SNC 2D
Grade 10 Science, Academic
Unit: Light and Geometric Optics

The Big Ideas:

- Light has characteristics and properties that can be manipulated with mirrors and lenses for a range of uses.
- Society has benefited from the development of a range of optical devices and technologies.

Some tips on using this manual:

1. Put this manual in your binder, then remove the staple. As you work on a lesson on any given day, just remove those sheets from your binder to work on them.
2. This manual is available on the class moodle. All links are live links from the moodle.
3. Write dates beside the Days on the table of contents.
4. Cross off Days as they are completed. That way, should you miss a day, you can easily refer to which day Day you have to make up.

Adapted and compiled from many sources (especially *Physics by Inquiry, L McDermott*) by Mike Doig

Table of contents page

Contents

Homework:
****this table might be ammended by your teacher as you progress through the unit**

Day	Homework
Lesson 1	Read 11.1 (pg 463-469) Take notes on all sections, especially uses of EM waves in society. Do pg 469 #1 -5, 9 **Please bring your laptops tomorrow.
Lesson 2	**TASK:** 1. Complete the exploration guide/sheet from explorelearning.com 2. Complete the 5 assessment questions under the Gizmo
Lesson 3	Read 11.4 (pg 479 - 481) + take notes Do pg 481 #2, 5 Read 11.6 (pg 484 - 486) + take notes Do pg 486 #1, 2, 5 **Additional help** http://www.physicsclassroom.com/Class/refln/u13l2c.cfm Gizmo - Laser reflection at www.explorelearning.com

Lesson 4	Read 11.7 (pg 488 - 492) + take notes on page 492 Do pg 493 #9 **Additional help** http://www.physicsclassroom.com/mmedia/optics/lr.cfm
Lesson 5	Finish worksheets from class
Lesson 6	Read 11.9 (pg 496 - 501) + take notes Do pg 501 #1, 2, 3, 5, 10 **Additional help** Check out http://www.physicsclassroom.com/mmedia/index.cfm#optics and have a look at the links under "Ray Diagrams for Concave Mirrors" and "Image Formation for Convex Mirrors"
Lesson 7	**Additional help** Gizmo - ray tracing (mirrors) at www.explorelearning.com
Lesson 8	
Lesson 9	Finish all worksheets from class. Note that the link for the llama worksheets also includes the answers.
Lesson 10	Read 12.1 (pg 515 - 519) + take notes Do pg 519 #1, 2, 7 Read 12.4 (pg 524-525) + take notes Do pg 525 #1-4, 7, 8, 10 **Additional help** http://phet.colorado.edu/en/simulation/bending-light -Click on "run now', and check out "Intro" Gizmo - refraction at www.explorelearning.com
Lesson 11	Do prelab for tomorrow`s lab. You will not be admitted into class without it completed.
Lesson 12	Pre-lab must be completed and will be checked by your teacher before the beginning of the lab
Lesson 13	Read 12.5 (pg 526 - 531) + take notes Read 11.2 and 11.3 and take notes.
Lesson 14	We are only covering convex lenses Read 13.1 (pg 551- 553) + take notes Read 13.3 (556 - 561) + take notes **Additional help** http://phet.colorado.edu/sims/geometric-optics/geometric-optics_en.html

	Be sure to click on "Principal Rays"
Lesson 15	Finish worksheets Gizmo - ray tracing at www.explorelearning.com
Lesson 16	Finish llama sheets (print them off if you didn't get a copy in class) Points to clarify: 1. When describing the location of an image, use language like, "in between mirror and F", or "beyond F". 2. Note how we represent lenses in diagrams (a double-headed arrow to show convex lens).
Lesson 17	Read 13.4 (pg 562 - 566) Do pg 566 #1-4

Name:______________ Partner 2:________________
Partner 1:___________ Partner 3:________________

Lesson 1 Viewing the Visible Spectrum

By the end of this lesson, students will know what the difference between white light and monochromatic light. They will also know how light behaves when passes from air into a prism, then back into air.

Activity A - Define the following terms in your words:

Medium____

____

Electromagnetic Spectrum____

____

Visible light____

____

Monochromatic light ____

____

Activity B – Seeing Colours

1. **Perform** *(as a group)* Detach the paper titled Part A – Viewing the visible spectrum and conduct your work on that page.
   Trace your actual prism and shine light on the prism as instructed on the sheet. For the ray that gives you the most colours, show how the light is coming out of the prism. Draw these lines on the paper, using different colours

   Be sure every group member performs this activity on their own sheet – do not simply copy results from one sheet to another.
2. **Observe** *(as a group)* How many colours can you see in the spectrum? List them.

3. **Apply** *(as a group)* Where, in nature, can you see a similar visible spectrum?

 Name:______________ Partner 2:________________
Partner 1:___________ Partner 3:________________

When white light travels through a prism of this shape, a spectrum is created. This is because:
-the side that light enters the prism and the side that light leaves the prism are not parallel.
-light has traveled from one medium (air) to another (plastic or glass) causing refraction (bending of light)
-different colours of light refract (bend) different amounts, because they all have different wavelengths (symbol for wavelength = λ)

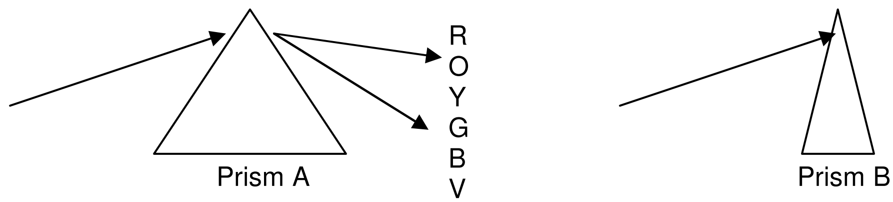
Activity C – Seeing white

4. **Predict** *(as a group)* After a prism has been used to create a spectrum, it is possible to recombine that spectrum into white light. Predict how many and the orientation of the prisms required to do so. Show your prediction with a sketch

5. **Test** *(as a group)* Test your prediction. Was your prediction right or wrong? Can you reform white light or not? Make drawings of any prism arrangements you test and circle any successful arrangements

Activity D – Affecting the spectrum

Consider the diagram below showing Prism A and Prism B.



6. **Discuss** *(as a group)* Identify the difference(s) between Prism A and B.

Name:______________ Partner 2:_________________
Partner 1:___________ Partner 3:_________________

7. **Predict** *(as a group)* sketch what you think the spectrum would look like as the light comes out of prism B

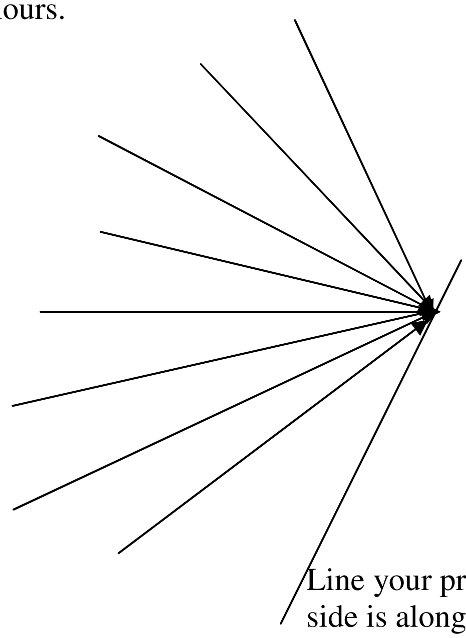
8. **Test** *(as a group)* Obtain the materials needed to test you prediction and do so. Make any adjustments to your prediction.

Name:______________ Partner 2:________________

Partner 1:____________ Partner 3:________________

Part A – Viewing the visible spectrum

Shine your ray box along these different lines. Circle the one that shows the most colours.



Line your prism up so one side is along this line, then trace your prism.

Fold along this line

Name:______________
Partner 1:___________
Partner 2:_________________
Partner 3:_________________

Lesson 2 Gizmo: Basic Prisms

Enrolling at ExploreLearning.com
Follow these simple steps to enroll in your teacher's class:

Step 1: Go to http://www.explorelearning.com.

Step 2: Click on the "Enroll in a Class" button in the upper right hand corner of the web page.

Step 3: Type in your teacher's class code: ___________________________
(get code from your teacher)

Click "Continue" and follow the directions on the site to complete your enrollment.

Step 4: Write down your username and password.

username: ___________________________

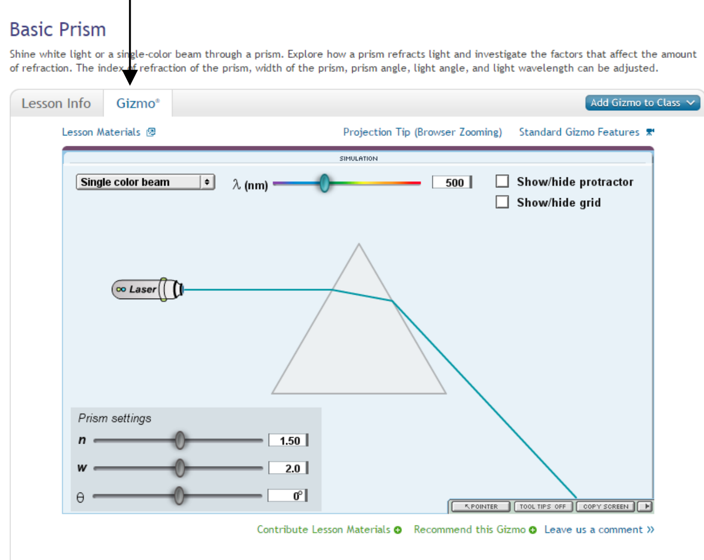
password: ___________________________

Congratulations! Now that you're enrolled, you can login any time using just your username and password (no class code required).

You are now to work on the Gizmo called "Basic Prisms". To do this, you are to open the Gizmo, as well as the Student Exploration Sheet. When working on the Student Exploration Sheet, you will be given instructions on how to effectively use the Gizmo for learning purposes.

Click here for the Gizmo

Click here for the Exploration Guide



 Name:______________ Partner 2:________________
Partner 1:___________ Partner 3:________________

Lesson 3 Observing an object in a plane mirror

Materials – mirrors with black backing, foam board, pins, ray box, card with slit and supports

Activity 1 - Predict and test
Imagine you and your friends are in the gym, playing with a basketball. Your friend is going to roll the ball on the floor at an angle towards the wall.

1. **Predict** *(as a group)* Draw a bird's eye view of a diagram showing the angle they will roll the ball to the wall, and where you will stand in order to catch the ball after it hits the wall. Label all angles.

