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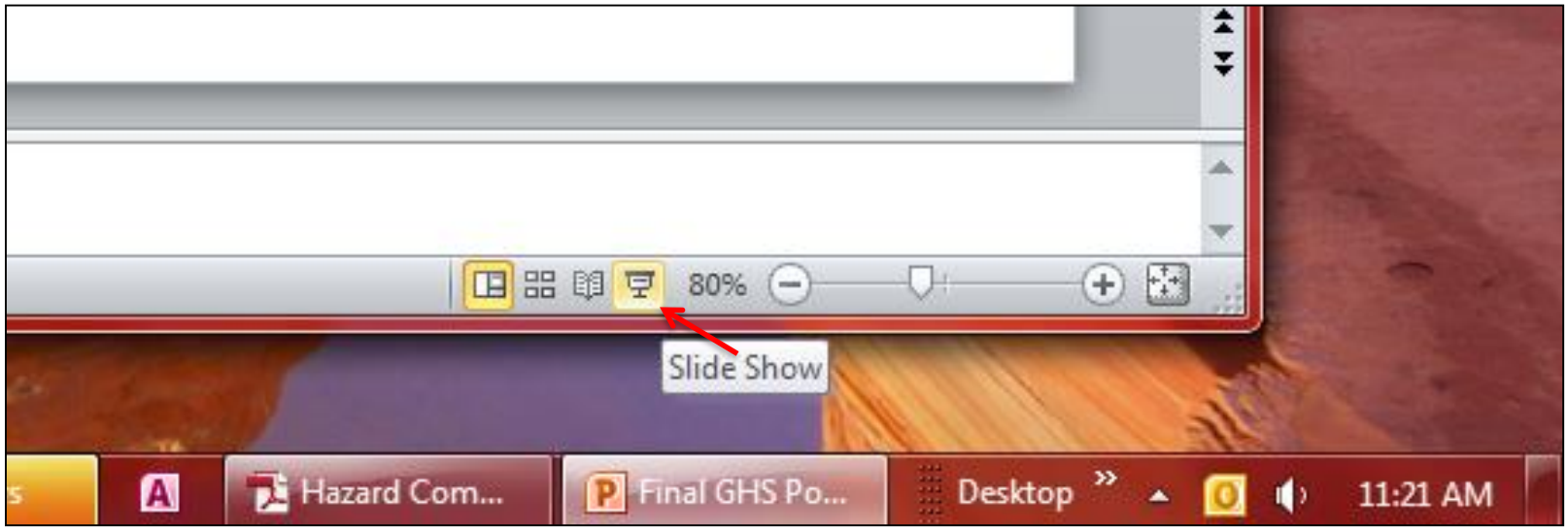

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X-RAY TRAINING

DIAGNOSTIC MODULE

Created 9/2013

X-RAYS

- X-rays are a type of ionizing electromagnetic radiation.
- X-rays are a valuable tool, but there are associated health risks.
    - These risks can be minimized by adhering to certain principles and practices as explained in this module.
- X-rays are capable of traversing great distances and have the ability to penetrate material.
- However, they can be blocked or attenuated by shielding made from dense materials such as lead and concrete.

