Radiological Safety Short Course

Conducted by:

The Office of Radiological Safety

Georgia Institute of Technology

Atlanta, Georgia

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Health Physics - A Profession for the Atomic Age

Health Physics is a new and interesting profession in the atomic age which is devoted to the protection of man and his environment from unwarranted radiation exposure. The goal of the health physicist is to help mankind to enjoy all of the vast benefits resulting from use of the atom while protecting him from radiation exposure. In achieving his goal he must help radiation workers comply with rigid rules and regulations which are required by federal and state laws for their own protection and that of the general public. These laws not only dictate the amount of radiation exposure a radiation worker may receive, but also limits to a specific value for each radioisotope the amount that is permitted in air and water.

This rapidly growing profession, which is only about 30 years old, has been instrumental in making the atomic industry one of the safest and cleanest in the world today. It is estimated that there are some 15,000 people in the entire world who are actively engaged in practicing Health Physics as a profession.

The Health Physics profession is both challenging and rewarding, requiring a wide spectrum of knowledge and formal education, coupled with good judgment and practical ability. A strong demand exists for more health physicists. Increasingly, colleges and universities are offering advanced degrees in Health Physics, or Radiological Health, as it may be called. Further information and answers to specific questions related to this new atomic age profession of Health Physics may be obtained from the Office of Radiological Safety at the Nuclear Research Center, Georgia Institute of Technology, Atlanta, Georgia.

HEALTH PHYSICS
Georgia Tech
Phone: 894-3605

OUTLINE

SHORT COURSE IN RADIOLOGICAL SAFETY

(INTRODUCTION)

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E. How to limit exposure to radiation

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E. Juno

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OUTLINE

SHORT COURSE IN RADIOLOGICAL SAFETY

(RADIATION FROM RADIOISOTOPES)

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OUTLINE

SHORT COURSE IN RADIOLOGICAL SAFETY

(RADIATION PRODUCING MACHINES)

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   A. X-ray diffraction
   B. Electron Microscope
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   B. Ionization chambers
   C. Neutron meters

VI. Radiation Beams
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VII. Personnel Monitoring
   A. Procedure for obtaining film badge
   B. Proper use of film badge
   C Other personnel monitoring
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STUDENT NOTES

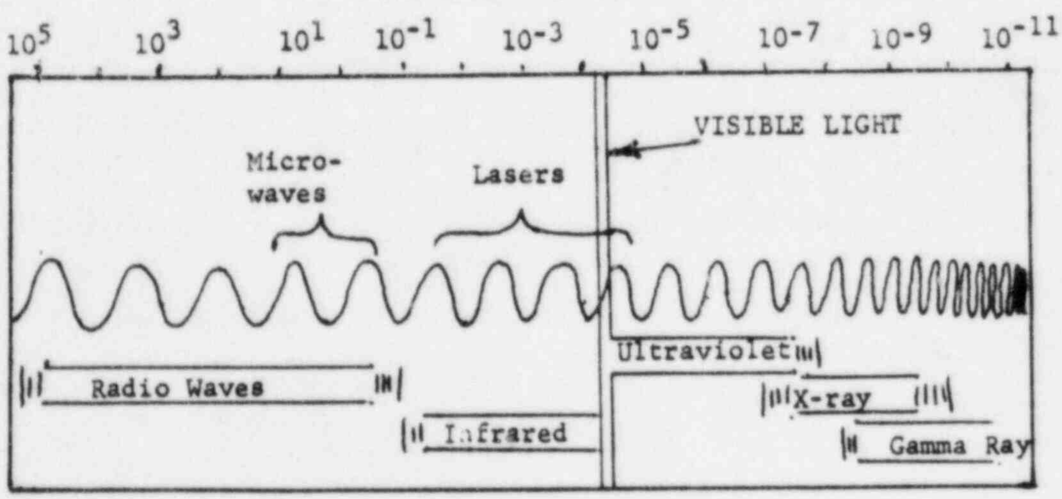
BASIC RADIATION TECHNOLOGY

A. What is Radiation

Radiation is the emission and propagation of energy through space or through a material medium in the form of invisible rays or particle. Radiation is as old as the universe. Stars are intensely radioactive; our earth, now only slightly so. Ever since its first appearance, man has been exposed to both visible and invisible radiation from the sun. Like sunshine and lightning, radiation from radioactive substances until the last thirty years occurred only in nature

Since 1895 when Roentgen in Germany discovered the X-ray, we have learned much about radiation. In 1896 in France, Becquerel found that the element uranium, which had been discovered a hundred years earlier, was naturally radioactive. Pierce and Marie Curie in France isolated the naturally radioactive element radium in 1903. In 1905 Einstein in Germany derived his theory of relativity which in part reads $E = mc^2$, or energy equals mass times the square of the speed of light. This famous theory gave other scientists the tip off that materials like radium could be an almost endless source of power. Many other important discoveries followed, such as the artificial production of radioactive substances. In 1942 the United States, under the direction of Enrico Fermi, an Italian emigrant, caused the first atomic chain reaction. Since this time the importance of natural radioactive substances like radium has been gradually replaced by reactor or other artificially produced isotopes which give off energy in the form of radiation.

