Speaker’s Profile

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What is radiation?

• Radiation is energy that radiated or transmitted in the form of rays or waves or particles.
• Radiation is the spontaneous emission of a stream of particles or electromagnetic waves in nuclear decay.
• Radiation has a wide range of energies that forms the electromagnetic spectrum.
• The spectrum has two major divisions: non-ionizing and ionizing radiation.
Non-ionizing Radiation has insufficient energy to remove electrons from atoms.

Ionizing Radiation has sufficient energy to break down chemical bonds and/or removes electrons from atoms.
Part I

Ionising Radiation
Radiation vs Radioactivity

- **Radiation** is the emission of energy from a source, either by particles or photons.

- **Radioactivity** is radiation that is from a change in the nucleus of an atom, other forms of radiation are usually the emission of energy from a change in the electron orbits.
Smoke Detectors

Alpha particles from americium-241 (red lines) ionize the air molecules (pink and blue spheres). The ions carry a small current between two electrodes. Smoke particles (brown spheres) attach to ions reducing current and initiate alarm.
Luminous Watches

Hands and dials contain H-3 or radium that glows in the dark
X-rays and fluoroscopes are used to look inside the body
Ionizing Radiation

• Two fundamental types
  - **Particulate**: radiation in the form of particles
e.g. alpha, beta, neutrons
  - **Wave**: radiation in the form of electromagnetic wave
e.g. Gamma rays, X-rays
Types of Radiation

• Alpha
  – Identical to a helium nucleus (2 p and 2 n in one tightly bound particle)

• Beta
  – Energetic electron ejected from the nucleus of an atom
  – One neutron is converted to one proton and one electron
Types of Radiation (cont’d)

- Gamma
  - Electromagnetic radiation from nucleus
- X-ray
  - Electromagnetic radiation from orbital electrons
- Neutrons
Penetrating Distances

- Alpha
- Beta
- Gamma and X-rays
- Neutron
Units for Activity

• The rate of radioactive decay is described by the nuclear disintegrations per unit time:
  – Becquerels (Bq)
  – 1 Bq = 1 disintegration/second (dps)

Old unit for Activity = Curie
1 Ci = 3.7X10^{10} dps
Radioactive Decay

• Radioisotopes can regain stability by nuclear transformation (radioactive decay) emitting radiation in the process.

• Radioactive decay can also be characterized by Half-Life, \( T_{\frac{1}{2}} \)
  – \( T_{\frac{1}{2}} \) is the time required for \( \frac{1}{2} \) of a collection of atoms of that nuclide to decay
  – Decay is a random process which follows an exponential curve
**Half-Life $T_{\frac{1}{2}}$**

- Time taken for the activity of a sample to halve as a result of radioactive decay
- Use of $T_{\frac{1}{2}}$
  - To calculate activity of radioactive material on hand at a given time.
Calculation of Activity at time $t$

- $A = A_0/2^N$
  - $A_0$ = Original Activity
  - $A$ = Activity at time $t$
  - $N$ is the number of half lives expired in time, $t$
  - $N = t/T_{1/2}$

* Unit for $t$ & $T_{1/2}$ must be the same

- Unit for Activity is Becquerel, Bq
Radiation Decay is exponential

- $A = A_0/2^N$
- Initial activity, $A_0$, of a vial of Tc-99m was 80 GBq, $T_{1/2}$ for Tc-99m is 6 hours
  - After 6 hours, one half life, $A = 40$ GBq
  - After 12 hours, two half life, $A=20$ GBq
  - After 24 hours, four half lifes, $A=5$ GBq
How Does Radiation Harm You?

• Ionizing properties of radiation
• Lead to molecular changes and form chemical species that are harmful to the chromosome material
• Harm can come from changes in construction and function of the cells.
• Radiation can cause:
  – Early death of the cell or prevention or delay of cell division
  – Permanent modification which is passed on to daughter cells
Biological Effects

Chromosome

Cell

Radiation

Chemical bond break
Biological Effects of Radiation

• Alpha particles
  – Short range in air
  – Penetrate less than one tenth of a mm in human tissue
  – Significant internal hazard

• Beta particles
  – Energetic betas can travel a few mm in human tissue
  – Skin or eye hazard
  – Also a significant hazard if inhaled or ingested

• Gamma rays and x-rays
  – Highly penetrating electromagnetic radiations
  – If taken into the body it presents an internal radiation hazard
  – Irradiating the whole body
Deterministic Effects
-the doctrine that all events are determined by causes deemed to be external to the will

- Severity of certain effects on humans will increase with increasing dose
- Damage depends on absorbed dose
- **Threshold exists** above which the effects will occur.
- E.g. cataract, infertility etc.

