**Light Demonstrations and Three Models of Light**

**PART 1: The Ray Model (Grade 10 Science)\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
KEY IDEAS**: Grade 10 optics deals with images formed by mirrors and lenses. It is assumed that students already understand how light travels and how we see light. Studies have shown that this is not the case.   
**KEY TOOLS**: Lasers, mirrors, LED flashlights, pinhole cameras.

[](http://www.google.ca/url?sa=i&rct=j&q=light+bulb&source=images&cd=&cad=rja&docid=YsfYs9LKP8dWeM&tbnid=Lud4f80iNY6vNM:&ved=0CAUQjRw&url=http://en.wikipedia.org/wiki/Incandescent_light_bulb&ei=sLpeUZ23K-nM2gWJiYG4AQ&bvm=bv.44770516,d.b2I&psig=AFQjCNH0Px2ynz0naMrcoZ658i7wjJAYAQ&ust=1365249067768424)

**PART 2: The Wave Model (Grade 10 Science and Grade 12 Physics) \_\_\_  
KEY IDEAS**: How are the ray and wave models connected? Students in grade 10 should have a brief introduction to the wave model of light and students in grade 12 should see where the ray model breaks down and how the wave model is more fundamental.   
**KEY TOOLS**: Lasers, pins, slits, pencils, 3-D glasses.

**[](http://www.google.ca/url?sa=i&rct=j&q=light+bulb&source=images&cd=&cad=rja&docid=YsfYs9LKP8dWeM&tbnid=Lud4f80iNY6vNM:&ved=0CAUQjRw&url=http://en.wikipedia.org/wiki/Incandescent_light_bulb&ei=sLpeUZ23K-nM2gWJiYG4AQ&bvm=bv.44770516,d.b2I&psig=AFQjCNH0Px2ynz0naMrcoZ658i7wjJAYAQ&ust=1365249067768424)**

**PART 3: The Quantum Model (Grade 12 Physics) \_\_\_\_\_\_\_\_\_  
KEY IDEAS**: Light energy comes in discrete bundles - called photons. This means that light cannot be a wave. A new model is needed. The quantum model is very accurate and useful - but non-intuitive.   
**KEY TOOLS**: Videos of experiments, thought experiments, LED’s, quantum eraser.

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thought experiments with questions, correcctions thatel of light. ns cam through one slit and the horizontal ones came throug

**[](http://www.google.ca/url?sa=i&rct=j&q=light+bulb&source=images&cd=&cad=rja&docid=YsfYs9LKP8dWeM&tbnid=Lud4f80iNY6vNM:&ved=0CAUQjRw&url=http://en.wikipedia.org/wiki/Incandescent_light_bulb&ei=sLpeUZ23K-nM2gWJiYG4AQ&bvm=bv.44770516,d.b2I&psig=AFQjCNH0Px2ynz0naMrcoZ658i7wjJAYAQ&ust=1365249067768424)**

You can find more information and the answers to the questions in the teacher file on the OAPT website <http://www.oapt.ca/conference/2013/roberta_tevlin_2013.html> there are more resources on my website <http://roberta.tevlin.ca/> Feel free to email me [Roberta@tevlin.ca](mailto:Roberta@tevlin.ca) if you have questions or suggestions.

**PART 1: The Ray Model: Grade 10 Science\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

1. **Rays and Laser Pointers**: A laser pointer is directed at the ceiling and everyone can see a bright red spot there but they can’t see the light in the space between the laser pointer and the ceiling.

laser

eyes

ceiling

1. **Predict** where the spot of light will be in the diagram above. **Explain**.

1. **Explain** how all three eyes can see the same laser spot. Use words below and draw arrows on the diagram above.

1. **Predict** what you will see if water is sprayed between the laser and the wall. **Explain**.
2. **Explain** how one eye can see the whole beam. Use words below and draw dashed arrows on the diagram above.
3. **Rays and mirrors:** A laser pointer is pointed at a wall, where it forms a spot. What will happen if a mirror is placed there? The red spot will be
4. the same B) fainter C) brighter D) gone

Draw rays on the diagram below to explain your answer.

laser

eyes

wall

1. **Rays and a Handheld Pinhole Camera**:
2. Take off your glasses, if you wear them. Put the tube of the pinhole camera up to one eye and shut the other one. Look at the different light sources provided. Discuss what you see with your group members and record your observations.
3. Below is a diagram of the pinhole camera. The ‘pinhole’ refers to the tiny hole in the aluminum foil. Use rays and words to explain how it forms an image of the three circles on the wax paper.

aluminum foil

cardboard tube

wax paper

1. **Rays and a Large Pinhole Camera Hat**
2. Find a safe place to stand, away from stairs, roadways etc. Put the box over your head with the pin hole at the back of your head. Tuck the fabric around your neck so that no light gets in. Look at the side of the box in front of you. The images will get clearer as you eyes adapt to the darkness. What do you see?
3. Draw rays on the diagram below showing how the person in the box can see the tree and what it looks like. Use words to explain how the light rays form the image of the tree. .