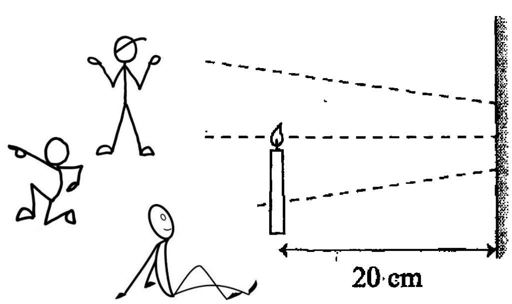
2. **Test** *(as a group)* Test your prediction. Was your prediction correct? If yes, what did you consider when making your prediction. If no, correct your prediction.

Activity 2 - Observe

3. **Observe** *(individually)* Obtain a plane mirror and have a look at yourself. Compare the image in the mirror with the object (you). Are they the same size? Orientation? What happens to the image as you move towards the mirror or away from it?

Activity 3 - Observe and explain
Three friends stand behind a candle that is positioned 20 cm in front of a plane mirror. They observe the image of the candle, and each of them points a ruler in the direction of the image they see in the mirror. The dashed lines in the illustration indicate the orientation of their rulers.

4. **Sketch** *(individually)* Use a ruler and pencil to extend the dashed lines behind the mirror. Where these lines intersect locates the image of the candle relative to the mirror.



Name:______________ Partner 2:_________________

Partner 1:___________ Partner 3:_________________

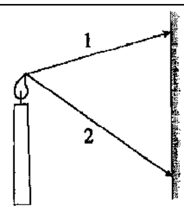
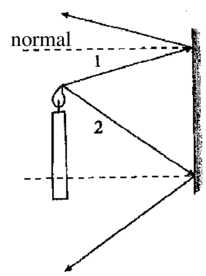
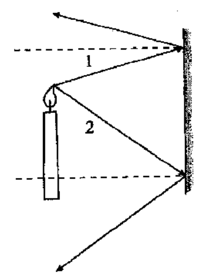
The image is always formed by the intersection of reflected rays (either real or virtual). To the three friends looking at the mirror, light seems to be coming from that image location. The dashed lines on the same side of the mirror as the candle are actually reflected light rays that have bounced off the mirror.

5. **Explain** *(as a group)* Suggest a rule that explains the location of the image that a plane mirror forms of an object (for example, the flame of the candle).

Activity 4 - Reason and Explain

6. **Sketch** *(as a group)* Use two arbitrary rays to explain why the image of the candle is at the same distance behind the mirror as the candle is in front of the mirror. Use the following diagrams to help you.

***note – a "normal" is a reference line. It is always 90˚ the surface. Any angles are measured between a ray and the normal.*

 Two rays beginning from a point on the candle and moving toward the mirror	 The same rays after reflection from the mirror. *Do the reflected rays shown above ever meet? If not, how does the mirror form an image?*	 *Extend the reflected rays back behind the mirror to find the image of the candle.* The fact that light travels in a straight line while traveling in a medium is called linear propagation. Our brains believe this so strongly that we see the reflected light rays as coming from the image, not the object.

7. **Prove** *(as a group)* Use geometry (similar angles/triangles) to prove that the image is the same distance from behind the mirror as the candle is in front.

 Name:______________ Partner 2:_________________
Partner 1:___________ Partner 3:_________________

Activity 5 – Experiment

Simplification - Don't worry about drawing the width of the beam of light. Just use a line to represent the light ray.

For this experiment, you will need a mirror, a ray box and comb, an index card and stand, a pin, foam board. Do your work on the activity sheet provided.

Be sure every group member performs this activity on their own sheet – do not simply copy results from one sheet to another.

On the sheet of paper provided, set up the ray box, index card (in Location 1) and mirror as shown.

8. **Sketch** *(individually)* Sketch the path of light on the paper (you will need to remove the mirror and index card and use a ruler to do this accurately). Show the beams that are **incident** on and **reflected** from the mirror. Draw arrow heads to indicate the direction the light travels.

9. **Sketch** *(individually)* Draw where you have to place your eye to see the light bulb in the mirror on the grid paper.

The bulb that you see in the mirror is called the image of the bulb.

Replace the bulb by a pin at the same location.

10. ***Observe*** *(individually)* Where must you place your eye to see the image of the pin?

11. **Reason** *(as a group)* How does the line that you drew in Part A compare to the path of the light from the pin to your eye in Part B?

Move the index card to Location 2, but keep the pin in the same location.

12. **Predict** *(as a group)* Where must you place your eye to see the image of the pin? Explain.

 Name:______________ Partner 2:________________
Partner 1:___________ Partner 3:________________

13. **Test** *(as a group)* Check your prediction. On the paper, mark the path that light takes from the pin to your eye. Draw arrow heads to indicate the direction the light travels along the path.

In the preceding experiment, you drew lines with arrow heads (⟶) to indicate the path of light. These are called rays. A diagram in which rays are used is called a ray diagram.

Summary

Activity 1

1. When viewed in a plane mirror, is the image bigger, smaller or the same size as the object?

Activity 2

2. Light bounces off a mirror in a similar fashion to a ball bouncing off a wall. Make a statement regarding the angles involved when light bounces off a wall.

Activity 3

3. How can you locate the image of an object in a mirror?

4. For a plane mirror, what do you know about the distance from the image to mirror (d_i) and the distance from the object to the mirror (d_o)?

Activity 4

5. Create a diagram showing how light bounces off a mirror. Include the following labels: incident ray, reflected ray, θ_i, θ_r, normal, mirror. Your diagram should obey the law of reflection, which states that $\theta_i = \theta_r$

Activity 5

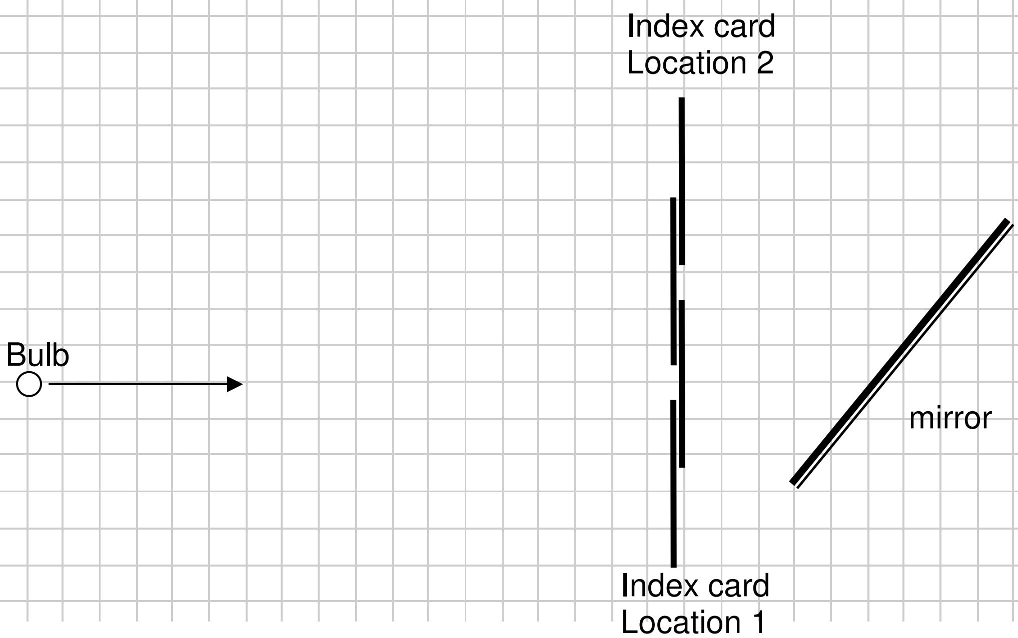
6. Luminous objects emit light (like a light bulb). Non-luminous objects do not emit light (like a pin). Why can we see non-luminous objects?

7. In this activity, in order to see either the light bulb or the pin, you should have had to place your eye in the same location. Why?

Name:______________ Partner 1:____________

Partner 2:_________________ Partner 3:_________________

Activity 5 worksheet



Name:______________ Partner 2:_________________
Partner 1:___________ Partner 3:_________________

Lesson 4 How do we locate an image in a flat mirror?

By the end of this lesson, you will be able to describe parallax and use the method of parallax to locate the image (which can be seen in a mirror) of an object.

Activity 1 – find the paper

Close one eye and place your open eye at table level. Have your partner tear the corer of this sheet of paper, scrunch it into a small ball and drop it onto the table.

Hold your finger above the table and then move your finger until you think it is directly above the piece of paper. Move your finger straight down and see if it was actually directly above the paper.

Try this procedure several times, with your partner dropping the piece of paper at different locations. Keep your open eye at table level. After several tries, switch roles with your partner.

1. Were you and your partner consistently able to locate the piece of paper?

2. How can you account for the fact that when your finger misses the piece of paper, your finger is in front of the paper or behind it, but not to the left or right of the paper?

3. Try to develop a group strategy that allows you to consistently locate the piece of paper with your finger.

Activity 2 – discovering parallax

Have your partner hold a pen and a pencil vertically, one above the other about 1.0 meter in front of you. Then have your partner move one of them about 15 cm closer to you.

Cover one eye, then move your head so that they appear to be directly in line with one another. Now move your head from side to side.

4. Describe what you observed.

Name:______________ Partner 2:________________
Partner 1:___________ Partner 3:________________

Again, cover one eye and move your head so that they appear one directly above the other.

5. If you move your head to the right, which pencil appears to be on the right: the one closer to you or farther from you?

6. If instead you move your head to the left, which pencil appears to be on the left: the one closer to you or farther from you?

The separation distance of the pen and pencil (or any two objects being observed) will affect how much parallax is observed.

7. As you move the pen and pencil closer together, do you observe more or less parallax?

In the previous experiment, you observed that there is an apparent change in the relative location of the pen and pencil when you move your head from side to side. This effect is called *parallax*. Parallax is when it looks like something is moving relative to another object, but this is just because the observer is moving (all the objects are stationary).

Activity 3 – using parallax

8. Describe how you can use parallax to determine which of the two objects is closer to you.

9. How must the two objects be located relative to one another if you observe no effect of parallax when you move your head from side to side?

 Name:______________ Partner 2:________________
Partner 1:___________ Partner 3:________________

10. Explain how you could use parallax in **Activity 1 – find the paper** (with one eye covered) to tell whether your finger is:
    a. Directly over the piece of paper

    b. In front of the paper

    c. Behind the paper

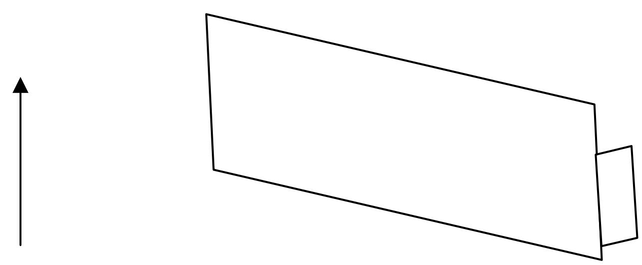
Repeat **Activity 1 – find the paper** and test the method that you have devised.

11. Have our partner hold two pencils in front of you as in part A of **Activity 2 – discovering parallax**. Close one eye and use the method of parallax to direct your partner as to which direction to move the upper pencil until it is directly above the lower pencil.

