SCHOOL OF ELECTRICAL ENGINEERING
& TELECOMMUNICATIONS

INTRODUCTORY LABORATORY SAFETY

MANUAL FOR EET STUDENTS

March 2012 Edition

Preface

All engineering students are required to have a basic knowledge of laboratory safety as it is instrumental to engineering learning and part of the foundation of professional engineering practice.

This manual introduces basic safe practices, and covers the School's primary hazard, namely electricity, in some detail. The aim of this manual is to acquaint students with some of the safety requirements in the School, and in particular those of the Electronics laboratories on Level 1 of the building.

Students must read and understand the material contained in it, and pass the associated test, before being allowed to work in the electronics (or other) laboratories. It provides an awareness of the potential hazards and risks that may be present in any laboratory work that you undertake during your undergraduate course.

The School has an excellent safety record. We hope and expect you to play your part in preserving this.

Acknowledgements
This new edition of the student safety manual contains material derived from various sources, used in earlier documents produced within the School. Particular thanks are given to former thesis students Lydia Aristuti & Jacinta Xiujun Goh and former members of staff Trevor Blackburn & Kevan Daly.

June, 2011

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1. Introduction: engineering & safety

A major concern of engineering profession is safety. It is integral to professional practice. Indeed, you will find it embedded within Engineers Australia's *Code of Ethics* (2010):

> *"Practise engineering to foster the health, safety and well-being of the community and the environment."*

It is fundamental, then, that you learn about safety – both principles and practices – from the very start of your practical work in Electrical (or any other) Engineering. You will frequently return to safety in later courses.

At some point during your professional career, you will have leadership responsibilities. Your education, in part, is to equip you for such responsibilities. These will include the safety of others.

In many respects, safety is about good habits, both habits of thought and habits of action. Start them now. Remember that it is more difficult to break a bad habit than start a good one. You can consider that this handbook contains an outline of the habits associated with the safe use of electricity.

The basic principles of safety that apply in all situations are introduced in §2. You will use these ideas frequently. General practices sufficient for your classes in the electronics labs, but relevant to work in all School laboratories, are found in §3 and §5. Detailed information about safely using electricity can be found in §4. This is, of course, the School's special interest. There is also the necessary administrative information explaining how you can help improve safety, etc, in §6 and §7.

This manual ***doesn't contain all you will learn about safety*** during your BE study. It cannot. There are within this School and others more hazards than those detailed herein, e.g. machinery, lasers, and dangerous substances. Some of these are briefly introduces in §8. More specific, more detailed material about such hazards will be introduced, if and when it is needed in later study.

2. Principles of safety

The two fundamental components of safety are your knowledge and your attitude.

(i) First, ***know the dangers*** (or hazards) so that you can take precautions and know how to take them. This may mean you need to do some research; it may mean a lot of research. Military strategy will tell you that you can never know too much about your enemy. Don't be amongst those who don't want to know something, believing (?) "What they don't know can't hurt them." Your knowledge of the hazard allows you to implement suitable features in a system's design and to make suitable administrative arrangements.

(ii) Knowing is insufficient. Whether you choose to implement safety precautions or not follows from ***your attitude to safety*** and is a demonstration of what you think is important. Safety comes from your wanting to be safe and being concerned for the safety of others.

Returning to professional ethics, this is your *duty of care*. All knowledge of safety is irrelevant if it makes no difference to the designs chosen. Note that ‘others’ may include people who have no direct involvement in the project but are still affected; note, too, that it is a concern that endures beyond the initial implementation of a system.

Remember: *“**Think first. Act carefully**.”*

While nobody wants them, ***accidents do happen***. Not wanting an accident means actively seeking to ***prevent*** one. It does not mean failing to ***prepare*** for one should it happen. There are several causes for accidents. Typically,

- human error;
- human ignorance;
- the physical failure of hardware (e.g. metal fatigue); and/or
- random external events.

As an engineer, you have a duty to minimise both the chance of the system failing and the effects of a failure, if and when it occurs.

When it comes to fulfilling this responsibility for safety, there are some established, useful processes available to follow.

2.1 Hazard management

The following steps outline one procedure for handling a hazard. Remember that a ***hazard*** is anything that could compromise the safety of any of the stakeholders of a system.

1. ***Identify the hazard***. The hazard is the ***causal*** agent (e.g. the laser, electricity, sulphuric acid, curiosity of children) of what might go wrong. Until you know what the actual hazard is, no mitigation is possible.

2. ***Assess the risk*** of the hazard (see §2.3 below). This involves two steps: determine the ***severity of all possible consequences*** and also the respective ***likelihood of each of these occurring***. This, in turn, may require research and may end up being both very time-consuming and very uncertain, particularly as some consequences are unknown.

3. ***Control the hazard***, to reduce the risk (see §2.2 below).

4. ***Monitor the effectiveness*** of the controls. As with all innovation, there is an element of experimentation about any safety measures, so collecting information will be informative.

5. Periodically ***review*** the management of the hazard. New information may become available, not least from the experience of operating the system, as in the previous step. New people may be involved or the existing personnel become more competent. You can think of more possibilities.

2.2 Hierarchy of hazard controls

After any hazard is identified, it can be controlled in the following ways. This is in the **decreasing** order of effectiveness.

1. Try to ***eliminate*** the hazard.
Clearly the safest option is to remove the hazard completely, for then the associated risk vanishes. However, in most cases a hazard is intrinsic to the activity and so must remain.

2. Seek to ***substitute*** the hazard with a less dangerous hazard.

3. Re-design the system (so-called ***engineering controls***)
   (i) to limit human contact with the hazard,
   (ii) to reduce the possibility of human error (a study in itself), and
   (iii) so that, should the system fail, it will fail with minimal adverse outcomes.
In your redesigns, always consider the whole system, not just particular components. A hazard may only be a hazard because of the context.

4. Introduce relevant procedures (so-called ***administrative controls***).
These may include such things as restricting access, having suitable emergency procedures, training people, or simply posting warning signs. (Incidentally, you should learn to "read" safety information signs.) These also include those important engineering activities of monitoring and ***maintenance.***

5. Issue ***personal protective equipment*** (PPE).
PPE may be clothing or eye-protection, and also items such as insulated tools that protect the user.

2.3 Assessing risks

1. Identify the ***context***. Who is or might be involved? Where will the activity occur? When is it scheduled? The level of risk may depend upon any or all of these.

