Radiation Safety

Radiation Safety

J. S. BALLARD

OPEN OREGON EDUCATIONAL RESOURCES

Contents

Learning Objectives: **ANSI/ASNT CP-105- 2016 Section 1(1.1-1.4)**

Upon completion of this unit, the student will be able to:

- Understand and explain the historical significance of Industrial Radiography.
- Explain the aspects and significance of radiation safety.
- Explain and Differentiate between Ionizing and non-ionizing radiation
- Describe the meaning of ALARA as it applies to industrial radiation exposure
- Prepare for ASNT (American Society for Non-Destructive Testing) TC-1A Radiation Safety Certification Exam

Learning Activities:

- 1 Lecture and discussion and unit reading materials
- 2 Guest Speaker – LBCC Radiation Safety officer (RSO)
- 3 Radiation Safety Article Review #1

Learning Resources:

- 4 Significant Historical Figures in Radiography
- 5 Units of measurement
- 6 Glossary

Evaluation:

- 7 Guest Speaker Evaluation
- 8 Article Review #1
- 9 Quiz #1

Homework Assignment due next Tuesday: Research one Industrial incident that has occurred involving radiation (Gamma source or X-ray) Write a brief summary (typed, double spaced…) and be prepared to discuss with the class on Tuesday.

Next Week: Math, Radiation, and a quiz

Unit 1 History & Introduction Printable Word File

About This Book

Radiation Safety (NDT 130) is the first in a series of Industrial Radiographic Testing classes taught at Linn Benton Community College (LBCC) in Albany, Oregon. 40 hours of Radiation Safety training is required of any individual working with x-ray and Gamma radiation sources in industrial radiographic testing, including industrial radiographic inspection students. NDT 130 is part of LBCC's two-year Associate of Applied Science program in Non-Destructive Testing (NDT).   The purpose of this OER is to provide students with a comprehensive textbook aligned with the NDT 130 course as taught at LBCC. NDT 130 is taught in accordance with ASNT, SNT TC-1A recommended practice and topical outline following ANSI/ASNT CP-105 2016 guidelines (page 63) for Basic Radiographic Physics Course and Appendix A (pages 113-114) for Radiation Safety topical outline.

The OER is organized so each unit represents approximately a week in our term and includes printable Word documents at the end of each Unit section. Included at the conclusion of each section is a Spanish translation in a printable Word File.

About This Book Printable Word File

Acknowledgements

Developing and writing curriculum are just some of the duties involved in being the instructor of a new NDT program. Finding affordable, quality technical resources is a challenge facing all instructors and the lack of availability for the Career and Technical Education fields compounds the difficulty of the quest. LBCC and Open Oregon Educational Resources have provided the opportunity for our diverse OER team to collaborate, creating this Radiation Safety OER. It seems only appropriate to point to the recent data (https://www.linnbenton.edu/news/open-educational-resources-fall-2018.php) showing that OER has saved students over $3 million in textbook costs in the last 3 years!

Jason S. Ballard earned his Associate of Applied Science Degree in Metallurgy from LBCC in 1991 and went on to earn his BS and Masters in Education from Western Oregon University. Jason spent over 20 years as a high school manufacturing instructor before taking a positon with LBCC in 2016 as a full time NDT instructor. Tasked with building a new NDT program and developing a progressive curriculum, Oregon OER was a perfect fit. As the primary author of the Radiation Safety OER, Jason brought together an outstanding team to assist in the work.

Performing the peer review of the OER for content accuracy was Seaton McLennan. Seaton is the current Co-Chairman of the LBCC NDT department with over 30 years of Metallurgy and NDT experience. Seaton taught Metallurgy and Materials Testing for 25+ years until his retirement in 2004. In 2014, regional and local aerospace casting industries pushed for a new NDT Program at LBCC and Seaton came out of retirement to build the new program. Seaton is highly respected in the region, having trained most of the area Level-III NDT inspectors currently employed at ATI Cast Albany, ATI Cast Millersburg, Selmet, and PCC in Portland, Oregon to name a few!

Creating an affordable curriculum for LBCC students was the primary task of this OER. Another goal was to translate all of the glossaries and other sections into Spanish to better accommodate and encourage Spanish speakers and readers to take NDT 130 with an opportunity to learn in their native language. To accomplish this task Susan Mejia was recruited to translate the material, and NDT student Ricardo Ortiz Ramirez was tasked with peer reviewing Susan's translations for technical content specific to NDT.

Susan, born and raised in rural Oregon, moved to Mexicali, Mexico with her husband and family where she learned to read and write Spanish fluently. Since her return to Oregon, Susan has worked as an interpreter and translator for children and families in rural Oregon schools. Susan's work on the OER is a great service to our education community, providing ELL students an opportunity to study and learn technical subject matter such as Radiation Safety, leading to high-wage, sustainable careers in NDT.

Ricardo Ortiz Ramirez contributed uniquely to the OER. With his ability to read and write Spanish, coupled with the fact he is an NDT student and employed as a professional NDT inspector, Ricardo provided the perfect skills and familiarity with NDT to evaluate and edit Susan's translations. Ricardo is a dual citizen of Mexico and the United States. He was born in Mexico and enrolled in elementary school when his family emigrated to the U.S. Ricardo learned to read and write Spanish from his oldest sister and now shares his bilingual abilities with the Career and Technical Education community.

LBCC OER Librarian Michaela Willi Hooper shared research strategies, copyright expertise and feedback on all of the OER, providing countless hours of support. Her passion to provide affordable resources is commendable and greatly appreciated.

Acknowledgments Printable Word File

UNIT 1: HISTORY OF RADIATION SAFETY

Learning Objectives: ANSI/ASNT CP-105- 2016 Section 1(1.1-1.4)

Upon completion of this unit, the student will be able to understand and explain the historical industrial radiographic contributions and significance of:

- Wilhelm Conrad Rontgen
- Marie and Pierre Curie
- Henri Becquerel
- Radiographic History in the U.S.
- Prepare for ASNT (American Society for Non-Destructive Testing) TC-1A Radiation Safety Certification Exam
- Sneak Preview: ALARA, Math, Time-Distance-shielding

Learning Activities:

- Lecture and discussion and unit reading materials
- Guest Speaker – LBCC Radiation Safety officer (RSO)
- Radiation Safety Article Review #1
- Sneak Preview – lecture & Worksheet

Learning Resources:

- Significant Historical Figures in Radiography
- NRC Website
- Glossary

Evaluation:

- Guest Speaker Evaluation
- Article Review #1
- ALARA Article Review
- Quiz #1

Unit 1 Outline: Printable Word File

Unit 1 Outline: Español

Wilhelm Conrad Rontgen

Photo of Wilhelm Conrad Röntgen by Life Photo Archive is Public Domain.

Wilhelm Conrad Roentgen was the German engineer and physicist credited with the discovery of X-ray in 1895. Rontgen's discovery is one of the greatest scientific discoveries leading to diagnostic advances in the medical industry and later in the field of non-destructive testing. Rontgen generated the first medical X-ray image of his wife's hand pictured below:

First medical X-ray by Wilhelm Röntgen of his wife Anna Bertha Ludwig's hand is Public Domain.

The following are links to articles and videos providing detailed information about Roentgen – the German engineer & Physicist credited with the discovery of X-ray in 1895.

- The Life of Wilhelm Conrad Roentgen (article from the *American Journal of Roentgenology*)
- Nov. 8, 1895: Roentgen Stumbles Upon X-Rays (article from *Wired* Magazine).
- Roentgen video biography (from CloudBiography's Youtube channel):
- Another Roentgen video biography (from Quantum Laser Pointers' Youtube channel)

1.1 Wilhelm Conrad Rontgen Printable Word File
1.1 Wilhelm Conrad Rontgen: Español

Marie & Pierre Curie

Marie Curie, one of the most honored scientists of all time, is credited for the discovery of radium and received the 1903 Nobel Prize in physics along with her husband Pierre and fellow physicist Henri Becquerel. In 1911 Curie received the Nobel Prize in chemistry for her scientific research and breakthroughs with radium, and polonium making her not only the first woman in history to receive the Nobel Prize, but also the only person – man or woman – to ever receive Nobel Prizes in two separate disciplines. Her name lives on with "Curie", (Ci) used as a unit of radioactivity.

Marie Curie by Henri Manuel is in the Public Domain.

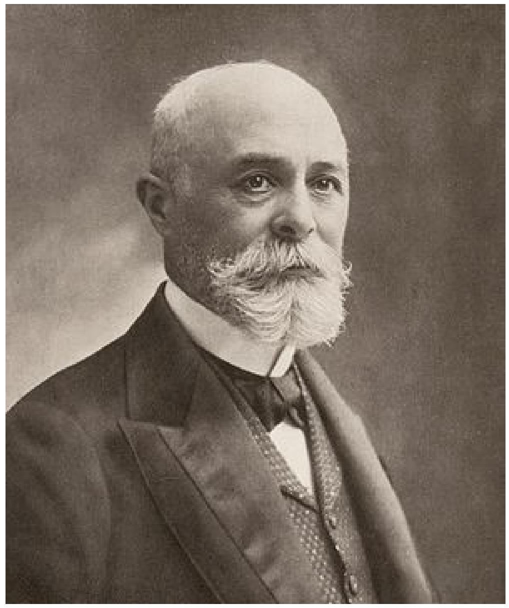
Pierre Curie by Dujardin is in the Public Domain.

The following are links to a video and articles providing detailed information about Marie Curie and her tremendous contribution to science.

- Wikipedia article on Marie Curie
- Marie Curie video documentary (from Woodlawn School's YouTube channel)

1.2 Marie & Pierre Curie Printable Word File
1.2 Marie & Pierre Curie Español

Antoine Henri Becquerel



Henri Becquerel by Paul Nadar is in the Public Domain.

Henri Becquerel was a French physicist performing ground-breaking research at the same time as Wilhelm Rontgen and the Curies. His work in the discovery of "spontaneous radioactivity" earned him a share of the 1903 Physics Nobel Prize along with Marie and Pierre Curie. Similar to Curie, Becquerel has a unit named after him for radioactivity – the SI unit "Becquerel" (Bq)

The following are links to documents and videos on the life and scientific contributions made by Henri Becquerel.

- Becquerel biography (Nobel Prize Organization magazine article)
- Wikipedia biography of Becquerel
- Video biography of Becquerel from Health Apta's Youtube channel

1.3 Becquerel Printable Word File

Henri Becquerel Español

Radiation History in the U.S.

Edison & Dally

In the late 1890's Thomas Edison learned of the recently discovered "X-rays" and began to research and experiment along with his research assistant Clarence Dally. Their lack of understanding of the hazards involved with X-radiation led to the painful, early death of Dally.

A shoe fluoroscope at the US National Museum of Health and Medicine. Public Domain.

From the 1920's well into the 1950's shoe companies used fluoroscopes like the one pictured above to "look" into the feet of potential customers in an effort to ensure a better shoe fit for the customer. While mostly a gimmick to generate sales, the fluoroscopes also generated dangerous levels of radiation and exposed thousands of people unnecessarily – all in the name of marketing and sales.

By the late 1940's, Scientists and health regulatory agencies around the world began to research and question the safety of these shoe fitting fluoroscopes. By 1953 the US FDA recommended not using the machines on children and in 1957 Pennsylvania was the first state to ban the use of the machines altogether. The last recorded Shoe fitting X-ray machine still in use was in Boston in the early 1970's.

Read more about Clarence Dally at Smithsonian.com.

For more information, see the following videos:

- Shoe store fluoroscopes video
- X-ray shoe fit check 1920s

1.4 Radiation History in the U.S. Printable Word File

1.4 Radiation History in the U.S. Español

ALARA Article Reviews

Learning Objective:

- Review an article to gain an understanding of ALARA , both Pros & Cons

Resources:

- ALARA Historical Article from Specialists in Radiation Protection.
- Is ALARA reform needed? A criticism of ALARA abuse. Great historical article from the American Nuclear Society.

The Task: Read the NRC definition of ALARA and the 2 articles cited above provide responses to the following:

1. Define ALARA:
2. When did ALARA become the law:
3. How do you determine exactly what ALARA is? Explain:
4. Where do green gamma rays come from?
5. Where do yellow gamma rays come from?
6. Where do red gamma rays come from?
7. In a few sentences, explain the point of what Dr. Eric P. Loewen was getting at in his article "Is ALARA reform needed?"
8. Do you agree or disagree with with Dr. Loewen's assertions? Why or why not?

ALARA Article Reviews – Printable Word Files
    ALARA Article Reviews Español

Sneak Preview Note & Worksheet

Learning Objective:

1. A quick snapshot at the basic radiological safety concepts that will be at the center of the entire Radiation Safety Course
2. Understand and apply the Inverse Square Law as it pertains to Radiation Safety
3. Learn how we protect ourselves: Time, Distance & Shielding

Resources:

1. NRC.gov

Learning Activities:

1. **ALARA definition in NRC's glossary**

ALARA: As defined in Title 10, Section 20.1003, of the Code of Federal Regulations (10 CFR 20.1003), ALARA is an acronym for "as low as (is) reasonably achievable," which means making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.

2. 1977 – ALARA became the law!
3. Complete ALARA article reviews (see worksheet)
4. With **ALARA** in mind, let's take a look at **Time, Distance & Shielding**
5. The concept and practical applications of Time, distance & Shielding are not overly complicated and make sense when keeping the public safe and ourselves from radiation over-exposure. Take a few minutes to read this explanation on the NRC website and then write a brief summary of what think are the main points the NRC wants you as a radiographer to "take-away" from their information.
6. <u>**Write Summary:**</u>
7. **Math:** ...and the math helps us to determine when we've met ALARA. Radiographers use laws of physical science coupled with mathematics to keep their radiation exposure "***As Low As is Reasonable Achievable***."
8. The Inverse Square Law: $\frac{I^1}{(I_2)} = \frac{(d_2)\,2}{(d_1)\,2}$ (where I_1 is the initial intensity of radiation, d_1 is the initial distance, and d_2 is the final distance, and I_2 is the final intensity)
9. Radiographers use the Inverse Square law to solve for safe **DISTANCES** (d) and to solve for the **INTENSITY** (I) of radiation. Think Safety. Think: ***Time, Distance, Shielding***
10. Let's take a look at the NRC's examples of how Radiographers apply the Inverse Square Law to calculate radiation Dosage.
11. To further break down this formula for determining safe distance and safe intensities, we will spend more time later practicing the math.
12. One more mathematical tool radiographers use in their time, distance, SHIELDING tool box is a shielding formula known as the Half Value Layer formula which calculates the thickness, and number of layers of a

shielding material required to reduce the radiation intensity to a safe dose rate (2 mR/hr) the formula is as follows:

13. **Half Value Layer (HVL):**
14. In your own words, explain why radiation intensity decreases over distance**.**

1.9 Unit 1 -Sneak Preview Worksheet – Printable Word File

Sneak Preview Español

Unit #1 Glossary of Terms

Curie: (Ci) is the unit of measurement of the amount of radioactivity of a substance, named after Marie and Pierre Curie. 1 Ci = 3.7×1010 disintegrations per second (rate of decay)

Fluoroscope – an imaging technique that uses X-rays to obtain real-time images of the inside of an object. This technology was abused in the 1950's by shoe companies to "fit" an individual's foot to a specific shoe.