Stochastic Effects
-determined by a random distribution of probabilities

- Severity of effects are independent of absorbed dose
- Under certain exposure conditions, the effects may or may not occur.
- There is no threshold and the probability of having the effects is proportional to the dose absorbed.
- E.g. radiation induced cancer, genetic effect
Sources of Radiation

- **Sealed source**
  - Radioactive materials sealed inside metal/plastic.
  - Most sealed sources can be handled without concern that the radioactive material will be dispersed onto hands or clothing.

**Plated**
May be covered by Mylar, aluminum, steel or plastic.
Sealed source

Sealed sources are used

- in many laboratory devices, such as Radiation counters, gas chromatographs (with ECD), and portable gauges.

- as check sources, calibration sources for the detectors
Unsealed Source

- Liquid radioactive material used in research
Internal & External Exposure to Radiation

• Internal exposure
  – Radioactive material is taken into the body
    • Inhalation of radioactive fumes or aerosols
    • Ingestion of radioactive materials
    • Absorption through skin and mucous membranes

• External exposure
  – Radioactive source is outside of the body, exposure occurs when handling or in proximity to these sources
NEW YORK, Dec. 1, 2006
Alexander Litvinenko former Russian spy who died from radiation poisoning. (AP)

(CBS) An Italian intelligence expert who was one of the last people to see a former KBG agent alive before he died of radiation poisoning has tested positive for the same poison, according to British media.

**What is Polonium 210?**
Po-210 is a radioactive material that occurs naturally at very low concentrations in the environment; although it can be produced in university or government nuclear reactors, it requires expertise to do so.

Po-210 emits alpha particles, which carry high amounts of energy that can damage or destroy genetic material in cells inside the body.

Po-210 is a particularly energetic radionuclide, giving off 5,000 times more alpha particles than does the same amount of radium. Po-210 is used in some industrial applications such as static eliminators, which are devices designed to eliminate static electricity in processes such as paper rolling, manufacturing sheet plastics, and spinning synthetic fibers.

**Is Po-210 harmful to humans?**
Po-210 is a radiation hazard only if it is taken into the body through breathing or eating or by entering a wound. This "internal contamination" can cause irradiation of internal organs, which can result in serious medical symptoms or death. Po-210 is not an external hazard to the body—neither polonium nor its radiation will penetrate intact skin or membranes. Most external traces of it can be removed through careful washing.

**Who is at risk for contamination?**
People will not be exposed to radiation (irradiated) simply by being near a person who is internally contaminated with Po-210. Health care workers who are providing care for a contaminated patient will not be exposed to Po-210 unless they inhale or ingest contaminated bodily fluids. Normal hygiene practices in hospitals for microbial contamination will be sufficient to protect workers from radiological contamination.
The Radioactive Trail

Oct 28, K arrives carrying Po-210. Picked up in BMW, traces of radiation found on passenger seat.

Oct 29, K spends night in MIL’s house. Radiation found in house.

Oct 30, K goes to immigration office. Signed card is contaminated.

Oct 31, K spends night in ex-wife’s apartment. Couch is contaminated.

Nov 1, K met L at bar in Millenium Hotel, London. Within hours L is seriously ill.

Nov 3, K flies to Moscow. Plane is contaminated. K is admitted to hospital.

Nov 3, L is admitted to hospital.

Nov 23, L dies of radiation poisoning. Large quantities of Po-210 found in urine.
Working Safely with Radiation

- ALARA principle
- Time, distance and shielding
- Safe work practices
ALARA

• Exposures are kept As Low Achievable As Reasonably Achievable / Allowable
  – Formal ALARA program
  – Keeping all doses, releases, contamination and other risks low
Methods of Achieving ALARA

- Time
- Distance
- Shielding
Safe Work Practices

- Rehearse operations without radioactive material
- Inform others in the area of the use of radioactive material
- Minimize the time spent near radioactive materials.
- Use remote handling tools like tweezers or forceps to handle stock vials.
Safe Work Practices

• Do not handle the stock vial for an extended period of time
• Use appropriate shielding
• Minimize the amount of material handled. Only use what you need, put the rest away
Safe Work Practices

• Make sure the material is properly contained.
  – Drip trays lined with absorbent material
  – Stabilize glassware to prevent it from tipping
  – Dry powder use a glove bag or box
• Transport items in shielded secondary containers.
Safe Work Practices

