Health & Safety Technical Guidelines

HS-TG-03/2

Non Ionized Radiation & Laser Safety

Produced by

HSS – Facilities & GS Department

Table of Contents

Purpose

The purpose of this document is to protect the health and well-being of all Qatar University (**QU**) staff, students, Contractors and visitors, and to prevent damage to property,equipment, facilities, and the environment associated with the usage of Non-Ionized Radiation & Laser lights as part of the university's activities. This document provides guidelines on the application of the requirements and principles of the QU Health & Safety Management System (**HSMS**) to activities associated.

Scope & Responsiblities

Scope

This HS Technical Guideline applies to all operations and activities associated with QU activities where Non-Ionized Radiation & Laser lights is involved, such as laboratories, to enable the effective management of the associated HS aspects and risks.

Responsibilities:

Top Management

QU top management shall allocate sufficient resources for the effective implementation of the HSMS, including the application of this HS Technical Guideline, and ensure that QU employees, students, contractors and visitors are aware of their responsibilities through appropriate regulation, delegation and communication.

Other Accountabilities

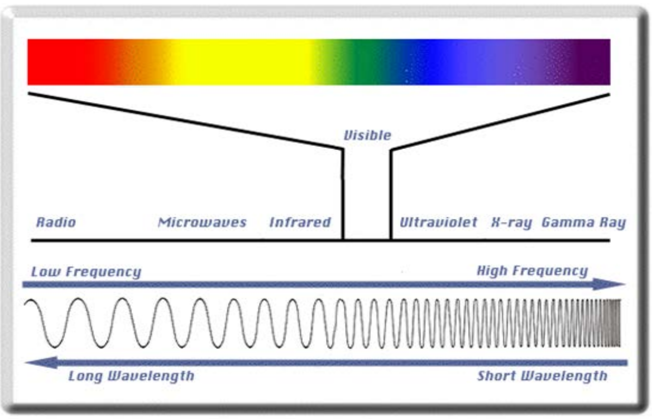
The QU HSS and the HS Committee are accountable to the QU Top Management for the implementation of this HS Technical Guideline.
Vices of President (VPs), , Deans, Directors, Managers, Head Sections/Units and Project Managers are accountable to the QU Top Management for the application of this HSETechnical Guideline in areas under their supervision.
All QU staff is responsible for performing their duties by complying with the requirements of this HS Technical Guideline.

INTRODUCTION TO NIR

Regulatory Requirements

QU HS Health and Safety team has the role of providing safety information and monitoring exposure to operators of NIR equipment in order to reduce risk of injury and prevent overexposure. This guide is designed to provide information about such hazards. The UW enforces all Local & international protection standards relevant to each range of hazard, in particular the Threshold Limit Values (TLVs) e. g. the **ACGIH** (American Conference of Governmental Industrial Hygienists).

The Electromagnetic Spectrum



Like ionizing radiation, such as x-rays and gamma rays, NIR is a part of the electromagnetic (EM) spectrum and is propagated as waves through a vacuum or some medium. However, NIR differs from ionizing radiation because it consists of lower quantum energies and, therefore, has different biological effects. NIR displays its own unique personality.

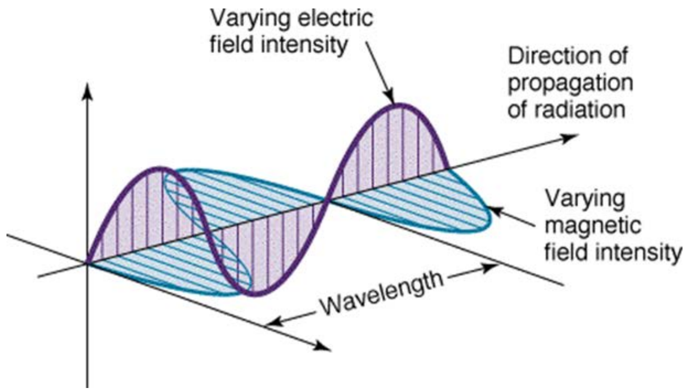
Since NIR shares the same wave characteristics as ionizing radiation it can be described in terms of its wavelength, frequency, and energy. Though compared to its ionizing sibling, NIR is longer, less frequent, and lazier. It can still, though, inflict a good deal of damage.

NIR is most often described as being bound by the following characteristics:

NIR CHARACTERISTICS

Wavelengths:	100 nm to 300,000 km
Frequencies:	3.0 PHz to 1 Hz
Photon energy:	1.987×10^{-18} J to 6.6×10^{-34} J

Each characteristic (wavelength, frequency, and energy) will be discussed below. Basic Wave Concept



Electromagnetic radiation is the propagation of energy. This energy consists of oscillating electric and magnetic fields, which are transverse and perpendicular to each other. An electromagnetic wave is essentially then made up of fields which are inter-related and interdependent. Both fields can exert a force. An electric field can affect an electric charge (for example, an electron). And a magnetic field can, in turn, affect a moving charge (current).

Electromagnetic theory as developed by Maxwell and others describes a magnetic field that varies in time and that induces a perpendicular electric field. The changing electric field, likewise, induces a perpendicular magnetic field. The two fields in essence produce each other and propagate together. The different regions of the EM spectrum have different properties but they are all propagated at the same speed in a vacuum: 3 x 108 m per second, known as the speed of light, usually designated as c. The velocity of the EM wave in a medium, however, is determined by the electric and magnetic properties of that medium.

The image of a wave, of course, is a simplified representation of the EM spectrum. Electromagnetic waves are not simply waves, but have a dual nature. They can be described has having a wave action with wave effects, but under some circumstances, especially at higher energies, they can behave as a bundle of waves (a photon) and can interact with matter as a particle would.

Wavelength (λ)

The names of the different EM regions essentially refer to the methods of wave generation or detection. There is no sharp distinction between the regions, though customarily they have been defined as having the following dimensions:

Ionizing

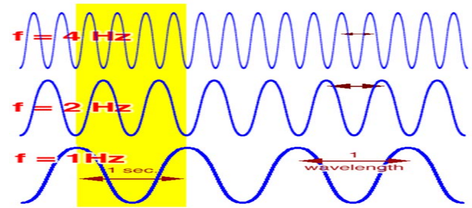
Gamma and x-rays **λ** < 1 nm (10-9 m)

Non-ionizing

Ultraviolet	1 - 400 nm
Visible	400 -700 nm
Infrared	700 - 1,000,000 nm (1 millimeter)
Microwave	1 mm - 1 m
Radiofrequency	1 m – 100 km

The range for NIR is quite large, from 100 nanometers in the ultraviolet to over 300,000 km in the radiofrequency region. Each range of wavelengths is absorbed differently by the human body, resulting in different biological effects.

Frequency



The number of waves that pass a fixed point during an interval of time is referred to as the **wave frequency (f** or the Greek letter **v)**. Frequency is measured by counting the number of waves that pass a fixed point in one second. From one wave crest to another is called a **cycle**, so frequency is often described as cycles per second (or **Hertz**). One wave, or cycle, per second would therefore have a frequency of 1 Hertz (Hz).
Since EM waves travel at the speed of light (in a vacuum), if the wavelength of any wave is given, then the frequency can be derived, and vice versa:

$$f = c/\lambda$$

Example: The frequency of a given wave is 7.5×10^{14} Hz. What would be the wavelength?

Answer:

$$f = c/\lambda$$

$$7.5 \times 10^{14} \text{ Hz} = \frac{3 \times 10^{8} \text{ m/sec}}{\lambda}$$

$$\lambda = \frac{3 \times 10^{8} \text{ m/sec}}{7.5 \times 10^{14} \text{ Hz}} = 4 \times 10^{-7} \text{ m or } 400 \text{ nm}$$

A wavelength of 400 nm would place this wave in the visible region of the EM spectrum and would be interpreted by us as being violet.

Energy

Unlike ionizing radiation, NIR does not have energy levels high enough to ionize a molecule, that is, eject an electron. Usually a photon energy near **1.987×10^{-18} J (12.4eV)** is needed to ionize atoms.
Gamma and x-rays, as well as UV radiation near a 100 nm wavelength, have sufficient energy to ionize molecules and are, therefore, considered to be ionizing radiation. In general, the UV portion of the spectrum is not included in the ionizing region because UV at wavelengths less than 295 nm are filtered by the atmosphere. UV at these short wavelengths, however, can be produced in some types of lasers, so would, under these circumstances, be considered ionizing.
The energy of any given wave on the EM spectrum is proportional to its frequency, described in the equation:

$$E = hf$$

where h is Planck's constant (6.63×10^{-34} J/sec).

Example: If we measure a band of light and find that its photon energy is 0.1 eV, what would be the wavelength of this light? What would be its color?

Answer:

$$E = hf = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{E}$$

$$\lambda = \frac{(6.6 \times 10^{-34} \text{ J/sec})(3 \times 10^{10} \text{ cm/sec})}{(0.1 \text{ eV})(1.6 \times 10^{-19} \text{ J})}$$

$$\lambda = 1.24 \times 10^{-3} \text{ cm} = 12.4 \text{ μm}$$

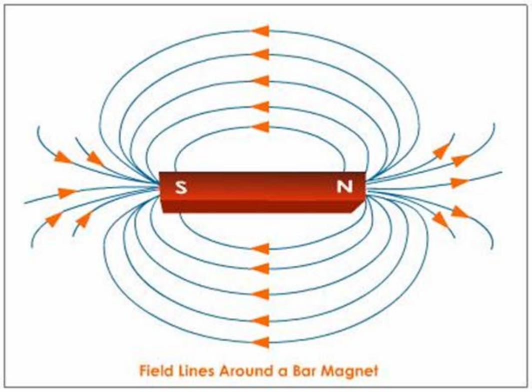
This would place the measured light in the infrared region of the spectrum. In this guide each region of the EM spectrum that is defined as non-ionizing will be examined in terms of hazards as well as levels of safety responsibility.

STATIC MAGNETIC FIELDS

Magnetic Fields
Magnetic fields are associated with magnets. Magnetic fields of force are created by the motion of a magnet's electrons and the alignment of its atoms. The greater the magnetic flux density of a magnet, the greater the chance for potential hazard. Magnetic fields are generally measured in either Gauss (G) or Tesla (T).

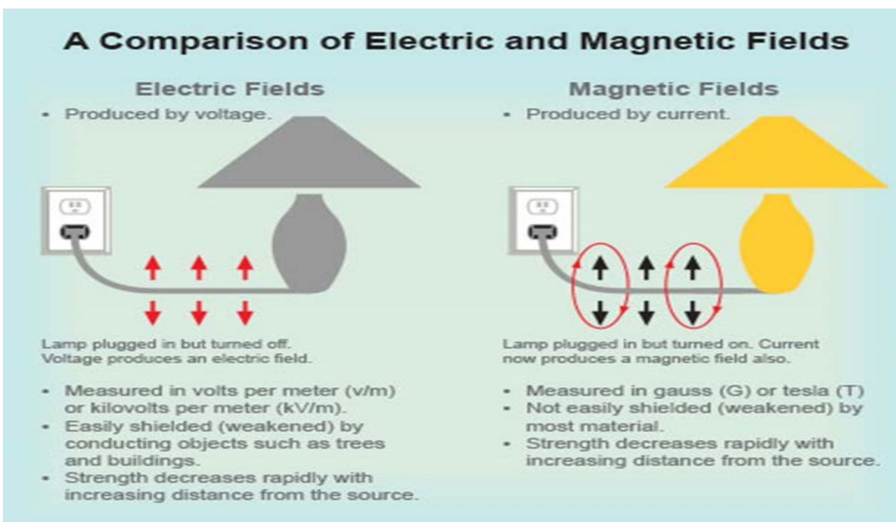
10,000 Gauss = 1 Tesla (T) 1

Gauss = 0.1 mT = 100 μT.