Marie Curie: Curie was the first woman awarded the Nobel Prize for her discovery of the radioactive elements Polonium and Radon. Curie is the only person – male or female – to win the Nobel Prize twice.

Pierre Curie: husband, research partner and co-Nobel Prize recipient of Marie Curie.

Becquerel (Bq) – Si unit for measuring radioactivity.

Henri Becquerel – French physicist that shared the 1903 Nobel Prize with Marie and Pierre Curie for his discovery of "spontaneous radioactivity"

Radiation: Energy in transit. Either as particles or electromagnetic waves.

RSO – Radiation Safety Officer – required for any company, education, medical or research facility that uses any form of Gamma or X-ray radiation.

Radioactivity: The characteristic of various materials to emit ionizing radiation.

Roentgen (R) – is a unit of measurement to the exposure of ionizing radiation, specifically Gamma radiation and X-rays, named after the German physicist.

Roentgen – Wilhelm Conrad Roentgen discovered the X-ray while doing research in Germany on November 8th, 1895

X-ray – a type of ionizing radiation formed in a Cathode Ray Tube (CRT) when high velocity electrons flow from the cathode to the anode.

Unit 1 NDT Glossary of Terms: Printable Word File

Unit 1 NDT Glossary of Terms Español

UNIT 2: IONIZING RADIATION & UNITS OF MEASUREMENT

Learning Objectives: ANSI/ASNT – CP-105- 2016 Section 1 & 2
Upon completion of this unit, the student will be able to define, understand and apply the following:

- Ionizing Radiation
- Alpha, Beta, Gamma Review
    - Isotope vs. Radioisotope
- ALARA
- Time, Distance, Shielding
- Radiation Intensity & Units
- Basic Atomic Theory
    - Elements & Atoms
    - Molecules & compounds
    - Atomic Particles, number, weight, structure

Learning Activities:

- Lecture and discussion
- PowerPoint of Basic Atomic Theory
- Radiation Safety Article Review #1
- Radiation Safety Article Review #2
- Flash-Cards

Learning Resources:

- Units of measurement handout
- Glossary

Evaluation:

- Article Reviews

Unit 2 Outline – Printable Word File
1 Unit 2 outline Español

Ionization Defined

Ionizing radiation (ionizing radiation) is radiation that carries enough energy to liberate electrons from atoms or molecules, thereby ionizing them. Ionizing radiation is made up of energetic subatomic particles, ions or atoms moving at high speeds (usually greater than 1% of the speed of light), and electromagnetic waves on the high-energy end of the electromagnetic spectrum.

Gamma rays, X-rays, and the higher ultraviolet part of the electromagnetic spectrum are ionizing, whereas the lower ultraviolet part of the electromagnetic spectrum, and the lower part of the spectrum below UV, including visible light (including nearly all types of laser light), infrared, microwaves, and radio waves are all considered non-ionizing radiation. The boundary between ionizing and non-ionizing electromagnetic radiation that occurs in the ultraviolet is not sharply defined, since different molecules and atoms ionize at different energies. Conventional definition places the boundary at a photon energy between 10 eV and 33 eV in the ultraviolet (see definition boundary section below).

Typical ionizing subatomic particles from radioactivity include alpha particles, beta particles and neutrons. Almost all products of radioactive decay are ionizing because the energy of radioactive decay is typically far higher than that required to ionize. Other subatomic ionizing particles which occur naturally are muons, mesons, positrons, and other particles that constitute the secondary cosmic rays that are produced after primary cosmic rays interact with Earth's atmosphere. Cosmic rays are generated by stars and certain celestial events such as supernova explosions. Cosmic rays may also produce radioisotopes on Earth (for example, carbon-14), which in turn decay and produce ionizing radiation. Cosmic rays and the decay of radioactive isotopes are the primary sources of natural ionizing radiation on Earth referred to as background radiation. Ionizing radiation can also be generated artificially using X-ray tubes, particle accelerators and any of the various methods that produce radioisotopes artificially.

Ionizing radiation is not detectable by human senses, so radiation detection instruments such as Geiger counters must be used to indicate its presence and measure it. However, high intensities can cause emission of visible light upon interaction with matter, such as in Cherenkov radiation and radio luminescence. Ionizing radiation is used in a wide variety of fields such as medicine, nuclear power, research, manufacturing, construction, and many other areas, but presents a health hazard if proper measures against undesired exposure are not followed. Exposure to ionizing radiation causes damage to living tissue, and can result in mutation, radiation sickness, cancer, and death.

Ionizing Radiation Defined Printable Word File

2 Ionizing Radiation Defined Español

ALARA

ALARA: As Low As is Reasonably Achievable

The ALARA Acronym comes out of the NRC (Nuclear Regulatory Commission) Code of Federal Regulations, Title 10, Section 20.1003. ALARA means, "To make every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken." The NRC Code goes on to explain what the practical limits might entail and the importance and practicality of taking extreme measures to keep both radiation workers and the general public safe.

2 -ALARA – Printable Word File

Time, Distance, and Shielding

Learning Objective:

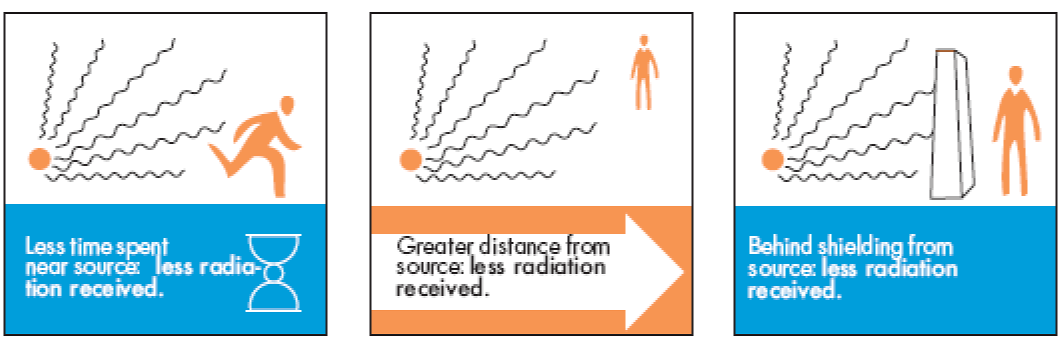
- Understand the concept and real-world application of Time, Distance and Shielding as it pertains to Radiation Safety.

Radiation Safety is accomplished through a variety of strategies and is pertinent to several high-risk career areas. Radiation safety protocol will look different for an airline pilot than it does for a gamma radiographer and likewise, a medical X-ray technician has yet a different set of constraints (patients, the public). The concept of Time Distance and Shielding in an effort to achieve ALARA is relevant to all exposure risk careers, but our primary focus here is industrial radiography – both gamma and X-rays.

From the NRC:

Time, distance, and shielding measures minimize your exposure to radiation in much the same way as they would to protect you against overexposure to the sun (as illustrated in the figure below):

- **Time:** For people who are exposed to radiation in addition to natural background radiation, limiting or minimizing the exposure time reduces the dose from the radiation source.
- **Distance:** Just as the heat from a fire is less intense the further away you are, so the intensity and dose of radiation decreases dramatically as you increase your distance from the source.
- **Shielding:** Barriers of lead, concrete, or water provide protection from penetrating radiation such as gamma rays and neutrons. This is why certain radioactive materials are stored under water or in concrete or lead-lined rooms, and why dentists place a lead blanket on patients receiving x-rays of their teeth. Similarly, special plastic shields stop beta particles, and air stops alpha particles. Therefore, inserting the proper shield between you and a radiation source will greatly reduce or eliminate the dose you receive.



Time, distance, shielding from NRC.gov is in the Public Domain.

- 2 -Time, Distance & Shielding – Printable Word File

Radiation Units

Roentgen(R): is a unit of measurement to the exposure of ionizing radiation in air, produced from X-rays and gamma rays.

More specifically, it is *defined* as the electric charge freed by such radiation in a specified volume of air divided by the mass of that air.

Named after German physicists Wilhelm Roentgen who is credited with the discovery of X-rays in 1895.

1 Roentgen is equal to 1,000 MilliRoentgens (mR)

Milli-Roentgen (mR): This is a smaller unit of measuring ionizing radiation.

1,000 mR = 1 R

The safe radiation exposure rate for the public is 2 mR/hour.

The safe radiation exposure rate for a certified radiographer is 5 mR/hr

Sievert (SI): is the SI unit of measuring the radiation dose and therefore the effect on the body. 1 Sievert is equal to 100 REM's (Roentgen Equivalent Man)

Activity: The rate of decay of a radioactive material.

In simple terms, the Activity (measured in ci or Bq) can be thought of as the amount of radiation

Different gamma sources have different activity levels.

Curie (Ci): the unit used to describe the rate of decay or **ACTIVITY** of a radioactive material in disintegrations per second.

1 ci = 37,000,000,000 disintegrations per second

(That is, 37 Billion disintegrations per second)

Or (3.7 x 10 10 dps)

Becquerel (Bq): the **SI** unit to measure the activity in a radioactive material.

1 Bq = 1 disintegration per second

Specific Activity: describes the activity per unit of mass of an isotope.

Different isotopes have differing Specific Activities

When performing gamma radiography, the Specific Activity can be factored in on how the source will behave – a smaller source physical size will have a smaller focal spot and thus may have better definition on the finished radiographs.

Radioactive Half-life: the amount of time required for ½ of the original number of radioactive atoms to decay or change into daughter atoms.

Unit 2 Radiation Units of Measurement – Printable Word File

Unit 2 – Radiation Units Español

Article Review #1

How Radiation Sickness Works (from How Stuff Works)

Learning Objective & Task to Complete: with information provided from the "Howstuffworks" article linked above, write a short paragraph explaining each of the following terms:

Ionizing Radiation:
Alpha Particles:
Beta Particles:
Gamma Rays:
– Article Review #1 – Printable Word File
Unit 2 Article Review #1 Español

Article Review #2; Why so many units?

REM, RAD, Roentgen, Curie, Becquerel, Sieverts – Why are there so many different units to measure radiation?

Read the following article from Slate and summarize in one to three paragraphs sharing your opinion as to whether or not the various units are a problem? Explain.

Sievert, Gray, Rem, and Rad: Why are there so many different ways to measure radiation exposure?

Article Review #2- Printable Word File

Flash Cards

Learning Objective:

- Create your own set of flash cards from the Radiation Safety Lecture handout
- Reading, writing, and synthesizing information will assist in your memorization of the general knowledge of Radiation Safety

Lab Task(s):

- Upon receiving lecture, demonstration, Glossary and instruction…
- Create a set of Flash-cards writing the Vocabulary term on one side with the definition on the other
- Create one additional Flash Card in which you have created a unit review question (or Test Question?). You will use your lecture notes and handouts to compose the question.
- Show your completed Flash Cards to the instructor for assignment credit. Don't be surprised to see one of your Flash Card questions on the unit quiz!

Flash-Cards Assignment – Printable Word File
flash cards Español

Unit #2 Glossary of Terms

ALARA: "As Low As Reasonably Achievable" Personnel working in the field are required to keep their radiation exposures ALARA.

Atom: The fundamental basic building block of matter made up of three subatomic particles called protons, neutrons, and electrons. The basic unit of a chemical element of the periodic chart.

Curie: (Ci) is the unit of measurement of the amount of radioactivity of a substance, named after Marie and Pierre Curie. 1 Ci = 3.7×10^{10} disintegrations per second (rate of decay)

Becquerel (Bq) – Si unit for measuring radioactivity.

Electromagnetic spectrum: A continuum of electric and magnetic radiation encompassing all wavelengths.

Electron: a stable subatomic particle with a charge of negative electricity, found in all atoms.

Ion: an atom or molecule with a net electric charge due to the loss or gain of one or more electrons. A positively or negatively charged atom or molecule.

Ionization: The removal of electrons from an atom. The essential characteristic of high-energy radiations when interacting with matter.

Ionizing Radiation: a type of radiation that is able to disrupt atoms and molecules on which they pass through, giving rise to ions and free radicals.

Isotopes: atoms with same atomic number and chemical properties as element atoms; the nucleus has same number of protons but a different number of neutrons and thus, a different atomic mass.

Neutron: a subatomic particle with about the same mass as a proton but without an electric charge. Neutrons are present in all atoms except the Hydrogen atom.

Particulate (or particle) Radiation: is the radiation of energy by means of fast-moving subatomic particles. Alpha particles, Beta particles, neutrons, and positrons are examples of particulate radiation.

Photons: Discrete particles of light or electromagnetic radiation hypothesized to explain the corpuscular theory of radiant energy.

Proton: a subatomic particle present in all atomic nuclei, with a positive electric charge equal in magnitude to that of an electron, but of opposite sign.

Radiant energy (Qe): Energy transmitted through a medium by electromagnetic waves. Also known as radiation.

Radiation: Energy in transit. Either as particles or electromagnetic waves.

Radioactivity: The characteristic of various materials to emit ionizing radiation.

Roentgen (R) – is a unit of measurement to the exposure of ionizing radiation, specifically Gamma radiation and X-rays, named after the German physicist.

SI: The International System of units of measurement. Includes most of the base units formerly called metric.

X-ray – a type of ionizing radiation formed in a Cathode Ray Tube (CRT) when high velocity electrons flow from the cathode to the anode.

Unit 2 Glossary of Terms – Printable Word File

Glossary of Terms Español

UNIT 3: BASIC ATOMIC THEORY & SCIENCE

Learning Objectives: ANSI/ASNT CP-105- 2016 Section 2,3, 5 & 6
Upon completion of this unit, the student will be able to define and understand the following:

- Review of Units 1 & 2
    - ALARA
    - Radiation Intensity units
- Time, Distance & Shielding…
- More Science: (2.0 Fundamental Properties of Matter)
    - Isotopes
    - Stable vs. Unstable atoms
    - Radioactive half-life
    - Radioactive Decay
    - Specific Activity
    - Fission
    - Fusion
- More Math:
    - Inverse Square Law
    - Calculating Half-Life and Activity of Gamma Sources

Learning Activities:

- Lecture and discussion

Learning Resources:

- Units of measurement handout
- Glossary

Evaluation:

- Inverse SQ. Law Worksheet #1
- Article Review #4

Unit 3- Outline: Printable Word File
Unit 3 outline Español

Science of Gamma Radiography

As an ASNT-TC-1A, level-I radiographer trainee, having a general understanding of the scientific principles, terminology and mathematical formulas is critical to your personal safety as well as the safety of others (co-workers, supervisors, general public). Once we have a solid foundation of the science, we can then safely learn the intricacies in the field of radiography.

