Light

Name

Teacher

Block
See Physics Classroom
Light Waves and Matter

Read from Lesson 2 of the Light Waves and Color chapter at The Physics Classroom:
http://www.physicsclassroom.com/Class/light/u12l2a.html

MOP Connection: Light and Color: sublevel 1

1. A light wave is an electromagnetic wave which has both an electric and magnetic component associated with it. Electromagnetic waves are often distinguished from mechanical waves. The distinction is based on the fact that electromagnetic waves_____.
   a. can travel through materials and mechanical waves cannot
   b. come in a range of frequencies and mechanical waves exist with only certain frequencies
   c. can travel through a region void of matter and mechanical waves cannot
   d. electromagnetic waves cannot transport energy and mechanical waves can transport energy
   e. electromagnetic waves have an infinite speed and mechanical waves have a finite speed

2. Consider the diagram below. It represents the beginnings of an electromagnetic spectrum below. Complete the diagram by labeling the following regions: ultraviolet, infrared, x-ray, radio wave, gamma radiation, and microwave radiation.

   ![Electromagnetic Spectrum Diagram]

   - Long \( \lambda \)
   - Low \( f \)
   - Visible Light
   - Ultraviolet
   - X-ray
   - Gamma

   High \( f \)

3. Which region of the electromagnetic spectrum has the highest frequency?

4. Which region of the electromagnetic spectrum has the longest wavelength?

5. Which region of the electromagnetic spectrum will travel with the fastest speed?

6. It is known that electromagnetic waves with longer wavelengths have a greater ability to bend around obstacles that get in their path. This ability to bend around obstacles is referred to as diffraction. Electromagnetic waves with strong diffraction properties are used in communication. Which two regions of the spectrum have the greatest ability to diffract?

7. It is known that electromagnetic waves with high frequency are more capable of causing damage to the organs of living things. Which two regions of the spectrum have the tendency to cause the greatest damage to humans?

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Addition & Subtraction of Light

Name: B:

Addition of Light (beams):
In the figure below, write the names of the colors that are produced when red, blue, and green are overlapped.

Subtraction of Light (filters):
In the figure below, write the names of the colors of light when filters subtract light.

What are the primary colors of light? R, G, B
What are the secondary colors of light? C, M, Y
What colors are complimentary? Y-B, G-M, R-C

Why do red objects look red? K reflects, RB absorb
Why do yellow objects look yellow? RG reflect, B absorbs
How are rainbows formed? White light separates into component colors (ROYGBIV)
1. What pair of primary and secondary colors of light add to make white?
   - Any primary + its complementary color

2. What pairs of primary and secondary colors of paint mix to make black?
   - Any primary + its complementary color

3. What is the result of the following combinations of light or dyes?
   a. Blue light + Red light = \( B + R = \text{Magenta} \)
   b. Red light + Green light = \( R + G = \text{Yellow} \)
   c. Blue paint + Red paint = ______________________
   d. Red paint + Green paint = ______________________
   e. White light passing through a yellow filter = ______________________
   f. White light – Blue light = \( \text{RGB} - B = \text{RG} = \text{Yellow} \)
   g. White light passing through a magenta filter = ______________________
   h. White light – Green light = \( \text{RGB} - G = \text{RB} = \text{Magenta} \)
   i. White light passing through a red filter = ______________________

4. What is the result of the following combinations of light:
   a. Red + Blue + Green = \( \text{RGB} = \text{White} \)
   b. White – Red = ______________________
   c. Blue + Yellow = ______________________
   d. Magenta + Green = ______________________
   e. Yellow – Green = ______________________
   f. Yellow + Cyan – Magenta = ______________________
   g. Yellow + Blue – Cyan = ______________________
   h. White – Yellow = ______________________
   i. Yellow – Red = ______________________
   j. Yellow + Cyan – Blue – Red = ______________________
Hit the Lights

Background:
You are in charge of the stage lighting for the school play. There are 8 different colored costumes worn by the actors. Determine how they would look when illuminated with different colored lights. Objects appear a certain color because they contain pigments that absorb some colors and reflect others. The kind of light that illuminates them also affects their color.

