Name: ______________________________ Grade: Date:

Girls in STEM: Light and Optics workbook

Thank you for participating in the physics workshop! Today we will learn and investigate light and how it interacts with everyday objects.

Form a group of 3 or 4 to work together. As you go through the activities, remember to discuss the questions with your group and try to come up with theories and hypothesis on your own. If you get stuck on any part of the activities, ask an instructor or volunteer for help.

There are extra questions in each activity, called “Challenge Questions”. These are intended for when you finish the activity early, and are geared towards Grades 8 and 9. You do not have to attempt these questions, but you may find them to be very interesting!

Activity 1: Water, Oil, and Glass.

Refractive index is a measure of how much light bends at the surface of an object. You may have noticed this before by looking at a straw in a glass of water and seeing how the straw seems to bend at the boundary between the water and the air. Of course, you knew that the straw itself wasn’t bending – it turns out that light itself was bending due to the different refractive index of water and air.

In this activity, we will investigate this strange relationship further, by looking at how light bends in oil, water, and glass.

CAUTION: While oil and water are not dangerous substances, be careful when handling the test tubes and beakers! Do not spill the water or oil onto the desks, and be very careful not to drop the beakers or test tubes.

Your experiment set up:

- 2 glass beakers, one filled with water and one filled with oil
- 4 glass test tubes, 2 filed with water and 2 filled with oil

What you have to do:

1. Place a test tube of water and a test tube of oil in each beaker
2. Study each beaker. What do you see? Are there any differences or similarities between the test tubes in the beakers? Is there anything strange? Write down your observations in the box below. Discuss your findings with your group!

3. Why do you think you saw what you did? Can you think of any explanations for any strange behaviour? Write your hypothesis in the box below.

<u>Challenge Question:</u> Given that you know the refractive index of water is 1.33, oil is 1.467, and glass is 1.517, can you revise your hypothesis? If so, discuss your new idea with your group and write down your new theory in the box below. *Hint*: Try rounding the refractive indices to 1 decimal place, so you would have 1.3 for water, and 1.5 for glass and oil.

4. Once you are finished analyzing and observing the oil and water test tubes and beakers, place the apparatus back into the container carefully and put it to the side so that it will not be in your way for the remainder of the workshop.

<u>Activity 2: Reflection and Refraction</u>

So far we have discussed reflection and refraction as two separate phenomena, but they can happen at the same time. In fact, they usually do happen at the same time!
In this activity you will observe how reflection and refraction happen in a prism, which is a transparent (see through) material.

<u>Your experiment setup:</u>

- A box of prisms, specifically a trapezoidal prism
- A light box. This is a black box that needs to be plugged into an electrical socket.
- A piece of white paper.

What you have to do:

1. Find your trapezoidal prism. If you don't think you have one in your set, please notify the instructor.
2. Assemble and turn on your light box. There are 3 ways in which light can exit the light box, you'll be using the side with a knob and moveable wheel. If you are not sure you're using the right side of the light box, please ask the instructor for help. Lay the light box on its side so that the light from the wheel side shines along your desk.
3. You'll notice that your light box on the wheel side has many options for light. Turn the knob so that only 1 ray of light is shining along the desk.
4. Place the white sheet of paper along this ray of light. This will help you see the ray better.
5. Place the prism on the white sheet in the path of the light – what do you see?

6. Does what you see change depending on which side of the prism you have facing the light? How does it change? Try all sides of the prism – it may be easiest to include a sketch and label each side of the prism accordingly.

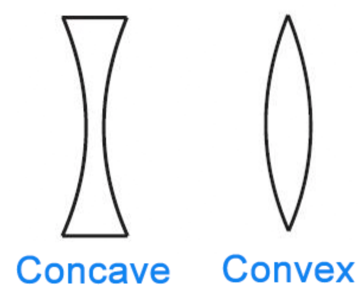
7. Lastly, draw a ray diagram for your prism. This means you should draw the prism, the incoming (or incident) ray of light, the reflected ray from the surface of the prism, and the refracted ray through the prism. Your drawing does not have to be precise, just a sketch.

Challenge Question: How does your sketch in 8 change as you rotate the prism? Why? Discuss this with your group.

