ELECTRICAL SAFETY

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Basics :

- **Current**: The movement of electrical charge measured in ampere (amps).
  Voltage: Measure of electrical force or potential difference in volts.
  Watt: Unit of electric power, equals the voltage multiplied by current (W=V x A).
  Resistance: Opposition to current flow measured in ohms.
  Conductors: Materials that have little resistance to electricity.
  Insulators: Materials that have high resistance to electricity.
  Grounding: A conductive connection to the earth serving as a sink for the current that is used as a protective measure against static electricity build-up.

  The relation between voltage, current and resistance is given by **Ohm's law**:

  $$V \text{ (volts)} = I \text{ (amps)} \times R \text{ (Ohms)}$$

Colour code for

- The three wires inside an electrical cord are color coded:
- SINGLE PHASE
  - **Red** : Live AC voltage,
  - **Black** : Neutral return,
  - **Green**: Ground, no current.
- THREE PHASE
  - **Red** : Live AC voltage,
  - **Yellow** : Neutral return,
  - **Blue**: Ground, no current

HAZARD

- **Injuries**
- Injuries caused by electricity include electrical shock, burns, and falls due to electrical shocks and burns. Electrocution is a fatal electrical shock. Electrical shock occurs when current passes through the body. The severity of the shock depends on:
  - Amount of current flowing through the body,
  - Path of current through the body,
  - Length of time the body is in the circuit.
- Note: Low voltage or low current does NOT mean low hazard! Less than 10 milliampere can cause a painful shock and loss of muscular control, and 50 milliampere can be fatal (see the table below for more details).
- Electricity seeks all paths and not just the path of least resistance to reach lower potential.
- **Fire Hazards**
- Too much current flowing through a wire can cause a power cord to overheat and start a fire. Sparks from electrical equipment can ignite flammable materials.

Effect of alternating electric current during a hand-to-foot shock of one second duration:

Current	Reaction
1 milliamp	Just a faint tingle.
5 milliamps	Slight shock felt. Disturbing, but not painful. Most people can "let go." However, strong involuntary movements can cause injuries.
6-25 milliamps (women) 9-30 milliamps (men)	Painful shock. Muscular control is lost. This is the range where "freezing currents" start. It may not be possible to "let go."
50-150 milliamps	Extremely painful shock, respiratory arrest (breathing stops), severe muscle contractions. Flexor muscles may cause holding on; extensor muscles may cause intense pushing away. Heart fibrillation possible. Death is possible.
1,000-4,300 milliamps (1-4.3 amps)	Rhythmic pumping action of the heart ceases. Muscular contraction and nerve damage occur; death likely.
10,000 milliamps (10 amps)	Cardiac arrest and severe burns occur. Death is probable.
15,000 milliamps (15 amps)	Lowest overcurrent at which a typical fuse or circuit breaker opens a circuit!

Source: Kouwenhoven WB [1968]. Human Safety and Electrical Shock. Electrical Safety Practices, Monograph 112, Instrument Society of America, P. 93.

GENERAL RULES FOR ELECTRICAL SAFETY

- Use electrical cords only if they are in good condition. Cords must not be cracked, frayed, or have corroded prongs.
- Do not use 3-to-2 prong adapters unless other grounding provisions have been made. Plug 3-prong plugs into 3-prong outlets.
- Use power strips that have circuit breakers or fuses. Do not link power strips in series.
- Do not leave cables and cords unsecured and hanging in areas where they can pose a trip and movement hazard. Place cords so that they are not subjected to mechanical stress or temperatures that could damage the insulation.
- Do not conceal cords behind or attach electrical cords to building surfaces.
- Do not leave electrical circuits exposed. Use electrical tape to insulate wires or use a guard as cover to prevent accidental contact.
- Do not block access to electrical panels.
- Do not install standard electrical equipment in locations where flammable gases, vapors, dusts, or other easily ignitable materials are present. If electrical equipment is used in a chemical fume hood, elevate it to allow efficient air flow.
- Keep electrical equipment at a minimum in high-moisture areas (e.g., wash rooms, cold rooms).