**PART 2: The Wave Model: Grade 10 Science and Grade 12 Physics\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

1. Why do light rays bend when they go from one medium to another?
2. **Refraction Dance**:
3. **PhET simulation**: <http://phet.colorado.edu/en/simulation/bending-light>
4. **Lasers and Pencils**: A laser beam is pointed at the wall. You will view the spot on the wall   
   through the slit formed by two vertical pencils. What will you see through the slit?
5. B) C) D) it depends on \_\_\_\_\_\_

Explain:

1. **Lasers and Pins**: A laser beam is directed at a pin in front of a wall. What will you see on the wall?
2. one spot B) two spots C) many spots D) it depends on \_\_\_\_\_\_

Explain:

1. **3-D Glasses**: Put on a pair of the glasses and close one eye. Look at another filter. Rotate the filter until it looks black. Put another filter in between your glasses and the first filter and rotate it until light can get through. How can you explain this?
2. **Slinky**
3. **Vectors**

**PART 3: The Quantum Model: Grade 12 Physics**

1. **Double-Slit Experiment**: Light was sent through two narrow slits that were very close together. It produced an interference pattern. Now very, very, very dim light is now sent through the same apparatus. What will the pattern look like? Watch the **Challenge of Quantum Reality** 5:57 – 6:16.
2. fainter B) smaller C) spotty D) invisible

Explain:

Which experiment demonstrates the concept of **wave-particle duality** most clearly to a student?

1. blackbody radiation B) photoelectric effect

C) Compton effect D) double slit experiment

Explain:

1. **Polarization thought experiments**:
2. A photon of unpolarized light heads toward a polarizing filter. What passes through?

A) a photon B) half a photon C) nothing D) either a photon or no photon

Explain:

b) A photon passed through a vertical filter and heads toward another vertical one. What passes?

A) a photon B) half a photon C) nothing D) either a photon or no photon

Explain:

c) A photon passed through a vertical filter and then heads toward one at 45o. What is the probability that the photon passes through the second filter?

A) 0% B) 12.5% C) 25% D) 50%

Explain:

d) An unpolarized photon is heading toward a vertical filter, then one at 45o and then a horizontal one. What is the probability that the photon passes through all three filters?

A) 0% B) 12.5% C) 25% D) 50%

Explain:

1. **Quantum Eraser**: Use the patterns below to answer the following three questions.

A). B) C) D) it depends on \_\_\_

a) A beam of laser light heads toward a double-slit. Which will you see?

Explain:

b) A beam of laser light heads toward the double-slit. There is a vertical polarizer over one slit and a horizontal polarizer over the other. Which image will you see?

Explain:

1. A third polarizer is placed between the slits and the screen. What will you see?

Explain:

1. Perhaps the most important concept in quantum physics is **entanglement**. This is where two quantum objects are connected across space so that they can instantly affect each other. Certain crystals can take one photon and break it into two photons with identical wavelength and polarization.
2. How is the energy of the first photon related to that of the other two?
3. The photons have no polarization until they are measured. However, once one of the pair is measured, we know that the other has exactly the same polarization. What is odd about that?

1. A double slit experiment was done with pairs of entangled photons. One photon of the pair was sent toward double slits and the second was sent in a different direction. The slits were covered with opposite polarizing filters. A polarizing filter was used to measure the photons that the photons that did not go through the slits. What happened? Why?

**More Information**;

1. Detailed answers to these worksheets can be found at <http://roberta.tevlin.ca/Workshops.htm>
2. More activities, demonstrations, worksheets, resources and day-by-day lessons for the 12 U physics can be found at <http://roberta.tevlin.ca/12U%20Course/12U%20Course%20Main.htm>
3. Feel free to email me with questions, corrections and suggestions at [roberta@tevlin.ca](mailto:roberta@tevlin.ca)