PHYS12 CH:22.5 When Radiation Heals

Medical Applications of Radioactivity

Mr. Gullo

December 2025

Outline

The Paradox of Radiation

How can radiation both
cause and cure cancer?

The Paradox of Radiation

How can radiation both
cause and cure cancer?

The same nuclear physics that powers weapons also heals millions.

The Paradox of Radiation

How can radiation both
cause and cure cancer?

The same nuclear physics that powers weapons also heals millions.

Understanding this paradox requires understanding cells, DNA, and targeted destruction.

Learning Objectives

By the end of this lesson, you will be able to:

- **22.5:** Describe how nuclear imaging works (radioisotope imaging, PET)

Learning Objectives

By the end of this lesson, you will be able to:

- **22.5:** Describe how nuclear imaging works (radioisotope imaging, PET)
- **22.5:** Describe the ionizing effects of radiation and how they can be used for medical treatment

22.5 Seeing the Invisible

Nuclear radiation has two critical properties for medicine:

22.5 Seeing the Invisible

Nuclear radiation has two critical properties for medicine:

1. **Gamma rays penetrate tissue** - they can travel through your body

22.5 Seeing the Invisible

Nuclear radiation has two critical properties for medicine:

1. **Gamma rays penetrate tissue** - they can travel through your body
2. **Radiation depends on the nucleus, not the molecule** - we can tag compounds with radioactive isotopes

22.5 Seeing the Invisible

Nuclear radiation has two critical properties for medicine:

1. **Gamma rays penetrate tissue** - they can travel through your body
2. **Radiation depends on the nucleus, not the molecule** - we can tag compounds with radioactive isotopes

The Universal Tool

Put a radioactive isotope in a drug. Track where the drug goes. See what's happening inside the body.

22.5 The Tagged Compound

Radiopharmaceutical

A compound tagged with a radioactive isotope and used for medical purposes.

22.5 The Tagged Compound

Radiopharmaceutical

A compound tagged with a radioactive isotope and used for medical purposes.

How it works:

- Drug concentrates in specific organs or tissues

22.5 The Tagged Compound

Radiopharmaceutical

A compound tagged with a radioactive isotope and used for medical purposes.

How it works:

- Drug concentrates in specific organs or tissues
- Radioactive tag emits gamma rays

22.5 The Tagged Compound

Radiopharmaceutical

A compound tagged with a radioactive isotope and used for medical purposes.

How it works:

- Drug concentrates in specific organs or tissues
- Radioactive tag emits gamma rays
- Detectors outside the body track the location and concentration

22.5 The Tagged Compound

Radiopharmaceutical

A compound tagged with a radioactive isotope and used for medical purposes.

How it works:

- Drug concentrates in specific organs or tissues
- Radioactive tag emits gamma rays
- Detectors outside the body track the location and concentration
- Computer creates an image showing function, not just structure

22.5 Applications of Radiopharmaceuticals

Different isotopes target different tissues:

22.5 Applications of Radiopharmaceuticals

Different isotopes target different tissues:

- **Radioactive iodine:** Thyroid gland function

22.5 Applications of Radiopharmaceuticals

Different isotopes target different tissues:

- **Radioactive iodine:** Thyroid gland function
- **Radioactive thallium:** Blood flow and heart muscle activity

22.5 Applications of Radiopharmaceuticals

Different isotopes target different tissues:

- **Radioactive iodine:** Thyroid gland function
- **Radioactive thallium:** Blood flow and heart muscle activity
- **Radioactive gallium:** Cancer imaging

22.5 Applications of Radiopharmaceuticals

Different isotopes target different tissues:

- **Radioactive iodine:** Thyroid gland function
- **Radioactive thallium:** Blood flow and heart muscle activity
- **Radioactive gallium:** Cancer imaging
- **Bone-seeking compounds:** Detect tumors and healing points

22.5 Applications of Radiopharmaceuticals

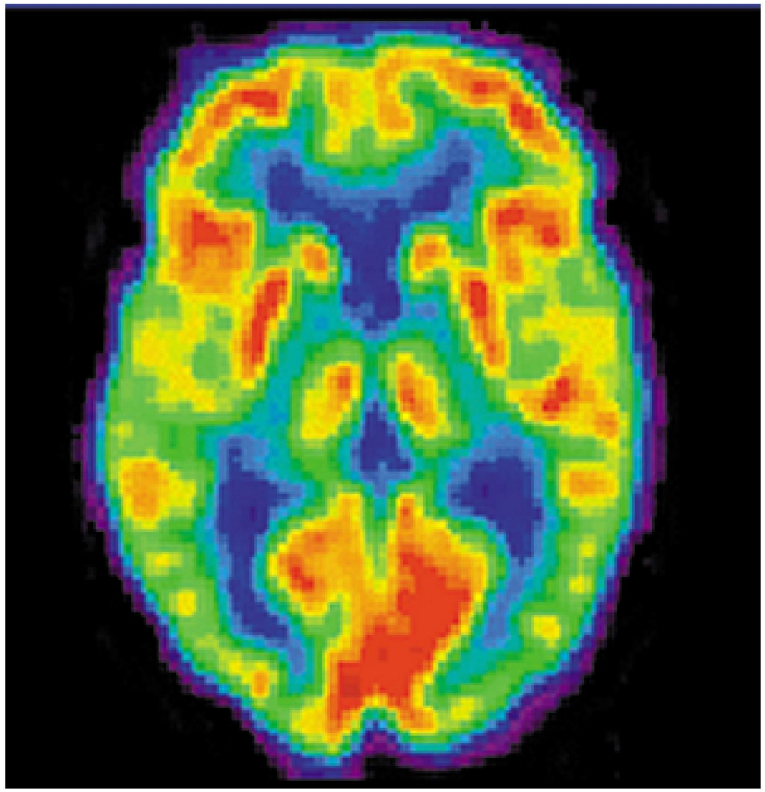
Different isotopes target different tissues:

