PHYS 1403 Stars and Galaxies

Topics for Today's Class

1. How do we explain the motion of energy?
2. What is a wave and what are its properties
3. What is an electromagnetic spectrum?
4. What is a black body and what are the black body law of radiation?
5. How do atoms give off electromagnetic radiation?
6. What is a spectrum, and how do we see it?

How do we explain the motion of energy?

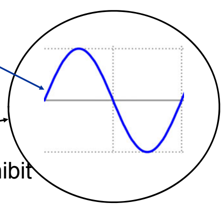
We can see light from stars traveling light years to reach us. How does this energy travel?

Physicist and Astronomers use two models to describe the motion of energy.

The wave model

and the

Particle model



Light is considered to exhibit dual nature

Wikimedia Commons

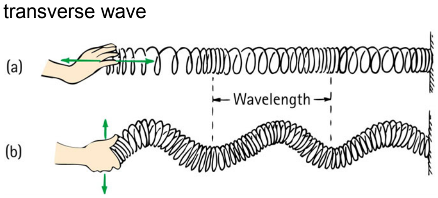
What is a Wave, and what are its properties?

Vibration are wiggle in time
Wave are wiggle in space and time
What do Waves do?
  Waves transport Energy
  Light is a type of wave

Transverse and Longitudinal Waves

Two common types of waves that differ because of the direction in which the medium vibrates compared with the direction of travel:

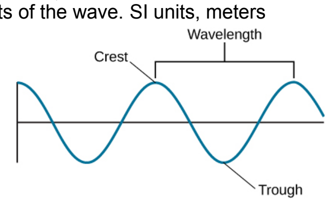
- longitudinal wave
- transverse wave



Wave Description

Vibration and wave characteristics

- Amplitude (A)
  - distance from the midpoint to the crest or to the trough. SI unit depend on physical quantity
- Wavelength (λ)
  - distance from the top of one crest to the top of the next crest, or distance between successive identical parts of the wave. SI units, meters



Wave Description

- Frequency (ν)
- Wavelength, frequency and speed are related.

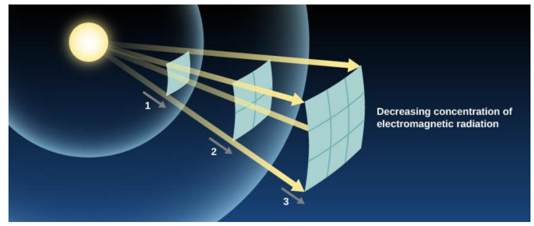
$$\lambda\nu = v$$

Always true not matter what type of wave

- For electromagnetic waves $v = c$

Intensity of Waves

- Inverse Square Law for Light. 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.



Light as a Particle

- Light can also appear as particles, called photons (explains, e.g., photoelectric effect).
- A photon has a specific energy E, proportional to the frequency f:
- If we combine the particle nature with wave nature we can get the energy of the wave.

$$E = h\nu$$

h is called the Planck constant

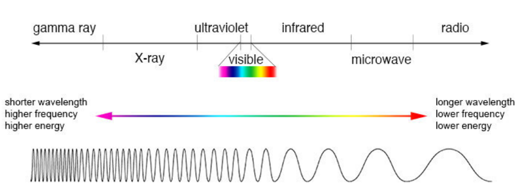
What is Electromagnetic Spectrum?

Topics

1. Definition
2. Diagram
3. Visible Waves
4. Energy of Different Waves

Energy of Different Waves

An electromagnetic spectrum is an assemblage of waves according to increasing energy.



Imagine the Universe! - NASA

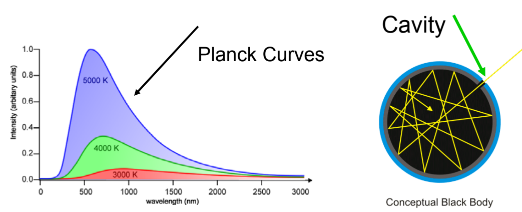
How do we explain Radiation?

Topics

1. What is a Blackbody Radiator?
2. Planck Curve
3. Stefan's Boltzmann Law
4. Wein's Displacement Law
5. Celestial bodies produce Blackbody radiation?

What is a Black Body?

- Black Body Radiator. A hypothetical object that emits Electromagnetic radiation and whose spectrum is continuous with a peak in the wavelength that corresponds to the temperature of the object.
- Planck curve is a distribution of energy vs. Wavelength.



