Radiation Safety

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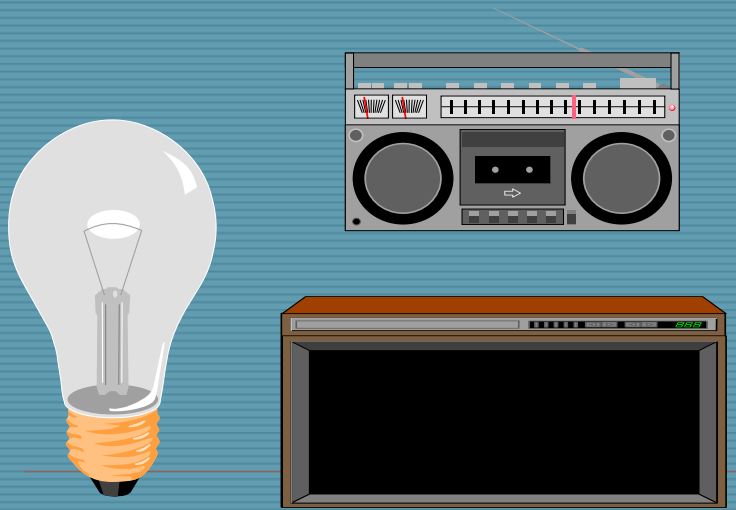
What is radiation?

- **Radiation**, as used in physics, is energy in the form of waves or moving subatomic particles.
- Radiation can be classified as *ionizing* or *non-ionizing radiation*, depending on its effect on atomic matter. The most common use of the word *"radiation"* refers to ionizing radiation.
- Ionizing radiation has enough energy to ionize atoms or molecules while non-ionizing radiation does not.
- *Radioactive material* is a physical material that emits ionizing radiation.

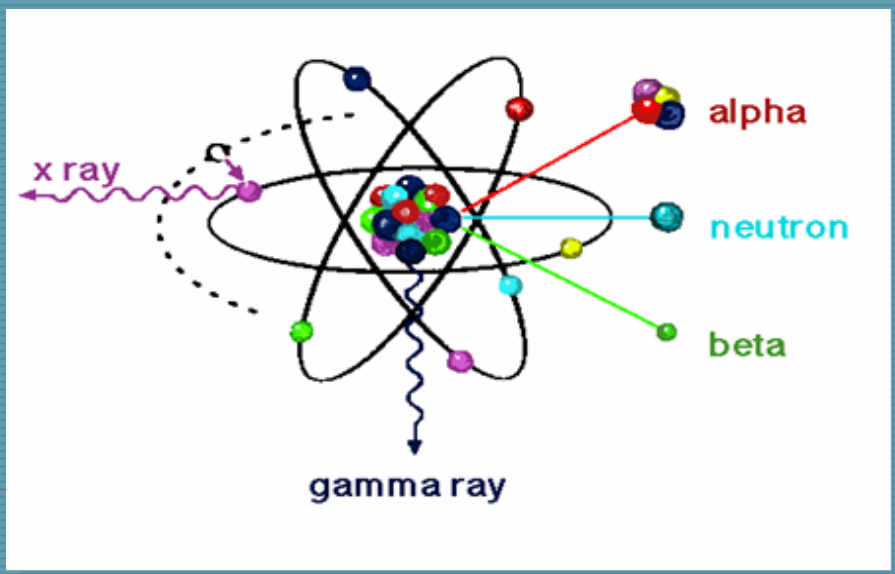
Two types of radiation

RF μwave infrared visible uv x ray γ-ray cosmic

Non Ionizing - does not have enough energy to remove electrons from surrounding atoms.



Ionizing Radiation - can deposit energy in neighboring atoms resulting in the removal of electrons.

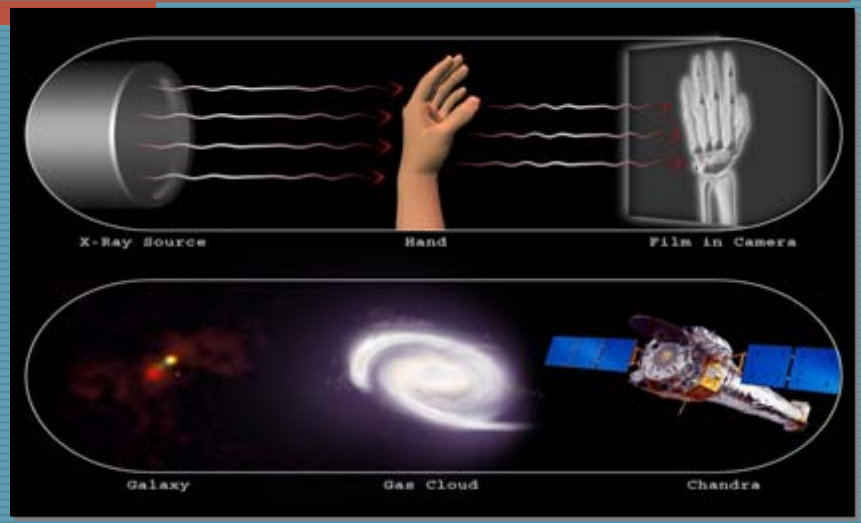


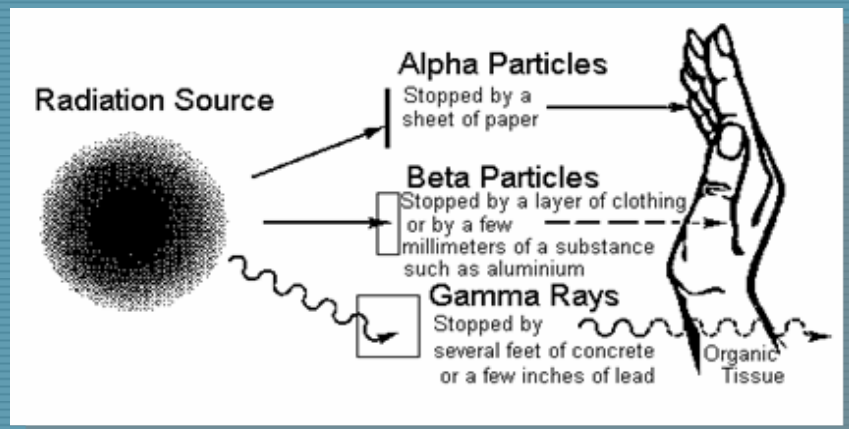
What is radiation?

- Non-ionizing
  - Thermal radiation (heat radiation)
  - Radio waves
  - Microwave radiation, as used in microwave ovens
  - Infrared radiation (IR), produced by heat
  - Visible light that is visible to the naked eye
  - Ultraviolet radiation (UV) is electromagnetic radiation with a wavelength shorter than that of visible light, but longer than soft X-rays.
- Ionizing
  - X-rays, used in radiography for medical diagnosis
  - Gamma radiation usually emitted, radioactive atoms, by the nucleus

What is radiation?