- **Radioactive iodine:** Thyroid gland function
- **Radioactive thallium:** Blood flow and heart muscle activity
- **Radioactive gallium:** Cancer imaging
- **Bone-seeking compounds:** Detect tumors and healing points

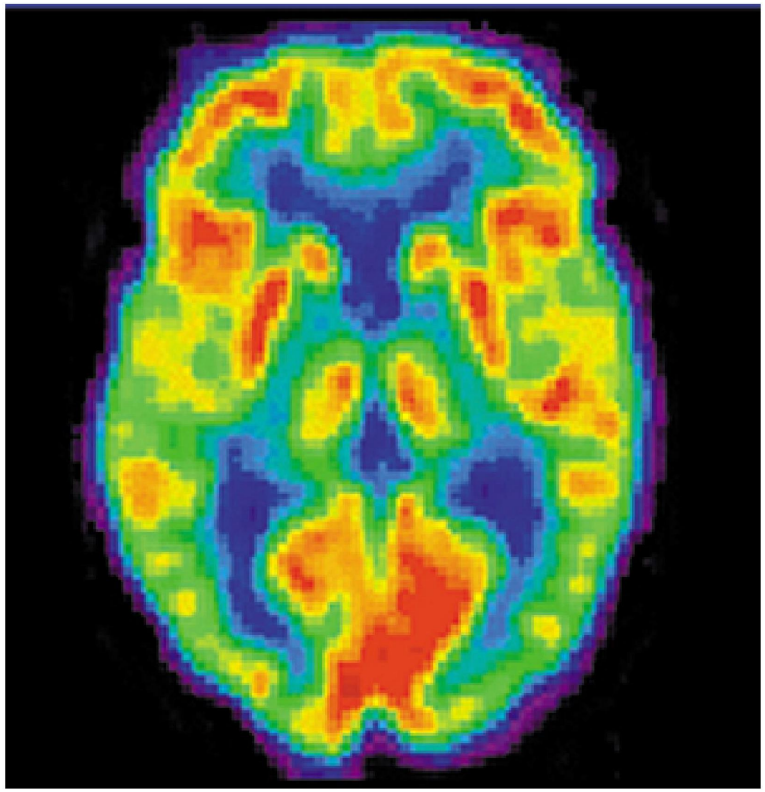
The Mental Model

Each isotope is like a specialized spy, reporting from specific locations in the body.

22.5 Brain Imaging with Radiopharmaceuticals



22.5 Brain Imaging with Radiopharmaceuticals



Brain scan of patient with Alzheimer's disease using a radiopharmaceutical.

22.5 The Anger Camera

22.5 The Anger Camera

Components:

- Lead collimator narrows gamma ray beams
- Scintillator converts gamma rays to visible light
- Photomultipliers convert light to electrical signals
- Computer creates image from detector array

22.5 SPECT: Adding the Third Dimension

Single-Photon-Emission Computer Tomography

Rotating gamma camera creates 3D image with better contrast than Anger camera alone.

22.5 SPECT: Adding the Third Dimension

Single-Photon-Emission Computer Tomography

Rotating gamma camera creates 3D image with better contrast than Anger camera alone.

How it works:

- Array of detectors rotates around patient

22.5 SPECT: Adding the Third Dimension

Single-Photon-Emission Computer Tomography

Rotating gamma camera creates 3D image with better contrast than Anger camera alone.

How it works:

- Array of detectors rotates around patient
- Computer combines images from multiple angles

22.5 SPECT: Adding the Third Dimension

Single-Photon-Emission Computer Tomography

Rotating gamma camera creates 3D image with better contrast than Anger camera alone.

How it works:

- Array of detectors rotates around patient
- Computer combines images from multiple angles
- Creates cross-sectional slices (like CT scan)

22.5 SPECT: Adding the Third Dimension

Single-Photon-Emission Computer Tomography

Rotating gamma camera creates 3D image with better contrast than Anger camera alone.

How it works:

- Array of detectors rotates around patient
- Computer combines images from multiple angles
- Creates cross-sectional slices (like CT scan)
- Trade-off: Better 3D detail, but lower spatial resolution

22.5 PET: The Antimatter Scanner

What if we could use
antimatter annihilation
to map brain activity?

22.5 PET: The Antimatter Scanner

What if we could use
antimatter annihilation
to map brain activity?

Positron Emission Tomography (PET):
Uses isotopes that emit positrons (β^+ particles).

