VERSION A

PART I.

Using the SCANTRON sheet answer the questions in Part I.

1. If the object distance for a thin lens is 600 cm and the image distance is 300 cm, what is the focal length in cm?

   a. 100 b. 200 c. 300 d. 150 e. 50

2. An antelope is at a distance of 20.0 m from a converging lens of focal length 30.0 cm. The lens forms an image of the animal. If the antelope runs away from the lens at a speed of 5.00 m/s, how fast does the image move? Does the image move toward or away from the lens?

   a. 1.16mm/s away from the lens
   b. 1.16mm/s toward the lens
   c. 2.32mm/s away from the lens
   d. 2.32 mm/s toward the lens
   e. none of the above

3. Estimate the distance in cm between the central bright region and the third dark fringe on a screen 5.00 m from two slits 0.500 mm apart, when the slits are illuminated by 500 nm light.

   a. 3.47 b. 2.15 c. 1.75 d. 1.50 e. 1.25

4. A soap bubble ($n = 1.35$) is floating in air. If the thickness of the bubble wall is 115 nm, what is the wavelength in nm of the light most strongly reflected?

   a. 662 b. 621 c. 653 d. 615 e. 631

5. Monochromatic light is beamed into a Michelson interferometer. The movable mirror is displaced 0.382 mm, causing the interferometer pattern to reproduce itself 1 700 times. Determine the wavelength of the light(in nm).?

   a. 449nm b. 674nm c. 898nm d. 299nm e. none of the above

6. At what distance (in km) could one theoretically distinguish two automobile headlights separated by 1.5 meters? Assume a pupil diameter of 0.5 cm and yellow headlights seen at wavelength 5×10^{-7} m. Assume eye fluid has an average *n=1.33*

   a. 6 b. 12 c. 9 d. 3 e. 16

7. Light reflected off a plate-glass window (n = 1.5) is found to be completely polarized at angle-of-incidence q. Find q.

   a. 56.3° b. 5.7° c. 21.2° d.18.6 e. 33.7°

Version B

1. If the object distance for a thin lens is 300 cm and the image distance is 300 cm, what is the focal length in cm?

   a. 100 b. 200 c. 300 d. 150 e. 50

2 An antelope is at a distance of 20.0 m from a converging lens of focal length 30.0 cm. The lens forms an image of the animal. If the antelope runs toward the lens at a speed of 5.00 m/s, how fast does the image move? Does the image move toward or away from the lens?

   a. 1.16mm/s away from the lens b. 1.16mm/s toward the lens
   c. 2.32mm/s away from the lens d. 2.32 mm/s toward the lens
   e. none of the above

3 Estimate the distance in cm between the peak of the central bright region and the fifth dark fringe on a screen 5.00 m from two slits 0.500 mm apart, when the slits are illuminated by 500 nm light.

   a. 3.47 b. 2.15 c. 1.75 d. 1.50 e. 1.25

4 A soap bubble ($n = 1.35$) is floating in air. If the thickness of the bubble wall is 123nm, what is the wavelength in nm of the light most strongly reflected?

   a. 664 b. 621 c. 653 d. 615 e. 631

5 Monochromatic light is beamed into a Michelson interferometer. The movable mirror is displaced 0.382 mm, causing the interferometer pattern to reproduce itself 1 500 times. Determine the wavelength of the light(in nm).?

   a. 449nm b. 509nm c. 898nm d. 299nm e. none of the above

6 At what distance in km could one theoretically distinguish two automobile headlights separated by 1.35 meters? Assume a pupil diameter of 0.4 cm and yellow headlights seen at wavelength 450nm. Assume eye fluid has an average $n=1.33$

   a. 6 b. 12 c. 13 d. 14 e. 16

7 Light reflected off a plate-glass window ($n = 1.45$) is found to be completely polarized at angle-of-incidence q. Find q.

