

# Physics

## JZL1001913C

### summer semester 2020/2021

**Wednesday, 18:20 - 19:50**

**Friday, 18:20 - 19:50**

**virtual room (ZOOM)**

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**room 213, building L-1**



# Magnetism

## - short review

Magnetic  
field

$$B = \frac{F}{qv\sin\theta}$$

Unit

$$1 \text{ Tesla} = 1\text{T} \\ = 1\text{N}/(\text{A}\cdot\text{m})$$

Magnetic Flux  
 $\Phi = BA\cos\theta$

Unit

$$1 \text{ Weber} = 1\text{T} \\ = 1 \text{ Wb}$$

Magnetic  
Permeability  
 $\mu = B/H$

Unit

$$1\text{Wb}/(\text{A}\cdot\text{m})$$

Quantities:

- Magnetic field
- Magnetic Flux
- Magnetic Permeability

The Lorentz force:

$$\mathbf{F} = Bq\mathbf{v}\sin\theta$$

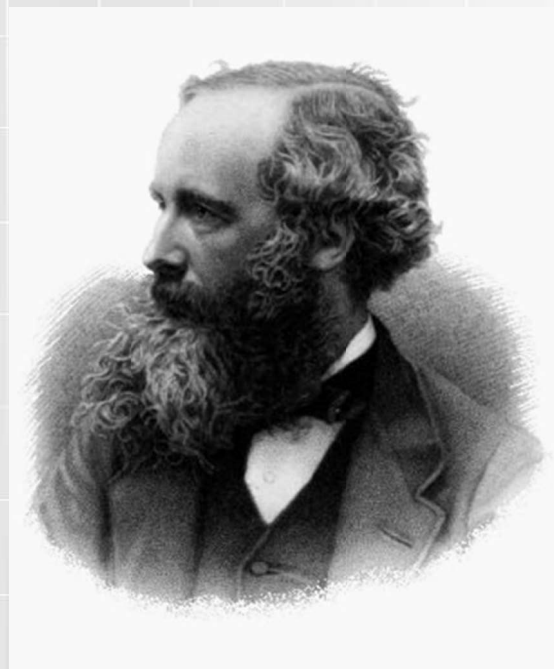


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# Electromagnetic Waves

Maxwell brought together all the work that had been done by brilliant physicists such as Oersted, Coulomb, Gauss, and Faraday, and added his own insights to develop the overarching theory of electromagnetism. Maxwell's equations are paraphrased here in words because their mathematical statement is beyond the level of this text. However, the equations illustrate how apparently simple mathematical statements can elegantly unite and express a multitude of concepts—why mathematics is the language of science.

Maxwell formulated a complete electromagnetic theory, represented by Maxwell's equations.





# Maxwell's equations

1. Electric field lines originate on positive charges and terminate on negative charges. The electric field is defined as the force per unit charge on a test charge, and the strength of the force is related to the electric constant  $\epsilon_0$ , also known as the permittivity of free space. From Maxwell's first equation we obtain a special form of Coulomb's law known as Gauss's law for electricity.
2. Magnetic field lines are continuous, having no beginning or end. No magnetic monopoles are known to exist. The strength of the magnetic force is related to the magnetic constant  $\mu_0$ , also known as the permeability of free space. This second of Maxwell's equations is known as Gauss's law for magnetism.
3. A changing magnetic field induces an electromotive force (emf) and, hence, an electric field. The direction of the emf opposes the change. This third of Maxwell's equations is Faraday's law of induction, and includes Lenz's law.
4. Magnetic fields are generated by moving charges or by changing electric fields. This fourth of Maxwell's equations encompasses Ampere's law and adds another source of magnetism—changing electric fields.



