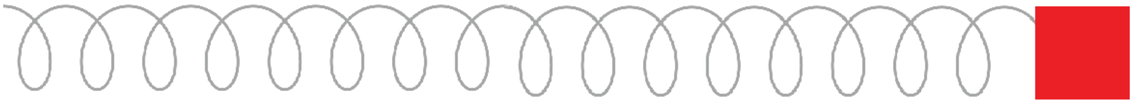
Kapitel 14

14.7. When a body of unknown mass is attached to an ideal spring with force constant 120 N/m, it is found to vibrate with a frequency of 6.00 Hz. Find (a) the period of the motion; (b) the angular frequency; (c) the mass of the body.

a) $T = {}^{1}/_{f} = 0.167\ s$

b) $\omega = 2\pi f = 37.7\ rad$

c) $m = \frac{k}{\omega^2} = 0.0844\ kg$



14.9. An object is undergoing SHM with period 0.900 s and amplitude 0.320 m. At t = 0 the object is at x = 0.320 m and is instantaneously at rest. Calculate the time it takes the object to go (a) from x = 0.320 m to x = 0.160 m and (b) from x = 0.160 m to x = 0.

$x(t) = A \cos \omega t$

a) $x(t) = 0.160\ m \Rightarrow \cos \omega\, t = \frac{0.160}{0.320} = \frac{1}{2} \Rightarrow \omega t = \frac{\pi}{3} \Rightarrow t = \frac{\pi}{3\omega} = \frac{\pi T}{6\pi} = \frac{T}{6} = 0.150\ s$

b) $x(t) = 0 \Rightarrow \cos \omega\, t = 0 \Rightarrow \omega t = \frac{\pi}{2} \Rightarrow t = \frac{\pi}{2\omega} = \frac{\pi T}{4\pi} = \frac{T}{4} = 0.225\ s$

$0.225 - 0.150 = 0.075\ s$

14.24. A small block is attached to an ideal spring and is moving in SHM on a horizontal, frictionless surface. The amplitude of the motion is 0.250 m and the period is 3.20 s. What are the speed and acceleration of the block when x = 0.160 m?

$$E = ½mv_x^2 + ½kx^2 = ½kA^2 \qquad T = 2\pi\sqrt{\frac{m}{k}}$$

$$v_x = \sqrt{\frac{k}{m}\cdot(A^2 - x^2)} = \frac{2\pi}{T}\sqrt{(A^2 - x^2)} = 0.377\ m/s$$

$$a_x = \frac{F_x}{m} = -\frac{kx}{m} = -\frac{4\pi^2 x}{T^2} = -0.617\ m/s^2$$

14.27. A 0.500-kg glider, attached to the end of an ideal spring with force constant k = 450 N/m, undergoes SHM with an amplitude of 0.040 m. Compute (a) the maximum speed of the glider; (b) the speed of the glider when it is at x = -0.015 m; (c) the magnitude of the maximum acceleration of the glider; (d) the acceleration of the glider x = -0.015 m; (e) the total mechanical energy of the glider at any point in its motion.

$$E = \frac{1}{2}kA^2 = \frac{1}{2}mv_x^2 + \frac{1}{2}kx^2 \qquad -kx = ma_x$$

a) $v_{x,max} = \omega A = \sqrt{\frac{k}{m}}\cdot A = 1.20\ m/s$

b) $v_x = \sqrt{\frac{k}{m}\cdot(A^2 - x^2)} = \pm 1.11\ m/s$

c) $a_{x,max} = \omega^2 A = \frac{k}{m}A = 36\ m/s^2$

d) $a_x = -\frac{kx}{m} = +13.5\ m/s^2$

e) $E = \frac{1}{2}kA^2 = 0.360\ J$

Kapitel 15

15.6 •• A fisherman notices that his boat is moving up and down periodically, owing to waves on the surface of the water. It takes 2.5 s for the boat to travel from its highest point to its lowest, a total distance of 0.62 m. The fisherman sees that the wave crests are spaced 6.0 m apart. (a) How fast are the waves traveling? (b) What is the amplitude of each wave? (c) If the total vertical distance traveled by the boat were 0.30 m but the other data remained the same, how would the answers to parts (a) and (b) be affected?

a) $v = \frac{\lambda}{T} = \frac{6.0}{5.0} = 1.2\ m/s$

b) $A = \frac{0.62}{2} = 0.31\ m$

c) $Allt\ blir\ detsamma\ utom\ amplituden\ som\ blir\ 0.15\ m$

15.8 • A certain transverse wave is described by

$$y(x, t) = (6.50\text{ mm}) \cos 2\pi\left(\frac{x}{28.0\text{ cm}} - \frac{t}{0.0360\text{ s}}\right)$$

Determine the wave's (a) amplitude; (b) wavelength; (c) frequency; (d) speed of propagation; (e) direction of propagation.

$y(x,t) = A\cos 2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)$

a) $A = 6.50\ mm$

b) $\lambda = 28.0\ cm$

c) $f = \frac{1}{T} = 27.8\ Hz$

d) $v = f\lambda = \frac{\lambda}{T} = 7.78\ m/s$

e) $-\ framför\ tidstermen\ \Rightarrow\ längs\ den\ positiva\ x\text{-}axeln$

15.19 • A thin, 75.0-cm wire has a mass of 16.5 g. One end is tied to a nail, and the other end is attached to a screw that can be adjusted to vary the tension in the wire. (a) To what tension (in newtons) must you adjust the screw so that a transverse wave of wavelength 3.33 cm makes 875 vibrations per second? (b) How fast would this wave travel?

$$\mu = \frac{0.0165}{0.750} kg/m$$

a) $v = \sqrt{\frac{F}{\mu}} = f\lambda \Rightarrow F = \mu(f\lambda)^2 = 18.7\ N$

b) $v = f\lambda = 29.1\ m/s$

15.23 • A horizontal wire is stretched with a tension of 94.0 N, and the speed of transverse waves for the wire is 492 m/s. What must the amplitude of a traveling wave of frequency 69.0 Hz be in order for the average power carried by the wave to be 0.365 W?

$$P_{av} = \frac{1}{2}\mu(\omega A)^2 v = \frac{F(\omega A)^2}{2v} \Rightarrow A = \sqrt{\frac{2vP_{av}}{F\omega^2}} = 4.51\ mm$$