As a group, take the all your copies to your teacher to discuss these activities. Your teacher will evaluate your work on the spot.

Activity 4 – the pin in the mirror

Obtain 4 identical pins, a mirror that stands up, a piece of single sided scrap paper and a piece of foam board. Stick one pin upright about 10 cm in front of the mirror. We will call this the "object pin". Set this all up on the sheet of paper as shown to the right.



12. Look at the image of the object pin in the mirror. Apply the strategy for using parallax that you outlined in questions #1 and #11 to line up a second pin with the image of the object pin.

Move your head to a new location and repeat #13

13. Is there a unique location where all observers would agree that the image is located (provided they can see an image)? Check your answer experimentally.

 Name:______________ Partner 2:________________
Partner 1:___________ Partner 3:________________

Summary

14. If you have correctly used the method of parallax to locate the image of an object in a mirror, and then you move your head side to side, what would you observe as you look in the mirror?

Two students are discussing results from today's class. Marie says, "*when I looked at the pin in the mirror, I saw the image of the pin on the back of the mirror*". To which Isaac replied, "*the image isn't actually on the back of the mirror…*"

15. Isaac is correct, but his response seems unfinished. Complete his response – where is the image located? Strengthen your response by including information from today's lesson, or yesterday's lesson.

As a group, take the all your copies to your teacher to discuss these activities. Your teacher will evaluate your work on the spot.

In **Activity 3 – using parallax**, you developed a strategy for finding the location of an object using the effect of parallax. Next, you applied your method to find the location of an image of an object in a mirror. We refer to the process of using parallax to determine the location of an image as the *method of parallax* or *locating an image by parallax.*

In the following experiments, we determine the location of an image by another technique called *ray tracing*. This technique is based on our model for light in which we envision light as being emitted in all directions by luminous objects, such as light bulbs, or as being reflected in all directions by non-luminous objects, such as nails or pins.

Name:______________ Partner 1:___________ Partner 2:________________ Partner 3:________________

Lesson 5 How do we see an image in a plane mirror?

In the following experiments, we determine the location of an image by a new technique called *ray tracing*. This technique is based on our model for light in which we envision light as being emitted in all directions by luminous objects, such as light bulbs, or as being reflected in all directions by non-luminous objects, such as nails or pins.

By the end of this lesson, you should be able to locate the image of an object in a flat mirror by 3 methods: i) using parallax ii) tracing lines of sight iii) applying the law of reflection.

Activity 1: Part A – Drawing lines of sight

Steps:

a) At the end of this package is an observation sheet labelled "**Activity 1 – Part A**". Tape this to a piece of cardboard or foam board. Tape both of these to your desk.
b) Stick an object pin in at one end of the paper.
c) Place your eye where indicated on the paper and look at the **object pin**. *Do not move your head side to side as you did in previous activities.*
d) Line up two other pins so that they appear to be in line with the **object pin**. *Again, keep your head still.*
e) The two pins determine your line of sight to the pin. Use a ruler to draw your line of sight from the pin to your eye. Include arrow heads to show the direction the light traveled
f) Repeat the procedure from the two other eye locations and mark the lines of sight.

Questions:

1. Do you determine your line of sight more accurately by placing the pins close together or far apart?

2. If you were given 2 or more lines of sight for an object, how could you determine where the object was located? *Use words and a diagram to answer this*

Name:______________ Partner 2:________________
Partner 1:___________ Partner 3:________________

Activity 1: Part B – Drawing lines of sight

Steps:

a) Turn the observation sheet over and use the "**Activity 1: Part B**" sheet. You will see that the location of the mirror is given to you, as well as **Location 1**.
b) Place your eye where indicated on the paper and look at the **image** of the pin.
c) Push two pins into the foam board so that, **from your location** these two appear to be in the same line of sight with the **image** of the object pin.
d) Use a ruler to draw your line of sight from the image to your eye.
e) Repeat the procedure above from the other eye location.

New Locations:

f) Repeat steps 1-5 for two other locations of your choice of the object pin. One group member is to use this location for the remainder of this activity. The other group members should choose different locations: close to the mirror, farther from the mirror, and closer to the edge of the mirror.
g) The above instructions may have to be adapted, depending on the location of your object pin. Clearly identify where you had to put your eye to make each observation.

Questions:

3. Can you tell the location of the image from the single line of sight that you have drawn? Explain.

4. How can you use the lines of sight that you drew to determine the location of the image of the pin?

5. Would all observers who can see the image of the pin agree on its location? Explain.

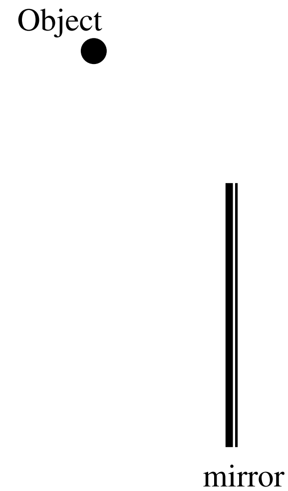
6. Use the method of parallax to determine the location of the image of the pin.

7. Does the method of parallax yield the same image location as you found above?

8. Based on your observations, describe the relationship between the object location, the image location, and the location of the mirror.

Name:______________ Partner 1:___________ Partner 2:________________ Partner 3:________________

Activity 2 – Using lines of sight



An object is placed near a mirror as shown (imagine it's a pin)

a) On the diagram, draw a solid line to represent rays of light from the object to the mirror. In other words, draw an incident rays from the object to the mirror.

b) Show the path of reflected light also (use a protractor and a normal line to find the reflected ray – if you don't know how to do this, call your teacher over).

Questions:

9. If you placed your eye on the reflected ray and looked back towards the mirror, what would you see?

10. Does a single ray alone give you enough information to determine the location of an image?

11. Draw a second indecent ray from the object to the mirror at a different angle. Make sure to also draw the normal and the reflected ray.

12. Describe how to use the two rays you have drawn to determine the image location. Show the image location on your diagram.

Name:______________ Partner 2:________________
Partner 1:___________ Partner 3:________________

As a group, take the all your copies to your teacher to discuss these activities. Your teacher will evaluate your work on the spot.

Summary

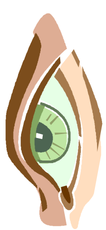
In this course, when you are asked to use ray tracing to determine the location of an image, always draw at least two rays. Use a solid line with an arrow head (——>——) to indicate the actual path of a ray of light. Use a dashed line (– – – –) to extend a ray behind a mirror to indicate a path that light only appears to have taken. Make this correction to your work on activity 1 and 2.

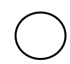
When looking at an object in flat mirror (also called a plane mirror), the image is the same distance away from the mirror as the object. In fact, the image has all the same attributes as the object – they both are either right side up, or upside down; they both are the same height (magnification is 1x), they are same distance from the mirror. Also, the image is described as a virtual image. This is because it is created inside the mirror and is found by the intersection of dashed lines (which are virtual lines)

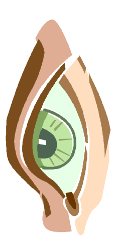
13. After today's lesson, Marie and Albert went out for dinner. Albert made the comment that, so far, this optics unit seems a little disjointed – after 4 lesson, he said he didn't see how the lessons related to each other. Give some tips to Marie regarding how she should respond to Albert, illustrating how the lessons are in fact related to each other [the lessons have been: What is light? (working with triangular prisms), Gizmo: Basic Prisms; Observing an object in a plane mirror (where you first observed the law of reflection); How do we locate an object in a plane mirror (related to parallax)]. This is most effectively done using a graphical organizer (a flow chart or a concept map – check out page 642 in your textbook for ideas on graphical organizers).

Name:_______________ Partner 2:__________________
Partner 1:____________ Partner 3:__________________

Activity 1 - Part A







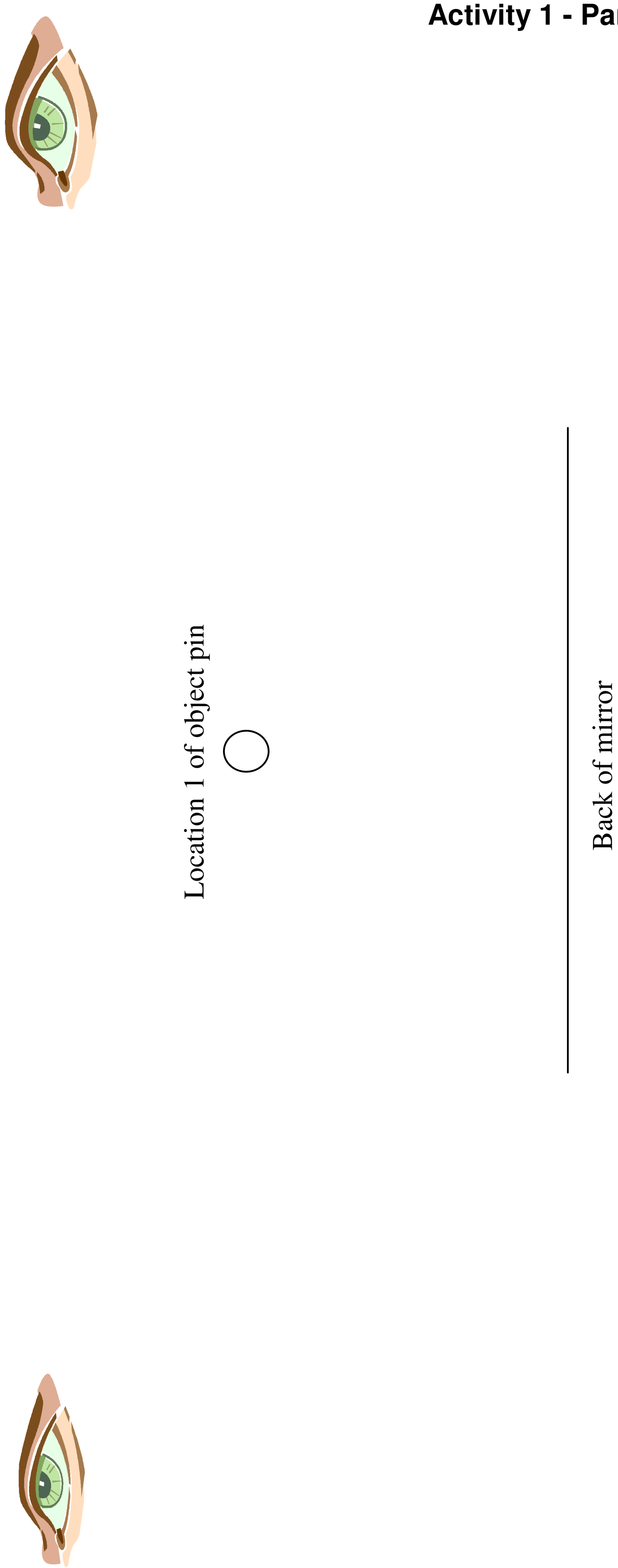
Name:______________

Partner 1:___________

Partner 2:_________________

Partner 3:_________________

Activity 1 - Part B



 Name:______________ Partner 2:________________
Partner 1:___________ Partner 3:________________

Lesson 6 Introduction to curved mirrors

Materials: concave mirror, a convex mirror, a flexible mirror, ray box with filter

By the end of this lesson, you should be able to draw a normal to a curved mirror and use it to apply the law of reflection to a curved mirror.