# Speed of light

Maxwell calculated that electromagnetic waves would propagate at a speed given by the equation

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

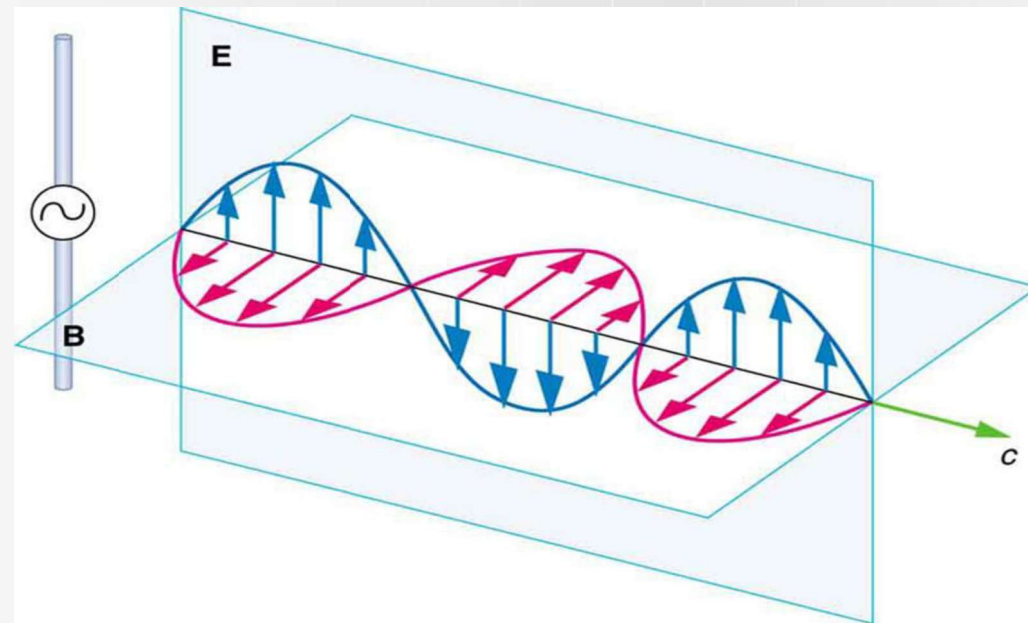
When the values for  $\mu_0$  and  $\epsilon_0$  are entered into the equation for  $c$ , we find that

$$c = \frac{1}{\sqrt{(8.85 \times 10^{-12} \frac{\text{C}^2}{\text{N} \cdot \text{m}^2})(4\pi \times 10^{-7} \frac{\text{T} \cdot \text{m}}{\text{A}})}} = 3.00 \times 10^8 \text{ m/s}$$

which is the speed of light. In fact, Maxwell concluded that light is an electromagnetic wave having such wavelengths that it can be detected by the eye.



# Electric and Magnetic Waves: Moving Together



A part of the electromagnetic wave sent out from the antenna at one instant in time. The electric and magnetic fields ( $E$  and  $B$ ) are in phase, and they are perpendicular to one another and the direction of propagation. For clarity, the waves are shown only along one direction, but they propagate out in other directions too.



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# Example 1

What is the maximum strength of the  $B$  -field in an electromagnetic wave that has a maximum  $E$  -field strength of  $1000 \text{ V/m}$ ?





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# Experiment: Antennas

For your TV or radio at home, identify the antenna, and sketch its shape. If you don't have cable, you might have an outdoor or indoor TV antenna. Estimate its size. If the TV signal is between 60 and 216 MHz for basic channels, then what is the wavelength of those EM waves?

Try tuning the radio and note the small range of frequencies at which a reasonable signal for that station is received. (This is easier with digital readout.) If you have a car with a radio and extendable antenna, note the quality of reception as the length of the antenna is changed.