• Do not contaminate writing materials
• Segregate items used with radioactive materials with those used with non-radioactive materials.
• Protective clothing shall be worn when handling contamination may be expected.
Safe Work Practices

- Personal with tears/breaks in skin should wear waterproof tape to seal such breaks or not manipulate radioactive material.
- Personnel shall monitor themselves (and their work surfaces) for contamination after each use of radioactive material.
Safe Work Practices

- Eating, drinking, smoking and mouth pipetting is prohibited.
- Items that are routinely contaminated (centrifuges, water baths, tongs, etc) should be clearly labeled.
- Hands should be monitored and washed before leaving the lab.
Waste Handling Process

- Store in a safe location with proper shielding until the waste has decayed to a low level
  - Must be < 1 microSv/hr or 0.1 mrem/hr
- Proper shielding:
  - Beta emitters – Perspex enclosure
  - Gamma emitters – Lead shielding
Waste Handling Process (cont’d)

• Place in secondary containers
• Proper labeling and designate the storage area with clear signages
• OSHE will organize central collection every 4 to 6 months depending on level at the departments
General Requirements

- Radiation worker must be >18 years old
- Have license or be registered as a radiation worker
- Wear personal monitoring device
- Undergo medical exam within 12 months prior to application
Part II

Non Ionising Radiation
What Is NIR?

• Energy waves of oscillating electric and magnetic fields travelling at the speed of light

• Energy levels not great enough to cause the ionization of atoms

• Includes spectrum of UV, IR, microwave (MW), radio frequency (RF), extremely low frequency (ELF) and visible light
Electromagnetic Spectrum

The diagram illustrates the electromagnetic spectrum, showing different regions such as gamma rays, X-rays, UV, infrared, microwaves, and radio waves. It also indicates the relationship between wavelength and energy, with shorter wavelengths corresponding to higher energy and longer wavelengths to lower energy. The visible light spectrum is highlighted between 380 nm and 750 nm.
Why Is It Dangerous?

- Wide range of occupational settings
- Can pose a considerable health risk to exposed workers if not properly controlled
Examples of NIR

<table>
<thead>
<tr>
<th>Types of NIR</th>
<th>Wavelength and/or Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultraviolet Radiation (UV)</td>
<td>180nm – 400nm</td>
</tr>
<tr>
<td>Visible Radiation (VR)</td>
<td>400nm – 700nm</td>
</tr>
<tr>
<td>Infrared Radiation (IR)</td>
<td>700nm – 1mm</td>
</tr>
<tr>
<td>Laser Radiation (UV/VR/IR)</td>
<td>Range between UV, VR &amp; IR</td>
</tr>
<tr>
<td>Radiofrequency (RF) / Microwave (MW)</td>
<td>&gt;1mm</td>
</tr>
<tr>
<td>Extremely Low Frequency (ELF)</td>
<td>&lt; 300Hz</td>
</tr>
<tr>
<td>Ultrasound</td>
<td>f &gt; 16kHz</td>
</tr>
</tbody>
</table>
Lasers

- Stands for **Light Amplification by Stimulated Emission of Radiation**
- Produces an intense, highly directional beam of light is emitted
- Monochromatic – one specific wavelength
- Coherent - each photon moves in step with the others
Types of Lasers

- Commonly designated by the type of lasing material employed:
  - **Solid-state lasers** - lasing material distributed in a solid matrix
  - **Gas lasers** – use gases like helium and helium-neon
  - **Excimer lasers** - (the name is derived from the terms *excited* and *dimers*) uses reactive gases, such as chlorine and fluorine, mixed with inert gases such as argon, krypton or xenon
Types of Lasers

• Commonly designated by the type of lasing material employed:
  - **Dye lasers** - complex organic dyes, such as rhodamine 6G, in liquid solution or suspension as lasing media
  - **Semiconductor lasers** - sometimes called diode lasers, are not solid-state lasers. Generally very small and use low power.
Classification of Lasers

• Emission wavelength
• Emission duration
• Power output
• Accessible emission levels (AELs)
# Classes of Laser