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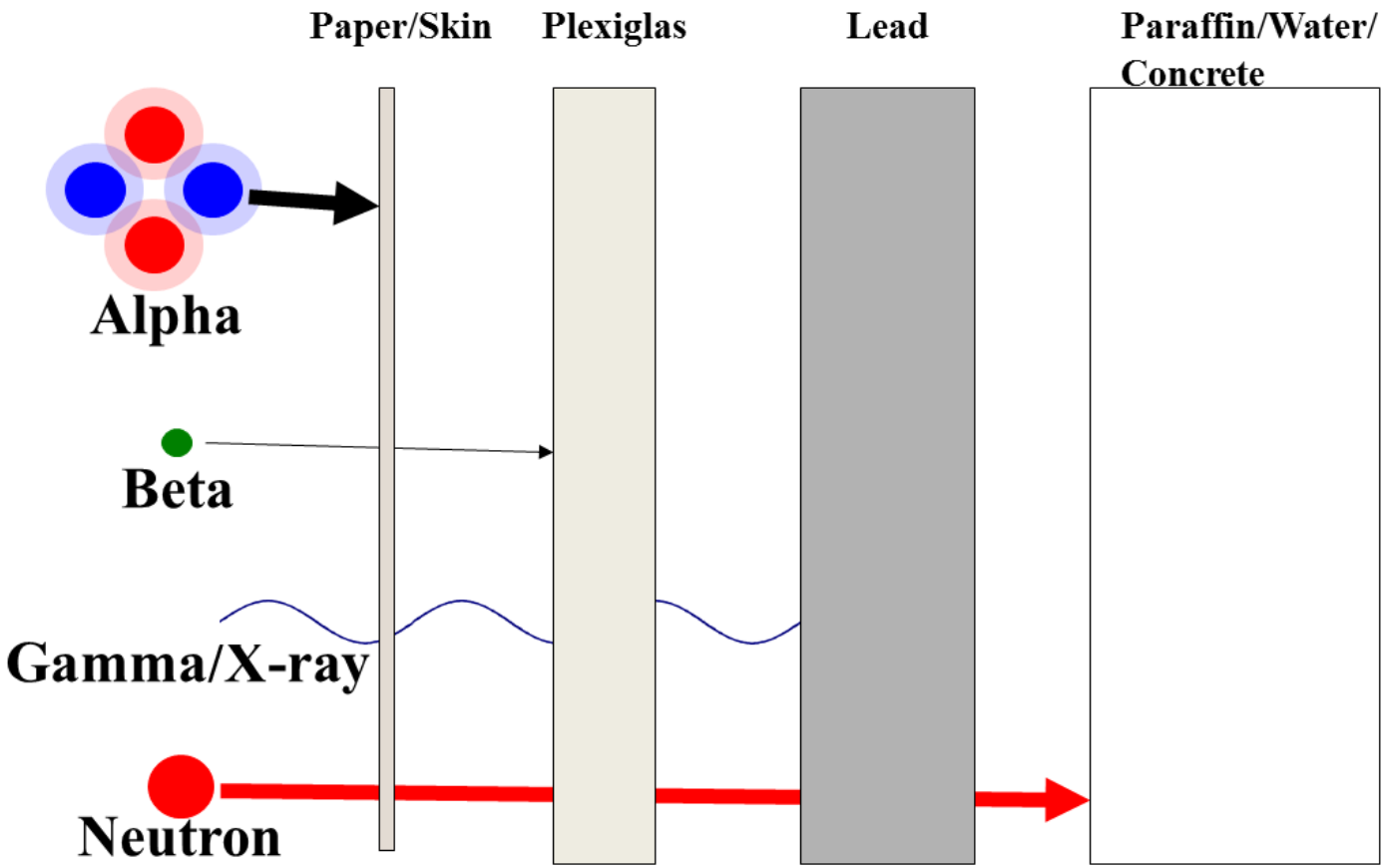
X-RAY SHIELDING



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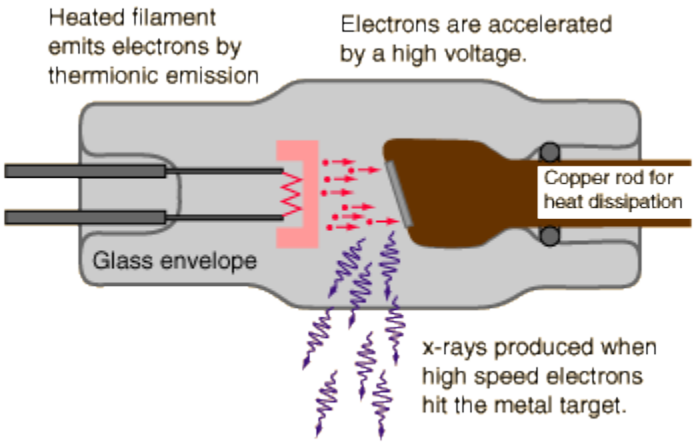
X-RAY PRODUCTION

- X-rays are produced when electrons, that have been accelerated using a high voltage source, are abruptly decelerated by hitting a metal target.
- Some of the energy of the electrons that impinge upon the target are converted into X-rays.
- X-ray production is proportional to operating potential (kVp) and current (mA)