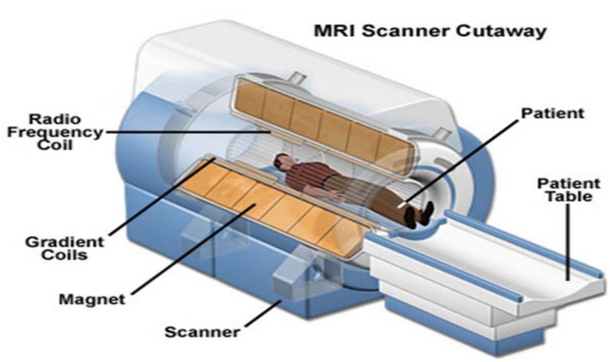


Field Lines Around a Bar Magnet

Magnetic fields can surround any electrical device when there is a flow of current. The magnetic field increases in strength as the electric current increases.



Applications
Most sources of static magnetic fields are either an **MRI** (Magnetic Resonance Imaging) unit or an **NMR** (Nuclear Magnetic Resonance) system. There are also several large magnets used for instructional purposes.



Hazards

Several reviews of laboratory and epidemiological research have been conducted by national and international organizations. None of the reviews has found a correlation between health hazards and static magnetic fields encountered in residential and occupational environments. There is no direct evidence that such fields are mutagenic or carcinogenic, nor are they likely to cause developmental abnormalities or chronic effects below an exposure of 20,000 G. Some of the conclusions of these reviewing organizations are provided below:

American Conference of Governmental Industrial Hygienists (ACGIH), 1993, concluded that:
"no specific target organs for deleterious magnetic field effects can be identified at the present time … Although some effects (of static magnetic fields) have been observed in both humans and animals, there have not been any clearly deleterious effects conclusively demonstrated at magnetic field levels up to 2T (2000 mT)."

2T = 20,000 G

International Commission on Non-Ionizing Radiation Protection (ICNIRP), 1994, concluded that:
"current scientific knowledge does not suggest any detrimental effect on major developmental, behavioral and physiological parameters in higher organisms for transient exposure to static field densities up to 2 T (2000 mT). From analysis of the established interactions, long-term exposure to magnetic flux densities of 200 mT should not have adverse consequences."

Although there is no direct evidence of health hazards, there are indirect effects, such as flying ferromagnetic objects which can cause injury. Sometimes magnetic interference can occur with cardiac pacemakers and other precision electronic equipment. Safety standards, therefore, should be followed by individuals and patients who may enter areas of large magnetic fields, such as in the vicinity of MRI machines.

Effects and Levels

Compass may be deflected **0.1 G**

Earth's magnetic field **0.5 G**

Precision instruments or TV monitor colors may be affected. **1.0 G**

Cardiac pacemakers and other implanted electronic devices may be affected **5.0 G**

Credit cards, magnetic storage systems, and analog watches may be damaged **10.0 G**

Ferromagnetic objects can become projectiles **10.0 G**

Cathode-ray devices and tubes may malfunction **20.0 G**

Field around small permanent magnets & Audio-speaker magnets at 1 cm from poles **10.0 to 100 G**

Magnetic Resonance Imaging (MRI) **1500 to 20000 G**

Due to the possible effect on older pacemakers, owners of large magnets should have visible markers as to where the magnetic field is ≥ 5.0 Gauss.

Related Effects

In addition to the effects of a magnetic field there are hazards not directly associated with the magnet itself but can pose a safety hazard. Essentially they fall into two categories: electrical and quench effects.

Electrical Hazards
Some electrically conductive materials (non-magnetic) can form resistance due to induced eddy currents. Electrical supply circuits and magnetic cores should be grounded to prevent voltages, induced by eddy currents, from building up.

Another concern can be exposed leads. If a metal tool, for example, should come in contact with an exposed lead it could result in an electrical short, which can then form an arc flash and possibly vaporize the tool. More importantly, if the terminal voltages exceed 50V and if the inductive energy is greater than 0.5J (due to the loss of conductor continuity), ***the result can be the electrocution of anyone who touches an exposed, energized lead.***

Quench Hazards
With superconducting magnets there is the chance of a sudden discharge of magnetic field energy, which can cause serious injury to personnel (via electrical shock or burns) or damage to equipment. This sudden discharge is known as quench. Eddy currents can form, as well as a great deal of heat. If a superconducting magnet does quench, in addition to the electrical energy and heat discharge, there can be a sudden venting of boiled-off cryogens, leading to cryo-burns. When quenching occurs there will also be an unexpected loud noise which may startle personnel and cause other injuries.

Safety Standards
The University enforces the **ACGIH (2004)** standard with regards to static magnetic source safety. The recommended limits are as follows:

ACGIH (2004)		
	Occupational Continuous Exposure (whole body)	**600 G**
	Occupational Extremity Exposure	**6,000 G**
	Ceiling Exposure (whole body)	**20,000 G**
	Ceiling Exposure (extremity)	**50,000 G**

The above levels are for routine occupational exposures on a daily, 8-hour-time-weighted basis. **Persons with the following conditions are NOT eligible for MRI scanning:**

Aneurysm vascular clips, intracranial bypass graft clips, eye orbital prostheses (metal shank anchors), metal middle and inner ear prosthesis, cardiac pacemakers, recent post operative cases with metal clips or wire implants, and some types of implanted therapeutic devices with metal (such as insulin pumps). Individuals with bullet or shrapnel fragments must have eligibility evaluated by a physician. Individuals with certain metal implants are eligible for scanning, such as tantalum mesh plates and gold or amalgam fillings in teeth.

Responsibilities

Health & Safety (H & S)
The will provide training when requested by the Department, supervisor, or individual. Upon request, Radiation Safety can monitor an area for potential hazards and provide recommendations.

Department
The Department will notify Health & Safety when magnetic equipment is scheduled to be purchased or transferred.

Supervisor
The supervisor will ensure that all appropriate signage is posted and that the 5 Gauss line, clearly indicated.

Will make sure that all personnel or visitors entering the magnetic field area are qualified to do so and that they understand the potential hazards.

Personnel
Individuals will obtain authorization to enter a designated static magnetic field area from the supervisor or department. will also check and comply with all posted requirements.

Superconducting Magnets: Additional Information

With **Nuclear Magnetic Resonance (NMR), Magnetic Resonance Imaging (MRI),** and other superconducting magnetic equipment there are a number of unique safety concerns. Health & Safety is responsible for determining specific hazards for each facility housing such magnetic sources, identifying hazardous areas, reviewing safety precautions, and providing training when needed.

Supervisors and principal investigators are responsible for ensuring that all personnel are trained to perform safely the tasks assigned to them and that all protective control measures are maintained. Non-user staff such as administrators and custodians should also be trained not to enter the magnet room. Supervisors are responsible for ensuring that work done, in the vicinity of high magnetic fields, by facilities personnel or contractors will be carried out appropriately and safely. All contract work should be reviewed for safety concerns prior to scheduling.

Magnetic Field Hazards

- Ferromagnetic objects shall be kept outside a pre-determined radius in order to prevent those objects from becoming projectiles, which can cause severe injury to personnel as well as equipment damage. Examples of such ferromagnetic objects are fire extinguishers, tools, radios, wheelchairs, keys, defibrillators, jewelry, hearing aids, magnetic stirring bars, watches, scissors, badges, flashlights, etc.
- If the magnetic field is 100 gauss or greater, gauss lines of 100, 10, and 5 gauss should be clearly indicated. No work stations should be within the 5 gauss line, nor should the line intrude into public thoroughfares, nor entrances or exit spaces. This also includes locations above and below the magnet room.
- All gas cylinders shall be secured. If used within the 100 gauss line, all tools should be non-magnetic. Magnetic objects in general should be secured or kept outside the 100 gauss line.
- Magnetically-sensitive equipment, such as implants and cardiac pacemakers, can be adversely affected, resulting in injury or death. **All individuals with pacemakers are restricted to areas that have a magnetic field of less than 5 gauss**.
- Metallic implants (even if not ferromagnetic) can move in a magnetic field and in some cases become dislodged. In cases of a rapidly changing field, eddy currents could possibly be induced in an implant, resulting in a serious heating of the implant. Examples of such implants include pins, shrapnel, insulin pumps, aneurysm clips, cochlear implants, and prosthetic limbs.
- All magnetic storage media, especially credit cards, can be destroyed by magnetic fields. Credit and ATM cards should be kept beyond the 10 gauss line.
- Room size should be considered when installing an NMR. During a quench event nearly half of the helium volume will boil off very rapidly and form a white vapor above the magnet. Once a quench begins (boil off of cryogens when the magnetic field is lost) it will not stop until all the helium boils off. The result is a very large and expanding vapor cloud. The room must be large enough to accommodate the initial cloud. Exhaust ventilation must be adequate for the room under quench event conditions.
- If room size or ventilation is inadequate, then helium vent pipes should be installed to the quench valve, or oxygen monitor-connected exhaust fans should be used.

Cryogen Hazards

- Both liquid helium and liquid nitrogen are colorless and odorless. If a sudden magnetic quench occurs then these gases can now displace oxygen in the magnet room, causing asphyxiation. Oxygen sensor alarms should be installed.
- Liquid helium is at – 452°F and liquid nitrogen is at – 320°F. The liquid itself or its vapors can cause severe frostbite.
- During cryogen filling operations personnel shall use at least thermal gloves, face shields, lab coats, long pants, and covered shoes. Proper procedures for filling and transport should always be followed. At least two staff members should be present during filling.
- Quench prevention is paramount. Training of personnel should include quench prevention and emergency procedures, including evacuation.

Fire Hazards

- Magnetic systems fire can cause the magnet to dangerously rupture.
- If a magnetic quench occurs the extreme cold of the gases may cause the air to condense on surfaces. The moisture on these surfaces is most likely liquid oxygen and would be a potential fire hazard.
- At minimum, one fire extinguisher (that is magnetically compatible) should be available just outside the magnet room.

Other Hazards

- Caution should be taken around high energy power supplies to prevent accidental contact. Every attempt should be made to keep power cords and cables off the floor and reduce tripping hazards. Evacuation routes should be clearly visible. Unescorted visitors should never be allowed in the area of high magnetic fields.
- Electrical transformers could be magnetically saturated above 50 gauss.
- If flooding occurs there could be the risk of electrocution.

Signage

- The appropriate signage shall be posted at all entrances to the magnet room indicating the hazards and prohibiting unauthorized personnel in the area.

Emergency Procedures

- Emergency procedures are specific for each facility and should be organized with the assistance of Radiation Safety and posted.

Magnetic Field Units and Conversion Factors

- Magnetic Fields are generally measured in tesla (T) or millitesla (mT). In the US, fields are often measured in gauss (G) or milligauss (mG):

1T = 1,000 mT **1G = 1,000 mG** **1T = 10,000G** **1mT = 10,000mG**

Safe Handling of Cryogenic Substances

A superconducting magnet uses two types of cryogens, liquid helium and liquid nitrogen. Cryogenic liquids can be handled easily and safely provided certain precautions are obeyed. The recommendations in this section are by no means exhaustive, and when in doubt the user is advised to consult the supplier.
Types of substances:
The substances referred to in these recommendations are nitrogen, helium and air. Contact your cryogen supplier or HS for the appropriate MSDS sheets for these cryogens.

- **Helium**: This is a naturally occurring, inert gas that becomes a liquid at approximately 4K. It is colorless, odorless, non-flammable and non-toxic. In order to remain in a superconducting state the magnet is immersed in a bath of liquid helium.
- **Nitrogen**: This is a naturally occurring gas that becomes liquid at approximately 77K. It is also colorless, odorless, non-flammable and non-toxic. It is used to cool the shields, which surround the liquid helium reservoir.

Cryogen transport Dewars:

During normal operation, liquid cryogens evaporate and will require replenishment on a regular basis. The cryogens will be delivered to site in transport Dewars. ***It is essential that these cryogen transport Dewars are non-magnetic.***

Physical properties:

Safe handling of cryogenic liquids requires some knowledge of the physical properties of these liquids, common sense and sufficient understanding to predict the reactions of such liquids under certain physical conditions.