22.5 The Physics of PET

Positron-electron annihilation:

22.5 The Physics of PET

Positron-electron annihilation:

1. Radiopharmaceutical emits positron (e^+)

22.5 The Physics of PET

Positron-electron annihilation:

1. Radiopharmaceutical emits positron (e^+)
2. Positron encounters electron (e^-) in tissue

22.5 The Physics of PET

Positron-electron annihilation:

1. Radiopharmaceutical emits positron (e^+)
2. Positron encounters electron (e^-) in tissue
3. **Annihilation:** Both particles destroyed

22.5 The Physics of PET

Positron-electron annihilation:

1. Radiopharmaceutical emits positron (e^+)
2. Positron encounters electron (e^-) in tissue
3. **Annihilation:** Both particles destroyed
4. Two gamma rays created, each with 0.511 MeV energy

22.5 The Physics of PET

Positron-electron annihilation:

1. Radiopharmaceutical emits positron (e^+)
2. Positron encounters electron (e^-) in tissue
3. **Annihilation:** Both particles destroyed
4. Two gamma rays created, each with 0.511 MeV energy
5. Gamma rays travel in **exactly opposite directions**

22.5 The Physics of PET

Positron-electron annihilation:

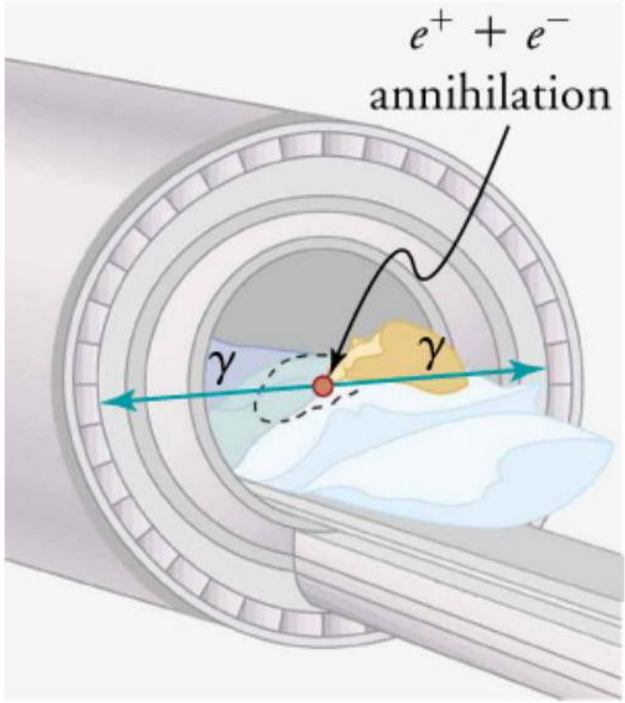
1. Radiopharmaceutical emits positron (e^+)
2. Positron encounters electron (e^-) in tissue
3. **Annihilation:** Both particles destroyed
4. Two gamma rays created, each with 0.511 MeV energy
5. Gamma rays travel in **exactly opposite directions**

The Universal Law

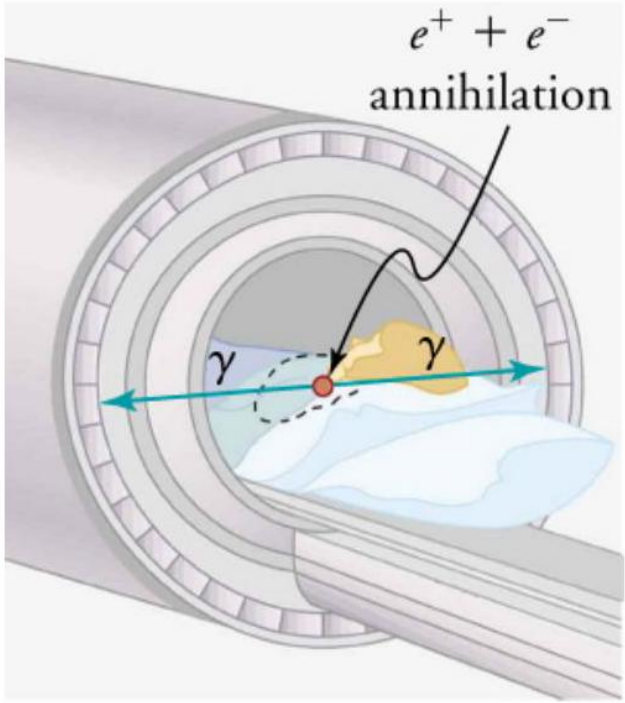
$$E = mc^2$$

Mass converts to energy: electron mass = 0.511 MeV per gamma ray.

22.5 PET Detector Design



22.5 PET Detector Design



Detectors on opposite sides detect simultaneous 0.511 MeV photons, pinpointing annihilation location.