2. Identify the ***hazards*** associated with the activity, noting the existing ***control measures*** in place for each of them.

3. Only now identify the ***possible adverse consequences***. Then, for each consequence, estimate the likelihood of it happening, given the controls that are in place. Sometimes the probability is easy to determine, based on historical events. However, most 'extreme' outcomes are what are known as ***very low likelihood events*** and their probabilities are, thus, very, very hard to calculate reliably on the basis of the past. Extrapolating into the future assumes continuity with the past and an accident is a form of discontinuity, effectively almost by definition. The risk associated with each hazard follows as the product probability of the outcome and its likelihood. Within this analysis, a minor but frequent consequence is as big a risk as a catastrophic outcome that is very rare. The ***overall risk*** is determined by considering all these different outcomes simultaneously.

It is only illusory to accept risk assessments as 'objective.' Any assessment depends on the quality of the data. It is difficult to assign probabilities to an untried innovation; nor can we honestly quantify 'severity,' although aspects of severity (e.g. how many broken bones) can be measured. Again, it is entirely subjective which measure is chosen. Often a risk assessment uses probabilities estimated at a level to validate what someone wants to do anyway and severities are indexed by an aspect chosen to support that same decision.

Furthermore, a risk assessment can never determine whether a given risk should be taken. That is a subjective decision and depends not only on the overall risk, but also on both the possible benefits and who is bearing the risk. This shows why the person with the authority to make to choice should ***consult*** with those affected.

Note that in all your courses, the risks of the assigned experiments have been assessed by the staff. However, ***you will need to complete the risk assessment*** for any experiments you do as part of your final year thesis.

Six step safety method (*after Cadick*)

1. THINK - BE AWARE
Persons must be aware of any potential hazards in the laboratory at all times. Risks should be assessed before starting any experiment.

2. UNDERSTAND YOUR PROCEDURES
Be familiar with all safety procedures, as outlined by the relevant expert authority (in your case the School).

3. FOLLOW YOUR PROCEDURES
All safety procedures should be followed closely at all times.

4. USE APPROPRIATE SAFETY EQUIPMENT
Appropriate safety equipment must be used when there is a possibility of accidents, such as electric shock, arcs or electrical fires.

5. ASK IF YOU ARE UNSURE
Always ask questions or seek advice from laboratory staff, if you are unsure of what to do in any particular situation.

6. DO NOT ANSWER IF YOU DO NOT KNOW
Do not answer any safety-related questions if you are unsure of the answer.

3. Safety in the electronics laboratories

This section outlines some general safe practices to be followed in the electronics laboratories. Detailed discussion of electricity, a major hazard in the School's experimental activities, is deferred to §4.

When you are working in the electronics labs, you will be ***under supervision of a teacher***. In the first instance, you should ask your class demonstrator all your questions about safety in the laboratory. You will not be permitted to work alone in a School laboratory until you have completed much more training, typically associated with a thesis project.

3.1 General laboratory precautions

The primary laboratory safety consideration is this:

NEVER do anything that poses a needless or excessive risk to anyone.

This means not to you, not to anyone else. This principle applies everywhere, always. Of course, we cannot have an explicit rule about everything. That is why you need to understand that this principle applies. For example, we don't explicitly forbid you from using teeth as a wire-stripper. However, such behaviour will not be tolerated. It is not being careful; it is reckless, posing an unnecessary risk to yourself.

Any student who fails to abide by safety requirements WILL BE REMOVED from the class.

This is for everyone's protection.

The general rules applying to use of all the School's experimental laboratories are prominently displayed in all laboratories.

These regulations MUST be followed by everyone at all times.

Some rooms have a second list of regulations, too, specifically relevant to that space. Many of these rules are directly related to safety.

Personal conduct

Footwear must protect against what may be dropped on a foot or may have been left as waste on the floor. Dropped tools or stubbing a toe on an off-cut of wire can cut. Loose footwear (e.g. thongs) is a tripping hazard when you need to move quickly in an emergency. ***Students who wear inappropriate footwear will be removed from class.*** They have been in the past. (item #2)
More about footwear can be found here:
www.eet.unsw.edu.au/sites/default/files/ohslab-footwear.pdf

Accidentally spilling food or drinks on bench-tops can cause a short-circuit in or malfunction of electrical equipment so no eating or drinking in any labs. (item #3)

Mobile phones may cause signal interference (as well as disturbing other laboratory users) so do not use your phone at any time within a laboratory. (#7)

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Laboratory Regulations

1. All laboratory users must undergo induction and agree to comply with laboratory rules. They must read any required safety manuals.
2. No bare feet or exposed, open footwear (e.g. sandals) are permitted.
3. Food and drink are not to be consumed at any time in laboratories.
4. Under no circumstance is the 240 V, 50 Hz mains power to be used for any purpose other than that approved by the School. Only authorised personnel are allowed to alter power connections (50 V above) or connect any equipment to mains power.
5. Tampering with or removal of any laboratory equipment is strictly forbidden.
6. Data network connections should not be altered. Personal equipment may not be connected to the School data network without first obtaining permission.
7. Personal mobile phones are not to be operated at any time within a laboratory.
8. Students are expected to conduct themselves in a reserved manner at all times. All noise is to be kept to a minimum.
9. All bags should be stored under benches.
10. Students should clean and tidy their workstations when they have finished and return all leads before leaving the laboratory.
11. Faulty equipment should be reported to laboratory staff who may not otherwise be aware of the problem.

Bench-tops should be clear of bags and any other clutter to provide more work-space and to avoid unintended contact with electrical equipment, e.g. cables or wires, which, in turn, might cause accidents. Aisles must also be kept clear to allow unimpeded passage and avoid tripping hazards. This includes clear of electrical cables and CRO leads, too. (#9)

Many drugs, including alcohol and some medications, can impair your thinking (judgment) and slow your reactions. ***Any student displaying such adverse effects, no matter what drugs, will be excluded from laboratory classes*** until the effect ceases. If you are under prescribed medication, discuss your circumstances with the lecturer (or Dr Eaton) to make alternative arrangements.

Fatigue, too, is known to impair judgment. ***Do not work in a laboratory if you are too tired to think clearly.***

Electrical infrastructure and equipment

Two types of power outlets are used in the laboratories. Earthed ones are normally used. Isolated, non-earthed outlets should be used only if your experiment specially requires them. Equipment must be connected to the correct outlet, i.e. matching specifications. Please consult laboratory staff or demonstrator if necessary. (#4)

Only legally authorised personnel are allowed to alter power connections (above 50 V) or connect any equipment directly to mains power. Wiring of the 240 V plug or any internal wiring of equipment must not be interfered with.