General Safety Rules
General safety rules for handling cryogenic substances include, but are not limited to:

- Cryogenic liquids remain at a constant temperature by their respective boiling points and will gradually evaporate, even when kept in insulated storage vessels (Dewars).
- Cryogenic liquids must be handled and stored in well ventilated areas.
- Passengers should never accompany cryogens in an elevator. There is a risk of asphyxiation.
- The very large increase in volume accompanying the vaporization of the liquid into gas and the subsequent process of warming up is approximately 740:1 for helium and 680:1 for nitrogen.

Cryogen Transport Dewars
The rules concerning the cryogen Dewars used to transport cryogenic liquids include, but are not limited to:

- All cryogen Dewars transporting cryogenic liquids must not be closed completely as this would result in a large buildup of pressure. ***This will present an explosion hazard and may lead to large product losses!***
- All cryogen transport Dewars must be constructed of non-magnetic materials.

Health Hazards
Main health hazard related rules include, but are not limited to:

- Evacuate the area immediately in the event of a large spillage.
- Provide adequate ventilation in the room to avoid oxygen depletion. Helium can displace air in the upper area of a room and cold nitrogen can displace air in the lower area. Please see the "Ventilation" section for detailed information.
- Do not come in direct contact with cryogenic substances in liquid or vapor form (or as low temperature gases), since they will produce "cold burns" on the skin similar to burns.

First Aid
First aid rules include, but are not limited to:

- If any of the cryogenic liquids come into contact with eyes or skin, immediately flood the affected area with large quantities of cold or tepid water and then apply cold compresses.
- Never use hot water or dry heat.
- Medical advice should be sought immediately!

Protective Clothing
Protective clothing rules include, but are not limited to:

- Protective clothing must be worn mainly to avoid cold burns. Therefore dry leather or cryogenic gloves must be worn when handling or working with cryogenic liquids.
- Gloves must be loose fitting so that they can be removed easily in case of liquid spillage.
- Goggles must be worn to protect the eyes.
- Any metallic objects (e.g. jewelry) should **not** be worn on those parts of the body which may come into contact with the liquid.

Others
Other rules of handling cryogens include, but are not limited to:

- Handle the liquids carefully at all times. Boiling and splashing will always occur when filling a warm container.
- Beware of liquid splashing and rapid flash off of cryogens when immersing equipment at ambient temperature into the liquid cryogens. This operation must be carried out very slowly.
- When inserting open ended pipes into the liquid, never allow open ended pipes to point directly towards any person.
- Use only metal or Teflon® tubing connected by flexible metal or Teflon® hose for transferring liquid nitrogen. Use only gum rubber or Teflon® tubing.
- Do not use Tygon® or plastic tubing. They may split or shatter when cooled by the liquid flowing through it and could cause injury to personnel.

Dewar

Smoking

Please obey the following basic rules concerning smoking:

- Do not smoke in any rooms in which cryogenic liquids are being handled.
- Designate all rooms in which cryogenic liquids are being handled as "No Smoking" areas, using appropriate signs

Additional facts and precautions

- While nitrogen and helium do not support combustion, their extreme cold Dewar causes oxygen from the air to condense on the Dewar surfaces, which may increase the oxygen concentration locally.
- There is a particular fire danger if the cold surfaces are covered with oil or grease, which are combustible. ***Self-ignition could occur!***

Properties	Nitrogen	Helium
Molecular weight	28	4
Normal boiling point (°C) (°K)	-196 77	-269 4.2
Approximate expansion ratio: volume of gas a 15°C and atmospheric pressure produced by unit volume of liquid at normal boiling point	680:1	740:1
Density of liquid at normal boiling point ($kg\ m^{-3}$)	810	125
Color (liquid)	None	None
Color (gas)	None	None
Odor (gas)	None	None
Toxicity	Very low	Very low
Explosion hazard with combustible material	No	No
Pressure rupture if liquid or cold gas is trapped	Yes	Yes
Fire hazard: combustible	No	No
Fire hazard: promotes ignition directly	No	No
Fire hazard: liquefies oxygen and promotes ignition	No	No

Refill of Liquid Helium

Read This First!

- ✓ Please read this carefully and make it accessible to anybody working with the magnet system.
- ✓ A shielded superconducting NMR Magnet System can be operated easily and safely provided the correct procedures are obeyed and certain precautions observed.
- ✓ The recommendations in this section cannot cover every eventuality and if any doubt arises during the operation of the system, the user is strongly advised to contact the supplier.

General Rules When Handling Liquid Helium
Be aware of these general rules including, but not limited to:

- Liquid helium is the coldest of all cryogenic liquids.
- Liquid helium will condense and solidify any other gas (air) coming into contact with it.
- Liquid helium must be kept in specially designed storage or transport Dewars.
- Dewars should have a one way valve fitted on the helium neck at all times, in order to avoid air entering the neck and plugging it with ice.
- Only vacuum insulated pipes should be used for liquid helium transfer. Breakdown of the insulation may give rise to the condensation of oxygen.

The Helium Vessel
The superconducting NMR magnets contain an inner vessel with liquid helium.

- The helium vessel should be checked weekly for boil-off and helium level.
- Use a helium flow meter or a helium gas counter!
- A one way valve is supplied to be mounted on the helium manifold to ensure that the helium neck tubes cannot be locked by the ingress of air or moisture. This valve should be mounted at all times except during a helium transfer.

Refill of Liquid Helium
Please follow the following instructions concerning the refill of NMR magnets with liquid helium:

- Refill the helium vessel within the specified hold time period and certainly before the level falls below the allowed ***minimum*** level listed in the magnet manual.

Important Note: Transfer of liquid helium can be done easily and safely, provided:

- ➢ The handling of the helium transfer line is correct,
- ➢ The helium transfer line is not damaged, and
- ➢ The transfer pressure does not exceed 2 psi.

Never insert a warm helium transfer line into the cryostat, since the warm helium gas could lead to a quench of the magnet!
Always allow the helium transfer line to cool down to helium temperature before inserting it into the right helium neck tube. You should see liquid helium leaving of the short end transfer lines for a few moments, before inserting it into the right helium neck tube.
Rapid Helium Transfer
Do not remove the nitrogen security flow system during any transfer liquid helium!
During a rapid transfer of liquid helium, super cooling of the liquid nitrogen occurs. This can lead to the following:

- Decrease of static boil off to zero, and producing a negative pressure in the nitrogen vessel
- Transfer of air or moisture that can be sucked into the necks of the vessel, and which would solidify and create ice blockages.

Refill of Liquid Nitrogen

Read This First!

Please read this carefully and make it accessible to anybody working with the magnet system.

- ✓ A shielded superconducting NMR Magnet System can be operated easily and safely provided the correct procedures are obeyed and certain precautions observed.
- ✓ The recommendations in this section cannot cover every eventuality and if any doubt arises during the operation of the system, the user is strongly advised to contact the supplier.

Condensing Oxygen

Minimize contact with air. Be aware of the following facts and precautions, contact with air occurs:

- Since liquid nitrogen is colder than liquid oxygen, the oxygen in the air will condense out.
- If this happens for a period of time, the oxygen concentration in the liquid nitrogen may become so high that it becomes as dangerous as handling liquid oxygen. This applies particularly to wide necked Dewars due to the large surface area.
- Therefore, ensure that contact with air is kept to a minimum.

Nitrogen Flow System

A pressure relief valve is provided for the nitrogen vessel to ensure that at least the rear neck tube cannot be blocked by the ingress of air or moisture. ***This valve shall be mounted at all times even when the vessel is being refilled.***

Refill of Liquid Nitrogen

Other general rules include, but are not limited to:

- Do not allow liquid nitrogen to spill onto the room temperature bore closure flanges when the refilling the nitrogen vessel
- Place gum rubber tubes or Teflon® tubes on the nitrogen neck tubes during refill!
- ***Stop the transfer immediately when the vessel is full.*** Failure to observe this can lead to the freezing of the O-rings and a subsequent vacuum loss of the magnet cryostat.

Ventilation

General Safety Rules Concerning Ventilation

General safety rules concerning ventilation include, but are not limited to:

- Cryogenic liquids, even when kept in insulated storage Dewars, remain at a constant temperature by their respective boiling points and will gradually evaporate. These Dewars must always be allowed to vent or dangerous pressure buildup will occur.
- Cryogenic liquids must be handled and stored in well ventilated areas.
- The very large increase in volume accompanying the vaporization of the liquid into gas and the subsequent process of warming up is approximately 740:1 for helium and 680:1 for nitrogen.

Ventilation During Normal Operation

Superconducting magnets use liquid nitrogen and liquid helium as cooling agents, and a boil-off of liquid cryogens is expected during the normal operation of the magnet system, as follows:

- Normal boil-off of liquids contained in the magnet based on the given boil-off specifications
- Boil-off of cryogens during the regular refills with liquid nitrogen and liquid helium.

The gases are nontoxic and completely harmless as long as adequate ventilation is provided to avoid suffocation. Rules for ventilation during normal operation include but are not limited to:

- The NMR magnet system should never be in an airtight room. The magnet location should be selected such that the door and the ventilation can be easily reached from all places in the room.
- Room layout, ceiling clearance and magnet height should be such that an easy transfer of liquid nitrogen and helium is possible. This will considerably reduce the risk of accidents.

Emergency Ventilation During a Quench and During Magnet Installation

A separate emergency ventilation system should be provided to prevent oxygen depletion in case of a quench or during the magnet installation. During a quench, an extremely large quantity of helium gas (i.e. 1,500 to 21,000 ft^3 depending on the magnet type) are produced within a short time.

During the installation and cooling of superconducting magnets, under certain conditions, large volumes of nitrogen or helium gases may be generated.

Emergency Exhaust

There are various types of emergency exhaust that can be implemented to avoid oxygen depletion during a quench or during the installation of the magnet system. These include, but are not limited to:

Active exhaust: This solution is based on a motorized fan, vents, and exhaust duct pipe that is not connected to the magnet itself. The exhaust should be activated both automatically by an O2 sensor, as well as manually by a switch in the room. The latter is needed during magnet installation and regular refills to prevent cryogen build-up in the room by evacuating them faster than the regular HVAC system.

Passive exhaust: This solution is based on louvers in the ceiling that open by the gas due to the overpressure of helium gas during a quench.

- **Quench pipe**: This solution is based on a pipe connected directly to the magnet, which is then routed to the outside of the building. It is important to note the following:
- Ideally, the helium exhaust from the magnet should be vented directly to the outside of the building in case a quench occurs.
- The ducting to the outside of the building should be of large enough diameter to avoid excessive pressure build up due to the flow impedance of the duct.
- The location of the exit end of the exhaust duct must not allow unrestricted access to anyone other than service personnel; in addition the exit opening should be protected from the ingress of rain, snow or any debris which could block the system.
- It is also essential to ensure that any gas which vents from the exhaust duct cannot be drawn in to any air conditioning or ventilation system intakes. The location of the duct's exit should be carefully sited to prevent this from happening in all atmospheric conditions and winds.
- Insulation of accessible exhaust piping should also be provided to prevent cold burns during a quench.

Exhaust for magnet pits: Special attention to ventilation and emergency exhaust must be given when magnets are placed inside pits. Magnet pits are confined spaces with a possibility of increased risk of oxygen depletion if appropriate exhaust measures are not taken.

- Nitrogen is heavier than the air and starts filling the pit from the bottom during the magnet pre-cool or regular nitrogen fills
- It is essential to provide a low exhaust system down inside the pit to efficiently evacuate the nitrogen gas and prevent oxygen depletion

Oxygen Monitor and Level Sensors

An oxygen monitor is required inside the magnet room. The following sensors should be provided:

Above the magnet: One oxygen level sensor above the magnet, to detect low oxygen level

Close to floor: One oxygen level sensor 1ft off the floor of the magnet room

Down in the pit: One additional oxygen level sensor 1ft off the bottom of the pit, in case the magnet is located inside a pit.

