Laser Safety

Department of PHYSICS & ASTRONOMY
THE UNIVERSITY OF UTAH

Characteristics of Lasers

- Wavelengths include ultra-violet (100-400nm), visible (400-700nm), and infrared.
- Narrow linewidth
- Collimated beam has **extremely high intensity** which diminishes only slowly with distance.

Primary Dangers of Lasers

- Damage of the retina or other eye tissue
- Damage of skin tissue (burns)
- Toxicity of chemicals (dyes, gases used in some lasers)
- Electrocution by high-voltage power supplies
- Fire

Eye injuries

- 190-315 nm: Light absorbed by cornea can cause inflammation (keratitis) and/or deformation. Keratitis usually heals in 2-4 days.
- 315-400nm (UV A): Risk of cataract formation in eye.

Eye injuries

- 400-1400 nm: Light passes through lenses of the eye and focuses on retina.
  - If eye is focused on distance, the laser intensity at the retina could be many orders of magnitude greater than inherent laser intensity.
  - Greatest danger when looking directly into beam or when looking at a specular (mirror-like) reflection of the beam.

Why can lasers burn holes in retina?

- **High intensity** despite relatively low power (due to collimation)

(power = energy/unit time ; intensity=power/unit area)

- Narrow line width (no chromatic aberration that diverges light when passing through eye's lens)
- **Invisible lasers** can enter eye unnoticed
- The lens of the eye, if focused on large distance, will focus the laser beam approximately onto the retina. That means, the intensity is even higher at the retina compared to the intensity before the eye.

Maximum Permissible Exposures (ANSI Standard) (MPE)

- Green Laser approx. 3 μW*0.25s (time to close eye through blinking)
- HeNe laser (632nm) 50 μW*0.25s
- Even red class IIIa laser pointers (5 mW) exceed permissible levels by a factor of 100 during the “blinking time”.
- Damage threshold for laser pulses shorter than 1 μs is thousands of times lower than for cw lasers.

→**Almost all direct laser beams and their specular reflections can cause irreparable damage to the retina.**

Specular Reflection: Mirror-like from smooth reflective surface

Diffuse Reflection: Reflection from a rough surface

Laser Dyes

Many laser dyes are mutagenic (can change DNA) and thus potentially carcinogenic (can cause cancer) and essentially all are hazardous.

If you must handle laser dyes: GET SPECIAL TRAINING FIRST

Some examples of issues and dangers

- DCM* is by far the worst. Handle it only with gloves in a fume hood.
- Of the eight coumarins tested, 102/480, LD 490 and 7/535 showed mutagenic effects.
- Of the multiphenyls tested, only terphenyl was found to be mutagenic.
- Cresyl violet and Nile blue are mutagenic and toxic.
- Kiton Red, oxazine and carbazine are not mutagenic.
- No mutagenic effects were found among rhodamines.

* 4-Dicyanomethylene-2-methyl-6-p-dimethylaminostyryl-4H-pyran (DCM)

High Voltage Power Supplies

- Always be vigilant around high-voltage power supplies for lasers.
- People have died by electrocution from the high voltage present in many laser systems.
- If voltages above 15KV are used, ensure that your exposure to potential x-ray emission is negligible.

Protective Clothing/Eyewear

- For high-power lasers, protective gloves and clothing may be required so that you do not suffer accidental burns.
- Depending on the laser classification, appropriate protective eyewear may be required.

Laser Classifications

ANSI (American National Standards Institute)

Accessible Emission Limit (AEL)=
Maximum Permissible Exposure Limit (MPE) x Area of Limiting Aperture(LA)
(LA depends on wavelength and other factors)

Class		
I	• No accessible laser radiation in excess of class 1 AEL (for any exposure time).	Exempt from beam-hazard control measures / inherently safe.
II	• CW and repetitively pulsed • 400nm<λ<700nm **(visible light only)** • Do not exceed class 1 AEL for durations less than 0.25s (blinking of eye). • Maximum average radiant power 1mW.	**Blinking reflex (aversion response) can prevent eye damage.** Deliberately staring into beam will result in eye damage.
IIIa	• Accessible output between 1-5 times class 1 AEL for λ<400nm and λ>700nm. • Accessible output less than 5 times class 2 AEL for 400nm<λ<700nm • Output powers 1-5mW. Maximum power density 2.5mW/cm^2.	Many laser pointers in this category. Class 3a lasers are mostly dangerous in combination with optical instruments which change the beam diameter. **Protective eyewear not required.** Skin burns only possible with a focused laser.