22.5 PET Applications

PET is extensively used for:

22.5 PET Applications

PET is extensively used for:

- **Brain disorders:** Alzheimer's, Parkinson's, epilepsy

22.5 PET Applications

PET is extensively used for:

- **Brain disorders:** Alzheimer's, Parkinson's, epilepsy
- **Metabolic mapping:** Which brain regions are active during tasks

22.5 PET Applications

PET is extensively used for:

- **Brain disorders:** Alzheimer's, Parkinson's, epilepsy
- **Metabolic mapping:** Which brain regions are active during tasks
- **Cancer detection:** Tumors consume more glucose

22.5 PET Applications

PET is extensively used for:

- **Brain disorders:** Alzheimer's, Parkinson's, epilepsy
- **Metabolic mapping:** Which brain regions are active during tasks
- **Cancer detection:** Tumors consume more glucose
- **Heart function:** Blood flow and oxygen usage

22.5 PET Applications

PET is extensively used for:

- **Brain disorders:** Alzheimer's, Parkinson's, epilepsy
- **Metabolic mapping:** Which brain regions are active during tasks
- **Cancer detection:** Tumors consume more glucose
- **Heart function:** Blood flow and oxygen usage

Real-World: Mapping Thought

PET can show which parts of brain activate when you speak, close your eyes, or solve math problems.

22.5 The Double-Edged Sword

The Paradox

Ionizing radiation:

- Can cause cancer, burns, and hair loss
- Can treat and cure cancer

How do we understand this?

22.5 The Double-Edged Sword

The Paradox

Ionizing radiation:

- Can cause cancer, burns, and hair loss
- Can treat and cure cancer

How do we understand this?

The Universal Truth

All effects of ionizing radiation come from one source:
Damage to DNA molecules inside cells.

22.5 DNA: The Code of Life

DNA structure:

- Long, double-helix molecules

22.5 DNA: The Code of Life

DNA structure:

- Long, double-helix molecules
- Contains genetic codes that govern cell function

22.5 DNA: The Code of Life

DNA structure:

- Long, double-helix molecules
- Contains genetic codes that govern cell function
- Every cell experiences up to 1 million DNA damage events per day

22.5 DNA: The Code of Life

DNA structure:

- Long, double-helix molecules
- Contains genetic codes that govern cell function
- Every cell experiences up to 1 million DNA damage events per day
- DNA repair ability is vital for survival

22.5 DNA: The Code of Life

DNA structure:

- Long, double-helix molecules
- Contains genetic codes that govern cell function
- Every cell experiences up to 1 million DNA damage events per day
- DNA repair ability is vital for survival

The Mental Model

DNA is like the source code for your body. Radiation introduces bugs. The cell tries to debug.

22.5 When Repair Fails

A cell with damaged DNA repair ability can:

22.5 When Repair Fails

A cell with damaged DNA repair ability can:

1. **Senescence:** Enter permanent dormant state (retires)

22.5 When Repair Fails

A cell with damaged DNA repair ability can:

1. **Senescence:** Enter permanent dormant state (retires)
2. **Apoptosis:** Commit programmed suicide (cell death)

22.5 When Repair Fails

A cell with damaged DNA repair ability can:

1. **Senescence:** Enter permanent dormant state (retires)
2. **Apoptosis:** Commit programmed suicide (cell death)
3. **Unregulated division:** Become cancerous (tumor)

22.5 When Repair Fails

A cell with damaged DNA repair ability can:

1. **Senescence:** Enter permanent dormant state (retires)
2. **Apoptosis:** Commit programmed suicide (cell death)
3. **Unregulated division:** Become cancerous (tumor)

Civilian View vs. Reality

Civilian: "Radiation always causes cancer."
Physicist: "Radiation damages DNA. Outcome depends on dose, cell type, and repair ability."

22.5 Why Radiation Kills Cancer

The Vulnerability

Cancer cells reproduce rapidly. Radiation damages DNA most during cell division.

22.5 Why Radiation Kills Cancer

The Vulnerability

Cancer cells reproduce rapidly. Radiation damages DNA most during cell division.

Cancer cells are MORE sensitive to radiation than normal cells.

22.5 Why Radiation Kills Cancer

The Vulnerability

Cancer cells reproduce rapidly. Radiation damages DNA most during cell division.

Cancer cells are MORE sensitive to radiation than normal cells.

The Strategy

Target rapidly dividing cancer cells while minimizing damage to slowly dividing normal cells.

22.5 Why Radiation Kills Cancer

The Vulnerability

Cancer cells reproduce rapidly. Radiation damages DNA most during cell division.

Cancer cells are MORE sensitive to radiation than normal cells.

The Strategy

Target rapidly dividing cancer cells while minimizing damage to slowly dividing normal cells.

This is why radiation can both cause and cure cancer.

22.5 The Central Challenge

Therapeutic Ratio

$$\text{Therapeutic Ratio} = \frac{\text{Abnormal cells killed}}{\text{Normal cells killed}}$$

22.5 The Central Challenge

Therapeutic Ratio

$$\text{Therapeutic Ratio} = \frac{\text{Abnormal cells killed}}{\text{Normal cells killed}}$$

Goal of radiotherapy:

- Maximize dose to cancer cells

22.5 The Central Challenge

Therapeutic Ratio

$$\text{Therapeutic Ratio} = \frac{\text{Abnormal cells killed}}{\text{Normal cells killed}}$$

Goal of radiotherapy:

- Maximize dose to cancer cells
- Minimize dose to normal cells

22.5 The Central Challenge

Therapeutic Ratio

$$\text{Therapeutic Ratio} = \frac{\text{Abnormal cells killed}}{\text{Normal cells killed}}$$