In this course, we are training for industrial radiography; gamma-ray radiography and X-ray radiography. Each method has its own set of safety concerns and protective measures to follow in order to keep everyone safe and to follow the ALARA principle.

Gamma Radiography is used widely throughout industrial radiography fields such as oil and chemical pipelines, large casting and forging inspections, and a variety of other specialized applications. Gamma radiography has the benefit of portability and superior penetration to that of X-ray. The main disadvantage however is that the X-ray machine can be turned off with a power switch and gamma cannot. Furthermore, the process of creating the gamma sources (radioactive activation) and disposing of spent or decayed sources is costly and potentially hazardous. To reiterate the earlier statement, it is critical for radiographers to have a solid understanding of the sources and processes they are working with.

- **Nuclear Fission:** When the nucleus of a stable atom splits upon impact of another particle and splits into 2 smaller parts. The resulting atoms are not the same element as the parent atom and are considered unstable and radioactive. This is the process by which Industrial isotopes (Cobalt 60, Iridium 192, Cesium 137) are created. For more information, see this nuclear fission video from Study.com.
- **Nuclear Fusion**: This is what scientists claim powers the sun and could be the answer to all of mankind's energy needs. In this chemical reaction, two or more atomic nuclei are combined to form one (or more) different atomic nuclei. For more information, see this Wikipedia entry on nuclear fusion.

- **Half-Life:** the amount of time required for ½ of the original number of radioactive atoms to decay or change into daughter atoms. The original term was "half-life period" coined by physicist Ernest Rutherford when he discovered the principle in 1907. Rutherford went on to receive the 1908 Nobel Prize in Chemistry. For more information, read this historical profile of Rutherford from sciencehistory.org.

The table below shows some common isotopes and their respective half-life values:

- **ISOTOPE** **½ LIFE**
- Uranium 238 4.5 Billion Years
- Potassium 40 450 million Years
- Radium 226 1600 years
- Iodine 128 25 minutes
- Cobalt 60 5.27 Years
- Iridium 192: 73.83 Days
- Cesium 137 30 years
- Thulium 170 128.6 Days

Science of Gamma Radiography: Printable Word File

Science of radiography Español

Inverse Square Law

Learning Objective:

- Understand the application of the Inverse Square Law as it pertains to Radiation Safety
- Apply the Inverse Square law to create safe distances, times, or radiation amounts.

Inverse Square law: The radiation Intensity is inversely proportional to the square of the distance. Notice in the diagram that as the distance doubles, the area quadruples and thus, the initial radiation amount is spread over that entire area and is therefore reduced, proportionately.

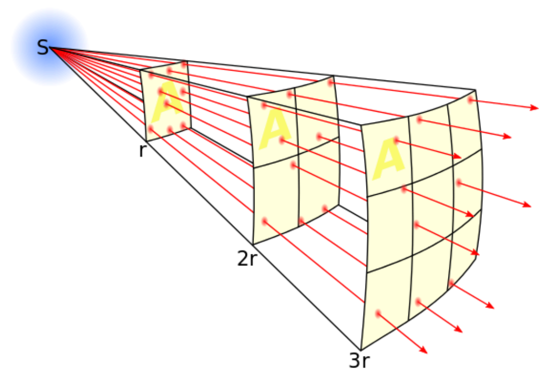
Imagine we are trying to expose a piece of x-ray film (radiograph) and we move the x-ray source twice as far away on each shot, will the film be more or less exposed ? Therefore, while the inverse square law pertains to radiation safety, it also helps us to determine source to film distances (SFD), time of x-ray exposure, and the intensity (KV) of our x-ray tube.

$$\frac{I_1}{I_2} = \frac{D_2^2}{D_1^2}$$

I_1 = Intensity with a distance measured as (R/hr or mR/hr)
D_1 = Distance with an intensity (usually measured in feet)
I_2 = Intensity without a Distance
D_2 = Distance without Intensity

To solve for Intensity (I_2) means that we want to know what the radiation intensity is at a given, second location or known distance (D_2). **To solve for Intensity use the following formula:**

$$I_2 = \frac{I_1 x D_1^2}{D_2^2}$$



Inverse Square Law by Borb is CC BY-SA 3.0

To solve for a safe distance (D_2), we are calculating how far away from the radiation source (gamma or X-ray) we need to be to achieve either 2mR/hr or 5mR/hr. **To solve for a safe distance use the following formula:**

$$D_2 = \sqrt{\frac{I_1 x D_1^2}{I_2}}$$

Inverse Square Law Formula: Printable Word File

Worksheet

Review:

1. Write out the Inverse Square Law and define each of the variables.
2. Write out the formula to find "New Intensity".
3. Write out the formula to find the "New Distance"

Part 1:

4. We have 209 mr/hr @ 17", what is our intensity at 6 feet?
a. Does the difference in units matter? Y or N?
b. How do we resolve the difference in units?
c. Solve for our new intensity.

5. We have 4.301 R/hr @ 3M, what is our intensity at 15 feet?
a. Units?
b. What's the intensity in R/hr?
c. What's the intensity in mr/hr?
d. Show your work

6. We have 4.301 R/hr @ 3M, what is our intensity at 37 feet?
a. Units?
b. What's the intensity in R/hr?
c. What's the intensity in mr/hr?
d. Show your work

7. We have 65 R/hr @ 1 ft., what is our intensity at 25 feet?
a. Units?
b. What's the intensity in R/hr?
c. What's the intensity in mr/hr?
d. Show your work

8. We have 97 R/hr @ 1 ft., what is our intensity at 25 feet?
a. Units?
b. What's the intensity in R/hr?
c. What's the intensity in mr/hr?
d. Show your work

Part 2: Solving for D_2 New Distance

9. Write out the formula solving for D_2

10. We have 199 mr/hr @72", and our desired I_2 is the safe to public radiation dosage.
a. What is the safe for public Radiation Dose?
b. How far do we need to be? Solve for (D_2) in Feet.

11. We know that 1 ci of iridium 192 emits 5.2 R/hr @ 1ft. so a 2 ci source of IR 192 would emit how many R/hr @ 1ft?

12. We now have a 100 ci source of IR 192.

c. How many R/hr @1 ft?
d. What is the “Caution: Radiation Area” working dosage?
e. Solve for D_2 and assume I_2 is the Caution dosage of:

13. Cobalt 60 emits 14 R/hr/ci @ 1ft.

f. How many R/hr is emitted at 1 ft. with a 100 ci source of Co 60?
g. Solve for D_2 and assume I_2 is the public safe dosage of 2 mr/hr.

14. Cobalt 60 emits 14 R/hr/ci @ 1ft.

h. How many R/hr is emitted at 1 ft. with a 100 ci source of Co 60?
i. Solve for D_2 and assume I_2 is the “Caution Radiation Work Area” dosage of 5mr/hr

15. We now have a 100 ci source of IR 192.

j. How many R/hr @1 ft?
k. Solve for D_2 and assume I_2 is the “caution Radiation Work Area” dosage of 5mr/hr.

Inverse SQ law worksheet: Printable Word File

Unit #3 Glossary of Terms

Alpha Particle: A positive electrically charged particle of radiation consisting of two protons and two neutrons (same as a helium nucleus). It is emitted from the nucleus of many radioactive materials during radioactive decay. Alpha particles have a very low kinetic energy and therefore can be stopped by a sheet of paper or clothing. However, if ingested, alpha particles have a Quality Factor (QF) of 20 times that of straight gamma or X-ray radiation, making them dangerously toxic if inhaled or ingested.

Daughter isotope: The compound remaining after the parent isotope (original isotope) has undergone decay.

Disintegration (Decay): The transformation of radioactive atoms into a stable state resulting in energy (radiation) and particle emission.

Gamma Rays: High energy, short wavelength electromagnetic radiation emitted during radioactive decay.

Gamma Radiography: Radiographs (film, DDA plates, CR, CT) are exposed using a gamma ray camera or radiograph shooting machine which can be portable, fixed in a cabinet or located in a vault.

Gamma Source (source): Industrial gamma radiography typically uses a man-made (activated) radiation source (Cobalt-60, Iridium-192, and Cesium-137). These sources are typically created for specific purposes and applications.

Half-Life: the amount of time required for ½ of the original number of radioactive atoms to decay or change into daughter atoms.

Half-Life Ir 192: 74 days

Half-Life Co 60: 5.3 years

Half-Life Cs 137: 30.17 years

Half- life Calculator

Inverse Square Law: A law of nature which describes the relationship of radiation intensity to distance from the source of radiation, stated mathematically as "the intensity of radiation is inversely proportional to the square of its distance from the source". Radiographers use this mathematical principal to calculate safe distances and radiation dose rates for known distances while exposing radiographs with either X-ray or Gamma radiation.

Nuclear Fission: The process by which the nucleus of a stable atom splits upon impact of another particle and splits into 2 smaller parts. The resulting atoms are not the same element as the parent atom and are considered unstable and radioactive. This is the process by which Industrial isotopes (Cobalt 60, Iridium 192, Cesium 137) are created.

Nuclear Fusion: a nuclear reaction in which atomic nuclei of a lower atomic number fuse to form a heavier nucleus with the release of energy. The sun is an example of this process.

Radioactive: A state in which atoms have excess energy and are unstable. The nucleus disintegrates or decays in the process of becoming stable. This disintegration results in the emission of radiation and we measure this with the Curie (Ci)

Glossary of Terms: Printable Word File

Glossary Español

UNIT 4: RADIATION TYPES & MIDTERM REVIEW

Learning Objectives: ANSI/ASNT CP-105- 2016 Section 2,3

Upon completion of this unit, the student will be able to define and understand the following:

- Review of Units 1, 2 & 3
  - ALARA
  - Radiation Intensity units
  - Inverse Square law application
  - Time, Distance & Shielding…

Learning Activities:

- Lecture and discussion
- Math Review Worksheet
- Midterm Review Worksheet

Learning Resources:

- Units of measurement handout
- Glossary

Evaluation:

- Math Review worksheet #2
- Midterm Review Worksheet
- Quiz #2

Unit 4- Outline: Printable Word File

Unit 4 Outline Español

Review Quiz #2

1. Who is credited for discovering the X-ray?
2. Who is the only person to receive the Nobel Prize for science twice?
3. ALARA stand for:
4. What are radiographers trying to achieve with ALARA? Explain:
5. Which of the following are used primarily in radiography?
a. Gamma sources
b. Radio Waves
c. X-rays
d. Microwaves
e. Both A and C
6. What are the components of an atom?
a. Neutrinos, electrons, protons.
b. Positrons, neutrinos, electrons.
c. Electrons, neutrons, positrons, negatrons.
d. Protons, electrons, neutrons,
7. The elements, Cobalt and Nickel are shown as stable elements on the periodic Table.
a. True
b. False
8. Radiation is defined as:
a. Ionized Beta Alpha particles
b. Energy in transit, either as particles or electromagnetic waves
c. Heat and light emitting only from gamma sources like uranium or the sun
d. Energy that does not burn or ionize
9. An Ion:
a. An atom or part of an atom with a + or a – charge
b. A long, long time
c. Is not harmful to humans
d. None of the above
10. Two distinct types of radiation are:
a. Alpha and Omega
b. Particulate and Electromagnetic
c. Positive and negative
d. None of the above
11. An Alpha particle:
a. Is a type of ionizing radiation
b. Is not harmful to humans if it remains outside the body and is not inhaled
c. Is not considered as harmful to humans as Beta or Gamma radiation
d. All of the above are correct
12. Alpha particles are most dangerous to humans when:
a. Alpha particles come into contact with skin
b. Operating an X-ray cabinet
c. If Alpha particles are ingested or inhaled
d. Alpha particles are basically harmless to humans
13. Beta Particles:

a. Have almost zero mass and travel at almost the speed of light
b. Travel several meters in air
c. Has either a + or − charge
d. All of the above are true
14. Only Gamma radiation can ionize matter.
a. True
b. False
15. Which of the following are examples of "non-ionizing" radiation?
a. Near UV and radio waves
b. Visible light and Microwaves
c. Infrared
d. All of the above
16. Which of the following are two types of electromagnetic radiation used for industrial radiography?
a. X-rays and Microwaves
b. Gamma and X-rays
c. Gamma and Radio waves
d. Infrared and UV
17. Which of the following type of nuclear reactions is used to create isotopes for industrial radiography?
a. Nuclear Fission
b. Nuclear Fusion
18. Which of the following nuclear reactions is occurring on the sun?
a. Nuclear Fission
b. Nuclear Fusion
19. The term used to describe the decay of an isotope to one half of the original value is:
a. Radioactive decay
b. Half value layer
c. Time, Distance, Shielding
d. Half-Life
20. The main difference between Gamma radiation and X-ray radiation is:
a. Speed of radiation travel
b. The source of radiation
c. Penetrating power
d. X-ray is not very dangerous
21. What is the safe dosage rate for the public?
a. 2 R/hr
b. 20 mr/hr
c. 2 lamda per M
d. 2 mr/hr
22. Define the R/hr explaining what it is measuring:
23. 1 Rontgen = how many mr?
24. Three factors to keep us safe in regards to working with radiation are:
a. Time, distance and shielding
b. Water, sunscreen, and math
c. Inverse Square Law, OSkosh, and lead
d. None of the above
25. Write out the Inverse Square Law and define each of the variables.
26. How do we use the inverse square law in regards to radiation safety?
27. Write the formula for solving for the New Intensity (I2):

28. We have 25 R/hr @ 12”, what is our intensity at 10 feet?
a. Does the difference in units matter? Y or N?
b. Write out the equation and Solve for our new intensity.
29. We have 37 R/hr @ 3M, what is our intensity at 75 feet?
a. Units?
b. What’s the intensity in mr/hr?
30. Write the formula to solve for a New Distance (D2):
31. We know that 1 ci of iridium 192 emits 5.2 R/hr @ 1ft. So a 75 ci source of IR 192 would emit how many R/hr @ 1ft?
32. Using a 75 ci source of IR 192 at 12”, Calculate the distance (D2) to the “safe for public dosage.”
a. What is that dosage rate?
b. Show your work.
33. Cobalt 60 emits 14 R/hr/ci @ 1ft.
a. How many R/hr is emitted at 1 ft. with a 63 ci source of Co 60?
b. Solve for D2 and assume I2 is the public safe dosage of 2 mr/hr

Unit #4, Quiz #2: Printable Word File
Quiz #2 Español

Math Review Worksheet

To solve for a distance use the following formula:

$$D_2 = \sqrt{\frac{I_1 x D_1^2}{I_2}}$$

D = Distance   I = Intensity in Röntgens

To solve for Intensity use the following formula:

$$I_2 = \frac{I_1 x D_1^2}{D_2^2}$$

D = Distance I = Intensity in Röntgens

Iridium 192: 0.48 R/hr/ci @ 1M or 5.2 R/hr/ci @ 1'

Iridium 192 Half-life is 73.83 (74) Days

Cobalt 60: 1.30 R/hr/ci @ 1M or 14 R/hr/ci @ 1'

Cobalt 60 Half-life is 5.247 years

1 R = 1000 mr 1M = 3.28 ' = 39.37" 1" = 2.54 cm, 1' = 30.48 cm

HVL Formula: Io = Original Intensity; Id = Desired intensity

1. We know that 1 ci of iridium 192 emits 5.2 R/hr @ 1ft. so a 2 ci source of IR 192 would emit how many R/hr @ 1ft?
2. We have 25 R/hr @ 12", what is our intensity at 10 feet?

a. Does the difference in units matter? Y or N?

b. Write out the equation and Solve for our new intensity.

c. ANSWER:

3. We have 37 R/hr @ 3M, what is our intensity at 75 feet?

a. Are your units converted?

b. What's the intensity in mr/hr?

a. ANSWER:

4. We know that 1 ci of iridium 192 emits 5.2 R/hr @ 1ft. So a 75 ci source of IR 192 would emit how many R/hr @ 1ft?
5. Using a 75 ci source of IR 192 at 12", Calculate the distance (D2) to the "safe for public dosage."

a. What is the Safe Public Dose?

b. Show your work.

c. Answer:

6. We have 199 mr/hr @72", and our desired I2 is the safe to public radiation dosage.

a. What is the safe for public Radiation Dose?

b. How far do we need to be? Solve for (D2) in Feet.