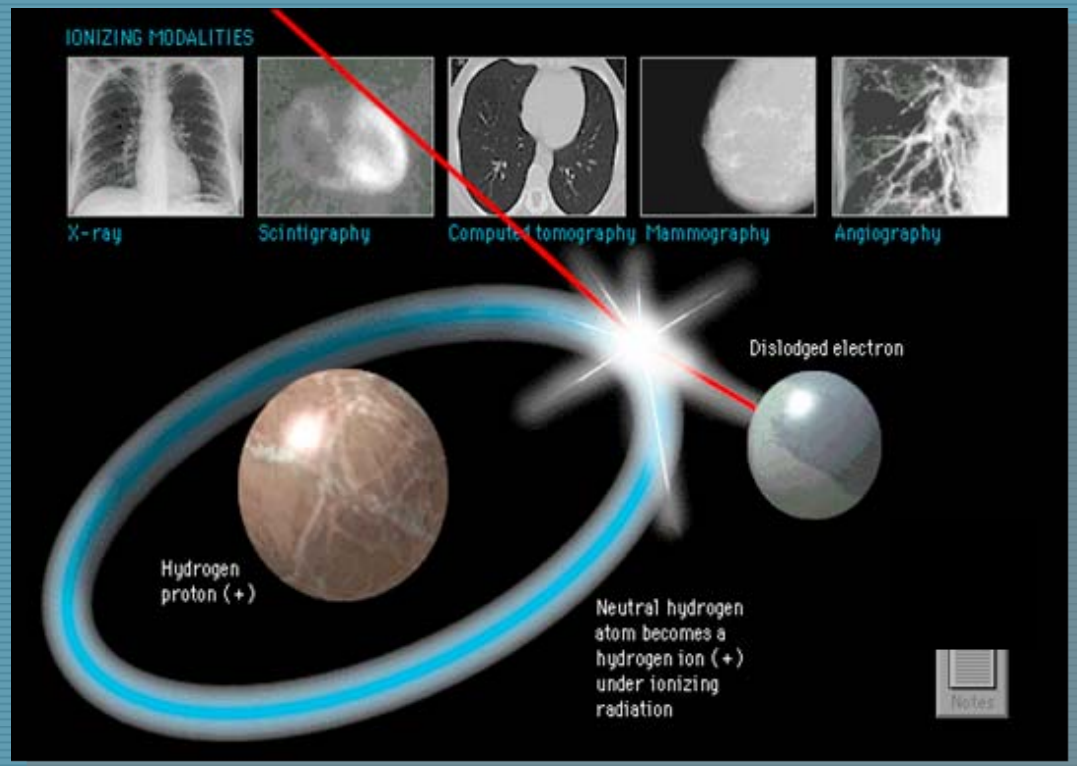
Radiation is energy in the form of waves or particles. Radiation high enough in energy to cause ionization is called **ionizing radiation**. It includes particles and rays given off by radioactive material, stars, and high-voltage equipment. Ionizing radiation includes x-rays, gamma-rays, beta particles, alpha particles, and neutrons.





What is radiation?

Without the use of monitoring equipment, humans are not able to "find" ionizing radiation. In contrast to heat, light, food, and noise, humans are not able to see, feel, taste, smell, or hear ionizing radiation.



Radiation Fundamentals

- **Definition of Radiation:** The transfer of energy, in the form of particles or waves as it passes through a medium.
- **Radioactive Material:** A material-solid, liquid or gas-which emits radiation spontaneously.
- **Radiation Producing Device:** A device capable of producing ionizing radiation, except those devices with radioactive material as the only source of radiation.

Radiation Fundamentals

- **Dose or Radiation dose:** a generic term that means absorbed dose or dose equivalent. The units for does equivalent are the REM or the Sievert.
- **Absorbed dose:** the energy imparted by ionizing material. The units of absorbed dose are the RAD or the Gray.

Radiation Fundamentals

- **RAD:** is a unit used to measure a quantity called absorbed dose. This relates to the amount of energy actually absorbed in some material. It does not describe the biological effects of the different radiations.

- **REM:** the special unit of any of the quantities expressed as dose equivalent.

The dose equivalent in Rems is equal to the absorbed dose in rads multiplied by the quality factor (1 Rem = 0.01 Sievert).

The quality factor for x rays is 1.

1 RAD of X-ray exp. = 1 REM

Radiation Fundamentals

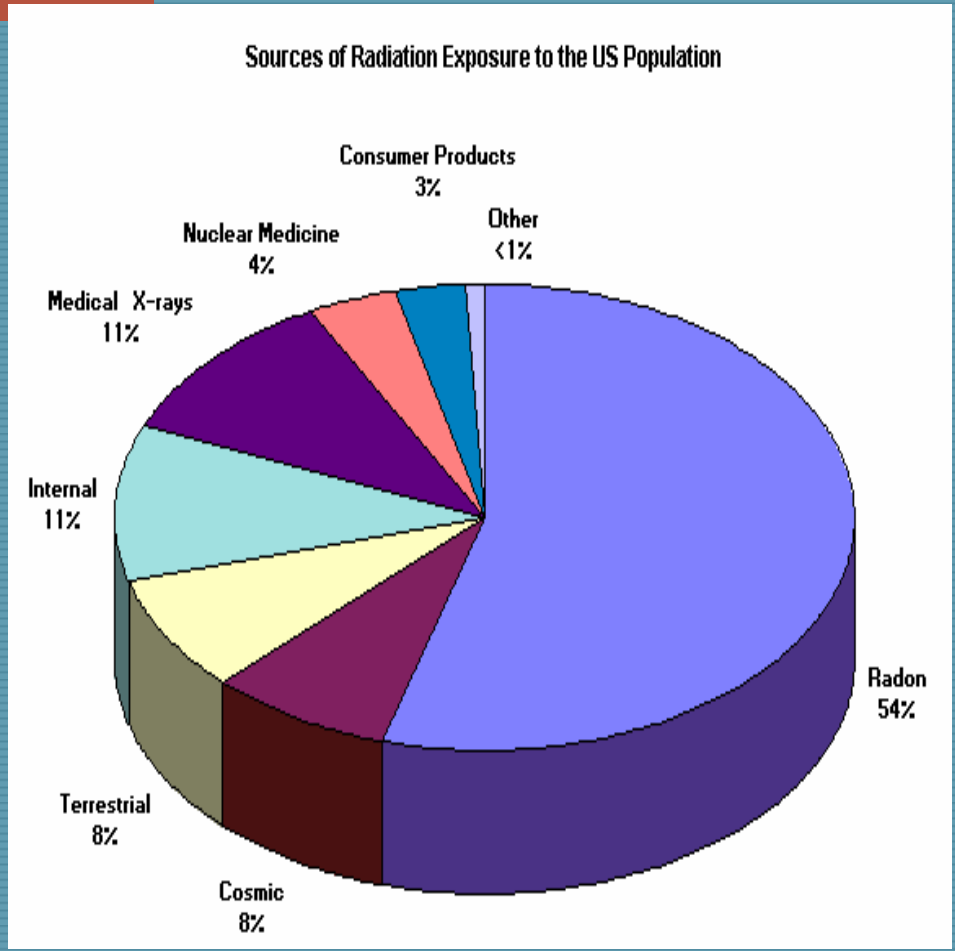
- **Gray (Gy):** the Systems International unit of absorbed dose, 1 gray is equal to an absorbed dose of 1 Joule / kilogram (1 Gy =100 rads).

- **Sievert:** the SI unit of any of the quantities expressed as dose equivalent(1 Sv = 100 Rems).

- **Declared pregnant woman:** a woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception.

What is Background Radiation?

Radioactive materials surround us constantly; radioactive materials are located in the air we breath, the ground we walk on, even inside of our bodies. It consists of radiation from cosmic sources; naturally occurring radioactive materials, including radon and global fallout as it exists in the environment from the testing of nuclear explosive devices.



An individual in USA receives an average of 270mRem annual exposure from background.

What is safety?

- **Safety** is the state-of-art-of-being-"safe. The condition of being protected against physical, social, spiritual, financial, political, emotional, occupational, psychological, educational or other types or consequences of failure, damage, error, accidents, harm or any other event which could be considered non-desirable. This can take the form of being protected from the event or from exposure to something that causes health or economical losses. It can include protection of people or of possessions.
- There also may indicate the ability to protect against external harm events, and the not dangerous or harmful for human being.
- Safety can be limited in relation to some guarantee or a standard of insurance to the quality and unharmful function of an object or organization. It is used in order to ensure that the object or organization will do only what it is meant to do.
- Eliminating all risk, if even possible, would be extremely difficult and very expensive. A safe situation is one where risks of injury or property damage are low and manageable.

What are X-rays?

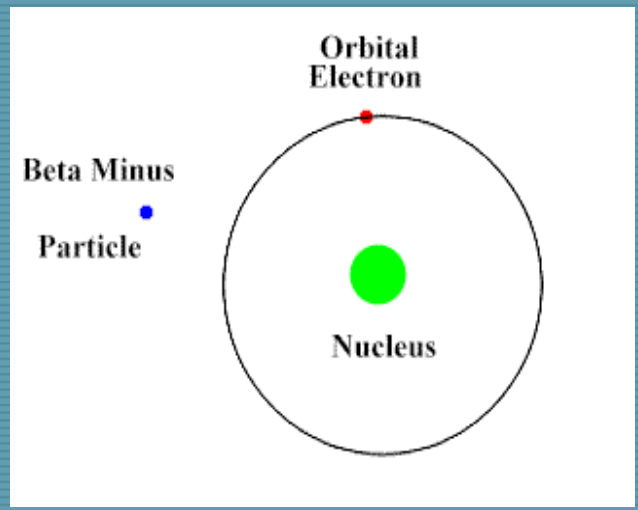
X-rays were discovered in 1895 when Wilhelm Conrad Roentgen observed that a screen coated with a barium salt fluoresced when placed near a cathode ray tube. Roentgen concluded that a form of penetrating radiation was being emitted by the cathode ray tube and called the unknown rays, ***X-rays***.