Electrical Apparatus

- The floor near electrical apparatus must be dry and equipment must not be operated with wet hands.
- Insulated wire must be used for all electrical connections.
- Electrical apparatus which produce even the slightest shock presents a potential danger and be disconnected and checked up immediately.
- Electrical cables must never be allowed to come into contact with hot surface, which would burn the insulation and cause a short circuit.
- Electrical plugs and switches must not be fixed near wash area or where they can come in contact with water.
- Electrical wires or cables must not be laid along the passage, which can become a trip hazard and can also cause damage to the insulation.
- Electrical fittings must be fixed at a height over the work bench, either against the wall or on rack so that accidental spillage of water on the bench cannot get to the electric connections.
- Electrical equipment must be switched off after use.
- Bare wares must not be used in sockets. Use three pin plugs.
- Go through the safety instructions given in the user/operating manual of the equipment before using the same.

EXTENSION CORDS

- Extension cords are not a replacement for permanent wiring. Install outlets in areas where electricity is needed permanently.
- Extension cords should NOT run through holes in walls, ceilings, floors, doors, or through windows and should be inspected before each use.
- Use only 3-prong extension cords with a listing from Underwriters Laboratories (UL) or other reputable testing labs.
- **Cord Ratings**
- Choose an extension cord appropriate for the current that will be flowing through it to avoid overheating. The required wire thickness depends on the power consumption of the equipment and the length of the extension cord. Check the equipment power requirements; calculate it by multiplying the voltage by the current. For example, a saw drawing a current of 5 amps at 120 volts requires 5 x 120 = 600 watts. Use an extension cord with a rating of at least 600 watts.
- Extension cords have information regarding the wire size, construction type, and temperature range printed along the length of the cord. The size of the wires is given by the gauge. The lower the gauge number, the thicker the wire. The table below lists the minimum wire size for a given cord length and current as directed by the National Electrical Code:

EXTENSION CORD: **NEC recommended wire size (gauge) for extension cord length**

Amps	Cord length (feet)			
	25'	50'	100'	150'
0 - 6 amps	18 ga	16 ga	16 ga	14 ga
10 amps	18 ga	16 ga	14 ga	12 ga
10 - 12 amps	16 ga	16 ga	14 ga	12 ga
12 - 16 amps	14 ga	12 ga	Not recommended	

- Other information presented on the cord indicates the construction type and conditions for use, for example:
- **S** = Hard service cord (600V)
  SJ = Junior hard service cord (300V)
  E = Thermoplastic elastomer insulation
  T = Thermoplastic insulation
  O = Oil resistant thermoplastic elastomer jacket
  OO = Oil resistant thermoplastic elastomer jacket and insulation
  X = Cross-linked polyolefin insulation
  W = Damp and wet conditions

Safety devices & Repairing Electrical Equipment

- **EQUIPMENT FUSES AND CIRCUIT BREAKERS**
- Fuses and circuit breakers are safety devices that protect equipment from high currents or voltages and prevent overheating of electrical wires. They are rated for a certain voltage and maximum current and come in two types: fast and slow blowing. When choosing fuses and circuit breakers, use appropriate amp rating (e.g., 10 amps, 15 amps) and type. Never replace blown fuses with fuses of higher ratings. Always disconnect the circuit or unplug equipment before inserting an in-line fuse. Never insert in-line fuses into a live circuit. If the new fuse blows again, determine the reason, or have the equipment checked by an electrician or the manufacturer.
- **REPAIRING ELECTRICAL EQUIPMENT**
- Only perform repairs referred to by the manufacturer's instructional manual. Any other work should only be performed by personnel certified by the manufacturer.
- Turn the equipment off and leave it plugged in. Let it stand for a few minutes for capacitors to discharge.
- Once capacitors have had time to discharge, unplug the equipment.
- When servicing highly sensitive electronic components (e.g., electron multipliers or computer boards) that could be damaged by static electricity, ground yourself using an anti-static wrist band. Connect the wrist band to the ground.