15.40 • A 1.50-m-long rope is stretched between two supports with a tension that makes the speed of transverse waves 48.0 m/s. What are the wavelength and frequency of (a) the fundamental; (b) the second overtone; (c) the fourth harmonic?

$$f_n = \frac{nv}{2L}; \quad \lambda_n = {}^{2L}/_{n}$$

a) $f_1 = \frac{v}{2L} = 16.0\ Hz; \quad \lambda_1 = 2L = 3.00\ m$

b) $f_3 = 3f_1 = 48.0\ Hz; \quad \lambda_3 = {}^{\lambda_1}/_{3} = 1.00\ m$

c) $f_4 = 4f_1 = 64.0\ Hz; \quad \lambda_4 = {}^{\lambda_1}/_{4} = 0.75\ m$

15.49 • **Guitar String.** One of the 63.5-cm-long strings of an ordinary guitar is tuned to produce the note B_3 (frequency 245 Hz) when vibrating in its fundamental mode. (a) Find the speed of transverse waves on this string. (b) If the tension in this string is increased by 1.0%, what will be the new fundamental frequency of the string? (c) If the speed of sound in the surrounding air is 344 m/s, find the frequency and wavelength of the sound wave produced in the air by the vibration of the B_3 string. How do these compare to the frequency and wavelength of the standing wave on the string?

a) $v = 2Lf_1 = 311\ m/s$

b) $v = \sqrt{\frac{F}{\mu}}$ om F ökar med 1% ökar v med en faktor $\sqrt{1.01}$ och därmed även f_1

$f_1' = f_1 \cdot \sqrt{1.01} = 246\ Hz$

c) $v = f\lambda$ frekvensen påverkas inte $\Rightarrow \frac{\lambda_{luft}}{\lambda} = \frac{v_{luft}}{v} \Rightarrow \lambda_{luft} = 1.40\ m$

Kapitel 16

16.15 •• **Longitudinal Waves in Different Fluids.** (a) A longitudinal wave propagating in a water-filled pipe has intensity $3.00 \times 10^{-6}\ \mathrm{W/m^2}$ and frequency 3400 Hz. Find the amplitude A and wavelength λ of the wave. Water has density $1000\ \mathrm{kg/m^3}$ and bulk modulus 2.18×10^9 Pa. (b) If the pipe is filled with air at pressure 1.00×10^5 Pa and density $1.20\ \mathrm{kg/m^3}$, what will be the amplitude A and wavelength λ of a longitudinal wave with the same intensity and frequency as in part (a)? (c) In which fluid is the amplitude larger, water or air? What is the ratio of the two amplitudes? Why is this ratio so different from 1.00?

$B_{luft} = 1.42 \cdot 10^5\ Pa; \quad \rho_{luft} = 1.20\ kg/m^3$

a) $I = \frac{1}{2}\rho(\omega A)^2 v = \frac{1}{2}\sqrt{\rho B}(\omega A)^2 \Rightarrow A = \sqrt{\frac{2I}{\sqrt{\rho B}\omega^2}} = 9.44 \cdot 10^{-11}\ m; \quad \lambda = \frac{v}{f} = \frac{1}{f}\sqrt{\frac{B}{\rho}} = 0.434\ m$

b) $A = \sqrt{\frac{2I}{\sqrt{\rho B}\omega^2}} = 5.64 \cdot 10^{-9}\ m$

$\lambda = \frac{1}{f}\sqrt{\frac{B}{\rho}} = 0.101\ m$

c) De mycket tätare vattenmolekylerna behöver en mindre amplitud för att överföra samma mängd energi.

16.26 • The fundamental frequency of a pipe that is open at both ends is 594 Hz. (a) How long is this pipe? If one end is now closed, find (b) the wavelength and (c) the frequency of the new fundamental.

$f_n = \frac{nv}{2L}; \quad \lambda_n = {}^{2L}/_{n} \quad \textit{öppen pipa}$

$f_n = \frac{nv}{4L}; \quad \lambda_n = {}^{4L}/_{n} \quad n\ udda \quad sluten\ pipa$

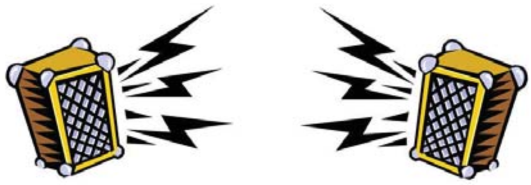
$v = 344\ m/s$

a) $L = \frac{v}{2f_1} = 28.9\ cm$

b) $\lambda_1 = 4L = 1.16\ m$

c) $f_1 = \frac{v}{4L} = 297\ Hz$

16.36 • Two loudspeakers, *A* and *B*, are driven by the same amplifier and emit sinusoidal waves in phase. The frequency of the waves emitted by each speaker is 172 Hz. You are 8.00 m from *A*. What is the closest you can be to *B* and be at a point of destructive interference?



$v = 344\ m/s$

$|r_A - r_B| = (n + ½)\lambda; \quad \lambda = \frac{v}{f} \Rightarrow |r_A - r_B| = 2.00 \cdot (n + ½)$

$Minsta\ värdet\ på\ r_B\ hittas\ då\ r_B < r_A \Rightarrow r_B = r_A - 2.00 \cdot (n + ½)$

$Minsta\ värdet\ på\ r_B\ hittas\ när\ n = 3 \Rightarrow r_B = 1.00\ m$

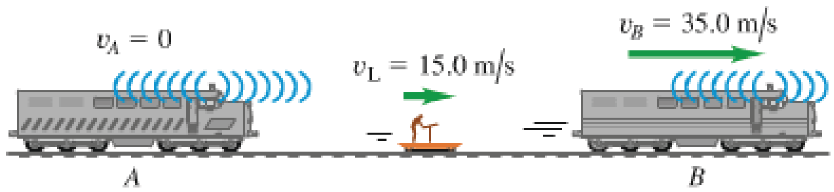
16.40 •• Two guitarists attempt to play the same note of wavelength 6.50 cm at the same time, but one of the instruments is slightly out of tune and plays a note of wavelength 6.52 cm instead. What is the frequency of the beat these musicians hear when they play together?