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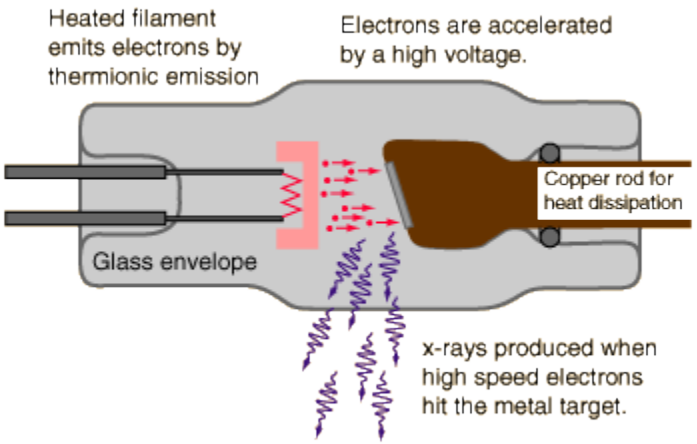
X-RAY PRODUCTION

- When the X-ray unit is not operating or it is powered down, the high voltage is not applied and X-rays are not produced.
- Therefore, there is no danger present when the machine is not operating or it is powered down.



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BIOLOGICAL EFFECTS, DOSE LIMITS AND GENERAL RADIATION SAFETY

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DOSE

- Radiation induced biological effects result from the deposition of energy from the interactions of incident radiation with the target tissue. Therefore, radiation damage is approximately proportional to the 'Absorbed dose'. Absorbed dose is defined as:
  - The quotient of the energy absorbed from radiation interacting with the target tissue and the mass of the target tissue.

$$Absorbed\ Dose = \frac{Energy\ Absorbed}{Tissue\ Mass}$$

  - Units: rad or Gray (Gy)
- Effective Dose Equivalent (hereafter simply referred to as "dose")
  - Takes into account the biological effectiveness of that particular radiation, and tissue sensitivity.
  - More useful that absorbed dose
  - Units: rem or Sievert (Sv)

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BIOLOGICAL EFFECTS

- Acute exposures
  - One-time event
  - High level doses involved (> 100 rem)
  - Symptoms appear quickly (within days to weeks)
  - This type of exposure is virtually improbable with X-ray units.
- Chronic exposures
  - Long-term
  - Low level doses involved
  - Effects will appear slowly because the body has time to heal itself after exposure. The effects, if any, will appear 20-30 years after exposure.

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INJURIES FROM LARGE EXPOSURES

Injuries experienced as a result of radiation exposure include the following:

- Radiation burns from acute exposures
- Radiation sickness from both acute and chronic exposures
- Long-term effects from acute and chronic exposures

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RADIATION BURNS

- Occur as a result of an acute localized exposure.
- Radiation burns can occur from a wide range of exposures and usually result from a direct exposure to the primary beam.
- The hands, fingers and eyes are the parts of the body most commonly at risk.
- The severity of the burn will depend on the dose received, the length of the exposure , the energy of the x-rays and the sensitivity of the individual.
- Burns can be caused with exposures of 300 rem, but normally do not become apparent below exposures of at least 600 rem.

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RADIATION SICKNESS

- Occurs when a large dose is received to the whole-body.
- Symptoms usually will not start to appear unless the exposure is greater than 100 rem delivered within a few hours. Blood changes can occur at exposures as low as 25 rem.
- If a whole-body dose of 400-500 rem is received, approximately 50% of those exposed will die within 30 days if untreated (LD50/30). Recovery is likely with medical care although the exposed individual will suffer several months of illness.
- Exposure to a dose in excess of 700 rem to the entire body in a short period of time will likely result in death within a few weeks.
- If the radiation dose is spread over several weeks, a person may survive a whole-body dose as large as 1000 to 2000 rem.