Activity 3: Concave and Convex Prisms

You're now familiar with the trapezoidal prism and how light interacts with it at various angles and on different sides.

You may have noticed that there are 2 other prisms in your set up: a concave prism (bending in) and a convex prism (bending out). Now we will investigate the behaviour of light when it interacts with these 2 prisms.



Your experiment setup:

- A concave and a convex prism
- A light box
- A white sheet of paper

What you have to do:

1. Set your light box to the wheel and knob side, like in Activity 2. Place the white sheet of paper in front of the light box so you can better see the rays.
2. Turn the wheel to the 3 ray setting (when 3 rays of light are emitted from the light box).
3. Place the concave prism along the path of the 3 rays. What do you see? What happens to the rays? Draw a sketch of what you see.

4. Place the convex prism along the path of the 3 rays. What do you see? What happens to the rays? Draw a sketch of what you see.

Challenge Question: Compare and contrast what you found for the concave and convex prisms. Why do you think you saw what you did? Discuss with your group and try to incorporate the laws of reflection and refraction that you've learned.

Activity 4: Making White Light

We've looked at 3 different kinds of prisms and the different ways that light interacts with them. We can use this knowledge and apply it towards a new problem: creating white light.
You may have heard before that white light is a combination of all the colours, or that white light can be split up into different colours of light. Keep this in mind as you go through the activity.

Your experimental setup:

- 3 prisms: trapezoidal, convex, and concave
- A light box
- A white sheet of paper

What you have to do:

1. Using the light box, turn the wheel to the coloured ray option. This option has a red section, a green section, and a blue section.
2. Place the white sheet of paper in front of the light box so you can clearly see the different coloured light against the sheet.
3. Use the 3 prisms you have separately, together, or in any other combination with the coloured rays to make white light. Remember that this light can be a single point or a whole ray – any amount of white light will count here.
    a. What prism(s) did you use to create white light?

    b. What kind of white light did you create? (a ray, a point, etc)

    c. Did you find more than one way to make white light? If so, how?

Challenge Question: Can you explain why your particular combination(s) created white light? How does it relate to white light being a combination of the other colours of light?

Activity 5: Focal Points

Now we have learned how concave and convex prisms interact with light. One thing to note is that when a prism is very thin, we call it a lens. Another way to say this is that a prism has 4 sides and a lens only has 2. When light passes through the concave/convex sides of a lens or a prism, the same physical phenomena of light occur – lenses are just easier to manipulate and use.

We'll be focusing on the behaviour of light through concave and convex lenses for the rest of the activities. In this activity we will investigate another qualitative property of concave and convex prisms/lenses: a focal point. A focal point is where light rays converge for these prisms, or rather where all the light focuses in to a dot.

A. Let's find WHERE the focal points are for our convex and concave prisms.

Your experimental setup:

- Concave prism, convex prism
- A white sheet of paper
- A light box

What you have to do:

1. Turn your lightbox onto the 3 ray setting. Place the white sheet of paper in front of the light box so you can see the light rays better.
2. Place the convex prism in the path of the 3 rays of light. What do you see? Can you find where the focal point is? Is it before the prism (between the lightbox and the prism) or after the prism?

3. Place the concave prism in the path of the 3 rays of light. What do you see? Can you find where the focal point is? Is it before the prism or after the prism?

Challenge Question: Draw a ray diagram for the convex and concave prisms with the 3 rays passing through them. Draw and label where the focal point is in each case.

B. Now we know where (qualitatively) the focal points are for convex and concave prisms. If you did the Challenge Question, compare your sketch to the instructor's. We will now try to quantify the focal points for your prisms – or in other words, assign a number to them.

<u>Your experimental setup:</u>

- A concave prism, a convex prism
- A light box
- A white sheet of paper
- A ruler
- An image to focus on

<u>What you have to do:</u>

1. Keep the same set-up that you had for part A of this activity: the light box on the 3 ray setting with the white sheet of paper in front to aid in seeing the light rays.
2. Place the convex prism in the path of the 3 light rays. Identify where the focal point is and use the ruler to measure the distance. It may be useful to draw a sketch to accompany your measurement.

3. Place the convex prism in the path of the 3 light rays. Identify where the focal point is and use the ruler to measure the distance. It may be useful to draw a sketch to accompany your measurement.