$v = 344\ m/s$

$f = \frac{v}{\lambda} \qquad f_{beat} = |f_A - f_B| = \left|\frac{v}{\lambda_A} - \frac{v}{\lambda_B}\right| = 16.2\ Hz$

16.45 • Two train whistles, A and B, each have a frequency of 392 Hz. A is stationary and B is moving toward the right (away from A) at a speed of 35.0 m/s. A listener is between the two whistles and is moving toward the right with a speed of 15.0 m/s (Fig. E16.45). No wind is blowing. (a) What is the frequency from A as heard by the listener? (b) What is the frequency from B as heard by the listener? (c) What is the beat frequency detected by the listener?

Figure **E16.45**



$$f' = f \cdot \frac{v - v_L}{v - v_S} \qquad v = 344\ m/s$$

a) $f' = 392 \cdot \frac{344 - 15.0}{344} = 375\ Hz$

b) $f' = 392 \cdot \frac{344 + 15.0}{344 + 35.0} = 371\ Hz$

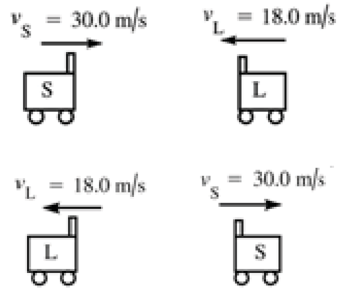
c) $f_{beat} = |f_a - f_b| = 4\ Hz$

16.49 • A car alarm is emitting sound waves of frequency 520 Hz. You are on a motorcycle, traveling directly away from the car. How fast must you be traveling if you detect a frequency of 490 Hz?

$$f' = f \cdot \frac{v - v_L}{v - v_S} \qquad v = 344\ m/s$$

$$v - v_L = v\frac{f'}{f} \Rightarrow v_L = v\left(1 - \frac{f'}{f}\right) = 19.8\ m/s$$

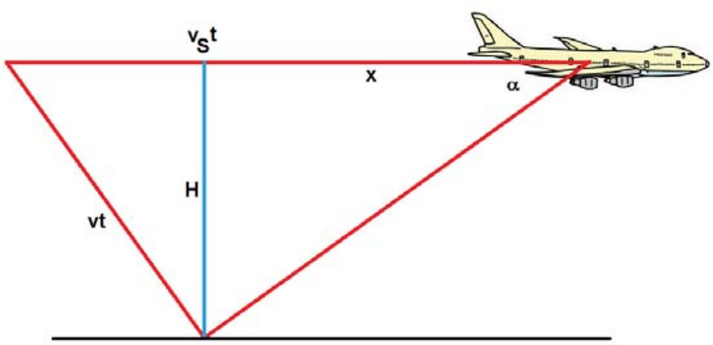
16.50 • A railroad train is traveling at 30.0 m/s in still air. The frequency of the note emitted by the train whistle is 262 Hz. What frequency is heard by a passenger on a train moving in the opposite direction to the first at 18.0 m/s and (a) approaching the first and (b) receding from the first?



$f' = f \cdot \frac{v - v_L}{v - v_S}$ $v = 344\ m/s$

a) $f' = 262 \cdot \frac{344+18}{344-30} = 302\ Hz$ b) $f' = 262 \cdot \frac{344-18}{344+30} = 228\ Hz$

16.55 •• A jet plane flies overhead at Mach 1.70 and at a constant altitude of 950 m. (a) What is the angle α of the shock-wave cone? (b) How much time after the plane passes directly overhead do you hear the sonic boom? Neglect the variation of the speed of sound with altitude.



$v = 344\ m/s;$ $v_S = 1.70 \cdot v$

a) $\sin\alpha = \frac{v}{v_S} \Rightarrow \alpha = \sin^{-1}\frac{1}{1.70} = 36.0°$

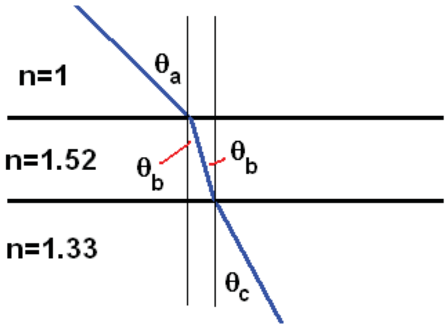
b) $\tan\alpha = \frac{H}{x} \Rightarrow x = \frac{H}{\tan\alpha}$ $\Delta t = \frac{x}{v_S} = \frac{H}{1.70 \cdot v \tan\alpha} = 2.24\ s$

33.12 •• A horizontal, parallel-sided plate of glass having a refractive index of 1.52 is in contact with the surface of water in a tank. A ray coming from above in air makes an angle of incidence of 35.0° with the normal to the top surface of the glass. (a) What angle does the ray refracted into the water make with the normal to the surface? (b) What is the dependence of this angle on the refractive index of the glass?

$$n_a \sin\theta_a = n_b \sin\theta_b = n_c \sin\theta_c$$

a) $\sin\theta_c = \frac{1}{1.33}\sin 35{,}0° \Rightarrow \theta_c = 25.5°$

b) Denna vinkel är oberoende av glasets brytningsindex



33.13 •• In a material having an index of refraction n, a light ray has frequency f, wavelength λ, and speed v. What are the frequency, wavelength, and speed of this light (a) in vacuum and (b) in a material having refractive index n'? In each case, express your answers in terms of *only* f, λ, v, n, and n'.

a) $f_0 = f;\quad \lambda_0 = n\lambda;\quad c = nv$

b) $f' = f_0 = f;\ \lambda' = \frac{\lambda_0}{n'} = \frac{n\lambda}{n'};\quad v' = \frac{c}{n'} = \frac{nv}{n'}$

33.26 • A beam of light strikes a sheet of glass at an angle of 57.0° with the normal in air. You observe that red light makes an angle of 38.1° with the normal in the glass, while violet light makes a 36.7° angle. (a) What are the indexes of refraction of this glass for these colors of light? (b) What are the speeds of red and violet light in the glass?

a) $n = \frac{\sin\theta_a}{\sin\theta_b}$

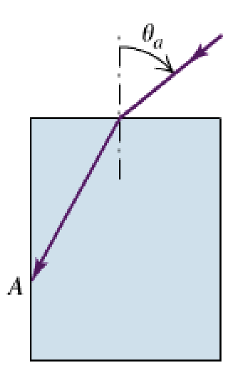
För rött: $= 1.36$ **För violett:** $n = 1.40$