Goal of radiotherapy:

- Maximize dose to cancer cells
- Minimize dose to normal cells
- Achieve highest possible therapeutic ratio

22.5 The Central Challenge

Therapeutic Ratio

$$\text{Therapeutic Ratio} = \frac{\text{Abnormal cells killed}}{\text{Normal cells killed}}$$

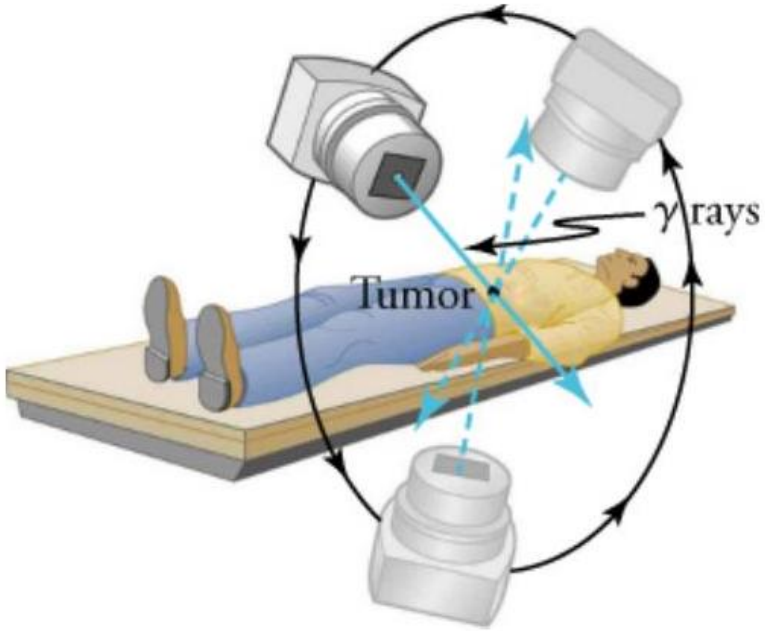
Goal of radiotherapy:

- Maximize dose to cancer cells
- Minimize dose to normal cells
- Achieve highest possible therapeutic ratio

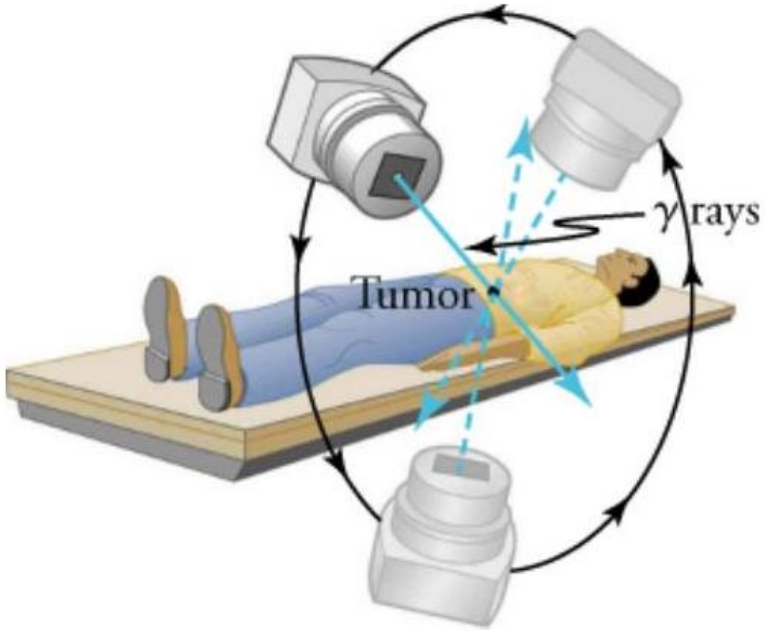
The Trade-off

Radiation doesn't distinguish cancer from normal cells - only rapidly dividing from slowly dividing.

22.5 Geometric Targeting

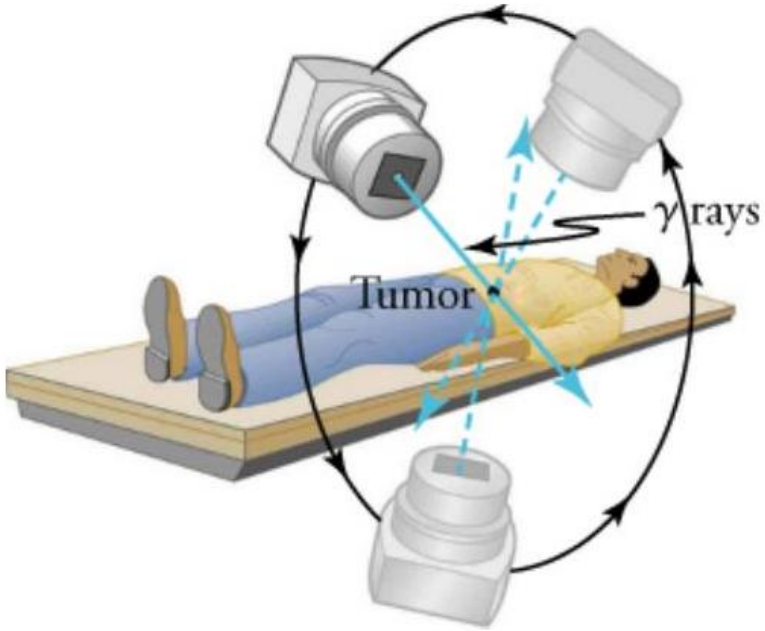


22.5 Geometric Targeting



Strategy: Rotate ^{60}Co gamma source around patient. All beams intersect at tumor.