What are X-rays?

- X rays are a form of electromagnetic radiation which arises as electrons are deflected from their original paths or inner orbital electrons change their orbital levels around the atomic nucleus.
- X rays, like gamma rays, are capable of traveling long distances through air and most other materials. Like gamma rays, x rays require more shielding to reduce their intensity than do beta or alpha particles.
- X and gamma rays differ primarily in their origin: x rays originate in the electronic shell, gamma rays originate in the nucleus.

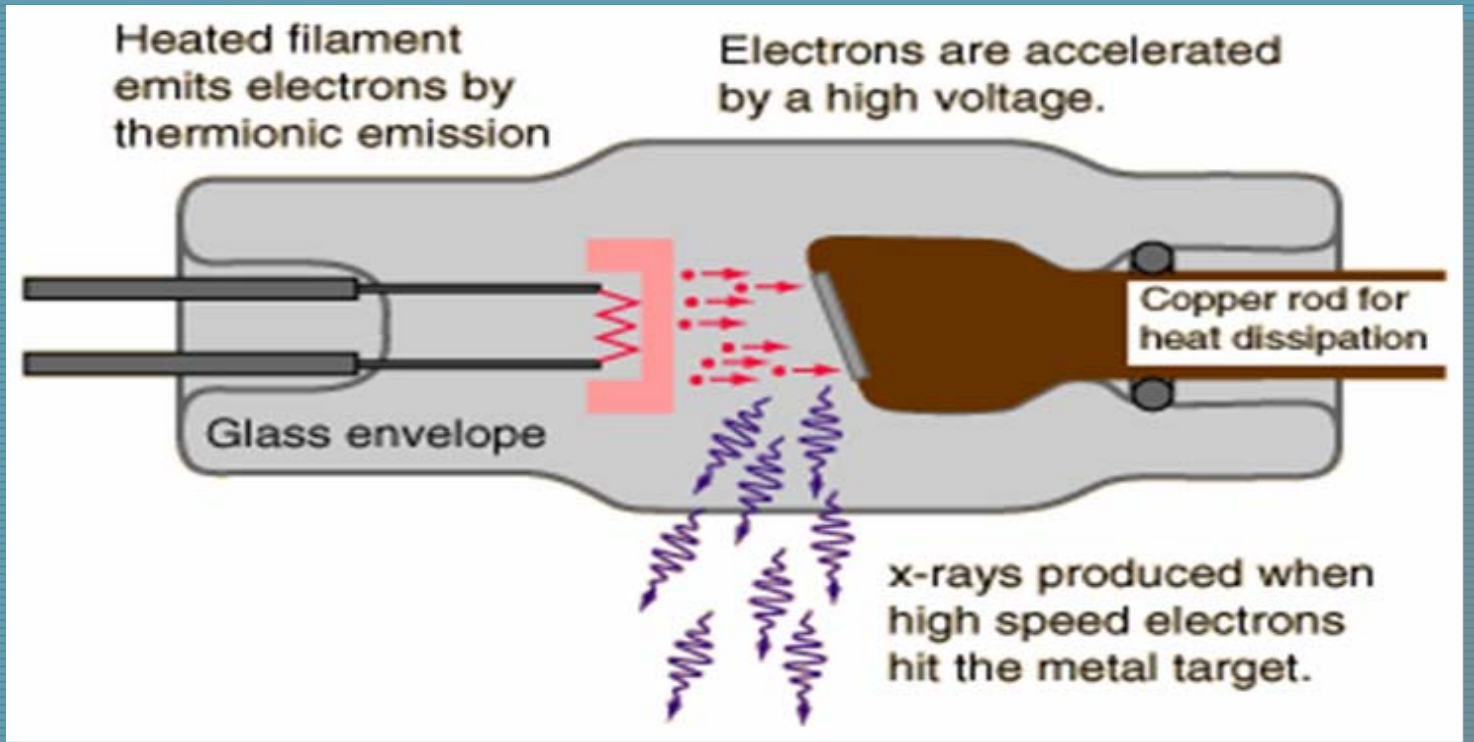
What are X-rays?

- X-rays are photons (electromagnetic radiation) which originate in the energy shells of an atom.
- X rays are produced when accelerated electrons interact with a target, usually a metal absorber, or with a crystalline structure.
- This method of x ray production is known as bremsstrahlung.
- The bremsstrahlung produced is proportional to the square of the energy of the accelerated electrons used to produce it, and is also proportional to the atomic number (Z) of the absorbed.



X-ray tube

An x-ray tube requires a high source of voltage, a means to accelerate the electrons, and a target to stop the high-speed electrons.



X-ray tube

In passing through matter, energy is transferred from the incident x-ray photon to electrons and nuclei in the target material. An electron can be ejected from the atom with the subsequent creation of an ion. The amount of energy lost to the electron is dependent on the energy of the incident photon and the type of material through which it travels. There are three basic methods in which x-rays interact with matter: photoelectric effect, Compton scattering, and pair production.

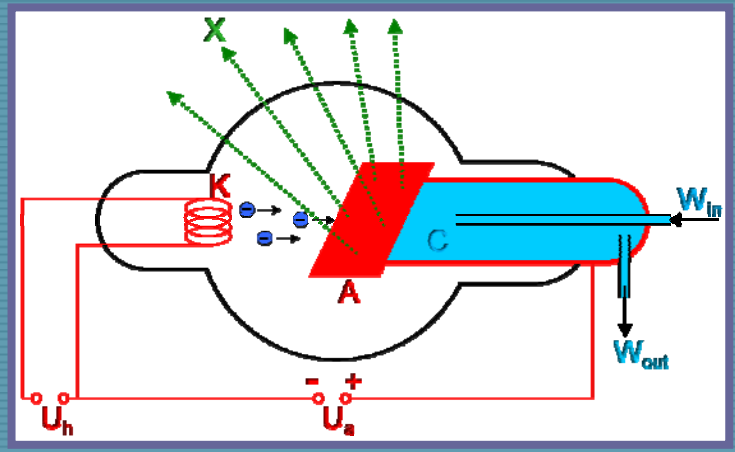
Early X-Ray Tube (1899): This tube is a specimen of the first type of gas x-ray tube to incorporate a water-cooled anode. The hollow anode was supplied with water by gravity feed from a supply held in the side bulb. This type of tube was introduced by Mueller about 1899.

X-ray tube

- Historically, the first X-ray tube was invented by sir William Crookes. It was used to make a visible fluorescence on minerals. The **Crookes tube** is also called discharge tube or cold cathode tube.
- It is a glass bulb with around a thousandth of sea-level atmospheric pressure of air (approximately 100 pascals or 1 torr). It contains an aluminum cathode with a curved shape to concentrate the electron flow on the anode, or "target".
- A high tension (known in the US as voltage) is made between the electrodes; this induces an ionization of the residual air, and thus an electron flow or "discharge" from the cathode to the anode. When these electrons hit the target, they are slowed down, producing the X-rays (Bremsstrahlung and X-ray fluorescence of the target).
- This tube can not produce X-rays continuously. It is no longer used on modern devices.

X-ray tube

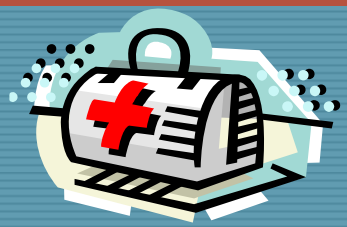
The Crookes tube was improved by William Coolidge in 1913. The **Coolidge tube**, also called **hot cathode tube**, is the most widely used. It works with a very good quality vacuum (about 10-4 Pa, or 10-6 Torr). In the Coolidge tube, the electrons are produced by thermionic effect from a tungsten filament heated by an electric current. The filament is the cathode of the tube. The high voltage potential is between the cathode and the anode, the electrons are thus accelerated, and then hit the anode. There are two designs: end-window tubes and side-window tubes. In the end-window tubes, the filament is around the anode, the electrons have a curved path.