The term radiation or radiant energy, when unqualified, usually refers to electro-magnetic radiation. Such radiation commonly is classified according to frequency, infrared, visible light, ultra-violet, X-ray, and gamma ray. In the nuclear business, we have extended the meaning to corpuscular emissions (particles) such as alpha, beta, and neutron, and rays of mixed or unknown types as cosmic radiation.



The Electromagnetic Spectrum

$$\text{Frequency} = \frac{\text{Velocity of Light}}{\text{Wave Length}}$$

B. Types of Radiation

Particle	Symbol	Charge	Mass	Remarks
Alpha	α	+2	4	Double ionized helium atom
Beta	β	-1	1/1840	"Nuclear" electron
Gamma	γ	0	0	Electro-magnetic radiation from nucl.
X-ray	X-ray	0	0	Electro-magnetic radiation produced by orbital elect. shieft
Neutron	n	0	1	High and low energy

Alpha - A fast moving particle having a double positive charge (two protons and two neutrons), has high ionization characteristics but low penetrating capabilities, and is stopped by a sheet of paper. It does not constitute a dose hazard generally, but may be extremely injurious once the particle gains admittance to the body through ingestion or inhalation of alpha emitting material. Alpha radiation is considered to present a hazard twenty times greater than that of beta or gamma radiation (OF 20). It does not penetrate skin surface.

Beta - A high speed particle having a single negative charge, travels several hundred times further in matter than an alpha particle of the same energy. Beta radiation is able to penetrate the skin surface; therefore, it is an external body hazard. Particle is stopped by about 1/25 of an inch of aluminum. If the particle emitter is taken into the body, it is highly hazardous to the internal body tissues.

Gamma - An electromagnetic wave with short wave lengths and high frequency, causes ionization mainly by secondary means. It interacts with matter to produce charged particles which ionize. It can destroy tissue and inflict serious burns quite rapidly. Gamma is capable of deep penetration and requires several inches of lead to stop it.

X-Ray - Penetrating electromagnetic radiations having wave lengths shorter than those of visible light. They are usually produced by bombarding a metallic target with fast electrons in a high vacuum. In nuclear reactions it is customary to refer to photons originating in the nucleus as gamma rays, and those originating in the extranuclear part of the atom as X-rays. These rays are sometimes called Roentgen rays after their discoverer, W. C. Roentgen. X-rays are similar to gamma rays (but usually less energetic) in that they can destroy tissue and inflict serious burns. Most frequently used X-rays are stopped by 1/4" of lead or less.

Neutron - A particle with no electrical charge. Its speed and range is quite varied. The neutron causes ionization by secondary means, that is, by reacting or colliding with another element resulting in other types of radiation being given off. The neutron in striking another element causes that element to become artificially radioactive and emit beta or gamma radiation. Neutrons are frequently classified as thermal or fast. Thermal neutrons have a QF of 5, and fast neutrons have a QF of 10. The number of neutrons of an unknown energy to produce 1 rem of radiation is 14 million (14×10^6) per square centimeter upon the body.

Other Types of Radiation

a.	X-ray	g.	Radar
b.	Ultraviolet	h.	Positron
c.	Microwave	i.	Neutrino
d.	Laser	j.	Electron
e.	Infrared	k.	Proton
f.	Cosmic	l.	Deuteron

C. Radiation Units and Terms

Dose - The amount of radiation energy absorbed per unit of mass in anything. When applied to man it is the amount of radiation energy absorbed per unit mass by the body or by any portion of the body. The word exposure is sometimes used instead of dose when it applies to man.

Dose Rate - Radiation dose delivered per unit time. Frequently expressed in millirem per hour (mrem/hr).

Curie (Ci) - That quantity of a radioactive material disintegrating at the rate of 3.7×10^{10} atoms per second (not to be confused with dose measurements.) Note: A five curie source of cesium-137 would not give you the same dose rate as a five curie cobalt-60 source because there is an energy difference.