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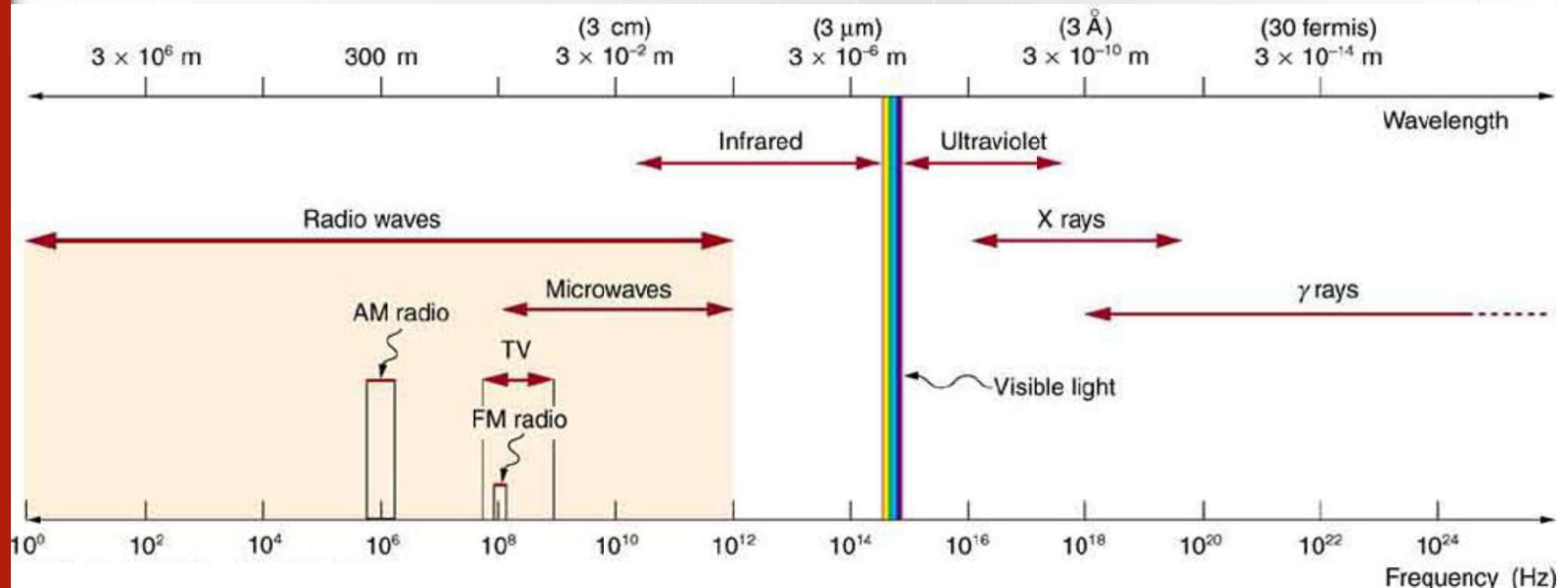
# Types of electromagnetic waves

Type of EM wave	Production	Applications	Life sciences aspect	Issues
Radio & TV	Accelerating charges	Communications Remote controls	MRI	Requires controls for band use
Microwaves	Accelerating charges & thermal agitation	Communications Ovens Radar	Deep heating	Cell phone use
Infrared	Thermal agitations & electronic transitions	Thermal imaging Heating	Absorbed by atmosphere	Greenhouse effect
Visible light	Thermal agitations & electronic transitions	All pervasive	Photosynthesis Human vision	
Ultraviolet	Thermal agitations & electronic transitions	Sterilization Cancer control	Vitamin D production	Ozone depletion Cancer causing
X-rays	Inner electronic transitions and fast collisions	Medical Security	Medical diagnosis Cancer therapy	Cancer causing
Gamma rays	Nuclear decay	Nuclear medicine Security	Medical diagnosis Cancer therapy	Cancer causing Radiation damage



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# Electromagnetics spectrum



The electromagnetic spectrum, showing the major categories of electromagnetic waves. The range of frequencies and wavelengths is remarkable. The dividing line between some categories is distinct, whereas other categories overlap.



# Rules of thumb

Three rules that apply to electromagnetic waves in general are as follows:

- High-frequency electromagnetic waves are more energetic and are more able to penetrate than low-frequency waves.
- High-frequency electromagnetic waves can carry more information per unit time than low-frequency waves.
- The shorter the wavelength of any electromagnetic wave probing a material, the smaller the detail it is possible to resolve.

Note that there are exceptions to these rules of thumb.



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# Radio and TV Waves

The broad category of radio waves is defined to contain any electromagnetic wave produced by currents in wires and circuits. Its name derives from their most common use as a carrier of audio information (i.e., radio). The name is applied to electromagnetic waves of similar frequencies regardless of source. Radio waves from outer space, for example, do not come from alien radio stations. They are created by many astronomical phenomena, and their study has revealed much about nature on the largest scales.

There are many uses for radio waves, and so the category is divided into many subcategories, including microwaves and those electromagnetic waves used for AM and FM radio, cellular telephones, and TV.