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DOSE LEVELS FOR BIOLOGICAL EFFECTS

Acute Whole-Body Exposure	
Symptom	**Dose (rem)**
Blood Cell Changes	25-50
Nausea, Diarrhea	100
Hair Loss	250
Erythema	300
Sterility/Death ($LD_{50/30}$*) - no treatment	450 - 500
No Recovery Expected (LD_{100}**)	
Gastrointestinal Syndrome	1000
Central Nervous System Syndrome	>2000

* The dose of radiation expected to cause death to 50 percent of an exposed population within 30 days
** The dose of radiation expected to cause death to 100 percent of an exposed population

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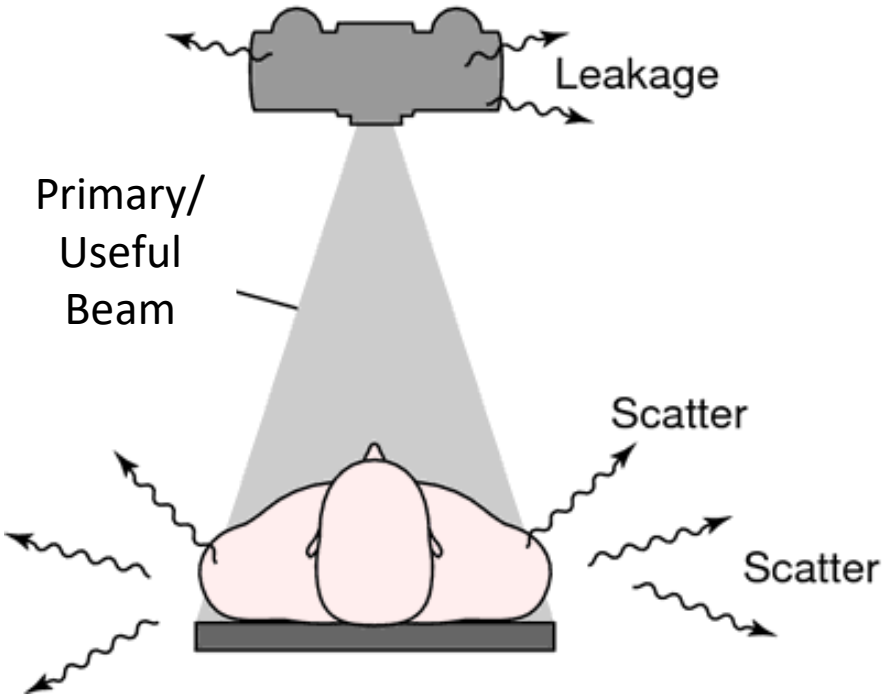
LONG-TERM EFFECTS

- Long-term effects resulting from chronic exposure to ionizing radiation include carcinogenesis, life span shortening, and cataract formation. The principle delayed effect from chronic exposure to radiation is an increased incidence of cancer.

- Long-term effects of an acute exposure to radiation are often classified as leukemia and other cancers, radiation-induced life shortening, genetic effects and embryonic effects.
  - Genetic defects are less likely than cancer, and not as serious, therefore, the risk of developing cancer from radiation exposure is more significant.
  - Radiation exposure in-utero can result in spontaneous abortions, congenital abnormalities, impairment of growth and mental functions, and increased incidences of leukemia.

EXPOSURE: SCATTER AND LEAKAGE

- Primary/Useful Beam: radiation which passes through an aperture of the source housing by a direct path from the x-ray tube or a radioactive source located in the radiation source housing.
    - The hands, fingers and eyes are the parts of the body most commonly at risk.
- Scatter Radiation: radiation that scatters from radiation interactions between the primary beam radiation and material.
- Leakage Radiation: radiation emanating from the source assembly except the useful beam and that radiation produced when the exposure switch or timer is not activated.
- Scatter and Leakage present the potential for low-level chronic exposure that may lead to unnecessary over-exposures and biological effects for the users.



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EXPOSURE/DOSE LIMITS

- In an effort to reduce the risk of potential health effects caused by radiation, regulatory agencies have set exposure/dose limits for those working with radiation and radiation producing devices.

- These limits are put in place to create an upper limit of how much radiation a worker is allowed to be exposed to within a certain time period.

- The limits are created such that, an individual who is exposed to the maximum allowable quantity of radiation, is well below the cut-off for the onset of serious health effects.

- X-ray limits are set forth by the Indiana State Department of Health (ISDH).