Activity 1 - observe and explain
An observation sheet has been provided to you at the end of this package.

In all your diagrams, always include arrow heads on your light rays to indicate what direction the light is traveling.

1. Working on that sheet, shine a single ray of light from a ray box towards a concave mirror. Trace the path of the incident ray and reflected ray. Include where you expect the **normal** to be.

2. Repeat this for up to 5 incident rays. Use different colours if possible.

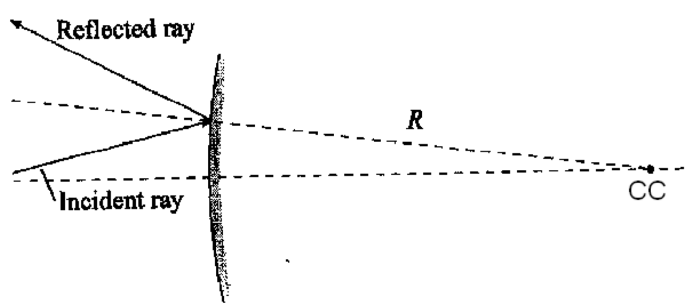
Have this diagram checked by your teacher.

3. Imagine the curved mirror is a portion of a circle (or even better, a sphere). Where do all the **normal lines** meet? *(if you can't picture this, actually draw a circle that has your mirror as part of it's perimeter)*

4. What mathematical term is used to describe the distance from where the normal lines meet to the edge of the sphere (or, in this case, the surface of the mirror)?

We treat curved mirrors as if they are cut from a circle. A line from the centre of the circle to the mid-point of the mirror is called the principle axis. The centre of the circle is called the **centre of curvature** and is where all normal lines intersect. This applies to both concave and convex mirrors.

Get a convex mirror and shine the light from a ray box towards it (the mirror is a piece of a circle of radius R). The light reflects similarly as shown in the illustration.



Convex mirror

Name:______________ Partner 2:________________
Partner 1:___________ Partner 3:________________

5. On the previous diagram, label the normal and explain the behaviour in terms of the law of reflection.

Activity 2 – playing with mirrors.

In all your diagrams, always include arrow heads on your light rays to indicate what direction the light is traveling.

Get a flexible piece of mirror. Using a ray box and a single slit, shine a ray onto the mirror at different angles and see how it behaves. Then, gently push in on the mirror's sides so it bends slightly.

6. What happens as the mirror gets more curved?

Change the filter on the ray box so you get 5 parallel rays of light. Repeat the steps above.

7. What happens as the mirror gets more curved? You may want to use two diagrams to answer this question – one with a mirror with a small curve, one with a mirror with a large curve.

Activity 3 – finding the focal point

In all your diagrams, always include arrow heads on your light rays to indicate what direction the light is traveling.

Use the observation sheet provided.

Put your concave mirror on the sheet and shine the ray box with 5 slits so that the middle slit runs along the principle axis. Adjust the set up so the reflected rays meet on the principal axis.

8. Trace your mirror.

 Name:______________ Partner 2:_________________
Partner 1:____________ Partner 3:_________________

9. Trace the path of 3 incident rays. This is best done by putting 2 dots along each incident ray, removing all your equipment and using a ruler to draw the path of the rays.

The **reflected rays** from incident rays which are parallel to the principle axis all pass near the same point. This point is called the focal point (f)

10. Use a protractor to draw your **normal lines** as you did in activity 1. Use these to locate the centre of curvature.

11. What observations can you make concerning the distance from focal point to the mirror and distance from the centre of curvature to the mirror?

There are two types of curved mirrors – **spherical** and **parabolic**. Because of the geometric properties of each of these shapes, the concepts of centre of curvature and focal point cannot be applied to both of them. In class, we will deal with spherical mirrors. A spherical mirror **has** a centre of curvature - this is where all normal lines meet. A spherical mirror **does not** have an exact focal point. However, we will use the simplification that the focal point exists halfway between the centre of curvature and the mirror.
It is also due to the geometry of a spherical mirror that spherical aberration occurs in images created with these mirrors. For more information on this, read your textbook.

Activity 4 – Predict and test
Using the concave mirror and single slit ray box, answer this question:

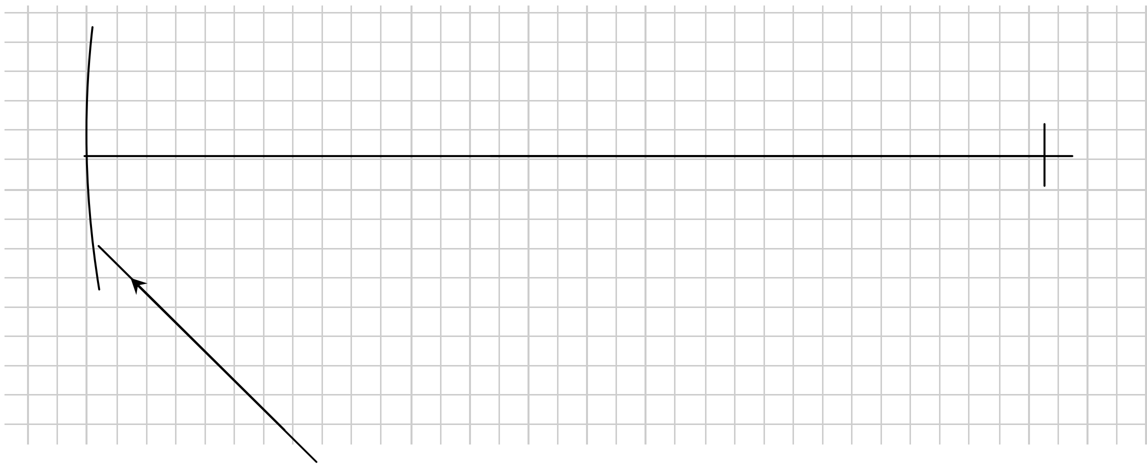
12. **Predict** Draw a precise diagram showing what will happen if you aim a ray of light so it cross the principal axis at the focal point before hitting a concave mirror?

13. **Test** Use your worksheet and diagram from activity 3 to test your hypothesis.

 Name:______________ Partner 1:___________ Partner 2:________________ Partner 3:________________

Summary

14. Consider the following diagram



You have been given an incident ray and the centre of curvature of the mirror. Use this information to:

a. Draw a normal line
b. Use the normal line and law of reflection to draw an accurate reflected ray.
c. Label the angle of incidence (θ_i) and angle of reflection (θ_r)

15. Look at all the diagrams you created today. There is a concept called the reversibility of light. Theorize what this concept states

Name:______________ Partner 2:_________________

Partner 1:____________ Partner 3:_________________

Activity 1

Put your curved mirror near here and trace it

Principle axis

Name:______________ Partner 1:___________

Partner 2:________________ Partner 3:________________

Activity 3

Put your curved mirror near here and trace it

Principle axis

 Name:______________ Partner 1:___________ Partner 2:_________________ Partner 3:_________________

Lesson 7 Catch up day

Lesson 8 Images in curved mirrors

Introduction

In this lab, you will investigate the relationship between the distance from the mirror to the object [d_0] and the distance from the mirror to the image [d_i].

Prelab

If you have a curved mirror, can it's focal point ever change? ________________________________

What does the location of the focal point depend on? ________________________________

Materials

- hand held concave mirror
- metre stick
- paper screen
- Object - single filament bulb
- lens holder

Getting started

Your teacher will demonstrate how to determine the focal length of a hand-held mirror. Use that procedure to determine the focal length of your mirror

Focal length = ____________

Hypothesis

Make a prediction – as the object gets closer to the mirror, what will happen to the distance to the image?

Show your work to your teacher at this point.

Procedure

Your goal is collect enough data with the materials provided to convincingly verify or refute your hypothesis. Discuss with your partners and outline a few steps that you take to collect the data required to test your hypothesis.

Name:______________ Partner 2:________________
Partner 1:___________ Partner 3:________________

Analysis

1. Plot a graph of d_0 vs d_i, placing d_0 on the x axis.

Table 1: Measurements of distances	
d_O (m)	d_i (m)

2. Why did you stop when $d_0 = f$; where is the image if d_0 is $< f$?

Conclusion

What is the relationship between d_i and d_0?

 Name:_____________ Partner 1:___________ Partner 2:________________ Partner 3:________________

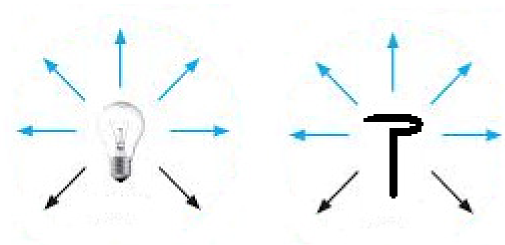
Lesson 9 Finder rays for curved mirrors

Review your previous activities where you and your group explored how to use the law of reflection to see how light bounces off curved mirrors.
How do you know where to draw the normal when you are dealing with curved mirrors?

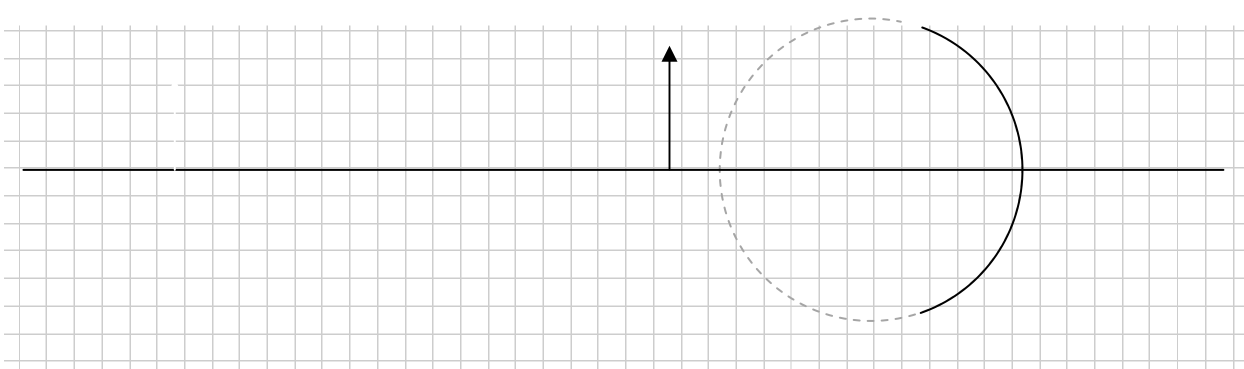
When dealing with a plane mirror, what caused the creation of an image?