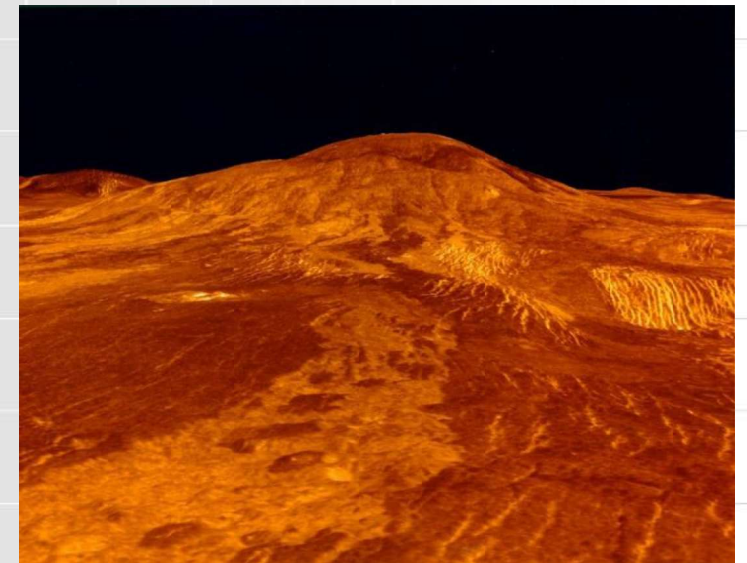


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# Microwaves

Microwaves are the highest-frequency electromagnetic waves that can be produced by currents in macroscopic circuits and devices. Microwave frequencies range from about  $10^9\text{Hz}$  to the highest practical LC resonance at nearly  $10^{12}\text{Hz}$ . Since they have high frequencies, their wavelengths are short compared with those of other radio waves—hence the name “microwave.”

Microwaves can also be produced by atoms and molecules. They are, for example, a component of electromagnetic radiation generated by thermal agitation. The thermal motion of atoms and molecules in any object at a temperature above absolute zero causes them to emit and absorb radiation.







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# Infrared Radiation

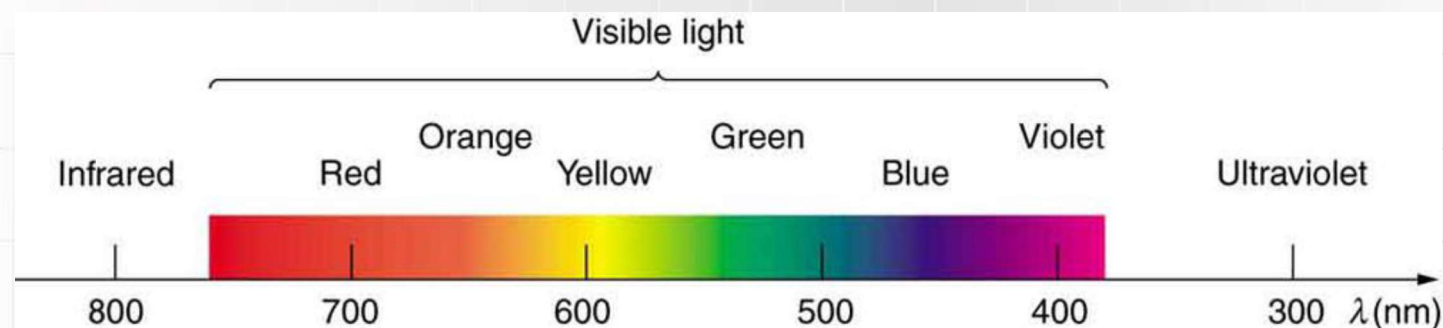
The microwave and infrared regions of the electromagnetic spectrum overlap. Infrared radiation is generally produced by thermal motion and the vibration and rotation of atoms and molecules. Electronic transitions in atoms and molecules can also produce infrared radiation.





# Visible Light

Visible light is the narrow segment of the electromagnetic spectrum to which the normal human eye responds. Visible light is produced by vibrations and rotations of atoms and molecules, as well as by electronic transitions within atoms and molecules. The receivers or detectors of light largely utilize electronic transitions. We say the atoms and molecules are excited when they absorb and relax when they emit through electronic transitions.

