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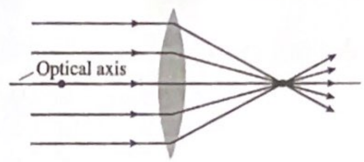
LAB. RAY OPTICS: CONVEX AND CONCAVE LENSES

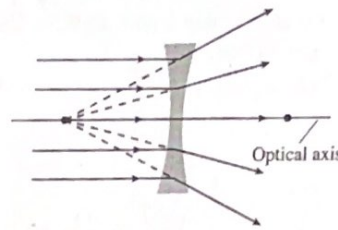
AP PHYSICS II

Driving Question | Objective

How do incident rays on Convex and Concave lenses behave once they pass through the principle plane?

Perform an experiment to determine the focal lengths of each lens then use that data to discover some other interesting properties about lenses.





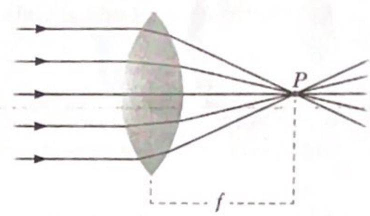
Conducting Your Experiment

It is your group's responsibility to conduct an experiment regarding the analysis of behavior of convex (converging) and concave (diverging) lenses. You will use information that you find to determine the relationship of important segments of lens diagrams such as Focal Points, Principle Planes, and Optical Axes.

Materials and Equipment

- Light Source
- Small Convex Lens
- Large Convex Lens
- Small Concave Lens
- Metric Ruler

Background



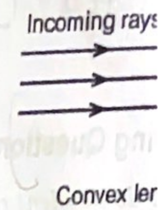
Parallel light rays entering a converging (double-convex) lens change direction as the rays are refracted at both the front (incident) and back (emergent) surfaces of the lens. If we assume that the path of the light entering the lens is perpendicular to the plane of the lens, the final refracted angle of the ray as it leaves the lens will direct it to a focal point P along the optical axis. The distance from the lens to P is known as the focal length f of the lens.

This behavior is a result of refraction, the geometric properties of the lens shape, and angles at which the incoming light rays strike the surface of the lens. Given the shape of the lens, its focal length can be quantified using a complex formula involving the curvature at each lens surface, the thickness of the lens, and the index of refraction for both air and the lens material. However, if we assume that the thickness of the lens is very small, the equation simplifies to a form involving only the distance between the lens and the object and the lens and the image produced by the lens.

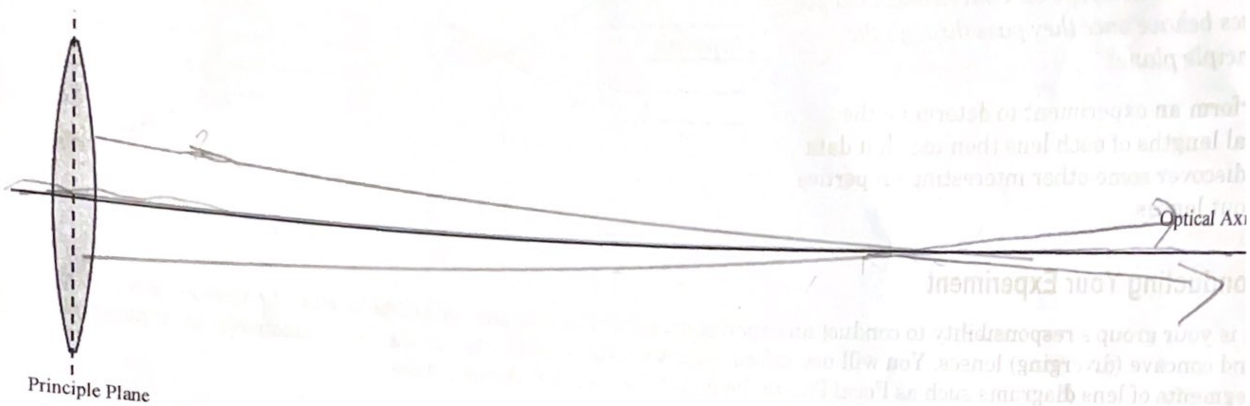
We see similar characteristics with a diverging (double-concave) lens as well. If we assume that the path of the light entering the lens is perpendicular to eh plane of the lens, the final refracted angle of the ray as it leaves the lens can be virtually traced to a focal point. In this lab, you will be using the principles of Snell's Law and refraction and summarizing the behaviors 3 rays follow when incident to a convex or concave lens.