Under no circumstance is the 240 V, 50 Hz mains power to be used for any purpose other than that approved by the School. Work not specifically associated with a School course may only be carried out with the prior approval of the laboratory staff. Please consult laboratory staff if working on other projects, especially if they require the use of any laboratory equipment. In all cases, ***work may only be done under appropriate supervision***. (#4)

Laboratory equipment, e.g. oscilloscopes, is designed to be safe if used in compliance with the manufacturer's operational guide. However, there is added risk if the equipment is modified to accommodate a particular experiment, e.g. if the earth in an oscilloscope is removed to prevent an earth loop during measurement. Tampering with any laboratory equipment may cause the malfunction of equipment or personal injury. (#5)

Faulty laboratory equipment might pose danger to laboratory users if operated unknowingly. It may result in personal injury or malfunction of other equipment. Faulty equipment should be reported immediately to laboratory staff, who may not otherwise be aware of the problem. Faulty equipment must be clearly tagged and taken out of service for repair. ***Do not remove or ignore such tags.*** They are there for everyone's protection, the next user's as much as your own. (#11)

Insulated tools

Insulated tools are standard hand tools with a covering of electrical insulation such that only a minimum amount of metallic surface is exposed, e.g. a screwdriver with a plastic-coated blade. They are used to prevent shock or arc when the user is in contact with or near an energized conductor.

Generally, buy the best tools you can afford. You want them to last your professional lifetime.

3.2 Soldering

There will be times you need to solder. When you do, you need to solder safely. There are 3 associated hazards: electricity, heat, and fumes. When you solder, proceed as follows.

(i) Always leave the soldering iron in the guard when not in use; never touch the iron's tip; wait until the solder has cooled and set before touching the components. When you are finished, turn it off.
(ii) Goggles or safety glasses must be worn, as a precaution against hot solder flicking or splattering.
(iii) Windows must be open to keep the area ventilated, or use a fume displacement unit.
(iv) Only solder within the designated spaces in the electronics laboratories.

On the wall near the soldering stations, you will find a document, a ***safe work procedure***, entitled *Soldering*. It contains the relevant safety information. There are other such safe work procedures on the walls of other laboratories, too. These describe the activities done therein. The laboratory regulations are a safe work procedure.

4. Electricity: hazards & precautions

The most severe consequence of an accident with electricity is electrocution, which is the extreme form of electric shock and can result in death. There are, though, other things that can happen. This section briefly surveys the consequences of electric shock, how it occurs and some standard ways to reduce its chance of happening. It concludes with consideration of other consequences of electrical faults in systems.

4.1 Physiological effects of electric current

Electric shock is the physical stimulation that occurs when electric circuit passes through the body. The effect that electric shock has on the body depends on the magnitude of the current flow, the body parts through which the current flows, and the general physical condition of the person being shocked. Depending on the current path through the body and the magnitude and duration of current transmitted, electric shock may have these effects on the human body.

Damage and burns to tissue: Electric current can result in severe tissue damage through burning. It is mostly deep burns, as it occurs from the inside of the body where the growth centres are destroyed. If vital internal organs are involved, the burns can be fatal.

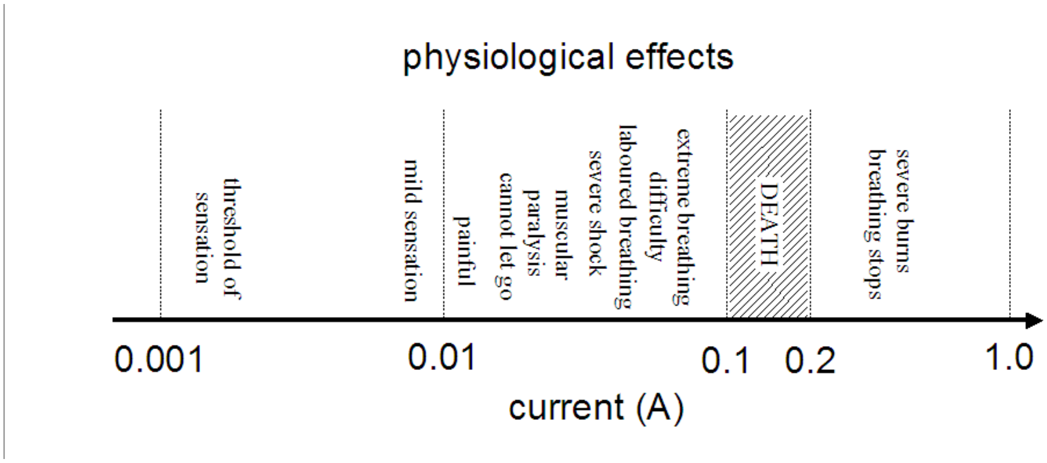
Involuntary muscular contraction: Involuntary muscular contraction is an effect of the current. At low currents the contraction may cause the "no-let-go" effect - the hand is unable to release a live conductor when grasped. If the lung muscles are affected, respiration might stop and asphyxiation occur.

Ventricular fibrillation: The last of the body's muscles to be affected are the heart muscles. If the heart is affected, ventricular fibrillation or irregular heartbeats can occur and result in death.

"It's the current that kills."

This is not generally understood. Although the mains voltage supply or similar poses a definite hazard, quite ***low voltages are equally dangerous***, if the resistance of the body between contact points is low enough. This resistance depends on contact area, skin moisture, etc. While any current over 10 mA is capable of producing painful to severe shock, currents between 100 and 200 mA are lethal. Currents above 200 mA, while producing severe burns and unconsciousness, do not usually cause death, if the victim is given immediate attention. Such excessive currents, though, may cause permanent damage.

How physiological effects depend upon current is indicated in the Figure below. This is only ***approximate*** and ***varies with the individual***. Several points should be noted.



(i) There is very little difference between 'mild' and 'painful' sensations, 8 to 12 mA. The *threshold of perception* is the minimum value of current that can be sensed when flowing through a person. Some factors that affect the threshold of perception are contact area, conditions of contact (dry, wet, pressure, temperature), and the physiological characteristics of the individual. For AC, the accepted value is about 0.5 mA, independent of the duration of flow; for DC, the nominal value of this threshold is 2 mA.