22.5 Geometric Targeting



Strategy: Rotate ^{60}Co gamma source around patient. All beams intersect at tumor.

- Tumor receives high dose from all directions
- Surrounding tissue receives low dose from each beam

22.5 Targeted Radiopharmaceuticals

Method: Tag antibodies with radioactive isotopes.

22.5 Targeted Radiopharmaceuticals

Method: Tag antibodies with radioactive isotopes.

How it works:

1. Extract antibodies from patient's immune system

22.5 Targeted Radiopharmaceuticals

Method: Tag antibodies with radioactive isotopes.

How it works:

1. Extract antibodies from patient's immune system
2. Culture them in lab

22.5 Targeted Radiopharmaceuticals

Method: Tag antibodies with radioactive isotopes.

How it works:

1. Extract antibodies from patient's immune system
2. Culture them in lab
3. Load them with short-range radioisotope

22.5 Targeted Radiopharmaceuticals

Method: Tag antibodies with radioactive isotopes.

How it works:

1. Extract antibodies from patient's immune system
2. Culture them in lab
3. Load them with short-range radioisotope
4. Return to patient

22.5 Targeted Radiopharmaceuticals

Method: Tag antibodies with radioactive isotopes.

How it works:

1. Extract antibodies from patient's immune system
2. Culture them in lab
3. Load them with short-range radioisotope
4. Return to patient
5. Antibodies concentrate in abnormal tissue they were designed to fight

22.5 Targeted Radiopharmaceuticals

Method: Tag antibodies with radioactive isotopes.

How it works:

1. Extract antibodies from patient's immune system
2. Culture them in lab
3. Load them with short-range radioisotope
4. Return to patient
5. Antibodies concentrate in abnormal tissue they were designed to fight
6. Radiation destroys cancer cells locally

22.5 Side Effects and Limitations

Radiopharmaceuticals can damage:

22.5 Side Effects and Limitations

Radiopharmaceuticals can damage:

- **Liver:** Filters blood, exposed to radiopharmaceutical

22.5 Side Effects and Limitations

Radiopharmaceuticals can damage:

- **Liver:** Filters blood, exposed to radiopharmaceutical
- **Kidneys:** Eliminate waste, including radioactive compounds

22.5 Side Effects and Limitations

Radiopharmaceuticals can damage:

- **Liver:** Filters blood, exposed to radiopharmaceutical
- **Kidneys:** Eliminate waste, including radioactive compounds
- **Bladder:** Stores radioactive urine before elimination

22.5 Side Effects and Limitations

Radiopharmaceuticals can damage:

- **Liver:** Filters blood, exposed to radiopharmaceutical
- **Kidneys:** Eliminate waste, including radioactive compounds
- **Bladder:** Stores radioactive urine before elimination

The Limit

Technique is limited by tolerable damage to organs that process and eliminate the radiopharmaceutical.

22.5 Measuring Damage

To quantify biological effects, we need a dose unit.

22.5 Measuring Damage

To quantify biological effects, we need a dose unit.

The Rad (Radiation Absorbed Dose)

$$1 \text{ rad} = 0.01 \text{ J/kg}$$

Amount of ionizing energy deposited per kilogram of tissue.

22.5 Measuring Damage

To quantify biological effects, we need a dose unit.

The Rad (Radiation Absorbed Dose)

$$1 \text{ rad} = 0.01 \text{ J/kg}$$

Amount of ionizing energy deposited per kilogram of tissue.

Key point: Must specify which tissue received the dose.

- Whole-body dose
- Localized dose (e.g., forearm)

Attempt: Radiation Dose Calculation

The Challenge (3 min, silent)

A 60.0-kg person is exposed to ionizing radiation over their entire body and absorbs 1.80 J of energy.

Given:

- Mass = 60.0 kg
- Energy absorbed = 1.80 J

Find: Whole-body radiation dose in rads

Can you calculate the dose? Work silently.

Compare: Dose Calculation

Turn and talk (2 min):

1. What formula relates energy, mass, and dose?
2. How do you convert J/kg to rads?
3. What conversion factor did you use?

Compare: Dose Calculation

Turn and talk (2 min):

1. What formula relates energy, mass, and dose?
2. How do you convert J/kg to rads?
3. What conversion factor did you use?

Name wheel: One pair share your approach (not your answer).