Experimental Design Pt. 1 – Incident Rays Parallel to the Optical Axis

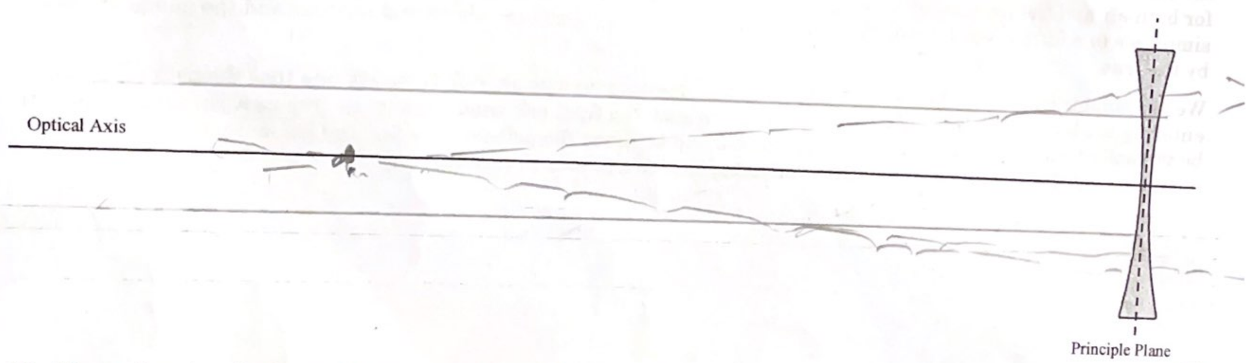
1. Place the light source on the LEFT side of this paper and set it to emit 3 rays of light.
2. Before placing the lens down, shine the 3 parallel rays parallel to the Optical Axis, as seen in the figure to the right.



3. Once you are lined up with the optical axis, place the Small Convex Lens in the designated slot below.



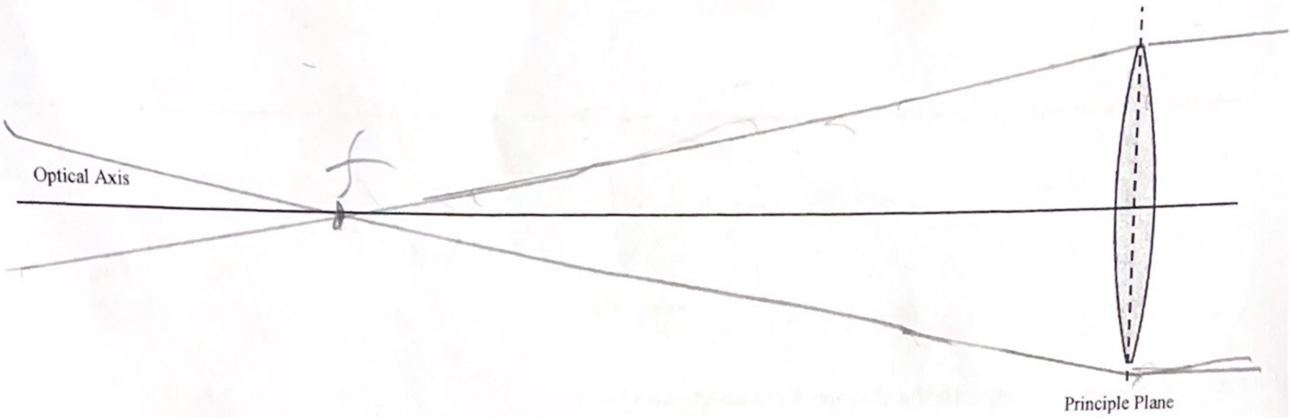
4. The point at which the refracted light rays converge is called the focal point of the lens. Use a straight edge to trace these light rays before and after being refracted through the lens.
5. **Focal Point** – A point on the Optical Axis which refracted rays (real or virtual) will intersect only if the incident ray is parallel to the optical axis. See the image at the top right of this paper for an example.
6. What is the Focal Length (distance from the principle plane to the focal point)? f = 13. Cm
7. If you shine incident rays the opposite way through the Small Convex Lens (having the light source on the right), will the rays intersect on the other side of the lens? ______?
8. How many focal points would you say this lens has? one.
9. With the light source still on the LEFT side of the paper, repeat the procedure with the Small Concave Lens and use the space below to sketch the incident and refracted rays.