Two Laws of Blackbody Radiation

- The Stefan-Boltzmann law:
  - The *hotter* an object is, the *more energy (Luminosity L)* it emits

$$L = E = \sigma * T^4$$

Where, E = Energy Flux = Energy given off in the form of radiation, per unit time and per unit surface area [J/s/m^2]

$\sigma = 5.7 \times 10^{-8}$ J/sm^2/K^4 Stefan-Boltzmann constant

Two Laws of Blackbody Radiation (cont'd.)

- Wien's Law:
  - The peak of the black body spectrum shifts towards shorter wavelengths when the temperature increases

$$\lambda_{max} \approx 3{,}000{,}000 / T\ (^oK)$$

where T is the temperature in Kelvin

or

$$T\ (^oK) \approx 3{,}000{,}000 / \lambda_{max}\ (nm)$$

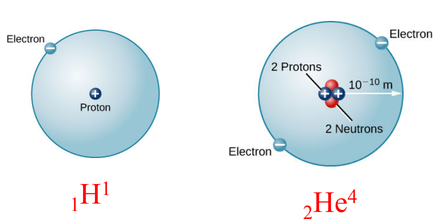
So if we know λ_{max} we can find the surface temperature of stars.

How do Atoms give off Electromagnetic Radiation?

Topics

1. Hydrogen and Helium Atoms?
2. Isotopes
3. What holds atoms together?
4. Excited Atoms
5. Bohr's Model of Atom

Hydrogen and Helium Atom



Most Abundant Atoms in the Universe

thinglink.com

Isotopes

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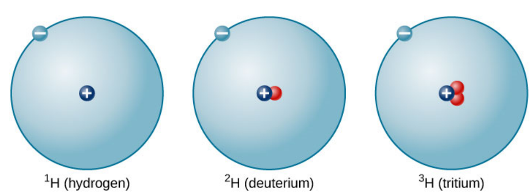
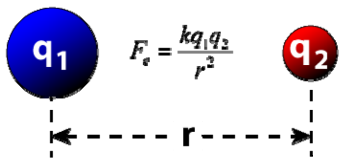


- **Isotopes of Hydrogen**. A single proton in the nucleus defines the atom to be hydrogen, but there may be zero, one, or two neutrons. The most common isotope of hydrogen is the one with only a single proton and no neutrons.

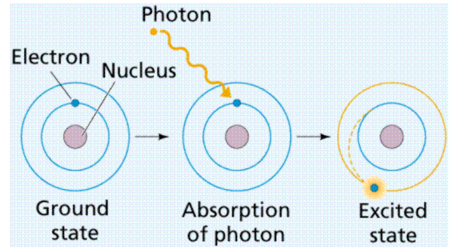
What Holds the Atom Together?



Charles-Augustin de Coulomb (1736-1806)
Electrons in an atom are bound to the nucleus via an electric force called coulomb force.
Electrons are negative and Nucleus is positive so attraction force.
k is a constant $k = 9.0 \times 10^9 N.m^2/C^2$
Even though k is large, the charges are extremely small and that makes the electric force very small and short range.

Apulsephysics.com

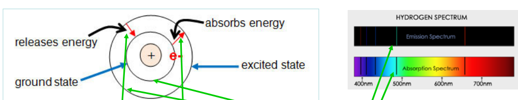
What is an Excited Atom



- Incoming photon can be absorbed if it has the correct energy
- It causes the electron to jump to a higher energy level

scienceonline.com

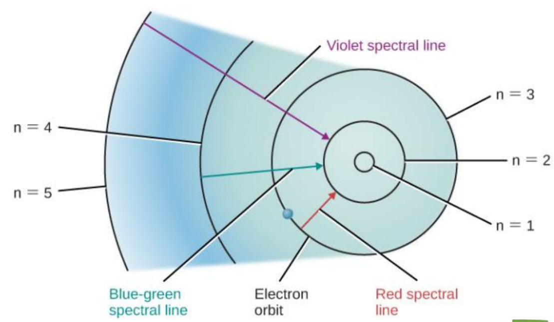
Bohr Model of the Atom



- Electron and an atom can only occupy discrete (quantized) energy levels.
- Photons are emitted / absorbed when an electron makes a transition from one energy level to another
  - Wavelength depends upon the energy difference between the two levels ($\Delta E = E_f - E_i$).
  - Each spectral line represents an electron transition between two energy levels
  - Each element has a unique set of spectral lines that can be used to identify its presence