Getting Ready:
Navigate to the Stage Lighting Interactive at TPC (http://www.physicsclassroom.com).
Home Page ==> Physics Interactives ==> Light and Color ==> Stage Lighting

Tap Launch Interactive. Resize the Interactive as desired. Tap the various lights to change the light that shines on the actor. Tap the actor to change it to an actor with a different color. Explore the appearance of the actors under different color conditions. Record your observations in the table by indicating the color appearance; use color names or abbreviations (W, θ, R, G, Y, B, M, or C).

Data:

<table>
<thead>
<tr>
<th>Actor</th>
<th>White R+G+B</th>
<th>Black θ</th>
<th>Red R</th>
<th>Green G</th>
<th>Yellow R+G</th>
<th>Blue B</th>
<th>Magenta R+B</th>
<th>Cyan B+G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>K</td>
<td>K</td>
<td>K</td>
<td>K</td>
<td>K</td>
<td>K</td>
<td>K</td>
<td>K</td>
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<tr>
<td>Red</td>
<td>R</td>
<td>K</td>
<td>R</td>
<td>K</td>
<td>R</td>
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<td>R</td>
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<tr>
<td>Green</td>
<td>K</td>
<td>K</td>
<td>G</td>
<td>G</td>
<td>K</td>
<td>K</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>Yellow</td>
<td>Y</td>
<td>K</td>
<td>R</td>
<td>G</td>
<td>Y</td>
<td>K</td>
<td>R</td>
<td>G</td>
</tr>
<tr>
<td>Blue</td>
<td>B</td>
<td>K</td>
<td>K</td>
<td>K</td>
<td>K</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Magenta</td>
<td>M</td>
<td>K</td>
<td>R</td>
<td>K</td>
<td>R</td>
<td>B</td>
<td>M</td>
<td>B</td>
</tr>
<tr>
<td>Cyan</td>
<td>C</td>
<td>K</td>
<td>K</td>
<td>G</td>
<td>G</td>
<td>B</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>W</td>
<td>K</td>
<td>R</td>
<td>G</td>
<td>Y</td>
<td>B</td>
<td>M</td>
<td>C</td>
</tr>
</tbody>
</table>
Analysis:

1. Based on your observations, what are the two factors that affect the color that objects appear?
   A. ________________________________
   B. ________________________________

2. Complete this paragraph:
   The additive primary colors of light are Red (R), Green (G), and Blue (B). When these three primary colors of light are added together, the result is White (W) light. Mixing two primary colors of light in equal intensities produces a secondary light color. For instance, Red light and Green light add together to produce yellow light. And Red light and Blue light add together to produce magenta light. Finally, Green light and Blue light add together to produce cyan light.

3. When white light shines on the yellow costume, the costume absorbs light and reflects G and R light. The yellow costume would appear...
   a. ... red if illuminated with R light or with M light or with ___ light.
   b. ... green if illuminated with G light or with C light or with ___ light.
   c. ... black if illuminated with B light or with ___ light or with ___ light.

4. When white light shines on the cyan costume, the costume absorbs light and reflects G and B light. The cyan costume would appear...
   a. ... blue if illuminated with R light or with M light or with ___ light.
   b. ... green if illuminated with G light or with Y light or with ___ light.
   c. ... black if illuminated with B light or with ___ light or with ___ light.

5. When white light shines on the red costume, the costume absorbs G and R light and reflects R light. The red costume would also appear ...
   a. ... red if illuminated with R light or with Y light or with ___ light.
   b. ... black if illuminated with G light or with B light or with C light.

   Magenta objects reflect red & blue, so absorb green light. If green light is absorbed, it cannot be reflected & seen.