   a. 56.3° b. 55.4° c. 21.2° d.18.6 e. 33.7°

VERSION C

1. If the object distance for a thin lens is 300 cm and the image distance is 150 cm, what is the focal length in cm?

   a. 100 b. 200 c. 300 d. 150 e. 50

2 An antelope is at a distance of 20.0 m from a converging lens of focal length 30.0 cm. The lens forms an image of the animal. If the antelope runs toward the lens at a speed of 10.00 m/s, how fast does the image move? Does the image move toward or away from the lens?

   a. 1.16mm/s away from the lens b. 1.16mm/s toward the lens
   c. 2.32mm/s away from the lens d. 2.32 mm/s toward the lens
   e. none of the above

3 Estimate the distance in cm between the peak of the central bright region and the fourth dark fringe on a screen 5.00 m from two slits 0.500 mm apart, when the slits are illuminated by 500 nm light.

   a. 3.47 b. 2.15 c. 1.75 d. 1.50 e. 1.25

4 A soap bubble (n = 1.35) is floating in air. If the thickness of the bubble wall is 123nm, what is the wavelength in nm of the light most strongly reflected?

   a. 664 b. 621 c. 653 d. 615 e. 631

5 Monochromatic light is beamed into a Michelson interferometer. The movable mirror is displaced 0.382 mm, causing the interferometer pattern to reproduce itself 1 500 times. Determine the wavelength of the light(in nm).?

   a. 449nm b. 509nm c. 898nm d. 299nm e. none of the above

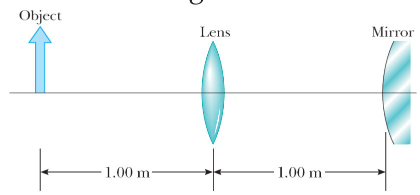
6 At what distance in km could one theoretically distinguish two automobile headlights separated by 1.35 meters? Assume a pupil diameter of 0.4 cm and yellow headlights seen at wavelength 450nm. Assume eye fluid has an average $n=1.33$

   a. 6 b. 12 c. 13 d. 14 e. none of the above

7 Light reflected off a plate-glass window (n = 1.45) is found to be completely polarized at angle-of-incidence q. Find q.

   a. 56.3° b. 55.4° c. 21.2° d.18.6 e. 33.7°

1 The lens and mirror in have focal lengths of +80.0 cm and –50.0 cm, respectively. An object is placed 1.00 m to the left of the lens as shown. Locate the final image, formed by light that has gone through the lens twice. State whether the image is upright or inverted, and determine the overall magnification.



2 An air wedge is formed between two glass plates separated at one edge by a very fine wire as shown. When the wedge is illuminated from above by 600-nm light and viewed from above, 30 dark fringes are observed.

a) Calculate the radius of the wire. (8p)

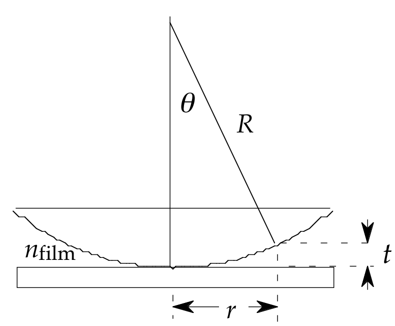
b) Calculate the number of dark fringes visible in this setup if the space between the glass plates was filled with fluid of refractive index $n_{fluid}=1.4$ ($n_{fluid} < n_{glass}$). (5p)

3 a) A circular radar antenna on a Coast Guard ship has a diameter of 2.10 m and radiates at a frequency of 15.0 GHz. Two small boats are located 9.00 km away from the ship. How close together could the boats be and still be detected as two objects?

b) A diffraction grating has 4 200 rulings/cm. On a screen 2.00 m from the grating, it is found that for a particular order *m*, the maxima corresponding to two closely spaced wavelengths of sodium (589.0 nm and 589.6 nm) are separated by 1.59 mm. Determine the value of *m*.