Half-Life - Time required for a radioactive substance to lose 50% of its activity by decay. Each radionuclide has an unique half life.

Roentgen (R) - An exposure unit used in measuring X-ray and gamma radiation only (83 ergs/gram air absorbed) or (93 ergs/gram tissue).

Radiation Absorbed Dose (rad) - A dose unit used in measuring all types of radiation absorbed dose in any material (100 ergs/gram any material).

Roentgen Equivalent Man (rem) - A unit used as a measure of the dose or exposure of any ionizing radiation to body tissue in terms of its estimated biological effect relative to a dose of one Roentgen of X-rays.

Quality Factor (QF) - A factor by which absorbed doses (RAD) are to be multiplied to obtain the rem unit. RAD x QF = rem.

Type of Radiation	rad	QF	rem
X-ray	1	1	1
Gamma Ray	1	1	1
Beta	1	1	1
Alpha	1	20	20
Fast Neutrons	1	10	10
Slow Neutrons	1	5	5

Isotope - Atoms of the same chemical element having the same number of electrically charged particles (the same atomic number) but with a different number of neutral particles in the nucleus (different atomic weight). Some isotopes are radioactive (radioisotopes), and some are not (stable).

Maximum Permissible Concentration (MPC) - Values are established by the NRC. The concentrations of radioactive isotopes permissible in the air or water.

Ionization - The process or the result of any process by which a neutral atom or molecule acquires either a positive or a negative charge.

D. Sources of Radiation at Georgia Tech

1. Reactor - Source of thermal and fast neutrons
2. Van de Fraaff - Source of protons, deuterons, electrons (some X-rays), and neutrons
3. Cockroff-Walton neutron generator - Source of 14 Mev neutrons
4. Isotopes - Alpha, beta, gamma, neutron
5. Subcritical core - Alpha, beta, gamma, neutron (not great quantity)
6. Cs-137, Ba-137 irradiator - Source of beta, gamma
7. X-ray machines - Source of X-rays
8. Electron microscopes - Source of X-rays
9. 100,000 curies Co-60 - Source of gamma

E. How to Limit Exposure to Radiation

Exposure to radiation can be limited in three ways - time, distance, and by shielding.

Time - The exposure can be kept at acceptable levels by restricting the time spent in the radiation area. (Observe time limits).

Distance - The intensity of radiation from a source of radiation decreases with the distance from the source. Double the distance and you cut the exposure rate from X-ray or gamma rays to one quarter.

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

Where: I_1 = Radiation intensity at some chosen distance from a source
I_2 = Radiation intensity at some further distance from a source
D_1 = Distance from source where the radiation intensity is I_1
D_2 = Distance from source where the radiation intensity is I_2

Basic Radiation Technology

Shielding - The shielding varies in nature and thickness, depending upon the energy and type of the particles or waves. Alpha are stopped by a sheet of paper or the surface layer of the skin on our bodies; beta by a quarter of an inch of wood or an 1/8" or metal; gamma rays and X-rays by concrete or lead; and neutrons by paraffin, cadmium, and water (low Z).

F. Activation versus Contamination

1. Activation requires the bombardment of an atom by neutron or other particles to make radioactive. (Will not rub off easily).

2. Contamination can be something that has been activated but is loose and spreads easily. (Will rub off).

G. Some Sources of Radiation Safety Information

1. Basic Radiological Health (Course Manual)
2. Radiological Health Handbook, U. S. Dept. of Health Education, and Welfare, Public Health Service.
3. Radiation Safety Manual, Ga. Tech; Ga. State
4. NRC Rules and Regulations, Title 10, Part 20, Standards for Protection Against Radiation, and Parts 30, 40, and 70.
   State of Georgia Rules and Regulations for Radioactive Materials & X-ray Chapter 290-5-23; Chapter 290-5-22
5. Health Physics Office, Georgia Tech Personnel - Phone no. 894-3605-3621.