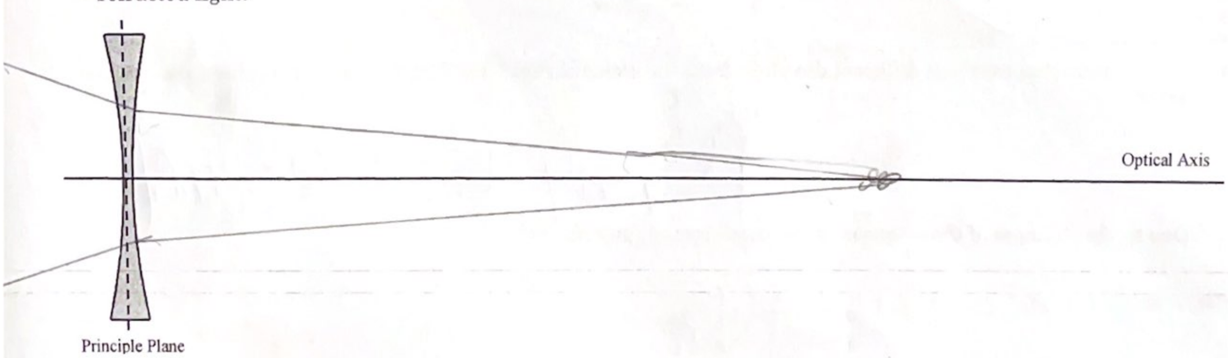
10. After refraction, do the real light rays intersect? If not, do the virtual rays of the refracted light intersect? Identify this location on your sketch above.
11. Focal Length: f = 13.

Experimental Design Pt. 2 – Incident Rays Aimed at Focal Points

1. Set the light source to output only a single ray.
2. Indicate, to scale, where the focal point of the Small Convex Lens is located on the left side of the lens.
3. Before placing the lens in the slot, aim an incident ray to first go through this focal point, then strike the position of the lens.
4. Once everything is lined up, place the Small Convex Lens on the designated slot and observe what happens with the refracted rays.



5. Try this a couple more times from different angles, assuring that it first passes the focal point, then hits the lens.
6. What do you notice about the direction of refracted rays? They are parallel.
7. In the previous sections, you concluded that if an incident light ray was parallel to the Optical Axis, it would refract to the focal point. Would your findings in this section imply that a ray of light is reversible in its trajectory through a lens?
8. We will attempt to do this with the Small Concave Lens. First indicate, based on Pt. 1, the location of the Focal Point of this lens on the right-hand side. Do not place the lens on the slot yet. Make sure the light source is still on the <u>LEFT</u> side of the paper and aim it at the focal point. Make sure this incident ray is not parallel to the Optical Axis. Once you are lined up, place the Small Concave Lens on the designated slot and observe the refracted light.

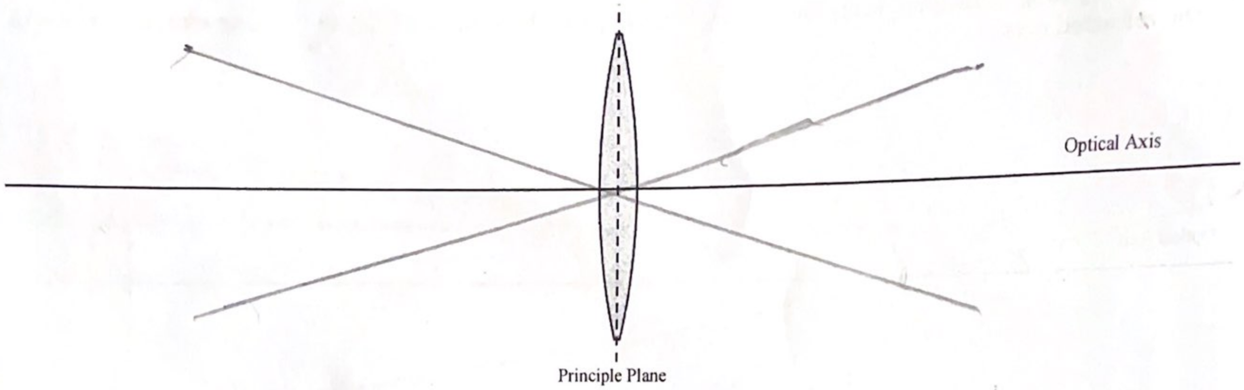


9. Try this a couple more times with different angles of incident rays.
10. What do you notice about the direction of the refracted ray? The angle of refraction decreases.

