

Document ID: 11_30_98_1

Date Received: 1998-11-30 **Date Revised:** 1999-01-04 **Date Accepted:** 1999-01-04

Curriculum Topic Benchmarks: S11.3.1, S11.3.3, S11.3.4

Grade Level: [6-8] Middle School

Subject Keywords: photon, light, transmission, absorption, scattering, particle

Rating: easy

Particle Man and the Photon

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Concept: When a photon (a very small increment of energy) encounters a substance one of three things may happen. (1) The photon may be transmitted -- it passes through without alteration. (2) The photon may be absorbed -- the photon never leaves the particle. (3) The photon may be scattered -- it's path may be altered.

Materials: Step 1: A small ball. Step 2: Overhead projector, 4 clear cups (glass or plastic), 4 different liquids (milk, water, black ink, grape juice), flashlight. . Optional: music by They Might Be Giants: "Particle Man".

The demonstration (Step 1): The students need to be comfortable with two technical words before you begin: photon and radiation. They should know that light is the radiation that we can see. We can think of light or radiation as a stream of photons.

We do this with two people. One of us stands in the front of the room with a big paper "P" taped to his shirt. He is Particle Man. He explains: "I am a particle of a substance." For example, a water droplet. The other person stands about 10 feet away with the ball. The second person is the ball tosser. Hold up the ball:

"This is an incoming photon. Are you ready particle man?"

"Yep. I'm ready. Let me have it."

"Are you sure you're ready?"

The more patter and build up, the better the student response.

OK, Particle Man. Here comes the photon.

The tosser gently tosses the ball towards Particle Man. Particle man dodges the ball without letting it touch him. TRANSMISSION! The photon passes through without changing its path.

The ball is given back to the tosser. Repeat the procedure. "Are you ready Particle Man?" "Yep, I'm ready. Let me have it." "OK, Here comes the photon." This time Particle Man catches the ball, and draws it towards his body like a football running back. ABSORPTION! The photon never leaves the particle.

One more time. Here comes the photon. This time Particle Man deflects the ball with his hand. SCATTERING! The photon changed direction.

Step 2: Turn on the overhead projector and place the 4 cups each filled with a different liquid on the projector. Look at the projection.

- The water demonstrates transmission. Most of the light is passing through the water and appearing on the screen. This is just like the ball passing by Particle Man with no change.
- The black ink demonstrates absorption. None of the photons are making it through the ink to get to the screen. All the light is absorbed just like when Particle Man caught the ball and kept it.
- The milk demonstrates scattering. Look on the screen. Like the ink, none of the photons make it to the screen, but these photons are not absorbed. Where do they go? Hold the cup up and shine a flashlight at the bottom of the cup. In a darkened room you will see the light “leaking out” of the side of the cup. Do the same for the ink. No leakage. The reason milk is white is that it scatters photons to your eye and therefore appears bright. The reason ink is black is that it absorbs all of the photons and sends nothing to your eye. The milk is deflecting photons from their path as did Particle Man when he hit the incoming photon.
- The grape juice represents a color selective absorption. All the photons except at the purple wavelength are absorbed. The purple photons are transmitted and scattered. You can use the flashlight to check for scattering.

Conclusion: Some substances transmit, some absorb, some scatter and some combine more than one process.

Options: We work this as a pair. If you are going solo, take the role of Particle Man and choose a responsible student-volunteer to toss the ball to you. The other thing we do that enhances the lesson is to play the song “Particle Man” by They Might Be Giants. The music is fun, but it adds nothing to the science. We never seem to have black ink around. Chocolate syrup works fine.

Acknowledgment: The idea behind Step 2 was taken from Craig F. Bohren’s book Clouds in a Glass of Beer [1987, Wiley&Sons, New York, 195pp.]. This is an excellent reference, although we felt we had to start from a more basic level in order to reach a younger audience. Thus Particle Man was born.