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EXPOSURE/DOSE LIMITS

ISDH Occupational Exposure Limits	
Section	Limit (rem/quarter)
Whole Body (Head and trunk; active blood-forming organs, lens of eyes; or gonads)	1.25
Skin of the whole body	7.5
Extremities (Hands and forearms; feet and ankles)	18.75

Additional Exposure Limits	
Pregnant Workers	0.5 rem/year
Non-Occupational (General Public)	0.1 rem/year
Minors	10% of ISDH occupational limits for adult workers

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PREGNANT X-RAY USERS

- Pregnant individuals should take all precautions possible to keep exposures to the embryo or fetus as low as possible.
- Extra precautions are taken by Purdue University for a Declared pregnant woman.
- *Declared pregnant woman* means a woman who has voluntarily informed Purdue, in writing, of her pregnancy and the estimated date of conception.
- If a declaration is made, it must be given to the Radiation Safety Officer (RSO) in writing.

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PREGNANT X-RAY USERS

- Once in effect, the pregnant worker's exposure limit will be reduced from 5 rem/year to 0.5 rem/year.
- In addition, that worker will be given a fetal dosimeter to monitor the dose received by the embryo or fetus.
- The declaration remains in effect until the declared pregnant woman withdraws the declaration in writing or is no longer pregnant.

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ALARA

- The risk of adverse health effects (e.g. cancer) occurring can be decreased by decreasing your dose.
- The goal is not only to remain below the exposure limits, but to keep it even lower by trying to keep doses As Low As Reasonably Achievable (ALARA).
- ALARA is not just a good idea, it is **REQUIRED** by law.
- There are several practices that will help you to keep your dose As Low As Reasonably Achievable (ALARA).
- The practice of keeping doses ALARA when using X-ray devices is mandated by the Indiana State Department of Health under *410 IAC 5 Rule 4: Protection and Exposure Standards*.

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ALARA PRACTICES-TIME

- Decreasing the time spent in a radiation area results in a lower accumulated dose.
  - Plan all work efficiently.
  - Follow the procedures or optimization techniques to avoid having to retake an X-ray.
  - Remember, X-rays units do not produce radiation unless they are in operation.

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ALARA PRACTICES-DISTANCE

- The greater the distance between you and the X-ray unit, the lower the dose.
    - Your goal is to never allow the distance between you and the unit to become zero.
    - Avoid the need to hold the patient during an exposure.

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ALARA PRACTICES-SHIELDING

- Always use shielding. The greater the shielding, the lower the dose.
  - Lead and concrete works well to attenuate X-rays.
  - Available shielding includes:
    - Lead lined doors
    - Shielded X-ray control room
    - Shielded glasses
    - Leaded aprons, thyroid collars, gloves and gonadal shields.
  - REM and your department will ensure sufficient shielding is available

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ALARA PRACTICES-DOSIMETRY

- Dosimetry measures your dose. This allows REM personnel to monitor your accumulated dose, and ensure that you do not exceed Purdue and regulatory dose limits.
- Dosimeters DO NOT protect you from radiation. They only measure your dose.
- If you are assigned dosimetry, you MUST wear it when using devices that produce radiation.
- When exposures exceed specified low trigger limits of 100 milirem during the period (monthly or bimonthly) the user is notified.
  - A form must be completed and returned to acknowledge that the user is aware of the exposure and will take steps to reduce if possible.

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ALARA PRACTICES-DOSIMETRY

- Whole body dosimeters (top right) should be worn on the torso of the body. If wearing a leaded apron, it should be worn outside. If you are given two whole body dosimeters, the second is worn behind the leaded apron.
- Ring dosimeters (bottom right), if used, should be worn on the hand receiving the highest dose, with the letters facing the palm side.
- Do not store dosimetry near sources of radiation, and always return your dosimetry at the end of each period for processing.
- A dosimetry report for each period is available by contacting REM. REM personnel will help you understand your dosimetry report.

Wear this on palm side

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ALARA PRACTICES-RESTRAINT DEVICES

- Restraint devices or retention bands should be used whenever possible.

- As a last resort should anyone stay in the room to restrain patients
    - This person should never stand in the primary or useful beam and should always use protective aprons and gloves.