4. Now you know where the focal points are for the convex and the concave prisms. Now try looking through the prisms. Focus on the image after the Challenge Questions. What do you see with the convex prism for:
    a. Closer than the focal length?

b. At the focal length?

c. Farther than the focal length?

<u>Challenge Question:</u> Go back to questions 2 and 3 and answer the additional question: Where did you measure the focal point FROM? In other words, where would "0" be on your scale? Think about both the concave and convex prisms and where their focal points are. Should you prescribe one of the measurements as negative to correspond with position? Which one and why? Be sure to discuss with your group. Redraw your sketches here to match your discussions.

<u>Challenge Question:</u> Go back to question 4 and redo a,b,c for a concave lens. You'll notice that this isn't quite as straightforward; why?

Focusing Image:

Activity 6: Magnifying Glass

From activity 5, you may be able to guess that magnifying glasses are really just glorified convex lenses. Now that you are more familiar with convex prisms and how they interact with light, you're ready to start applying that knowledge to everyday objects.

Your experimental setup:

- A convex lens
- An image to focus on

What you have to do:

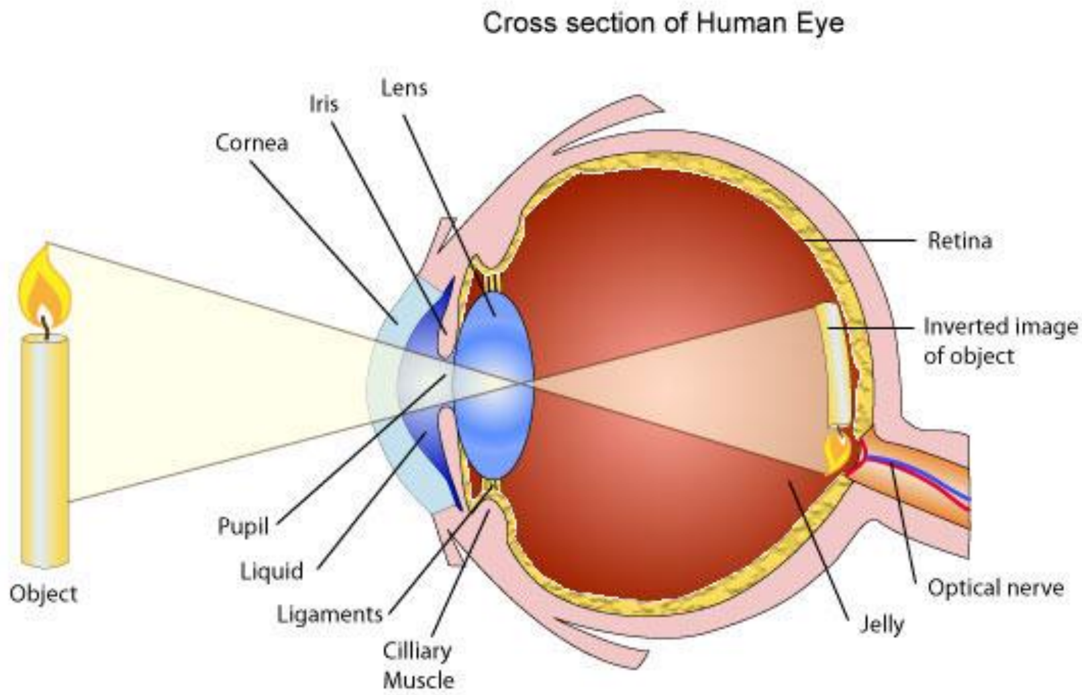
1. Sketch a ray diagram of how you think a magnifying glass works. Feel free to use the convex lens provided to help you think and analyse what you already know. This is tricky, work with you group to puzzle it out.

Challenge Question: Check out "Take away" activity 1! Think about how you would implement the activity and answer the questions. Discuss it with your group and see if you can find the focal lengths of multiple magnifying glasses to compare together.

Activity 7: Eyeballs!

We have learned a lot about how light interacts with convex and concave prisms and that this can be used in real-life applications. Not only are lenses and light bending used in things that we make, but it also happens in our bodies!

Think of the eye.