Reveal: The Dose

Self-correct in a different color:

Step 1: Energy per mass

$$\frac{1.80\ \text{J}}{60.0\ \text{kg}} = 0.0300\ \text{J/kg}$$

Reveal: The Dose

Self-correct in a different color:

Step 1: Energy per mass

$$\frac{1.80 \text{ J}}{60.0 \text{ kg}} = 0.0300 \text{ J/kg}$$

Step 2: Convert using $1 \text{ rad} = 0.01 \text{ J/kg}$

Reveal: The Dose

Self-correct in a different color:

Step 1: Energy per mass

$$\frac{1.80 \text{ J}}{60.0 \text{ kg}} = 0.0300 \text{ J/kg}$$

Step 2: Convert using $1 \text{ rad} = 0.01 \text{ J/kg}$

$$\text{Dose} = \frac{0.0300 \text{ J/kg}}{0.01 \text{ J/kg per rad}} = \boxed{3.00 \text{ rad}}$$

Reveal: The Dose

Self-correct in a different color:

Step 1: Energy per mass

$$\frac{1.80 \text{ J}}{60.0 \text{ kg}} = 0.0300 \text{ J/kg}$$

Step 2: Convert using 1 rad $= 0.01$ J/kg

$$\text{Dose} = \frac{0.0300 \text{ J/kg}}{0.01 \text{ J/kg per rad}} = \boxed{3.00 \text{ rad}}$$

Check: 1.80 J over 60 kg is small energy per mass, so low rad dose. Reasonable!

22.5 Not All Radiation Is Equal

For same dose in rads, effects depend on:

22.5 Not All Radiation Is Equal

For same dose in rads, effects depend on:

- Type of radiation (α, β, γ, X-ray, neutron)

22.5 Not All Radiation Is Equal

For same dose in rads, effects depend on:

- Type of radiation (α, β, γ, X-ray, neutron)
- Type of tissue (eyes, bone, muscle)

22.5 Not All Radiation Is Equal

For same dose in rads, effects depend on:

- Type of radiation (α, β, γ, X-ray, neutron)
- Type of tissue (eyes, bone, muscle)

Relative Biological Effectiveness (RBE)

Number expressing relative damage from a given type of radiation.

22.5 Not All Radiation Is Equal

For same dose in rads, effects depend on:

- Type of radiation (α, β, γ, X-ray, neutron)
- Type of tissue (eyes, bone, muscle)

Relative Biological Effectiveness (RBE)

Number expressing relative damage from a given type of radiation.

- X-rays, γ rays: RBE $\approx$ 1
- Beta particles: RBE $\approx$ 1-2
- Alpha particles: RBE $\approx$ 10-20
- Neutrons: RBE $\approx$ 3-10

22.5 Why Alpha Is Deadly Inside

Alpha particles:

- Short range (stopped by skin)

22.5 Why Alpha Is Deadly Inside

Alpha particles:

- Short range (stopped by skin)
- High ionization density

22.5 Why Alpha Is Deadly Inside

Alpha particles:

- Short range (stopped by skin)
- High ionization density
- Damage concentrated in small volume

22.5 Why Alpha Is Deadly Inside

Alpha particles:

- Short range (stopped by skin)
- High ionization density
- Damage concentrated in small volume
- Difficult for cells to repair clustered damage

22.5 Why Alpha Is Deadly Inside

Alpha particles:

- Short range (stopped by skin)
- High ionization density
- Damage concentrated in small volume
- Difficult for cells to repair clustered damage

Civilian View vs. Reality

Civilian: "Alpha is safe - can't penetrate skin."
Physicist: "Alpha is safe OUTSIDE. Deadly INSIDE."

22.5 The Rem: Dose Equivalent

Roentgen Equivalent Man (rem)

$$\text{rem} = \text{rad} \times \text{RBE}$$

Dose unit accounting for both energy deposited AND biological effectiveness.

22.5 The Rem: Dose Equivalent

Roentgen Equivalent Man (rem)

$$\text{rem} = \text{rad} \times \text{RBE}$$

Dose unit accounting for both energy deposited AND biological effectiveness.

Example: 2.00 rad of alpha radiation (RBE = 20)

$$\text{Dose} = 2.00 \text{ rad} \times 20 = 40.0 \text{ rem}$$

22.5 The Rem: Dose Equivalent

Roentgen Equivalent Man (rem)

$$\text{rem} = \text{rad} \times \text{RBE}$$

Dose unit accounting for both energy deposited AND biological effectiveness.

Example: 2.00 rad of alpha radiation (RBE = 20)

$$\text{Dose} = 2.00 \text{ rad} \times 20 = 40.0 \text{ rem}$$

The Mental Model

Rads measure energy deposited. Rems measure biological damage.

22.5 Dose Categories

Dose Levels

- **Low dose:** Less than 10 rem
- **Moderate dose:** 10-100 rem
- **High dose:** Greater than 100 rem

22.5 Dose Categories

Dose Levels

- **Low dose:** Less than 10 rem
- **Moderate dose:** 10-100 rem
- **High dose:** Greater than 100 rem

Important: These are for whole-body exposure in less than one day.

22.5 Dose Categories

Dose Levels

- **Low dose:** Less than 10 rem
- **Moderate dose:** 10-100 rem
- **High dose:** Greater than 100 rem

Important: These are for whole-body exposure in less than one day.

Key Point

Dose spread over time allows repair. Same total dose over weeks causes less damage than in one day.

