SOURCE Lesson Plans Detail

The Duality of Light

Topic	Waves and the Particle/Wave Theory of Light
Program	Brown Science Prep
Developed by	Mark Sabbagh
Developer Type	Undergraduate students

Overview / Purpose / Essential Questions

- What is energy?
- How can it manifest itself?
- What is a wave?
- How do we know light is both a wave and a particle?
- How can waves/light transform energy?
- Matter (mass) is energy.
- How does the duality of light reflect a change in scientific thinking?

Performance / Lesson Objective(s)

The goal of this lessons is to have students fully understand what energy as a concept, and how it manifests itself physically. At the same time, the lesso aims at detailing the scientific mode of thinking through the question of what exactly light is.

Lesson Materials

Smoke Ring Cannon

Ripple Tank

Lesson Motivation

Energy is an extremely important concept to all fields of science and having a firm grasp of the idea will allow students to understand many real world phenomena better. Also, the duality of light is a great metaphor for what scientists quest to understand and how sometimes the answers we get provide further questions.

Lesson Activities

Smoke ring cannon demonstration, ripple tank activity to show different wave properties, and demonstration of a light diffraction pattern.

Procedure

Open demonstration:

Smoke Ring Cannon, technically not wave, however, a good demonstration of energy travelling through air

Begin with a discussion of energy

- Have students give their own definitions/examples
- Energy can be defined as the ability a physical system has to do work on another physical system.
  - § Feel free to expand on whether energy is something abstract or concrete. Is energy a thing or an action waiting to happen?

Discuss mechanical waves

- During this part of the lesson, either draw a transverse wave on the board or have two students use a piece of string to create a wave. Refer to either when explaining

- A wave is a disturbance that travels through space. Alternatively, they are transferences of energy from one point to another through a medium.
  - KEY POINT: the particles of the medium are not displaced, rather the energy is what moves.
  - Do some demo utilizing students as air particles and some object as energy. The students/air assist the object/energy from goin from point A to point B
- Define crest, trough, amplitude, period, wavelength, and any other terms you see fit to discuss

· Activity to illustrate various properties of waves

- Basically we're going to use water ripples to illustrate reflection, refraction, and diffraction
- Need a ripple tank (http://en.wikipedia.org/wiki/Ripple_tank#Demonstrating_wave_properties)
- Reflection
  - Just have a metal bar on other end
- Refraction
  - Use sheet of glass to create shallower water
- Diffraction
  - Create small opening
- Diffraction pattern
  - Two small openings
  - Interference is when two waves superpose with each other to either increase or decrease amplitude.
  - Point out dark and light bands

· ***Discuss light***

- See what students know
- Discuss particle theory of light
  - Newton proposed light was made up of tiny particles moving in a straight line at a certain velocity
  - These are photons. Discrete "packets" of light.
  - Compare to electrons. Theory developed by Albert Einstein to explain black body radiation
    - When you heat up a stove it glows. Why?
      - Thermal energy excites the atoms of the metal exciting electrons. These then drop back down to ground state and release a photon.
      - Feel free to discuss energy levels of atoms.
- Discuss wave theory of light
  - Try and not mention that light is a wave. Here can show a demonstration of the double slit experiment showing lights diffraction pattern
    - Have students try and explain the observation.
  - Back in groups work with students in trying to reconcile two very different observations.
    - On one hand we have photons which explain blackbody radiation, something a wave theory can't explain
    - On the other hand we see a diffraction pattern. But we said waves need a medium. Light can travel through a vacuum.
    - Duality of light aka wave-particle theory
      - Light is both a wave and a particle.
      - Electromagnetic radiation
        - Light is a magnetic field perpendicular to an electric field that is capable of propagating itself.
- Matter is energy. (mass is energy)
    - INTERESTING IDEA: Light is both a wave and a particle, electromagnetic radiation and a photon. Now the former is in essence energy itself, electromagnetic energy. The latter is matter. Thus, matter is energy.
    - DeBroglie hypothesizes all matter has a wavelength. How could you show matter is energy? That all matter/particles are also waves?
      - If possible get students to suggest by showing another particle (an electron) behaves like a wave. That is produces a diffraction. *Don't tell them, try and get them to reach the conclusion*.
      - In fact electrons do produce a diffraction pattern: still trying to find a good video

· ***Change in scientific thinking***

- Originally light thought to be particles. Then shown to be waves. Then Einstein comes up with photons. Then all matter is thought to be both wave and particle. Small discussion of quantum mechanics, how Einstein didn't like it due to uncertainty involved.
- Point is like energy and the world, scientific ideas are constantly changing. Reason it's so great.

Wrap up / Conclusion

Ask students what they think light is.

Ask students what implications these results have on science as a whole.

Supporting Web Information

Wikipedia

http://www.stevespanglerscience.com/experiment/air-cannon-smoke-ring-vortex-launcher)
http://en.wikipedia.org/wiki/Ripple_tank#Demonstrating_wave_properties)

Pre Assessment Plan

Draw a diagram of a wave and have them label parts

Ask what light is

Explain the duality of light

Post Assessment Plan

Repeat questions of pre-assessment plan

Alignment Info

Audience(s)	High school students
STEM Area(s)	Physics
Standard(s)	*Physical Sciences (RI GSE) PS1.9-11.2a* Students demonstrate an understanding of characteristic properties of matter by … using given data (diagrams, charts, narratives, etc.) and advances in technology to explain how the understanding of atomic structure has changed over time. *Physical Sciences (RI GSE) PS3.9-11.10a* Students demonstrate an understanding of waves by … investigating examples of wave phenomena (e.g. ripples in water, sound waves, seismic waves). *Physical Sciences (RI GSE) PS3.9-11.10b* Students demonstrate an understanding of waves by … comparing and contrasting electromagnetic waves to mechanical waves. *Physical Sciences (RI GSE) PS3.9-11.10c* Students demonstrate an understanding of waves by … qualifying the relationship between frequency and wavelength of any wave.
Activity Type(s)	Hands-on Lecture
Grade Level(s)	High School
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