THE DUAL NATURE OF ELECTROMAGNETIC RADIATION

30 JULY 2013

Lesson Description

In this lesson, we:

- Describe EM radiation as a wave and a particle with properties of both.
- Understand the conditions under which EM radiation behaves as a wave diffraction experiment.
- Understand the conditions under which EM radiation behaves as a particle - photoelectric effect.

Key Concepts

Electromagnetic Radiation as both Waves & Particles

Electromagnetic waves travel at 3 x 10^8 m·s^{-1} with many of the properties of waves such as:

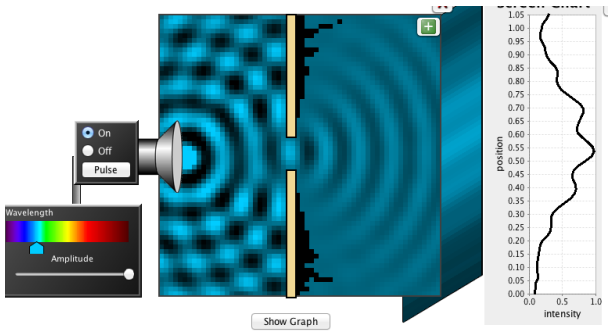
- Reflection
- Refraction
- Diffraction

Electromagnetic radiation also behaves like a particle when absorption in materials occurs.

So sometimes it is better to use wave models, and others particle models.

EM Radiation as Waves

Light behaves like a wave when shone through a small slit in the single slit diffraction experiment.



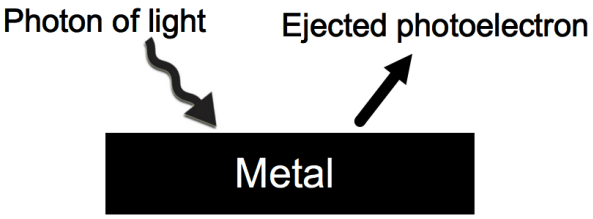
Light bends as it exits the slit and interference occurs. This shows as light bands and dark bands.

The constructive interference results in light bands while destructive interference results in dark bands.

EM Radiation as Particles

When light lands on metal surfaces, an electron is emitted.

The interesting observation when this is done is that the energy that falls on the surface is delivered in separate "packets" called photons.



Why the photoelectric effect proves light is made of particles:

1. Waves transmit energy through their amplitude.
2. If the wavelength is too short, no electrons are emitted. Not even when the amplitude is increased!
3. If the minimum frequency is used, any amplitude of light releases electrons.

To calculate the energy of these photons we can use the formula below:

$$E = hf = \frac{hc}{\lambda}$$

Terminology

EM Radiation

Electromagnetic radiation (waves at right angles vibrating on both magnetic and electric fields.)

Radiation

Energy which moves away from a point in all directions.

Wave

A repeating vibration or oscillation of potential energy.

Particle

A small piece of matter.

Photoelectron

An electron ejected from a metal by a photon.

Photon

A particle of EM radiation.

Diffraction

The bending of wave around a barrier.

Demonstration

Did you know that you can only see because of the the photoelectric effect? Photon move electrons in the retina of the eye and they move to make nerve impulse, allowing us to see.

Use a cellphone camera to look at the LED on a TV remote. The infrared radiation from the LED on the end of the TV remote does not meet the threshold frequency of our eyes and hence we can not see it!

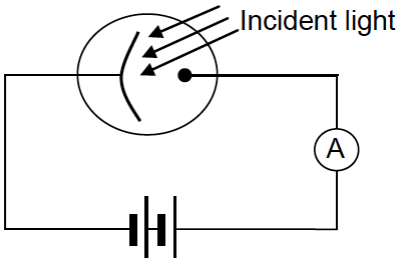
Further proof that intensity will not cause photoelectrons is that we cannot see the intense radio waves from antennae and cellphone masts. No matter the intensity, they do not cause the photoelectric effect to occur within our eyes.

Questions

Question 1

(Adapted from DOE Mar 2012 Question 2.10)

The diagram below shows light incident on the cathode of a photocell. The ammeter registers a reading.



Which ONE of the following correctly describes the relationship between the intensity of the incident light and the ammeter reading?

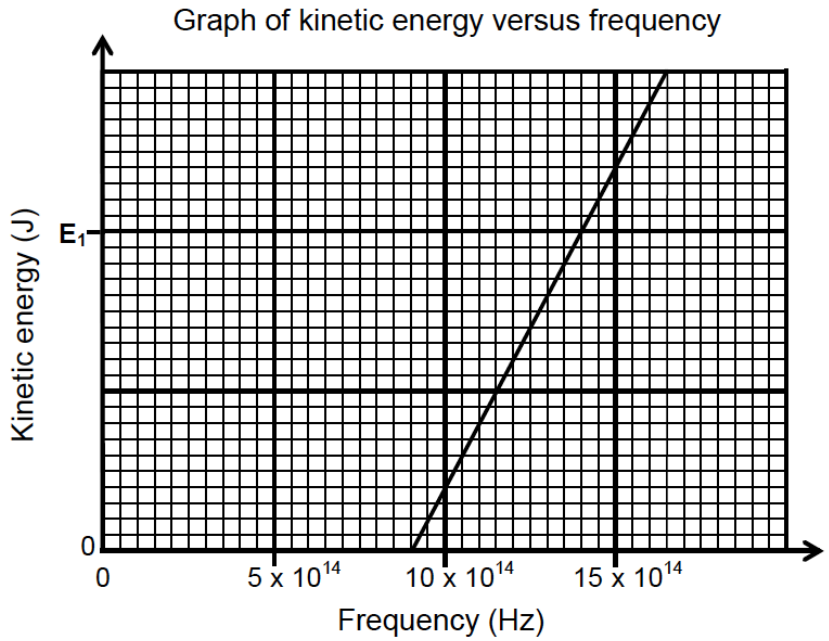
	INTENSITY	AMMETER READING
A	Increases	Increases
B	Increases	Remains the same
C	Increases	Decreases
D	Decreases	Increases

(2)

Question 2

(Adapted from DOE Mar 2012 Question 2.11)

During an investigation, light of different frequencies is shone onto the metal cathode of a photocell. The kinetic energy of the emitted photoelectrons is measured. The graph below shows the results obtained.



a.) For this investigation write down the following:
   i. Dependent variable (1)
   ii. Independent variable (1)
   iii. Controlled variable (1)

b.) Define the term *threshold frequency*. (2)

c.) Use the graph to obtain the threshold frequency of the metal used as cathode in the photocell. (1)

Links

- http://www.mindset.co.za/learn/xtra
- http://www.education.gov.za/Examinations/PastExamPapers/tabid/351/Default.aspx
- http://phet.colorado.edu