Lens Basics
• A lens is merely a carefully ground piece of transparent material which refracts light rays in such a way as to form an image.
There are two types of lenses.

**Convex Lens** (Converging)
- Thicker in the middle than at the ends

**Concave Lens** (Diverging)
- Thinner in the middle than at the ends
Anatomy of a Lens

- Optical Axis
- Focal Points
- Optical Center
- Lens
- Principal Axis
Anatomy of a Lens

- Optical Axis
- Focal Points
- Optical Center
- Lens
- Principal Axis
## Mirrors vs. Lenses

<table>
<thead>
<tr>
<th>Mirrors</th>
<th>Lenses</th>
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</thead>
<tbody>
<tr>
<td><strong>Opaque</strong></td>
<td><strong>Transparent</strong></td>
</tr>
<tr>
<td>Reflected Rays</td>
<td>Refracted Rays</td>
</tr>
<tr>
<td>Incident Rays and</td>
<td>Incident Rays and</td>
</tr>
<tr>
<td>Reflected Rays</td>
<td>Emergent Rays</td>
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<tr>
<td>Converging = Concave</td>
<td>Converging = Convex</td>
</tr>
<tr>
<td>Diverging = Convex</td>
<td>Diverging = Concave</td>
</tr>
</tbody>
</table>
Image Formation in Lenses
The examples below illustrate how lenses can distort light.

- **Convex**
- **Concave**
- **Converging Lens**
- **Diverging Lens**
A converging lens causes light rays that are parallel to the principal axis to converge, or meet, at one point (the principal focus).
Converging Lens with labels

- optical centre
- secondary principal focus
- principal focus
- principal axis
• A **diverging lens** causes parallel light rays to diverge, or spread apart.
Diverging Lens with labels

- Optical centre
- Principal focus (F)
- Secondary principal focus (F')
- Principal axis

[Diagram showing the path of light rays through a diverging lens, including the optical centre, principal focus, and secondary principal focus.]
• Objects will also be distorted when viewed through a lens.

Convex

Concave
• We can use ray diagrams to predict how an image will look through a lens.
# Rules for Converging Lens Ray Diagrams

<table>
<thead>
<tr>
<th>Incident Ray</th>
<th>Refracted Ray</th>
<th>Diagram (Thin lens)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parallel to Principal Axis</td>
<td>Through focus</td>
<td><img src="image1.png" alt="Diagram 1" /></td>
</tr>
<tr>
<td>Through optic Centre</td>
<td>Ray moves along same path</td>
<td><img src="image2.png" alt="Diagram 2" /></td>
</tr>
<tr>
<td>Through focus</td>
<td>Parallel to principal axis</td>
<td><img src="image3.png" alt="Diagram 3" /></td>
</tr>
</tbody>
</table>
Summary of Rules for Converging Lenses

- $F'$ = secondary principal focus
- $F$ = principal focus
- Optical centre
- Principal axis

$2F'$ and $2F$ are the positions of the object and image, respectively, when the object is placed at the focal length.
Consider the following situation:

Remember the point where the lines intersect is where the image is formed. Notice that if you looked at **this** candle through **this** convex lens, the candle would appear smaller and inverted!
1. A ray parallel to the principal axis is refracted as if it had come through the principal focus (F).
2. A ray that appears to pass through the secondary principal focus (F’) is refracted parallel to the principal axis.
3. A ray through the optical centre (O) continues straight through on its path.
• Consider the following situation:

Notice that if you looked at this candle through this concave lens, the candle would appear smaller.
We describe how an image looks by explaining how each of the four variables below change.

<table>
<thead>
<tr>
<th>Image Characteristics</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Size (or Magnification)</td>
</tr>
<tr>
<td></td>
<td>Enlarged or Diminished</td>
</tr>
<tr>
<td>A</td>
<td>Attitude</td>
</tr>
<tr>
<td></td>
<td>Upright or Inverted</td>
</tr>
<tr>
<td>L</td>
<td>Location</td>
</tr>
<tr>
<td></td>
<td>Object side or Opposite side of lens</td>
</tr>
<tr>
<td>T</td>
<td>Type</td>
</tr>
<tr>
<td></td>
<td>Real or Virtual</td>
</tr>
</tbody>
</table>
What is a Virtual Image?

- A virtual image is an optical illusion.
- You can see an image, but no light is actually there. It simply appears to be there!
Real and Virtual Images

• A **real image** can be projected on a screen
• A **virtual image** can be seen but cannot be projected on a screen.
Instructions: Draw ray diagrams for the following converging lenses and provide a S.A.L.T summary at the end.

- Group 1: Object Beyond 2F'
- Group 2: Object at 2F'
- Group 3: Object Between 2F' and F'
- Group 4: Object on F'
- Group 5: Object Before F'
- Group 6: Test 1 Diverging Lens
• Each group must have one expert from each original group.

• Your task: To guide your group through the drawing you perfected. Have them draw it too!

• At the end, everyone should have 4 drawings and 4 L.S.A.L.T tables!
Object beyond $2F'$

- smaller
- inverted
- between $F$ and $2F$
- real
Object at 2F'
Object between $F'$ and $2F'$

- larger
- inverted
- beyond $2F$
- real

Object between $F'$ and $2F'$

- $2F'$
- $F'$
- $F$
- $2F$
Object at $F'$

no clear image formed (emergent rays are parallel)
Object between $F'$ and the Lens

- larger
- upright
- behind the lens
- virtual
Object in a Diverging Mirror

(iv)

2F  F  F'  2F'

Diagram showing an object at 2F, resulting in an image at F'.
Diverging Mirror

- smaller
- upright
- same side as object
- virtual