Laser Classifications

ANSI (American National Standards Institute)

Class		
IIIb	• Maximum average radiant power 500mW for 0.25s (=0.125 Joules) for 180nm<λ<400nm or 1400nm<λ<1mm. • Lasers with 400nm<λ<1400nm exceeding class 3 AEL cannot emit an average radiant power greater than 500mW for 0.25 s (=0.125 Joules) or radiant energy greater than 0.03 Joules per pulse.	**Will cause damage** if beam enters eye directly. Can easily cause **permanent eye damage** from exposures of 1/100th of a second or less. Specular reflections dangerous. **Protective eyewear needed.**
IV	• Exceed class 3b AEL. • **Highly dangerous** • Output powers of more than 500mW.	Even diffuse (and of course specular) reflection can be hazardous to skin and eye within the nominal hazard zone.

Generally one can state that a laser is more dangerous with:

(i) Higher power

Higher power means more energy deposited in tissue during exposure time and greater likelihood of permanent tissue damage.

(ii) Less visibility of its wavelength

Infrared and ultraviolet light will not cause the blinking reflex (aversion response) of the human eye, This means the retina will be exposed longer and the damage will therefore be greater

(iii) Higher intensity (stronger focus of the light)

Stronger focus means more power per area which means that the damage may be more localized but at the same time worse.

Safety Precautions for Class 3 Lasers (eye and specular reflection hazard)

- **Do not aim** laser at a person's eye.
- **Do not let laser beam enter eye**.
- Wear laser **safety eyewear** if MPE (Maximum Permissible Exposure) is exceeded.
- **Do not view beam directly with optical instruments**.
- Depending on laser, a **key switch** may be necessary to prevent unauthorized use of laser.
- It is best to **enclose beam path** as much as possible.
- It is best to operate laser in a **controlled access area**.
- **Remove** unnecessary specular **reflecting objects** from beam path (e.g., shiny metal surfaces…..).
- During alignment avoid placing eye near the axis of beam path. Consider **alignment eyewear** to reduce danger.
- **Mount lasers firmly** to avoid unintended directional change.
- Post laser **hazard warning signs** at entrances to laser use area.

Safety Precautions for Class 4 Lasers (fire, eye and skin hazard, diffuse reflection hazard)

- **Review** laser **safety procedure** before operating laser.
- **Enclose beam path** as much as possible.
- **Laser must be in a controlled access area** secured by **entryway controls** (e.g., warning lights, interlocks, protective eyewear,…).
- Assure that laser has a **key switch master control** and that only authorized, properly trained individuals operate the laser.
- **Protective laser eyewear must be available and must be worn by all personnel within the laser controlled area.**
- For laser beams which pose a serious fire and skin hazard: Use appropriate shielding between beam area and personnel.
- Keep beam path above or below eye level of sitting or standing people.
- Use **remote** firing of laser, video monitoring, or remote viewing through a laser safety shield whenever feasible.
- If full laser power is not needed, **reduce laser beam output** with laser output filters and shutters – ideally to less than hazardous levels.
- **Mount lasers firmly** to avoid unintended directional change.
- **Beam backstops**: Diffusely reflecting and made of **fire resistant material**.
- Post laser **hazard warning signs** at entrances to laser use area.

Important when using protective eyewear

- Does the eyewear in your lab match the laser wavelength you are using?

- **If you have lasers of different wavelength in your lab:** Are you using the eyewear that matches the laser wavelength you are using?