7. Name all the possible colors that a magenta object could appear:
   Red, Blue, Magenta

Credits:
This activity was inspired by Judy Kolb Rieke of Ursuline Academy in St. Louis. Thanks Judy!

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This document should NOT appear on other websites.
Light Reflection

Read from Lesson 1 of the Reflection chapter at The Physics Classroom:
http://www.physicsclassroom.com/Class/refln/u13l1a.html
http://www.physicsclassroom.com/Class/refln/u13l1b.html
http://www.physicsclassroom.com/Class/refln/u13l1c.html

MOP Connection: Reflection and Mirrors: sublevel 1

1. Place a letter in the blank in order to classify the following objects as being either luminous (L) or illuminated (I) objects.
   L Sun  I Moon  I Person
   I Whiteboard  L Light bulb  L Candle

2. These diagrams are intended to represent the path of light from an object to an eye as the eye sights at the image of the object. Each diagram is incorrect. Discuss what makes them incorrect.

   a. [Diagram]
   b. [Diagram]

   Discussion: ____________________________
   ____________________________
   ____________________________
   ____________________________
   ____________________________
   ____________________________

3. State the law of reflection in the space below.

Consider the diagram at the right in answering the next three questions.

4. The angle of incidence is denoted by angle B.

5. The angle of reflection is denoted by angle C.

6. If an incident ray of light makes an angle of 35° with the mirror surface then the angle of reflection is ______________ °.

7. Why do windows of distant houses appear to reflect the sun only when rising or setting? Explain in words. Use the diagram to help, drawing appropriate light rays on the diagram.

   [Diagram]

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Light, Reflection and Mirrors

8. Use the law of reflection and the embedded protractor in order to draw the reflected ray associated with the given incident ray for the following plane mirror situations. (Markings are provided at 15° increments.)

9. Now for a research question:

In this unit we will often discuss how the reflection of light from a mirror results in the formation of an image. The term image as used here has an obvious context - physics. But the term image has numerous other contexts - psychology (a positive self-image), religion (created in God's image), business (the company's image), medicine (an x-ray image), etc.

Your research question involves finding a dictionary and looking up the definition of the word image. Write down several meaningful definitions from several contexts in the spaces below. (If you do not have a dictionary at home then you can use dictionary.com or wikipedia.org.)

a. 

b. 

c. 

d. 

e. 

10. Now write in your own words a personal definition of what you believe an image of an object is:
1. An incident ray of light enters a piece of glass at a 28° angle. If we know the index of refraction of the glass to be 1.60, then what is the angle of refraction when entering air?

\[ \sin \theta_1 \cdot n_1 = \sin \theta_2 \cdot n_2 \]

2. Draw an incident ray going through air (n=1.00) and the refracted ray going through water (n=1.30)?

3. Draw an incident ray in glass (n=1.60) and a refracted ray in air (n=1.00).

4. Light travels through a liquid and contacts the surface at an angle of 50°. If the light is bent at an angle of 77° when entering the air, then what is the index of refraction of the liquid?

\[ \frac{\sin \theta_1}{\sin \theta_2} = \frac{n_2}{n_1} \]

5. Light moves through water at an angle of 46° and goes through a piece of glass at an angle of 31°. What is the index of refraction of the glass if the water has an index of refraction of 1.33?

\[ \frac{\sin \theta_1}{\sin \theta_2} = \frac{n_2}{n_1} \]

6. An incident ray of light travels through plastic at a 19° angle towards water. If we know the index of refraction of the plastic is 1.33, then what is the angle of refraction when entering water?

\[ \frac{\sin \theta_1}{\sin \theta_2} = \frac{n_2}{n_1} \]

7. What is the speed of light moving through corn oil (n=1.47)?

\[ \frac{c}{v} = \frac{3 \times 10^8}{1.47} = \frac{3 \times 10^8}{v} = 2.04 \times 10^8 \text{ m/s} \]