7. We now have a 100 ci source of IR 192.

a. How many R/hr @1 ft? 520 R/hr

b. What is the "Caution: Radiation Area" working dosage?

c. Solve for D2 and assume I2 is the Caution dosage of:

8. Cobalt 60 emits 14 R/hr/ci @ 1ft.

a. How many R/hr is emitted at 1 ft. with a 100 ci source of Co 60? 1,400 R/hr

b. Solve for D2 and assume I2 is the public safe dosage of 2 mr/hr.

9. Cobalt 60 emits 14 R/hr/ci @ 1ft.

a. How many R/hr is emitted at 1 ft. with a 100 ci source of Co 60?

b. Solve for D2 and assume I2 is the "caution Radiation Work Area" dosage of 5mr/hr

10. We now have a 100 ci source of IR 192.

a. How many R/hr @1 ft?

b. Solve for D2 and assume I2 is the "caution Radiation Work Area" dosage of 5mr/hr.

11. Assuming a source has a ½ life of 20 years, how old would the source be in 3 half- lives?

a. 20 years

b. 40 years

c. 60 years

d. 120 years

12. If a radiographer has 60 mR at the surface of the exposure device, what would the reading be after 2 half- lives?

a. 15 mR

b. 40 mR

c. 80 mR

d. 10 mR

13. The use of 4 half-value layers will reduce the exposure by a factor of:

a. 4 times

b. 8 times

c. 16 times

d. 32 times

14. If a radiographer has 98 Ci of Ir-192, after 148 days how many Curies would be left?

a. 49 Ci

b. 22 Ci

c. 12 Ci

d. 24.5 Ci

15. A cobalt source has decayed from its original activity after 3 half-lives. Originally it was 88 Ci. Its current activity is:

a. 44 Ci

b. 22 Ci

c. 11 Ci

d. 8 Ci

16. A cobalt source of 73 Ci is exposed for a full 60 minutes. Assume a 14.0 R/Ci factor, shooting through a 3 half-value collimator. What would the restricted area be on the cold or collimated side of the collimator?

a. 149 ft

b. 162 ft.

c. 211 ft

d. 253 ft

17. A radiographer and assistant are standing in a 2 mR/hr field. What would the assistant's total dose be after 4 hours?

a. 2.0 mR

b. 4.0 mR

c. 6.0 mR

d. 8.0 mR

18. You have 24 exposures to make. Your shot time is 5 min per exposure and you're showing 30 mR/hr. What will your total dose be at the end of the shift?

a. 30 mR

b. 60 mR

c. 120 mR

d. 240 mR

19. A radiographer is receiving 100 mR at the crank assembly. The crank assembly is 25 ft in length. Where would the " RADIATION AREA" sign be posted?

a. 111.8 ft

b. 221.3 ft
c. 343.7 ft
d. 176.8 ft
20. A radiographer is receiving 100 mR/hr at the crank assembly. The crank assembly is 25 ft in length. How long will it take for the radiographer to receive a total dose of 50 mR?
a. 30 min
b. 60 min
c. 90 min
d. 120 min
21. Assume that 0.19 in. of lead is 1 half-value layer. How many half-value layers would you have with a sheet of lead 0.57" in thickness?
a. 1 HVL
b. 3 HVL
c. 5 HVL
d. 2 HVL
22. Assume 0.19" of lead is 1 half-value layer, and you have a total of 3 half-value layers of lead between you and 100 mR, what would your exposure rate be?
a. 50 mR
b. 25 mR
c. 12.5 mR
d. 33 mR
23. Assume 0.5 " of steel equals 1 half-value layer for Ir-192. How many half-value layers would you have with 1.5" of steel?
a. 3.28 HVL
b. 3.0 HVL
c. 3.05 HVL
d. 0.328 HVL
24. Assuming 0.19" of lead is 1 HVL. A piece of lead 0.38" thick would reduce the exposure rate by:
a. 25%
b. 50%
c. 75%
d. 100%
25. A monitored person may receive up to 5,000 mR per year (5 R/year). What would be considered an excessive amount of radiation exposure to that individual?
a. Exposures of more than 100 mR in one week
b. Any exposure over 1,250 mR in a quarter
c. Any unnecessary exposure to radiation
d. Exposures of 500 mR/hr

Unit #4 Math Review Worksheet: Printable Word File
MATH questions Español

Unit #4 Glossary of Terms

Alpha Particles: Ionizing, particulate radiation, which can be deadly if ingested or inhaled. They are basically a Helium atom with a +2 charge, can travel only a few centimeters, can be stopped by a sheet of paper, and generally are not considered as dangerous as gamma radiation or Beta particles UNLESS they get inside the body – then they are easily absorbed by the cells and this is a dangerous condition.

Atom: The fundamental basic building block of matter made up of three subatomic particles called protons, neutrons, and electrons. The basic unit of a chemical element of the periodic chart.

Curie: (Ci) is the unit of measurement of the amount of radioactivity of a substance, named after Marie and Pierre Curie. $1\ Ci = 3.7\times10^{10}$ disintegrations per second (rate of decay)

Beta Particles: Ionizing, particulate radiation with almost zero mass (about 8,000 times smaller than Alpha particles) Travels several meters in air and travels at high velocity approaching the speed of light.

Electron: a stable subatomic particle with a charge of negative electricity, found in all atoms.

Gamma Radiation: is a penetrating, ionizing, electromagnetic radiation arising from the radioactive decay of atomic nuclei, containing the shortest wavelength of the electromagnetic spectrum.

Half-Life: the amount of time required for ½ of the original number of radioactive atoms to decay or change into daughter atoms.

Half-Life Ir 192: 74 days

Half-Life Co 60: 5.3 years

Half-Life Cs 137: 30.17 years

Half- life Calculator

Ion: an atom or molecule with a net electric charge due to the loss or gain of one or more electrons. A positively or negatively charged atom or molecule.

Ionization: The removal of electrons from an atom. The essential characteristic of high-energy radiations when interacting with matter.

Ionizing Radiation: a type of radiation that is able to disrupt atoms and molecules through which it passes, giving rise to ions and free radicals.

Isotopes: atoms with same atomic number and chemical properties as element atoms; the nucleus has same number of protons but a different number of neutrons and thus, a different atomic mass and unlike radioisotopes can be relatively stable.

Daughter isotopes: In nuclear physics, a decay product (also known as a daughter product, daughter isotope, radio-daughter, or daughter nuclide) is the remaining nuclide left over from radioactive decay.

Neutron: a subatomic particle with about the same mass as a proton but without an electric charge. Neutrons are present in all atoms except the Hydrogen atom.

Nuclear Fission: The process by which the nucleus of a stable atom splits upon impact of another particle into 2 smaller parts. The resulting atoms are not the same element as the parent atom and are considered unstable and radioactive. This is the process by which Industrial isotopes (Cobalt 60, Iridium 192, Cesium 137) are created.

Nuclear Fusion: a nuclear reaction in which atomic nuclei of a lower atomic number fuse to form a heavier nucleus with the release of energy. The sun is an example of this process.

Particulate (or particle) Radiation: is the radiation of energy by means of fast-moving subatomic particles. Alpha particles, Beta particles, neutrons, and positrons are examples of particulate radiation.

Photons: Discrete particles of light or electromagnetic radiation hypothesized to explain the corpuscular theory of radiant energy.

Proton: a subatomic particle present in all atomic nuclei, with a positive electric charge equal in magnitude to that of an electron, but of opposite sign.

Radiation: Energy in transit. Either as particles or electromagnetic waves.

Radioactivity: The characteristic of various materials to emit ionizing radiation.

Radioisotope: an isotope by nature that is always unstable, containing high levels of nuclear energy.

Roentgen (R) – is a unit of measurement to the exposure of ionizing radiation, specifically Gamma radiation and X-rays, named after the German physicist Wilhelm Conrad Röntgen.

milli-Roentgen (mR): One thousandth of a Roentgen (1/1000)

SI: The International System of units of measurement. Includes most of the base units formerly called metric.

X-ray – a type of ionizing radiation formed in a Cathode Ray Tube (CRT) when high velocity electrons flow from the cathode to the anode.

Unit #4 Glossary of Terms: Printable Word File

Glossary of Terms Español

UNIT 5: ACTIVITY, HALF LIFE, & HALF VALUE LAYERS

Learning Objectives: ANSI/ASNT CP-105- 2016 Section 2, 3
Upon completion of this unit, the student will be able to define and understand the following:

- Review of Units 1, 2, 3 & 4
- Activity
  - Common Radioisotopes
    - Ir-192
    - Co-60
    - CS-137
- Half Life
- Half Value Layer (HVL)

Learning Activities:

- Lecture and discussion
- Midterm Exam

Learning Resources:

- Glossary

Evaluation:

- Radiation Safety Review Worksheet
- Midterm Exam

Unit 5- Outline: Printable Word File
Unit 5 Outline Español

Activity, Half Life & Half-Value Layers

Activity: Named after Nobel Prize recipient Marie Curie, the curie (ci) is the unit used to describe the rate of decay or activity, of a radioactive material in disintegrations per second. One curie equals 37,000,000,000 (37 billion) disintegrations per second. In the SI system, the Becquerel (Bq) is the unit of activity, which is equal to one disintegration per second.

Specific Activity: The specific activity of an isotope is used to describe the activity per unit of mass or weight (i.e. Curies per gram or Becquerel's per gram)

A high specific activity indicates that a source of a given activity will have a smaller physical size (smaller focal spot) which will yield better definition with radiographs.

In addition, there is less self-absorption in high specific activity sources because there is less matter to attenuate or absorb the radiation.

One phenomena radiographers deal with is how rapidly the rate of decay affects the usefulness and associated hazards of a radioactive isotope. To help define and quantify this dilemma, the radioactive Half-Life is as follows:

Half-life (symbol t1/2) is the time required for a quantity of an isotope to reduce to half its initial value. The term is commonly used in nuclear physics to describe how quickly unstable atoms undergo, or how long stable atoms survive, radioactive decay. The term is also used more generally to characterize any type of exponential or non-exponential decay. For example, the medical sciences refer to the biological half-life of drugs and other chemicals in the human body.

The original term, half-life period, dating to Ernest Rutherford's discovery of the principle in 1907, was shortened to half-life in the early 1950s.[1] Rutherford applied the principle of a radioactive element's half-life to studies of age determination of rocks by measuring the decay period of radium to lead-206.

So why does the radiographer care about half-life? There are two reasons:

1. The radiographer's safety protocols are dependent on calculating safe distances (Inverse Square Law Formula) and known radiation emissivity at any given distance from the gamma source. This can only be accomplished if the number of curies of the source is known. For example, if a radiographer is using a 100-curie (ci) source of Iridium – 192 to take radiographs, the technician will know 5.2 R/h are emitted for each ci at 1 foot; therefore, a little math tells us that 100ci source multiplied by 5.2 R/h/ci has a total of 520 R/h. Appropriate shielding and safe distances (ALARA) will be calculated based on these calculated numbers.
2. Radiographers have the task of taking pictures – radiographs – of whatever job they are working (Aerospace parts, oil line pipe welds, bridge structures, nuclear cooling tubes, etc..) As in the safety protocols in item #1 above, radiographers must calculate exposure times (how long to expose film and DDA's to the gamma radiation)

Now, let's just fast forward the scenarios above 74.3 days (the half-life of Ir-192) and now our 100 ci source has decayed to 50 ci from the original 100 ci source, all of the safety protocols and exposure times have changed. Less shielding and distance are needed but more exposure time is needed to take the same radiographs.

ALARA: maintaining our individual radiation exposure to "As Low As is Reasonably Achievable" involves the principals of Time, Distance and Shielding. As has been demonstrated throughout this radiation safety course, scientific and mathematical principals are the tools we use to determine what exactly is a safe Time or Distance as it relates to radiation exposure. Likewise, we use mathematical tools to determine the value of our radiation Shielding to determine the Half-Value Layers (HVL).

HVL (Half Value Layer): The amount (thickness) of a given shielding material needed to reduce the radiation emissivity by one-half its value. We use the following math formula to determine the how thick of material it will take to reduce the radiation to a safe rate of emissivity.

HVL Formula: Io = Original Intensity Id = Desired intensity

$$Log[\frac{Io}{Id}]/\ Log2$$

What the HVL formula above accomplishes for the radiographer is how many HVL's are needed to reduce an original intensity to a desired intensity. For instance, in our Radiography lab the lead lining in our 300 KV X-ray cabinets was calculated to a thickness that would provide an emissivity of 2mR/hr or less at one inch from any exterior point on the cabinet. However, how do we know how much lead, steel or concrete to use?