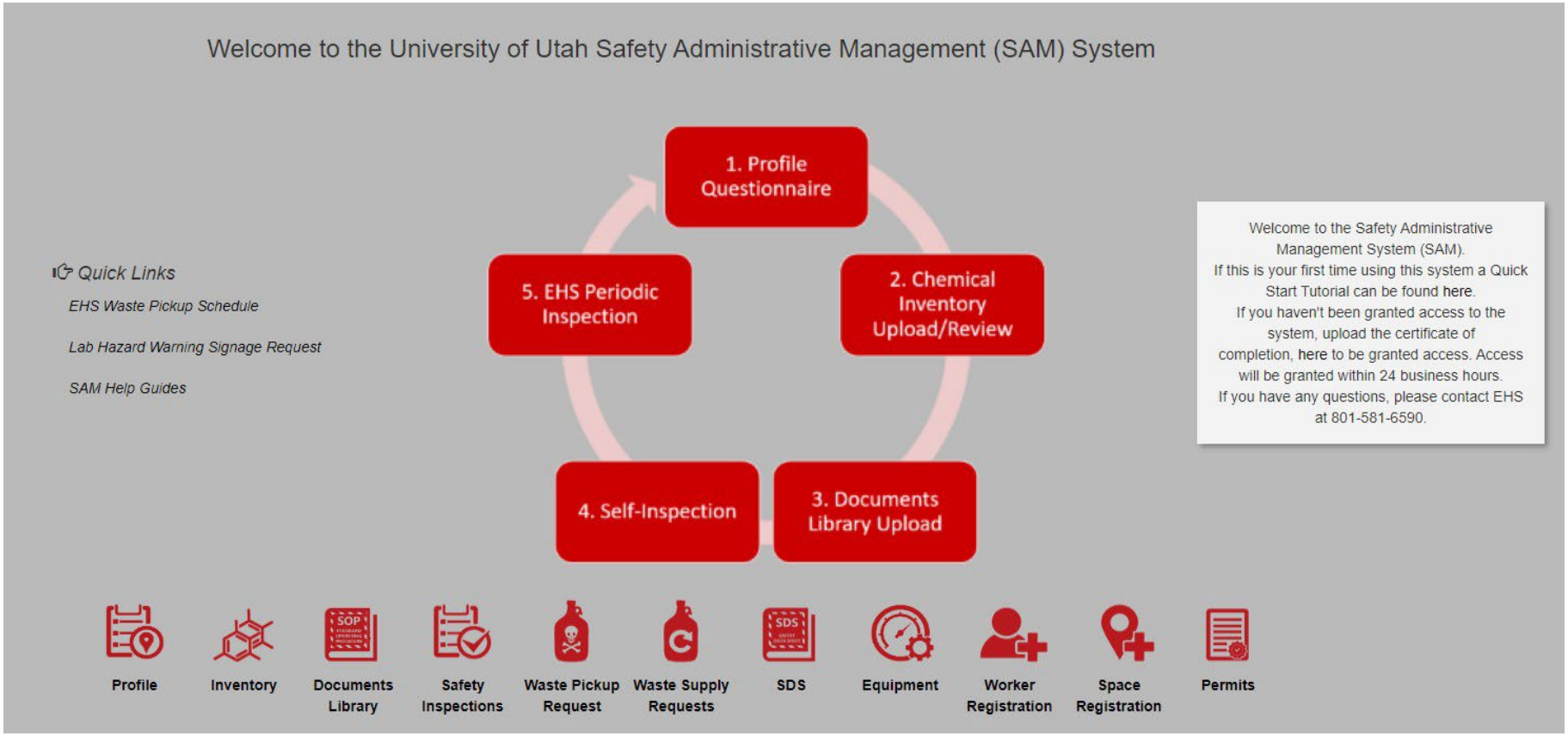
Important for all PIs

- **Lasers must be registered in SAM** with EHS - especially important for class 3b or class 4 lasers!

- **Lower power lasers must also be registered in SAM**.

When you do your annual self-inspection and you are filling out the information for NIR (non-ionizing radiation) sources, only class 3b and class 4 are mentioned explicitly. To register lower class lasers choose “other” on the form and then write in what other types of lasers you have.

