"Just checking."
Schedule

- **HW set #11** will open Tues. Nov. 18\(^{th}\) and is due on Tues. Nov. 25\(^{th}\) at 7am.
  - Third mid-term is Nov. 25\(^{th}\) at 6pm

- **HW set #12** will open Wed. Nov. 26\(^{th}\) and is due on Wed. Dec. 3\(^{rd}\) at 7am.

- Corrections for the third exam will open Wed. Nov. 26\(^{th}\) at 5pm and are due Mon. Dec. 8\(^{th}\) at 7am.
  - Final exam is Dec. 8\(^{th}\) at 5:45-7:45pm.
Midterm Exam #3

- Last mid-term is Tues. Nov. 25th at 6pm.
  - Section 1 in N100 BCC (Business College)
  - Section 2 in 158 NR (Natural Resources)
- Covers homework sets #9, 10 and 11!
  - Chapters 32-35 in textbook
- Allowed one page (both sides) of notes and calculator.
- Bring photo id.
- Email Prof. Tollefson (tollefson@pa.msu.edu) if need make-up exam and explain why.
  - Make-up exam will be Wed. Nov. 26th at 8am
- Review in class on Monday.
Review – Mirrors (Fig. 35-6)

- Plane – flat mirror
- Concave – caved in away from object
- Convex – flexed out toward object
- Real images on side where object is, virtual images on opposite side
- Plane and convex mirrors make only virtual images
- Concave mirrors can produce both real and virtual images
**Review – mirrors (Fig. 35-7)**

- **Spherical mirrors** have focal point, $r$ is radius of curvature
  \[ f = \frac{1}{2} r \]

- Find focal length, $f$ from
  \[ \frac{1}{p} + \frac{1}{i} = \frac{1}{f} \]
  - Object distance $p$ is +
  - Image distance $i$ is + for real images, - for virtual images
  - $f$ is + for concave, - for convex
Review - mirrors

- Ratio of image’s height $h'$ to object’s height $h$ is called lateral magnification, $m$

$$|m| = \frac{h'}{h}$$

- Magnification also equal to

$$m = -\frac{i}{p}$$

- $m$ is + if image has same orientation as object
- $m$ is - if image is inverted from object
- Plane mirror $m = +1$
# Review - mirrors

<table>
<thead>
<tr>
<th>Mirror Type</th>
<th>Object Location</th>
<th>Image Location</th>
<th>Image Size</th>
<th>Image Type</th>
<th>Image Orientation</th>
<th>Sign of $f$</th>
<th>Sign of $i$</th>
<th>Sign of $m$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plane</td>
<td>Anywhere</td>
<td>$i = -p$</td>
<td>Equal</td>
<td>Virtual</td>
<td>Same</td>
<td>$\infty$</td>
<td>-</td>
<td>+1</td>
</tr>
<tr>
<td>Concave</td>
<td>$p &lt; f$</td>
<td>Anywhere</td>
<td>Bigger</td>
<td>Virtual</td>
<td>Same</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Concave</td>
<td>$f &lt; p &lt; 2f$</td>
<td>$i &gt; 2f$</td>
<td>Bigger</td>
<td>Real</td>
<td>Invert</td>
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</tr>
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</tr>
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</table>
Refracting surfaces (Fig. 35-10)

- Images can be formed by refraction through transparent material.
- Object O on left in medium with \( n_1 \).
- Normal to refracting surface is radial line through center of curvature C.
  - Ray bends toward normal if \( n_2 > n_1 \).
  - Ray bends away from normal if \( n_2 < n_1 \).
Refracting surfaces (Fig. 35-10)

- **Real images** - when refraction directs ray towards central axis
- **Virtual images** - when refraction directs ray away from central axis
- **Real images** on side of refracting surface that is opposite the object, **virtual images** on same side as object
Referring to the image, the text reads:

**Referring to the image, the text reads:**

- **Relation for radius of curvature of refracting surface**
- **Object is in medium of** $n_1$
- **Object distance** $p$ **is +**
- **Image distance** $i$ **is + for real image, - for virtual image**
- **If object faces convex refracting surface radius** $r$ **is +,** **faces concave surface** $r$ **is -**
  - Reverse of sign convention for mirrors

The equation shown in the image is:

$$\frac{n_1}{p} + \frac{n_2}{i} = \frac{n_2 - n_1}{r}$$
Thin Lenses (Figs 35-12)

- Light rays bent by refraction form an image
- **Converging** - lens with convex refracting sides
- **Diverging** - lens with concave sides
Thin lenses images (Figs 35-13)

- Real images form on opposite side of lens from object, virtual images on same side
- **Diverging lens** only produces smaller, same orientation, virtual images (like convex mirror)
- **Converging lens** (like concave mirror) can produce both real and virtual images depending on where the object is in relation to the lens’ focal point
Thin lenses have a focal point on each side of lens.

Focal length, $f$ same as mirror:

\[
\frac{1}{p} + \frac{1}{i} = \frac{1}{f}
\]

Lens maker’s equation – for lens in air, $r_1$ is radius of lens surface nearest the object, $r_2$ is other surface:

- $r$ is + for convex surface,
- - for concave surface.

\[
\frac{1}{f} = (n - 1) \left( \frac{1}{r_1} - \frac{1}{r_2} \right)
\]
Thin lenses images (Figs 35-15)

- Lateral magnification $m$ same as for mirror
  \[ m = - \frac{i}{p} \]

- For a system of lenses or mirrors the total magnification $M$ is product of each $m$
  \[ M = m_1 m_2 m_3 \ldots \]

- Work through system of lenses one by one - use image from one lens as object for next lens
# Thin Lenses

Converging lens = concave mirror

Diverging lens = convex mirror

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<tbody>
<tr>
<td>Converging</td>
<td>$p &lt; f$</td>
<td>Anywhere</td>
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<td>Virtual</td>
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Human Eye

- Has a converging lens which makes real, **inverted** images at the retina

- **Near point** is the closest distance which our lens can focus light on the retina
  - Distance increases with age
  - Typically at age 10 is 18cm, at 20 is 25cm, at 40 is 50cm, at 60 is 500cm or more
  - For problems will use 25cm for human eye

- **Nearsighted** – correct with a diverging lens

- **Farsighted** – correct with converging lens