4 A plano-convex lens has index of refraction *n*. The curved side of the lens has radius of curvature *R* and rests on a flat glass surface of the same index of refraction, with a film of index n_{fluid} between them, as shown.
The lens is illuminated from above by light of wavelength λ.
Show that the dark Newton's rings have radii given approximately by

$$r \approx \sqrt{\frac{m\lambda R}{n_{film}}}$$



(b) How does the n_{fluid} value compared to that of n_{glass} affect this situation (explain)

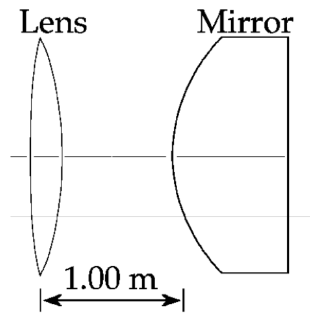
(c)When 650-nm light is incident normally, 55 bright rings are observed with the last one right on the edge of the lens. What is the radius of curvature of the convex surface of the lens?

(d) What is the focal length of the lens?

5 Use the Fermat Principle to obtain The Law of Reflection.

ANSWER 1

Start with the first pass through the lens.



$q_1 = 400\text{ cm}$ to right of lens

For the mirror,

$p_2 = -300\text{ cm}$

$$\frac{1}{q_2} = \frac{1}{f_2} - \frac{1}{p_2} = \frac{1}{(-50.0\text{ cm})} - \frac{1}{(-300\text{ cm})}$$

$q_2 = -60.0\text{ cm}$

For the second pass through the lens,

$p_3 = 160\text{ cm}$

$$\frac{1}{q_3} = \frac{1}{f_1} - \frac{1}{p_3} = \frac{1}{80.0\text{ cm}} - \frac{1}{160\text{ cm}}$$

$q_3 = \boxed{160\text{ cm to the left of lens}}$

$$M_1 = -\frac{q_1}{p_1} = -\frac{400\text{ cm}}{100\text{ cm}} = -4.00$$

$$M_2 = -\frac{q_2}{p_2} = -\frac{(-60.0\text{ cm})}{(-300\text{ cm})} = -\frac{1}{5}$$

$$M_3 = -\frac{q_3}{p_3} = -\frac{160\text{ cm}}{160\text{ cm}} = -1$$

$M = M_1 M_2 M_3 = \boxed{-0.800}$

Since $M<0$ the final image is $\boxed{\text{inverted}}$.

For destructive interference in the air,
(since there is a phase shift of pi between the incident rays reflected fromt the top (glass air) and bottom (air-glass) interfaces

$$2t = m\lambda .$$

For 30 dark fringes, including the one where the plates meet,

$$t = \frac{29(600 \text{ nm})}{2} = 8.70 \times 10^{-6} \text{ m} .$$

Therefore, the *radius* of the wire is

a) $$r = \frac{t}{2} = \frac{8.70 \ \mu\text{m}}{2} = \boxed{4.35 \ \mu\text{m}} .$$

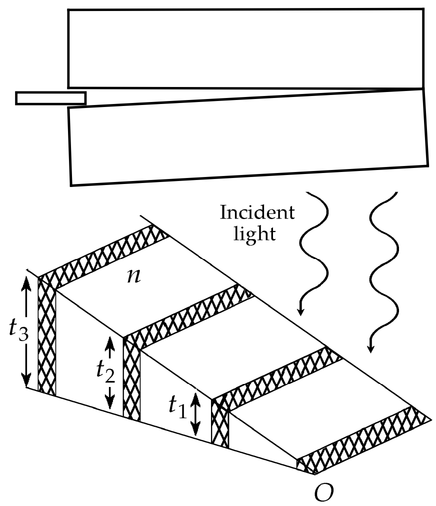


FIG. P27.19

b) Since the refractive index of the fluid filling the gap is less than the refractive index of the glass, there will be no change in the phase relations of the incident rays reflected from the top (glass air) and bottom (air-glass) interfaces
Dark fringe condition is given by:

$2t = m\frac{\lambda}{n_{fluid}}$ so that $m = 2t\frac{n_{fluid}}{\lambda}$ and $m_{\max} = 2t\frac{n_{fluid}}{\lambda} = 2 \times 8.70x10^{-6} \times \frac{1.4}{600 \times 10^{-9}} = 2 \times 8.70 \times \frac{1.4}{6} \times 10 = 40.6$

Since m=0 is dark fringe too ,and the fragment of 41st dark fringe will be showing on the edge.