22.5 Immediate Effects of Radiation

Whole-body exposure effects:

22.5 Immediate Effects of Radiation

Whole-body exposure effects:

- **0-25 rem:** No detectable clinical effects

22.5 Immediate Effects of Radiation

Whole-body exposure effects:

- **0-25 rem:** No detectable clinical effects
- **25-100 rem:** Temporary decrease in white blood cells

22.5 Immediate Effects of Radiation

Whole-body exposure effects:

- **0-25 rem:** No detectable clinical effects
- **25-100 rem:** Temporary decrease in white blood cells
- **100-200 rem:** Nausea, fatigue, vomiting

22.5 Immediate Effects of Radiation

Whole-body exposure effects:

- **0-25 rem:** No detectable clinical effects
- **25-100 rem:** Temporary decrease in white blood cells
- **100-200 rem:** Nausea, fatigue, vomiting
- **200-500 rem:** Severe blood cell damage, hemorrhage

22.5 Immediate Effects of Radiation

Whole-body exposure effects:

- **0-25 rem:** No detectable clinical effects
- **25-100 rem:** Temporary decrease in white blood cells
- **100-200 rem:** Nausea, fatigue, vomiting
- **200-500 rem:** Severe blood cell damage, hemorrhage
- **500+ rem:** Usually fatal within weeks without treatment

22.5 Immediate Effects of Radiation

Whole-body exposure effects:

- **0-25 rem:** No detectable clinical effects
- **25-100 rem:** Temporary decrease in white blood cells
- **100-200 rem:** Nausea, fatigue, vomiting
- **200-500 rem:** Severe blood cell damage, hemorrhage
- **500+ rem:** Usually fatal within weeks without treatment

Context

Average background radiation: $\sim$0.3 rem/year
Chest X-ray: $\sim$0.01 rem
CT scan: $\sim$1 rem

What You Now Know

The Revelations

1. Nuclear imaging uses radiopharmaceuticals to see function, not just structure

What You Now Know

The Revelations

1. Nuclear imaging uses radiopharmaceuticals to see function, not just structure
2. Gamma cameras, SPECT, and PET create images from radiation outside body

What You Now Know

The Revelations

1. Nuclear imaging uses radiopharmaceuticals to see function, not just structure
2. Gamma cameras, SPECT, and PET create images from radiation outside body
3. PET uses antimatter annihilation to pinpoint isotope location

What You Now Know

The Revelations

1. Nuclear imaging uses radiopharmaceuticals to see function, not just structure
2. Gamma cameras, SPECT, and PET create images from radiation outside body
3. PET uses antimatter annihilation to pinpoint isotope location
4. Radiation damages DNA - effects depend on dose and repair ability

What You Now Know

The Revelations

1. Nuclear imaging uses radiopharmaceuticals to see function, not just structure
2. Gamma cameras, SPECT, and PET create images from radiation outside body
3. PET uses antimatter annihilation to pinpoint isotope location
4. Radiation damages DNA - effects depend on dose and repair ability
5. Cancer cells are more sensitive to radiation than normal cells

What You Now Know

The Revelations

1. Nuclear imaging uses radiopharmaceuticals to see function, not just structure
2. Gamma cameras, SPECT, and PET create images from radiation outside body
3. PET uses antimatter annihilation to pinpoint isotope location
4. Radiation damages DNA - effects depend on dose and repair ability
5. Cancer cells are more sensitive to radiation than normal cells
6. Radiotherapy maximizes therapeutic ratio through targeting

What You Now Know

The Revelations

1. Nuclear imaging uses radiopharmaceuticals to see function, not just structure
2. Gamma cameras, SPECT, and PET create images from radiation outside body
3. PET uses antimatter annihilation to pinpoint isotope location
4. Radiation damages DNA - effects depend on dose and repair ability
5. Cancer cells are more sensitive to radiation than normal cells
6. Radiotherapy maximizes therapeutic ratio through targeting
7. Dose units: rad (energy), RBE (effectiveness), rem (biological damage)

Key Equations

$$1 \text{ rad} = 0.01 \text{ J/kg} \tag{1}$$

$$\text{rem} = \text{rad} \times \text{RBE} \tag{2}$$

$$\text{Therapeutic Ratio} = \frac{\text{Abnormal cells killed}}{\text{Normal cells killed}} \tag{3}$$

The Cosmic Connection

The same nuclear forces that power stars
now heal human bodies.

The Cosmic Connection

The same nuclear forces that power stars
now heal human bodies.

From Rutherford's gold foil to PET scanners in hospitals.

The Cosmic Connection

The same nuclear forces that power stars
now heal human bodies.

From Rutherford's gold foil to PET scanners in hospitals.

From $E = mc^2$ to cancer therapy.

The Cosmic Connection

The same nuclear forces that power stars
now heal human bodies.

From Rutherford's gold foil to PET scanners in hospitals.

From $E = mc^2$ to cancer therapy.

Physics doesn't just explain the universe - it saves lives.

Homework

Complete the assigned problems

posted on the LMS

Temporary page!

LaTeX was unable to guess the total number of pages correctly. A
was some unprocessed data that should have been added to the
this extra page has been added to receive it.
If you rerun the document (without altering it) this surplus page
away, because LaTeX now knows how many pages to expect for t
document.