SCREENING FORM: Large Magnetic Sources

Please check if you have any of the following items:

Cardiac pacemaker or defibrillator
Aneurysm clips
Intercranial bypass graft clips
Neurostimulator (TENS Unit) or insulin pump
Vascular clip or intravascular filter, coil or stent, swan ganz
Artificial heart valves
Pacing wires
Any metallic body such as shrapnel, gunshot wound, BB pellet
Any ear implants/Hearing aids
Any eye implants
Tattoo eyeliner
Any orthopedic items (i.e. pins, rods, screws, nails, wires, or plates)
Any surgical clips, wire sutures, or surgical staples
(*some implants are okay, such as tantalum mesh plates and gold or amalgam tooth fillings*)
Prosthesis or artificial limb or joint replacement
Dentures
Nitroglycerin or Nicotine patches
Penile Implant or IUD or diaphragm
Have you ever in your lifetime been a metal worker, grinder, welder, machinist, etc. as a hobby or profession?
Do you have any pieces of metal in your eyes?

SIGNATURE **DATE**

ELF (EXTREMELY LOW FREQUENCY)

STATIC ELECTRIC FIELDS AND SUB-RADIOFREQUENCIES (Below 30 kHz)

Electric Fields

Electric fields are created when there is a difference in voltage. The stronger the voltage difference, the stronger the electric field. The strength of an electric field is measured in volts per meter (V/m) and there is an electric field present even when no current flows. Electric fields around a wire or appliance will disappear when the appliance is unplugged or switched off at the wall. An electric field will still exist, however, around the cable behind the wall.

When there is a current of electricity magnetic fields are then created. The difference between the electric component and magnetic component of an EM field (EMF) can be summarized in the following chart (from WHO):

Electric Fields	Magnetic Fields
1. Electric fields arise from voltage. 2. Their strength is measured in volts per meter (V/m). 3. An electric field can be present even when a device is switched off. 4. Field strength decreases with distance. 5. Most building materials shield electric fields to some extent.	1. Magnetic fields arise from current flows. 2. Their strength is measured in amperes per meter (A/m). Commonly, EMF investigators use a related measure, flux density in microtesla (μT) or millitesla (mT) instead. 3. Magnetic fields exist as soon as a device is switched on and current flows. 4. Field strength decreases with distance from the source. 5. Magnetic fields are not attenuated by most materials.

AC and DC Electric Fields

A static electric field does not vary over time. Direct Current (DC) is an electric current flowing in one direction and due to the current flow a magnetic field is produced. Any battery-powered device is an example of DC.

Time-varying electromagnetic fields are produced by AC (Alternating Current). Such currents reverse their direction at regular time intervals. Appliances that use electricity which is at a frequency of 60 Hz (60 cycles per second) will have an electromagnetic field that will change its orientation 60 times every second. Such AC currents produce fields that are in the range of **ELF** (Extremely Low Frequency).

The sub-radiofrequencies discussed in this section can be arranged in context to other, more energetic, frequencies. Those frequencies which are designated as radiofrequency or as microwaves are covered in the next section.

Sub-radiofrequencies

FREQUENCY RANGE	WAVELENGTH	NAME
< 30 Hz	----	Sub-ELF
30 – 300 Hz	≥ 1000 km	Extremely Low Frequency (ELF)
300 Hz – 3 kHz	1000 km – 100 km	Voice Frequency
3 kHz – 30 kHz	100 km – 10 km	Very Low Frequency (VLF)

Radiofrequencies

FREQUENCY RANGE	WAVELENGTH	NAME
30 kHz – 300 kHz	10 km – 1 km	Low Frequency (LF)
300 kHz – 3 MHz	1 km – 100 m	Medium Frequency (MF)
3 MHz – 30 MHz	100 m – 10 m	High Frequency (HF)
30 MHZ – 300 MHz	10 m – 1 m	Very High Frequency (VHF)

Microwaves

FREQUENCY RANGE	WAVELENGTH	NAME
300 MHz – 3 GHz	1 m – 10 cm	Ultra High Frequency (UHF)
>3 GHz – 30 GHz	10 cm – 1 cm	Super High Frequency (SHF)
30 GHz – 300 GHz	10 mm – 1 mm	Extremely High Frequency (EHF)

Infrared

FREQUENCY RANGE	WAVELENGTH	NAME
> 300 GHz	< 1 mm	Infrared

Applications

There are many natural and artificial sources of electromagnetic fields:

Natural sources
In the atmosphere, when there is a build-up of electric charges due to the action of thunderstorms, electric fields are produced.

Artificial sources
An electrical device, such as a motor, will produce static electric fields as well as magnetic fields (when there is current).

Hazards

When electric fields act on conductive materials (such as the human body) they can affect the distribution of electric charges at the surface of that material and cause electric current to flow through the body and into the ground.

So the predominant concern with electric fields is the potential for electrical shock, especially from high voltages.

In recent years there has been additional concern about the effects of low levels of electromagnetic radiation. In response, the World Health Organization (WHO) has undertaken a long-term project to examine any hazards at such levels. The ongoing project is known as the International EMF Project. Since 1996 its purpose has been to bring together current scientific knowledge from a large number of international sources.

"After analyzing over 25,000 scientific articles WHO has so far concluded that the evidence does not support any concerns about health effects from low level electromagnetic fields":

Effects on general health
Reported symptoms have included headaches, anxiety, nausea, fatigue, and loss of libido. There is no evidence to date that exposure to low level electromagnetic fields produces these symptoms.

Effects on pregnancy outcome
WHO and other organizations concluded that there is no increased risk of spontaneous abortion, malformation, low birth weight, or congenital disease.

Cataracts
WHO concluded that there is no evidence to support the production of cataracts in the general public after exposure to low levels of EMF.

Cancer
The studies to date are very inconsistent. No large increases in risk have been found for any cancer in children or adults.

Hypersensitivity and Depression
There is no real evidence to support some claims of electromagnetic hypersensitivity, manifesting itself as headaches, depression, lethargy and sleeping disorders.

The studies continue, however, especially with regard to long-term cell phone use. So far, the absence of health effects could mean that there genuinely are none, or it could indicate that small effects are undetectable with present methods.

Safety Standards
The standards reflect the major concern which is for high voltages of electromagnetic fields. **The ACGIH** (American Conference of Governmental Industrial Hygienists) has set Threshold Limit Values (TLVs®) to be used as guides in controlling exposure.

60 Hz electric fields: Individuals with **pacemakers** should be kept out of areas where the electric field exceeds 1 kV/m (determined by either measurement or calculation).

0 Hz (DC) – 100 Hz: Occupational exposures should not exceed a field strength of **25 kV/m**.

100 Hz – 4 kHz: A ceiling value for exposure is determined by the following formula:

$$TL = \frac{2.5 \times 10^6}{f}$$

where **f** is the frequency in Hz, and E_{TL} is the electric field strength in volts per meter (V/m).

4 kHz – 30 kHz: The ceiling value is **625 V/m**.
"*All ceiling values are intended for both partial and whole-body exposures*".

As a comparison, some of the following appliances and their electric field strengths are listed:

Electric Appliance (50 Hz)	Electric Field Strength (V/m) (at 30 cm)	Electric Appliance (50 Hz)	Electric Field Strength (V/m) (at 30 cm)
Stereo receiver	180	Hair dryer	80
Iron	120	Color TV	60
Refrigerator	120	Coffee maker	60
Mixer	100	Vacuum cleaner	50
Toaster	80	Electric oven	8
Light bulb	5		

Responsibilities

Health & Safety

- Will assist supervisors and personnel in evaluating hazards from sub-radio-frequencyradiation emitting equipment.
- Will provide measurements of exposure in order to determine hazard levels or possible interference with other equipment.
- Will provide guidance on controlling exposures or interference.

Department

- Will ensure that supervisors provide appropriate protective equipment to personnel.

Supervisor

- Will be informed about all hazards pertaining to equipment that are electrical or emit sub-radio-frequencies.
- Will ensure that personnel are trained and that they comply with all safety requirements.
- Will ensure that all appropriate signage is posted.
- Will contact Radiation Safety if hazards are unclear.

Personnel

- Will comply with all safety controls associated with their work.
- Will complete all training that is required for their job.
- Will take all of their concerns about electric fields or radio-frequencies either to the supervisor or contact Radiation Safety.

Microwave/RF Frequency

A more detailed designation of RF and MW radiation is described below, using the band designations of navigation, radio and broadcasting:

Radiofrequencies

FREQUENCY RANGE	WAVELENGTH	NAME
30 kHz – 300 kHz	10 km – 1 km	Low Frequency (LF)
300 kHz – 3 MHz	1 km – 100 m	Medium Frequency (MF)
3 MHz – 30 MHz	100 m – 10 m	High Frequency (HF)
30 MHZ – 300 MHz	10 m – 1 m	Very High Frequency (VHF)

Microwaves

FREQUENCY RANGE	WAVELENGTH	NAME
300 MHz – 3 GHz	1 m – 10 cm	Ultra High Frequency (UHF)
>3 GHz – 30 GHz	10 cm – 1 cm	Super High Frequency (SHF)
30 GHz – 300 GHz	10 mm – 1 mm	Extremely High Frequency (EHF)

Applications

There are many sources of RF radiation:

- ✓ **High power sources such as amplifiers, high-frequency electrical transformers, etc.**
- ✓ **Radio and TV transmitters**
- ✓ **Tracking and acquisition radar (including air traffic control radar, weather radar)**
- ✓ **Traffic radar**
- ✓ **Some waveguides and coaxial cables**
- ✓ **Microwave relay systems (telephone communications)**
- ✓ **Microwave ovens**
- ✓ **Induction heating systems (forging, annealing, tempering, brazing, soldering)**
- ✓ **Dielectric heating systems**
- ✓ **There are also many medical applications of RF energy. A medical technique called diathermy uses the ability of RF to rapidly heat tissues that are below the body's surface. Such heating can be therapeutic to injured tissue.**

Hazards

There is much in the scientific literature concerning the "biological effects" of RF. But as mentioned a biological effect does not necessarily suggest a biological "hazard" (when health is affected).

Radio-frequency energy can produce heat in body tissue, resulting in skin burns, internal burns, and damage to organs, especially the eye and gonads. The degree of damage is contingent on the source power level, the frequency and wavelength of the source, and the distance and shielding from the source.

Power densities on the order of 100 mW/cm^2 can result in the heating of biological tissue and an increase in body temperature. If the body cannot dissipate the excessive heat generated, then there could be tissue damage.

The eyes and the testes are particularly vulnerable to heating by RF because blood circulation in these parts of the body is low and heat, therefore, is not dissipated easily. Studies have concluded that the environmental levels of RF encountered by the general public are *far below* the levels that can produce significant heating of tissue. In the workplace, however, there may be RF emitting sources that could require safety restrictions.

The frequency of the RF is important in determining how much energy is absorbed by tissue and, therefore, is reflective of RF's potential for harm. The measure of tissue absorption is the SAR (Specific Absorption Rate) and is expressed in watts per kilogram (W/kg) or milliwatts per gram (mW/g).

In the far field: the whole-body absorption of RF by a standing human adult has been determined to occur at a maximum rate when the RF frequency is between 80 and 100 MHz. This means that more restrictive limits are imposed on exposures in the Very High Frequency (VHF) range.

At low levels of RF exposure, when significant heat increase does not occur, the evidence for biological effect is very ambiguous. Such effects are sometimes referred to as "non-thermal," which refers to certain changes in immune response, neurological effects, behavioral effects, and DNA changes (the induction of cancer, etc.). But again, **the studies are highly inconclusive** and the ones that have shown effects have not, so far, been independently reproduced.

