Physics in Entertainment and the Arts

Chapter XIII

Light

Particle or Wave?
- Experiments show that light is a wave
  - It can reflect, refract, interfere, and diffract
  - Sometimes all at once!
- Experiments show that light is a particle
  - It can impart motion to objects via collisions
- So which experiments are correct?

Reflection of Waves
- The image you see of yourself in a mirror is the end result of a chain of events
  - Light waves reflect off you onto the mirror, then reflects off the mirror into your eyes

Refraction of Waves
- The speed of light in a vacuum \( c \) is a constant (186,000 miles/second)
  - independent of frequency
- The speed of light in other materials is always slower
  - and is dependent on frequency!
  - blue light moves more slowly through air than red light

Diffraction of Waves
- Light waves can bend (diffract) around the edges of objects

The Photoelectric Effect
- Light Reflection/Refraction/Diffraction All at Once!?
Particle and Wave

• Experiments show that light is both a particle and a wave!!

• So how do we describe light?

• We use a wave-like particle called a photon
  – Or is it a particle-like wave?

Particle and Wave

• A photon is a microscopic bundle of energy called a quantum
  – You can think of it as a small piece of a wave

• If you could (you can’t) take a photograph of a photon, it might look like this:

Particle and Wave

• The photon may be several feet long, but has a wavelength of several millionths of an inch
  – for visible light anyways…

• Since the photon has a length of millions of wavelengths
  – it can be thought of as a "continuous wave" which carries energy

Particle and Wave

• The only important characteristic of a photon is the energy it carries which can be described in any of 4 equivalent ways

  Energy  Frequency
  Wavelength  Color

  Physicists use any and all of these to describe a photon

An Electromagnetic Wave

• An electromagnetic wave is a propagating set of mutually perpendicular Electric and Magnetic Fields

A Dipole Antenna

• In the last chapter we saw that applying an alternating current (AC) to a wire
  – generates an alternating Electric Field which propagates away from the wire

  • Because the AC is moving electrons
    – the current also generates a Magnetic Field which propagates away from the wire in tandem with the Electric Field

  • Because the two propagating fields are mutually perpendicular
    – and also perpendicular to their direction of motion (a transverse wave)
    – …they constitute an electromagnetic wave!

An Electromagnetic Wave

• An electromagnetic wave always propagates at the same speed in a vacuum (or in air)...

  • In a vacuum (or in air)
    – \( c = 186,000 \text{ miles/second} \)
    – \( c = 670 \text{ million mph} \)