0. 34-4

Image distance = object distance

Camera should be focused at
Distance \( (2)(1.2 \text{ m}) = 2.4 \text{ m} \)

2. 34-18

See example 4, p. 1122

\[ d' = \frac{d}{n} = \frac{2.0 \text{ m}}{1.33} = 1.5 \text{ m} \]
\[ n_{\text{air}} \sin \theta = n_{\text{water}} \sin 30 \]

\[ \theta = \sin^{-1} \left( \frac{n_{\text{water}}}{n_{\text{air}}} \sin 30 \right) \]

\[ \theta = \sin^{-1} [1.335 \times 0.30] = 42^\circ \]

---

4. 34-24

**Speed of light in crown glass**: \( v = \frac{c}{n} \)

- \( v \) also equals to \( \frac{d}{t} \)  
  \( (d = \text{thickness of crown glass}) \)
  \( (t = \text{transit time}) \)

\[ \frac{c}{n} = \frac{d}{t} \quad \rightarrow \quad t = \frac{dn}{c} \]

\[ \Delta t = t_{\text{blue}} - t_{\text{red}} = \frac{d}{c} (n_{\text{blue}} - n_{\text{red}}) \]

\[ \Delta t = \frac{1 \times 10^{-3} \text{m}}{3 \times 10^8 \text{m/s}} (1.530 - 1.510) = 6.67 \times 10^{-10} \text{s} \]

*This kind of dispersion changes the shape of the light pulse ... can be a big issue for fiber optic communications ...*
Light from bottom suffers two refractions. As in Example 1, 
\[ OP \tan \theta_1 = OP' \tan \theta_2. \]

And similarly,
\[ AP' \tan \theta_2 = AP'' \tan \theta_2. \]

Now, \( AP' = AO + OP' \). Therefore,
\[ AP'' \tan \theta_2 = (AO + OP') \tan \theta_2 = AO \tan \theta_2 + OP \tan \theta_2 = AO \tan \theta_2 + OP \tan \theta_1 \]

Hence,
\[ AP'' = \frac{AO \tan \theta_2 + OP \tan \theta_1}{\tan \theta_3} \]
But since angles are small, \( \tan \theta \approx \theta \). Hence,
\[ AP'' = AO(\tan \theta_2 / \theta_3) + OP(\tan \theta_1 / \theta_3) \]
But for small angles \( n_3 \theta_3 = n_2 \theta_2 \). Therefore,
\( \theta_2 / \theta_3 = n_3 / n_2 \) and \( \theta_1 / \theta_3 = n_3 / n_1 \)

Therefore,
\[ AP'' = AO(n_3 / n_2) + OP(n_3 / n_1) \]

Here, \( AO = 10 \text{ cm}, \ OP = 10 \text{ cm}, \ n_1 = 1.33, \ n_2 = 1.48, \ n_3 = 1.00. \)

Therefore, \( AP'' = \) distance bottom appears from top =
\[ 10 \left( \frac{1.00}{1.48} \right) + 10 \left( \frac{1.00}{1.33} \right) = 14.2 \text{ cm} \]

b) \( \Delta t = 2.0 \text{ mm} \left( 1 - \frac{1}{1.5} \right) = 0.67 \text{ mm}. \)

c) \( \Delta t = 8.0 \text{ mm} \left( 1 - \frac{1}{1.5} \right) = 2.57 \text{ mm}. \)
By (16) \( \theta_c' \),
\[ \theta_c' = \sin^{-1}(1/n) = \sin^{-1}(1/1.5) = 42°. \]
This is smallest angle that can be made with normal to surface.
Therefore, largest angle that can be made with surface
\[ = (90 - 42)° = 48°. \]

Let this distance be \( x \).
Then, shark can be seen when
\[ x/5m < \tan \theta_c \text{ and } \theta_c = 48.75°. \]
Therefore,
\[ x = 5m \tan (48.75°) = 5.7 \text{ m}. \]
8 \[ M = - \frac{s'}{s} = 2.0 \]
\[ s' = -2.0s \]
\[ \frac{1}{s} + \frac{1}{-2.0s} = \frac{1}{f} \]
\[ s = \frac{1}{2}f = \frac{1}{2}(20 \text{ cm}) = 10 \text{ cm} \]

9 \[ 34-71 \]

