing apparatus) must be used whenever hazardous gas cylinders are being installed or changed.

Figure 23: Hazardous gases categorization

7. Emergency Response and Evacuation

Using signage and regular safety lectures, all users of a building must know the actions they need to perform if they stumble across an emergency. The response must be contingent on the severity of the emergency. For example, smaller fires may require the use of a fire extinguisher, while gas leaks need a global alarm.

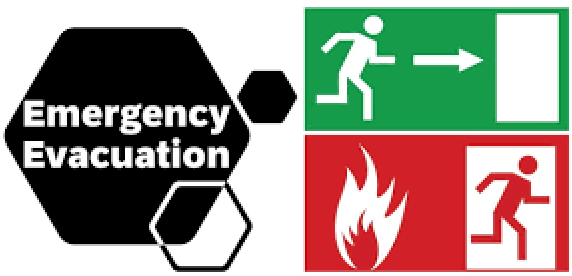


Figure 24: Emergency Evacuation Sign Board

Figure 25: Flowchart of Emergency Evacuation

7.1 Emergency evacuation

All buildings are required to have an emergency evacuation plan that allows all occupants to exit the building, establishes a chain of command, demarcates responsibilities, and establishes rules for liaising with external emergency services. The primary responsibility for defining the fire exit plan rests with the safety champion or coordinator of the department that administers the building. The safety champion or coordinator can take help from LSC to formulate the plan. The emergency plan must follow the following guidelines:

7.1.1 Strategy

- All buildings must have a method to announce an emergency that mandates evacuation. This can be a simple public address system or a manual or automatic fire alarm.
- All buildings must designate a network of emergency exits and assembly points such that all occupants of a lab can exit the building and reach the safe assembly point within 2 minutes of a global alarm.
- The number of these exits and assembly points depends on the size and layout of the building.
- The location of emergency exits and assembly points must be clearly shown on signage posted at strategic locations, e.g. corridors, break-out spaces, lecture halls, assembly points, etc.

- Assembly points are where occupants assemble during an emergency. Hence, the location of these assembly points must be carefully chosen. The assembly points must be far from the hazards, e.g. electrical yards, gas cylinders, chemical storage, etc. Assembly points cannot be in the path of emergency vehicles.
- All labs must identify the route to the nearest emergency exit from each lab ("emergency escape route"). This route must be clearly posted inside each lab. See example.Emergency escape routes cannot include elevators. Only stairs can be used during emergencies.
- During emergencies, emergency vehicles such as ambulances and fire trucks must be able to reach the premises. This requires a suitably wide thoroughfare that is always free of obstruction (i.e., no parked vehicles, bikes, or storage). Ideally, the emergency vehicles should have 360° access to the building.
- None of the doors that are part of the emergency evacuation strategy can ever be blocked or physically locked. They can only be latched or electronically locked so that they can be opened in an emergency by anyone.

7.1.2 Action on hearing an alarm

All users of a building must know the actions they need to perform if they hear the evacuation alarm. For most of the occupants, this response will be an evacuation to an assembly point. Some people might have additional responsibilities, e.g. members of the emergency response team (ERT).

7.1.2.1 Emergency response team (ERT)

ERT is a group with the primary responsibility of responding to an emergency. The roles and responsibilities may change with the department and associated hazards. At its very core, ERT is in charge of ascertaining the validity of the emergency, calling external emergency vehicles, managing the assembly points, liaising with the institute and external safety and security teams, and issuing the “all-clear” in consultation with the lab in charge.

- ERT must be constituted in a department composed of faculty and permanent staff. A part of ERT must be “on-call” 24x7. The composition of ERT must be communicated to the LSC by the department chair. The ERT is assumed to be technically familiar with all the hazards in a department. This might require the ERT to conduct periodic audits in their respective departments.
- Each assembly point must have a designated leader who is in charge of taking attendance or headcount. This and any pertinent information given by the evacuating public can be escalated to the ERT.
- ERT is the only one who can issue an “all-clear” after an evacuation in consultation with the lab in charge. No one can enter the building until ERT has issued the all-clear.