GENERAL RULES: WORKING WITH ELECTRICITY

- Wear Personal Protective Equipment (PPE) and follow the techniques below when working with electricity:
- **There must be at least two (2) people in the laboratory while working onlive circuits or chemical processing.**
- NEVER wear rings, watches, bracelets, necklaces, or other electrically conductive jewelry.
- Avoid being grounded. Stay at least 6 inches away from all metal materials, walls, and water sources.
- Wear shoes with thick, insulating soles or use non-conductive mats.
- Probe hot wires and components with only one hand to prevent current from passing through your chest cavity and injuring your heart. Place the other hand at your side, in a pocket, or in a belt loop away from conducting materials.
- Use tools designed for electrical work that have a non-conductive cover. Electrically insulated gloves are also available.
- Use voltmeters with appropriate rating for the voltage to be tested. A standard voltmeter could explode when subjected to a high voltage

GENERAL RULES: WORKING WITH ELECTRICITY(2)

- **Consider all circuits to be "hot" unless proven otherwise.**
- Whenever possible, completely de-energize the system before performing any work. If work has to be performed on “hot” components, you need to be qualified for this type of work. Contact your school’s electronics shops or people responsible for facilities and services for help.
- **When making measurements, form the habit of using only one hand at a time. No part of a live circuit should be touched by the bare hand.**
- **Keep the body, or any part of it, out of the circuit. Where interconnecting wires and cables are involved, they should be arranged so people will not trip over them.**
- **Be as neat a possible. Keep the work area and workbench clear of items not used in the experiment.**
- **Always check to see that the power switch is OFF before plugging into the outlet. Also, turn instrument or equipment OFF before unplugging from the outlet.**
- **When unplugging a power cord, pull on the plug, not on the cable.**

GENERAL RULES: WORKING WITH ELECTRICITY(3)

- **When disassembling a circuit, first TURN OFF the source of power.**
- **"Cheater" cords and 3-to-2 prong adapters are prohibited unless an adequate separate ground lead is provided, the equipment or device is double insulated, or the laboratory ground return is known to be floating.**
- **No ungrounded electrical or electronic apparatus is to be used in the laboratory unless it is double insulated or battery operated.**
- **Keep fluids, chemicals, and beat away from instruments and circuits. Report any damages to equipment, hazards, and potential hazards to the laboratory instructor. If in doubt about electrical safety, see the laboratory instructor. Regarding specific equipment, consult the instruction manual provided by the manufacturer of the equipment. Information regarding safe use and possible- hazards should be studied carefully.**
- **Emergency switch to be provided in all equipment**
- **Earting to be proper for all equipment [to be checked regularly]**

ELECTRICAL LOCKOUT-TAGOUT

- Lockout-tagout is a safety procedure used by licensed electricians during repair and maintenance work to make sure electric power is disconnected and not turned back on before work is finished. **NEVER remove a lockout-tagout device! This could endanger someone's life.**Examples of electrical lockout-tagout devices are shown below:

ACTIONS TO HANDLE ACCIDENT: Electrical Shock

- **Prevention**
- To prevent electrical shock from occurring, make sure all cords are grounded and keep all electrical areas (including floor space) dry during performance of the experimental operation.
- **Accidents**
- Assume that the power is still on. Locate the main power switch and turn off.
- **IMPORTANT: DO NOT TOUCH VICTIM OR LIVE WIRES UNTIL IT IS CONFIRMED THAT THE POWER IS OFF. DO THIS BEFORE TOUCHING THE VICTIM.**
- If a live wire is trapping the victim, turn off main power switch.
- Once electrical contact has been broken, check if victim is conscious and breathing.
- **First Aid**
- If breathing has stopped, begin artificial respiration and get medical attention immediately.
- If cardiac arrest has occurred. Get immediate medical attention.
- Treat any burns if they occur.
- **Miscellaneous**
- Have an electrician inspect the accident area and get permission before turning electricity back on.