The Properties of Light

Did you read chapter 11 before coming to class?

A. Yes
B. No

Review: The distance between similar parts of a wave is referred to as

a) Frequency
b) Wavelength
c) Wave speed
d) Refraction

Review: The number of wave crests that pass a point in a given time is a measure of

a) Frequency
b) Wavelength
c) Wave speed
d) Refraction

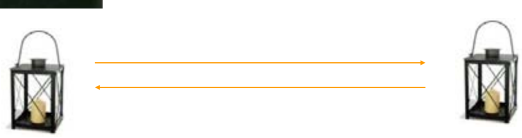
Review: A pencil appears "bent" when placed partially under water. This is due to

a) Reflection
b) Interference
c) Diffraction
d) Refraction

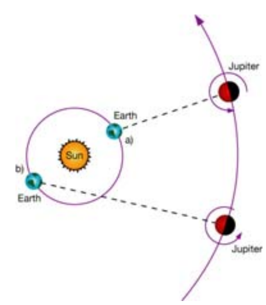
Measuring the speed of light: Galileo

I was unable to make sure whether the facing light appeared instantaneously. But if not instantaneous, light is very swift.

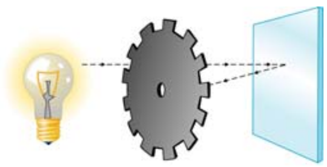
Galileo



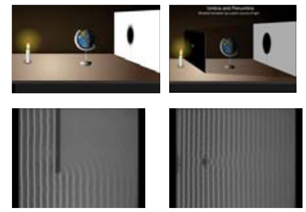
Measuring the speed of light: Roemer

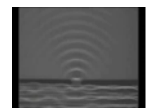


Measuring the speed of light: Armand Fizeau



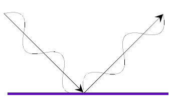
So what is light? Newton thought light was a particle because it cast sharp shadows

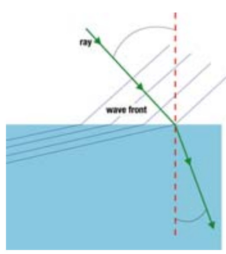




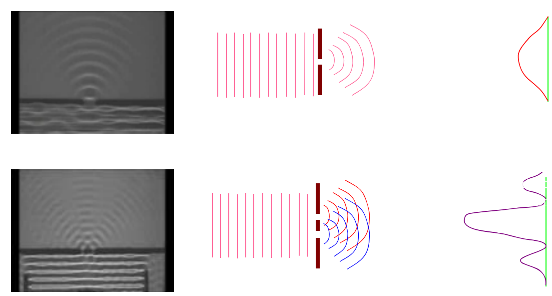
Wave Diffraction produces “soft edges” whether or not you have a pinhole.

Particles also reflect and refract when certain assumptions are made about an interface

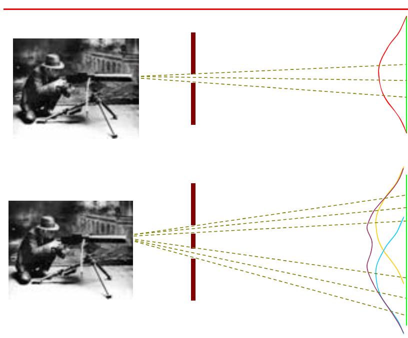




Diffraction is distinctly a wave phenomenon

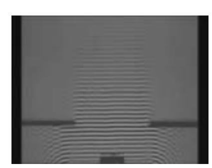


What happens when particles strike slits?



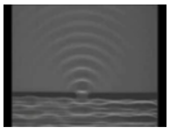
Thomas Young showed that light showed wave properties, it just has a very short wavelength

Thomas Young

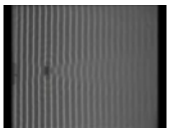


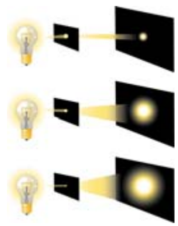
Light exhibits diffraction


Thomas Young

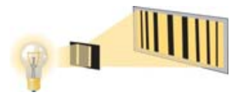


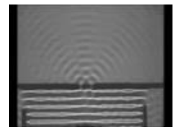

Simeon Poisson





Thomas Young showed that light showed wave properties, it just has a very short wavelength





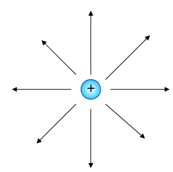
Light exhibits interference

So light has wave properties. What is waving?

- A "field" associate attributes with a point in space.
  - A temperature field:

Hot Warm Cold

Electric and Magnetic fields describe how a magnet or charged particle respond



Maxwell came up with equations that showed that the electric and magnetic fields could "wave"

God said

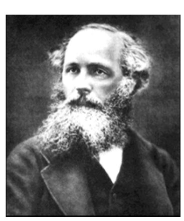
$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}$$

$$\nabla \cdot \mathbf{B} = 0$$

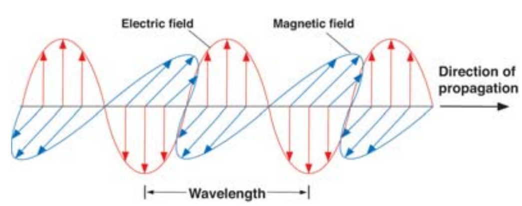
$$\nabla \times \mathbf{E} + \frac{\partial \mathbf{B}}{\partial t} = 0$$

$$\nabla \times \frac{\mathbf{B}}{\mu_0} - \epsilon_0 \frac{\partial \mathbf{E}}{\partial t} = \mathbf{J}$$

and there was light!