Have your work checked by your teacher. You must get this point correct before moving on.

By the end of this lesson, you should be able to locate the image of an object in a curved mirror (both concave and convex), without the use of a protractor.
Whether we are considering a luminous object, such as a light bulb, or a non-luminous object, such as a pin, we know that there are infinite light rays leaving the object, going in all directions.



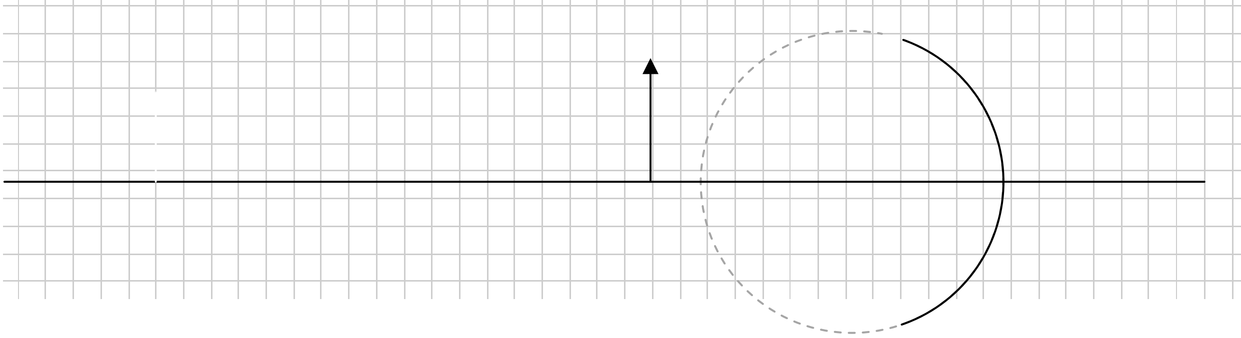
1. To locate the image of this object, we need to use any two random rays leaving the tip of the arrow. For the object below, draw two incident rays towards the mirror and us the law of reflection and the centre of curvature to see how they reflect. Use a different colour for each set of incident-reflected rays. The concave mirror comes from a circle with radius of 2 cm. *Use this information to label the focal point (f) and the centre of curvature (cc).*



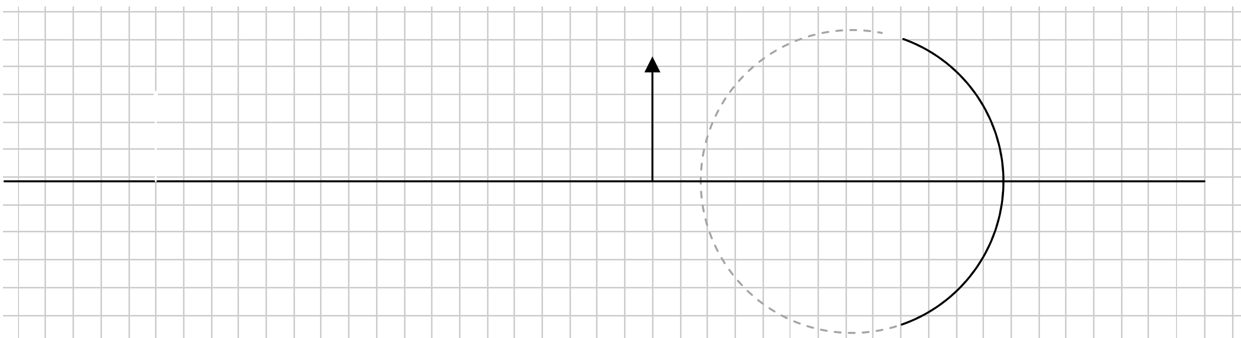
 Name:______________ Partner 2:_________________
Partner 1:____________ Partner 3:_________________

We know there are infinite incident rays we could have drawn. As a group, consider the three *special* incident rays described below. For each ray, use the law of reflection and a protractor to see how the ray is reflected. Use a different colour on each diagram.

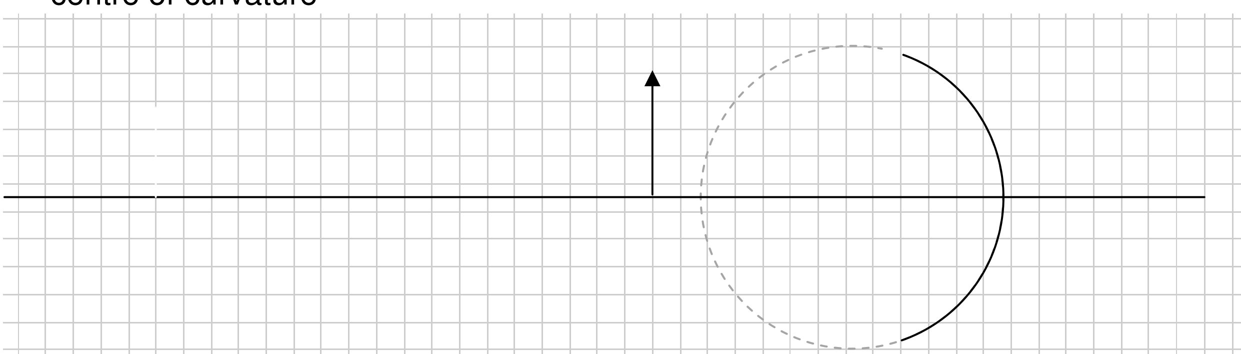
2. Draw an incident ray leaving the tip of the object and travels parallel to the principle axis.



3. Draw an incident ray leaving the tip of the object that passes through the focal point



4. Draw an incident ray leaving the tip of the object and travels passes through the centre of curvature



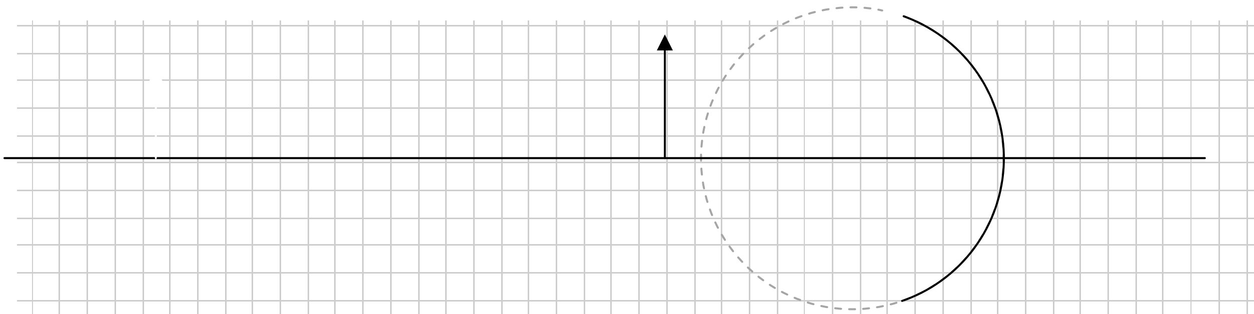
We can always use these three rays to locate an image.

5. Summarize your results by completing these sentences

*An incident ray parallel to the principle axis is reflected*__________________________
*An incident ray that passes through the focal point is reflected*_____________________
*An incident ray that passes through the centre of curvature is reflected*_______________

Name:______________ Partner 1:___________ Partner 2:________________ Partner 3:________________

Now draw all 3 rays on the same diagram. Once you label CC and F, you should not need to draw any normal lines.



As in dealing with plane mirrors, what creates the image?

Sometimes an image is created in front of the mirror, and sometimes behind the mirror. Review the SALT acronym as outlined in your textbook.

Give the SALT characteristics for the image created by the mirror above.

 Name:______________ Partner 1:___________ Partner 2:________________ Partner 3:________________

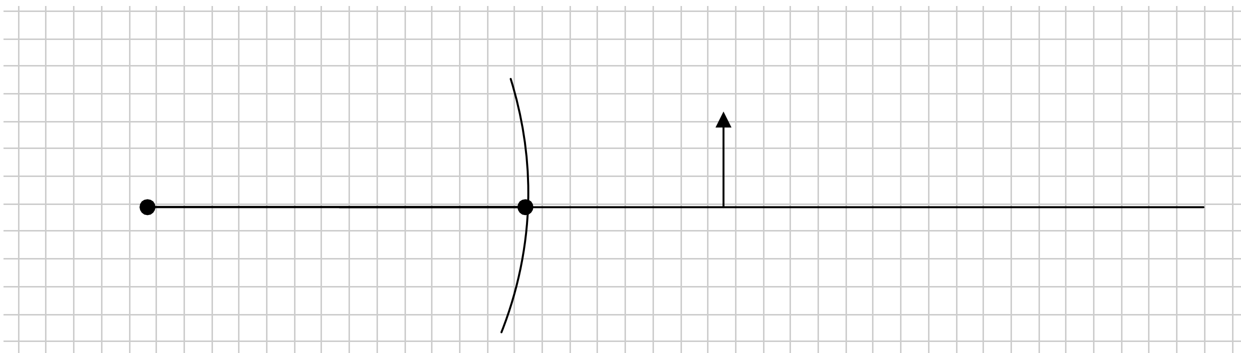
Summary
In the following diagrams, you are given an object, a mirror and the centre of curvature. You are to :

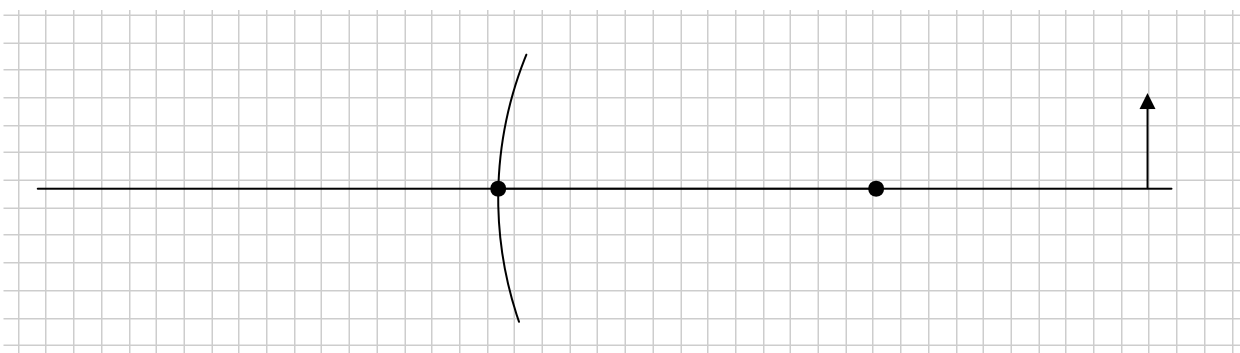
a. Decide if the mirror is concave or convex, based on the location of the object

b. Use the centre of curvature (CC) to locate the focal point

c. Use the CC and F to draw 3 pairs of incident and reflected rays

d. Draw the image and give its characteristics (SALT)





No matter if you are dealing with a plane mirror or curved mirror, the image is always found by the **intersection of the reflected rays**. As you practice these ray diagrams on your homework sheets, you will find that, for convex mirrors, the reflected rays always intersect behind the mirror. However, for concave mirrors, this could happen either in front of the mirror, or inside the mirror, depending on the location of the object. You will have to practice a ray diagrams with the object located at a number of different locations

Name:______________ Partner 1:___________ Partner 2:________________ Partner 3:________________

Lesson 10 Introduction to refraction

By the end of this lesson, you should be familiar with the terms optical density and index of refraction. Also, you should be able to predict if light will bend towards the normal or away from the normal, as it passes from one medium to another.