Safety Standards

Maximum Permissible Exposure (MPE)

There are several regulating organizations that have set exposure limits (MPEs) and guidelines for RF radiation, such as ACGIH, ANSI/IEEE, NCRP, FCC, EPA, FDA, NIOSH and OSHA. Most RF safety limits are described in terms of electric and magnetic field strengths as well as in terms of power density.

At lower frequencies the limits are better expressed as electric and magnetic field strength values.

For transmitters operating at 300 kHz – 100 GHz exposure is described as power density.

Limits for Occupational/Controlled Exposure (MPEs)
Radiofrequency and Microwave TLVs®

Electromagnetic Fields (f = frequency in MHz)				
Frequency	**Power Density, S (mW/cm2)**	**Electric Field Strength, E (V/m)**	**Magnetic Field Strength, H (A/m)**	**Average Time E^2, H^2, or S**
30 kHz –100 kHz		614	163	6
100 kHz – 3 MHz		614	16.3/f	6
3 MHz – 30 MHz		1842/f	16.3/f	6
30 MHz – 100 MHz		61.4	16.3/f	6
100 MHz – 300 MHz	1	61.4	0.163	6
300 MHz – 3 GHz	f/300			6
3 GHz – 15 GHz	10			6
15 GHz – 300 GHz	10			616,000/f1.2

The MPE limits are time-averaged. It is possible to exceed the MPE for short periods as long as the average exposure over an appropriate period (6 minutes) does not exceed the MPE. This type of situation usually only occurs in the workplace. ***For localized partial-body exposures (such as w ith cell phones) the FCC expresses limits in SAR.***

Maximum Current (mA)

Some organizations such as ACGIH incorporate limits for currents induced in the human body by RF.

Specific Absorption Rate (SAR)	
Occupational/Controlled Exposure	General/Uncontrolled Exposure
(100 kHz – 6 GHz)	(100 kHz – GHz)
< 0.4 W/kg whole-body	< 0.08 W/kg whole-body
≤ 8 W/kg partial-body	≤ 1.6 W/kg partial-body

Induced and Contact Radiofrequency Currents Maximum Current (mA)				
Frequency	**Through Both Feet**	**Through Either Foot**	**Contact**	**Averaging Time**
30 kHz – 100 kHz	2000 f	1000 f	1000 f	1 second
100 kHz – 100 MHz	200	100	100	6 minutes

Responsibilities

Health & Safety (H & S)

When requested Health & Safety staff will measure RF field strengths in areas where there may be potential problems, as well as advise personnel as to exposure limits and methods that will reduce exposure.

Department

Will ensure that supervisors have provided appropriate protective measures pertaining to RF systems used.

Supervisor

Will make sure that all RF-emitting equipment properly located, shielded, & has appropriate interlock systems.
Will provide all personnel with information on RF equipment techniques and safety measures.
Will ensure that only qualified personnel will operate potentially hazardous RF systems.
Will abide by all safety requirements while operating RF systems.
Will take RF safety concerns to the supervisor or contact Radiation Safety.

Radio Waves & Health " In-Building Solutions"

In-Building Mobile Solutions

In Building Mobile solutions and technologies for high-quality mobile communications in indoor environments, such as offices, shopping malls, hospitals and airports. Sometimes people ask questions about the safety of these in-building radio communication systems. The aim of this guide is to answer these questions and to provide facts and information that is easy to understand.

Exposure to radio waves

In all mobile communication systems, the terminals communicate with fixed base stations by exchanging low-power radio signals. These radio signals, or radio waves, are radio frequency (**RF**) electromagnetic fields (**EMF**) of the same type as those used for television and radio broadcasting.
Mobile communications use radio waves in the frequency range between **400** and **2500** MHz.
A well-known property of all radio waves is that part of the carried energy may be absorbed in and exposed by. To ensure that such RF energy absorption is kept far below the level where potentially adverse heating effects might occur, national and international health authorities have specified exposure limits. The radio wave exposure from mobile communications equipment is below these limits.

Science and Research:

Radio waves have been used for more than one hundred years in different kinds of applications, including wireless communications. The increasing use of radio triggered the interest to investigate whether radio waves can cause adverse health effects. Over the past sixty years numerous studies have been conducted. Based on this research, limits for human exposure to RF fields have been set by scientific organizations. The World Health Organization (**WHO**) and several national and international expert groups have reviewed the research on radio waves, mobile telephony and health. The overall conclusion of these reviews has consistently been that **RF** fields from mobile phones and base stations have not been shown to cause any adverse health effects.

“None of the recent reviews have concluded that exposure to the RF fields from mobile phones or their base stations causes any adverse health consequence.” WHO fact sheet 193, June 2000 (1)

Communications Safety

However, WHO and others still recommend additional research concerning RF exposure and health to further improve the basis for health risk assessment. At present, several ongoing research projects comply with the WHO recommendations.

Guidelines and limits

The most widely adopted RF exposure guidelines are those developed by the International Commission on Non-Ionizing Radiation Protection (**ICNIRP**).

These are endorsed by the World Health Organization (**WHO**) and have been adopted in the European Council Recommendation, 1999/519/EC [2]–[3].

S*pecific* ***A****bsorption* ***R****ate* (**SAR**) is the quantity used to specify basic restrictions for both general public and occupational exposure in the frequency range between **10** MHz and **10** GHz.

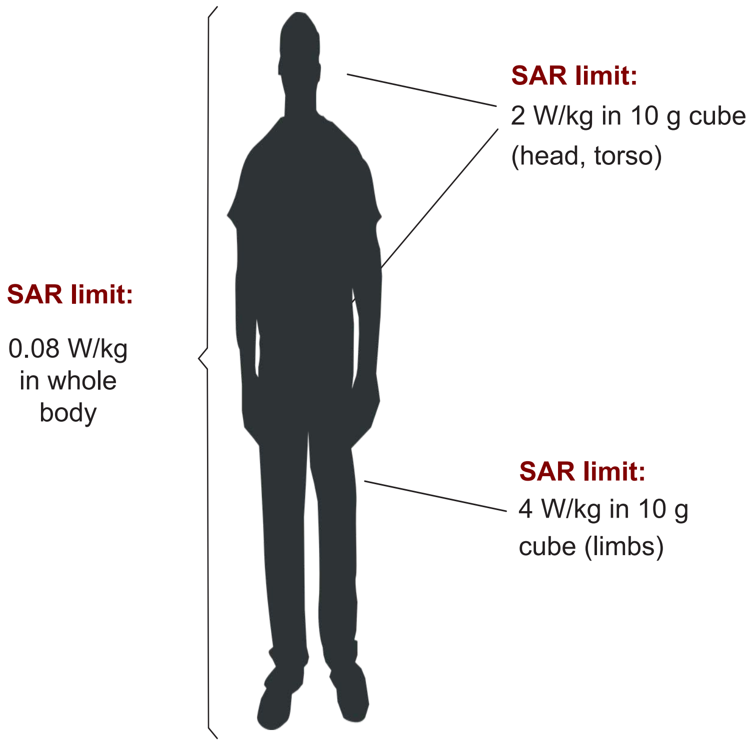
SAR is a measure of the rate of RF energy absorption in the body expressed in units of watts per kilogram (**W/kg**).

ICNIRP guidelines specify both whole-body and localized SAR values (***averaged in any 10 g of tissue***). The values specified in the figure below are valid for exposure of the general **public**.

For **occupational exposure**, the allowed values are **five times** higher.

The SAR values are to be averaged over any **six-minute** period of exposure. This reflects the fact that it takes some time for the body temperature to rise when exposed to RF fields.

Radio transmitters with maximum output power levels of less than **20** mW, such as low-power **Bluetooth** devices, cannot in any situation cause RF exposure levels that exceed the basic restrictions. Because SAR is normally difficult to determine, reference levels expressed in terms of power density (**W/m2**) – and the corresponding electric field strength (**V/m**) and magnetic field strength (**A/m**) values – have been developed for Radio transmitters with maximum output power levels less than **20** mW cannot in any situation cause RF exposure levels that exceed the **ICNIRP** restrictions.



comparison with exposure quantities in air. The reference levels, which are frequency dependent, have been chosen to ensure that the basic SAR restrictions cannot be exceeded in any exposure situation.

This means that additional safety margins have been introduced.

The reference levels are primarily applicable in the far field from a radio transmitter.
For partial-body near-field exposures, the reference levels are very conservative. In fact, the reference levels may be exceeded in near-field exposure situations, even though the exposure is in compliance with the basic restrictions.

ICNIRP reference levels for general public exposure. The corresponding power density reference levels for occupational exposure are five times higher.

Electromagnetic interference

A wide variety of wireless applications uses radio waves of different frequencies, output power levels and modulation schemes.

Electromagnetic fields from these applications can interfere with the functions of other electronic devices.

The three most important **factors** affecting the risk of electromagnetic interference are the transmitted **power** level, **immunity** of the electronic device and **distance** to the transmitter.

The risk of interference increases with transmitted power and decreases with distance and improved immunity.
The radio signal's frequency and characteristics might also affect the risk of interference. Generally, equipment is more immune to high-frequency signals than to low-frequency signals and less immune to pulsed signals than continuous signals.
Digital mobile phones (for instance **GSM** and **UMTS**) automatically reduce their power when used in environments with good coverage, thereby reducing the risk of interference. The table below contains information about frequency, pulse repetition rate, and terminal output power levels for the most common mobile phone systems.

Medical devices, pacemakers and hearing aids

Telecommunication products have to meet electromagnetic compatibility (**EMC**) requirements that limit the emission outside the specified frequency range of operation. Likewise, EMC requirements for medical equipment specify immunity limits below which the product should work satisfactorily. The **I**nternational **E**lectrotechnical **C**ommission (**IEC**) issued a revised standard for medical equipment in 2001, specifying an immunity level of **3** V/m for non-life-supporting equipment. Life-supporting equipment should be able to work satisfactorily in environments with electric field strength levels of up to **10** V/m. Cardiac **pacemakers** and **hearing aids** can be susceptible to wireless equipment such as mobile phones. However, the immunity of these products has increased immensely in recent years. **Pacemakers** sense electrical signals in the **heart** and are activated when anomalies occur. It has been shown that strong electromagnetic fields can affect **pacemakers**.
At very short distances between a mobile phone and a pacemaker, there is a risk that radio signals might interfere with the operation of the **pacemaker**.
This risk is very low and no case of injury has been reported due to such interference.
Manufacturers recommend that pacemaker patients should always maintain a distance of at least **fifteen centimeters** between an activated mobile phone and the pacemaker.
Modern **hearing aids** have good immunity, and sounds from interference solely occur at very close distances to a digital mobile phone in use. Nowadays, there is virtually no risk of interference when other people use mobile phones. Interference from one's own phone can occur, however. These problems can be **avoided** by using **handsfree** equipment, which increases the distance to transmitter. **Large** hearing aids used behind the ear are usually **more** sensitive than small devices worn in the ear or ear canal.

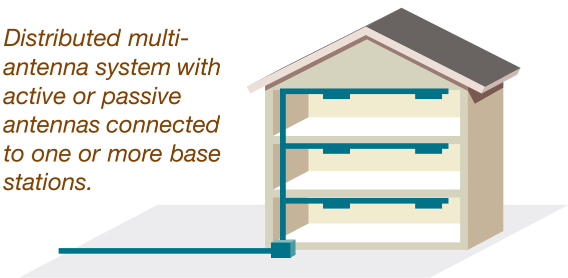
Factors affecting the risk of interference:

- Transmitted power
- Distance to source
- Immunity
- Frequency
- Signal characteristics

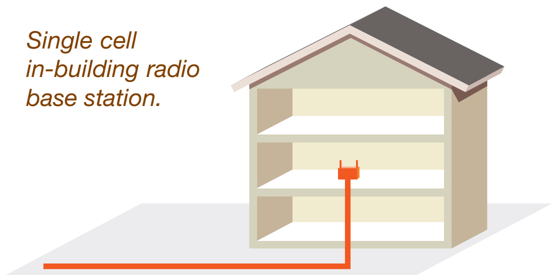
In the frequency range 80 MHz to 2.5 GHz the specified immunity levels for electric field strength are 10 V/m for life-supporting equip-ment and 3 V/m for non-life-sup-porting equipment.
(IEC 60601–1–2, 2001)

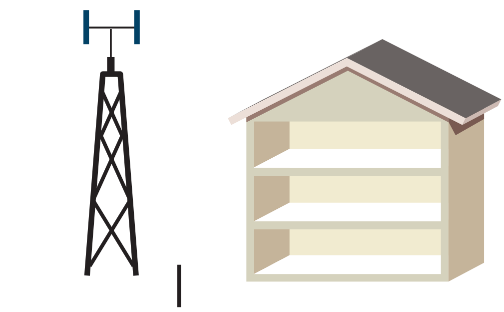
In-building systems:

Distributed multi-antenna system with active or passive antennas connected to one or more base stations.