You may have heard before that what we see, when processed by the eye, is actually upside down, or inverted. This is indeed the case, and your brain is conditioned to turning the images right side up again.

As you can see in the above diagram, the lens of our eyes is a convex lens, much like the lenses and prisms you've been investigating today! Let's investigate what happens to light inside the eye. Where this is the last activity, you may not have time to complete it – that's ok!

Your experimental set up:

- Your eyeballs (Just kidding!)

What you have to do:

1. Think about what needs to happen inside the eye for you to ***FOCUS*** on what you're seeing. Sketch a ray diagram to show what happens in a normal eye (one without near sightedness or far sightedness). You only need to include the shape of the eye, the lens, and the path of light. Be sure to have appropriate labels!

2. Keeping what a normal eye should do in mind, consider the case of near sightedness, or not being able to see things far away. What would change about the ray diagram you have for 1? What does that mean for the lens of the eye? Sketch a ray diagram for nearsightedness and describe how the lens of the eye would be different from a normal eye.

3. Now consider the case of far sightedness, or not being able to see things up close. What would change about the ray diagram you have for 1, and how would it be different from the ray diagram you have for 2? What does that mean for the lens of the eye? Sketch a ray diagram for far sightedness and describe how the lens of the eye would be different from a normal eye.

<u>Challenge Question:</u> Take a look at "Take away" activity 2! Now that you know what near and far sightedness look like and how it effects light in the eye, how do we correct for this? Think about the answer, and if you have any of the "corrections" (eye glasses) in your group, use the 3 ray light setting on the light box to see how they work!

Take away activities: Apply what you've learned and continue to investigate!

Activity 1: Magnifying glass

Find a magnifying glass in your home or school and see if you can discover its focal length. Try this with more than one and see how they compare. Some things to take note of during your investigation:

- What are the magnifying glass lenses made of? How does this effect the focal length?
- What is the refractive index of these materials?
- Is there a relationship between refractive index and focal length?
- Are certain materials preferred for magnifying glasses? Why? Is it related to focal length or refractive index?

Activity 2: Eyeballs!

We discussed how near and far sightedness are caused by deformities in the lens of the eye, and hence change the focal length of the lens of the eye. Many people are near or far sighted, so there must be a way to correct for these shifted focal lengths: eye glasses! Usually when someone is diagnosed as near or far sighted, they are given a prescription for glasses.

Glasses are nothing more than lenses in a fancy frame so they can fit on your face. From our previous discussions in the workshop activities, we know that concave and convex lenses can bend light in different directions. What sort of lenses do glasses have to be to correct for near and far sightedness? Should they be the same type of lens to correct for both or should they be different?

Try this: What do different glasses prescriptions mean? If someone has a strong prescription, how does that differ from a weak prescription? Can you draw ray diagrams to support your theory? For these questions, you may want to consider:

- What does needing a strong prescription mean about the patient? About their eyes?
- Where would the focal point of their eyes be in comparison to a weak prescription patient or a normal eye (in both the case of far and near sightedness)?

Now try holding up different types of eye glasses to a light ray source, something similar to our 3 ray option on the light box. What happens for:

- A strong prescription for a near sighted person?
- A weak prescription for a near sighted person?
- A strong prescription for a far sighted person?
- A weak prescription for a far sighted person?

How does this compare with your theory? Do you need to revise anything about your hypothesis?

***Feel free to search for the answers from reliable sources, such as your science teacher or an optometrist.

Useful definitions:

- Law of Reflection: The angle of the incident ray and the reflected ray are the same. Or, the incident ray and the reflected ray are symmetric.

- Law of Refraction: Snell's Law $n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$, or light bends at the surface of materials with different refractive indices n, bending more with larger differences between the refractive indices.

- Concave prims/lens bend in, Convex prisms/lens bend out

- A lens has 2 sides, whereas a prism has 4 – typically making a lens a thin version of a prism.

- Magnifying glasses and the lens of the eye are both convex lenses.

- Focal point: where the incoming light on a prism or lens focuses to a point.

- Focal length: The distance from the centre of the lens or prism to its focal point.

- Near sightedness: can see things close up, but not far away.

- Far sightedness: can see things far away, but not close up.