We know that light travels in a straight line while traveling in a medium. This is called linear propagation. Light also travels at a constant speed in a medium. However, when light passes from one medium to another, the speed will change. A result of this change in speed, it is possible that the direction of the light will change. We call this bending of light **refraction**. The speed of light in a medium is defined by what the material is made up of; we refer to this property as the "optical density of a material".

1. **Predict** What do you think is the relationship between a materials optical density and the speed that light will travel in that medium?

Without the help of a textbook, define the following terms:

Incident Ray: ____

____

Reflected Ray: ____

____

Refracted Ray: ____

____

Part A: Observing Refraction

1. Get a rectangular prism and ray box.
2. Shine the ray box on one side of the block. Notice how it bends at the first side it is incident upon, and also how it comes out the far side. Play with different angles of incidence to see the effect on the refracted rays.

Part B: Tracing Refraction

1. On the back of this sheet, trace the outline of the rectangular prism.

 Name:______________ Partner 2:_________________
Partner 1:___________ Partner 3:_________________

2. Shine a ray of light onto the block, with an angle of incidence of at least 40°.
3. Put a few dots along both the incident ray and the refracted ray. Remove the light and prism and use a ruler and pencil to trace the path of the ray of light. Use arrow heads to indicate the direction of the light ray. Be sure to include the path of light inside the box, even if you can't see it.

Trace your block in the space below.

Analysis

1. Use different colours and a legend to indicate any incident rays, refracted rays and reflected rays.
2. Draw a normal on both surfaces of the block. Label any angles of incidence (θi), angles of reflection (θ_r), and angles of refraction (θ_R).
3. Do you think the ray inside the block is an incident ray or a refracted ray? Explain.

4. Using a dotted line, extend your original incident ray in a straight line directly through the tracing of the prism. Compare it the final refracted ray. What can you say about these two lines.

 Name:______________ Partner 1:___________ Partner 2:________________ Partner 3:________________

Lesson 11 TIR & Fibre Optics

By the end of this lesson, you will be familiar with Total Internal Reflection, the critical angle of a material and how technology uses these concepts.

Activity 1: Exploring Refraction

Get a ray box, filter and semi-circular block. Just like when you did your lab, **it is important to shine the ray box at the middle of the flat side of the block to avoid 2 instances of refraction.**

1. **Predict -** When light travels from a fast medium to a slow medium (or a less optically dense medium to a more optically dense medium), which direction does it bend?

2. **Test –** use your materials to test your prediction. Draw a sketch of your results. To test this, you will be shining the light on the flat side first (air = fast medium), and having the ray come out the curved side (block = slow medium).

3. **Predict and test –** Reverse the direction of light so that it travels from a slow medium to a fast medium. Think about how you expect the light to travel then perform the test and draw a picture of your results.

Name:______________ Partner 1:___________ Partner 2:________________ Partner 3:________________

Activity 2: Making Measurements

Consider light shining on the flat side of the block. There is only one point of refraction, and light is traveling from a fast medium to a slow medium. Marie says, *"for every angle of incidence between 0° and 90°, there will be a refracted ray and therefore an angle of refraction".*

4. **Confirm** – use the polar graph paper to test Marie's statement. Record your observations in Table 1.

Table 1: Fast medium to slow medium

θ_i	θ_R
10°	
20°	
30°	
40°	
50°	
60°	
70°	
80°	
88°	

Recall the principle of reversibility – light will follow exactly the same path if its direction of travel is reversed.

Consider light shining on the curved side first, traveling along a radius, then hitting the flat side of the block at the middle. Again, there is only one point of refraction (at the flat side) and the light is now traveling from a slow medium to a fast medium.

5. **Predict** – without doing any math, and based solely on the information in Table 1, predict what the approximate value for the refracted angle will be for the angles listed in Table 2.

6. **Explain** - On what did you base your prediction?

Table 2: Slow medium to fast medium

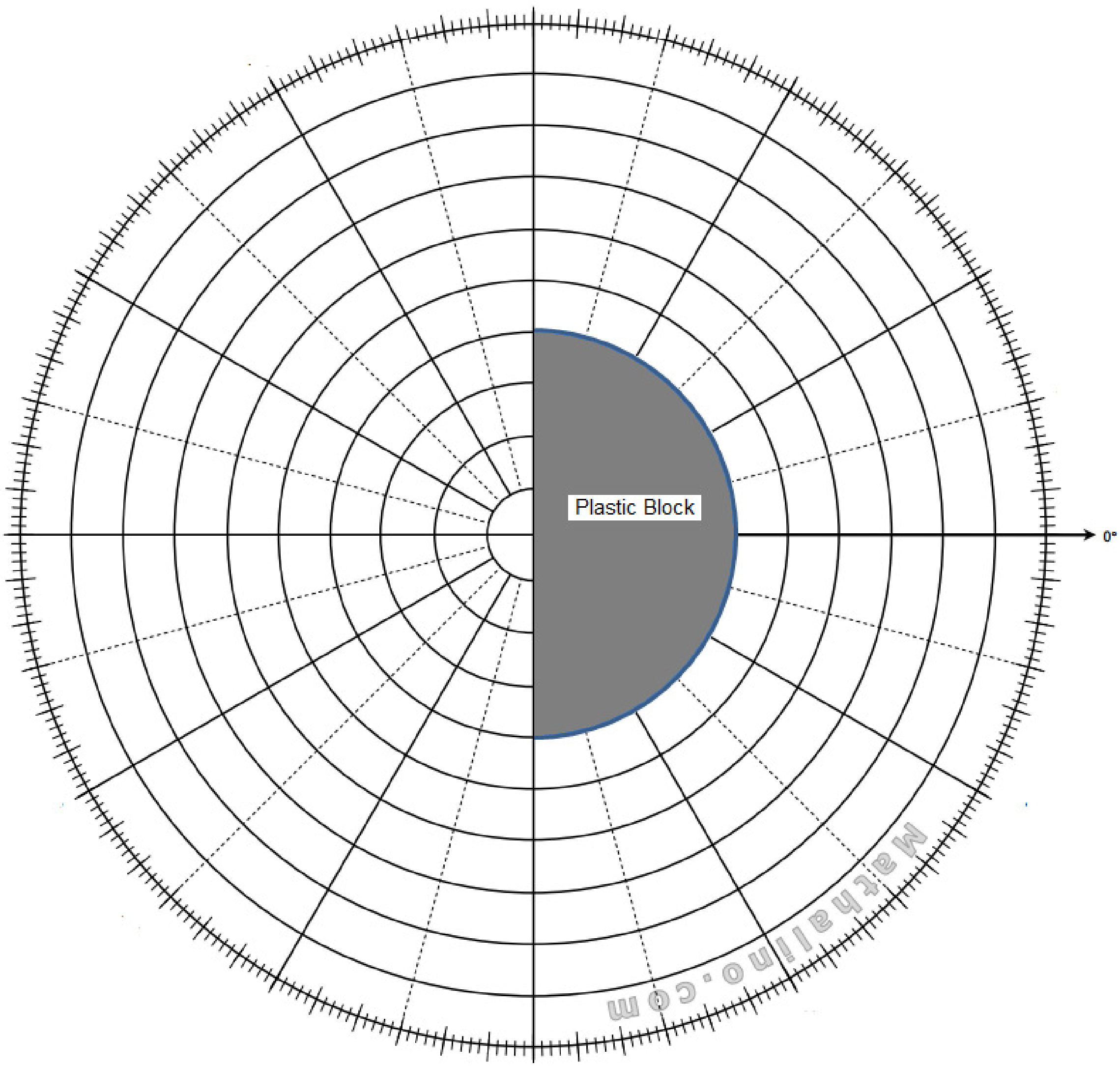
θ_i	θ_R
6°	
30°	
42°	
60°	
80°	

7. **Test –** Shine the light ray at those angles and make any corrections to your predictions.

When light travels from a slow medium to a fast medium, the angle of refraction is always bigger than the angle of incidence. Because of this, the angle of refraction will reach a value of 90° before the angle of incidence does. The angle of incidence that corresponds with an angle of refraction equal to 90° is called the **critical angle.** Any angle of incidence greater than the critical angle will give **total internal reflection**.
Two criteria must be satisfied in order to observe total internal reflection:
1. Light must be traveling from a slow medium to a fast medium.
2. The angle of incidence must be greater than the critical angle.

8. **Sketch** – draw two diagrams for the same block, one that shows refraction, and one that shows total internal reflection. Label your diagram: boundary, normal, θ_i, θ_R, θ_r, slow medium, fast medium

Name:_____________ Partner 1:___________ Partner 2:________________ Partner 3:________________



Activity 3: Fibre optics

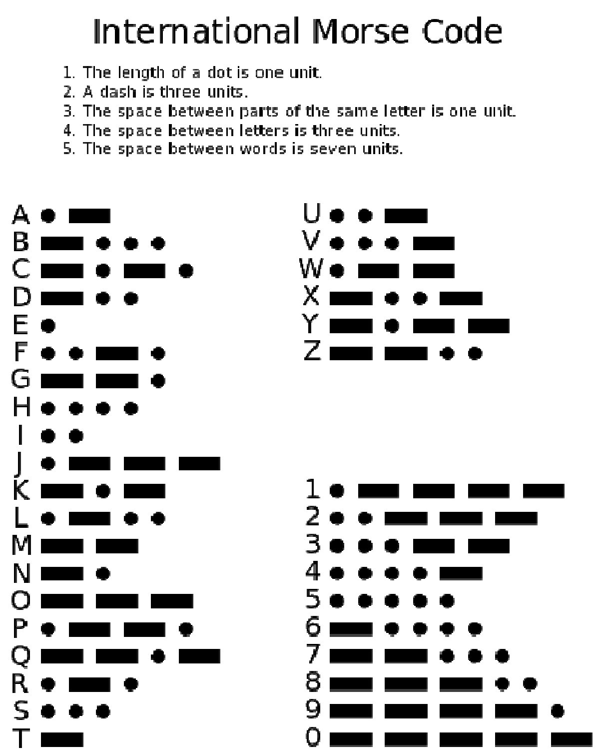
Lasers are classified according to safety (1 being the safest, 4 being the most dangerous). Lasers used in this activity are deemed very safe. However, it is never safe to point a laser directly into someone's eye. This can have the same results as getting a sunburn on one's retina. Keep all lasers pointed down – they should only shine the desk or floor. They should not shine on the walls or ceiling. Failure to follow this safety rule, or failure to use good judgement in dealing with your laser will result in your removal from class.