Texasgateway.org

Bohr Model of Hydrogen Atom



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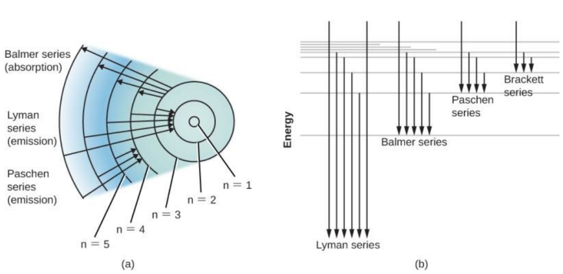
Possible Transitions for Hydrogen Atom



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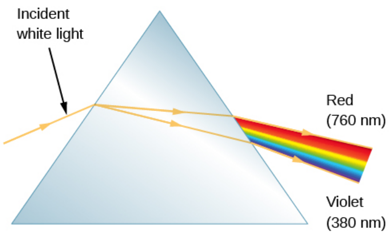
What is a Spectrum and How do we see it?

Topics
1. Colors of White Light
2. Spectroscope
3. Finger Printing the Atom
4. Stars are Black Body Radiators
5. Three Kinds of Spectra
6. Why is Spectroscopy of Stars Important?

Colors of White Light



- **Action of a Prism.** 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.

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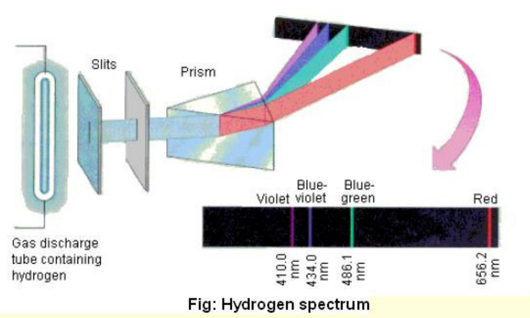
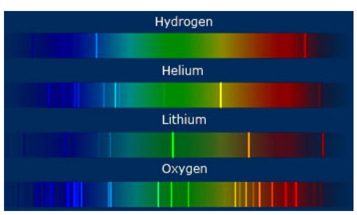
Spectroscope



A Spectroscope Can Show a Spectrum of an Atom

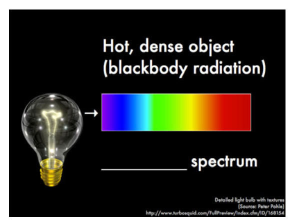
Finger Printing the Atom

- Every atom and molecule has its own distinct spectrum
- Spectra differ in number of lines and the spacing between the lines
- The configuration of energy levels of each chemical element is Unique

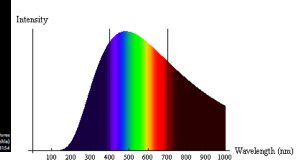


Wonderwhizkid.com

Hot Objects are Black Body Radiators



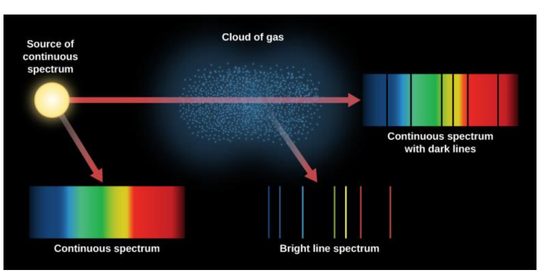
Blackbody Radiator



Spectrum of a Hot Source: Continuous Spectrum

http://astro.unl.edu/classaction/animations/light/meltednail.html

Three Kinds of Spectra



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Why is Spectroscopy of Stars Important?

- Spectra of Stars and Spectroscopy can
  - allow us to determine the temperature of stars.
  - allow us to determine the chemical composition of stars.
  - allow us to determine the radial velocity of stars.
  - allow us to determine density of gas in a star.

Wednesday class this week

- Complete Class Assignment 5

Acknowledgment

- The slides in this lecture is for Tarleton: PHYS1411/PHYS1403 class use only
- Images and text material have been borrowed from various sources with appropriate citations in the slides, including PowerPoint slides from adopted text book.