






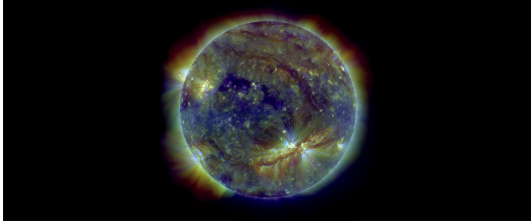
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**ASTRONOMY**  
Chapter 5 RADIATION AND SPECTRA  
PowerPoint Image Slideshow





**5.1 THE BEHAVIOR OF LIGHT** 





▶ **Our Sun in Ultraviolet Light (fig 5.1).** This photograph of the Sun was taken at several different wavelengths of ultraviolet, which our eyes cannot see, and then color coded so it reveals activity in our Sun's atmosphere that cannot be observed in visible light. This is why it is important to observe the Sun and other astronomical objects in wavelengths other than the visible band of the spectrum. This image was taken by a satellite from above Earth's atmosphere, which is necessary since Earth's atmosphere absorbs much of the ultraviolet light coming from space.

**Maxwell's Theory of Electromagnetism** 



▶ **James Clerk Maxwell (1831–1879) Fig 5.2.** Maxwell unified the rules governing electricity and magnetism into a coherent theory.

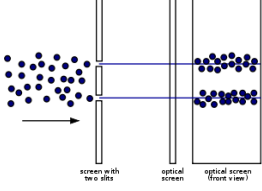
**Dual nature of light** 



▶ **Making Waves (fig 5.3).** An oscillation in a pool of water creates an expanding disturbance called a wave.

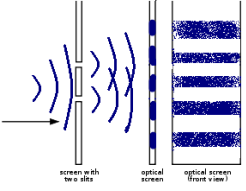
**Double Slit Experiment**

**Light as a particle**



screen with two slits    optical screen    optical screen (front view)

**Light as a wave**



screen with two slits    optical screen    optical screen (front view)

### The Wave-Like Characteristics of Light

Wavelength

Crest

Trough

▶ **Characterizing Waves (Fig 5.4).** Electromagnetic radiation has wave-like characteristics. The wavelength ( $\lambda$ ) is the distance between crests, the frequency ( $f$ ) is the number of cycles per second, and the speed ( $c$ ) is the distance the wave covers during a specified period of time (e.g., kilometers per second).

### Light as a Photon

- ▶ Particles of light are called **photons**.
- ▶ Each photon has a wavelength and a frequency.
- ▶ The energy of a photon depends on its frequency.

### Wavelength, Frequency, and Energy

$$\lambda \times f = c$$

$\lambda$  = wavelength,  $f$  = frequency  
 $c = 3.00 \times 10^8$  m/s = speed of light

- ▶ The shorter the wavelength the higher the frequency

$$E = h \times f = \text{photon energy}$$

$h = 6.626 \times 10^{-34}$  joule  $\times$  s

- ▶ The shorter its wavelength the higher the photon energy

### Propagation of Light

Decreasing concentration of electromagnetic radiation

- ▶ **Inverse Square Law for Light (Fig 5.5).** As light radiates away from its source, it spreads out in such a way that the energy per unit area (the amount of energy passing through one of the small squares) decreases as the square of the distance from its source.

### 5.2 THE ELECTROMAGNETIC SPECTRUM

The Electromagnetic Spectrum

gamma rays, X rays, ultraviolet, visible, infrared, microwaves, radio

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### Types of Electromagnetic Radiation

- ▶ gamma rays
- ▶ X-rays
- ▶ ultraviolet
- ▶ visible light
- ▶ infrared
- ▶ microwave
- ▶ radio waves

Shorter waves, Longer waves

Gamma, X-ray, Ultra violet (UV), Visible, Infrared (IR), Microwave, Radio

Thermosphere (ionosphere)

Stratosphere (ozone layer at 20-30 km; jet fly at 10 km)

Troposphere (weather)

Optical "window"

Radio "window"

### How does light interact with matter?

- ▶ **Emission**
  - ▶ Light bulb
- ▶ **Absorption**
  - ▶ Red chair
- ▶ **Transmission**
  - ▶ Glass (window)
  - ▶ Mirror or snow
- ▶ **Reflection or scattering**
  - ▶ Snow
  - ▶ Mirror

### Radiation and Temperatures

Intensity (arbitrary units)

Wavelength  $\lambda$  (nm)

Temperature: 5000 K, 4000 K, 3000 K, 2000 K

•  $\lambda$  maximum

- ▶ **Radiation Laws Illustrated (Fig 5.8).** This graph shows in arbitrary units how many photons are given off at each wavelength for objects at four different temperatures. The wavelengths corresponding to visible light are shown by the colored bands. Note that at hotter temperatures, more energy (in the form of photons) is emitted at all wavelengths. The higher the temperature, the shorter the wavelength at which the peak amount of energy is radiated (this is known as Wien's law).