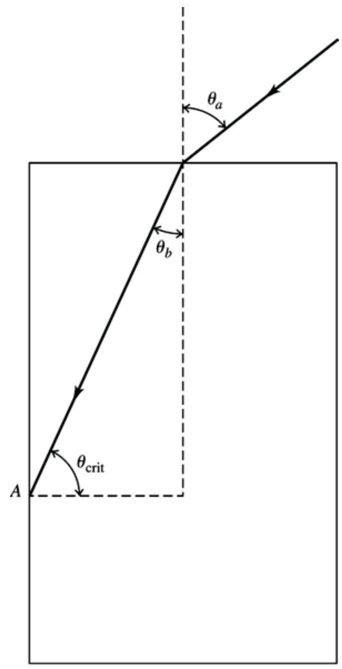
b) $= \frac{c}{n}$

För rött: $= 2.21 \cdot 10^8\ m/s$ **För violett:** $v = 2.14 \cdot 10^8\ m/s$

33.43 •• A ray of light is incident in air on a block of a transparent solid whose index of refraction is n. If $n = 1.38$, what is the *largest* angle of incidence θ_a for which total internal reflection will occur at the vertical face (point A shown in Fig. P33.43)?

Figure **P33.43**





Den kritiska infallsvinkeln vid A: $\sin\theta_{crit} = \frac{1}{n}$

Brytningen vid ovansidan: $\sin\theta_a = n\sin\theta_b$

Men $\theta_b = 90° - \theta_{crit} \Rightarrow \sin\theta_a = n\sin(90° - \theta_{crit}) = n\cos\theta_{crit} =$

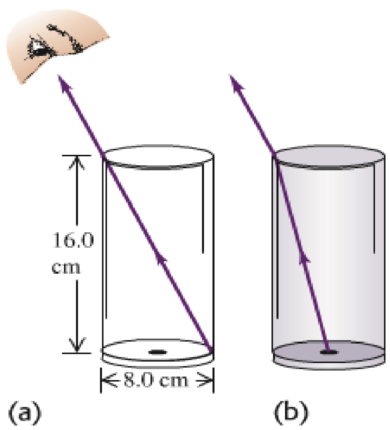
$= n\sqrt{1-\sin^2\theta_{crit}} = n\sqrt{1-\frac{1}{n^2}} = \sqrt{n^2-1}$

$\sin\theta_a = 0.951 \Rightarrow \theta_a = 72.0°$

Om θ_a **är större än** $72.0°$ **blir infallsvinkeln vid A mindre och vi får ingen totalreflektion.**

33.49 • You sight along the rim of a glass with vertical sides so that the top rim is lined up with the opposite edge of the bottom (Fig. P33.49a). The glass is a thin-walled, hollow cylinder 16.0 cm high. The diameter of the top and bottom of the glass is 8.0 cm. While you keep your eye in the same position, a friend fills the glass with a transparent liquid, and you then see a dime that is lying at the center of the bottom of the glass (Fig. P33.49b). What is the index of refraction of the liquid?

Figure **P33.49**



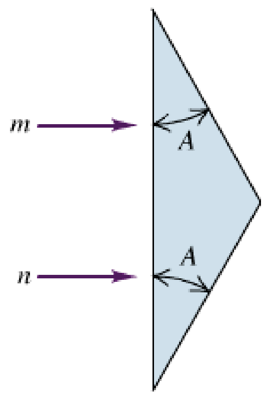
$$\tan\theta_a = \frac{1}{2};\quad \tan\theta_b = \frac{1}{4};\quad \sin\alpha = \frac{\tan\alpha}{\sqrt{1+\tan^2\alpha}}$$

$$\sin\theta_a = \frac{1}{\sqrt{5}};\quad \sin\theta_b = \frac{1}{\sqrt{17}}$$

$$n = \frac{\sin\theta_a}{\sin\theta_b} = \sqrt{\frac{17}{5}} = 1.84$$

33.53 •• The prism shown in Fig. P33.53 has a refractive index of 1.66, and the angles *A* are 25.0°. Two light rays *m* and *n* are parallel as they enter the prism. What is the angle between them after they emerge?

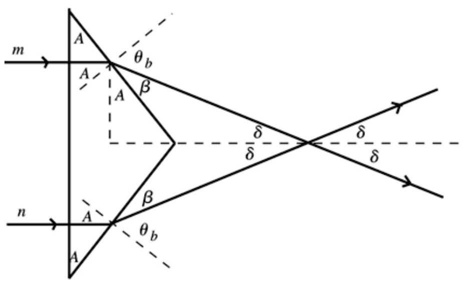
Figure **P33.53**



Strålarna passerar den första ytan vinkelrätt, d.v.s. ingen brytning.

Vid andra sidan blir infallsvinkeln $\theta_a = 25.0°$ och brytningsvinkeln blir $\sin\theta_r = n\sin\theta_a \;\Rightarrow\; \theta_r = 44.6°$

Den övre strålen kommer därför att peka neråt med vinkeln $44.6° - 25.0° = 19.55°$, jämfört med den ursprungliga riktningen. P.s.s. kommer den undre strålen att peka $19.55°$ uppåt.
Den totala skillnaden blir $2 \cdot 19.55° = 39.1°$.

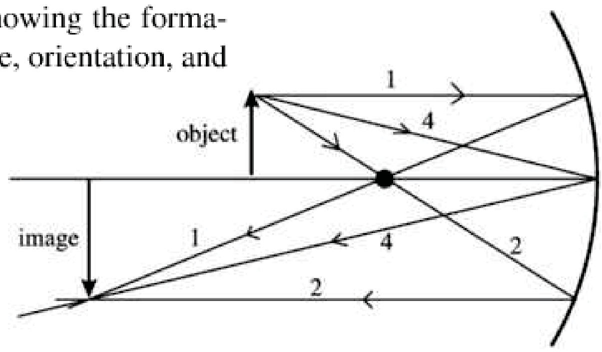


34.5 • An object 0.600 cm tall is placed 16.5 cm to the left of the vertex of a concave spherical mirror having a radius of curvature of 22.0 cm. (a) Draw a principal-ray diagram showing the formation of the image. (b) Determine the position, size, orientation, and nature (real or virtual) of the image.