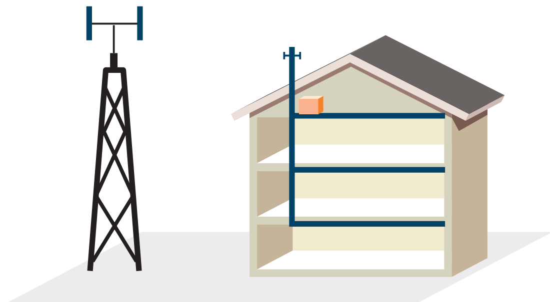


Single cell in-building radio base station.





Outdoor antennas connected to macro or micro radio base stations, installed for instance on a mast or on a nearby building.



Repeater used to provide in-building coverage from a surrounding macro cell.

There are many ways to build a mobile communications network to obtain good coverage and capacity in an indoor environment. One possibility is a dedicated in-building network with antennas placed inside the building. Another alternative is to use pico cell base stations with integrated antennas. Still other solutions are to put outdoor antennas nearby or to extend an existing network using a repeater. Each alternative has different advantages regarding covera-ge, capacity and cost. Four different approaches are shown to the left.

Radio wave exposure from antennas:

In-building systems with distributed antennas can be plan-ned in various ways. The more antennas used the lower the output power level needed for good coverage and capacity. The antennas can transmit in one (directional), two (bi-direc-tional) or all directions (omni-directional). The maximum input power for in-building antennas, and pico radio base sta-tions with integrated antennas, is usually less than 30 dBm (1 W). Another antenna solution makes use of leaky cables. This solution is mainly used in basements and culverts. The *Effective Isotropic Radiated Power* (EIRP) is typically between 0 dBm and 20 dBm (1 mW–100 mW) in a distri-buted in-building antenna system. The EIRP can be higher (up to one or a few watts) for solutions with few antennas. Usually the systems are balanced in such a way that all anten-na output power levels are more or less the same.
For distributed antenna configurations with 1 W input power, the RF exposure compliance distance for the general public is less than 10 cm. For the typical output power levels mentioned above, the basic restrictions will not be exceeded even at the surface of the antenna cover. The compliance distances for occupational exposure are even shorter than those for the general public.
Due to the very short compliance distances, these antennas do not require any special RF exposure safety instruc-tions. Installation and maintenance personnel can work close to antennas in operation without being exposed to levels exceeding the basic restrictions. Touching an antenna for short times will not lead to exposure levels that exceed the SAR limits. However, it is advisable that the antenna should be placed where it cannot be easily reached by the general public.

Directional panel antenna
Gain: 7 dBi

Bi-directional antenna
Gain: 5 dBi

Omni-directional antenna
Gain: 2 dBi

At a distance of less than 10 cm the maximum RF exposure levels of typical in-building network antennas with 1 W input power or less, are below the ICNIRP basic restrictions.

Summary

- The radio frequency exposure from typical in-building network antennas is below established safety limits at a distance of 10 centimeters.
- Mobile phones used in indoor environments transmit with highly reduced output power; therefore the risk of electromagnetic interference to sensitive electrical equipment is low.
- Due to the low output power from in-building base station antennas, the field strength level at a distance of one meter is below the immunity levels of medical and other sensitive equipment, which means that the risk of electromagnetic interference is low.

References

1 **WHO**, "Electromagnetic fields and public health: mobile telephones and their base stations", World Health Organization, Fact sheet 193, revised in June 2000. www.who.org/emf

2 **ICNIRP**, "Guidelines for limi-ting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)", International Commission on Non-Ionizing Radiation Protection (ICNIRP), *Health Physics*, vol. 74, pp 494–522, April 1998. www.icnirp.org

3 1999/519/EC, **EU** "Council Recommendation of the 12 July 1999 on the limitation of exposure to the general public to electromagnetic fields 0 Hz to 300 GHz", *Official Journal of the European Communities*, July 30, 1999. europa.eu.int/comm/health/

Additional Resources

World Health Organization (WHO) International EMF Project is pooling resources and knowledge concerning electromagnetic fields and health. www.who.org/emf

National Radiological Protection Board (NRPB) gives advice and information on radiation protection in the UK. www.nrpb.org

Questions & Answers

What about "radiation" from mobile phones and base stations?

Mobile phones and base stations use radio waves (electromagnetic fields or non-ionizing radiation) to send and receive voice, text messages, pictures and other data. Radio waves have long been used for different types of wireless communication, such as radio and TV broadcasting. Do not confuse radio waves with radioactive radiation.

Is it true that using a mobile phone causes cancer or other health effects?

Extensive research over the course of many years has not established any conclusive evidence of a link between adverse health effects and the use of mobile phones.

Will an in-building mobile communication system cause electromagnetic interference to other electronic equipment?

Due to the low output power from in-building anten-nas and mobile terminals, the risk of electromagnetic interference is low and can be avoided with proper system design.

Are there any safety limits on human exposure to radio waves?

Yes. International and national health authorities, such as WHO, have adopted science-based safety guidelines specifying radio wave exposure limits. The limits have been set with wide margins to provide protection from established adverse effects on health.

Is it all right to be close to base station antennas?

Yes. There is only a small area in front of the anten-nas where exposure can exceed the safety limits. The size of this area varies from a few centimeters for in-building antennas to a few meters for outdoor antennas. The antennas are to be installed in a way that restricts people from entering this area.

Mobile Communication System data:

Technology	Frequency (MHz)	Maximum Output Power from terminal (W)		Pulse Repetition Rate, etc.
		Peak	Average	
CDMA	800 1900	0.2 0.2	0.2 0.2	Between 50 Hz and 800 Hz (full rate)1
CDMA 2000 (3G)	2000	0.25	0.25	Between 50 Hz and 800 Hz (full rate)1
GSM	800 900 1800 1900	2 2 1 1	0.25[2] 0.25[2] 0.125[2] 0.125[2]	217 Hz, Low-frequency components, 8 Hz, 2 Hz (DTX mode)
WCDMA (3G)	2000	0.25 0.125	0.25 0.125	Continuous transmission[3]
DECT	1900	0.25	0.01	100 Hz
Bluetooth	2450	0.001[4]	0.001[4]	Frequency-hopping technology
WLAN (IEEE 802.11b)	2450	0.1[4]	0.1[4]	Frequency-hopping or direct sequence technology

1) *Additional low-frequency components might exist due to fast power regulation*

2) *Higher average output power levels are possible when using GPRS multislot transmission*

3) *Low-frequency components might exist due to fast power regulation*

4) *Other power levels are also specified*

NON-LASER LIGHT SOURCES

Infrared (IR) and Visible Light
Infrared, visible, and ultraviolet radiation are all forms of the optical spectrum.

Infrared

Most of the sources that emit ultraviolet or visible light will probably emit infrared radiation (IR). The range of wavelengths included in the IR designation is usually from **0.78** to **1000** μmeters. The IR region has been further subdivided (International Commission on Illumination, CIE) into three biological areas:

(IR-A) 0.78 – 1.4 μm Near IR **(IR-B) 1.4 – 3 μm Middle IR** **(IR-C) 3 – 1000 μ Far IR**

***Note*: "0.78 μm = 780 nm"**
Infrared radiation is also referred to as thermal radiation or radiant heat and is emitted from any warm object. Many sources of IR, however, can emit a continuum of wavelengths. Like other electromagnetic regions IR can be reflected, absorbed, transmitted, refracted and diffracted.

Visible Light

Visible radiation is referred to as light and has a radiant energy wavelength between 400 and around 780 nm, includes blue light.

Applications

SOURCES OF OPTICAL RADIATION

Sunlight

This is the most common source of occupational exposure.

Artificial sources

Incandescent, fluorescent, discharge lamps
Flames, heaters, artificial black body sources
Welding arcs
IR lasers
IR lamps
General lighting
Visible lasers

Hazards

There are essentially five types of hazards to the skin and eye from IR and intense visible light:

1. **Thermal injury** to the retina which can occur at wavelengths from 400 to 1,400 nm. Lasers are usually the source of this kind of injury or a very intense xenon-arc source, resulting in a local burning of the retina.
2. **Blue-light photochemical injury** can occur at wavelengths from 400 to 550 nm. It is also known as *solar retinitis* or *eclipse blindness*.
3. **Near-infrared thermal injury to the lens** can occur at wavelengths from 800 to 3,000 nm, resulting in cataracts, even 10-15 years after exposure. This is often called "glass blower cataract."
4. **Thermal injury of the cornea and conjunctiva** is usually limited to laser radiation (around 1,400 nm to 1 mm).
5. **Thermal injury of the skin.** This type of injury is rare but can occur within the entire optical spectrum. IR above 3,000 nm is dissipated in the epidermis. IR absorption is also determined by the amount of pigment in the skin and the amount of carotene and oxygen in the blood.

Note: IR radiation up to 20-30 kJ/m^2 per minute has a beneficiary effect, by stimulating the immune system. From 50 to 100 kJ/m^2 per minute the effect is reversed.
In addition, there can be associated hazards with arc welding such as:

- Electrical shock
- A build-up of ozone and oxides of nitrogen
- Phosgene and hydrogen chloride production

For more information about welding arc radiant hazards, please see *SECTION ON ULTRAVIOLET RADIATION HAZARDS.*

Hazard Summary

Eye Effects	Skin Effects	Wavelength nm	Sources
Retinal Burn	Skin Burn Photochemical Reaction	Visible: 400-700 Near IR: 700-1400	welding arcs lasers heat lamps
Lens: cataract	Skin Burn	Middle IR: 1400-3000	lasers/photocopier light sources flash lamps/ welding arcs
Corneal Burn	Skin Burn	Far IR: 3000-10,000	lasers

Safety Standards

EYE

Most radiation exposure limits for wavelengths in the infrared and optical range are set for lasers. The ACGIH, though, has set limits (Threshold Limit Values, TLVs) which are based on animal studies as well as from retinal injuries due to viewing the sun and welding arcs.

For a white-light source, if the luminance of the source is less than 1 candela per centimeter squared (cd/cm^2) then the TLV will not be exceeded. Spectral data of the light source would only be required if it were greater than 1 candela. From that information the TLV can be calculated by Radiation Safety.

For blue light sources such as the sun, arc welding, plasma cutting, and the arc of discharge lamps, the effective radiances are extremely high, corresponding to permissible exposure times of only 0.6-40 seconds. Viewing such sources without eye protection can be very hazardous to the retina.

For infrared sources the guidelines are different depending on the part of the eye being protected:

Cornea and lens: For wavelengths between **770 nm and 3,000 nm**, infrared exposure in hot environments should be limited for periods greater than 1,000 seconds, to 10 mW/cm^2. For exposures of less than 1,000 seconds, the limit can be calculated.

Retina: Can be calculated if given the spectral radiance and total irradiance, using the ACGIH guidelines.

SKIN

There are currently no TLVs for skin exposure.

Responsibilities

Radiation Safety
Will provide Threshold Limit Values (TLVs) to ensure that personnel remain within the limits of visible and IR exposure.