(ii) The so-called 'let-go' current is a slightly higher value. The *threshold of let-go* is the maximum value of current at which a person holding electrodes can ***voluntarily let go of them***. It depends on contact area, shape & size of electrodes, and physiological characteristics of the individual concerned. For AC, this averages around 16 mA for men and 10 mA for women. There is, though, no definable value for DC below 300 mA. Above 300 mA, let-go is only possible after several seconds or minutes of shock duration. Only making and breaking sensation is felt and it leads to painful muscle contraction.

(iii) Currents in excess of the let-go threshold, up to say 80 mA, will cause severe pain and laboured breathing. If the casualty is still conscious, recovery is almost certain immediately exposure is removed. If exposure is allowed to continue, however, collapse, unconsciousness, or even death by asphyxia, may ensue. Recovery from the unconscious state, with symptoms resembling those of normal shock, is comparatively certain with resuscitation, although it could take several hours.

(iv) The biggest danger is ventricular fibrillation which leads to death in a few minutes because of the failure of the heart to maintain blood supply to the brain. The threshold of ventricular fibrillation is the minimum value of current that causes ventricular fibrillation. It, too, depends on physiological factors such as anatomy of the body, state of cardiac function, as well as electrical factors, e.g. contact area, duration and pathway of current flow and type of current.
For AC, above 500 mA, fibrillation may occur for shock duration below 0.1 s. It may also occur for current magnitude of several amps, if the shock falls inside the vulnerable period of the cardiac cycle. Reversible cardiac arrest may result when shocks last longer than one cardiac cycle.
The threshold of fibrillation for DC is several times higher than AC for shock duration longer that the cardiac cycle. If the shock duration is shorter than 200 ms, the threshold of fibrillation for DC is approximately the same as for AC (rms value).
Ventricular fibrillation can occur for currents between 100 and 200 mA (average) applied for a short time (order of 1 s or longer), and even for lower currents if applied for a longer time (5-10 s). Exposure to even small currents for extended periods might eventually cause fibrillation, but this is not certain. Chances of recovery are poor, since defibrillation procedures must be administered within a few minutes, i.e. application of a larger shock to clamp the heart, and then respiration support, if necessary.
When the flow of DC current is below 300 mA, a warm sensation is felt in the extremities. If there is transverse current up to 300 mA flowing through the body for several minutes, as time and current increases, this might cause reversible cardiac dysrhythmia, current marks, burns, dizziness, and unconsciousness. Unconsciousness occurs frequently when the current is above 300 mA.

(v) For high currents, say over 200 mA, the muscular contraction of the heart may be severe enough to clamp it (the basis of defibrillation), thereby preventing fibrillation, and the chance of recovery is good.

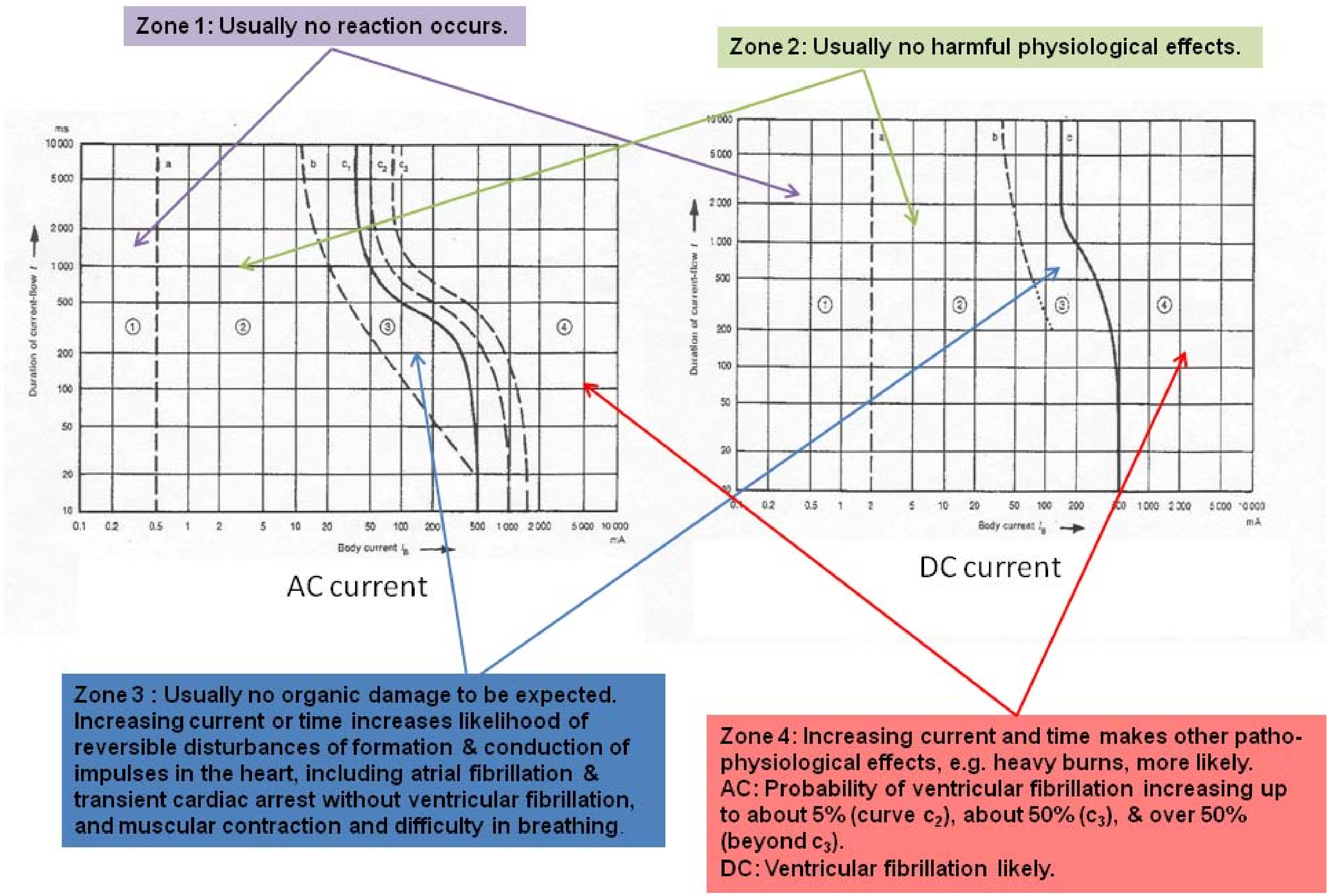
(vi) Very high currents (say above 250 mA) may cause

- complete respiratory inhibition due to damage to the nerve centre controlling breathing, resuscitation likely to be unsuccessful;
- irreversible and eventually fatal damage to nervous system;
- serious burns and delayed death due to damaged organs; and/or
- deep burns and sufficient body temperature rise to cause immediate death.