Coolidge side-window tube (scheme)
K: filament
A: anode
Win and Wout: water inlet and outlet of the cooling device (C)

Modern uses of the X-ray

- Medical
- Industrial
- Research
- Environmental
- Construction
- Teaching



- Imaging: Isotopic & Non Isotopic - Non Destructive Testing
- Gauges for precision: thickness, density, moisture, elemental makeup, sterility, airport security & bomb squads

Examples of X - Ray Generating Devices

Van de Graff Accelerator

Open Beam

XRD Tin/Polycarbonate/Leaded enclosure

Radiation Controls

- Administrative Controls
- Engineering Controls
- Personnel Protective Equipment (PPE)
- Warning Signs and Labels

Radiation Controls

Administrative Controls

Regulatory Requirements

- The Radiological Health Division from Department of Health of the Commonwealth of the Puerto Rico is the regulatory agency that oversees the use of the Radioactive Materials and Radiation Generator Source systems in Puerto Rico.
  - The Radiological Health Division also requires that a document, called the NOTICE TO EMPLOYEES be posted where persons operating X-Ray equipments, may view information on the rights and responsibilities of both employers and employees.
  - The Radiological Health Division requires that all Radiation Producing Devices (RPD) be registered. They must be notified when new RPD are purchased and when old units are disposed.

- Puerto Rico OSHA (PROSHA)
  - By the approved Law 16 of the August 5, 1975, state the every employer must provide a safe environment at the workplace.

- The Department of Labor of the Commonwealth of the Puerto Rico

- UPRM – Oficina de Seguridad, Seguridad Ocupacional y Ambiental (OSSOA)
  - Provide orientation about the X-rays.
  - Provide orientation about the Personal Protection Equipment (PPE).

- UPRM – Dept of Geology – X-ray Laboratory
  - The employer must provide a PPE.
  - The employee must use PPE.

X-ray Safety Fundamentals

Goals of this training presentation:

1. Understand what are X-rays.
2. Understands and manages the hazards of X-ray devices used in Earth-X-ray-Analysis-Center (EXACt!), X-ray Lab, Geochemistry Analysis at UPRM - Dept. of Geology.
3. Understand UPRM - EXACt! requirements and responsibilities for the safe use of X-ray devices.
4. Help you recognize and respond to unsafe conditions.

Analytical X-rays

This the most common type of research X-ray at UPRM-EXACt!

Three main uses:

- Diffraction [XRD]: X-ray scattering from crystalline materials. “fingerprint” of crystalline atomic structure. Check known library vs. unknown sample. Determine the composition of the materials.

- Fluorescence [XRF]: Analytical method for determining the elemental composition of a substance.

- Electron Microscopes [EM]: Produce X-rays when the primary electron beams strike the target material and metal parts of the apparatus. The casing of the machine and the leaded glass of the viewing port provide sufficient shielding such that virtually no radiation reaches the operator under normal operating conditions.

Hazards of Analytical of X-ray Equipment

1. **The primary beam:** The primary beam is most hazardous because of the extremely high exposure rates. Exposure rates of 4 x 10^5 R/min at the port have been reported for ordinary diffraction tubes.
2. **Leakage or scatter of the primary beam through cracks in ill fitting or defective equipment:** The leakage or scatter of the primary beam through apertures in ill fitting or defective equipment can produce very high intensity beams of possibly small and irregular cross section.
3. **Penetration of the primary beam through the tube housing, shutters or diffraction apparatus:** The hazard resulting from penetration of the useful beam through shutters or the x-ray tube housing is slight in well designed equipment. Adequate shielding is easily attained at the energies commonly used for diffraction and florescence analysis.
4. **Diffracted rays:** Diffracted beams also tend to be small and irregular in shape. They may be directed at almost any angle with respect to the main beam, and occasionally involve exposure rates of the order of 80 R/h for short periods.

UPRM – Dept of Geology Radiation Safety

- EXACt! is responsible for the safe use of radioactive materials and **Radiation Producing Devices (RPD)** at Department of Geology - UPRM.
- Radiological Health Specialist (Dept. of Health - Radiological Health Division personnel will perform a survey, at least annually, on each RPD in use by the University.
- Radiation Safety Staff are available to answer questions, address concerns and will perform surveys on suspect equipment.
- It is important that users of the XRD, XRF and EM immediately report to Radiation Safety Staff any condition that may be deemed as unsafe or that could result in a regulatory violation

User Requirements

- **New Equipment**
  - It can be difficult for Radiological Health Specialist to know when new equipment has been purchased. Contact Radiation Safety Staff at 787-265-2490, whenever a new device is installed so that it may be registered with the PR Gov., Dept of Health.

- **Disposal, Relocation or Transfer**
  - It is also important to contact Radiation Safety Staff, in the event that an existing device is removed from service for disposal or transferred to another facility, so that the University's inventory may be updated, and the PR Gov., Dept of Health notified. If a device that is moved from one campus location to another, Radiation Safety Staff should also be notified so that a survey may be performed and the inventory be revised.

- **Written Standard Operating Procedures (SOP)**
  - Each RPD's system is required to have a written SOP available to operators. This SOP is written by the PI and/or the Radiation Safety Staff responsible for the machine and is to be strictly adhered to at all times. Notify Radiation Safety Staff is the SOP is not available.

When else should a survey be performed?

- The Radiation Safety Office will perform a survey:
  - When the equipment is first installed.
  - During maintenance or alignment procedures that require the presence of a primary X-ray beam.
  - During and following maintenance that requires the disassembly or removal of key components such as a shutter, collimator, or x-ray tube replacement.
  - Following changes that could affect the scattered radiation field such as changes in shielding, beam stops, detector systems or the shield enclosure.

Training Requirements

- **Radiation Safety Training**
  - All persons who operate an EM, XRD, XRF and Cathodoluminescence microscope must receive radiation safety training from Radiological Safety Staff.
  - This presentation and the quiz that is associated with it, are designed to meet this requirement.

- **Operational Training**
  - All persons who operate an EM, XRD, XRF and Cathodoluminescence microscope must also receive instruction from the primary researcher (or their designee), on proper operating procedures in regard to radiation.
  - Adherence to these procedures, and other rules discussed in this presentation will ensure a safe working environment for the operator.
  - The operator must also demonstrate competency to the primary researcher/designee before the equipment may be operated without supervision.

Training Requirements

- **Personnel Requirements**

  MUST receive instruction in and demonstrate competence as to:

  - Identify hazards of operating X-Ray generating devices
  - Significance of warning and safety devices (Bypassing interlocks)
  - Written operating procedures-must be trained on each device
  - Symptoms of acute exposure & procedures for reporting actual or suspected exposure
  - Survey & personnel monitoring equipment

SOP's for Equipment

Standard operating procedures are required to be developed by Supervisor for each individual X-ray device:

- used under guidance and supervision of Authorized User
- beam shall be directed toward an unoccupied area (eg. wall)
- limit dimensions of beam
- adequate shielding
- energized equipment never unattended in unlocked area
- no repairs or sample adjustment when equipment energized

Required Documents for X-Ray Producing Devices

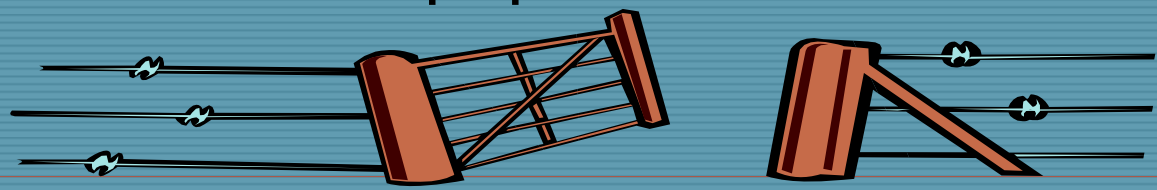
- Source housings and operational switches must be labeled
- Written operating procedures must be present for each device and must be read and understand by each person who will be using the device
- Log books must be present and must be used each time the X-ray producing device is energized.

Radiation Surveys and Safety Inspections

- The only way to ensure all the safety devices in place are working properly is to perform radiation surveys and safety checks.
- The Radiation Safety Office will perform these checks on an annual basis, as required by state regulations. Supervisors and users should also perform these checks at frequent intervals.