$$f = \frac{R}{2} = +11.0\ cm \qquad s' = \frac{sf}{s-f} = +33.0\ cm$$

$$y' = -\frac{ys'}{s} = -1.20\ cm$$

Bilden är reell och inverterad

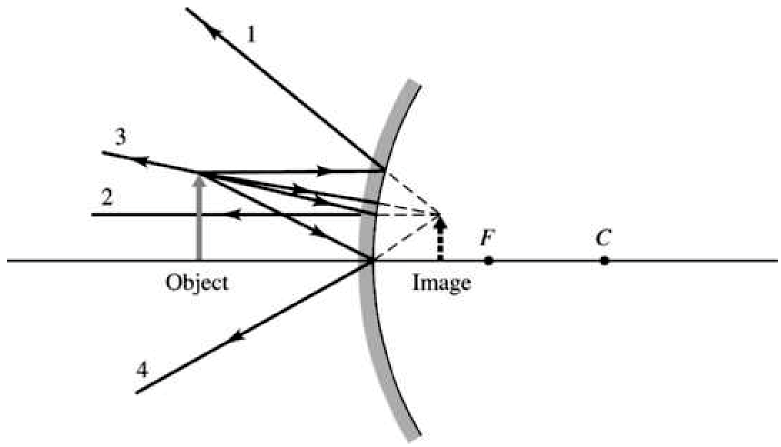


34.6 • Repeat Exercise 34.5 for the case in which the mirror is convex.

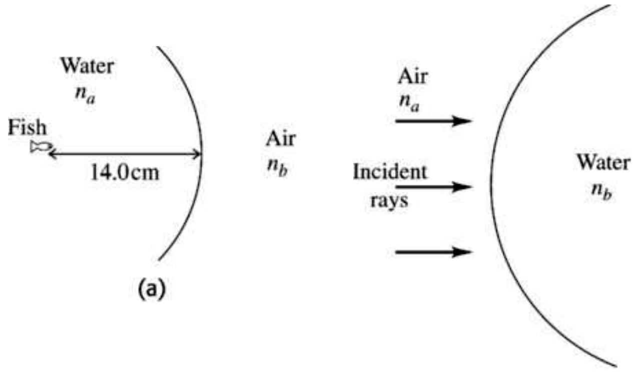
$$f = \frac{R}{2} = -11.0\ cm \qquad s' = \frac{sf}{s-f} = -6.60\ cm$$

$$y' = -\frac{ys'}{s} = -0.240\ cm$$

Bilden är virtuell och rättvänd



34.19 •• **A Spherical Fish Bowl.** A small tropical fish is at the center of a water-filled, spherical fish bowl 28.0 cm in diameter. (a) Find the apparent position and magnification of the fish to an observer outside the bowl. The effect of the thin walls of the bowl may be ignored. (b) A friend advised the owner of the bowl to keep it out of direct sunlight to avoid blinding the fish, which might swim into the focal point of the parallel rays from the sun. Is the focal point actually within the bowl?



(a) (b)

a) $R = -s$ **och**

$$\frac{n_a}{s} + \frac{n_b}{s'} = \frac{n_b - n_a}{R} \Rightarrow \frac{n_b}{s'} = -\frac{n_b - n_a}{s} - \frac{n_a}{s} = -\frac{n_b}{s} \Rightarrow s' = -s = -14.0 \text{ cm}$$

$$m = -\frac{n_a s'}{n_b s} = +1.33$$

b) > 0

$$s \to \infty \Rightarrow \frac{n_b}{s'} = \frac{n_b - n_a}{R} \Rightarrow s' = \frac{n_b}{n_b - n_a} R \approx 4R$$

Brännpunkten ligger utanför skålen.

34.25 • An insect 3.75 mm tall is placed 22.5 cm to the left of a thin planoconvex lens. The left surface of this lens is flat, the right surface has a radius of curvature of magnitude 13.0 cm, and the index of refraction of the lens material is 1.70. (a) Calculate the location and size of the image this lens forms of the insect. Is it real or virtual? Erect or inverted? (b) Repeat part (a) if the lens is reversed.

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right); \quad s' = \frac{sf}{s-f}; \quad y' = my = -\frac{s'y}{s}$$

a) $R_1 \to \infty;\ R_2 = -13.0\ cm$

$$f = +18.6\ cm; \quad s' = +107\ cm; \quad y' = -1.78\ cm$$

b) $R_1 = +13.0\ cm;\ R_2 \to \infty$

$$f = +18.6\ cm; \quad (s' = +107\ cm; \quad y' = -1.78\ cm)$$

Linsen fungerar på samma sätt i båda fallen. Bilden blir reell och rättvänd.

34.26 • A lens forms an image of an object. The object is 16.0 cm from the lens. The image is 12.0 cm from the lens on the same side as the object. (a) What is the focal length of the lens? Is the lens converging or diverging? (b) If the object is 8.50 mm tall, how tall is the image? Is it erect or inverted? (c) Draw a principal-ray diagram.

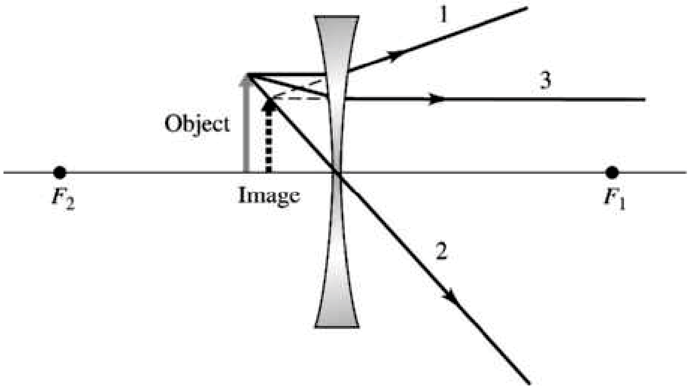
a) $s > 0; \quad s' < 0$

$f = \frac{ss'}{s+s'} = -48.0 \text{ cm} \;\; (\text{negativ lins})$

b) $y' = -\frac{s'y}{s} = +2.55 \; cm$

Bilden är virtuell och rättvänd.

c)



34.31 •• A double-convex thin lens has surfaces with equal radii of curvature of magnitude 2.50 cm. Looking through this lens, you observe that it forms an image of a very distant tree at a distance of 1.87 cm from the lens. What is the index of refraction of the lens?