7.2 Chemical Spill Response

Based on the chemicals stored and used in the laboratory, the lab in charge must anticipate the types of spills that can occur in their respective laboratories. It is their responsibility to obtain the necessary equipment (spill kits, personal protective equipment, and disinfection materials if biological materials are present in the laboratory) to respond to a spill prior to it happening.

- If the spill is too large, highly toxic, flammable, aggressive, or just scary, please call emergency response, press alarm, and evacuate.
- If and only if you can do so safely, attend to injured or exposed personnel and remove them from exposure.
- Alert people in the laboratory to evacuate. Alert people in the immediate area of the spill, and make sure that you are aware of the hazards associated with the material spilled. If the spilled material is flammable, turn off ignition and heat sources.
- Clean up the spill. Less experienced users should only clean up minor spills (<50 ml). For larger spills, call help of staff or experienced users.
- Acids and bases typically need neutralization kits.
- To clean up alkali metal spills, smother them with anhydrous sodium carbonate, calcium carbonate, powdered graphite, or sand.

- While cleaning up the spill, have adequate ventilation (open windows, fume hoods on) and proper protective equipment (minimum: gloves, splash goggles, and apron or lab coat).

Figure 26: Chemical spill safety barricade

7.3 Fire Response

- If you see fire, evaluate if you are in immediate danger. If you are safe, raise the alarm and evacuate.
- If the fire is small, try to contain the fire using a fire extinguisher. If you can't, call ERT. The emergency numbers must be near the landline. Give your name, location, nature of the emergency, and telephone number.
    - Once the fire is contained, call the lab in charge and the faculty in charge.
    - Try to assist any injured people around you. See section below on first aid.
- If you hear the fire alarm, immediately evacuate.

Figure 27: fire action board

- If confronted with smoke, keep near the floor. Smoke, heat, and toxic gases will normally rise to the ceiling.
- Do not use elevators, as they might not work during emergencies.
- Using the nearest emergency exit, exit the building.
- Go to the designated safe assembly point
- From the assembly point, call the lab in charge and the faculty in charge.
- Stay at assembly points until an "all-clear" is issued by the emergency response team.
- Inform ERT of any hazardous conditions (presence of inflammable or toxic chemicals or gases).

7.4 First-response (First-aid)

First aid is a specialist activity, so it is hard to be very specific about exactly what to do. Use common sense. The following points are primarily to sensitize you to the possibilities.

Figure 28: First Aid immediate response

7.4.1 General Injury

Do the following in this order (unless common sense says otherwise:

- If an individual is contaminated or exposed to a hazardous material in the laboratory, do what is necessary to protect his or her life without compromising your own. If you can do so safely, determine the nature of the hazardous material and communicate this information to the attending medical personnel.
- If the person is in contact with a live electrical circuit, do not touch him or her. Disconnect the power first by turning off circuit breakers or by dislocating the live wire with a non-conducting object.
- Do not move an injured person unless he or she is in further danger. Unnecessary movement can exacerbate injuries. Keep the victim warm and awake.
- Initiate first-aid treatment for the victim if trained or qualified to do so. In the case of severe bleeding, place a paper pad (from first-aid kit) or cloth on the cut and apply firm pressure to control the bleeding.
- Call the lab in charge and faculty in charge.

7.4.2 Burn Injury

Follow the following steps in this order:.

- The most effective method is to immediately deluge the victim with water in a safety shower. Water not only extinguishes the fire but also cools down the body by transporting the heat away, preventing further burns. Of course, there should be a water source, and you should be in a position to drag the victim to the source.