The chart below shows approximately how thick the shielding material needs to be in order to reduce the radiation emissivity by one-half. It is important to note that different gamma sources require differing thicknesses of shielding to achieve the HVL. Also, note the most common shielding used is lead, iron, and concrete, but a few others are included as they are the preferred shielding in some applications. Tungsten and depleted uranium shield the isotopes used in portable gamma radiograph "cameras" and water is a shielding material of choice in nuclear reactors.

Approximate Half Value Layers in cm (TVL in parentheses)

Energy (MeV)	Uranium	Tungsten	Lead	Iron	Concrete	Water
0.5			0.51	1.0	3.30	7.62
1.0			0.76	1.52	4.57	9.91
1.5			1.27	1.78	5.84	12.19
2.0			1.52	2.03	6.60	13.97
Ir-192	0.28	0.33	0.48	1.27	4.5	
Cs-137			0.65 (2.16)	1.6 (5.3)	4.8 (15.7)	
Co-60			1.2 (4.0)	2.1 (6.9)	6.2 (20.6)	
Ra-226			1.66(5.5)	2.2 (7.4)	6.9 (23.4)	

Unit #5 Activity, Half Life & HVL : Printable Word File

Radiation Safety Review Worksheet

<u>You have a 60 ci source of IR-192 at a distance of 30.48 cm. (IR-192 = 5.2R/hr/ci @1 foot)</u>

1. What is the radiation value of 60 ci of IR-192 at one-foot distance?
2. What is the radiation value at one meter?
3. What is the safe working radiation dose in mR?
4. What is the safe working radiation dose in R?
5. What is the safe public radiation dose in mR?

6. What would the calculated radiation emissivity be at 2 feet?

7. What would the calculated radiation emissivity be at 50 feet?

8. What would the calculated radiation emissivity be at 75 feet?

9. What would the calculated radiation emissivity be at 75 meters?

10. What would the calculated radiation emissivity be at 100 feet?

11. What would the calculated radiation emissivity be at 100 meters?

Radiation Safety Review Worksheet
Worksheet Español

Unit 5 Glossary of Terms

ALARA: "As Low As Reasonably Achievable" Personnel working in the field are required to keep their radiation exposures ALARA.

Gamma Rays: High energy, short wavelength electromagnetic radiation emitted during radioactive decay.

Gamma Radiography: Radiographs (film, DDA plates, and CR plates) are exposed using a gamma ray camera or radiograph-shooting machine, which can be portable, fixed in a cabinet or located in a vault.

Gamma Source (source): Industrial gamma radiography typically uses a man=made (activated) radiation source (Cobalt-60, Iridium-192, and Cesium-137). These sources are typically created for specific purposes and applications.

Half-Life: the amount of time required for ½ of the original number of radioactive atoms to decay or change into daughter atoms.

Half-Life Ir 192: 74 days

Half-Life Co 60: 5.3 years

Half-Life Cs 137: 30.17 years

Half- life Calculator

Biological half-life: the amount of time required for one half of a radioactive substance to be removed (from a human) by the natural biological processes (urination, sweating, bowel movements, vomiting)

HVL (Half-Value Layer): The amount (thickness) of a given shielding material needed to reduce the radiation emissivity by one-half it's value.

HVL Formula: Io = Original Intensity Id = Desired intensity

Ionizing Radiation: a type of radiation that is able to disrupt atoms and molecules on which they pass through, giving rise to ions and free radicals.

Time, Distance, and Shielding: These are the three basic tenets of Radiation Safety and the ALARA doctrine.

Week 5 Glossary of Terms

Glossary Español

UNIT 6: X-RAY

Learning Objectives: ANSI/ASNT CP-105- 2016 Section 2, 3

Upon completion of this unit, the student will be able to define and understand the following:

- Review of Units 1, 2, 3, 4 & 5
  - ALARA
  - Math Review
  - Permissible exposure limits
  - Radioisotopes
- X-ray
  - KV
  - mA
  - Time
- Shielding
  - HVL (Half -Value Layer) formula

Learning Activities:

- Lecture and discussion
- X-ray cabinet and controls tour
- HVL Math Worksheets

Learning Resources:

- X-ray Handout
- HVL Formula and online help
- Glossary

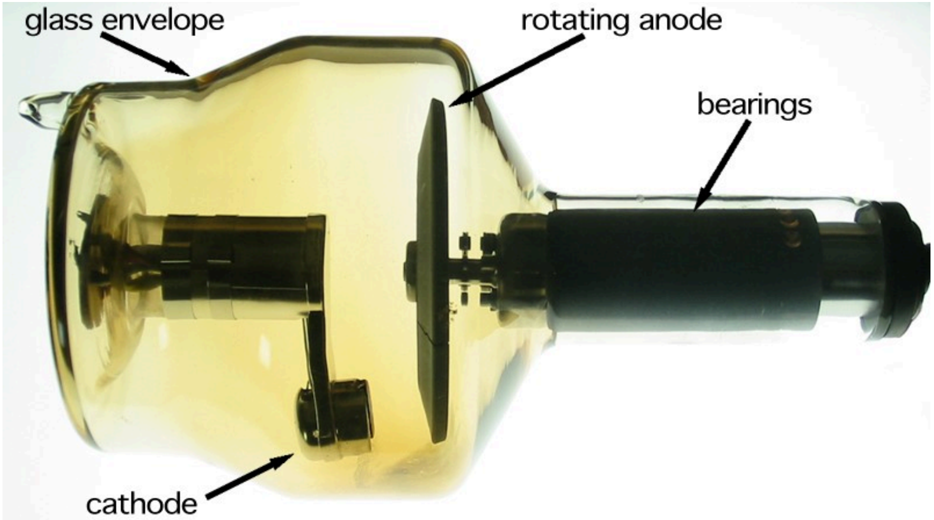
Evaluation:

- Unit 6 Worksheet
- Quiz #6

Unit 6- Outline Printable Word File

Unit 6 – Outline Español

X-ray Tube and Process



Typical rotating anode x-ray tube by Daniel W. Rickey is CC BY-SA 3.0.

X-Ray: X-ray, discovered by Wilhelm Conrad Roentgen in 1895 is widely used today both in the medical and industrial radiography fields. X-rays or x-ray photons are generated when high electrical voltage is introduced in a special vacuum tube via a hot cathode. The high-energy electrons are directed towards a metal Anode – usually a tungsten target – and when the electrons collide with the anode x-ray photons are generated and aimed in a specific direction and pattern, typically in an x-ray cabinet or vault.

The resulting x-ray photons are a non-particulate, ionizing radiation with the ability to penetrate matter. X-rays of the same energy level will be absorbed more readily by dense material as compared to less dense material. This is the reason lead, tungsten and concrete are used for shielding radiation. But since the x-rays (and gamma rays) are invisible, have no smell, and no taste, how do we know if we're being exposed to ionizing radiation? Look ahead to units 8 & 9 to learn about all of the radiation monitoring devices used to keep people safe and maintain ALARA.

When operating an industrial x-ray system typically the Level I or Level II radiographer will follow a procedure called a "technique" for taking an x-ray of a particular casting, forging, weldment or other part. X-ray tube adjustments and settings will include Kilo-voltage (kV), milliamperage (mA), and time, usually measured in seconds or minutes. There are many other settings such as source to film distance (SFD), fixturing of the part at specified angles and part orientation, image quality indicators (IQI) and much more. As the kV and mA increase, so does the amount and intensity of the X-ray photons.

Unit 6 X-Ray Lecture Printable Word File
Lecture Notes Español

Unit 6 Review Worksheet

1. Sketch and label an X-ray Tube:
2. The three basic means of providing personnel protection from radiation are:
3. A person receives 3 mr/hr at a certain distance from a radiation source. What would be their **exposure** if they remained at the same distance for 3 hours?
4. The inverse square law as applied to radiation protection states that:
   a. Radiation intensity varies inversely as the square of the time spent near the source.
   b. Radiation intensity varies proportionally with distance from the source.
   c. Radiation intensity varies inversely proportionally to the square of the distance from the source.
   d. Radiation intensity is making my brain go completely crazy.
5. Write out the equation to Solve for **Intensity**:
6. At 2 feet from a radiation source, the radiation measured is 300 R/hr. what is the intensity at 8 feet from the source?
7. A person standing 10 feet from an isotope is measuring 150 mr/hr. What would the intensity be at one foot?
8. Write out the equation to solve for Distance:
9. If the radiation intensity at 6 feet measures 40 R/hr, at what distance would the intensity be reduced to 10 R/hr?
10. Materials used in shielding radiation are most effective when they:
    a. Have a small number of electrons in their atoms.
    b. Are dense materials.
    c. Shield half of the radiation.
    d. All of the above
11. List three of the most common shielding materials used in order of the greatest shielding to the least shielding.
12. Write out the equation to solve for HVL:
13. If the radiation intensity at a certain point is 20 R/hr, how many HVL are required to reduce the intensity to 5 R/hr?
14. If the HVL of lead for Co-60 is 0.49 inches, what thickness of lead would be required to reduce 600 mr/hr of radiation to under 2 mr/hr?

Unit 6 Worksheet Printable Word File

Unit 6 Quiz

1. Sketch and label an X-ray Tube:

2. The symbol R means:

a. Rem
b. Rad
c. Roentgen
d. Radiation

3. The Roentgen (R) exposure is measured in:

a. Tissue
b. Water
c. A lab
d. Air

4. The symbol mR means:

a. Milliroentgen
b. Microroentgen
c. Megaroentgen
d. Millirem

5. Activity of radioactive material is measured in

a. Curies
b. Roentgens
c. Sieverts
d. grays

6. One Roentgen or 1R is equal to:

a. 100 milliroentgen
b. 1000 milliroentgen
c. 0.001 milliroentgen
d. 1 milliroentgen

7. Becquerels and Curies are units of measurement of:

a. Physical size of the source
b. Gray per hour
c. Decay rate
d. Roentgen per hour

8. Atoms that have excess energy and are unstable are known as:

a. Radioactive
b. Radioactivity
c. Balanced
d. Weighted

9. The area known as the center of an atom is called the:

a. Electron
b. Nucleus
c. Proton
d. Neutron

10. The process that results in the removal of orbital electrons from atoms resulting in the formation of ion pairs is called:

a. Excitation

b. Radioactivity
c. Decay
d. Ionization
11. After 6 half-value layers, what percentage of radiation would be received?
a. 50%
b. 25%
c. 8%
d. 1.6%
12. If a radiographer has 60 mR at the surface of the exposure device, what would the reading be after 2 half-lives?
a. 15 mR
b. 40 mR
c. 80 mR
d. 10 mR
13. A sealed source emits what?
a . Alpha particles
b. Beta particles
c. X-rays
d. Gamma rays
14. A radiographer and assistant are standing in a 2 mR/hr field. What would the assistant's total dose be after 4 hours?
a. 2.0 mR
b. 4.0 mR
c. 6.0 mR
d. 8.0 mR
15. You have 24 exposures to make. Your shot time is 5 minutes per exposure and your showing 30 mR/hr. What will be your total dose at the end of the shift?
a. 30 mR
b. 60 mR
c. 120 mR
d. 240 mR
16. Which of the following are used primarily in radiography?
a. Gamma sources
b. Radio Waves
c. X-rays
d . Microwaves
e. Both A and C
17. Radiation is defined as:
a. Ionized Beta Alpha particles
b. Energy in transit, either as particles or electromagnetic waves
c. Heat and light emitting only from gamma sources like uranium or the sun
d. Energy that does not burn or ionize
18. An Ion:
a. An atom or part of an atom with a + or a – charge
b. A long, long time
c. Is not harmful to humans
d. None of the above
19. Only Gamma radiation can ionize matter.
a. True
b. False

20. Which of the following are examples of “non-ionizing” radiation?
a. Near UV and radio waves
b. Visible light and Microwaves
c. Infrared
d. All of the above
21. Which of the following are two types of electromagnetic radiation used for industrial radiography?
a. X-rays and Microwaves
b. Gamma and X-rays
c. Gamma and Radio waves
d. Infrared and UV
22. The term used to describe the decay of an isotope to one half of the original value is:
a. Radioactive decay
b. Half value layer
c. Time, Distance, Shielding
d. Half-Life
23. The main difference between Gamma radiation and X-ray radiation is:
a. Speed of radiation travel
b. The source of radiation
c. Penetrating power
d. X-ray is not very dangerous
24. What is the safe dosage rate for the public?
a. 2 R/hr
b. 20 mr/hr
c. 2 lamda per M
d. 2 mr/hr
25. Write out the HVL Formula and identify what the variables stand for:

26. If the radiation intensity of Co60 at a certain point is 24R/hr, how many H.V.L are required to reduce the intensity to 5 R/hr?

a. How much lead (thickness) will be required to attain 5 R/hr in the calculation above?

b. How much concrete (thickness) will be required to attain 5 R/hr in the calculation above?

27. If the radiation intensity of Co60 at a certain point is 112R/hr, how many H.V.L are required to reduce the intensity to 5 R/hr?

a. How much lead (thickness) will be required to attain 5 R/hr in the calculation above?

b. How much concrete (thickness) will be required to attain 5 R/hr in the calculation above?

28. If the radiation intensity of Ir 192 at a certain point is 24R/hr, how many H.V.L are required to reduce the intensity to 5 R/hr?

a. How much lead (thickness) will be required to attain 5 R/hr in the calculation above?

b. How much concrete (thickness) will be required to attain 5 R/hr in the calculation above?

29. If the radiation intensity of Ir 192 at a certain point is 67R/hr, how many H.V.L are required to reduce the intensity to 5 R/hr?

a. How much lead (thickness) will be required to attain 5 R/hr in the calculation above?

b. How much concrete (thickness) will be required to attain 5 R/hr in the calculation above?

30. Write the formula for solving for the New Intensity (I2):

31. We have 50 R/hr @ 12”, what is our intensity at 10 feet?
Does the difference in units matter? Y or N?
Write out the equation and Solve for our new intensity.

32. We have 67 R/hr @ 1M, what is our intensity at 75 feet?

Does the difference in units matter? Y or N?

Write out the equation and Solve for our new intensity.

33. Write the formula to solve for a New Distance (D2):
34. We know that 1 ci of iridium 192 emits 5.2 R/hr @ 1ft. So a 100 ci source of IR 192 would emit how many R/hr @ 1ft?
35. Using a 100 ci source of IR 192 at 12", Calculate the distance (D2) to the "safe for public dosage."

What is that dosage rate?

Show your work.

36. We have a 100 ci source of CO 60:

a. How many R/hr do we have at 1 foot?

b. Calculate the distance (D2) to the safe working dosage for a radiographer.

c. Calculate the distance (D2) to the safe for public dosage.

