Light & waves
Chapter 5

Learning Outcomes, Objectives, & Goals

- **Appreciating** science in general, and astronomy in specific.
- **Understanding** how knowledge is gained and be critical of what you see and hear.
- **Developing** a working knowledge of the scientific method and how to apply it to real world situations.
- **Critically analyzing and evaluating** information, scientific or otherwise
- Learn some simple astronomical nomenclature/terminology.
- Develop a sense of what scientists know about the overall universe, its constituents, and our location
- Explain how electromagnetic radiation is used to reveal the properties of stars and planets.
- Understand the simpler concepts about light and the different processes that cause light to be emitted or absorbed
Overarching questions

• What words mean the same as light?
• What are the types of light?
• What are different properties of waves and how are they measured/calculated?
• How do photons interact with matter?
• What are the 3 types of spectra, what are their properties, and what determines which type an object displays?
• What is the Doppler effect and how does it work? Real life and astronomical applications.

Fancy words

• Visible light  = what people see
• Spectrum  = all of the types of ...
• Visible spectrum = ____________
• White = roughly even mixture of visible spectrum

• Electromagnetic radiation = Light
• Electromagnetic spectrum= ____________
Pre-test: Radio waves are a form of

0 1. Light
0 2. Sound
0 3. Both light and sound

5 ways light interacts with matter
1. Gets emitted. We’ll discuss 2 ways later.
2. Gets absorbed
3. Passes through ("transmitted")
4. Reflects (shiny things)
5. Scatters in many directions (most things)

See figures 5.2 & 5.3 on pages 151-152.
Calif. Science Standards for light

- From California Science Standards, grade 3:
  - Students know the color of light striking an object affects the way the object is seen.
  - Students know an object is seen when light traveling from the object enters the eye.

- And from grade 7:
  - Students know that for an object to be seen, light emitted by or scattered from it must be detected by the eye.
  - Students know light travels in straight lines if the medium it travels through does not change.
  - Students know that white light is a mixture of many wavelengths (colors) …
  - Students know light can be reflected, refracted, transmitted, and absorbed by matter.

Which does a movie screen do?

1. Scatter
2. Reflect
3. Emit
4. Absorb
5. Transmit
Which happens to light when it hits my shirt?

0 1. Scatter
0 2. Reflect

Which happens to light when it hits the Moon?

0 1. Scatter
0 2. Reflect
What color does a blue shirt ABSORB?

0 1. Absorb all except blue light
0 2. Absorb blue light

Waving

• What are some examples of waves?
• What is waving in each example? Which direction is it moving?
  – “Surface Waves in a Pond” animation [#1]
• Wave is a moving pattern carrying energy.
• Light acts like a wave. What is waving?
Wave properties

• Wavelength – see page 153
  – Size of wave; detecting/catching the wave
• Frequency – How often a wave passes by
  – units are: waves per second = Hertz (Hz)
• Speed = how fast one wave pattern moves (in units such as miles/hour)
  – “Anatomy of a wave” animation [#2]
• Amplitude = strength of wave.

Are frequency and speed the same thing?

0    1. Yes
0    2. No
### Light types – memorize this page!

Seven types of light, in order (see page 155)

(Highest frequency     smallest wavelength)

1. Gamma-rays
2. X-rays
3. Ultraviolet (UV) light = 10%
4. **Visible light = 45%** (VIB G YOR)
5. Infrared (IR) light = 35%
6. Microwaves
7. Radio waves

(Lowest frequency     longest wavelength)

- Speed of light \( = (\text{light wavelength}) \times (\text{light frequency}) \)
- **Constant number** = One number goes up, the other goes down

“Visible Light Waves” animation [last]

---

### Test 3 (out of 6) ends here

- See title
Light in your everyday life

- Your eyes see __________ light.
- When ________ light lands on your skin, your skin gets warmer.
- When ________ light lands on your skin, you get skin damage.
- When ________ light lands on your skin, you get radiation poisoning. (two answers)
- When ________ light lands on your skin, nothing changes unless a LOT lands on you. (two answers)
- Digital cameras see visible AND infrared light. Remote controls often use IR light. Look: cell phone + remote

More light in everyday life - invisible

- What kind of light does your body mostly emit (give off)?
- Want to see it?
- Neat fact: Blacklights emit some UV. Take a look.
What is the wavelength?