Security

- Only authorized users may have access to X-ray devices
- Energized equipment must be attended at all times
- Lock lab door when equipment not attended



Emergency Procedures

- Protection of personnel is always the first priority
- Call 911 and 787-268-7502 in case of:
  - serious injury combined with radiation exposure/radioactive contamination
  - fire or explosion in a radionuclide area
- In the case of suspected radiation exposure contact the UPRM - Radiation Safety Office 787-832-4040 ext. 3221, 3506 and 3886.
- Report any incidents of excessive exposure or theft to Radiation Safety Officer.
- If safe to do, de-energized equipment by turning power supply.
- Prevent further access by locking lab door.

Example of a UPRM Radiation Protection Plan (RPP)

All personnel involved in using a University of Puerto Rico – Mayagüez Campus (UPRM), Earth-X-ray-Analysis-Center (EXACt!), X-ray device must review this program and will be held accountable for violations.

1. Any PI that may have a research need to purchase, borrow, or build a radiation generating device (X-ray) shall notify UPRM-Radiation Safety Officer (RSO).
2. UPRM RSO will inspect X-ray devices and facilities annually during the month of March.
3. Any changes to an X-ray device (new tube, design modifications, etc.) MUST be approved by UPRM RSO. This X-ray machine will be used as it is currently configured and approved for operation by UPRM RSO.
4. This machine will be operated in accordance with the manufacturers operating and safety procedures.

Example of a UPRM Radiation Protection Plan (RPP)

5. A restricted area will be designated as needed by the UPRM RSO to protect personnel against undue risks from exposure to radiation.
6. X-ray device users will be persons authorized by the Principal Investigator and/or UPRM RSO.
7. Members of the public will be considered to be all persons other than those involved in the authorized use, surveillance, or inspection of this machine.
8. Declared pregnant workers may use X-ray after a dosimeter is obtained from UPRM RSO. The dosimeter device shall be worn at all times while using X-ray device in compliance with the approved Law 16 of the August 5, 1975, state the every employer must provide a safe environment at the workplace.

Radiation Controls

Engineering Controls

ALARA

Practice of keeping exposure to radiation:

As

Low

As

Reasonably

Achievable

Controlling Exposures-ALARA

- **ALARA is probably the most important acronym in radiation safety and it stands for- As Low As Reasonably Achievable.**
- **ALARA is a mandated legal requirement and can be maintained using three important methods:**
  - **Time-Decrease time in area (Practice, Dry runs) follow procedure!**
  - **Distance-Increase distance between you and the source-Avoid beam.**
  - **Shielding-Utilize shielding - add sheets of lead and use collimators.**

Primary Beam

Exposure to the primary beam usually only happens in accidental situations. The risk of exposures can be minimized by good engineering design, safety features such as fail-safe lights, and interlocks. A label with the words “Caution –High Intensity X-ray Beam” must be attached near the tube head or in the area of the primary beam path.

Leakage Radiation

1. Leakage radiation refers to the radiation field around a shielded tube, excluding the primary beam.
2. Leakage can occur around shutter assemblies, collimators, joints, and seams of the tube head assembly.
3. Surveys for any changes in the leakage radiation levels must always be done following X-ray tube, collimator, or shutter replacements.
4. However, you are not permitted to perform such replacements at any time without approval from the Radiation Safety Office.

Scattered Radiation

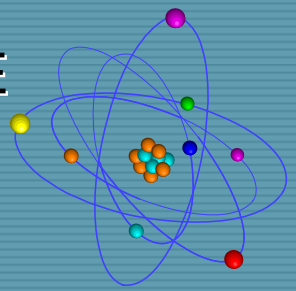
- Whatever the primary beam strikes (i.e. the sample, patient, detector, and beam stop) produces a field of scattered radiation.
- The scattered radiation field will be much lower in intensity and energy than the primary beam. It can easily be shielded.
- Most analytical systems use an enclosure shield that serves two purposes: to shield the user from the scattered radiation and keep the user's hands out of the primary beam.

Radiation Protection Basics

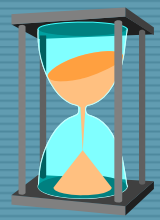
- The three principles of radiation protection, after knowing the amount and the type of radiation exposure are;
  - Time
  - Distance
  - Shielding

Radiation Protection Basics

- AMOUNT & TYPE OF RADIATION EXPOSURE

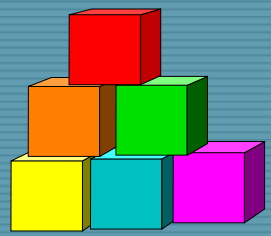


  - TIME



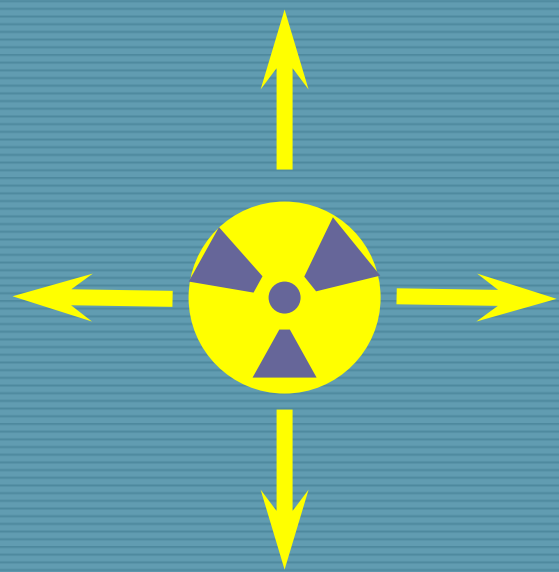
  - DISTANCE

  - SHIELDING



Time

- Decreasing the time spent near a radiation source decreases radiation exposure



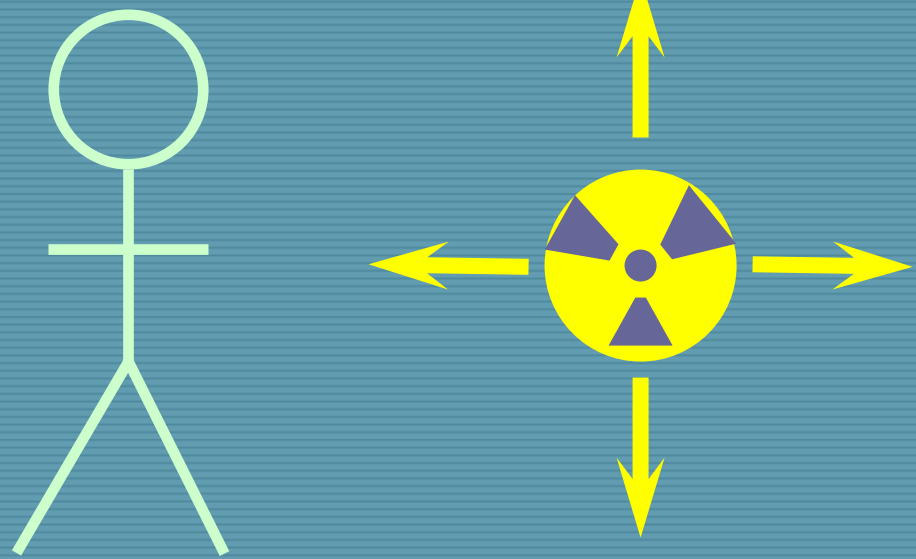
Time: Minimize Your Exposure Time

- Your radiation dose is a function of time.
  - Example: A medical X-ray unit may produce dose rates in the primary beam around 4000 REM per hour, but is only activated for a fraction of a second.

- Analytical systems however can produce dose rates up to 400,000 REM per minute (6000 REM per second), but the primary beam is usually always left ON!