- Once you have registered the lasers, EHS will ensure that you implement required safety features, PPE, and training as needed.


Welcome to the University of Utah Safety Administrative Management (SAM) System
Quick Links
EHS Waste Pickup Schedule
Lab Hazard Warning Signage Request
SAM Help Guides
1. Profile Questionnaire
2. Chemical Inventory Upload/Review
3. Documents Library Upload
4. Self-Inspection
5. EHS Periodic Inspection
Welcome to the Safety Administrative Management System (SAM).
If this is your first time using this system a Quick Start Tutorial can be found here.
If you haven't been granted access to the system, upload the certificate of completion, here to be granted access. Access will be granted within 24 business hours.
If you have any questions, please contact EHS at 801-581-6590.
Profile
Inventory
Documents Library
Safety Inspections
Waste Pickup Request
Waste Supply Requests
SDS
Equipment
Worker Registration
Space Registration
Permits

Laser Hazard Classes Overview

	Possible Wavelength Ranges				Type of Hazard			
Class	**UV (100-400 nm)**	**Visible (400-700nm)**	**Near IR (700-1400nm)**	**Far IR (1400-10^6nm)**	**Direct Ocular**	**Diffuse Ocular**	**Fire**	**Skin**
I	Yes	Yes	Yes	Yes	No	No	No	No
IIa	No	Yes	No	No	Only after 1000 s	No	No	No
II	No	Yes	No	No	Only after .25 s	No	No	No
IIIa	Yes	Yes	Yes	Yes	Yes	No	No	No
IIIb	Yes	Yes	Yes	Yes	Yes	When close to 0.5W (3b limit)	No	No
IV	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Engineering Control Measures (ANSI Z136.1)

	Laser Hazard Class					
Engineering Controls	I	IIa	II	IIIa	IIIb	IV
Protective Housing	Required	Required	Required	Required	Required	Required
Interlock on Protective Housing	R*	R*	R*	Required	Required	Required
Service Access Panel	R*	R*	R*	R*	Required	Required
Key Control					Recommended	Required
Protective Viewing Portals			R_MPE	R_MPE	R_MPE	R_MPE
Collecting Optics	R_MPE	R_MPE	R_MPE	R_MPE	R_MPE	R_MPE
Totally Open Beam Path - Control Measures					Required	Required
Partially Open Beam Path – Control Measures					Required	Required
Remote Interlock Connector					Recommended	Required
Beam Stop or Attenuator					Recommended	Required
Activation Warning Systems					Recommended	Required
Emission Delay						Required
Protective Windows					R_MPE	R_MPE

R* = Required if it contains an embedded class 3b or 4 laser

R_MPE = Required if the Maximum Permissible Exposure is exceeded

Administrative Control Measures (ANSI Z136.1)

	Laser Hazard Class					
Administrative Controls	I	IIa	II	IIIa	IIIb	IV
Written Laser Safety Procedures					Recommended	Required
Education and Training			Recommended	Recommended	Required	Required
Authorized Operating Personnel					Required	Required
Alignment Procedures			Required	Required	Required	Required
Control of Spectators					Recommended	Required
Service Personnel Training	R*	R*	R*	R*	Required	Required
Indoor Laser Controlled Area					Required	Required
Class 3b Laser Controlled Area					Required	
Class 4 Laser Controlled Area						Required
Temporary Laser Controlled Area	R*	R*	R*	R*		
Warning Labels (on laser housing)	Required	Required	Required	Required	Required	Required
Warning Sign Posting				Recommended	Required	Required

R* = Required if it contains an embedded class 3b or 4 laser

R_MPE = Required if the Maximum Permissible Exposure is exceeded

Protective Equipment (ANSI Z136.1)

	Laser Hazard Class					
Protective Equipment	I	IIa	II	IIIa	IIIb	IV
Eye Protection					R_MPE	Required
Skin Protection					R_MPE	Required

R_MPE = Required if the Maximum Permissible Exposure is exceeded

ANSI (American National Standards Institute) – older classification versus IEC (International Electrotechnical Commission) – newer classification