1. 1.5 meters
2. 2 meters
3. 3 meters
4. 4 meters
5. 7 meters
6. 8 meters
7. Not enough info to answer

What is the Amplitude?

1. 1.5 meters
2. 2 meters
3. 3 meters
4. 4 meters
5. 7 meters
6. 8 meters
7. Not enough info to answer
What is the frequency?

1. 1.5 meters
2. 2 meters
3. 3 meters
4. 4 meters
5. 7 meters
6. 8 meters
7. Not enough info to answer

Each drawing shows what passes you by during one second. Which wave has a higher frequency?

1. Top
2. Bottom
3. Same
Each drawing shows what passes you by during one second. Which wave travels faster?

0  1. Top
0  2. Bottom
0  3. Same

Analogy – instead of waves, vehicles on 405 freeway
- New freeway: speed limit is 10 mph
- 2 special lanes: limos & motorcycles
- All traffic is bumper-to-bumper, going 10 mph
- You stand by side of road and count # of vehicles that pass you after 30 seconds
- Which vehicle type went faster?
- Which do you see more of? What wave property does this match up to?
- What else is different about the 2 vehicles? Wave property?
- Which type of wave corresponds to limos? Motorcycles?
Which travels faster

0  1. Radio waves
0  2. Visible light
0  3. X-rays
0  4. same

California Elementary School
Science Standards for waves

• From California Science Standards, high school
  – Students know waves carry energy from one place to another.
  – Students know how to solve problems involving wavelength, frequency, and wave speed.
  – Students know radio waves, light, and X-rays are different wavelength bands in the spectrum of electromagnetic waves whose speed in a vacuum is approximately $3 \times 10^8$ m/s (186,000 miles/second).
Light acting as a particle

- We’ve been talking about light acting like a wave.
- Light also acts like a particle.
- Light particles are called ....
- The energy of a photon is related to the frequency.
  - High frequency photons have more energy than low frequency photons.

Which type of photon carries the most energy?

0 1. Radio wave
0 2. Microwave
0 3. Infrared (IR)
0 4. Visible
0 5. UV
0 6. X-ray
0 7. Gamma ray
Photons and humans

• Which type of photon carries the most energy?
• Which kind is most dangerous?
• Least dangerous?

Lecture Tutorial – SKIP THIS?

• 8 minutes – pages 45-47.
• Go.
Which of the light waves carries the most energy?

0 1. 1cm wavelength
0 2. 0.5 cm wavelength
0 3. 0.25 cm wavelength
0 4. All carry the same energy

Similar to figure 5.6

Quantized nature of atoms

- Atomic structure
- Examine figure 5.12 (page 163) – allowed energy levels in Hydrogen gas.
- General rules are:
  - Electrons can only be in specific energy levels.
  - Electrons can only gain/lose specific amounts of energy - when jump between allowed levels
  - When jumping down, electrons release energy in the form of photons.
    - Different energy jump → energy in the photon
    - How much energy for a photon: Hydrogen 3 → 2 transition?
- Review: lowest energy photons → highest
- See page 155.
  - Visible photons: energy ranges from 1.5 to 4 eV.
Are there any conditions under which an electron in a hydrogen atom can gain 2.6 eV of energy?

1. Yes
2. No

Can you see a photon that has 2.6 eV worth of energy?

1. Yes
2. No
Emission-line tubes - fluorescence

• Show incandescent light bulb to get the visible spectrum only.
• Show Hydrogen
• Each of the emission lines you see is caused when an electron jumps (up/down?) from _______ to ___.

Which color is the 3 → 2 electron transition in Hydrogen?

0 1. Red
0 2. Turquoise
0 3. Blue/Purple
Is the hydrogen $2 \rightarrow 1$ electron transition visible to you?