BONUS Questions:

37. How many R/hr are emitted at 1 foot from the 100 ci source of CO-60?
38. Calculate the number of HVL's needed to achieve a safe working dosage.
39. Calculate the thickness of lead required to achieve the safe working dosage in problem 38 above.

Unit 6 Quiz – Printable Word File

#6 Quiz Español

Unit 6 Glossary

Absorption: In NDT, absorption is the reduction of the intensity of any form of radiated energy as a result of energy conversion (absorption) in a medium, such as the conversion of sound energy into heat (compare attenuation)

Bremsstrahlung: Also known as "**breaking radiation**". Electromagnetic radiation produced when electrons' path and kinetic energy brings them close to the positive fields of atomic nuclei. In X-radiation, electrons strike a target provided for this purpose. The electrons slow down and give up kinetic energy called X-radiation photons.

Compton Effect or Compton Scattering: The mode in which a moderate energy photon transfers a portion of its energy to an outer shell electron and the remaining energy is redirected as a lower energy photon.

Electron: a stable subatomic particle with a charge of negative electricity, found in all atoms.

Gamma Radiation: is a penetrating, ionizing, electromagnetic radiation arising from the radioactive decay of atomic nuclei, containing the shortest wavelength of the electromagnetic spectrum.

HVL (Half-Value Layer): The amount (thickness) of a given shielding material needed to reduce the radiation emissivity by one-half it's value.

HVL Formula: Io = Original Intensity Id = Desired intensity

$$Log[\frac{Io}{Id}]/\ Log2$$

Ionizing Radiation: a type of radiation that is able to disrupt atoms and molecules on which they pass through, giving rise to ions and free radicals.

KV (Kilo voltage): Energy or amount of radiation

mA (milliamperes): Intensity, penetrating power of radiation

Photoelectric Effect: When light shines on metal, electrons can be ejected from the surface of the metal in a phenomenon known as the *photoelectric effect*. This process is also referred to as *photoemission*, and the electrons that are ejected from the metal are called *photoelectrons*. In terms of their behavior and their properties, photoelectrons are no different from other electrons.

Photons: Discrete particles of light or electromagnetic radiation hypothesized to explain the corpuscular theory of radiant energy.

Proton: a subatomic particle present in all atomic nuclei, with a positive electric charge equal in magnitude to that of an electron, but of opposite sign.

X-ray – a type of ionizing radiation formed in a Cathode Ray Tube (CRT) when high velocity electrons flow from the cathode to the anode.

Unit 6 Glossary of Terms Printable Word File
Unit 6 Glossary Español

UNIT 7: BIOLOGICAL EFFECTS

<u>Learning Objectives:</u> ANSI/ASNT CP-105- 2016 Section 2, 3

Upon completion of this unit, the student will be able to define and understand the following:

- Review of Units 1, 2, 3, 4, 5 & 6
  - Safety….
  - Math Review
  - X-ray Overview
  - HVL Calculations
- Biological Effects of Radiation
- RAD: Radiation Absorbed Dose
- REM: Roentgen Equivalent Man
- QF: Quality Factor

Learning Activities:

- Lecture & Discussion
-

Learning Resources:

- Glossary

Evaluation:

- Attendance Recorded
- Notes Reviewed

Unit 7- Outline Printable Word File
unit 7 OUTLINE Español

Effects of Radiation

Radiation Symptoms occur because of overexposure to radiation. Most are familiar with the effects of spending too much time in the direct sunlight on a hot summer's day – the result is a sunburn. Sunburns occur when an individual's skin is overexposed to the sun and the medical community has gone to great lengths educating people on the harmful effects of the suns radiation. These harmful effects vary from the uncomfortable red, enflamed skin to severe blistering demanding medical treatment. So how does one prevent a sunburn? Spend less TIME in the sun. Cover up your skin with clothes, shade, or sunscreen (SHIELDING). This sounds a lot like the ALARA principle of TIME, DISTANCE and SHIELDING.

We can feel the gentle warmth of the sun's rays on our body, but the damage being done is slow and the pain is a delayed response to the overexposure of sunlight. Likewise, the ionizing radiation of gamma and x-rays is invisible, it has no smell, but unlike the sun – it cannot be felt at all.

Biological effects of radiation fit into two general categories:

1. **Acute radiation exposure** is when an individual receives a high radiation dose over a relatively short period of time. Acute radiation exposure also called Acute Radiation Syndrome (ARS). ARS results when an individual receives a whole body exposure of 100 to 200 Rems or more (Roentgen Equivalent Man) over a 24-hour time period. The table below shows the likely symptoms associated with differing levels of exposure.
2. **Chronic radiation exposure** occurs over an extended or prolonged time and the results vary depending on the dose of exposure, duration of exposure and individual reaction to the over-exposure.

Roentgens (R), Radiation Absorbed Dose (RAD), Roentgen Equivalent Man (REM), and Quality Factor (QF) are units of radiation measurement and it is important for the radiographer to discern between them each.

Roentgens (R), is the unit of measuring radiation exposure in **AIR** for X-rays and gamma rays, which is based on the ionization produced in air. More specifically, the Roentgen is defined as "the radiation flux which will produce 2.083 x 109 ion pairs per cubic centimeter (one electrostatic unit of charge either positive or negative) at a standard temperature and standard pressure (0° C and 760 mm Hg). But for all practical purposes – commit to memory that Roentgens measure ionizing radiation in air.

Radiation Absorbed Dose (RAD) is the accepted unit of measurement of absorbed dose in **tissue**. 1 RAD represents 100 ergs of energy imparted per gram of material at the place of exposure.

Quality Factor (QF) is a factor or multiplier of the actual biological effects or damage of the specific radiation type on the human tissue. In a sense, not all Roentgens impart equal damage to tissue and therefore we use a QF multiplier to calculate for the Roentgen Equivalent Man (REM). Table 7A below will demonstrate the various QF value of differing ionizing radiation sources.

Roentgen Equivalent Man (REM) is defined as the quantity of ionizing radiation of any type which, when absorbed in a biological system, results in the same biological effects as one unit of absorbed dose in the form of low linear energy transfer (LET) radiation. More practically, REM is defined as the product of the RAD multiplied by the QF.

RAD x QF = REM

For example, an exposure to 1 R of gamma or X-rays is equal to 1 REM because the QF of gamma and X-rays is 1. However, an exposure to 1R of alpha particles is equal to 20 REM due to the QF of 20 for alpha particles. All things being equal, alpha particles are 20 times worse for human tissue than gamma or x-rays. It is critical for individuals working in nuclear facilities and performing gamma radiography to clearly understand the simple equation above to calculate the REM dose accurately.

The following data is compiled from the NRC and can be seen there in an expanded format.

TABLE7-A: Quality Factor (QF)

Types of Radiation	Quality Factor (QF)
X-Rays	1
Gamma Rays	1
Beta Particles	1
Neutron Radiation	10
High-Energy Protons	10
Alpha Particles	20

TABLE 7-B: Biological Effects based on Exposure Rates

Dose	Summary of Biological Effects
<5 rad	No immediate observable effects
~5 to 50 rad	Slight blood changes may be detected by medical evaluations
~50 to 150 rad	Slight blood changes will be noted and symptoms of nausea, fatigue, vomiting, etc. likely
~150 to 1,100 rad	Severe blood changes will be noted and symptoms appear immediately. Approximately 2 weeks later, some of those exposed may die. At about 300 – 500 rad, up to one half of the people exposed will die within 60 days without intensive medical attention. Death is due to the destruction of the blood forming organs. Without white blood cells, infection is likely. At the lower end of the dose range, isolation, antibiotics, and transfusions may provide the bone marrow time to generate new blood cells and full recovery is possible. At the upper end of the dose range, a bone marrow transplant may be required to produce new blood cells.
~1,100 to 2,000 rad	The probability of death increases to 100% within one to two weeks. The initial symptoms appear immediately. A few days later, things get very bad, very quickly since the gastrointestinal system is destroyed. Once the GI system ceases to function, nothing can be done, and medical care is for comfort only.
>2,000 rad	Death is a certainty. At doses above 5,000 rad, the central nervous system (brain and muscles) can no longer control the body functions, including breathing blood circulation. Everything happens very quickly. Nothing can be done, and medical care is for comfort only

week 7 Lecture Notes Printable Word File

Unit 7 Lecture Notes

Week 7 Glossary of Terms

Acute radiation exposure is when an individual receives a high radiation dose over a relatively short period of time. Acute radiation exposure also called Acute Radiation Syndrome (ARS). ARS results when an individual receives a whole body exposure of 100 to 200 Rems or more (Roentgen Equivalent Man) over a 24-hour period of time.

Alpha Particle: A positive electrically charged particle of radiation consisting of two protons and two neutrons (same as a helium nucleus). It is emitted from the nucleus of many radioactive materials during radioactive decay. Alpha particles have a very low kinetic energy and therefore can be stopped by a sheet of paper or clothing. However, if ingested, alpha particles have a Quality Factor (QF) of 20 times that of straight gamma or X-ray radiation, making them dangerously toxic if inhaled or ingested.

Beta Particle: negatively charged particles having mass and charge equal in magnitude to that of an electron.

Biological half-life: the amount of time required for one half of a radioactive substance to be removed (from a human) by the natural biological processes (urination, sweating, bowel movements, vomiting)

Chronic radiation exposure occurs over an extended or prolonged period of time and the results are often varied depending on the dose of exposure, duration of exposure and individual reaction to the over-exposure.

Gamma Radiography: Radiographs (film, DDA plates, CR plates) are exposed using a gamma ray camera or radiograph shooting machine which can be portable, fixed in a cabinet or located in a vault.

Gamma Source (source): Industrial gamma radiography typically uses a man=made (activated) radiation source (Cobalt-60, Iridium-192, and Cesium-137). These sources are typically created for specific purposes and applications.

Gamma Radiation: is a penetrating, ionizing, electromagnetic radiation arising from the radioactive decay of atomic nuclei, containing the shortest wavelength of the electromagnetic spectrum.

Ionizing Radiation: a type of radiation that is able to disrupt atoms and molecules on which they pass through, giving rise to ions and free radicals.

Neutron: a subatomic particle with about the same mass as a proton but without an electric charge. Neutrons are present in all atoms except the Hydrogen atom.

Particulate (or particle) Radiation: is the radiation of energy by means of fast-moving subatomic particles. Alpha particles, Beta particles, neutrons, and positrons are examples of particulate radiation.

Photons: Discrete particles of light or electromagnetic radiation hypothesized to explain the corpuscular theory of radiant energy.

Roentgens (R), is the unit of measuring radiation exposure in **AIR** for X-rays and gamma rays, which is based on the ionization produced in air. More specifically, the Roentgen is defined as "the radiation flux which will produce 2.083 x 109 ion pairs per cubic centimeter (one electrostatic unit of charge either positive or negative) at a standard temperature and standard pressure (0° C and 760 mm Hg). Nevertheless, for all practical purposes – commit to memory that Roentgens are a measure of ionizing radiation in air.

Radiation Absorbed Dose (RAD) is the accepted unit of measurement of absorbed dose in **tissue**. 1 RAD represents 100 ergs of energy imparted per gram of material at the place of exposure.

Quality Factor (QF) is a factor or multiplier of the actual biological effects or damage of the specific radiation type on the human tissue. In a sense, not all Roentgens impart equal damage to tissue and therefore we use a QF multiplier to calculate for the Roentgen Equivalent Man (REM).

Roentgen Equivalent Man (REM) is defined as the quantity of ionizing radiation of any type which, when absorbed in a biological system, results in the same biological effects as one unit of absorbed dose in the form of low linear energy transfer (LET) radiation. More practically, REM is defined as the product of the RAD multiplied by the QF.

X-ray – a type of ionizing radiation formed in a Cathode Ray Tube (CRT) when high velocity electrons flow from the cathode to the anode.

Week 7 Glossary of Terms Printable Word File

Week #7 Glossary Español

UNIT 8: MORE BIOLOGICAL EFFECTS OF RADIATION

Learning Objectives: ANSI/ASNT CP-105- 2016 Section 2, 3
Upon completion of this unit, the student will be able to define and understand the following:

- Review of Units 1, 2, 3, 4, 5, 6 & 7
  - Safety….
  - Review if R, RAD, QF, and Rem
- Biological Effects Continued
  - Somatic Effects
  - Genetic Effects
  - Teratogenic Effects

Learning Activities:

- Lecture & Discussion

Learning Resources:

- Glossary

Evaluation:

- NRC Research Assignment
- Week #8 Quiz

Unit 8- Outline Printable Word File
Unit 8 Outline Español

More Effects of Radiation

In previous units, the topic of the biological effects that radiation exposure has on the body and the units used to measure these exposures was addressed. Unit 8 will review those units and expand in to detail on the specifics of the biological effects of radiation exposure or rather *over-exposure*.

The Biological Effect of radiation poisoning or over-exposure to the whole body are divided into three general categories by the USNRC and they are:

1. **Somatic Effects:** a person receiving somatic effects might exhibit **prompt** symptoms such as minor to severe skin burns, cataracts on the eyes, and even severe internal organ and blood damage. A person might also experience **delayed** somatic effects such as cancer due to damaged and mutating cells in the body.
2. **Genetic Effects:** a person can experience genetic mutations and changes in their DNA that can be passed on to their offspring, although in some radiation exposure cases the victim becomes sterile and unable to reproduce.
3. **Teratogenic Effects:** this is when a developing embryo (baby) is expose to radiation and the result can be malformation of organs including various levels of mental retardation.

This effect differs from genetic effects in that the radiation caused damage to the baby after fertilization of the embryo as opposed to before to the parents (mother or father) DNA.

There is no question ionizing radiation exposure must be kept to a minimum and it is imperative for radiographers to be fluent in "radiation safety", prepared to keep themselves and everyone safe and to practice ALARA.

The Median Lethal Dose (MLD) is that radiation dose expected to cause death to 50 percent of an exposed population within 30 days (MLD 50/30). Typically, the MLD 50/30 is in the range from 400 to 450 rem (4 to 5 Sieverts) received over a very short period. Table 8-A displays the Annual Dose Limits as established by the NRC. It is interesting to note the different doses allowed based on age and body parts.

Table 8-A: Annual Dose Limits

	Adults (≥ yrs)	**Minors (<18 yrs)**
Whole body	5000 mrem/yr	500 mrem/yr
Lens of eye	15000 mrem/yr	1500 mrem/yr
Extremities	50000 mrem/yr	5000 mrem/yr
Skin	50000 mrem/yr	5000 mrem/yr
Organ	50000 mrem/yr	5000 mrem/yr

Table 8-B: similar to table 7-B in the previous chapter with a little variation in the biological effects of acute exposure on a human.