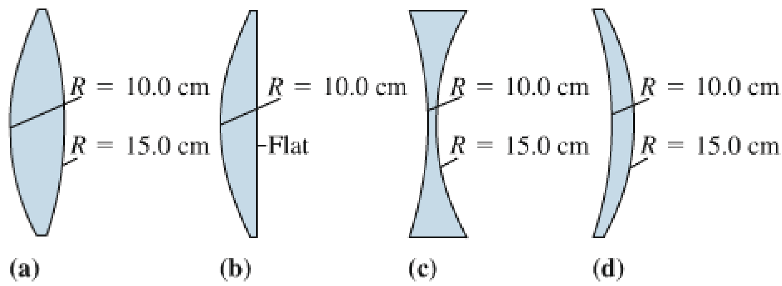
$s \to \infty \;\; \Rightarrow \;\; f = s'$

$R_1 = R; \quad R_2 = -R$

$\frac{1}{f} = (n-1)\left(\frac{1}{R} - \frac{1}{-R}\right) = \; (n-1)\frac{2}{R} \;\; \Rightarrow \quad \text{n} = 1 + \frac{R}{2f} = 1.67$

34.35 • For each thin lens shown in Fig. E34.35, calculate the location of the image of an object that is 18.0 cm to the left of the lens. The lens material has a refractive index of 1.50, and the radii of curvature shown are only the magnitudes.

Figure **E34.35**



$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$s' = \frac{sf}{s-f}$$

a) $R_1 = +10.0\ cm;\quad R_2 = -15.0\ cm$

$f = +12.0\ cm;\quad s' = +36.0\ cm$

b) $R_1 = +10.0\ cm;\quad R_2 \to \infty$

$f = +20.0\ cm;\quad s' = -180\ cm$

c) $R_1 = -10.0\ cm;\quad R_2 + 15.0\ cm$

$f = -12.0\ cm;\quad s' = -7.2\ cm$

d) $R_1 = -10.0\ cm;\quad R_2 - 15.0\ cm$

$f = -60.0\ cm;\quad s' = -13.8\ cm$

34.39 •• **Combination of Lenses I.** A 1.20-cm-tall object is 50.0 cm to the left of a converging lens of focal length 40.0 cm. A second converging lens, this one having a focal length of 60.0 cm, is located 300.0 cm to the right of the first lens along the same optic axis. (a) Find the location and height of the image (call it I_1) formed by the lens with a focal length of 40.0 cm. (b) I_1 is now the object for the second lens. Find the location and height of the image produced by the second lens. This is the final image produced bv the combination of lenses.

a) $s' = \frac{sf}{s-f} = +200\ cm;\quad y' = -\frac{ys'}{s} = -4.80\ cm$

Vi får en reell, inverterad, 4.80 cm hög bild 200 cm till höger om den första linsen.

b) $= +100\ cm;\quad y = -4.80\ cm$

$s' = \frac{sf}{s-f} = +150\ cm;\quad y' = -\frac{ys'}{s} = +7.20\ cm$

Vi får en reell, rättvänd, 7.20 cm hög bild 150 cm till höger om den andra linsen.

Notera att $m_1 = -4.00$ och $m_2 = -1.50$. Den totala förstoringen $m_{12} = m_1 \cdot m_2 = +6.00$

34.40 •• Combination of Lenses II. Repeat Problem 34.39 using the same lenses except for the following changes: (a) The second lens is a *diverging* lens having a focal length of magnitude 60.0 cm. (b) The first lens is a *diverging* lens having a focal length of magnitude 40.0 cm. (c) Both lenses are diverging lenses having focal lengths of the same *magnitudes* as in Problem 34.39.

a1) $s' = \frac{sf}{s-f} = +200\ cm; \quad y' = -\frac{ys\prime}{s} = -4.80\ cm$

Vi får en reell, inverterad, 4.80 cm hög bild 200 cm till höger om den första linsen.

a2) $s = +100\ cm; \quad y = -4.80\ cm$

$s' = \frac{sf}{s-f} = -37.5\ cm; \quad y' = -\frac{ys\prime}{s} = -1.80\ cm$

Vi får en virtuell, inverterad, 1.80 cm hög bild 37.5 cm till vänster om den andra linsen.

b1) $s' = \frac{sf}{s-f} = -22.2\ cm; \quad y' = -\frac{ys\prime}{s} = +0.533\ cm$

Vi får en virtuell, rättvänd, 0.533 cm hög bild 22.2 cm till vänster om den första linsen.

b2) $= +322.2\ cm; \quad y = +0.533\ cm$

$s' = \frac{sf}{s-f} = +73.7\ cm; \quad y' = -\frac{ys\prime}{s} = -0.122\ cm$

Vi får en reell, inverterad, 0.122 cm hög bild 73.7 cm till höger om den andra linsen.

c1) $s' = \frac{sf}{s-f} = -22.2\ cm; \quad y' = -\frac{ys\prime}{s} = +0.533\ cm$

Vi får en virtuell, rättvänd, 0.533 cm hög bild 22.2 cm till vänster om den första linsen.

c2) $= +322.2\ cm; \quad y = +0.533\ cm$

$s' = \frac{sf}{s-f} = -50.6\ cm; \quad y' = -\frac{ys\prime}{s} = +0.0837\ cm$

Vi får en virtuell, rättvänd, 0.0837 cm hög bild 50.6 cm till vänster om den andra linsen.

34.44 • When a camera is focused, the lens is moved away from or toward the film. If you take a picture of your friend, who is standing 3.90 m from the lens, using a camera with a lens with a 85-mm focal length, how far from the film is the lens? Will the whole image of your friend, who is 175 cm tall, fit on film that is 24 × 36 mm?

$$s' = \frac{sf}{s-f} = 8{,}69 \text{ cm}$$
$$y' = -\frac{ys'}{s} = 3.90\ cm$$

Eftersom filmens dimensioner är mindre än 3.90 cm får han inte plats.