8. The speed of light through a medium is $1.5 \times 10^8$ m/s. What is the index of refraction of the medium?

\[ n = \frac{c}{v} = \frac{3 \times 10^8}{1.5 \times 10^8} = 2.00 \]

9. What is the speed of light moving through Ruby (n=1.76)?

\[ \frac{c}{v} = \frac{3 \times 10^8}{1.76} = \frac{3 \times 10^8}{v} = 1.70 \times 10^8 \text{ m/s} \]
Snell’s Law

\[ n_1 \sin(\theta)_1 = n_2 \sin(\theta)_2 , \quad n_{\text{air}} = 1 \]

1) An incident ray of light enters a piece of glass at a 28° angle. If we know the index of refraction of the glass is 1.60 then what is the angle of refraction when entering air?

\[ 48.7° \]

2) (a) Is the refracted ray in air or water? explain

- Refracted ray is in air since the angle of refraction is greater than the angle of incidence. This happens when light rays move from more optically dense material to less optically dense material since the light ray will increase in velocity with decreasing optical density. Air is less optically dense than H₂O.

(b) Is the incident ray in glass or air? explain

- Similar reasoning...

- Air is less optically dense than glass, so light rays slow down and bend towards normal.

3) Light travels through a liquid and contacts the surface at an angle of 50°. If the light is bent at an angle of 77° when entering the air then what is the index of refraction of the liquid?

\[ n = 1.27 \]

4) Light moves through water at an angle of 46° and goes through a piece of glass at an angle of 31°. What is the index of refraction of the glass if the water has an index of refraction of 1.33?

\[ n = 1.86 \]

5) An incident ray of light travels through plastic at a 19° angle towards water. If we know the index of refraction of the plastic is 1.90 then what is the angle of refraction when entering water? (n_{\text{water}} = 1.33)

\[ 27.7° \]
6) You are standing in a swimming pool and see a dime in the water and it appears to be the size of a quarter. Draw a picture of what the light is doing and draw dotted lines for where light is perceived to be.

7) Light moves through oil at an angle of 58° and goes through a piece of glass at an angle of 29°. What is the index of refraction of the glass if the oil has an index of refraction of 1.33?

\[ n = 2.33 \]
Ray Diagrams for Concave Mirrors

Read from Lesson 3 of the Reflection chapter at The Physics Classroom:

http://www.physicsclassroom.com/Class/refl/u13l3d.html
http://www.physicsclassroom.com/Class/refl/u13l3e.html

MOP Connection: Reflection and Mirrors: sublevels 5 and 6

For the following mirrors and corresponding object positions, construct ray diagrams. Then describe the Location of the image, Orientation (upright or inverted) of the image, the relative Size of the image (larger or smaller than object), and the Type of image (real or virtual). For Case 4, merely construct the ray diagram.

NOTE: 1) All light rays have arrowheads that indicate the direction of travel of the ray.
2) Always draw in the image once located (an arrow is a good representation).
3) Exactness counts. Use a straightedge and be accurate.

Case 1: If the object is located "beyond" the center of curvature.

Description of Image:
Location: Between C & F
O: Upright or Inverted S: Magnified or Reduced T: Real or Virtual

Case 2: If the object is located at the center of curvature.

Description of Image:
Location: On CC
O: Upright or Inverted S: Magnified or Reduced T: Real or Virtual

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Light, Reflection and Mirrors

Case 3: If the object is located between the center of curvature and the focal point.

Description of Image:
Location: Behind CC
O: Upright or Inverted  S: Magnified or Reduced  T: Real or Virtual

Case 4: If the object is located at the focal point.

No Description Required

Rays never cross to form an image

Case 5: If the object is located between the focal point and the mirror.