Dose (Rads*)	**Effects**
25-50	First sign of physical effects (drop in white blood cell count)
100	Threshold for vomiting (withing a few hours of exposure)
320-360	~ 50% die within 60 days (with minimal supportive care)
480-540	~ 50% die within 60 days (with supportive medical care)
1,000	~ 100% die within 30 days

Week 8 Lecture Notes Printable Word File
Week 8 Notes Español

NRC Research Assignment

The NRC has a GINORMOUS website with a lot of information. Your job is to answer the following exactly as instructed. You can email the instructor your finished assignment as a file attachment or hand in a hard copy during the next class meeting.

1. What does USNRC stand for?
2. Search for the LD definition and then copy & paste the NRC definition in the space below:
3. Search for the "Dose Limit for the Embryo/Fetus of a Declared Pregnant.."
    - How many pages of information are there?
    - Summarize what scientific research and data indicate about embryo/fetus and radiation exposure on the last page of this NRC document:
4. Search for Incident Reports review the reports from the last couple of years. Copy and paste the report below and be prepared to discuss during the next class meeting.

Unit 8 – NRC Assignment Printable Word File
NRC Assignment Español

Unit 8 Glossary

Acute radiation exposure is when an individual receives a high radiation dose over a relatively short period of time. Acute radiation exposure also called Acute Radiation Syndrome (ARS). ARS results when an individual receives a whole body exposure of 100 to 200 Rems or more (Roentgen Equivalent Man) over a 24-hour period of time. The table below shows the likely symptoms associated with differing levels of exposure.

Biological Effects:

- **Somatic Effects:** a person receiving somatic effects might exhibit **prompt** symptoms such as minor to severe skin burns, cataracts on the eyes, and even severe internal organ and blood damage. A person might also experience **delayed** somatic effects such as cancer due to damaged and mutating cells in the body.
- **Genetic Effects:** a person can experience genetic mutations and changes in their DNA that can be passed on to their offspring, although in some radiation exposure cases the victim becomes sterile and unable to reproduce.
- **Teratogenic Effects:** this is when a developing embryo (baby) is expose to radiation and the result can be malformation of organs including various levels of mental retardation. This effect differs from genetic effects in that the radiation caused damage to the baby after fertilization of the embryo as opposed to before to the parents (mother or father) DNA

Annual Occupational Dose Limits: This is the maximum dose allowable by NRC for monitored radiographers and other occupations where radiation exposure occurs such as nuclear medicine, medical radiography, nuclear power plant reactors and research scientists.

Table 8-A: Annual Dose Limits

	Adults (≥ yrs)	**Minors (<18 yrs)**
Whole body	5000 mrem/yr	500 mrem/yr
Lens of eye	15000 mrem/yr	1500 mrem/yr
Extremities	50000 mrem/yr	5000 mrem/yr
Skin	50000 mrem/yr	5000 mrem/yr
Organ	50000 mrem/yr	5000 mrem/yr

Median Lethal Dose (MLD) is that radiation dose expected to cause death to 50 percent of an exposed population within 30 days (MLD 50/30). Typically, the MLD 50/30 is in the range from 400 to 450 rem (4 to 5 Sieverts) received over a very short period.

Unit 8 Glossary Printable Word File
Week 8 Glossary Español

Unit 8 Quiz

1. Sketch and label an X-ray Tube:
2. What does the following acronym represent? A L A R A
   a. As Low As Reasonably Achievable
   b. As Long As Radiation Absconds
   c. Laura's Radiation Principles
   d. Achievable Low Radiation Absorption
3. Which of the following type of nuclear reactions is used to create isotopes for industrial radiography?

a. Nuclear Fission
b. Nuclear Fusion

4. Which of the following nuclear reactions is occurring on the sun?

a. Nuclear Fission
b. Nuclear Fusion

5. The Roentgen (R) exposure is measured in:

a. Tissue
b. Water
c. A lab
d. Air

6. The unit that compares the biological effectiveness of the different types of radiation is the:

a. REM
b. RAD
c. Roentgen
d. QF

7. The abbreviation RAD stands for ___________________________

a. Radiation Absorbed Dose
b. Radical Man
c. Outrageousness
d. Roentgen Absorbed Dose

8. The abbreviation REM stands for:

a. Radiation Equivalent Mammal
b. Relative Equivalent Man
c. Roentgen Equivalent Man
d. Radical Equivalent Man

9. QF x RAD = what?

a. Radiation Equivalent Mammal
b. Roentgen Equivalent Man
c. Relative Equivalent Man
d. Radical Equivalent Man

10. An exposure of 5R of alpha particles is equal to:

a. 5 REM
b. 50 REM
c. 20 REM
d. 100 REM

11. The whole body radiation dose must normally be limited to a dose of:

a. 1 ¼ rems per calendar quarter.

b. 18 ¾ rems per calendar quarter.
c. 7 ½ rems per calendar year.
d. 5 rems per calendar year.
12. The earliest indications of radiation damage may be detected in the:
a. Nerve cells.
b. Skin cells.
c. Bone cells.
d. Blood cells.
13. The physical effects of radiation on the body of an individual receiving the radiation are called:
a. Somatic effects
b. Latent effects.
c. Genetic effects.
d. Radiosensitive effects.
14. The radiation effects which can be passed on to the offspring or to a later generation of a person receiving radiation are called:
a. Future effects.
b. Genetic effects.
c. Somatic effects.
d. Radiosensitive effects.
15. In relation to radiation effects, MLD stands for:
a. Maximum Lethal Dose
b. Median Lethal Dose
c. Minimum Legal Dose
d. Maximum Legal Dose
16. The MLD for humans is the radiation dose:
a. That causes the first death.
b. That causes slight, temporary blood changes.
c. That is considered lethal to all persons exposed.
d. That causes 50% of those exposed to die.
17. The MLD for humans is approximately______________ rems whole body exposure within 24 hour period.
a. 250 – 350 rem.
b. 400 – 500 rem.
c. 750 – 1,000 rem.
d. 1000 – 1,250 rem.
18. Devices attached to the clothing of people working in radiation areas for measurement of radiation are called:
a. Survey instruments.
b. G-M counters
c. Personnel monitoring devices.
d. Portable rate meters.
19. HVL stand for:
a. Half Value Layer
b. Half Value Luminescence
c. Half Vetted Layer
d. High Value Layer
20. Materials used in shielding radiation are most effective when they:
a. Have a small number of electrons in their atoms.
b. Are dense materials.

c. Shield half of the radiation.
d. Are light weight and portable

21. When a body tissue cell is damaged by radiation:

a. The cell may lose its ability to reproduce.
b. The cell may die.
c. Damage is caused by knocking an electron out of the orbit of its parent atom.
d. All of the above

22. Atoms that have excess energy and are unstable are known as:

a. Radioactive
b. Radioactivity
c. Balanced
d. Weighted

23. The process that results in the removal of orbital electrons from atoms resulting in the formation of ion pairs is called:

a. Excitation
b. Radioactivity
c. Decay
d. Ionization

24. After 6 half-value layers, what percentage of radiation would be received?

a. 50%
b. 25%
c. 8%
d. 1.6%

25. If a radiographer has 60 mR at the surface of the exposure device, what would the reading be after 2 half-lives?

a. 15 mR
b. 40 mR
c. 80 mR
d. 10 mR

26. A sealed source emits what?

a. Alpha particles
b. Beta particles
c. X-rays
d. Gamma rays

27. A radiographer and assistant are standing in a 2 mR/hr field. What would the assistant's total dose be after 4 hours?

a. 2.0 mR
b. 4.0 mR
c. 6.0 mR
d. 8.0 mR

28. You have 24 exposures to make. Your shot time is 5 minutes per exposure and your showing 30 mR/hr. What will be your total dose at the end of the shift?

a. 30 mR
b. 60 mR
c. 120 mR
d. 240 mR

29. Radiation is defined as:

a. Ionized Beta Alpha particles
b. Energy in transit, either as particles or electromagnetic waves

c. Heat and light emitting only from gamma sources like uranium or the sun
d. Energy that does not burn or ionize

30. An Ion:
a. An atom or part of an atom with a + or a – charge
b. A long, long time
c. Is not harmful to humans
d. None of the above

31. Only Gamma radiation can ionize matter.
a. True
b. False

32. Which of the following are examples of "non-ionizing" radiation?
a. Near UV and radio waves
b. Visible light and Microwaves
c. Infrared
d. All of the above

33. Which of the following are two types of electromagnetic radiation used for industrial radiography?
a. X-rays and Microwaves
b. Gamma and X-rays
c. Gamma and Radio waves
d. Infrared and UV

34. The term used to describe the decay of an isotope to one half of the original value is:
a. Radioactive decay
b. Half value layer
c. Time, Distance, Shielding
d. Half-Life

35. The main difference between Gamma radiation and X-ray radiation is:
a. Speed of radiation travel
b. The source of radiation
c. Penetrating power
d. X-ray is not very dangerous

36. What is the safe dosage rate for the public?
a. 2 R/hr
b. 20 mr/hr
c. 2 lamda per M
d. 2 mr/hr

37. We have 25 R/hr @ 12", what is our intensity at 10 feet in mr/hr?
a. What are you solving for?
b. Answer:

38. Using a 75 ci source of IR 192 at 12", Calculate the distance (D2) to the "safe for public dosage."
a. What are you solving for?
b. Answer:

39. We have an IR-192 source with an original strength of 50 ci received about 150 Days ago.
a. What is the ½ life of IR-192?
b. How many ½ lives did we decay to?
c. What is the current strength of this source? (In Curies)
d. What is the output of the source above at 1-foot distance?
e. What is the calculated radiation level at 1 meter?

40. If the H.V.L of lead for Co-60 is 0.49 inches, what thickness of lead would be required to reduce 600 mr/hr of

radiation to under 2 mr/hr?
a. Solving for?
b. Answer:

41. If the H.V.L of concrete for Co-60 is 2.6 inches, what thickness of concrete would be required to reduce 600 mr/hr of radiation to under 2 mr/hr?
a. Solving for?
b. Answer:

Unit 8 QUIZ Printable Word File

Week 8 QUIZ Español

UNIT 9: CAUTION SIGNAGE AND DETECTION DEVICES

Learning Objectives: ANSI/ASNT CP-105- 2016 Section 2, 3

Upon completion of this unit, the student will be able to define and understand the following:

- Review of Units 1, 2, 3, 4, 5, 6, 7 & 8
  - Safety….
  - Math Review
  - Gamma & X-ray
- Safety Signage & Personnel Monitoring Equipment
  - Safety Signage
  - Safety Zones
  - Radiation Limits
  - Survey Meter
  - Geiger Counter
  - Film Badge
  - Area Monitor
  - TLD's

Learning Activities:

- Lecture & Discussion
- Handling and use of monitoring equipment
- Demonstrate calibration and use of Dosimeters
- Expose a Dosimeter for proof of concept

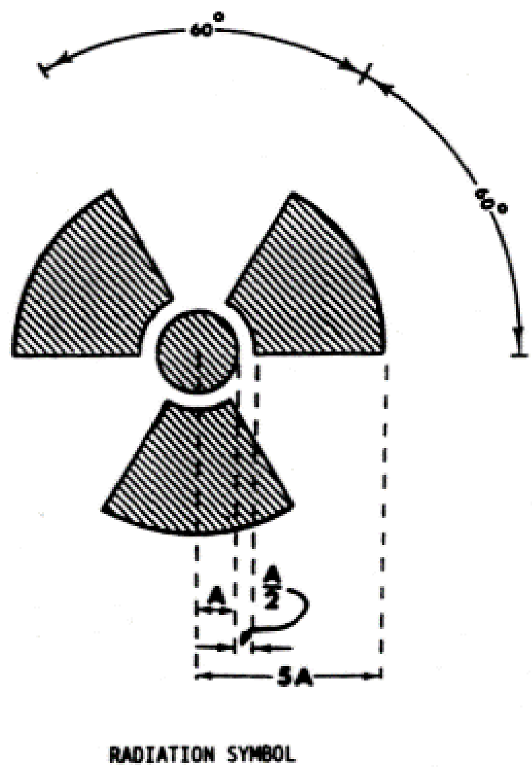
Learning Resources:

- Radiation signs and handouts
- Glossary

Unit 9- Outline Printable Word File

Unit 9- Outline Español

Caution Signage and Labels



Radiation Symbol from NRC is Public Domain.

The NRC provides detailed information on the signage to be used for every level and type of Radiation safety situation. It is the radiographer's responsibility to recognize and understand the significance of the variety of signs. The NRC dictates the color, wording, size, and geometric shape of Radiation caution signs in NRC Part 20.1901 as follows:

(a) *Standard radiation symbol.* Unless otherwise authorized by the Commission, the symbol prescribed by this part shall use the colors magenta, purple, or black on yellow background. The symbol prescribed by this part is the three-bladed design:

(1) Cross-hatched area is to be magenta, or purple, or black, and

(2) The background is to be yellow.

(b) *Exception to color requirements for standard radiation symbol.* Notwithstanding the requirements of paragraph (a) of this section, licensees are authorized to label sources, source holders, or device components containing sources of licensed materials that are subjected to high temperatures, with conspicuously etched or stamped radiation caution symbols and without a color requirement.

(c) *Additional information on signs and labels.* In addition to the contents of signs and labels prescribed in this part, the licensee may provide, on or near the required signs and labels, additional information, as appropriate, to make individuals aware of potential radiation exposures and to minimize the exposures.