EMERGENCY CALL (DAY OR NIGHT):

Georgia Tech Police 894-2500

Civil Defense 656-5500

Georgia State University Police 658-3333

BIOLOGICAL EFFECTS OF IONIZING RADIATION

Accute Dose (rem)	Probable Effect
0-25	No obvious injury
25-50	Possible blood changes but no serious injury
50-100	Blood cell changes, some injury, nc disability
100-200	Injury, possible disability, nauses and fatigue, possible vomiting
200-400	Injury and disability certain, death possible
400	Fatal to 50 percent
600 Or more	Fatal

GEORGIA TECH

HEALTH PHYSICS PORTABLE INSTRUMENTS

Instrument	Range
Film Badge: (Beta, Gamma, X-ray, Neutron)	10 mrem - 600 rem
Dosimeters:	
1. Nonself-reading type (gamma, X-ray)	1 mR - 200 mR
2. Self-reading type (low) (gamma, X-ray)	1 mR - 200 mR
3. Self-reading type (high) (gamma, X-ray)	1 mR - 20 R
4. Casualty-type dosimeters	For emergency
5. TLD (Beta, gamma, X-ray, neutron)	.1 mrem - 5 x 10^5 rem
Exposure Rate Meters:	
1. Juno (alpha, beta, gamma) (low level)	1 mR/hr - 5000 mR/hr
2. Juno (alphs, beta, gamma) (high level)	5 mR/hr - 25 R/hr
3. Cutie Pie (beta, gamma) (low level)	1 mR/hr - 2500 mR/hr
4. Cutie Pie (beta, gamma) (high level)	50 mR/hr - 250 R/hr
5. Jordan Rad Gun (beta, gamma)	.01 mR/hr - 10,000 R/hr
6. Cutie Pie TP (beta, gamma)	500 mR/hr - 5,000 R/hr
7. Cutie Pie (beta, gamma) (very low level)	.01 mR - 25 mR integrating
GM Survey Meter: (Not to be used to set exposure rates)	
1. Victoreen Thyac (beta, gamma)	(100 c/m - (80,000 c/m)
2. Nuclear Chicago (beta, gamma)	(400 c/m - (80,000 c/m)
3. Eberline E-120 (beta, gamma)	(100 c/m - (70,000 c/m)
Neutron Meter:	
1. RCL	Slow neutrons .024 - 24 mrem/hr Fast neutrons .48 - 480 mrem/hr
2. Kaman Nuclear	1 mrem/hr - 13,050 mrem/hr
3. Eberline, Model Nc-1 (^{N}slow)	.2 mrem/hr - 410 mrem/hr
4. Eberline, Model PNC-4 (^{N}slow) & (^{N}fast)	Slow neutrons .0385 mrem/hr-193 mrem/hr Fast neutrons .55 mrem/hr-4500 mrem/hr
5. Ludlum, Model 11 count rate meter with 10" poly sphere	Slow neutrons .024 mrem/hr-1120 mrem/hr Fast neutrons .46 mrem/hr
6. Nuclear-Chicago, Model 2112 with Model DN-3 neutron probe	Slow neutrons - 30 mrem/hr Fast neutrons .247 mrem/hr-370 mrem/hr
Alpha Meter:	
1. Eberline PAC-3G (alpha)	(100 c/m) - (100,000 c/m)
Other:	
1. Victoreen R meters	.01 mR - multi R
2. Rad Tad Chirper	10 mR/hr - 5 R/hr
3. Eberline Model PS-1	0.5 c/m - 2.0 x 10^6 c/m
4. Vibrating Reed Electrometer (VRE)	3 x 10^{-6} μCi/cc - > 1.4 x 10^{-2} μCi/cc for ^3H
5. Harshaw TLD Reader 2000	0.1 mrem - 5 x 10^6 rem

OTHER GEORGIA TECH

HEALTH PHYSICS INSTRUMENTS

Insturment	Manuracturer
G. M. Scaler (Alpha, Beta, Gamma) (with thin window)	Nuclear Chicago, Eberline
Alpha Scintillation Scaler (Alpha) (Zn S Crystal)	Baird-Atomic, Tracerlab
Gas Proportional System (Alpha, Beta) (100 Sample, Automatic Printout)	Beckman (Low-Beta II)
Liquid Scintillation System (100 Sample, Automatic Printout) (Tritium, Carbon-14, & other)	Nuclear Chicago (Mark I)
400 Channel Pulse Height Gamma Analyzer (Sodium Iodide Crystal)	Technical Measurement Corp.
Air Sampler (High Volume)	Staplex
Air Sampler (Low Volume) (Continuous flow)	Georgia Tech made; has filter, & activated charcoal cartridge
Air Sampler (Very Low Volume) (Continuous flow)	Georgia Tech made; bubbles air through water or clear oil for H-3 evaluation
Exposure Rate Meter & Intergrator (Panoramic Model 470A)	Victoreen, range 0.5 mrem/hr. 1000 rem/hr
1024 Channel Gamma Analyzer (Model 30) (Sodium Iodide Crystal)	Canberra
Triton Model III (Portable Tritium Air Sampler)	Johnston Laboratories