- The quickest option is the “stop, drop, and roll” drill. Just make sure to put some damp towels on the victim to reduce temperature once the flame is extinguished.
- If water is not available and drop/roll is not practical, blankets, coats, etc. can be used to smother the fire. Remember, try to smother, not fan the flames so they become more intense. Remember, even after the flames die down, the body continues to suffer damage due to all the trapped heat. So, apply some damp towels to reduce body temperature.
- In extreme cases, fire extinguishers can be used. However, understand the following:
    - CO2-type extinguishers tend to freeze. So, don’t focus spray on the same place for 10 seconds. Try to create a blanket of CO2 around the person so that the flames die down.
    - Extinguishers are designed to be aimed at the base of a fire. They don’t work well on surfaces, like the human body.
    - With foam-type extinguishers, you need to create a blanket around the burning person, which is hard and wastes precious seconds.
- If there is danger of further injury, move the victim. Otherwise, let them be.
- Call for an emergency response.
- Immerse the burned area in very cold or ice water until pain is not only relieved but also does not return when the burned area is removed from the water. If the burn cannot be immersed, apply ice-cold compresses.
- After ice treatment, cover the victim with a blanket to keep him or her warm and prevent hypothermia.
- If the burns are extensive, there is a high probability of the victim going into a shock, so try to keep the patient awake and calm.
- Be careful not to contaminate the burned area. Cover the burned area with sterile gauze or a sheet. Do not apply oily ointments, lotions, or cleansers to the burned area.
- Call the lab in charge and faculty in charge.

7.4.3 Chemical Spill on Body

Symptoms of chemical exposure may include irritation, burning sensations, coughing, wheezing, laryngitis, shortness of breath, headaches, and nausea and vomiting. If you feel any of these, contact a trauma centre immediately. If you come across a victim of chemical exposure:

- Remove the victim from contact with the chemical as promptly as possible.

- Affected areas of the skin should be thoroughly flushed with water (at least 15 minutes) by shower. Do not apply neutralizing or buffering agents. During flushing, goggles should be left on the victim until his head and face have been washed.
- Remove clothing contaminated with chemicals, but do not remove clothing that has burned onto the skin.
- Call for an emergency response.
- Call the lab in charge and faculty in charge.

Figure 29: Chemical Spill Response Procedure

7.4.4 Eye Injury

- Try to remove the foreign object if and only if it is loose and unattached. It is best to do this with a wet piece of clean cotton or with clean water.
- If the particle is on the cornea or is embedded in the eye, do not touch it.
- For splashes of chemicals in the eye or exposure of the eye to corrosive vapours, remove contact lenses if necessary and flush the eye thoroughly with water from an eye wash fountain for at least 15 minutes. Eyelids should be forcibly held apart so that the entire surface of the eye may be washed. Never apply a neutralizing solution as first aid.
- Call for an emergency response. Transfer the victim to a physician or ophthalmologist immediately.
- Call the lab in charge and faculty in charge.

7.4.5 Gas exposure:

- Do not enter the area if you expect oxygen depletion, explosive vapors, or toxic gases.
- Special equipment must be worn by the rescue party. If you don't have access to the equipment, just call an emergency response.
- Remove the victim from the contaminated atmosphere and move into the fresh air as quickly as possible.
- Call for an emergency response.
- Call the lab in charge and faculty in charge.

- If possible, identify the substance to which the victim was exposed. Provide the ambulance crew and physician with the chemical name and other relevant information. If possible, send the container and/or a label along with an MSDS with the victim to the nearby health centre.

7.4.6 Unknown

If the victim is unconscious, unresponsive, or unable to respond, and if you cannot ascertain the type of injury, assume the worst. If the lab has toxic gases, assume a gas leak. If the lab has hazardous chemicals, assume chemical exposure. If the lab has lasers, assume laser injury. In all cases, the priority is your own safety.

- Evaluate if you can safely enter the lab. If not, then just call the emergency response.
- If you can enter safely, see if you can help the victim.
- If the victim is in danger of continuous exposure, try to remove him.
- If the victim is not in danger of more exposure, leave him as is. Unnecessary movement may exacerbate injury.
- Call the emergency response.
- Call the lab in charge and faculty in charge.