Very high current shocks are rare and probably only occur at high voltages or from lightning strikes.

Curiously, the person who receives a potentially lethal shock would probably be better off getting a high dose (say 250 mA), thereby preventing fibrillation. If lucky, the person would be thrown clear and only need resuscitation.

Most serious accidents that occur in the home or in industry involve a current path through the chest (say hand to foot, or hand to hand) and the current magnitude anything up to that causing fibrillation.



source AS/NZS3859:1991

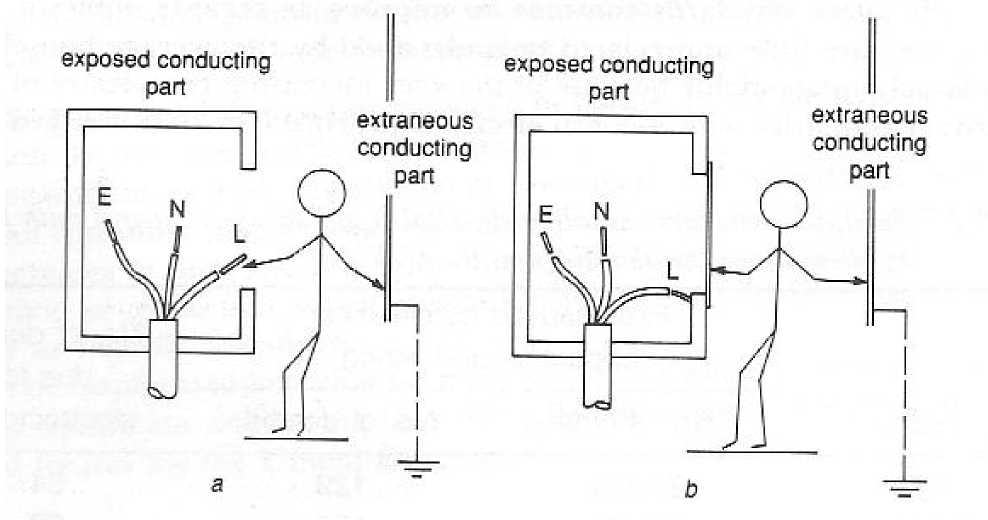
Finally, the following, relevant information may be of interest.

- Risks of shock are worst at power line frequencies, quickly losing effect above 1 kHz or below 10 Hz.
- Figures on body resistance are interesting. The volume resistance between the ears is 100 Ω and hand to foot about 500 Ω. However, the skin resistance is much higher, from 1 kΩ for wet skin up to 5 kΩ for normal skin. You would be idiotic to work near mains voltage with wet hands, as the 100 - 250 mA region is worst.
- 110 V systems are as dangerous as 240 V systems.

4.2 Causes of electric shock

Exposed live conductors

An exposed conductive part is ***any*** metalwork surrounding electrical equipment. An electric shock can be received from live metallic casing. This occurs when there is a partial elevation of voltage during the passage of an electrical fault current to earth or a full elevation when the casing is not earthed. A shock can also be received from exposed energized metallic parts (e.g. wiring) which normally carry a live voltage.



Direct contact (a) and indirect contact (b) with live wiring (from Greenwald)

Electric shocks can occur without the presence of a fault current. Some examples follow.

- Direct contact by touching the line and neutral or two phases of an energized supply. (This is a highly unlikely incident.)
- Direct contact with a live conductor when any part of the body is connected to earth.
- Indirect contact with an unearthed casing comprising an earth fault.

Improperly earthed equipment

The purpose of earthing equipment is to ensure that all exposed metal (i.e. conducting) surfaces are maintained at substantially earth potential, even during a fault condition when substantial current flows to earth. If the equipment is properly earthed, the circuit's over-current protection device will trip in the case of a low-resistance internal fault to an exposed metal surface. This will remove the hazard. In case of a fault with high internal resistance, equipment earthing will keep the exposed metal surfaces at or near earth [safe] potential. With improperly earthed equipment, both low- and high-resistance faults will energize the exposed metal parts to significant voltage levels, thereby causing the potential for serious electric shock if persons are in contact with the metal parts.

4.2.1 Electric currents and water

Electric shocks might occur when an individual is in water and electric currents are present. This is due to the energized conductor being exposed to the water. While water is not a good electrical conductor, it does nevertheless conduct some current and its danger is that it can spread over large surface areas of the body and thus diminish contact resistance with the skin. It can also cover insulating surfaces and make them live. The factors which will determine the current flow in such cases are

- shape and size of the conductor – water contact surface,
- shape and size of any insulating object covered with water,
- conductivity of the water, and
- resistance in the current path to earth.

When water is present, its relatively poor conductivity may mean that there exists a reasonably high resistance to earth. This can limit the current magnitude and thus any circuit over-current protection ***may not operate***.

4.3 Building safety into circuits

The following are examples of standard engineering controls of electrical hazards.

Fuses and circuit-breakers: A fuse or a circuit breaker protects a circuit from failure of the insulation of an unearthed conductor. It trips when the fault current exceeds the trip setting limit, and disconnects the power, thereby minimizing the hazard. Fuses and circuit breakers are over-current devices and ***do not protect against electric shock***. Their tripping current is almost always orders of magnitude greater than the current levels that can cause electrocution. They ***only protect equipment***.

Residual current devices (aka safety switches): A residual current device (RCD) incorporates a means for detecting a residual (or earth leakage) current, with an associated means of isolating the circuit if the residual current exceeds the trip level (normally 30 mA). It monitors the balance between the load current and the return current from the load and has a miniature core balance relay to detect earth leakage and an integrated circuit-breaker that also protects against overloading, short-circuit and earth leakage currents.
RCDs do not prevent electric shock. Instead, they respond very rapidly to earth leakage currents through the body and are designed to trip the supply before fibrillation has time to establish.
RCDs cannot provide universal protection. They only work if the current flows to earth through the body. ***The RCD will not provide protection, if a person is connected between the active and neutral***, with no earth leakage current.