 Name:______________ Partner 1:___________ Partner 2:_________________ Partner 3:_________________

9. **Explore** – obtain 2 semi-circular plastic blocks and a laser. Your goal is to set up the 2 blocks such that, when you shine the laser , you will observe total internal reflection in both blocks. *Hint – try to accomplish this in just one block first, then add the second block to your set up.*
   Trace the orientation of the two blocks that gave you the required result. See how many blocks you can line up and shine a light through the entire length.

Morse code is a method of communication used all over the world. It has been used throughout history on land, at sea and in air.

10. **Communicate –** work with a partner to practice the timing outline in the code (tap out time units). Then, try to communicate short words (ex: YMCI) or numbers to each other using the laser and Morse Code. Always shine the light on the desk or floor.



Fibre optic cables make use of total internal reflection and codes (but they don't actually use Morse code) for communication. Long, thin tubes of glass are able to carry data/information at the speed of light – much faster than traditional copper wires. These fibre optics are used in everything from TV/Internet providers (Bell Fibe) to world-wide communication networks. There are actually bundles of fibre optic cables running along the ocean floor from Europe to North America!

Figure 3: An example of a Fibre Optic cable

 Name:______________ Partner 1:____________ Partner 2:_________________ Partner 3:_________________

Lesson 12 Lab day 1

Handouts will be distributed in class

Lesson 13 Lab day 2

Lesson 14 Introduction to lenses

By now you have been introduced to the idea that light bends at a boundary when it passes from one medium to another. Today, you will look at how that information is used to build lenses!

Part A: Define the following:

Refraction: ____

____

Boundary: ____

____

More optically dense medium (ODM) vs less ODM:__________________________

____

____

Part B: Sketching!

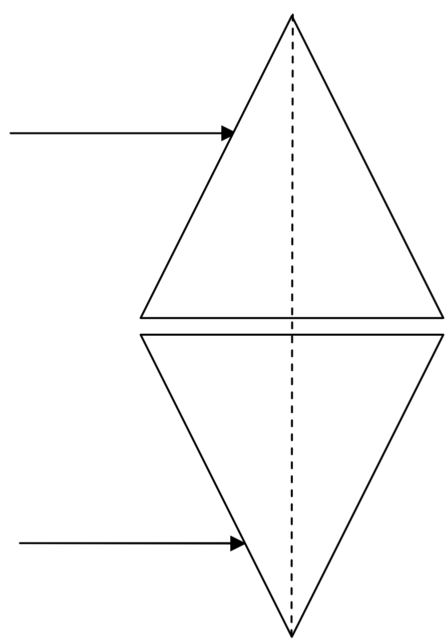
1. In a few different diagrams, show how light bends:
   a) When going from a more to less ODM, $\theta_i = 0°$
   b) When going from a more to less ODM, $\theta_i > 0°$
   c) When going from a less to more ODM, $\theta_i = 0°$
   d) When going from a less to more ODM, $\theta_i > 0°$

 Name:______________ Partner 1:___________ Partner 2:________________ Partner 3:________________

Part C: Putting it all together

*While working through this activity, angles are very important. Take note of which angles you think should be the same between the two **prisms** and take care to draw them equal!*

2. On each of the the prisms below:
   a) Note the indicent rays given in the diagram. At the intersection of the boundary (air to prism), draw a normal. Indicate θ_i.
   b) Inside the prism, and based on the idea that the ray travels from air to prism, show a refracted ray. Indicate θ_R such that it is less than θ_i.
   c) Continue the refracted ray through the prism until it is incident on the other side of the prism. At the intersection of the boundary (prism to air), draw a normal. Indicate θ_i.
   d) In the air, and based on the idea that the ray travels from prism to air, show a refracted ray. Indicate θ_R such that it is greater than θ_i.



Analysis

3. Your two final, emergent rays should meet at some point. Mark this with a big X What do you think this point represents?

4. Consider the distance from the broken line to your X. Based on your previous lessons, what do you think might affect this distance? That is, what could you change to change the distance to X?

 Name:______________ Partner 1:___________ Partner 2:________________ Partner 3:________________

Summary

Isaac made the statement *"light bends more in a slow medium than a fast medium".* This is not a valid comparison.

5. Why is Isaac's statement simply incorrect?

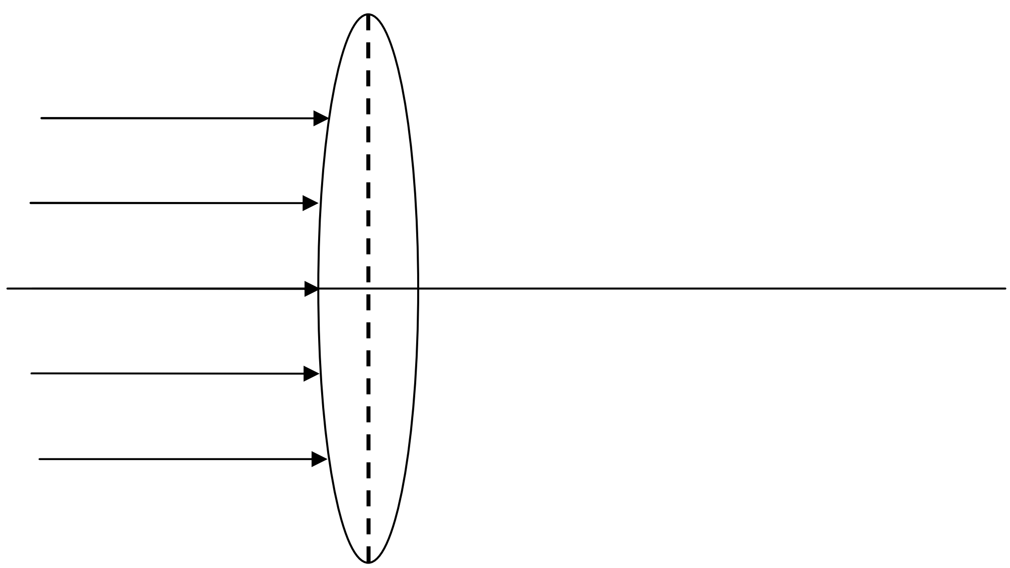
6. Use the proper wording to make a comparison between two situations where light bends different amounts.

 Name:______________ Partner 1:___________ Partner 2:________________ Partner 3:________________

Lesson 15 Ray diagrams for lenses

By the end of this lesson, you will be able to describe the attributes of an image created by a lens, and use a ray diagram to locate and draw the image of an object created by a lens.

Activity 1 – Parallel rays through a convex lens
Use a ray box with 5 slits and a lens to create the following situation:



1. **Predict** - On the diagram above, draw what you think will happen to the rays after they pass through the lens.

2. **Perform –**set up materials as shown and test your prediction. If it was incorrect, make any corrections to your drawing.

After refraction, the these rays all pass through the same point. This point is called the focal point (f) – the point through which **refracted rays** go after passing through a convex lens if all the incident rays are parallel to each other.

Activity 2 – reverse the direction

3. **Predict** – describe what you think would happen if you shine a single ray of light through the focal point towards the lens (the opposite direction from Activity 1).

Name:______________ Partner 1:___________ Partner 2:________________ Partner 3:________________

e

4. **Perform** – Use your ray box, lens and diagram to test your prediction. If you were wrong, describe what you saw. If you were correct, describe where you have seen a similar phenomenon to this.

A lens is an optical device that refracts light. Lenses can be divided into two categories according to shape: convex and concave. Convex lenses have at least one surface that curves outward and are thicker in the middle than at the edges. In contrast, concave lenses have at least one surface that curves inward and are thinner in the middle than at the edges.

Activity 3 – getting to know your lens

Obtain a convex lens.

5. Look at various objects through the lenses. Describe what you see. What factors affect what you see? (possibilities might include the following: distance from the object to the lens, distance of the lens to your eye, etc). Record your observations.

Look at a letter “e” through the lens. Hold the “e” so it is upright when you are looking at it without the lens.

6. Where can you hold the lens so that the “e” appears to be:

Upside down (inverted)?	
Right side up (erect)?	
Larger than it is in real life?	
Smaller than it is in real life?	
The same size as in real life?	

7. Hold the lens fixed in place about 30 cm from your eye. Place the “e” behind the lens and very close to it. Slowly move the “e” as far from the lens as you can. Describe your observations in words and with sketches.

Name:______________ Partner 1:___________ Partner 2:_________________ Partner 3:_________________

8. Hold the “e” at arm’s length in front of you and keep it there. Place the lens directly in front of the “e”, then move the lens slowly toward your eye. Describe your observations in words and with sketches.

9. When dealing with lenses, variables that can be discussed would be:
    a. Distance to the image
    b. Distance to the object
    c. Focal point
    d. Height of the image
    e. Height of the object

 Name:______________ Partner 2:_________________
Partner 1:____________ Partner 3:_________________

In the previous two experiments what variables were varied?

Activity 4 – Finding the focal point

Hold a lens in one hand so that light form a brightly lit distant source (ex: the houses at the far side of the field) passes through the lens and falls on a sheet of paper held in your other hand. Move the paper back and forth until a clear image of the object appears on the paper.

10. Describe the appearance of the image. Is it erect or inverted? Is it larger or smaller than the object?

11. Turn the lens around. Describe what happens to the image.

12. Move the paper back and forth. Describe what happens to the image.

As a group, take the all your copies to your teacher to discuss these activities. Your teacher will evaluate your work on the spot.

The distance from the lens to the screen is called the focal point.

13. Measure and record the focal point for the lens you have.

14. Find a group that has a different focal length for their lens. Compare the focal lengths and appearance for each lens. What characteristic about the lens determines its focal length?

Activity 5 – finding images

Name:______________ Partner 1:___________ Partner 2:________________ Partner 3:________________

Similar to mirrors, it is important not to confuse the term focal point (or focal length) with focused image. Again, like mirrors, the focal point of a lens depends on the construction of the lens (specifically, the curvature of the lens). This value cannot change for a lens. The distance to the focused image depends on the distance from the object to the lens. This value changes as an object moves closer to or further from the lens.

15. Use the optical bench and single filament light bulbs to perform experiments to answer these questions:

    a. as an object is moved towards a lens from a large distance away, how does the location of the image vary?

    b. as the object is moved toward the lens, how does the apparent size of the image vary?