Warning sign from NRC is Public Domain

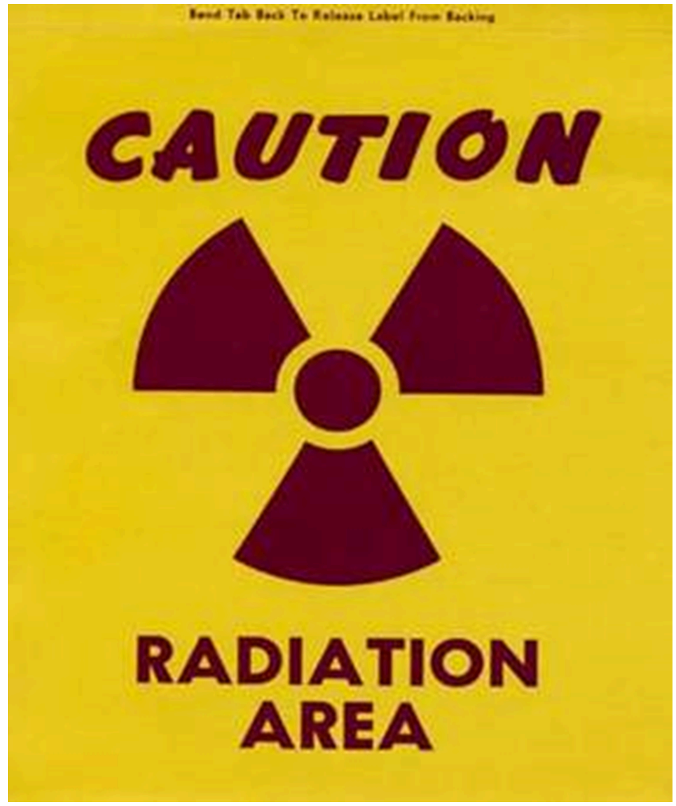
Radiation Caution Signs are divided into the categories of Radiation Area and Radioactive Material

Radiation Areas are covered in NRC Part 20.1003 and defined as follows:

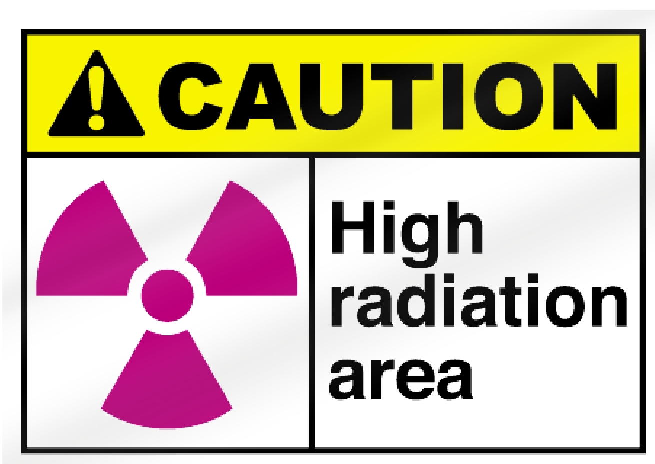
Radiation area means an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

Furthermore, a designation of "High Radiation Area" is spelled out in NRC Part 20.1003 as follows:

High radiation area means an area, accessible to individuals, in which radiation levels from radiation sources external to the body could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 mSv) in 1 hour at 30 centimeters from the radiation source or 30 centimeters from any surface that the radiation penetrates.



Caution sign from NRC is Public Domain.



Caution sign from NRC is Public Domain.

Radioactive Material container signage and labeling is specified in NRC Part 20.1904:

(a) The licensee shall ensure that each container of licensed material bears a durable, clearly visible label bearing the radiation symbol and the words "CAUTION, RADIOACTIVE MATERIAL" or "DANGER, RADIOACTIVE MATERIAL." The label must also provide sufficient information (such as the radionuclide(s) present, an estimate of the quantity of radioactivity, the date for which the activity is estimated, radiation levels, kinds of materials, and mass enrichment) to permit individuals handling or using the containers, or working in the vicinity of the containers, to take precautions to avoid or minimize exposures.

(b) Each licensee shall, prior to removal or disposal of empty uncontaminated containers to unrestricted areas, remove or deface the radioactive material label or otherwise clearly indicate that the container no longer contains radioactive materials.

The NRC divides Radioactive Signage (including shipping labels) into the following categories:

Radioactive White – I Label – radiation level at package surface is less than or equal to 0.5 mr/hr.

Radioactive I sign from NRC is Public Domain.

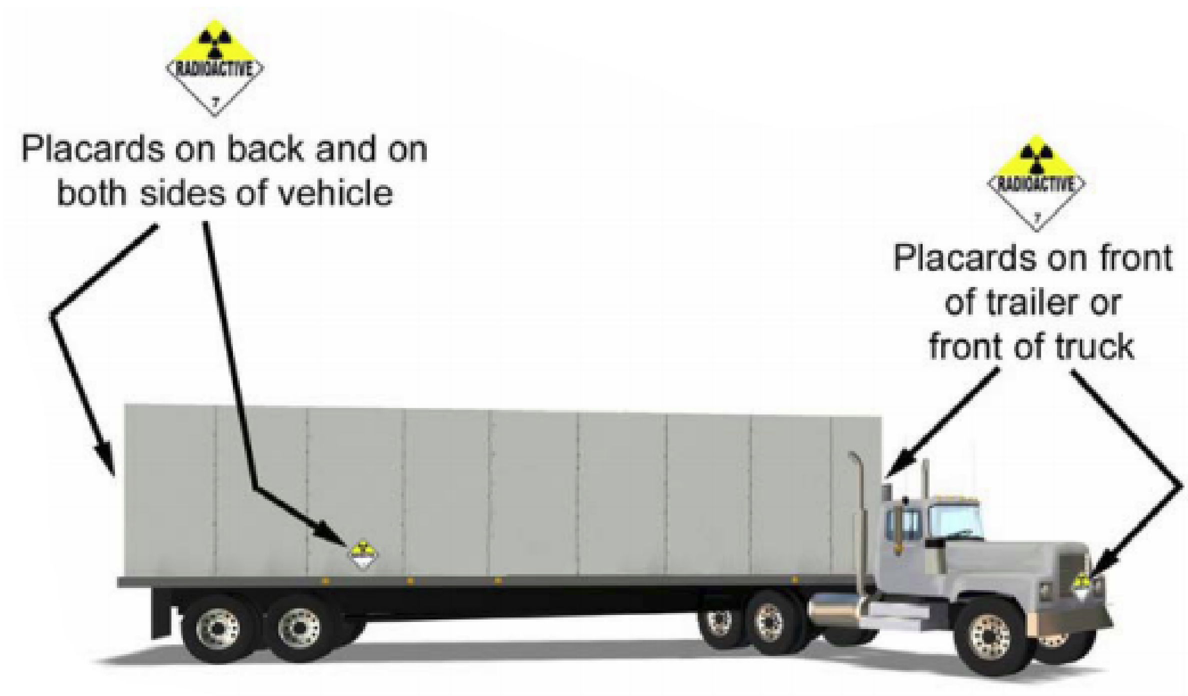
Radioactive Yellow – II Label – radiation level at package surface is greater than 0.5 mr/hr but is less than or equal to 50.0 mr/hr

Radioactive II sign from NRC is Public Domain.

Radioactive Yellow – III Label – radiation level at at package surface is greater than 50 mr/hr but is less than or equal to 200.0 mr/hr

Radioactive III sign from NRC is Public Domain.

Placards must be displayed on both sides and both ends of motor vehicle, freight containers, and rail cars when used for transporting radioactive materials bearing a "**RADIOACTIVE YELLOW III"** label as shown below (more info at NRC – Shipping Requirements):



Placard placement graphic from NRC is Public Domain.

Caution Signage Printable Word File
Caution Signage Español

Monitoring and Detection Devices

In the spirit of ALARA the field of radiography has developed safety protocols that have evolved over the years, and as the safety standards have improved the devices and tools used for monitoring radiation emission and dosage to personnel has progressed as well. In this final section, we will look at the required detection instruments required for a radiographer including the regulations associated with the operation and calibration of these devices. The following is a list of the detection instruments for radiographers:

- Survey Meters
- Area rate Alarm
- Pocket Dosimeter
- Film Badge – either a TLD (Thermoluminescent Dosimeter) or an OSL (Optically Stimulated Luminescent Dosimeter)

The **Survey Meter** is probably the radiographer's most important safety tool. When surveying the vast number of industrial radiation over-exposure incidents, many of them occurred because a radiographer did not use his or her survey meter or the survey meter was not calibrated and functioning properly. NRC requires that all survey meters be calibrated by a certified calibration agency every 6 months. This is the best insurance a radiographer has to protect against radiation over-exposure incidents.

Survey Meter by Scott Ballard is CC-BY 4.0

The two types of Survey Meters used in industry are the ion chamber and the Geiger-Muller (Geiger Counter).

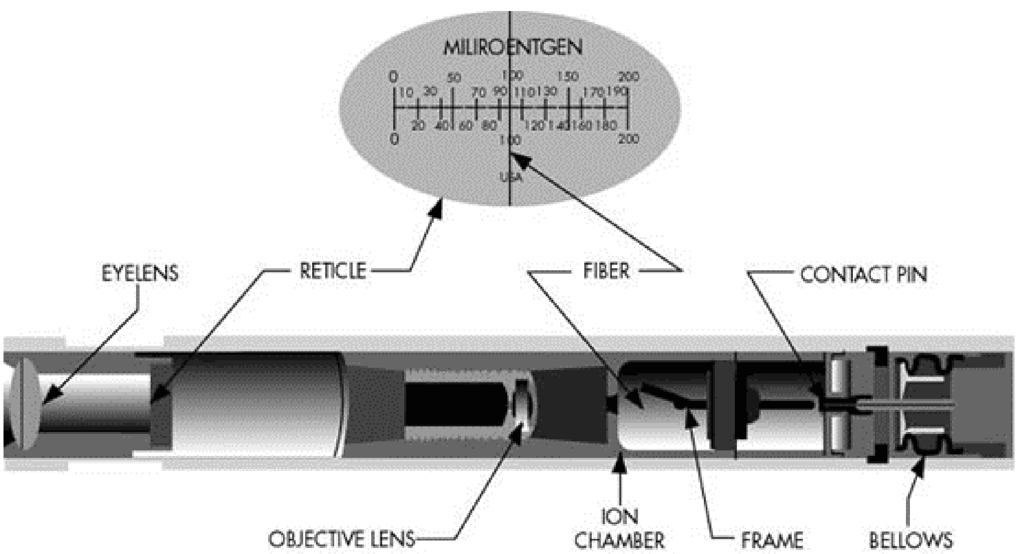
The I**on Chamber** uses an electric field (battery operated) which is applied across a volume of gas, between two electrodes. The ion chamber is capable of measuring all forms of ionizing radiation (x-ray, gamma, alpha, and beta particles) and is considered more reliable with X-ray.

The Geiger Muller (Geiger Counter) uses a gas-filled tube (cathode) surrounding a central electrode (anode) made of a fine tungsten wire. The counter detects individual particles or ions, however, too many ions will saturate the counter and it will lose accuracy. Although more sensitive than an ion chamber survey meter – Geiger counters are typically used to detect low to medium levels of radiation, but will lose accuracy measuring higher levels. For this reason, most industrial radiographers use the ion chamber survey meter.

Area Rate Alarms are just that – an alarm that sounds when the pre-set exposure rate is exceeded. The NRC requires that rate alarms be pre-set to 500 mR/hr, must be calibrated and tested annually and be +/- 20% of the true radiation dose rate to be considered calibrated and acceptable.

Area Rate Alarm by Scott Ballard is CC BY 4.0

Pocket Dosimeters provide immediate indication of accumulated dose and have a 0-200 mR range value required by NRC. Dosimeters must be calibrated (zeroed) at the beginning of each shift. A pocket dosimeter serves a similar purpose to the radiographer's film badge except a film badge records the dosage over a longer period (quarterly or annually). Radiographers can look at the dosimeter throughout the day, monitoring the dose they receive, further protecting themselves from over-exposure. Below is a cutaway view of a traditional dosimeter. There are also more user-friendly electronic dosimeters with digital readouts and built in alarms.



The final monitoring device is the radiographer's personal dosimetry, typically referred to as a "**Film Badge**". The purpose of the film badge is to keep a detailed record of quarterly, annual, and lifetime radiation doses received by the radiographer. In our educational setting, the film badges are sent in to a private monitoring company annually. The company reports to the radiography instructors, the RSO, and to the NRC. A few do's and don'ts with personal dosimetry:

- Always wear at work
- Do not wear away from work (home, lunch, parts store run)
- Do not wear when receiving a medical X-ray, MRI, CT scan, etc…
- Wear dosimetry badge outside of lead aprons

"**Film badge**" is a term we use almost generically, but is not the same as a TLD or OSLD. Film badges contain an actual film that is "exposed" and we read the exposure like we might read a radiograph that's been exposed. After use, the film is removed from a packet that protects it from light exposure and developed to measure exposure. The film badge is used to measure and record radiation exposure due to gamma rays, X-rays and beta particles. (Wikipedia)

A **TLD**, or thermoluminescent dosimeter is not actually a film badge but is worn like one and serves the same purpose of storing an individual's radiation dose over a period of months or even a year. TLD's can be re-set and reused.

An Optically stimulated luminescence Dosimeter **(OSLD)** is a device that operates on the process in which a pre-irradiated (exposed to ionizing radiation) material when subjected to an appropriate optical stimulation, emits a light signal proportional to the absorbed dose. The wavelength of the emitted light is the characteristic of the OSL material (Wikipedia)

Unit 9 Lecture Notes Personnel Monitoring Devices

Monitoring Devices Español

Unit 9 Glossary

Area Rate Alarms: an alarm that sounds when the pre-set exposure rate is exceeded. The NRC requires that rate alarms be pre-set to 500 mR/hr, must be calibrated and tested annually and be +/- 20% of the true radiation dose rate to be considered calibrated and acceptable.

Film Badge: The purpose of the film badge is to keep a detailed record of quarterly, annual, and lifetime radiation doses received by the radiographer. Film badges contain an actual film that is "exposed" and we read the exposure like we might read a radiograph that's been exposed. After use, the film is removed from a packet that protects it from light exposure and developed to measure exposure

The Geiger Muller (Geiger Counter) uses a gas-filled tube (cathode) surrounding a central electrode (anode) made of a fine tungsten wire. The counter detects individual particles or ions, however, too many ions will saturate the counter and it will lose accuracy.

OSLD Optically stimulated luminescence Dosimeter is used like a film badge to keep a detailed record of quarterly, annual, and lifetime radiation doses received by the radiographer. The device that operates on the process in which a pre-irradiated (exposed to ionizing radiation) material when subjected to an appropriate optical stimulation, emits a light signal proportional to the absorbed dose.

Pocket Dosimeters provide immediate indication of accumulated dose and have a 0-200 mR range value required by NRC. Dosimeters must be calibrated (zeroed) at the beginning of each shift. A pocket dosimeter serves a similar purpose to the radiographer's film badge except a film badge records the dosage over a longer period (quarterly or annually).

RSO – Radiation Safety Officer – required for any company, education, medical or research facility that uses any form of Gamma or X-ray radiation.

Survey Meter: a device (ion chamber or Geiger-Muller counter) used to take a real time reading of ionizing radiation emissivity.

TLD, or thermoluminescent dosimeter is used like a film badge to keep a detailed record of quarterly, annual, and lifetime radiation doses received by the radiographer. TLD's can be re-set and reused.

Unit 9 Glossary Printable Word File

Unit 9 Glossary Español

- Guest Speaker Notes– LBCC Radiation Safety officer (RSO)
- Unit 1 Quiz – Printable Word file
- Unit 2 Quiz – Printable Word file