Distance

- Increasing the distance from a radiation source decreases radiation exposure



Distance: Maximize the Distance

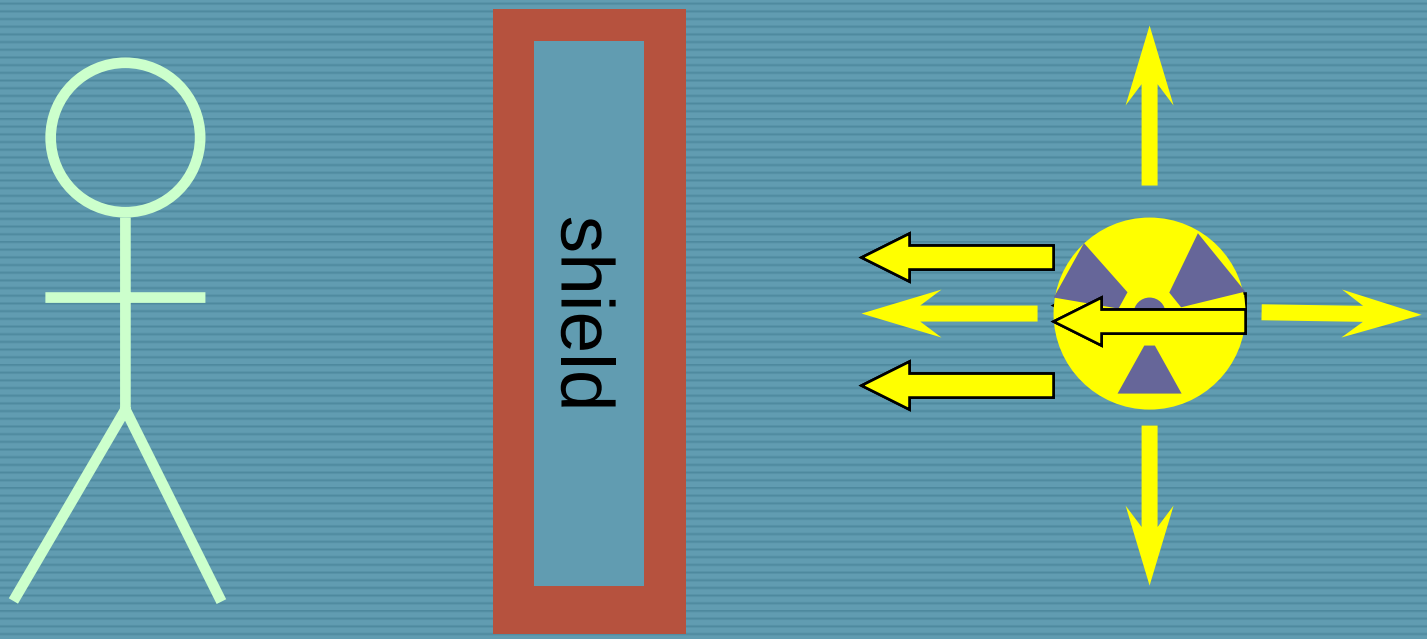
- As with all forms of radiation, increasing the distance between yourself and the source of radiation will decrease your dose.

- Ionizing radiation follows the inverse square law. Doubling the distance decreases the dose by a factor of four. Tripling the distance decreases the dose nine-fold!

Ionizing Radiation = 1 / r^2

Shielding

- Increasing the shielding of a radiation source decreases radiation exposure



Shielding: Use Appropriate Shielding

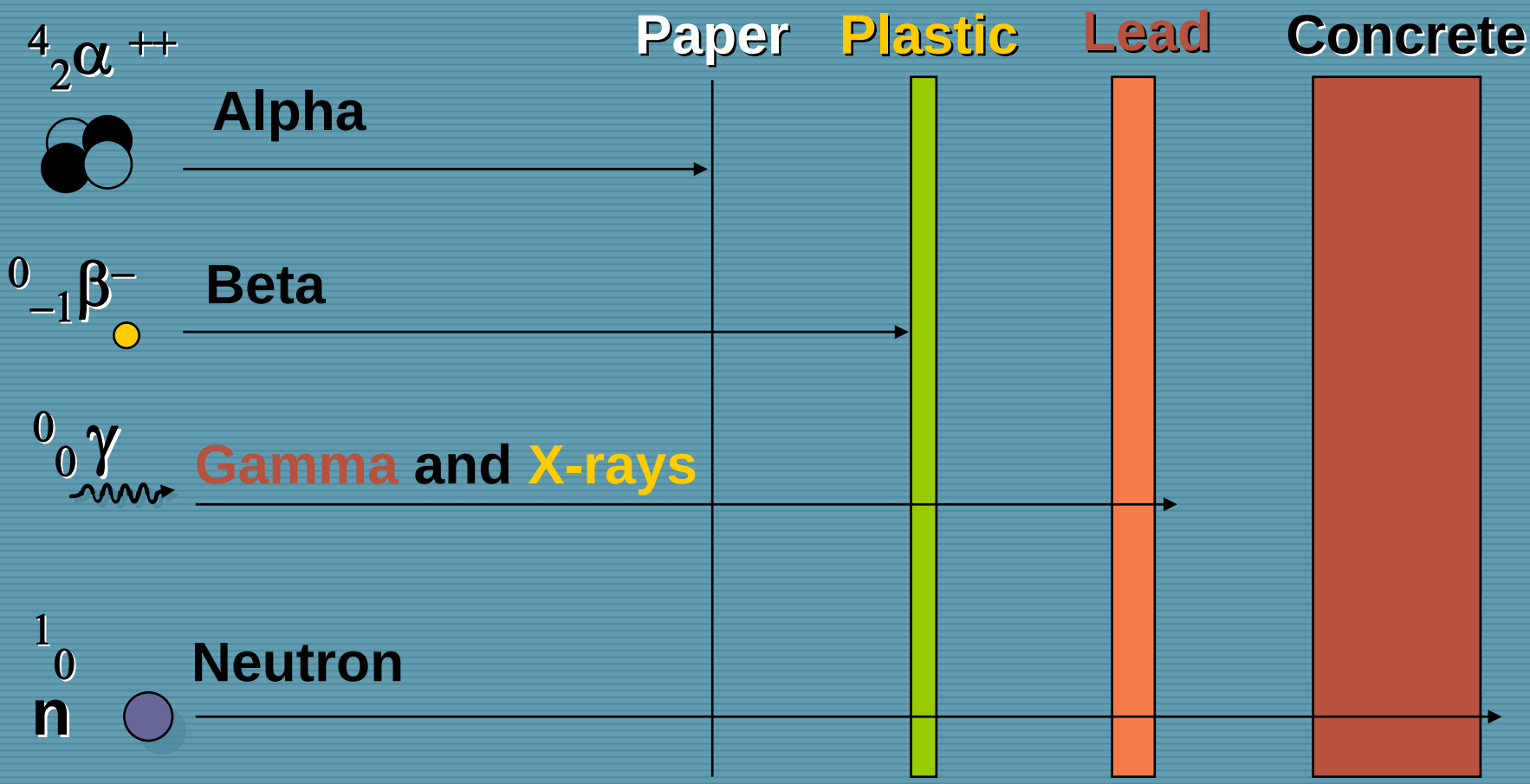
- Increasing the distance is not always the most practical means of reducing one's exposure.
- Shielding is the most common and usually cost effective means of keeping doses as low as reasonably achievable.
  - For example, if you work with radiography equipment, using a lead apron may be appropriate.
  - If you work with analytical X-ray equipment, using leaded Plexiglas instead of unleaded is preferred.

Shielding: Use Appropriate Shielding

- The materials that are used in the manufacture of EM are more than adequate for shielding an operator from the low energy X-ray radiation that is generated by these devices.
- Leaded glass is used to provide shielding at viewing and sample ports.
- Occasionally, lead foil is used at points along the beam path where exposures above background are detected

Shielding: Use Appropriate Shielding

Comparisons on shielding requirements for X-rays



Enclosure Shields & Interlocks

Most analytical systems have an enclosure shield designed to protect the user from the Radiation scattered off the sample, detector and beam stops.

NOT ALL ENCLOSURE SHIELDS ARE INTERLOCKED !!!!

Leak Test

- Annual leak test recommended or after equipment has been moved or modified.
- Dose rate must not exceed 5 μGray/h 5 cm from any accessible external surface
- Contact Radiation Safety Officer to arrange test

Radiation Controls

Personnel Protective Equipment (PPE)

Personnel Protective Equipment (PPE)

DOSIMETRY

- Devices monitor and record ionizing radiation doses
  (occupational exposure)
- Must distinguish from background radiation

Personnel Protective Equipment (PPE)

- record cumulative whole body dose (mSv)
- prevent over-exposure
- worn at the chest or waist levels
- Each badge is assigned to a specific individual and *cannot be* shared by others
- worn only at work and not taken off campus

Personnel Protective Equipment (PPE)

- badge must not be left in an area where it could receive a radiation exposure when not worn by the individual (e.g. on a lab coat or left near a radiation source).
- store badges in a dark area with low radiation background (in low light away from fluorescent or UV lights, heat and sunlight).
- lost or damaged badges should be reported immediately to the Radiation Safety Officer and a replacement badge will be issued.
- results from exposure monitoring are maintained and evaluated by the Radiation Safety Officer, the Department of Geology or the Human Resources.