34.53 •• **BIO** (a) Where is the near point of an eye for which a contact lens with a power of +2.75 diopters is prescribed? (b) Where is the far point of an eye for which a contact lens with a power of −1.30 diopters is prescribed for distant vision?

a) **Med objektet 25 cm framför ögat ska bilden hamna i ögats närpunkt**
$$f = \frac{1}{B} = 36.36\ cm$$
$$s' = \frac{sf}{s-f} = -80.0 \text{ cm}$$
Ögats närpunkt är på avståndet 80.0 cm

b) **Med objektet i oändligheten ska bilden hamna i ögats fjärrpunkt**
$$f = \frac{1}{B} = -76.92\ cm$$
$$s' = \text{f} = -76.9 \text{ cm}$$
Ögats fjärrpunkt är på avståndet 76.9 cm

34.54 • **BIO** **Contact Lenses.** Contact lenses are placed right on the eyeball, so the distance from the eye to an object (or image) is the same as the distance from the lens to that object (or image). A certain person can see distant objects well, but his near point is 45.0 cm from his eyes instead of the usual 25.0 cm. (a) Is this person nearsighted or farsighted? (b) What type of lens (converging or diverging) is needed to correct his vision? (c) If the correcting lenses will be contact lenses, what focal length lens is needed and what is its power in diopters?

a) **Personen ifråga är översynt (ser bra på långt håll men inte på korta avstånd)**
b) **Personen ifråga behöver positiva linser**
c) **s**$= \mathbf{25\ cm}$; $\mathbf{s' = -45.0\ cm}$; $\boldsymbol{f} = \frac{ss'}{s+s'} = +\mathbf{56.25}\ \boldsymbol{cm}$
   $\boldsymbol{B} = +\mathbf{1.78}$

34.63 •• The focal length of the eyepiece of a certain microscope is 18.0 mm. The focal length of the objective is 8.00 mm. The distance between objective and eyepiece is 19.7 cm. The final image formed by the eyepiece is at infinity. Treat all lenses as thin. (a) What is the distance from the objective to the object being viewed? (b) What is the magnitude of the linear magnification produced by the objective? (c) What is the overall angular magnification of the microscope?

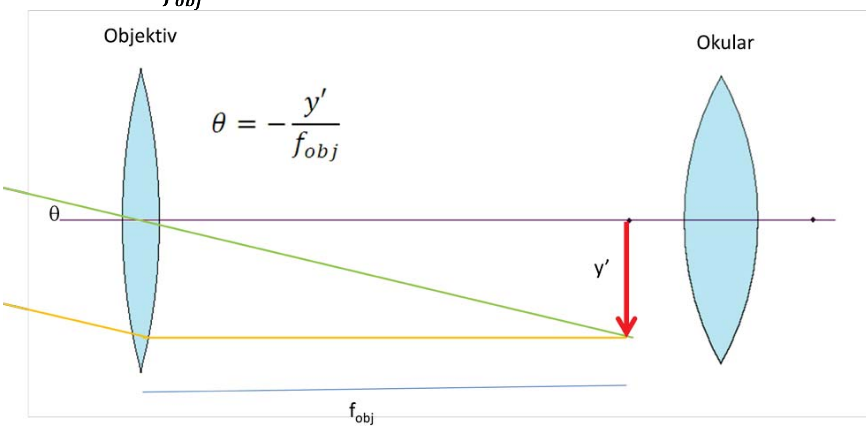
a) **Bilden ov objektet ska hamna i okularets brännpunkt.**
   $\boldsymbol{s'} = \mathbf{19.7 - 1.8 = 17.9}\boldsymbol{cm}$
   $\boldsymbol{s} = \frac{s' f_{obj}}{s' - f_{obj}} = \mathbf{8.37\ mm}$
b) $\boldsymbol{m_{obj}} = -\frac{s'}{s} = \mathbf{-21.4}$
c) **Okularets vinkelförstoring** $\boldsymbol{M_{ok}} = \frac{\sigma}{f_{ok}} = \mathbf{13.9}$
   Den totala vinkelförstoringen blir $\boldsymbol{M} = \boldsymbol{m_{obj}} \cdot \boldsymbol{M_{ok}} = \mathbf{-297}$

34.64 •• The eyepiece of a refracting telescope has a focal length of 9.00 cm. The distance between objective and eyepiece is 1.80 m, and the final image is at infinity. What is the angular magnification of the telescope?

$$\boldsymbol{f_{obj} = L - f_{ok} = 171\ cm;\ \ M = -\frac{f_{obj}}{f_{ok}} = -19.0}$$

34.66 •• Saturn is viewed through the Lick Observatory refracting telescope (objective focal length 18 m). If the diameter of the image of Saturn produced by the objective is 1.7 mm, what angle does Saturn subtend from when viewed from earth?

Vinkeln som Saturnus upptar är när man tittar från jorden är den samma som vinkeln i teleskopets objektiv $\boldsymbol{\theta = \frac{y'}{f_{obj}} = 9.4 \cdot 10^{-5}\ rad = 0.0054°}$



Kapitel 35

35.9 • Young's experiment is performed with light from excited helium atoms ($\lambda = 502$ nm). Fringes are measured carefully on a screen 1.20 m away from the double slit, and the center of the 20th fringe (not counting the central bright fringe) is found to be 10.6 mm from the center of the central bright fringe. What is the separation of the two slits?

$$d \sin\theta = m\lambda; \quad R \gg y \Rightarrow \sin\theta \approx \tan\theta = \frac{y_m}{R} \quad \Rightarrow \quad d = \frac{20\cdot\lambda R}{y_{20}} = 1.14\ mm$$

$$\left(\theta = \tan^{-1}\frac{y_m}{R} = 0.51°\ \text{är}\ en\ liten\ vinkel;\ \tan 0.51° = 0.00883;\ \sin 0.51° = 0.00883\right)$$

35.10 •• Coherent light with wavelength 450 nm falls on a double slit. On a screen 1.80 m away, the distance between dark fringes is 4.20 mm. What is the separation of the slits?

$$R \gg y \Rightarrow y_{m+½} = \frac{(m+½)\cdot\lambda R}{d} \Rightarrow \Delta y = \frac{\lambda R}{d} \Rightarrow d = \frac{\lambda R}{\Delta y} = 193\mu m$$

35.11 •• Two slits spaced 0.450 mm apart are placed 75.0 cm from a screen. What is the distance between the second and third dark lines of the interference pattern on the screen when the slits are illuminated with coherent light with a wavelength of 500 nm?