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REQUIREMENTS AND SAFETY

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INDIANA REGULATIONS

- Individuals who will be operating the X-ray equipment shall be adequately instructed in proper operating procedures for such equipment.

- Written safety procedures and rules shall be available to each individual operating x-ray equipment, including any restrictions of operating technique required for the safe operation of the particular x-ray system.

- In the vicinity of each x-ray control panel, a technique guide shall be provided for routine examinations performed utilizing that system.

- Standard/Normal Operating Procedures: Step-by-step instructions necessary to accomplish the imaging.

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INDIANA REGULATIONS

- Except for patients who cannot be moved out of the room, only the staff and ancillary personnel required for the medical procedure or training shall be in the room during the radiographic exposure. **IN ADDITION** to the patient being examined, others will be protected in the following manner:
    - All individuals shall be positioned such that no part of the body will be struck by the useful beam unless protected by 0.5 mm lead equivalent.
    - Staff and ancillary personnel shall be protected from direct scattered radiation by protective aprons or whole body protective barriers of not less than 0.25 mm lead equivalent.
    - Patients who cannot be removed from the room shall be protected from direct scattered radiation by whole body protective barriers of 0.25 mm lead equivalent or shall be positioned so that portion of the body nearest to the tube head is at least 2 meters from both the tube head and the nearest edge of the image receptor.
- Gonadal shielding of not less than 0.25 mm lead equivalent shall be used for patients who have not passed the reproductive age during radiographic procedures in which the gonads are in the useful beam, except for cases in which this would interfere with the diagnostic procedure.

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INDIANA REGULATIONS

- Individuals shall not be exposed to the useful beam, except for healing arts purposes and such exposure has been authorized by a practitioner of the healing arts. Deliberate exposure for training, demonstration, or other non-healing arts purposes is prohibited.
- The following apply when a patient or film must be provided with auxiliary support during a radiation exposure:
    - Mechanical holding devices shall be used when the technique permits.
    - The human holder shall be protected as required in the previous slide.
    - No individual shall be used routinely to hold film or patients.
        - In those cases where the patient must hold the film, except during intraoral examinations, any portion of the body other than the area of clinical interest struck by the useful beam shall be protected by not less than 0.5 mm lead equivalent material.

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DIAGNOSTIC X-RAY SAFETY FEATURES

- Since diagnostic machines are used in the diagnosis and treatment of humans and animals, additional safety measures must be put in place when dealing with such units.

- Diagnostic units will have an exposed primary beam delivering treatment directly to the user. Because this primary beam is accessible, extra care must be taken to ensure that those in the x-ray room are not exposed to levels of radiation that exceed what is necessary for treatment.

- All appropriate safety features and protective measures must be put in place to ensure that the exposures to the individuals receiving treatment and the users delivering the treatment are as low as possible.

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DIAGNOSTIC X-RAY SAFETY FEATURES

- Additional shielding for the control of scatter radiation
- Collimation (exposed area visible)
- Aluminum filtration
- Warning lights signaling when the unit is being energized
- “Dead-man” switch that allows the operator to control when the unit is energized
- Shielded room
- Shielded X-ray control room or shielded protective barriers

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DIAGNOSTIC X-RAY SAFETY PRACTICES

- If available, **ALWAYS** use the shielded control room or shielded protective barrier during radiographic exposures
- If auxiliary support for the patient is required, **ALWAYS** use a restraining device
    - If a human holder is required, **ALWAYS** follow the requirements stated previously
- **DO NOT** permit individuals other than staff required for the exposure to be present in the room during the radiographic exposure
- **ALWAYS** use shielding (e.g. lead aprons, thyroid collars, gonadal shielding, leaded gloves, etc.) as required by state law
- **ALWAYS** pay attention to the audible alarm that signals the radiographic exposure event. The conditions are safe when the audible alarm silences.
- **DO NOT** place any part of your body under the primary beam unless proper shielding is worn
- **ALWAYS** wear dosimetry. If wearing an apron, wear the whole body dosimeter outside the apron. If given two whole body dosimeters, wear the second underneath the lead apron. Wear the ring dosimeter beneath gloves

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FLUOROSCOPIC SAFETY FEATURES

