X-RAY SAFETY TRAINING

Objectives

- **DEFINE ionizing radiation.**
- **IDENTIFY sources of natural and manmade background radiation.**
- **DESCRIBE the ALARA principle.**
- **LIST major methods utilized to reduce external exposure.**
- **DIFFERENTIATE between X-rays and gamma rays.**
- **IDENTIFY how X-rays are produced.**

Objectives (continued)

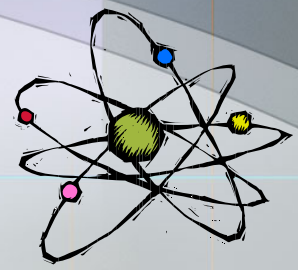
- **DESCRIBE how X-ray tube voltage and current affect photon energy and power.**
- **EXPLAIN how X-rays interact with matter.**
- **DISCUSS the effects of voltage, current, and filtration on X-rays.**
- **IDENTIFY factors that determine the biological effects of radiation exposure.**

Objectives (continued)

- **DIFFERENTIATE between an X-ray burn and a thermal burn.**
- **IDENTIFY the signs and symptoms of an acute dose from X-rays.**
- **IDENTIFY the instruments used for X-ray detection.**
- **IDENTIFY typical RPD warning devices.**
- **CONTRAST incidental and intentional X-ray devices.**
- **IDENTIFY open and enclosed beam installations.**

Atoms

- **Basic unit of matter**



- **Three primary particles**
  - **Protons – nucleus – positive charge**
  - **Neutrons – nucleus – no charge**
  - **Electrons – orbiting nucleus – negative charge**
- **Number of electrons and protons are normally equal**
- **Electron shell configuration determines chemical properties of atom**

Ionization

- **Process that will leave behind an electrically charged atom**
  - **Positive**
  - **Negative**
- **Free electrons**
- **Formed when ionizing radiation interacts with electrons causing it to be ejected form orbital**

Ionizing Radiation

- **Capable of producing ionization**

- **Examples:**
  - **Alpha particles**
  - **Beta particles**
  - **Gamma rays**
  - **X-rays, neutrons**
  - **High-speed electrons**
  - **other particles**

Non-Ionizng Radiation

- **Radiation that lacks the energy to produce ionization**

- **Examples:**
  - **Radio waves**
  - **Microwaves**
  - **Visible light**

Electromagnetic Radiation

- **X-rays and gamma rays are a form of electromagnetic radiation**

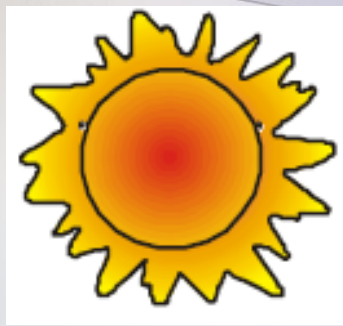
- **Differ in their point of origin**
  - **Gamma rays**
    - **Originate in nucleus of atom**
    - **Higher energy (MeV)**
  - **X-rays**
    - **Originate in electron shell**
    - **From free electrons decelerating in atom vicinity**
    - **Lower energy (KeV)**

Radiation Units

- **Roentgen (R)**
  - **Measure of ionization in air**
- **Rad (Gray)**
  - **Measure of energy absorbed per unit mass**
  - **Any material**
- **Rem (Sievert)**
  - **dose equivalent**
  - **Measure of energy absorbed per unit mass**
  - **Quality factors**

Background Radiation

- **Natural**
  - **Cosmic**
  - **Terrestrial**
    - **Radon**
    - **Internal**
- **Man-Made**
  - **Medical procedures**
  - **Consumer products**



Dose Limits

- Occupational doses based on biological effects of ionizing radiation
- Set by Nuclear Regulatory Commission and Texas Department of State Health Services

Whole Body (Total Effective Dose Equivalent)	5 Rem/yr
Extremity Skin Internal Organ (Committed Dose Equivalent)	50 Rem/yr
Lens of Eye	15 Rem/yr
Embryo/fetus	0.5 Rem/term
Minors/Public	0.1 Rem/yr

Ionizing Radiation Exposure Effects

- **Large dose exposure received in a short period of time.**
  - **50 to 100 Rem – nausea, vomiting, diarrhea**
  - **> 100 Rem – more severe effects**
  - **> 1000 Rem – survival unlikey, possible with medical treatment**

ALARA

- **Effects of chronic low level dose NOT precisely known.**
- **Keep radiation dose as low as reasonably achievable considering social and economical restraints.**
- **ALARA Program goal :**
  - **Keep radiation dose as far below the occupational dose limits and administrative control levels as is reasonably achievable.**
- **ALARA Program success:**
  - **Directly linked to a clear understanding and following of the policies and procedures.**

Exposure Reduction Methods

- **Quantity**
  - **Reducing the emission rate for electronically generated radiation results in lower exposure**
- **Time**
  - **Minimize time in radiation field to reduce overall exposure**
- **Distance**
  - **The further you are away from a point source the lower the radiation exposure rate**
  - **Dose is inversely proportional to the square of the distance**
- **Shielding**
  - **Certain types of materials will reduce exposure rate when between you and the source of the radiation**
  - **Lead, concrete, and steel effective for X-rays and gamma rays**