Description of Image:
Location: Apparently inside mirror
O: Upright or Inverted  S: Magnified or Reduced  T: Real or Virtual
Ray Diagrams for Convex Mirrors

Read from Lesson 4 of the Reflection chapter at The Physics Classroom:

http://www.physicsclassroom.com/Class/refl1/u13l4b.html
http://www.physicsclassroom.com/Class/refl1/u13l4c.html

MOP Connection: Reflection and Mirrors: sublevels 8 and 9

For the following mirrors and corresponding object positions, construct ray diagrams. Then practice the LOST art of image description. Identify the Location of the image, Orientation (upright or inverted) of the image, the relative Size of the image (larger or smaller than object), and the Type of image (real or virtual).

NOTE: 1) All light rays have arrowheads that indicate the direction of travel of the ray.
2) Always draw in the image once located (an arrow is a good representation).
3) Exactness counts. Use a straightedge and be accurate.

Case 1: Object is Relatively Close to Mirror

![Diagram of Case 1]

Description of Image:
Location: Apparently inside mirror in front of F
O: Upright or Inverted  S: Magnified or Reduced  T: Real or Virtual

Case 2: Object is Relatively Far Away from Mirror

![Diagram of Case 2]

Description of Image:
Location: Apparently inside mirror in front of F (closer to F than Case 1)
O: Upright or Inverted  S: Magnified or Reduced  T: Real or Virtual

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Ray Diagrams for Converging Lenses

Read from Lesson 5 of the Refraction and Lenses chapter at The Physics Classroom:

http://www.physicsclassroom.com/Class/refrn/u14l5da.html
http://www.physicsclassroom.com/Class/refrn/u14l5db.html

MOP Connection: Refraction and Lenses: sublevels 8 and 9

For the following lenses and corresponding object positions, construct ray diagrams. Then describe the Location of the image, Orientation (upright or inverted) of the image, the relative Size of the image (larger or smaller than object), and the Type of image (real or virtual). For Case 4, merely construct the ray diagram.

**NOTE:**
1) All light rays have arrowheads that indicate the direction of travel of the ray.
2) Always draw in the image once located (an arrow is a good representation).
3) Exactness counts. Use a straight-edge and be accurate.

**Case 1:** If the object is located beyond 2F:

Description of Image:
Location: **On opposite side of lens between F and 2F**
O: Upright or Inverted  S: Magnified or Reduced  T: Real or Virtual

**Case 2:** If the object is located at 2F:

Description of Image:
Location: **At 2F on opposite side of lens**
O: Upright or Inverted  S: Magnified or Reduced  T: Real or Virtual

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Light, Refraction and Lenses

Case 3: If the object is located between 2F and F:

Description of Image:
Location: On opposite side of lens after 2F
O: Upright or Inverted S: Magnified or Reduced T: Real or Virtual

Case 4: If the object is located at F:

No Description Required

Case 5: If the object is located between F and the lens:

Description of Image:
Location: On same side of lens in front of F
O: Upright or Inverted S: Magnified or Reduced T: Real or Virtual

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Ray Diagrams for Diverging Lenses

Read from Lesson 5 of the Refraction and Lenses chapter at The Physics Classroom:
http://www.physicsclassroom.com/Class/refrn/u14l5ea.html
http://www.physicsclassroom.com/Class/refrn/u14l5eb.html

MOP Connection: Refraction and Lenses: sublevels 10 and 11

For the following lenses and corresponding object positions, construct ray diagrams. Then describe the Location of the image, Orientation (upright or inverted) of the image, the relative Size of the image (larger or smaller than object), and the Type of image (real or virtual).

NOTE: 1) All light rays have arrowheads that indicate the direction of travel of the ray.
2) Always draw in the image once located (an arrow is a good representation).
3) Exactness counts. Use a straight-edge and be accurate.

Case 1: If the object is located far away from the lens:

![Ray Diagram Case 1](image)

Description of Image:
- Location: same side of lens in front of F
- O: Upright or Inverted
- S: Magnified or Reduced
- T: Real or Virtual

Case 2: If the object is located nearby the lens:

![Ray Diagram Case 2](image)

Description of Image:
- Location: same side of lens in front of F
- O: Upright or Inverted
- S: Magnified or Reduced
- T: Real or Virtual

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