### 5.3 SPECTROSCOPY IN ASTRONOMY

Incident white light

Red (760 nm)

Violet (380 nm)

- ▶ **Action of a Prism (Fig 5.9).** When we pass a beam of white sunlight through a prism, we see a rainbow-colored band of light that we call a continuous spectrum.

### Types of Spectra

Source of continuous spectrum

Cloud of gas

Continuous spectrum

Continuous spectrum with dark lines

Bright line spectrum

- ▶ **Three Kinds of Spectra (Fig 5.21).** When we see a lightbulb or other source of continuous radiation, all the colors are present. When the continuous spectrum is seen through a thinner gas cloud, the cloud's atoms produce absorption lines in the continuous spectrum. When the excited cloud is seen without the continuous source behind it, its atoms produce emission lines. We can learn which types of atoms are in the gas cloud from the pattern of absorption or emission lines.

### Continuous Spectrum

hot light source

prism

intensity

wavelength

Continuous Spectrum

- ▶ The spectrum of a common (incandescent) light bulb spans all visible wavelengths, without interruption.

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### Emission Line Spectrum

cloud of gas

prism

intensity

wavelength

Emission Line Spectrum

- ▶ A thin or low-density cloud of gas emits light only at specific wavelengths that depend on its composition and temperature, producing a spectrum with bright emission lines.

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## Absorption Line Spectrum

If light from a hot source passes through a cooler gas cloud, atoms in the cloud absorb light at wavelengths determined by the cloud's composition and temperature. We see dark absorption lines where the cloud has absorbed light of specific wavelengths (colors). The graph shows a dip in intensity at the wavelength of each absorption line.

hot light source, cloud of gas, prism, Absorption Line Spectrum, intensity, wavelength

► A cloud of gas between us and a light bulb can absorb light of specific wavelengths, leaving dark absorption lines in the spectrum.

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## 5.5 FORMATION OF SPECTRAL LINES

Balmer series (absorption), Lyman series (emission), Paschen series (emission), Energy, Balmer series, Lyman series, Paschen series, Brackett series, n = 1, n = 2, n = 3, n = 4, n = 5

► Energy levels

- ground state: An atom in its lowest energy state
- excitation: Atom absorbed energy thus, an electron is removed from atom "ionization"

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## Chemical Fingerprints

ionization, level 5, level 4, level 3, level 2, level 1, 121.6 nm, 102.6 nm, 97.3 nm, 95.0 nm, 656.3 nm, 486.1 nm, 434.0 nm, 410.1 nm, 121.6 nm, 102.6 nm, 97.3 nm, 95.0 nm

a Energy level transitions in hydrogen correspond to photons with specific wavelengths. Only a few of the many possible transitions are labeled.

b Because those atoms can absorb photons with those same energies, upward transitions produce a pattern of absorption lines at the same wavelengths.

c This spectrum shows absorption lines produced by upward transitions between level 2 and higher levels in hydrogen.

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## 5.6 THE DOPPLER EFFECT

train stationary, train moving to right, light source moving to right

a The whistle sounds the same no matter where you stand near a stationary train.

b For a moving train, the sound you hear depends on whether the train is moving toward you or away from you.

c We get the same basic effect from a moving light source (although the shifts are usually too small to notice with our eyes).

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## Measuring the Shift

Laboratory spectrum: Lines at rest wavelengths. Stationary

Object 1: Lines redshifted. Object moving away from us. Moving Away

Object 2: Greater redshift. Object moving away faster than object 1. Away Faster

Object 3: Lines blueshifted. Object moving toward us. Moving Toward

Object 4: Greater blueshift. Object moving toward us faster than object 3. Toward Faster

► Blueshift object is moving towards us.

► Redshift object is moving away from us.

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## Videos

► Dopler effect 5 min

## Reading

► 5.1

► 5.2

► 5.3

► 5.5

► 5.6

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