ANSI	IEC	Range	Hazard
I	1	< 1 μW	Safe under all conditions of normal use. May not be safe if viewed through telescope or microscope of sufficiently large aperture.
	1M	< 1 μW entering pupil, Total power < 0.5 W	No skin hazard; hazardous for eye if viewed through optical instruments. **DO NOT USE OPTICAL INSTRUMENT TO VIEW CLASS 1M LASER.**
II	2	< 1 mW; 0.25s, 400-700nm; Total power <0.5W	No hazard for skin or eye: protection by the eye reflex.
	2M	< 1 mW/Pupil 0.25s, 400-700nm; Total power <0.5W	No skin hazard; hazardous for eye if viewed through optical instruments. **DO NOT USE OPTICAL INSTRUMENT TO VIEW CLASS 2M LASER.**
IIIa	3R	< 5xClass 2; 0.25s, 400-700nm < 5xClass 1; 100s, invisible light	Considered "safe" if handled carefully with restricted beam viewing. Hazardous for the eye, but not for the skin.
IIIb	3B	> 3R, max 0.5W	Hazardous for both, eye and skin. Must never be viewed directly. Diffuse reflections (from paper or matte surfaces) are not harmful. Specular reflections dangerous. Protective eyewear typically required.
IV	4	> 3B	Hazardous for eye and skin, fire hazard. Even diffuse or indirect beam viewing can cause permanent and devastating eye damage.

Nominal Hazard Zone (NHZ)

The nominal hazard zone (ANSI Z136.1) = Space within which the level of direct, scattered, or reflected laser light emitted during laser operation exceeds the MPE.

The NHZ allows one to eliminate more restrictive Class 4 laser control measures if an area falls outside the NHZ. The NHZ, however, needs to be visibly identified with tape or other suitable means and at the entryway of the NHZ a warning sign indicating the laser hazard is required. This warning sign must include special precautions and instructions written on it.

VERY IMPORTANT

CAUTION:

Lab specific training is still needed when using a laser. This includes reading the laser operating manual carefully before attempting to use the laser!

Most likely emergencies/incidents – What to do?

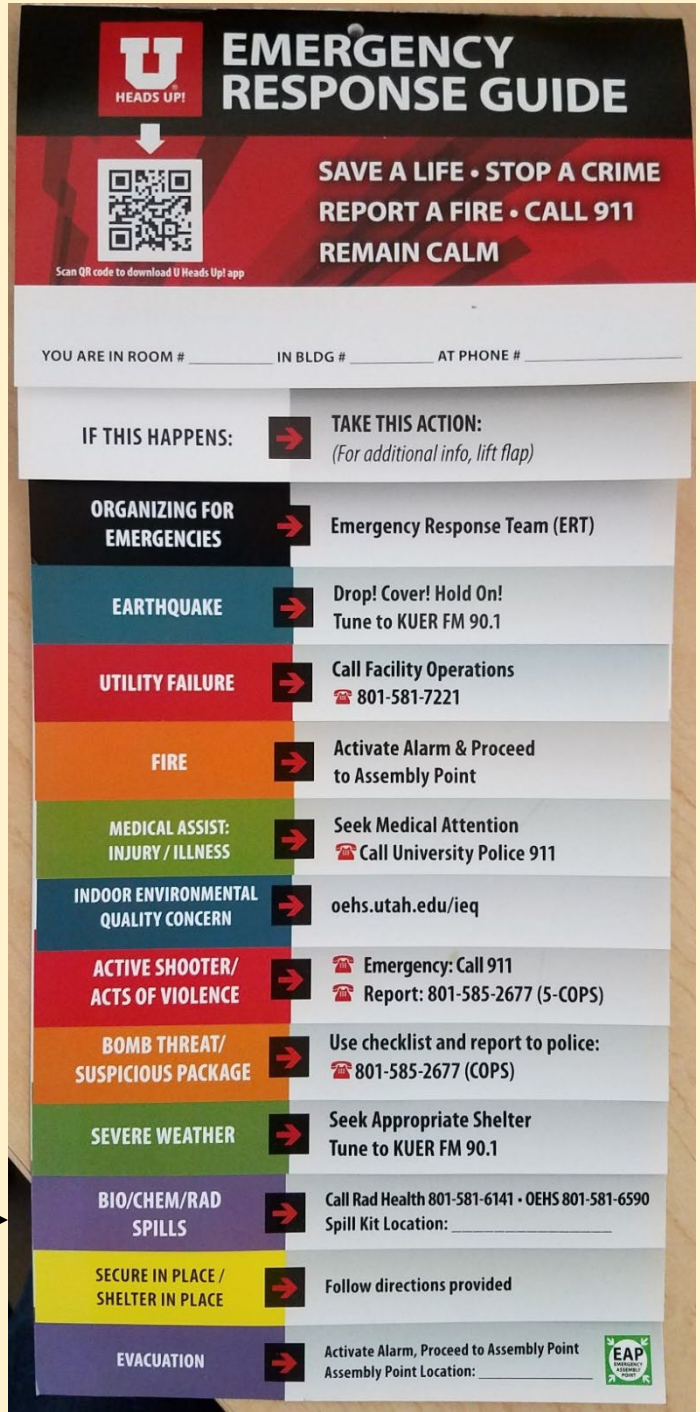
Eye damage (burns to retina):