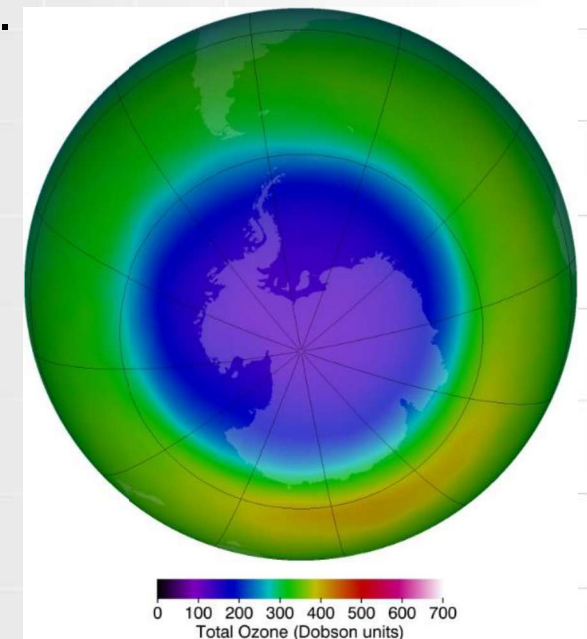
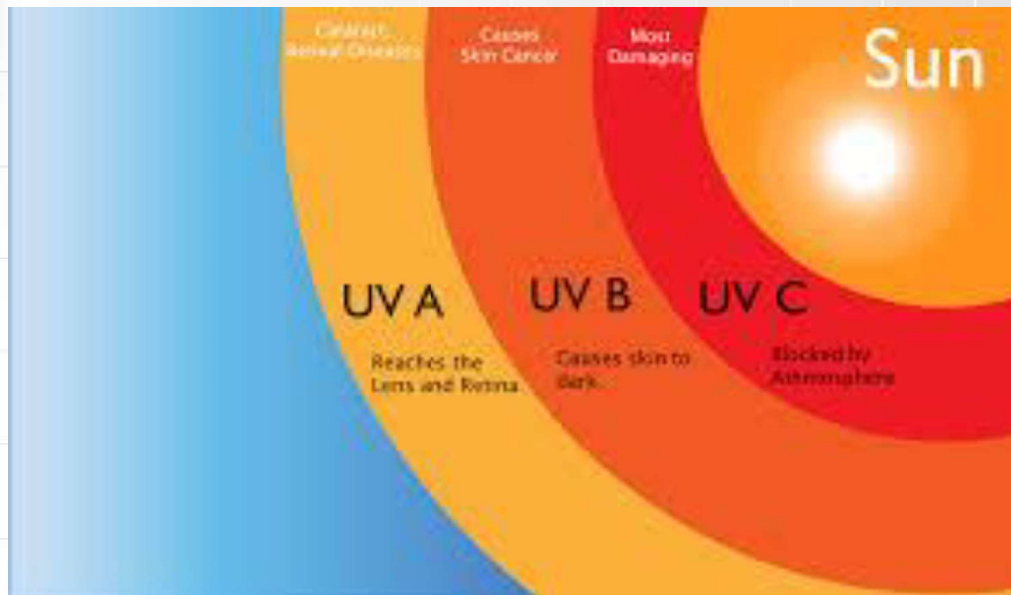






# Ultraviolet Radiation

Ultraviolet means “above violet.” The electromagnetic frequencies of ultraviolet radiation (UV) extend upward from violet, the highest-frequency visible light. Ultraviolet is also produced by atomic and molecular motions and electronic transitions. The wavelengths of ultraviolet extend from 400 nm down to about 10 nm at its highest frequencies, which overlap with the lowest X-ray frequencies. It was recognized as early as 1801 by Johann Ritter that the solar spectrum had an invisible component beyond the violet range.