Electromagnetic Radiation

- Consists of photons which are individual packets of energy
- Energy measured in ev

Radiation Type	Typical Energy	Typical Wavelengths
Radio Wave	1 μeV	1 m
Microwave	1meV	1 mm (10^{-3} m)
Infrared	1 eV	1 μm (10^{-6} m)
Red light	2 eV	6000 Angstrom
Violet light	3 eV	4000 Angstrom
Ultraviolet	4 eV	3000 Angstrom
X-ray	100 keV	0.1 Angstrom
Gamma	1 MeV	0.01 Angstrom

X-ray Production

- **Radiation producing devices**
  - **Electrons are accelerated through an electrical voltage potential and stopped in a target**
- **Bremsstrahlung**
  - **Braking radiation**
  - **When electrons hit anode the decelerate by emitting Bremsstrahlung X-rays**
- **Characteristic X-rays**
  - **Electrons change from one atomic orbital to another**
  - **Characteristic x-ray is produced**
  - **Energy is characteristic of the atom and can be used to identify the atom**

X-ray Beam

- **Individual photon energies given in electron volts**
- **Power of the beam given in Watts**
- **X-ray beam consists of spectrum of photon energies**
- **Photon energy distribution is varied by changing the voltage.**
- **The number of photons emitted is varied by changing the current**

Interaction with Matter

- **X-rays passing through material will:**
  - **Transmitted**
  - **Absorbed**
  - **Scattered**

- **Interaction dependent on**
  - **Photon energy**
  - **Type of material**
  - **Thickness of material**

X-ray Effects

- **Skyshine**
  - **Effect seen when X-rays scatter off of air molecules over or around shielding to create a radiation field on the other side of the shielding**
- **Streaming**
  - **Effect seen when X-rays pass through and around penetrations in shielding walls**

Power Effect on X-ray Production

- **Anode Target**
  - **Majority of high-speed electron energy converted to heat energy**
  - **Power delivered over short period, typically < 1 second**

- **Percentage of electron energy converted to X-rays**

$$7 \times 10 - 4 \times Z \times E$$

$Z = \text{Atomic number of element}$

$E = \text{maximum energy of incoming electrons (MeV)}$

Types of X-rays

- **Hard X-ray**
  - high energy photons
  - More penetrating = more desirable for radiography

- **Soft X-rays**
  - low energy photons
  - Less penetrating = absorbed near surface of material
  - Medical applications

Filtration

- **Filtration can be used to:**
  - **Harden the beam (remove lower energy photons) by using a few millimeters of**
    - **Aluminum**
    - **Copper**
  - **Filters with energy selective edges are used to obtain a monochromatic beam**
    - **By choosing the right element it is possible to absorb a band of high energy photons preferentially over an adjacent band of low energy photons.**

Biological Effects

- X-rays can penetrate body and ionize atoms.
- Radicals created that can break or modify chemical bonds.
- If in a critical biological molecule can cause:
  - Cell injury
  - Cell death
  - Radiation induced cancer
- Some cells may repair damage
- If enough cells in an organ affected, organ function may be impaired

Factors Affecting Biological Effect

- **Dose rate**
  - **Acute dose – dose received over short period**
  - **Chronic dose – dose received over long period**
- **Total dose received**
  - **The greater the total amount of radiation received the greater the biological effect**
- **Energy of radiation**
  - **The higher the energy the more penetrating the radiation**
- **Area of body exposed**
  - **Radiation dose to the whole body is more damaging than radiation dose received to a small area**

Factors Affecting Biological Effect (continued)

- **Individual sensitivity**
  - Some individuals are more sensitive than others
  - Age, gender, and overall health affect body's response
- **Cell sensitivity**

•Radiosensitive cells

- –Germinal
- –Hematopoietic
- –Epithelium of the skin
- –Epithelium of the gastro-intestinal tract

•Radioresistant Cells

- –Bone
- –Liver
- –Kidney
- –Cartilage
- –Muscle
- –Nervous system tissue

Burn Comparison

- **Thermal Burn**
  - Warning of heat or thermal burn during reaction
  - Harm done to outer, mature, skin layers
  - Deeper layers of skin can be affected depending upon burn severity
- **X-ray Burn**
  - No warning or sensation during reaction
  - No harm done to outer, mature, non-dividing skin layers
  - X-rays penetrate to deeper Basal layer of skin damaging or killing germinal cells
  - Sloughed off outer layer cells not replaced
  - X-ray burns slower to OR never heal

Symptoms of X-ray Burns

- ~ 600 Rads
  - Equivalent to first degree thermal burn or mild sunburn
  - Sensation of warmth or itching within a few hours
  - Reddening or inflammation of area
  - Dry scaling or peeling of skin
  - Acute dose to eye start cataract formation