Department
Will ensure that personnel have adequate protection on the job.

Supervisor
Will perform the initial Task Hazard Analysis (THA) for jobs entailing visible light and infrared sources.

Will provide engineering and administrative controls that will protect personnel from overexposure.

Will provide protection of employees, visitors, and subcontractors from overexposure, including goggles, shields, clothing, or protective creams.

Will provide written Standard Operating Procedures (SOPs).

In the case of injury, such as welder's flash or abnormal skin reddening, will report the injury to EHS and make sure medical treatment is received.

Personnel
Will wear personal protective equipment when it is required.

Will report any job-related injuries to the supervisor.

Aphakic (lens of the eye surgically removed) individuals will identify themselves to their supervisor and be informed of any special precautions.

UV HAZARDS

Ultraviolet (UV) Light Of all the regions of non-ionizing radiation UV has the highest photon energy. UV energy levels border on the highest visible range (blue light) as well as on the softest ionizing region of x-rays.

UV light includes wavelengths between approximately 400 nm and 100 nm. Around 100 nm the photon energy is equivalent to 12.4 eV, that is, the energy level that can produce ionization.
Within the UV region there are sub-regions of different wavelengths, which can result in distinctly different biological effects.

Wavelengths shorter than 180 nm are essentially absorbed by the atmosphere. The UV regions are usually designated has having the following wavelengths:

Region	Also known as	Wavelengths in nm	Hazard	Damage Mechanism
UV-A	near UV	315-400	lowest	cataracts
UV-B	mid UV	280-315	mid to high	skin or eye burns
UV-C	far UV	100-280	highest	skin or eye burns

- The UV-A is the so-called “black light” region, where fluorescence can be induced.
- UV-B is the skin erythemal region, which is the most harmful UV emitted from the sun.
- The UV-C region is essentially “germicidal” and can be produced by germicidal lamps, etc.
- Wavelengths between 180 and 315 nm (all of UV-B and part of UV-C) are known as “actinic and keratitic” because they produce biological effects on the skin.
- Wavelengths between 10 and 100 nm are known as the ionizing region of UV, but is absorbed the atmosphere.

Applications

In addition to the sun which is the most common source of UV, there are many artificial light sources. Some of these sources have inherent shielding. Others do not, so operators must use safeguards such as shielding and other protective equipment. Examples of UV sources that may exist on campus are:

Incandescent
Tungsten halogen lamps

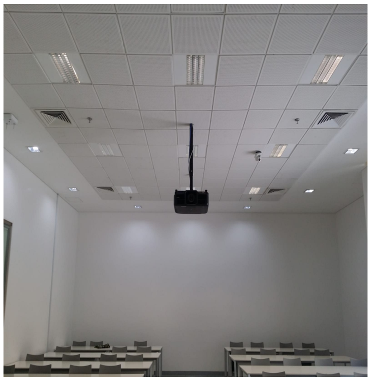
Electric discharges
Welding arcs
Carbon arcs

Fluorescent lamps

Biological safety cabinet lamps
Germicidal lamps
Transilluminators
Mineralights used to fluoresce geological samples
UV lamps for document examination (libraries)
Sunlamps (UV-B emitters)

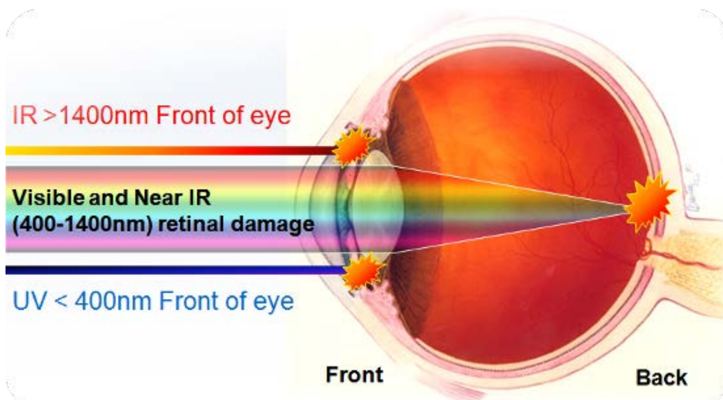
Gas discharges
Mercury lamps (low, medium, and high-pressure)
Mercury lamps with metal halides
Xenon lamps
Hydrogen and deuterium lamps
Flash tubes

Lasers
Excimer lasers (several wavelengths)
Nitrogen lasers (337 nm)
Tunable UV lasers
Helium-cadmium lasers (325 nm)



Germicidal UV Lamp

Hazards



The human eye and effects of light sources

Although the photochemical reactions of UV can be beneficial, such as being a major component in the production of vitamin D3, with large doses it can have acute destructive effects.

The critical organs for UV exposure are the eye and the skin, the most potent UV absorbers being proteins and nucleic acids. One photochemical reaction that is biologically important is ***the breakage of DNA strands***.

There are two main types of effects when referring to UV exposure: ***non-stochastic*** and ***stochastic*** effects. The non-stochastic effects are directly related to the radiant exposure and the effects may be either acute or late. The stochastic effects, however, pertain to the contribution of UV exposure to the increased risk in developing certain diseases.

There is a latent post-irradiation period before clinical symptoms appear, usually 4 –8 hrs. For mild exposures, a recovery should occur within 24 –28 hrs.

EYE

Wavelength < 320 nm (Far and Mid-UV)
The areas of the eye that are most affected by this range of UV are the ***corneal epithelium*** and conjunctiva (and somewhat the lens). The cornea is most sensitive to UV at 270 nm. The mechanism of damage tends to be photochemical, as opposed to thermal.

Over-exposure in this range can produce inflammation of the cornea, known as ***photokeratitis***. The symptoms include conjunctivitis, erythema of the face and eyelids, a sensation of “sand” in the eyes, photophobia, lacrimation, and blepharospasm (twitching of the eyelid). Usually the symptoms last 1 – 5 days, with no residual lesions.

The peak sensitivity of the cornea is considered to be 270 nm or 288 nm. The threshold at 270 nm for photokeratitis is 5 mJ/cm^2. Damage seems to be dependent on the total energy absorbed rather than the *rate* of energy absorption.

Wavelength > 320 nm (Near-UV)

A glucoside in the lens absorbs strongly below 368 nm, which results in protein denaturing in the lens, browning, and may eventually produce cataracts. The damage mechanism in this range is essentially thermal.

SKIN

The most common non-stochastic effect to the skin is erythema, which increases with increased UV dose. In severe cases there is blistering. Usually there is a latent period of about 1 – 8 hrs before the erythema appears. The minimum dose that can produce erythema is called the ***minimal erythema dose (MED)***. The MED depends on the wavelength of the UV, as well as the thickness and pigmentation of the skin.

Example: For Caucasian skin on the trunk, not recently exposed, the MED is about 200 J/m^2 for wavelengths between 250 and 300 nm. At longer wavelengths, such as between 330 and 400 nm, the MED is 2×10^5 J/m^2, considerably higher.

LATE EFFECTS

EYE

Non-stochastic effect:
cataracts.

Stochastic effects:
There is no direct evidence of tumors in the anterior chamber of the eye, though tumors have been induced in experimental animals using UV light. When melanoma of the eye does occur, it is most often in blue-eyed individuals.

SKIN

Non-stochastic effects :
After prolonged exposure the dermis can degenerate, resulting in premature aging. The epidermis can also develop **actinic keratosis**.

Stochastic effect:
Skin cancer is the most common effect and depends on the number of doses in addition to the duration of the exposure. UV irradiation with a wavelength below 320 nm seems to be more active in inducing tumors. Dark-pigmented skin, however, is less susceptible to carcinogenic.

WELDING ARC RADIANT HAZARDS

Welding operations can involve exposure to UV, blue light, and ozone. The following are types of welding that emit non-ionizing radiation:

SMAW (Shield Metal Arc Welding), also known as "stick" or "electrode" welding.

GTAW (Gas Tungsten Arc Welding), also known as "tungsten inert gas" (TIG) welding.

GMAW (Gas Metal Arc Welding), also known as manual inert gas (MIG) welding.

UV emission in the above types of welding increases with increased current

OZONE generation occurs during atmospheric interaction with UV-C. Ozone is a deep lung irritant and is formed during the above types of welding, with the exception of SMAW, where it is minimal. The amount of ozone generated is related to the type of metal used, as well as the type of shield gas.

Safety Standards

Exposure limits for UV radiation have been developed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the American Conference of Governmental Industrial Hygienists (ACGIH). These limits are based on thresholds below which acute effects would not be expected in a normal, light-skinned adult. These limits also assume that the threshold is not lower for chronic effects, such as cancer.

The University enforces the ACGIH's Threshold Limit Values (TLVs®) for occupational exposures to the skin or the eye. UV radiant exposure should not exceed the times listed in the table below in an 8 hr-period. The exposure time (t_{max}) is computed by dividing 0.003 J/cm^2 by the effective irradiance (E_{eff}), which is measured with instrumentation. E_{eff} is in watts per square centimeter.

$$T_{max} = \frac{0.003\ J/cm^2}{E_{eff}\ (W/cm^2)}$$

T_{max} = maximum exposure time in seconds.

E_{eff} = the effective irradiance relative to a monochromatic source at 270 nm in W/cm^2.
Note: 1 W = 1 J/

Exposure Duration	
Duration of Exposure Per Day	**Effective Irradiance (μW/cm^2)**
8 hours	0.1
4 hours	0.2
2 hours	0.4
1 hour	0.8
30 mins	1.7
15 mins	3.3
10 mins	5
5 mins	10
1 min	50
30 secs	100
10 secs	300
1 sec	3000
0.5 sec	6000
0.1 sec	30,000

In order to control the risk of injury in the workplace it is important that certain protective measures be maintained:

- **Engineering controls** could include providing sun cover for outdoor workers. For other UV light sources, blocking filters or barriers should be used when relevant.

- **Administrative controls** usually involve the posting of warning signs as well as coordinating safety training.

- **Personal Protective Equipment (PPE)** should be provided for individuals working outdoors or with UV light sources. For outdoor work a sunscreen with a minimum SPF of 15 should be available. Sunglasses should be close fitting and of a wrap-round design. Arc welders in particular should have purpose-specific protective equipment.

- **Training** should be available to all individuals who will be exposed to medium to high levels of UV radiation.

Responsibilities

Health & Safety
Health & Safety will provide training when requested by the Department, supervisor, or individual.

Radiation Safety can also monitor an area for any UV hazards on request, as well as investigate overexposures and provide recommendations for personal protection.

Health & Safety will provide signs and stickers for UV sources and maintain an inventory of UV equipment on campus.

Department
The Department will notify Health & Safety when new UV sources are obtained, sold or sent to Surplus Property. The Department will also ensure that personnel have the appropriate protective equipment, such as goggles, face shields and gloves.

Supervisor
The supervisor will ensure that personnel are trained and that they wear the appropriate UV personal protection. Training should include:

- Effects of UV light
- Measurement units of UV light
- UV exposure limits
- Protective equipment and shielding
- Medical emergency response

The supervisor will post signs or stickers near UV sources and will report any suspected UV overexposures to Radiation Safety.

Personnel
Individual workers will attend training and wear UV personal protection, if needed.
ndividuals will observe the UV duration limits and will report suspected overexposures to the supervisor and to Radiation Safety.

UFV Light: Frequently Asked Questions (FAQ)

1. **What are the symptoms of an overexposure to UV light?**

   If your skin has been overexposed there will be reddening within two to four hours. An overexposure to the eyes will result in some pain (due to inflammation) and a sensation of "sand" in the eye.

2. **What do I do if I feel I have been overexposed to UV light?**

   If you feel or even suspect that you have had an overexposure to UV radiation, please call Radiation Safety (206.543.0463) so that possible exposures can be measured, resulting in better directed health care if needed.

3. **Am I required to register my UV light source?**

   All UV light sources are inventoried and checked annually. If you have purchased or discarded a UV source, please notify Health & Safety.