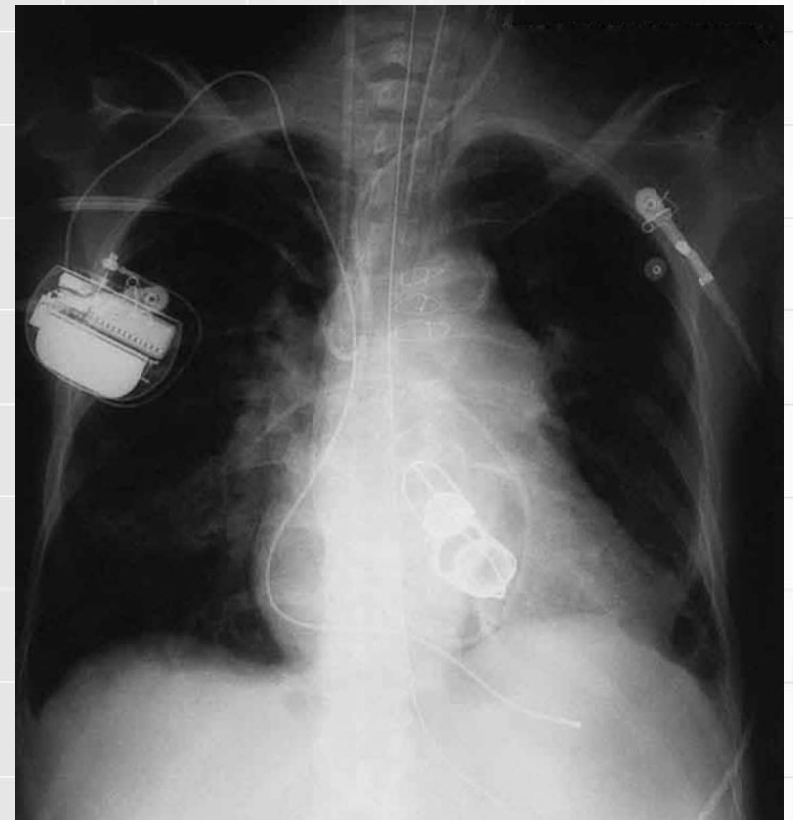


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# X-Rays

In the 1850s, scientists (such as Faraday) began experimenting with high-voltage electrical discharges in tubes filled with rarefied gases. It was later found that these discharges created an invisible, penetrating form of very high frequency electromagnetic radiation. This radiation was called an X-ray, because its identity and nature were unknown.

This shadow X-ray image shows many interesting features, such as artificial heart valves, a pacemaker, and the wires used to close the sternum.



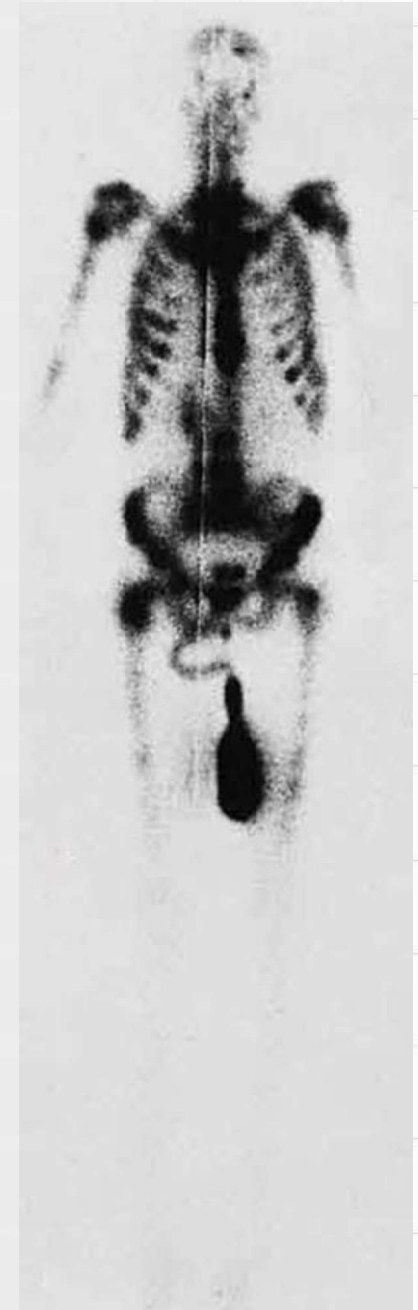


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# Gamma Rays

Soon after nuclear radioactivity was first detected in 1896, it was found that at least three distinct types of radiation were being emitted. The most penetrating nuclear radiation was called a gamma ray ( $\gamma$  ray) (again a name given because its identity and character were unknown), and it was later found to be an extremely high frequency electromagnetic wave.

In fact,  $\gamma$  rays are any electromagnetic radiation emitted by a nucleus. This can be from natural nuclear decay or induced nuclear processes in nuclear reactors and weapons. The lower end of the  $\gamma$ -ray frequency range overlaps the upper end of the X-ray range, but  $\gamma$  rays can have the highest frequency of any electromagnetic radiation.





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# Electromagnetic Waves

All right. So if you go to our website today, you will find I've assigned some problems and you should try to do them. They apply to this chapter.