Seek medical attention as soon as possible – consider going to the emergency room to get help quickly.

Skin burns:

There are several first aid kits available in the department. They typically contain something to put on burnt skin to relieve pain. Running cold water over burn site as soon as possible can help reduce blistering and skin damage. Consider seeking medical attention.

Emergency Response Guide – should be in every lab



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Injury

Minor and Major Injury/Illnesses:

Minor Injury/Illness

1. Apply First Aid, if trained
2. Obtain medical attention if necessary (see below)

For Faculty and Staff:

1. Report the incident to your supervisor
2. Consult Occupational and Environmental Health and Safety at **801-581-6590**
3. With your supervisor, complete form E-1: First Report of Injury

Major (Life-Threatening Injury/Illness

1. Activate Emergency Medical Services by calling **911**

For Faculty and Staff:

1. Report to Occupational and Environmental Health and Safety **801-581-6590** (Incident may need to be reported to OSHA within 8 hours)
2. With your supervisor, complete form E-1: First Report of Injury

www.hr.utah.edu/forms/lib/E1.pdf

To obtain medical attention for minor injuries contact:

Faculty and Staff
RedMed Employee Health clinic
(Union Bldg)
200 South Central Drive Suite 156
SLC, UT 84112
801-213-3303
RedMed@utah.edu