Protective earthing: The purpose of a protective earthing conductor is to make sure that any leakage current from the live parts within the equipment flows harmlessly, via a low resistance path, to earth. The resistance to earth from protective earthed parts in equipment must be low enough to allow sufficient fault current to flow to earth, thus ensuring that the over-current protection device in the final sub-circuit or fixed wiring opens quickly during insulation failure.

Double insulation: All live circuits must be insulated from earth and all earthed external connections. The purpose of double insulation is to minimize the possibility of an earth fault loop. It implies that there are two, physically separate insulations. The functional insulation is necessary for the proper operation of equipment, whereas the protecting insulation protects against electric shock when the functional insulation fails to work. Double-insulated equipment is not earthed because of the two levels of protection provided by the insulation. However, electrocutions may still occur with double insulation, especially ***if the equipment is used near water*** or if there are plug or flexible cord faults.

Extra-Low Voltage Operation: Extra-low voltages are those under 50 V AC or 120 V ripple-free DC (AS/NZS 3000: 2000). In general, extra-low voltages are considered relatively safe for direct contact. However, if the condition of the room changes, such as high humidity or a wet environment, contact resistance is decreased and this increases the probability of an electric shock, even at extra-low voltages.

4.4 Electricity and fire

Overcurrent occurs when too much load is placed in an electrical circuit, e.g. when too many items are plugged in. A component carrying too much current may fail catastrophically, spontaneously bursting into flames. Alternately, although heat may be successfully dissipated by the circuit itself, heat can still accumulate in nearby materials which, in turn, can ignite spontaneously. Examples of such materials are faulty insulation or simply a build up of dust. Note that the heat increase may be due to a blocked ventilation passage or a failed fan.

When the voltage across an open-circuit is sufficiently high, it will cause an *arc* (spark) between the two terminals. This arc then acts as an ignition source for combustible materials nearby, e.g. flammable insulation or plastic casing of equipment. This situation is notorious in Australia when lightning (an electric arc) causes a bush-fire.

The priority when dealing with an electrical fire is to ***disconnect the power*** so it becomes a 'normal' fire. If power cannot be disconnected, then starve the fire of oxygen by smothering it with the CO_2 or foam from an extinguisher, but ***only if trained in the use of extinguishers***. ***Do not use water***, which will spread the electrical hazard. All labs have CO_2-extinguishers, distinguished by black markings.

4.5 Working on live equipment

All voltages are potentially hazardous since contact with any live parts might allow substantial amounts of current to pass through the heart. This can be fatal.

Work on live equipment is only permitted if there is no alternative. Supervision is compulsory.

The standard precautions [AS/NZS2243.7: 1991] to take when working with live equipment are these.

- Never work alone on live equipment.
- Use only tools and test probes with insulated handles.
- Work one-handed, keeping the other hand in your pocket to prevent constructing a hand-to-hand path (which would necessarily go through your heart!).
- Use earth-leakage core-balance protection. This is mandatory.
- Avoid contact with any earthed metal in the vicinity of the equipment.
- Stand on an insulating mat, and wear insulated gloves.
- Use prominent warning signs and barriers if equipment with exposed live terminals is energized.
- If components must be touched, e.g. when a motor is being checked for overheating, use the back of the hand so that involuntary muscle contraction does not prevent withdrawal should the casing be alive.

5. In an emergency

In the event of **any emergency, including fire, ambulance and police requirements,**

stay calm and contact UNSW Security on extension 56666

from any phone in the University; or use *University Help Points*; or dial freecall 1800 626 003.

Carefully ***describe*** the emergency:

- ***location,***
- ***type*** of emergency,
- your name & contact details, and
- ***severity*** of the situation.

Also notify your supervisor, other students, staff, etc.

If you discover a **FIRE or similar emergency**,

i. ***Activate the fire alarm*** by breaking the glass alarm. To activate the fire alarm, break the glass and push the switch. Fire alarms are located in the corridors on every level.
ii. Close doors that may limit the spread of the emergency, but ***only if it is safe to do so***.
iii. Notify UNSW Security on extension 56666.
iv. Tackle the situation, but ***only if trained in appropriate emergency procedures***. All laboratories in the Electrical Engineering Building are equipped with CO_2-extinguishers. CO_2-extinguishers and fire hose reels are also located in the corridor foyer areas on every level.

Be careful. FIRE SPREADS VERY FAST! You don't get much time.

In the case of **any ELECTRICAL emergency**, e.g. electrocution or fire, ***disconnect the power***. Each of the electronics laboratories has a wall-mounted, red, emergency stop-button that shuts down all electrical power.

First-Aid
Each of the electronics laboratories has a first aid box. Signs throughout the building will direct you to the nearest first-aid box.

Ground Floor	rooms G1, G15, G17, G17a, G21C-E
First Floor	rooms 101,113,125, 115, 119, 120
Second Floor	rooms 201, 233
Third Floor	rooms 302, 313, 315, 322, 343
Fourth Floor	room 450

The following **First Aid Officers** are close to the electronics laboratories,

First Aider	phone	room
Gladys Fong	54000	G1
Roy Zeng	55507	G15
Zhenyu Liu	55508	G15
Bamini Pratheepan	54000	G1

In addition to first-aiders, the **emergency team** contains **floor/emergency wardens**.

