PowerPoint Lectures
to accompany
Physical Science, 8e

Chapter 7
Light

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Core Concept

Light is electromagnetic radiation– energy – that interacts with matter.

New Symbols for this Chapter

c-Speed of Light
n-Index of refraction
h-Planck's Constant

$$\theta_i = \theta_f$$

$$n = \frac{c}{v}$$

$$c = \lambda f$$

$$E = hf$$

Structure

- Regenerating co-oscillation of electric and magnetic fields
- Transverse waves
- Electric, magnetic and velocity vectors mutually perpendicular
- Electromagnetic spectrum

Sources of Light

- Matter constantly emits and absorbs radiation
- Emission mechanism
  - Accelerated, oscillating charges produce electromagnetic waves
- Absorption mechanism
  - Oscillating electromagnetic waves accelerate charges within matter
- Different accelerations lead to different frequencies
- Luminous
  - Producing light
  - The Sun versus the nonluminous Moon
- Incandescent
  - Glowing with visible light from high temperatures
  - Examples: flames, incandescent light bulbs

Blackbody/Thermal Radiation

Blackbody
- Ideal absorber/emitter of light
- Radiation originates from oscillation of near-surface charges

Increasing temperature
- Amount of radiation increases
- Peak in emission spectrum moves to higher frequency

Spectrum of the Sun

Properties of Light – Two Models

Light ray model
- Particle-like view
- Photons travel in straight lines
- Applications
  - Mirrors
  - Prisms
  - Lenses

Wave model
- Traces motions of wave fronts
- Best explains
  - Interference
  - Diffraction
  - Polarization

Light Interacts with Matter

- Interaction begins at surface and depends on
  - Smoothness of surface
  - Nature of the material
  - Angle of incidence
- Possible interactions
  - Absorption and transmission
  - Reflection
  - Refraction

Diffuse Reflection

- Most common visibility mechanism
- Each point reflects light in all directions
- Bundles of light from object are seen by the eye
- Colors result from selective wavelength reflection/absorption

Reflection Details

- Angles measured with respect to the "surface normal"
  - Line perpendicular to the surface
- Law of reflection

Image Formation

- Real image
  - Can be viewed or displayed at its location
  - Example - movie image on a screen
- Virtual image
  - Appears to come from a location where it is not directly visible
  - Examples: plane mirror, convex mirror, concave mirror

Refraction

- Light crossing a boundary surface and changing direction
- Reason: change in light propagation speed
  - Moving to a medium with a slower propagation speed
    - Light bends toward surface normal
  - Moving to a medium with a faster propagation speed
    - Light bends away from the normal

Refraction, cont.

- Mirages
- Critical angle
  - Light refracted parallel to surface
  - No light passes through surface - "total internal reflection"
  - Applications - fiber optics, gemstone brilliance

Refraction, cont.

- Index of refraction
  - A measure of light speed

Substance	Index of refraction	Light speed
Air	Approx. 1	~c
Water	1.333	0.75c
Glass	1.5	0.67c
Diamond	2.4	0.42c
BE condensate	18,000,000	38 mph!

Example 1 (Parallel Exercise Group B #5)

Acetone	1.3600000
Acrylic glass	1.4910000
Actinolite	1.6180000
Agalmatolite	1.5500000
Agate	1.5485000
Agate - Moss	1.5400000
Air	1.0002926
Alcohol	1.3290000

1) The speed of light through a transparent substance is $2.00X10^8$ m/s. What is the material?

Dispersion and Colors

- White light
  - Mixture of colors in sunlight
  - Separated with a prism
- Dispersion
  - Index of refraction varies with wavelength
  - Different wavelengths refract at different angles
  - Violet refracted most (blue sky)
  - Red refracted least (red sunsets)
  - Example: rainbows
- Wavelength/frequency related

Optics

- The use of lenses to form images
- Concave lenses
  - Diverging lenses
  - Vision correction/in association with other lenses
- Convex lenses
  - Converging lenses
  - Most commonly used lens
  - Magnifiers, cameras, eyeglasses, telescopes, …

The Human Eye

- Uses convex lens with muscularly controlled curvature to change focal distance
- Nearsightedness (myopia) - images form in front of retina
- Farsightedness (hyperopia) - images form behind retina
- Correction - lenses (glasses, contacts) used to move images onto retina

The Nature of Light
Wave-like Behavior

Diffraction
- Bending of waves around objects
- Shadows do not have sharp edges

The Nature of Light
Wave-like Behavior

Interference
- Young's two slit experiment
- Interference pattern - series of bright and dark zones
- Explanation - constructive and destructive interference

Wave-like Behavior - Polarization

- Alignment of electromagnetic fields
- Unpolarized light - mixture of randomly oriented fields
- Polarized light - electric fields oscillating on one direction

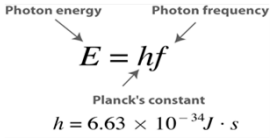
Wave-like Behavior - Polarization

- Unpolarized light - mixture of randomly oriented fields
- Polarized light - electric fields oscillating on one direction
- Two filters - passage depends on alignment
- Reflection polarization

Particle-like Behavior

Quantization of energy

- Energy comes in discrete quanta
- Used by Planck to explain blackbody radiation observations
- Particles of light = photons
- Detected in digital cameras with CCDs (charge-coupled devices)



Example 2 (Parallel Exercise Group B #14)

2) What is the energy of a photon of ultraviolet radiation with a wavelength of $3.00X10^{-7}$ m?

Photoelectric Effect

- Ejection of electrons from metal surfaces by photon impact
- Minimum photon energy (frequency) needed to overcome electron binding PE
- Additional photon energy goes into KE of ejected electron
- Intensity of light related to number of photons, not energy
- Application: photocells

Special Relativity

- Concerned with events as observed from different points of view
- Based upon Einstein's principles of
  - Consistent law principle
  - Constancy of speed principle

Special Relativity

- Shows that measurements of length, time, and mass are different in different moving reference frames
- The length of an object is shorter when moving.
- Moving clocks run more slowly.
- Moving objects have increased mass.

General Theory of Relativity

- Also called Einstein's geometric theory of gravity
- Gravitational interaction is the result of the interaction between mass and the geometry of space
- 4th dimensional "spacetime" structure