There will be 42 dark fringes.
(answering 41 dark fringes is acceptable too (m=40 +1 (for m=0))

Question 3

a)

$$1.22\frac{\lambda}{D} = \frac{d}{L}$$

$$\lambda = \frac{c}{f} = 0.020\,0 \text{ m}$$

$D = 2.10$ m $\qquad L = 9\,000$ m

$$d = 1.22\frac{(0.020\,0 \text{ m})(9\,000 \text{ m})}{2.10 \text{ m}} = \boxed{105 \text{ m}}$$

b) $d = \dfrac{1}{4\,200/\text{cm}} = 2.38 \times 10^{-6} \text{ m} = 2\,380 \text{ nm}$.

$d\sin\theta = m\lambda$ or $\theta = \sin^{-1}\left(\dfrac{m\lambda}{d}\right)$ and $y = L\tan\theta = L\tan\left[\sin^{-1}\left(\dfrac{m\lambda}{d}\right)\right]$.

Thus,

$$\Delta y = L\left\{\tan\left[\sin^{-1}\left(\frac{m\lambda_2}{d}\right)\right] - \tan\left[\sin^{-1}\left(\frac{m\lambda_1}{d}\right)\right]\right\}.$$

For $m = 1$,

$$\Delta y = (2.00 \text{ m})\left\{\tan\left[\sin^{-1}\left(\frac{589.6}{2\,380}\right)\right] - \tan\left[\sin^{-1}\left(\frac{589}{2\,380}\right)\right]\right\} = 0.554 \text{ mm}.$$

For $m = 2$,

$$\Delta y = (2.00 \text{ m})\left\{\tan\left[\sin^{-1}\left(\frac{2(589.6)}{2\,380}\right)\right] - \tan\left[\sin^{-1}\left(\frac{2(589)}{2\,380}\right)\right]\right\} = 1.54 \text{ mm}.$$

For $m = 3$,

$$\Delta y = (2.00 \text{ m})\left\{\tan\left[\sin^{-1}\left(\frac{3(589.6)}{2\,380}\right)\right] - \tan\left[\sin^{-1}\left(\frac{3(589)}{2\,380}\right)\right]\right\} = 5.04 \text{ mm}.$$

Thus, the observed order must be $\boxed{m = 2}$.

4The shift between the waves reflecting from the top and bottom surfaces of the film at the point where the film has thickness t is $\delta = 2tn_{\text{film}} + \frac{\lambda}{2}$, with the factor of $\frac{\lambda}{2}$ being due to a phase reversal at *one* of the surfaces.

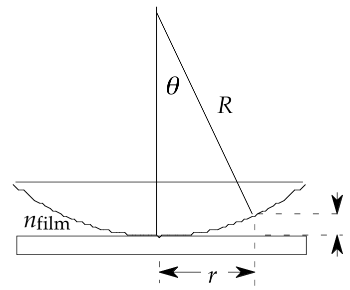


FIG. P37.62

For the dark rings (destructive interference), the total shift should be $\delta = \left(m + \frac{1}{2}\right)\lambda$ with $m = 0,\ 1,\ 2,\ 3,\ \ldots$. This requires that $t = \frac{m\lambda}{2n_{\text{film}}}$.

To find t in terms of r and R, $R^2 = r^2 + (R - t)^2$

so $r^2 = 2Rt + t^2$.

Since t is much smaller than R, $t^2 << 2Rt$

and $r^2 \approx 2Rt = 2R\left(\frac{m\lambda}{2n_{\text{film}}}\right)$.