Radiation Controls

Warning Signs and Labels

Warning and Safety Devices

Operators must be made aware of the significance of the various radiation warning and safety devices and interlocks incorporated into the equipment and the extra precautions necessary if the devices are absent or bypassed.

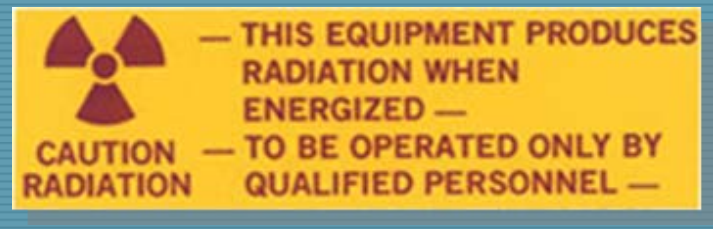
X-ray On Light

An “X-ray” or “HV On” light must be near the tube head. This warns the user that the tube is energized and generating X-rays.

Shutter Indication Lights

Whenever you change a sample, always check the shutter indication lights on both the control panel and the shutter assembly, to verify the shutter is in a closed and safe configuration.

Labels



A label bearing the words “Caution – High Intensity X-ray Beam” must be attached near the tube head or in the area of the primary beam path.

Labels

A label bearing the words “Caution Radiation – This Equipment Produces Radiation When Energized” must be near any switch that energizes the X-ray tube.

Warning Indicators

- X-ray system or equipment must be labeled with a sign stating ***"Caution Radiation – This Equipment Produces Radiation When Energized"***

Other X-ray System Hazards

1. Radiation is not the only safety concern you may encounter when working with X-rays. Electrical, chemical and temperature hazards may cause serious injury and even death.
2. Take time to identify the other possible safety issues and use proper safety controls to minimize the chance for injury.

Electrical

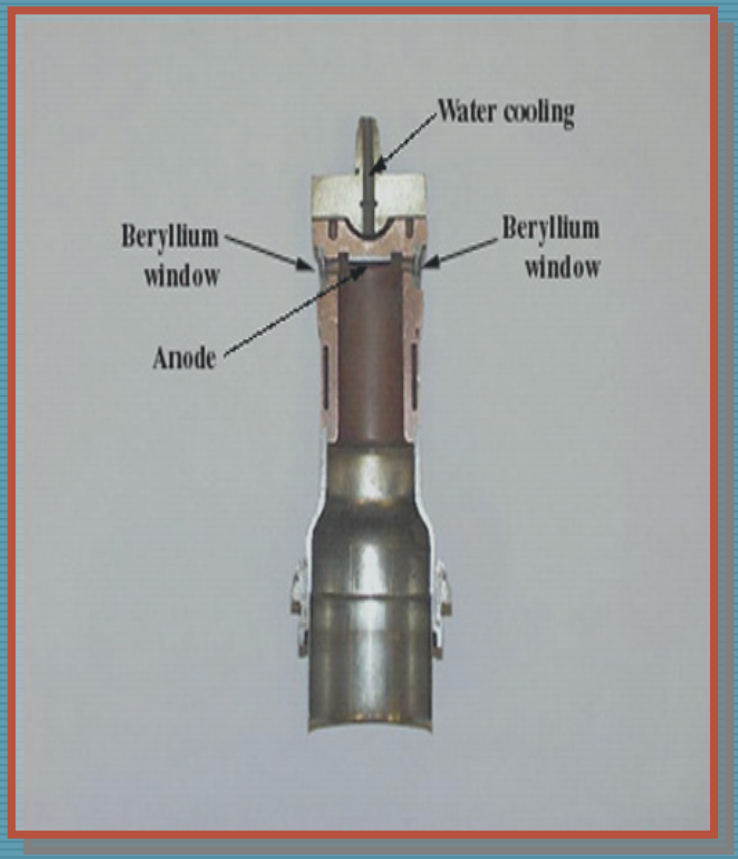
All X-ray systems operate on high voltage. The generator and other electrical components are normally enclosed in a protective cabinet that provides a barrier between open electrical terminals and the user. In this picture, the cabinet is located below the tube.

Electrical

- X-ray tube changes, maintenance and repairs are only to be performed by someone trained and experienced in electrical safety and must never be done by X-ray users.
- Cover panels (as seen here) must be replaced for user safety. Open wiring and high voltage are a DEADLY combination.

Chemical

- There are many chemical hazards associated with X-ray systems.
- Analytical X-ray tubes contain beryllium, a toxic metal.
- Unless they are being returned to the manufacturer, all X-ray tubes must be disposed of as hazardous waste.



Chemical

- Other chemical hazards include lead, oils, and sometimes even the material being analyzed.
- Many samples contain heavy metals that may also be toxic. Some users are even analyzing biological materials.
- Always contact EHS for guidance on chemical safety and proper waste disposal.

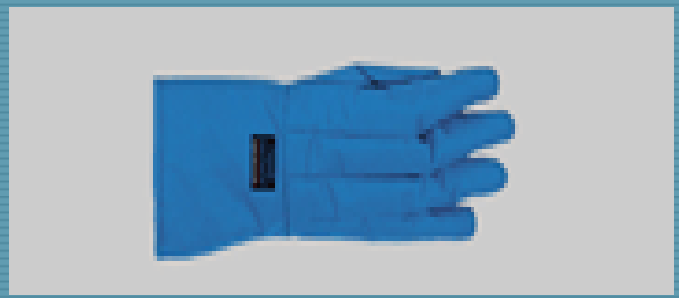
Temperature

- Many analytical systems use detectors cooled with liquid nitrogen, a cryogenic liquid with a temperature of -195 C!
- Splashes of liquid nitrogen on your hands will cause burns immediately. If it splashes in your eyes it can blind you!

Temperature

Filling dewars with liquid nitrogen usually results in the liquid boiling and splashing out of the spout and the dewar.

ALWAYS wear a shield to protect your face and eyes.



ALWAYS wear gloves to protect your hands.

Unsafe conditions

Examples of unsafe conditions: Access door interlocks do not work, shielding has been damaged, or viewing window is cracked.

If an unsafe condition arises with your X-ray device;

- Stop work!
- Turn power OFF to X-ray (An X-ray requires power to produce radiation)
- Notify your Principal Investigator, eXact! personnel and UPRM-Radiation Safety Office @ 787-832-4040 ext. 3221, 3506 and 3886.

Biological Effects

- X-Ray Effects
- Sources of Radiation Exposure
- Radiation Exposure Limits
- Causes of Exposure
- Main Causes of Accidents
- Radiation Dose
- Acute Exposure
- Why the Difference in Exposure Limits?

X-Ray Effects

The effects of x-ray exposure depends upon:

- **Duration - How fast the dose is delivered.**
- **Energy - How much energy was in the x-ray**
  - **Low Energy (<50 KeV) - damage only to skin or outer part of body**
  - **High Energy - damage to internal organs**
- **Total Dose - The magnitude of the dose**

Sources of Radiation Exposure

- The next step is to identify and address the possible sources of radiation exposure you may encounter with the X-ray system. There are three areas that pose a risk of radiation exposure to the user and bystanders;
  1. Exposure to the primary beam;
  2. Exposure to leakage from the tube housing;
  3. Exposure to the scattered radiation field.

Radiation Exposure Limits

- There are different exposure limits for different parts of the body
  - The whole body (consisting of the head, torso to knees, to elbows) has an annual exposure limit of 5 Rem
  - The extremities (consisting of the elbows and below and the knees and below) has an annual exposure limit of 50 Rem

Causes of Exposure

Any of these actions could cause an unnecessary exposure and a potential negative effect.