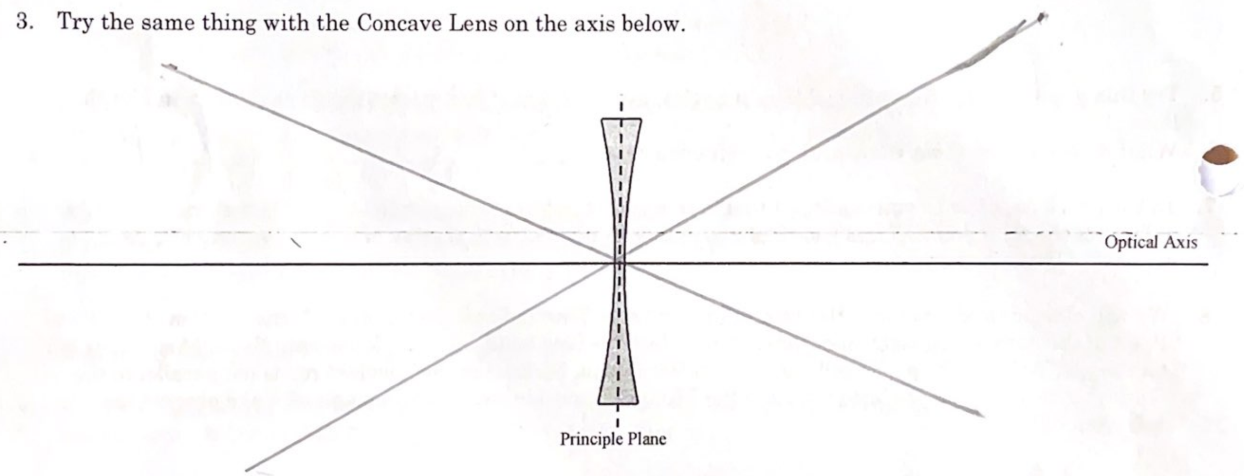
Experimental Design Pt. 4 – Incident Rays Aimed at the Center of a Lens

1. We next want to see what happens to light rays that are aimed at the geometric center of a lens. Again, set the light source to emit 1 ray.

2. Place the Small Convex Lens on the slot below and aim an incident ray which is <u>not</u> parallel to the Optical Axis toward the geometric center of the lens. This is the intersection of the Optical Axis and the Principle Plan. Record about 3 different incident rays as well as their respective refracted rays.



3. Try the same thing with the Concave Lens on the axis below.



4. Are the refracted rays in a different direction from the incident rays? Are they displaced at all from the original path?

Yes, only slightly displaced

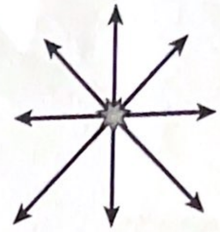
5. Due to the thinness of these lenses, it the displacement significant?