- Primary barrier
- Additional shielding for the control of scatter radiation
- Collimation (exposed area visible)
- Aluminum filtration
- Warning lights signaling when the unit is being energized
- “Dead-man” switch that allows the operator to control when the unit is energized
- Shielded room
- Shielded X-ray control room or shielded protective barriers

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FLUOROSCOPIC SAFETY PRACTICES

- Many procedures require staff to intermittently interact with the patient near the fluoroscopy system. The operator can reduce staff exposure by delaying fluoroscopy until these activities are completed and/or by alerting these personnel when imaging
- **DO NOT** permit individuals other than staff required for the exposure to be present in the room when operating the fluoroscopy unit
- If auxiliary support for the patient is required, **ALWAYS** use a restraining device
    - If a human holder is required, **ALWAYS** follow the requirements stated previously
- **ALWAYS** use shielding (e.g. lead aprons, shielded glasses, thyroid collars, gonadal shielding, leaded gloves, etc.)
- If possible, **DO NOT** place any part of your body under the primary beam unless proper shielding is worn
- **ALWAYS** wear dosimetry. If wearing an apron, wear the whole body dosimeter outside the apron. If given two whole body dosimeters, wear the second underneath the lead apron. Wear the ring dosimeter beneath gloves.

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MONITORING RADIATION EXPOSURE

- Exposure rates within the area will be determined when the unit is first installed. The initial inspection will ensure that there are no exposures in the area that would result in harm to the users.

- Annual inspections will be performed by an inspector approved by the State of Indiana to ensure that the exposure rates and X-ray/fluoroscopy unit are still within acceptable standards.

- Inspections of the unit should be requested by the lab staff if any of the following occur:
  - The unit is moved
  - The unit is altered in any way that may affect the interlocked safety features
  - The processes performed with the unit are significantly altered (for example: radically different target materials may have different scatter patterns which will result in different exposures)

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MONITORING RADIATION EXPOSURE

- If a user wishes to monitor their equipment, exposure rates can be determined by using a radiation survey meter.

- Radiation Survey Meters
  - Geiger-Mueller (GM) or Ion Chambers can be used to detect x-ray radiation. Either can be used to take measurements. Ion Chambers are better at making quantitative x-ray measurements than the GM meters.
  - However, if any leak is found in the unit, the appropriate steps should be taken to fix the leak and decrease exposure levels.

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ENFORCEMENT

Failure to comply with the rules or regulations set for by the ISDH or Purdue University can result in (depending on the severity of the violation):

- Re-training
- Loss of work privileges with x-ray producing devices
- Obtaining an injunction or court order to prevent a violation
- Civil penalties
- Criminal penalties
  - For willful violation of, attempted violation of or conspiracy to violate any regulation

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SECURITY

- Only the individuals that are listed as Approved Authorized Users on the specific x-ray project as defined by REM may have the ability to operate the x-ray unit(s).
  - If an unauthorized user is found using the unit, immediately notify the Supervisor/PI. REM should be contacted to schedule a training for the user in order for them to become authorized.
  - It is important for all those using the x-ray equipment to be:
    - Trained on the specific unit
    - Trained on x-ray awareness in order to be informed of safety requirements, hazards involved and ways to prevent unnecessary exposures
- Energized equipment must be attended by an authorized user at all times.

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EMERGENCY PROCEDURES

- Fire
  - Activate the building fire alarm system (fire pull station). If not available or operational, verbally notify persons in the building.
  - Notify the Fire Department at 911.
  - Isolate the area and evacuate the building:
    - Shut down equipment in the immediate area, if possible.
    - Close doors to isolate the area.
    - Use a portable fire extinguisher to control a small fire or assist in evacuation if possible.
  - Provide the fire/police teams with the details of the problem upon their arrival.
  - Notify REM (49-46371)

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REGULATIONS AND REM

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REGULATORY REQUIREMENTS

- Due to the potential risks involved regarding the operation of x-ray units, there are restrictions that must be met. These restrictions are meant to minimize the possibility and severity of exposure from these units.

- Regulatory authority comes from the State of Indiana, Purdue University and specific laboratory requirements.