4. **Are tanning devices a hazard?**

   Yes. Tanning booths and lamps are used because they produce greater amounts of UV radiation in a shorter time than is received from the sun, but the skin can still be damaged from such exposure, as can the eyes. Eye protection MUST be worn, otherwise corneal burns, cataracts, and sometimes retinal damage can result. Sunglasses are not acceptable. The American Medical Association (AMA) in 1994 passed a resolution to ban suntan equipment for non-medical purposes. Dermatologists have urged the FDA to take action. Currently, however, the tanning industry is fairly unregulated.

   If you are using prescription drugs, check with your doctor before using a tanning booth. Many drugs can increase your reaction to UV light, such as some antibiotics, high blood pressure medication, tranquilizers, diuretics, birth control pills, and oral diabetes medications.

   Examples of photosensitizing agents: Sulfanomide, Sulfonylurea, Clorthiazides, Phenothiazines, Antibiotics (e.g. Tetracycline), Griseofulvin, Nalidixin Acid, Furocoumarins (Psoralen), Estrogens/ Progesterones, Chlordiazepoxide (Librium), Triazetyldiphenolisatin (Laxative), Cyclamates, Porphyrins (Porphyria), Retin-A (Retinoic Acid).

5. **Are black lights a hazard?**

   Since black lights are in reality UVA they are not considered to be hazardous.

6. **How do I replace the UV lamps in a biosafety cabinet or dispose of a broken one?**

   Please contact Health and Safety at 3593/3648 or eso@qu.edu.qa

Laser Light Safety Guidelines

Lasers are classified to describe the capabilities of a laser system to produce injury to personnel. This classification rates from Class I lasers (no harm) to Class IV lasers like the 2000 Watt, carbon dioxide (let's cut thick steel) laser here on campus. The manufacturer is required to label Class II, III and IV lasers with a warning label which will also have the laser's classification printed on it.

Class I lasers are low powered devices that are considered safe from all potential hazards. Some examples of Class I laser use are: laser printers, CD players, CD ROM devices, geological survey equipment and laboratory analytical equipment. No individual, regardless of exposure conditions to the eyes or skin, would be expected to be injured by a Class I laser. *No* safety requirements are needed to use Class I laser devices.

Class II lasers are low power (< 1mW), visible light lasers that could possibly cause damage to a person's eyes. Some examples of Class II laser use are: classroom demonstrations, laser pointers, aiming devices and range finding equipment. If class II laser beams are directly viewed for long periods of time (i.e. > 15 minutes) damage to the eyes could result. Avoid looking into a Class II laser beam or pointing a Class II laser beam into another person's eyes. Avoid viewing Class II laser beams with telescopic devices. Realize that the bright light of a Class II laser beam into your eyes will cause a normal reaction to look away or close your eyes. This response is expected to protect you from Class II laser damage to the eyes.

Class III-a lasers are continuous wave, intermediate power (1-5 mW) devices. Some examples of Class III-a laser uses are the same as Class II lasers with the most popular uses being laser pointers and laser scanners. Direct viewing of the Class III-a laser beam could be hazardous to the eyes. *Do not* view the Class III-a laser beam directly. *Do not* point a Class III-a laser beam into another person’s eyes. *Do not* view a Class III-a laser beam with telescopic devices; this amplifies the problem.

Class III-b lasers are intermediate power (c.w. 5-500 mW or pulsed 10 J/cm^2) devices. Some examples of Class III-b laser uses are spectrometry, stereo lithography, and entertainment light shows. Direct viewing of the Class III-b laser beam is hazardous to the eye and diffuse reflections of the beam can also be hazardous to the eye. *Do not* view the Class III-b laser beam directly. *Do not* view a Class III-b laser beam with telescopic devices; this amplifies the problem. Whenever occupying a laser controlled area, wear the proper eye protection. Refer to the University of Kentucky Laser Safety Manual for complete instructions on the safety requirements for Class III-b laser use.

Class IV lasers are high power (c.w. >500mW or pulsed >10J/cm^2) devices. Some examples of Class IV laser use are surgery, research, drilling, cutting, welding, and micromachining. The direct beam and diffuse reflections from Class IV lasers are hazardous to the eyes and skin. Class IV laser devices can also be a fire hazard depending on the reaction of the target when struck. Much greater controls are required to ensure the safe operation of this class of laser devices. Whenever occupying a laser controlled area, wear the proper eye protection. Most laser eye injuries occur from reflected beams of class IV laser light, so keep all reflective materials away from the beam. Do not place your hand or any other body part into the class IV laser beam. The pain and smell of burned flesh will let you know if this happens. Realize the dangers involved in the use of Class IV lasers and please use common sense. Refer to the University of Kentucky Laser Safety Manual for complete instructions on the safety requirements for Class IV laser use.

Be mindful of *your* well-being when using laser devices; *laser safety only works when precautions are utilized*.

Laser Classifications Infographic table

ANSI and IEC laser classification	Class 1		Class 2		Class 3		Class 4	Notes
Sub-class	**Class 1**	**Class 1M**	**Class 2**	**Class 2M**	**Class 3R**	**Class 3B**	**Class 4**	
U.S. FDA laser classification	Class I	No special FDA class	Class II	No special FDA class	Class IIIa (definition is different but results are similar)	Class IIIb	Class IV	Newer ANSI/IEC number classes are now preferred over older FDA Roman numeral classes
Human-accessible laser power (for visible light)	For visible light, emits beam less than 0.39 milliwatts, or beam of any power is inside device and is not accessible during operation.		Emits visible beam of less than 1 milliwatt.		For visible light, emits beam between 1 and 4.99 milliwatts.	For visible light, emits beam between Class 3R limit (e.g. 5 milliwatts) and 499.9 milliwatts	For visible light, emits beam of 500 milliwatts (1/2 Watt) or more	Non-visible lasers emitting infrared or ultraviolet are not included in this chart. Only visible lasers are discussed.
Caution/warning indication	No special caution/ warning indication		No special caution/ warning indication		**CAUTION**	**WARNING**	**DANGER**	
Label descriptive text		DO NOT VIEW DIRECTLY WITH OPTICAL INSTRUMENTS	DO NOT STARE INTO BEAM	DO NOT STARE INTO BEAM OR EXPOSE USERS OF TELESCOPIC OPTICS	AVOID DIRECT EYE EXPOSURE	AVOID EXPOSURE TO BEAM	AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION	For visible-light lasers, the word "light" can be used instead of "radiation". The latter is more accurate for lasers emitting infrared and ultraviolet radiation.
EYE AND SKIN HAZARDS								
Eye hazard for intraocular exposure (having a direct or reflected beam enter the eye)	Safe, even for long-term intentional viewing. For visible light, usually applies when the laser is enclosed inside a device (ex: CD or DVD player) with no human access to laser light.	Safe for unaided eye exposure. May be hazardous if viewed with optical instruments such as binoculars or eye loupe.	Safe for unintentional exposure less than 1/4 second. Do not stare into beam.	Safe for unintentional (< 1/4 sec) unaided eye exposure. May be hazardous if viewed with optical instruments such as binoculars or eye loupe.	Unintentional or accidental exposure to direct or reflected beam has a low risk. Avoid intentional exposure to direct or reflected beam.	Eye hazard; avoid exposure to direct or reflected beam.	Severe eye hazard; avoid exposure to direct or reflected beam.	
Maximum or typical Nominal Ocular Hazard Distance (for 1 milliradian beam, exposure time less than 1/4 second)	Not an eye hazard -- does not apply	Consult an LSO as described in the Technical Note below	**NOHD of 0.99 mW beam:** 23 ft (7 m)	Consult an LSO as described in the Technical Note below	**NOHD of 4.99 mW beam:** 52 ft (16 m)	**NOHD of 499.9 mW beam:** 520 ft (160 m)	**NOHD of 1000 mW (1 Watt) beam:** 733 ft (224 m). **NOHD of 10 W beam:** 2320 ft (710 m)	Avoid eye exposure to a direct or reflected laser beam, within the NOHD. The closer you are to the laser, the greater the chance of hazard and the more serious the injury potential.
Eye hazard for diffuse reflection exposure (looking at the laser "dot" scattered off a surface)	None	Consult an LSO	None	Consult an LSO	None	Generally safe. Avoid staring at the laser "dot" on a surface for many seconds at close range.	To avoid injury, do not stare at laser "dot" on a surface. The light is too bright if you see a sustained afterimage, lasting more than about 10 seconds.	
Skin burn hazard	None	Consult an LSO	None	Consult an LSO	None	Can heat skin if beam is held long enough on skin at close range	Can instantly burn skin. Avoid direct exposure to the beam.	
Materials burn hazard	None	Consult an LSO	None	Consult an LSO	None	Can burn materials if beam is held long enough on substance at close range	Can instantly burn materials. Avoid direct exposure to the beam, for materials susceptible to burning.	Dark materials which absorb heat, and lightweight materials such as paper and fabric, are most easily burned by visible laser light.
VISUAL INTERFERENCE DISTANCES								
Maximum or typical flashblindness distance (FAA 100 μW/cm^2, for 1 milliradian beam, 555 nm green light)	Not applicable; beam is usually contained inside a device such as a CD or DVD player	Consult an LSO	**For a 0.99 mW beam:** 117 ft 36 m	Consult an LSO	**For a 4.99 mW beam:** 261 ft 80 m	**For a 499 mW beam:** 2.614 ft (1/2 mile) 797 m (0.8 km)	**For a 1 Watt beam:** 3,696 ft (0.7 mile) 1,127 m (1.1 km) **For a 10 W beam:** 11,689 ft (2.2 miles) 3,563 m (3.5 km)	Value given is for 555 nm, the green wavelength that appears brightest to the light-adapted human eye. This gives the longest hazard distance. To approximate for red laser light, divide the distance by about 5; for blue, divide by 20.
Maximum or typical glare distance (FAA 5 μW/cm^2, for 1 milliradian beam, 555 nm green light)	See above	Consult an LSO	523 ft 159 m	Consult an LSO	1,169 ft 356 m	11,689 ft (2.2 miles) 3,563 m (3.5 km)	**For a 1 Watt beam:** 16,531 ft (3.1 miles) 5,039 m (5 km) **For a 10 W beam:** 52,275 ft (9.9 miles) 15,933 m (16 km)	See above
Maximum or typical distraction distance (FAA 0.05 μW/cm^2 or 50 nanowatts/cm^2, for 1 milliradian beam, 555 nm green light)	See above	Consult an LSO	5,227 ft (1 mile) 1,593 m (1.6 km)	Consult an LSO	11,689 ft (2.2 miles) 3,563 m (3.5 km)	116,890 ft (22 miles) 35,628 m (35.6 km)	**For a 1 Watt beam:** 165,307 ft (31 miles) 50,386 m (50 km) **For a 10 W beam:** 522,746 ft (99 miles) 159,333 m (160 km)	See above
Technical Notes	For a 1/4 second exposure to accessible visible-light beams, Class 1 limits are the same as Class 2, and such lasers are usually labeled as Class 2.	We are unaware of any Class 1M laser devices intended for consumer use. If you do have such a laser, consult a qualified Laser Safety Officer for more detailed analysis.	Class 2 (and 2M) only applies to visible lasers. Infrared and ultraviolet lasers cannot be Class 2 (or 2M).	We are unaware of any Class 2M laser devices intended for consumer use. If you do have such a laser, consult a qualified Laser Safety Officer for more detailed analysis.	Class 3R is either: (1) From 1 to 4.99 mW into a 7mm aperture (e.g., pupil of the eye) or (2) five times the Class 2 limit of 2.5 mW/cm^2, which works out to be 12.5 mW/cm^2. The second method is used by LaserSafetyFacts to determine NOHD.			
	Class 1	**Class 1M**	**Class 2**	**Class 2M**	**Class 3R**	**Class 3B**	**Class 4**	
	Class 1		Class 2		Class 3		Class 4	