No

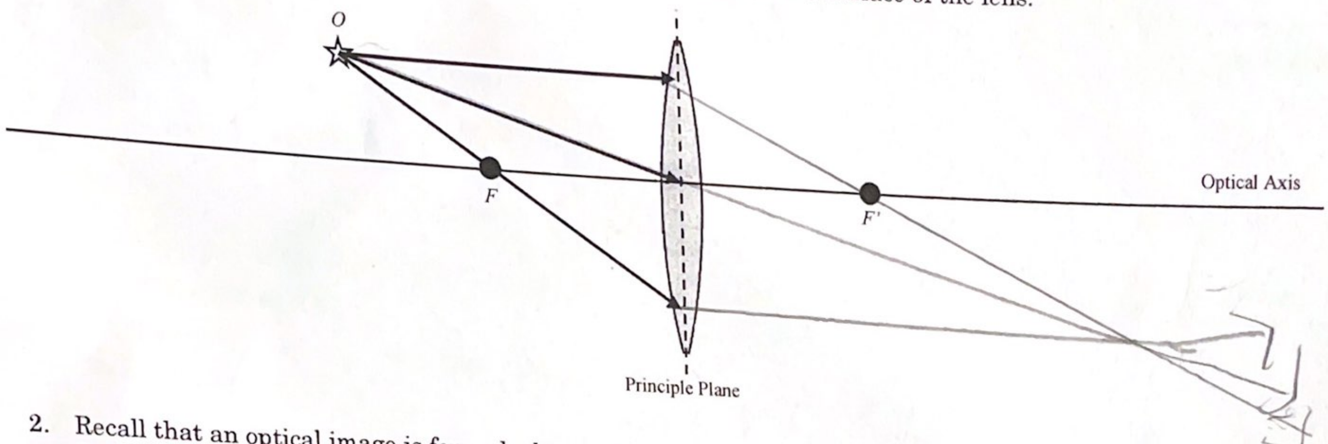
6. Now that you know what happens with incident rays aimed parallel to the optical axis, incident rays aimed at the focal point, and incident rays aimed at the geometric center of the lens, you are ready to put your discoverie to the test!

nalysis

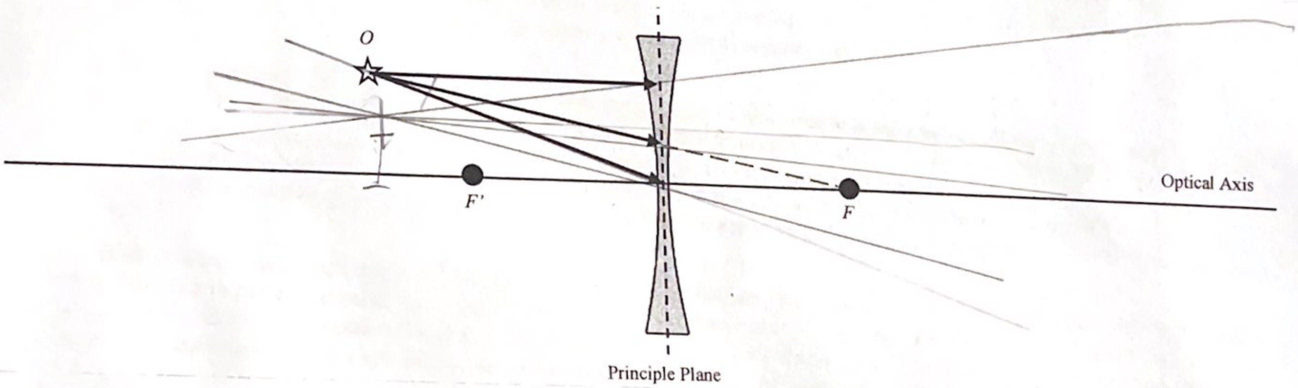
Ve know a point source object emits light in all directions, as seen in the image to the right. owever, keeping track of an infinite number of rays is impossible, so we are more interested in e actions and behaviors of 3 rays in particular: One incident ray parallel with the Optical Axis efore hitting the lens, one which passes through the Focal Point then hitting the lens, and one vhich is aimed at the geometric center. We know how these three particular rays will behave fter refraction by the lens. Feel free to use the lab equipment to confirm your results.



1. The picture below shows a hypothetical Convex (converging) Lens with a point source labeled "*O*" for "*Object*" located to the left of the left-sided Focal Point of the lens. The 3 important incident rays have been provided for you. Use what you have learned in this lab to draw the 3 refracted rays after passing through the lens. You should begin your tracing at the Principle Plane, rather than at the surface of the lens.



2. Recall that an optical image is formed where <u>refracted</u> light rays intersect (real or virtual). Is there an image formed by this lens? If so, draw a star and label it with an "*I*" for "*Image.*"
3. Is the image Real or Virtual? ___real___.
4. Below is a Concave (diverging) lens. Use what you have found in this lab to trace the refracted rays.



5. Recall that an optical image is formed where <u>refracted</u> light rays intersect (real or virtual). Is there an image formed by this lens? If so, draw a star and label it with an "*I*" for "*Image.*"

   Is the image Real or Virtual? ___virtual___.

7. Before leaving the lab table, please assure your light source is unplugged and any loose paper it recycled.

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