<table>
<thead>
<tr>
<th>Classes of Laser Systems</th>
<th>Power output or risk level</th>
<th>Other characteristics</th>
<th>Wavelength</th>
<th>Hazards</th>
<th>Examples</th>
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<tr>
<td><strong>Class 1</strong></td>
<td>Non-risk or exempt (&lt;0.39 μW)</td>
<td>Safe by virtue of laser power output and engineering design</td>
<td>UV; Visible; IR</td>
<td>Non-hazardous; No fire hazard</td>
<td>Nil</td>
</tr>
<tr>
<td><strong>Class 2</strong></td>
<td>Low power &amp; low risk (&lt;1mW)</td>
<td>Safe by virtue of normal aversion responses, engineering design or enclosure; warning label – “High risk class when access panels are removed”</td>
<td>Visible (400-700 nm)</td>
<td>No eye injury; No fire hazard</td>
<td>Barcode scanner; laser pointers; alignment lasers; indication lasers</td>
</tr>
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<tr>
<td>Class 3a</td>
<td>Medium power &amp; moderate risk (&lt;5mW)</td>
<td>Nil</td>
<td>Visible &amp; invisible lasers</td>
<td>Eye damaging if stared too long or binoculars is used; No fire hazard</td>
<td>Laser level gauge; Alignment laser; laser pointer; acupuncture laser; bio-simulation laser</td>
</tr>
<tr>
<td>Class 3b</td>
<td>Medium power &amp; moderate risk (&lt;500 mW)</td>
<td>Nil</td>
<td>UV; Visible; IR</td>
<td>Not hazardous for diffuse laser beam reflection; No fire hazard</td>
<td>Therapeutic; acupuncture; cosmetic; bio-simulation; range finders &amp; target designator</td>
</tr>
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## Classes of Laser

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<tr>
<td>Class 4</td>
<td>High power &amp; high risk (&gt;500 mW)</td>
<td>Nil</td>
<td>UV; Visible; IR</td>
<td>Hazardous for direct or diffused laser; Fire and skin burn hazard</td>
<td>High power industrial lasers, entertainment lasers; research &amp; medical lasers</td>
</tr>
</tbody>
</table>
Laser Applications
Laser Hazards

- **Eye injury**
  - Potential for injury to different structures of the eye depends on which structure absorbs the injury, e.g. cornea, lens or retina & the power of the laser
  - **Comparison**
    - Intensity of sun on retina is 100mW/mm²
    - Intensity of small 1mW HeNe laser on retina is 16,667mW/mm²

- **Dermal injury**
  - Potential for injury to different layers of the skin depends on the energy of the laser
  - Prolonged exposure to UV laser light leads to sunburn or even cancer
  - High intensity exposure will cause burns
Health Hazards

- Common cause of laser-induced tissue damage is thermal in nature
- Tissue proteins are denatured / destroyed due to the temperature rise following absorption of laser energy
- Exposure can result in damage to the eye and skin
- Human eye is most vulnerable to injury than human skin
Associated Hazards

Hazards that are not associated with the beam itself

- **Electrical**: Lethal electrical hazards from high power lasers.
- **Chemical**: Eximer, dye and chemical lasers, and welding or cutting fumes
- **Non-Beam Optical**: UV, Infra Red, or Visible Light
Laser Protection

• Engineering, Administrative
  – Warning signs, curtains, barriers to limit access
  – Protective housing for beam
  – Good SOP that details the
    • Hazards, good practice, recommended PPE, response to injury

• PPE
  – Appropriate eyewear
Safety Guides & Precautions for Laser Radiation

- Laser radiation should be discharged in a non-reflective and fire resistant background.
- Personnel should be cleared from an area for a reasonable distance on all sides of laser beams.
- Attach a warning sign to laser device in a conspicuous location to indicate the potential eye hazard associated with laser.
- Avoid looking into primary laser beam and specular reflection of laser beam, including those from lens surface.
Safety Guides & Precautions for Laser Radiation

• Prevent looking along axis of laser beam and avoid aiming the laser with eye.
• Keep pupils constricted, laser work should be in areas of high general illuminations so as to limit the energy that inadvertently enter the eyes.
• Instruct laser workers on potential eye hazards and limiting unnecessary exposure.
• Workers should have pre-employment eye examination and final eye examination.
Safety Guides & Precautions for Laser Radiation

- Use correct safety eyewear to filter out specific laser wavelength in order to provide eye protection, but it may only be partial.
- Avoid using binoculars or aiming telescopes to view direct laser beam or reflected laser beam from mirrors.
- The laser beam intensity should be greatly below the safe level for such situation.
- If needed, filter with sufficient optical density is placed in the protective eyewear or in the optical path of the telescope for such situation.
Regulations

- Covers specifically high power laser (Class 3b and 4)
- For a person to engage in any laser radiation work:
  - at least 18 years of age
  - adequately trained
  - has special knowledge in the safe use of laser
  - holds a **N3 license** to operate lasers
Regulations

• In addition, a license to use Class 4 medical lasers may be granted to registered medical practitioners and registered dentists only.
Work & Play Safe