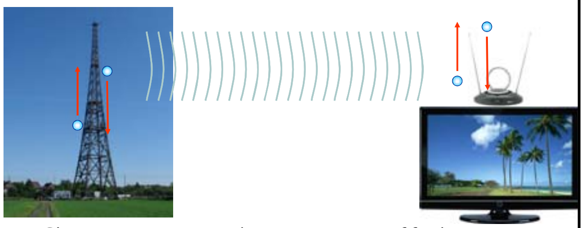


Light as an electromagnetic wave



No need for a propagation medium!

Accelerating Electrons



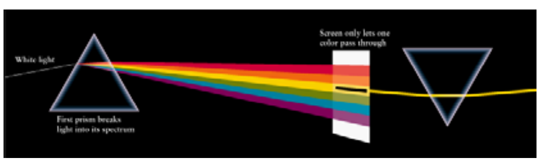
- Electromagnetic radiation is given off whenever electrons *accelerate*.
- Electromagnetic radiation, in turn, causes other electrons to accelerate. (TV, microwave oven)

Color

- Is the color in the glass or the light?

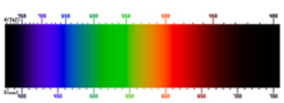
Color is associated with the frequency (wavelength) of the light

- Newton demonstrated that the colors were in the light and not created by the prism.
- Thomas Young demonstrated that color was associated wavelength.

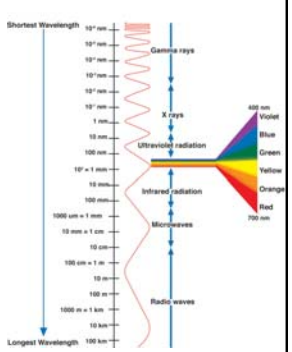


Come up with a model for why parts of this apple look red and other parts look green

The electromagnetic spectrum



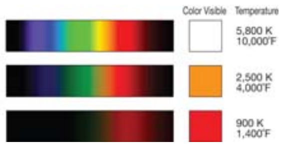
The pot at the end of the rainbow...



What we knew about light at 1900

- Light behaves as an electromagnetic wave
- Light diffracts, refracts, interferes, and reflects
- The frequency of light waves is perceived as color
- No propagation medium is required

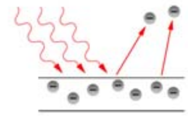
Objects glow with a characteristic color depending on temperature. The emission spectrum doesn't match what would be expected using classical electromagnetic theory.



The photoelectric effect

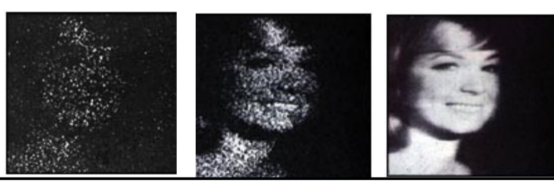
- Energy in a normal wave is proportional to amplitude.
  - What determines if a wave has enough energy to knock you over at the beach?
- However, in the photoelectric effect, it is the frequency, not the amplitude, that determines whether light can eject electrons!
  - Energy = h x (frequency)

    (h is just a small number)

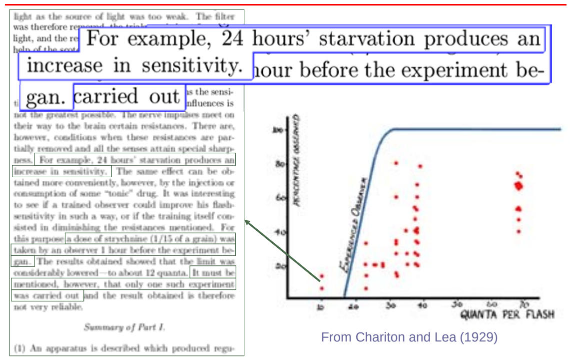


The Photoelectric Effect

- Explained if light is interacting like a ***particle*** with the electrons in the metal!
  - Each individual "photon" has an energy of *hf* where *h* = Planck's constant (very small) and *f* = frequency.
- Consider how film works…



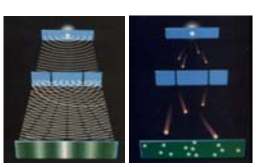
How many photons can you see?

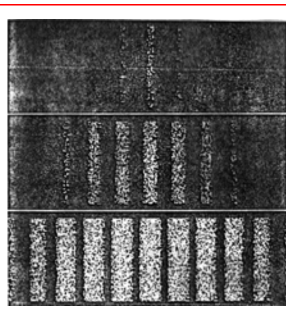


From Chariton and Lea (1929)

What gives?

- How can a particle make an interference pattern?
- How can a wave make individual spots?



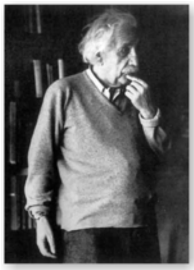


Double slit pattern with very low intensity light

Wave Particle Duality

- Light has both wave and particle properties
  - It behaves like a wave when unobserved (It travels through both slits like a wave)
  - It is detected like a particle (It hits the screen as individual dots)
- Light is light. Waves and particles are our conceptual models. Light doesn't have to match our models, we have to match our models to light.

If this bothers you, you are in good company!



"All these 50 years of pondering have not brought me any closer to answering the question, 'what are light quanta?' These days every Tom, Dick, and Harry thinks he knows it, but he is mistaken."

~ A. Einstein