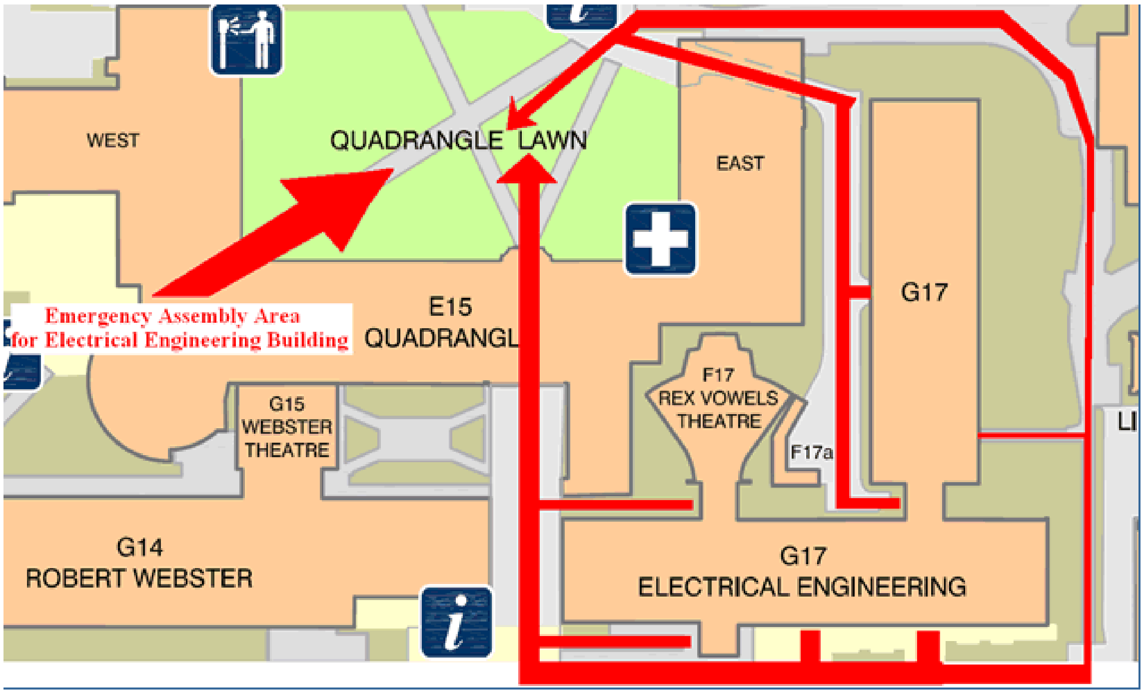
		phone	room
Chief Warden	Zhenyu Liu	55508	G15
Deputy Chief Wardens	Syed Rahman Roy Zeng	55507 55507	G15 G15
Level 1 **Floor Wardens** (cover electron labs)	Baburaj Karanayil Liyadipitiya Gamini	54991 55507	120B G15

5.1 Evacuation

What should you do if the alarm sounds while you are in the Electrical Engineering Building?

If the alarm sounds as a constant "*beeep-beeep-beeep-beeep*" ***prepare*** to evacuate and follow instructions from any public announcements or emergency team member. Save files, turn off equipment and remain calm.
If the alarm sounds as a rising "*whooop-whooop-whooop-whooop*" ***evacuate the building immediately***. Leave the building via the nearest safe emergency exit. Do not use the lifts. Proceed as directed to the official Evacuation Assembly Area, which is the ***Quadrangle Lawn*** to the west of the building.
Remain in the assembly area until notified by the Emergency Team that it is safe to return to the building.

Always remember:
- ***Follow all instructions from the Wardens.***
- Leave the building by the nearest safe exit.
- Do not delay to collect personal possessions.
- Do not run, push, overtake, etc.
- Do not use the lifts.



6. Reporting procedures

Safety can only improve if people are active about making it happen. For the safety of oneself and that of others in the building, please report any accidents as soon as possible, to the first aid officers or other responsible persons.

6.1 Incidents & hazards

An *incident* is when someone gets hurt. A *hazard* is something that only threatens safety.

Report all incidents and hazards.

Any incidents related to safety can be notified to the School, using either the on-line reporting system or discussion with the WHS Committee's Chair (Dr Iain Skinner) or the School's OHS Officer (Zhenyu Liu). Such matters might include the following:
- Any ***accidents which occur to you or to any other person*** - all accidents should be reported, even those that appear to be relatively innocuous.
- Potential hazards noticed within the School in any of its activities or places.

- Notification of any new safety matters that arise in new activities and that have not been dealt with before.

On-line reporting occurs within `myunsw`. Within your student profile tab, click on the *Report/Manage OHS&E Issues* link next to the *harm-2-zero* symbol. For detailed instructions, see

www.ohs.unsw.edu.au/ohs_reporting/index.html

Alternately, a member of staff can complete the report for you.

If you are unsure whether something really is a hazard, talk about it, as detailed next.

6.2 Improvements to safety

You can help improve safety by making suggestions and raising your concerns. Improved safety needs a collective effort. Knowledge advances by discussion.

OSRN has developed the following structure for "consultation."

1. In the first instance all safety concerns should be raised with your teacher, either the lab demonstrator or the lecturer-in-charge.

2. Your undergraduate School Committee Student Representative, namely the current President of ELSOC, who is *ex-officio* a member of the School's level 3 Committee. Visit ELSOC in room 244, or email: `president@elsoc.net`

3. Your School WHS Committee's Chair, Dr Iain Skinner (to contact see p 24)

4. Your Faculty WHS Coordinator, Rohan Singh-Panwar, who can be contacted for general or anonymous concerns. (to contact see p 24)

The School recognises its duty to consult with all stakeholders about WHS and, in particular, the raising and resolution of such concerns. It is committed to providing a safe workplace.

7. Students & UNSW – rights & duties

Every student has the right to work in a safe and healthy environment. Students, in turn, have the obligation to make this possible, by following the safety procedures and guidelines set by the School and described in this manual. Failure to follow these regulations may result in personal injury or risking the injury of another. This constitutes ***formal misconduct*** and may involve students being given a warning, expelled from the electronics laboratory and other laboratories, or, in the worst case, being expelled from the University.

The School has the responsibility to provide the safe and healthy environment, in accordance with the NSW Workplace Health and Safety Act (2011). This act requires UNSW, through its procedures, to ensure that safety measures are implemented, and that adequate and necessary steps have been taken to prevent and/or minimize risks or accidents. The School has consultation obligations and these are fulfilled by the processes outlined in §6.2 above. The

Regulations further require that the School takes steps to ensure that students are aware of any potential hazards and that the laboratory regulations are followed, by both staff and students.

The School has a committee responsible for considering **all safety concerns** raised by anyone. ELSOC's President (or nominee) is, ex-officio, a member to present the students' voice. The Committee's Chair is also available for consultations.

Students, too, have legal obligations, as set by the NSW Workplace Health and Safety Act (2011) which requires you to co-operate with the relevant safety directives of UNSW and not to cause a hazard to others. If you fail to do this and there is a 'reportable' incident – typically someone getting badly hurt – then you may get prosecuted.

Thesis/project work in laboratories
In all laboratory activity that is not part of a scheduled class, for example experimental work associated with a thesis, as a student, ***you must complete a risk assessment before starting the experimental work***. The relevant UNSW form (OHS017) should be used. This risk assessment form must be given to your supervisor, or to the laboratory supervisor, for approval prior to commencing the experimental work.

In summary, you are responsible to **be safe**, the School's responsibility is to **make this possible**.

