ANNOUNCEMENTS:

First in class Quiz at the end of class today
The energy change between levels is equal to the energy of the photon.

Larger energy jumps will be SHORTER wavelength photons!
Emission Spectra

- Emission for thin, hot gas where electrons are “excited” (in high energy states). Gas glows in specific colors.
  - This is our FINGERPRINT of the elements in the gas!
- Will eventually lose thermal energy through emitting photons, and cool!
If light with a continuous spectrum shines through a cloud of cool gas with electrons in low-energy states, the gas can absorb photons of the right energies to move electrons to excited states.
• Resulting spectrum shows DARK LINES of absorption.
  – Corresponds to wavelengths where the atom has absorbed a photon and excited an electron to a higher energy state

• Why don’t we see those atoms re-emit the same photon when they de-excite?
  – Atoms WILL emit these photons again and electrons fall back to ground state, BUT photons will be scattered in all directions and so most will be lost from our sight
Continuous Spectrum

- Hot solids/liquids/dense gases emit a continuous rainbow of light
  - Blackbody Radiation
Clicker Question

What causes spectral lines?

A. Black body radiation.
B. Electron energy transitions in the atom.
C. The Doppler shift of moving objects.
D. High frequency electromagnetic waves.
E. Protons and neutrons spinning in an atom.
What causes spectral lines?

A. Black body radiation.
B. Electron energy transitions in the atom.
C. The Doppler shift of moving objects.
D. High frequency electromagnetic waves.
E. Protons and neutrons spinning in an atom.
Clicker Question

What do we see at position 1?

A. Absorption Line Spectrum
B. Continuous Spectrum
C. Emission Line Spectrum
Clicker Question

What do we see at position 2?

A. Absorption Line Spectrum
B. Continuous Spectrum
C. Emission Line Spectrum
Clicker Question

What do we see at position 3?

A. Absorption Line Spectrum
B. Continuous Spectrum
C. Emission Line Spectrum
Kirchoff’s Laws

1) Hot solid, liquid, or dense gas
(continuum spectrum)

2) Continuous spectrum viewed through a cooler gas
(absorption line spectrum)

3) Thin, hot gas
(emission line spectrum)
Solar Spectrum (as seen from Earth)
Where could the dark lines in the Solar spectrum be coming from?

A. Absorption in the Sun’s atmosphere
B. Emission from the Sun’s atmosphere
C. Absorption in the interior of the Sun
D. Emission from the interior of the Sun
E. Absorption by the glass mirrors in the telescope used to collect the light
Where could the dark lines in the Solar spectrum be coming from?

A. Absorption in the Sun’s atmosphere
B. Emission from the Sun’s atmosphere
C. Absorption in the interior of the Sun
D. Emission from the interior of the Sun
E. Absorption by the glass mirrors in the telescope used to collect the light
Rules for Emission by Blackbody Objects

1. Hotter objects emit more total radiation per unit surface area.
   - Stephan-Boltzmann Law
   - $E$ is proportional to $T^4$

2. Hotter objects emit \textit{bluer} photons (with a higher average energy.)
   - Wien Law
   - $\lambda_{\text{max}} = 2.9 \times 10^6 / T(\text{Kelvin})$ [nm]
Humans emit blackbody radiation in the infrared
M16

4 million Year-old Cluster

Ionized Nebula

Surviving cloud
What is this object?

- Let’s use its spectral information to determine what it is.
What is this object?

Reflected Sunlight:
Continuous spectrum of visible light is like the Sun’s except that some of the blue light has been absorbed - object must look red
Thermal Radiation: Infrared spectrum peaks at a wavelength corresponding to a temperature of 225 K
What is this object?

Carbon Dioxide: Absorption lines are the fingerprint of CO$_2$ in the atmosphere.
What is this object?

Ultraviolet Emission Lines:
Indicate a hot upper atmosphere
What is this object?

Mars!
Measuring velocities without a stopwatch: the Doppler Shift

- Familiar shift in pitch of SOUND: higher when approaching, lower when receding

- Similar shift in frequency of light: higher frequency (blueshift) when approaching, lower frequency (redshift) when receding
Most easily used with absorption or emission lines where you know the zero-velocity (rest) wavelengths. Then, measure redshift or blueshift to get the velocity away or towards you.

**Laboratory spectrum**  
*Lines at rest wavelengths.*

**Object 1**  
Lines redshifted:  
Object moving away from us.

**Object 2**  
Greater redshift:  
Object moving away faster than Object 1.

**Object 3**  
Lines blueshifted:  
Object moving toward us.

**Object 4**  
Greater blueshift:  
Object moving toward us faster than Object 3.

© 2006 Pearson Education, Inc., publishing as Addison Wesley
QUIZ #1

1) You observe two stars in the sky; they are identical except that one is blue and the other is red. They emit blackbody radiation.

a) Which one is hotter? [2.5pt]
b) Which one is brighter? (i.e. has higher intensity). [2.5pt]
   Explain and motivate your answers for full credit.

2) The spectrum of the Sun displays a continuum with super-imposed absorption lines.

a) Are the absorption lines produced in an inner or outer layer with respect to the continuum? [2.5pt]
b) Is the outer layer cooler or hotter than the inner one? [2.5pt]
   Explain and motivate your answers for full credit.