- Putting fingers in X-ray beam to change sample
- Aligning X-ray beam visually
- Modification of shielding
- Failure to realize X-rays are emitted from several ports
- Failure to read & follow manufacturers X-ray operating instructions

Main Causes of Accidents

- Main causes of accidents when using X-Ray producing devices:
  - Poor equipment configuration,
  - manipulation of equipment when energized,
  - equipment failure,
  - inadequate training and failure to use the survey instrument.
- Accidents can often lead to what is know as an acute exposure or a large exposure occurring in a short period of time.

Radiation Dose

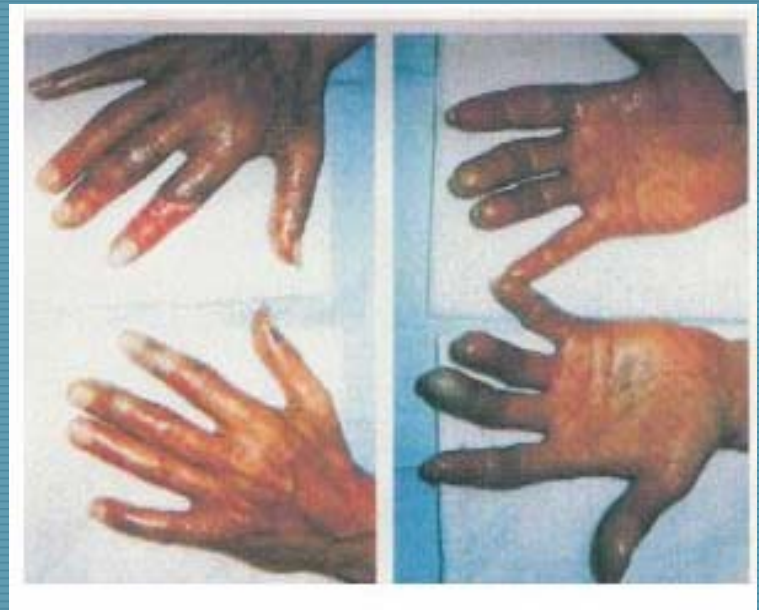
Dose Equivalent = Radioactive energy deposited in human tissue

- Unit of measure is Sievert (Sv)
- Old units still used are called rem
  - 1 Sv= 100 rem 1 mSv = 100 mrem

- In North America, the dose from natural sources is between 2 to 3 mSv per year (=200-300 mRem per year)
- Maximum allowable occupational exposure X-ray Worker = 50 mSv/y

Acute Exposure

- 25-100 REM: Minor blood changes
- 100-200 REM: Nausea, vomiting, diarrhea, hair loss, skin reddening
- 200-300 REM: Same as above plus internal bleeding
- Above 300 REM: Severe blood disorders & death
- >450 REM: LD 50 = 50% of test animals will die within 30 days without medical attention; blood transfusions & bone marrow transplants.



Why the Difference in Exposure Limits?

- Answer-Radiosensitivity: Cells of the human body respond to radiation differently, some are more sensitive than others i.e. Lymphatic and bone marrow.
- In other words, the cells in the region defined as your whole body are more sensitive to radiation than the cells in your extremities. Therefore, the annual exposure limit for your whole body is lower.

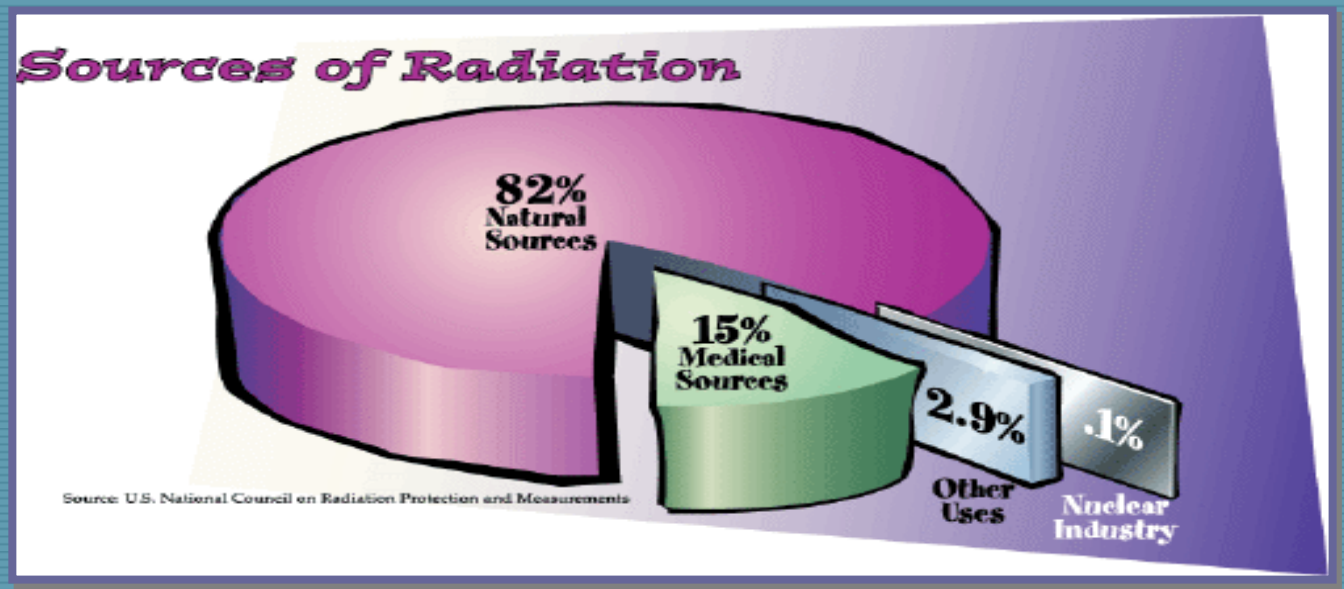
Summary

- *Background radiation*
- *Control of Exposure*
- *Radiation Protection Basics*
- *Signs & Labels*
- *Radiation Monitoring Equipment (PPE)*
- *Causes of Accidents*

Background Radiation

Summary

- Natural and manmade sources
- Radon ~ 55% of natural sources
- 11% from medical X-rays



Control of Exposure

Summary

ALARA = As Low As is Reasonably Achievable

The ALARA Principle is a philosophy of radiation safety that every reasonable effort should be made to minimize dose. This guiding philosophy has actually been incorporated in regulations for all entities that possess radioactive material. The ALARA provision in regulations facilitates proactive measures for radiation protection and safety.

Radiation Protection Basics

Summary

Exposure to any radiation is reduced if:

- **TIME** exposed to source is decreased
- **DISTANCE** from source is increased
- **SHIELDING** from source is increased

Signs & Labels

Summary

- X-ray warning signs or devices posted in visible location on equipment & door

- ENERGIZED EQUIPMENT

Radiation Monitoring Equipment Summary

With the use of a survey instrument we can determine the exposure rate in the area.

- ✓**A Pre-Operational Check must be completed prior to using an instrument. This check consists of a physical assessment, calibration check, battery check and response to radiation.**
- ✓**Readout is in milliRoentgen (mR) /hour.**
- ✓**Typical background is ~0.02 mR/h**
- ✓**Contact the RS Office should the device fail any of the checks.**

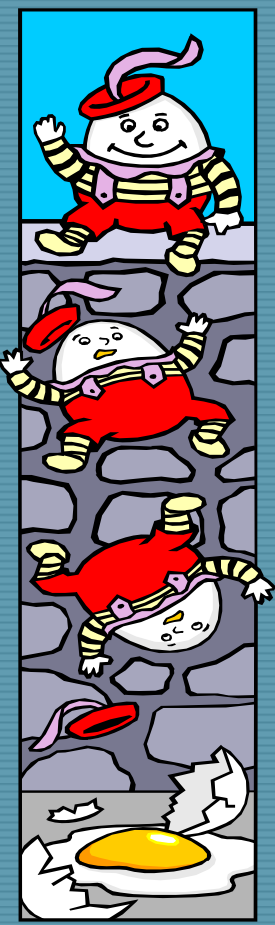
↳ **A survey is to be performed at the beginning, during and upon completion of using a x-ray generating device.**

Causes of Accidents

Summary

Accidents (i.e., exposure to individuals) caused by exposure to X-ray beam from either direct contact of primary beam or exposure to leakage or scatter.

- Lack of training
- Improper equipment configuration
- Handling samples when machine energized



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