The ray diagram drawn for this situation shows that the image will be inverted, real, and enlarged. Applying the lens formula gives,
\[ \frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \]
\[ \frac{1}{s'} = \frac{1}{f} - \frac{1}{s} = \frac{1}{18 \text{ cm}} - \frac{1}{30 \text{ cm}} \]
\[ s' = 45 \text{ cm} \]
Assume the lens with a focal length $f_1 = 40\text{ cm}$ is to the left of the lens with a focal length $f_2 = 60\text{ cm}$. If parallel rays of light approach from the left, the first lens focuses the light at a point 40 cm to its right, which is 30 cm to the right of the right lens. That image becomes the object for the lens on the right, which focuses the light at a distance given by the lens formula.

$$\frac{1}{s'} = \frac{1}{f} - \frac{1}{s} = \frac{1}{60\text{ cm}} - \frac{1}{-30\text{ cm}}$$

$s' = 20\text{ cm}$

This is located 20 cm to the right of the right lens. In this case of parallel rays of light approaching from the left, the effective focal length measured from the center of the two lens system is located at $f_{\text{left}} = 20\text{ cm} - 5\text{ cm} = 15\text{ cm to the right of the system center}$

If parallel rays of light approach from the right, the right lens focuses the light at a point 60 cm to its left, which is 50 cm to the left of the left lens. That image becomes the object for the lens on the left, which focuses the light at a distance given by the lens formula.

$$\frac{1}{s'} = \frac{1}{f} - \frac{1}{s} = \frac{1}{40\text{ cm}} - \frac{1}{-50\text{ cm}}$$

$s' = 22.22\text{ cm} = 22\text{ cm}$

This is located 22 cm to the left of the left lens. In this case of parallel rays of light approaching from the right, the effective focal length measured from the center of the two lens system is located at $f_{\text{right}} = 22\text{ cm} - 5\text{ cm} = 17\text{ cm to the left of the system center}$
The f number is defined as the focal length of the lens divided by its diameter, \( f = \frac{f}{d} \). The iris changes the effective diameter of the lens, but not its focal length. Since we want to relate the f number to an exposure time and the f number is related to the effective diameter, let's define a new parameter called the exposure \( E \), which is the product of the amount of light incident on the film (which is inversely proportional to the area) and the exposure time, \( E = At \). For the first f number, 1.7, the exposure time is \( \frac{1}{250} \) s, therefore the exposure is

\[
E = At_1 = \pi R_1^2 t_1 = \frac{\pi d_1^2}{4} t_1 = \frac{\pi (f_1 f_1)^2}{4} t_1
\]

Similarly, for the second f number, the same exposure results when the proper exposure time is used. Therefore, the exposure equations for both f numbers are set equal to each other. We then solve for the second exposure time for an f number of 8.

\[
\frac{\pi (f_2 f_1)^2}{4} t_1 = \frac{\pi (f_2 f_2)^2}{4} t_2
\]

\[
f_2^2 t_1 = f_1^2 t_2
\]

\[
t_2 = \frac{f_2^2 t_1}{f_1^2} = \frac{(8)^2 \left( \frac{1}{250} \right) \text{s}}{(1.7)^2} = 8.9 \times 10^{-2} \text{ s}
\]

(a) Since the image must be focused on the retina, the focal length of the eye is equal to the image distance 2.2 cm for an object placed at infinity.

(b) For an object placed at 25 cm from the eye, the focal length must be

\[
\frac{1}{f} = \frac{1}{s} + \frac{1}{s'} = \frac{1}{25 \text{ cm}} + \frac{1}{2.2 \text{ cm}}
\]

\[
f = 2.0 \text{ cm}
\]
The net angular magnification is, according to Equation 34.33,
\[ M = \frac{\Theta'}{\Theta} = \frac{s'}{s} = \frac{25 \text{ cm}}{s} = 550 \]
where \( s \) is found from the lens formula.
\[
\frac{1}{s} = \frac{1}{0.40 \text{ cm}} - \frac{1}{22.4 \text{ cm}}
\]
\[ s = 0.407 \text{ cm} \]
The ocular focal length is then
\[ \frac{25 \text{ cm}}{s'} = 550 \]
\[ f_{ocular} = \frac{25 \text{ cm}}{550} = 25 \text{ cm} \left( \frac{22.4 \text{ cm}}{0.407 \text{ cm}} \right) = 2.5 \text{ cm} \]
Then, then the ocular magnification is
\[ M_{ocular} = \frac{25 \text{ cm}}{2.5 \text{ cm}} = 10 \]

\[ M = \frac{\Theta'}{\Theta} = \frac{f_{objective}}{f_{ocular}} = \frac{90 \text{ cm}}{1.25 \text{ cm}} = 72 \]