Thus, where m is an integer, $\boxed{r \approx \sqrt{\frac{m\lambda R}{n_{\text{film}}}}}$.

b) If $n_{\text{fluid}} > n_{\text{glass}}$ or $n_{\text{fluid}} < n_{\text{glass}}$ the structure of the interferometric pattern would only be affected as far as the changes of the radii of each dark fringe.
However, if the $n_{\text{fluid}} = n_{\text{glass}}$
The dark fringes would become bring ones and vice versa. The radii of narrow bring fringes would correspond to the radii of the dark fringes from part (a)

c) Constructive interference in the reflected light requires $2t = \left(m + \frac{1}{2}\right)\lambda$. The first bright ring has $m = 0$ and the 55th has $m = 54$, so at the edge of the lens

$$t = \frac{54.5\left(650 \times 10^{-9}\ \text{m}\right)}{2} = 17.7\ \mu\text{m}.$$

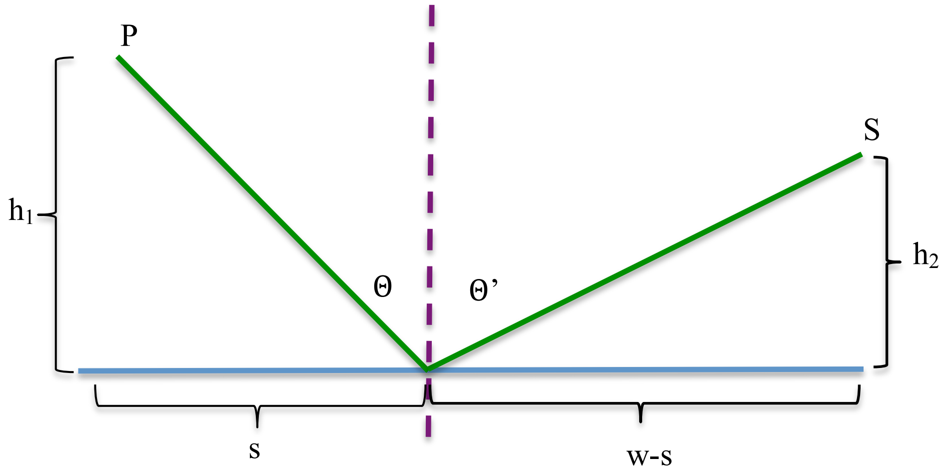
Now from the geometry in Figure 37.18, the distance from the center of curvature down to the flat side of the lens is

$$\sqrt{R^2 - r^2} = R - t \text{ or } R^2 - r^2 = R^2 - 2Rt + t^2$$

$$R = \frac{r^2 + t^2}{2t} = \frac{\left(5.00 \times 10^{-2}\ \text{m}\right)^2 + \left(1.77 \times 10^{-5}\ \text{m}\right)^2}{2\left(1.77 \times 10^{-5}\ \text{m}\right)} = \boxed{70.6\ \text{m}}$$

(d) $$\frac{1}{f} = (n - 1)\left(\frac{1}{R_2} - \frac{1}{R_2}\right) = 0.520\left(\frac{1}{\infty} - \frac{1}{-70.6\ \text{m}}\right) \text{ so } f = \boxed{136\ \text{m}}$$

5



Time it takes to travel from point
P to point S along the path shown is given by

$$t = \frac{\sqrt{s^2 + h_1^2}}{v} + \frac{\sqrt{(w-s)^2 + h_2^2}}{v}$$

According to the Fermat Principle, the actual path taken by light will be such that this time will be at minimum.
This corresponds to condition:

$$\frac{\partial t}{\partial s} = 0 \Rightarrow -\frac{1}{v}\frac{2s}{2\sqrt{s^2 + h_1^2}} - \frac{-2(w-s)}{2\sqrt{(w-s)^2 + h_2^2}} = 0$$

$$\frac{s}{\sqrt{s^2 + h_1^2}} = \frac{(w-s)}{\sqrt{(w-s)^2 + h_2^2}}$$

$$\sin\theta = \sin\theta'$$

$$\theta = \theta'$$