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STATE REGULATIONS

- The Indiana State Department of Health (ISDH) regulates the use of x-ray equipment in Indiana through Title 410 Indiana Administrative Code Article 5: Radiological Health. 410 IAC 5 Rule 2: Registration of Radiation Machine Facilities and Services.
  - 410 IAC 5 Rule 4: Protection and Exposure Standards.
  - 410 IAC 5 Rule 5: Non-Medical Radiography (includes x-ray fluorescent lead based analyzers).
  - 410 IAC 5 Rule 6.1: X-rays in the Healing Arts.
  - 410 IAC 5 Rule 8: Radiation Safety Requirements for Analytical X-Ray Equipment.
  - 410 IAC 5 Rule 9: Radiation Safety Requirements for Particle Accelerators.
  - 410 IAC 5 Rule 10: Notices, Instructions and Reports to Workers; Inspections.

UNIVERSITY RESPONSIBILITIES

- Radiation Safety Program: Authorized by Purdue University Executive Memorandum No. B-14
  - Radiation Safety Committee (RSC)
    - The mission of the Radiation Safety Committee is to ensure the safety of the University and community in the utilization of all radioactive materials and radiation producing devices at the University or by University faculty, staff or students.
  - Radiation Safety Officer (RSO) in the Department of Radiological and Environmental Management (REM)
    - Radiation Safety Staff

- Purdue Radiation Safety Manual

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REM RESPONSIBILITIES

- The Department of Radiological and Environmental Management (REM) administers the radiation safety with regard to x-ray equipment.
- REM is responsible for:
  - Performing a radiation survey and compliance inspection when x-ray equipment is first installed, and when equipment is relocated or reconfigured in any way that affects radiation safety;
  - Performing an annual survey and inspection of each x-ray machine;
  - Providing radiation monitoring badges (dosimetry) for x-ray users; and
  - providing x-ray safety training for x-ray users.
  - REM is also responsible for complying with regulations set forth by the Indiana State Department of Health, for the safe use of radiation producing devices such as X-ray units.
    - This is accomplished by providing training, calibration services, personnel dosimetry to monitor radiation exposure and consulting support for any safety issues identified by Purdue University employees and students.

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REM RESPONSIBILITIES

- REM is also responsible for complying with regulations set forth by the Indiana State Department of Health, for the safe use of radiation producing devices such as X-ray units.

- This is accomplished by providing several types of training, radioactive waste pickups, calibration services, personnel dosimetry to monitor radiation exposure and consulting support for any safety issues identified by Purdue University employees and students.

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CONTACT REM IF...

- You know or suspect there has been an overexposure to an individual
- The x-ray unit is to be moved or modified
- Personnel working on the project has been changed (added/dropped)

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GENERAL CONTACT INFORMATION

- Information: (765) 49-46371
- Fax: (765) 49-47403
- Office Location: CIVL B173
- Campus Mail: REM, CIVL
- Mailing Address:

  Radiological and Environmental Management
  550 Stadium Mall Drive
  West Lafayette, IN 47907-2051

- Web: http://www.purdue.edu/rem/

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RADIATION SAFETY GROUP

• **James Schweitzer, Ph.D.** Radiation Safety Officer (RSO)	49-42350 jfschweitzer@purdue.edu
• **Zach Tribbett** Health Physicist, Laser Safety Officer	49-41478 ztribbet@purdue.edu
• **Matthew Tang** Health Physicist	49-42721 mmtang@purdue.edu
• **Sharon K. Rudolph** Isotope Ordering & Distribution	49-47969 skrudolph@purdue.edu
• **Mike Nicholson** Waste Handling & Animal Hospital Support	49-40205 mlnicholson@purdue.edu
• **Jerry J. Gibbs** Waste Handling & Meter Calibration	49-40207 jjgibbs@purdue.edu

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END OF ANALYTICAL MODULE

- This concludes the PowerPoint portion of the training.
- Complete the test indicated below. You must have 75% of correct responses to pass.
  - Your results will be emailed to you, and will constitute as your certification of your successful completion of the online portion of your training, if you have passed.
- Submit a completed Form A-4 (make sure that both you AND your Principal Investigator have signed the form), and send through campus mail to: Sharon Rudolph/REM/CIVL

Click here to begin the test.

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