8. A preview of some other hazards in EE&T

Apart from the electronics laboratories, the School has many other laboratories and these contain more dangerous hazards than those to which you have been introduced above. ***Pay attention to warning signs on the laboratory doors***. All such hazards require more training, and induction to the relevant laboratory. All laboratories house electrical equipment, so this document remains relevant throughout your study.

It may surprise you to learn that the major causes of harm at UNSW are not associated with a technology.

Slippery & uneven surfaces
"*Look where you are going*." More to the point, report spills so they can be removed; report broken or uneven floors and walkways so repairs can be organised.

Ergonomics
The hazard most widely met by students is sitting too long at computers. Please see the advice from the OHS Unit about how to arrange your body, keyboard, mouse & screen to minimise ergonomic injuries (typically RSI).

www.ohs.unsw.edu.au/officesafety/workstation_setup.html

Advice from the University of Wollongong, though, may be easier to understand.

staff.uow.edu.au/ohs/workingsafely/workplaceerg/index.html

Click on *Quick guide* at the bottom.

Manual handling
Lifting heavy items is one of the major sources of injury in Australia. You will eventually in life need to know the correct techniques for lifting.

High Voltage
High voltages pose the same risk of electrocution as described in §4, but are more likely to cause arcing than those you will meet in the electronics labs.

RF electromagnetic radiation
Radiofrequency electromagnetic waves (including microwaves) are used in wireless experiments. Exposure to these is known to cause deep burns at high intensities. Physiological risks at low intensities are not yet definitively established.

Lasers
The Photonics Laboratories use both visible and invisible lasers up to class 4. These are housed in special rooms. Student projects may require use of class 3B lasers. Such lasers are not eye-safe.

Machinery
There is a machines labs housing motors and windmills (fans) and an automation lab containing robotic arms. The major dangers are being caught in or bumped by a moving part.

Dangerous goods & hazardous substances
The research activities of the School involve many solvents & flammable liquids, some compressed gases of which H_2 is arguably the most dangerous, and some caustic substances. The MSDS associated with each chemical's details its respective risks and required precautions, including storage and PPE. Labelling requirements are critical.

ANFF
The Centre for Quantum Computing makes nanostructures. It has its own, specialised training and induction programs.

9. Contacts, resources, references & training opportunities

You do not need to deal with safety on your own. UNSW is an educational institution and there is a diversity of expertise available. If you have any questions about safety, ***all you need to do is ask*** someone. As a student, in the first instance, this will be your teacher. You have no excuses. Just ask!

People who can help

School's **OHS Officer** (& Chief Building Warden G17):
Zhenyu Liu, phone 55508, rm G15
email `z.liu@unsw.edu.au`
to report any specific structural type of hazard, e.g broken windows, or any incident.

School's "**WHS Committee Chair**:"

Dr Iain Skinner, phone 9385 5153, rm 335

email `i.skinner@unsw.edu.au`

to discuss any incident related to safety within the School.

Faculty **WHS Coordinator**:

Rohan Singh-Pawar, phone 9385 7944 (fax 9385 6139), rm 211 Civil Eng building

email `r.sighpanwar@unsw.edu.au`

who can be contacted for general or anonymous concerns, within the School or wider.

Web-based resources

The School's WHS web-pages are the first place to look for EET related policies and information.

www.eet.unsw.edu.au/info-about/ohs

In particular, this provides detailed information about the School's processes as well as some guidance about working safely.

The **UNSW OHS Unit** provides a wealth of information on safety related topics, as well as the legislative requirements.

www.ohs.unsw.edu.au

This is also a gateway to all the UNSW policies, procedures, guidelines & forms that you will ever need.

For more information about emergencies, see **UNSW Security**

www.facilities.unsw.edu.au/safety-security

The OHS Student Representative Network (OSRN) recommends that you review these.

- **Engineering OHS** website, for general OHS information
  www.eng.unsw.edu.au/ohs
- UNSW **Personal Safety Handbook**:
  www.facilities.unsw.edu.au/forms/security-and-emergency-management#handbooks
- **Uni Life**
  studentlife.unsw.edu.au/life/a-safe-campus/
- UNSW **Security Alert** List
  To subscribe, email `majordomo@explode.unsw.edu.au` with the following in the email: "*subscribe sec-alert.*"

Standards Australia publishes many standards about safety - 1008 standards have "safety" in the title. Three of relevance to this document are

- AS/NZS2243 *Safety in laboratories* series
- AS/NZS3000 *Electrical installations*
- AS/NZS3859 *Effects of current passing through the human body.*

The quickest access to Australian standards is using the *weblinks* reached from the homepage of the UNSW OHS Unit.

Reference books

J. Cadick (1994), *Electrical Safety Handbook*, McGraw-Hill, Inc., USA

T. Kletz (2001), *An Engineer's View of Human Error*, 3rd edn, Inst Chem Eng, Rugby (UK)

Training

You might be interested in the following training courses.

- ***Laboratory Safety Awareness***. This introduces procedures for working with "nasties." You can enroll for this on-line, via `myunsw`. Click OHS Training at the bottom left of your profile-tab.
- ***Green Lab***. This discusses waste disposal procedures. It is on-line. To enroll see the School's OHS Officer.

There are a number of training videos and DVDs available through the Electronics Workshop, Room G15.

Additionally, you should give serious consideration to completing a ***First Aid*** course. Once upon a time it was a requirement to graduate with a BE, illustrating the emphasis the profession places on safety.

> *"One reason we are less happy with software solutions*[i.e. methods of working, training, instructing, etc] *is that continual effort - what I call grey hairs - is needed to prevent them disappearing. If a hazard can be removed or controlled by modifying the hardware or installing extra hardware, we may have to fight to get the money, but once we get it and the equipment is modified or installed it is unlikely to disappear.*
>
> *"In contrast, if a hazard is controlled by modifying a procedure or introducing extra training, we may have less difficulty getting approval, but the new procedure or training programme may vanish without trace in a few months once we lose interest. Procedures are subject to a form of corrosion more rapid and thorough than that which affects the steelwork. Procedures lapse, trainers leave and are not replaced. A continuous management effort - grey hairs - is needed to maintain our system. No wonder we prefer safety by design whenever it is possible and economic; unfortunately, it is not always possible and economic.*
>
> *"Furthermore, when we do go for safety by design, the new equipment may have to be tested and maintained. It is easy to install new equipment – all you have to do is persuade someone to provide the money. You will get more grey hairs seeing that the equipment is tested and maintained and that people are trained to use it properly and do not try to disarm it."*
>
> \- Kletz (2001)