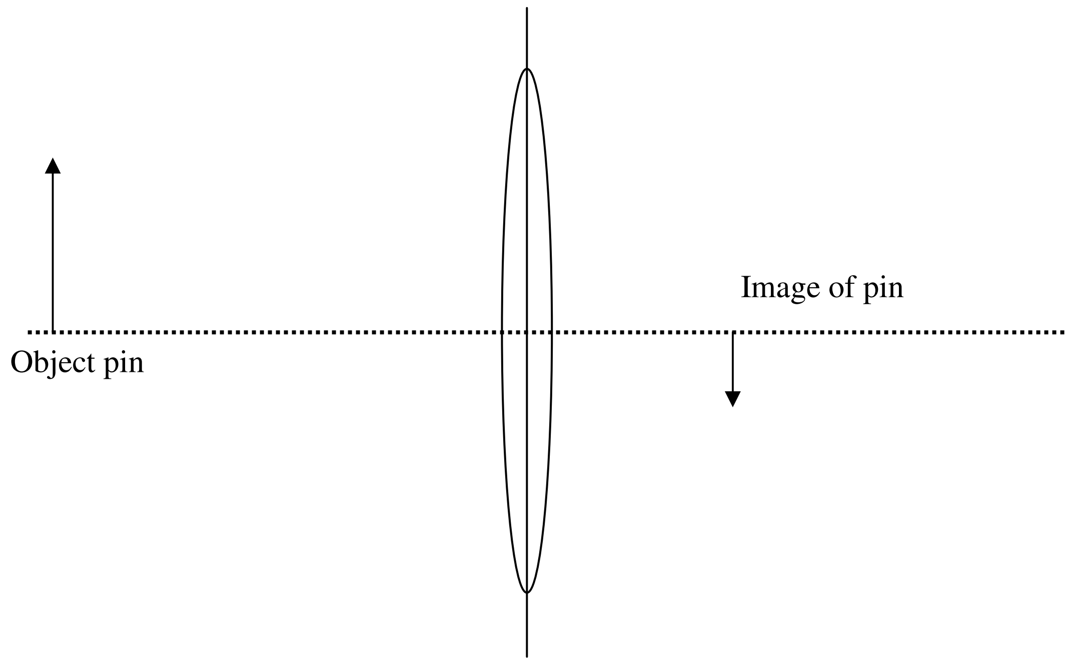
    c. for what range of object locations is the image erect? For what range of object locations is the image inverted?

    d. where must the object be located in order for the image to be on the opposite side of the lens as the object?

 Name:______________ Partner 2:_________________
Partner 1:____________ Partner 3:_________________

Activity 6 – building your ray diagram

The diagram below shows a pin near a convex lens. The image formed by the lens is shown on the diagram.



16. From the tip of the object pin, draw several rays, some of which pass through the lens. Those that hit the lens will be refracted such that they pass through the tip of the image, thus forming the image. Be sure your diagram shows this.

Summary

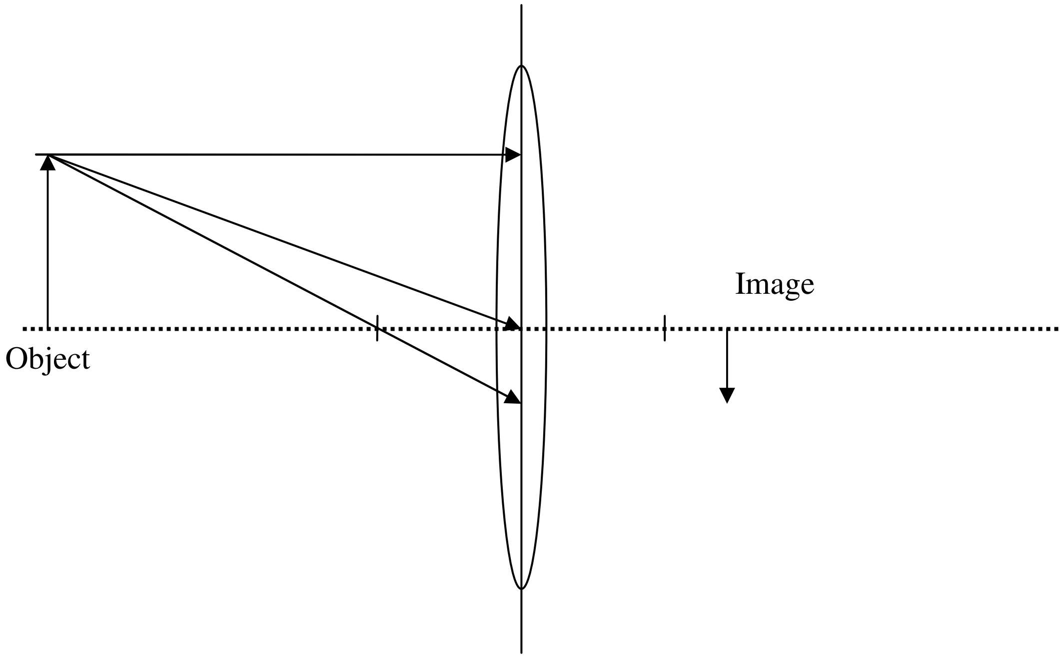
17. Get a cross section of a lens and a ray box. Use these pieces of equipment and knowledge from previous lessons to answer the following questions:
    a. If you have an incident light ray traveling parallel to the principal axis, how does it get refracted?

    b. If you have an incident ray passing through the focal point, how does it get refracted?

    c. If you have an incident ray passing through the optical centre, how does it get refracted?

 Name:______________ Partner 1:____________ Partner 2:_________________ Partner 3:_________________

Summarize your responses on the diagram below:



In drawing a ray diagram for a thin lens, it is customary to treat rays either as being refracted all at once at the center of the lens or to treat the lens as a line with no thickness. Refraction actually takes place at the two surfaces.

When drawing a ray diagram to locate the image of an object, we use the same conventions as when drawing ray diagrams for mirrors. That is:

- The image is formed by the intersection of refracted rays
- If real light rays do not intersect, check to see if they can be extended backwards to find a meeting point. If so, that is where the image is found. This would be a virtual image. All virtual light rays and images must be drawn with a dashed line.

 Name:______________ Partner 1:___________ Partner 2:________________ Partner 3:________________

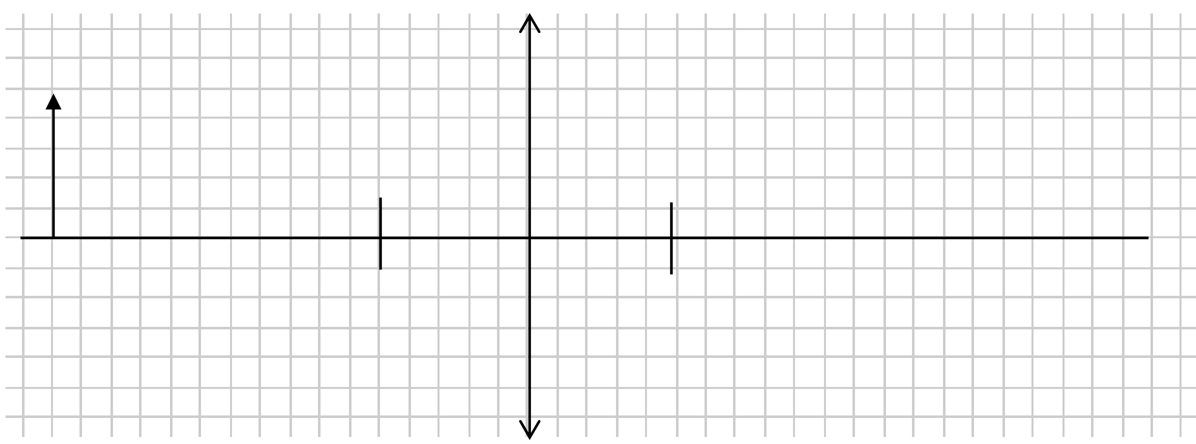
Lesson 16 Catch up

Lesson 17 The thin lens and magnification equations

Copy Table 1 from page 566 into the space below.

Question 1

We indicate a convex lens by using a double-headed arrow between the focal points. Locate the image of the object shown below in the convex lens and give the characteristics of the image.



Scale: 1 square = 1 cm x 1 cm

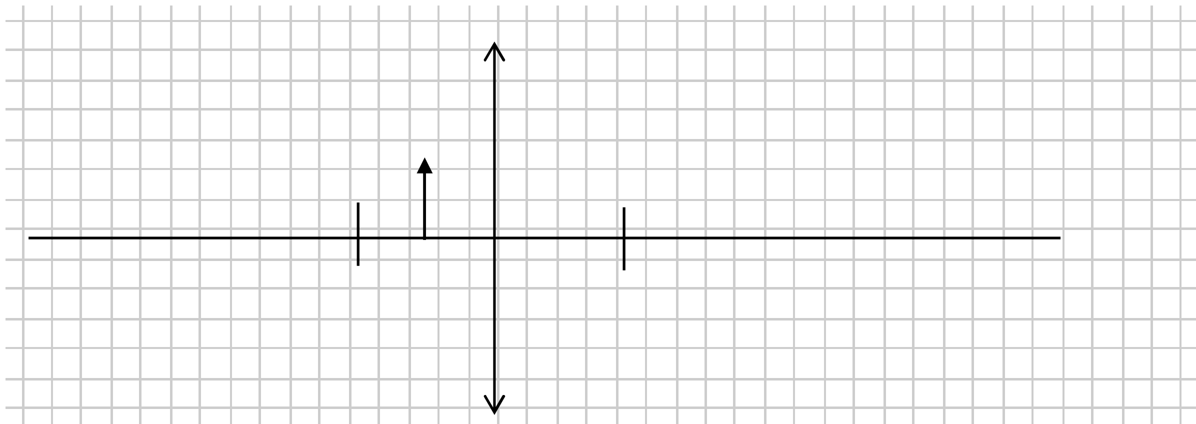
Write out the thin lens and the magnification equations below.

On the diagram above, label d_o, f, h_o. Use these values and the thin lens and magnification equations to calculate d_i and h_i. Be sure to use your negatives correctly. How close are your calculated values to your measured values on the diagram above?

 Name:______________ Partner 1:___________ Partner 2:________________ Partner 3:________________

Question 2

Locate the image of the object shown below in the convex lens and give the characteristics of the image.



Scale: 1 square = 1 cm x 1 cm

On the diagram above, label d_o, f, h_o. Use these values and the thin lens and magnification equations to calculate d_i and h_i. Be sure to use your negatives correctly. How close are your calculated values to your measured values on the diagram above?

There is a formula that exists which is used to compare an experimental or measured value to a given or accepted value, called "percent error". It looks like this:

$$\%error = \left(\frac{experimental - accepted}{accepted}\right) * 100\%$$

What do you think a positive or negative value represents?

For the two activities above, which values of d_i and h_i do you think are more accurate? The more accurate will be your accepted value and the other your experimental value. Calculate the % error for d_i and h_i for each question.