- ~ 1000 Rads
  - Equivalent to second degree thermal burn
  - Reddening or inflammation of area followed by swelling and tenderness
  - Blistering within 1 to 3 weeks
  - Can result in infection
  - Hand exposure can result in stiffness causing motion to be painful

Symptoms of X-ray Burns (continued)

- ~ 2000 Rads
  - Sever tissue damage similar to scalding or chemical burn
  - Intense pain and swelling within hours
  - Skin grafting may be required to heal wound
  - Damage to blood vessels also occur

- ~ 3000 Rads
  - Completely destroys tissue
  - Surgical removal (grafting) is required

Latent Effects of Radiation Exposure

- **Effects depend upon the amount of dose received**
  - **The higher the dose = the greater the risk**
- **No unique disease associated with exposure**
  - **Possibility of cancer**
- **Low Dose Rates**
  - **Not possible to quantify risk of cancer from low doses due to large natural cancer risk (~20%)**
  - **Estimates developed from high dose rate studies**
  - **Below 10 Rem health effects are too small to measure**
  - **Dose limits set to establish risk on par with workers in safe industries**

Factors Affecting X-ray Detection

- **Instrument selection based on type of energy of the radiation and the radiation intensity**
- **Correct operation of instrument based on instrument operating characteristics and limitations**
- **Calibration of instrument to known radiation field similar in type, energy , and intensity to the radiation field to be measured**

GM – Ion Chamber Comparison

- **Geiger-Mueller**
  - **Good sensitivity**
  - **Sensitive to both high and low energy photons**
  - **Normally read in cpm or dpm**
  - **Does NOT quantify a dose well**
  - **Good for detection**
  - **NOT good for measurement**
- **Ion chamber**
  - **Not as sensitive as GM**
  - **Measures energy deposited**
  - **Normally measure energy deposited in mR/hr or R/hr**
  - **GOOD for measurement of X-ray**

Personnel Monitoring Devices

- **Whole Body dosimeters**
  - Thermoluminescent dosimeters or film badges
  - Accurately measure doses down to 10 mrem
  - Sent to processor to be read
- **Extremity dosimeters**
  - Used to assess radiation dose to fingers and wrist
- **Pocket Dosimeters**
  - Pencil or electronic dosimeters
  - Give immediate readout
- **Alarming dosimeters**
  - Provide audible warning

Radiological Controls

- **Administrative controls**
  - **Postings**
  - **Warning signals**
  - **Warning labels**
  - **Work control documents**
- **Engineering controls**
  - **Interlocks**
  - **Shielding**

Radiological Postings

- **Purpose of postings**
  - **Inform workers of radiological conditions**
  - **Inform workers of entry requirements for an area**
- **General Posting requirements**
  - **Must contain standard radiation symbol colored magenta or black on yellow background**
  - **Conspicuously posted**
  - **May include instructions**
  - **Door postings must remain visible when open or closed**

Interlocks

- **Make X-ray production impossible**
- **Should be provided on doors and access panels**
- **ANSI Standards**
  - **Interlocks should be tested every 6 months**

Shielding

- **Manufacturer provides shielding in accordance with ANSI N43.2**
- **Should be surveyed to determine adequacy**
- **Analytical Systems**
  - **Enclosed Beam Systems**
  - **Dose rate at 5 cm does NOT > 0.25 mrem/hr**
- **Industrial Systems**
  - **Some completely enclosed in an interlocked and shielded cabinet**
  - **Larger systems enclosed in shielded rooms**

Warning Devices

- Current meter on X-ray control panel
- Warning light on or near control panel
- Warning light near any room door

Incidental vs. Intentional Comparison

- **Incidental X-ray Device**
  - **Produces X-rays that are not wanted or used as part of design purpose**
  - **Shield of device should preclude significant exposure**
  - **Examples**
    - **Computer monitors**
    - **Televisions**
    - **Electron microscopes**
    - **High voltage electron guns**
    - **Electron beam welding machines**
- **Intentional X-ray Device**
  - **Designed to generate an X-ray beam for a particular use**
  - **Examples:**
    - **X-ray diffraction systems**
    - **X-ray fluorescence systems**
    - **Flash X-ray systems**
    - **Medical X-ray systems**
    - **Industrial cabinet X-ray**
    - **Industrial non-cabinet X-ray systems**

Intentional Analytical Devices

- **Two types**
  - **Open beam**
    - **One or more X-ray beams are NOT enclosed**
    - **Acceptable for use only if enclosed beam is not practical**
  - **Enclosed beam**
    - **All X-ray paths are completely enclosed**
    - **No part of human body can be exposed during normal operation**

Intentional Industrial Devices

- Used for radiography
- Classes of industrial installations
  - Cabinet
    - X-ray in an enclosure, excludes individuals during process
  - Exempt Shielded
    - Provides high degree of safety
  - Shielded
    - Less shielding with more reliance on protective measures
  - Unattended
    - Does not require personnel in attendance
  - Open
    - X-ray paths not enclosed
    - Requires personnel at all times