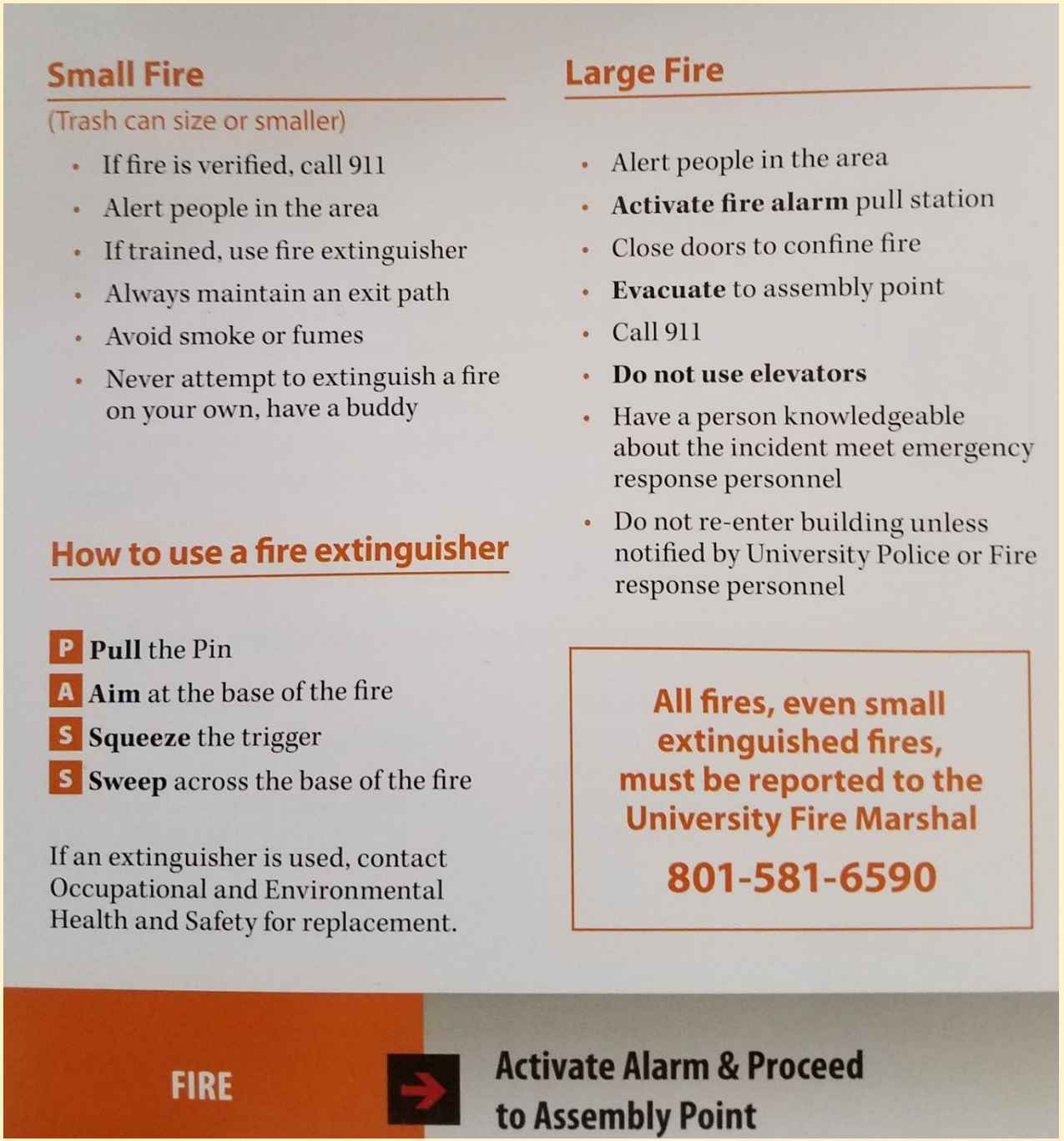
Students
Student Health Center
at the Madsen Health Center
555 South Foothill Blvd SLC, UT 84112
801-581-6431

Poisoning

Call the Utah Poison Control Center at **1-800-222-1222**
Free, confidential, expert poison help 24/7

POISON Help
1-800-222-1222

FIRE



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Spills

Minor Chemical/Biological Spill

1. Alert people in immediate area of the spill
2. Deny entry to spill area
3. Avoid vapors
4. Wear appropriate protective equipment
5. Use appropriate spill kit* to properly clean up spill—if necessary, contact OEHS for guidance
6. Place cleanup materials in appropriate container and submit OEHS pickup request.

Major Chemical/Biological Spill

1. Attend to injured personnel and remove them from area
2. Alert people in area to evacuate
3. Immediately contact OEHS **801-581-6590**. After hours contact University Police **801-585-2677 (5-COPS)**
4. Close doors and deny entry to affected area(s)
5. Have a person knowledgeable about the incident meet emergency response personnel

If you can only remember a little bit, remember this:

1. Lasers are **classified** according to danger level/type.
2. Lasers **must be registered** with EHS through SAM.
3. **Know the classifications and safety rules** before you use the laser!
4. It is **almost never safe to stare into a laser** or into the specular reflection of a laser.
5. If you deal with laser dyes: Read the MSDS and don't mess with the dye before you know all the ramifications and proper handling procedures.
6. This safety lecture does not replace your duty to read through and follow the safety instructions provided by the laser manufacturer.