0 1. Yes
0 2. No

Emission lines - animations

• “De-excitation of Atom & Emission” [4th row b]
  – Show other gas emission: He, Ne, O$_2$, N$_2$
  ➔ What can we conclude from these other emission spectra?
• “Energy Level Diagrams…” [3rd row b]
• “Composition Mystery” #2. [4th row b]
  – Why are emission lines useful?
• What can excite electrons?
  ➔ ____________ and ____________
• “Photo-excitation” [3rd row b]
• “Spectrum of Hot Low-density” [2nd row b]
3 types of spectra – page 164

• Emission – see specific colors
  – Occurs when …
  – Examples in everyday life: fluorescent bulb, CFL, neon lights, tossing salt into flame

• Continuous – (thermal emission)
  – Occurs when …
  – Dense objects
  – Examples in everyday life: incandescent bulb, electric stove, hot BBQ coals, other flames (orange part), lava, people, animals, most things cooling off

• Absorption – see ____________________
  – Production of Absorption Lines [2nd row b]
    • Telescope 1 first, then gas cloud added
  – Occurs when …
  – Example in everyday life: the Sun, all other stars

Which kind of spectrum do you see on page 149 (Secrets of Sunlight)?

0  1. Continuous
0  2. Emission
0  3. Absorption
Lecture Tutorial

- Pages 61-62, Types of Spectra
- AND pages 63-7
- 16 minutes. Go.
- Skip #4 on page 64.
- Pages 69-72 are STRONGLY RECOMMENDED. You will probably see test questions like those.

What kind of spectrum do stars give off?

1. Continuous
2. Emission
3. Absorption
Thermal emitters = continuous spectra

- Anything with a temperature is thermal emitter.
  - Examples include _________________.
  - Dense opaque objects show continuous spectrum.
- Light bulb demo
  - Thermal emitters emit ALL kinds of light.
- Stefan’s law (law 1)
  - English: hotter stars emit more light.
  - English part 2: Size also matters.
  - Star LUMINOSITY = (surface area) * Temp^4
    - Area (radius) discussed by your book in chapter 15 (p. 519-520 and the math insight on page 532)
- Wien’s law (law 2)
  - English: hotter stars look bluer, colder stars look redder.
  - Rule applies to all continuous/thermal emission light sources, such as ...
  - Peak emission type of light depends on Temperature:
    - Hotter = bluer peak.
    - Math version: peak w.L. * surf temp = constant
- Regular version of Figure 5.19, page 168
- Interactive version of 5.19
  - http://webphysics.davidson.edu/alumni/Mi.Lee/java/bb_mjl.htm is another version

Lecture Tutorials

- Luminosity, Temperature, and Size
- Teacher explain hot plate pictures. Which are hotter in drawing A, C.
- Pages 53-56.
- 15 minutes. Go.
Question 11) Which star is bigger?

1. S
2. X
3. Same

Lecture Tutorials

• Pages 57-60. 15 minutes again.
Are you here?

1. Yes
2. No

Doppler Effect – what is it?

- Sound maker demo
  - Close eyes & listen; describe
  - Match description with observation
Which kind of Doppler shift do we see for most objects in the universe?

1. Redshift
2. Blueshift

Redshift & blueshift

- Interactive figure 5.22
- Why called redshift & blueshift for light.
- Most stars, like the Sun have a __________ type of spectrum
- Doppler shift of lines [5th row top]
- Here’s why it works:
  - Doppler effect for Visible light [5th row top]
  - Doppler Shift & Velocity of Source [5th row t]
Applications of the Doppler effect

- Show “Several examples of motion” [5th b]
- Rotational line broadening: fig 5.24
- Speeding tickets!

What we learn from light spectra

- Stars & planets show _______ spectra
  - Which _________ lines we see tells us _______
  - Strength (bright/faint) of those lines tells us amount
  - For stars, width of lines tells us surface gravity
  - For stars, width also tells us rotation rate
- Thermal emitters show _______ spectra
  - Location of peak emission tells us _______.
  - ____________ also depends on that.
Doppler shift practice

- See also the Doppler Shift lecture tutorial in your workbook.
- See also the Doppler Shift Ranking Task handout. (If it’s not handed out, ask for it! Worst case scenario: it’ll be put onto the website.)

Overarching questions

- What words mean the same as light?
- What are the types of light?
- What are different properties of waves and how are they measured/calculated?
- How do photons interact with matter?
- What are the 3 types of spectra, what are their properties, and what determines which type an object displays?
- What is the Doppler effect and how does it work? Real life and astronomical applications.