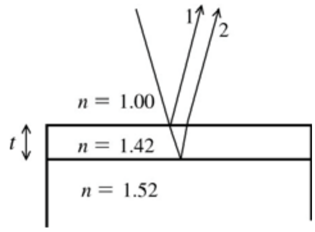
$$d \sin\theta = (m + ½)\lambda;\ \ d \gg \lambda \Rightarrow y_{m+½} = \frac{(m+½)\cdot\lambda R}{d} \Rightarrow \Delta y = \frac{\lambda R}{d} = 833\mu m$$

35.16 •• Coherent light that contains two wavelengths, 660 nm (red) and 470 nm (blue), passes through two narrow slits separated by 0.300 mm, and the interference pattern is observed on a screen 5.00 m from the slits. What is the distance on the screen between the first-order bright fringes for the two wavelengths?

$$d \gg \lambda \Rightarrow y_m = \frac{m\lambda R}{d}$$

$$\Delta y_1 = \frac{(\lambda_1 - \lambda_2)R}{d} = 3.17\ mm$$

35.25 • What is the thinnest film of a coating with $n = 1.42$ on glass ($n = 1.52$) for which destructive interference of the red component (650 nm) of an incident white light beam in air can take place by reflection?



$Destruktiv\ reflektion\ (båda\ reflektionerna\ mot\ tätare\ medium) \Rightarrow 2t = (m + ½)\frac{\lambda}{n}$

$Minst\ om\ m = 0 \Rightarrow t = \frac{\lambda}{4n} = \frac{650}{4 \cdot 1.42} = 114\ nm$

35.36 • Jan first uses a Michelson interferometer with the 606-nm light from a krypton-86 lamp. He displaces the movable mirror away from him, counting 818 fringes moving across a line in his field of view. Then Linda replaces the krypton lamp with filtered 502-nm light from a helium lamp and displaces the movable mirror toward her. She also counts 818 fringes, but they move across the line in her field of view opposite to the direction they moved for Jan. Assume that both Jan and Linda counted to 818 correctly. (a) What distance did each person move the mirror? (b) What is the resultant displacement of the mirror?

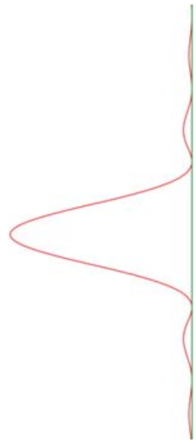
a) $y_1 = m \cdot \frac{\lambda_1}{2} = 818 \cdot \frac{606}{2} = 247854\ nm = 248\ \mu m$

$y_2 = -m \cdot \frac{\lambda_2}{2} = 818 \cdot \frac{502}{2} = -205318\ nm = -205\ \mu m$

b) $Total\ förflyttning\ 248 - 205 = 43\ \mu m$

Kapitel 36

36.1 •• Monochromatic light from a distant source is incident on a slit 0.750 mm wide. On a screen 2.00 m away, the distance from the central maximum of the diffraction pattern to the first minimum is measured to be 1.35 mm. Calculate the wavelength of the light.



$$a \sin\theta = m\lambda; \quad m = 1; \quad R \gg y \Rightarrow \lambda = \frac{ay}{R} = 506\, nm$$

36.4 • Light of wavelength 633 nm from a distant source is incident on a slit 0.750 mm wide, and the resulting diffraction pattern is observed on a screen 3.50 m away. What is the distance between the two dark fringes on either side of the central bright fringe?

$$a \sin\theta = m\lambda; \quad m = \pm 1; \quad R \gg y \Rightarrow \Delta y_{\pm 1} = \frac{2R\lambda}{a} = 5.91\, mm$$

36.12 •• Red light of wavelength 633 nm from a helium–neon laser passes through a slit 0.350 mm wide. The diffraction pattern is observed on a screen 3.00 m away. Define the width of a bright fringe as the distance between the minima on either side. (a) What is the width of the central bright fringe? (b) What is the width of the first bright fringe on either side of the central one?

a) $a\sin\theta = m\lambda;\quad = \pm 1;\quad a \gg \lambda \Rightarrow \Delta y_{\pm 1} = \frac{2R\lambda}{a} = 10.9\ mm$

b) $\Delta y_{1,2} = \frac{R\lambda}{a} = 5.43\ mm$

36.15 •• A slit 0.240 mm wide is illuminated by parallel light rays of wavelength 540 nm. The diffraction pattern is observed on a screen that is 3.00 m from the slit. The intensity at the center of the central maximum ($\theta = 0°$) is $6.00 \times 10^{-6}\ \mathrm{W/m^2}$. (a) What is the distance on the screen from the center of the central maximum to the first minimum? (b) What is the intensity at a point on the screen midway between the center of the central maximum and the first minimum?

a) $a\sin\theta = m\lambda;\quad = 1;\quad a \gg \lambda \Rightarrow y_1 = \frac{R\lambda}{a} = 6.75\ mm$

b) $I = I_0 \frac{\sin^2\left(\frac{\beta}{2}\right)}{\left(\frac{\beta}{2}\right)^2};\quad = \frac{2\pi a \sin\theta}{\lambda}$

den sökta vinkeln ges av $a\sin\theta = ½\lambda \Rightarrow \beta = \frac{2\pi ½\lambda}{\lambda} = \pi \Rightarrow$

$I = I_0 \frac{\sin^2\left(\frac{\pi}{2}\right)}{\left(\frac{\pi}{2}\right)^2} = I_0 \frac{4}{\pi^2} = 2.43 \cdot 10^{-6}\ W/m^2$

36.24 • Parallel rays of monochromatic light with wavelength 568 nm illuminate two identical slits and produce an interference pattern on a screen that is 75.0 cm from the slits. The centers of the slits are 0.640 mm apart and the width of each slit is 0.434 mm. If the intensity at the center of the central maximum is $5.00 \times 10^{-4}\ \mathrm{W/m^2}$, what is the intensity at a point on the screen that is 0.900 mm from the center of the central maximum?

$$I = I_0\left[\cos^2\left(\frac{\phi}{2}\right)\right]\frac{\sin^2\left(\frac{\beta}{2}\right)}{\left(\frac{\beta}{2}\right)^2};\quad \phi = \frac{2\pi d\sin\theta}{\lambda};\quad \beta = \frac{2\pi a\sin\theta}{\lambda}$$

$$R \gg y \Rightarrow \sin\theta \approx \tan\theta = \frac{y}{R} \Rightarrow \sin\theta = 0.0012$$

$$\phi = \frac{2\pi d\sin\theta}{\lambda} = 8.4956\, rad;\quad \beta = \frac{2\pi a\sin\theta}{\lambda} = 5.7611\, rad$$

$$I = I_0\left[\cos^2\left(\frac{8.4956}{2}\right)\right]\frac{\sin^2\left(\frac{5.7611}{2}\right)}{\left(\frac{5.7611}{2}\right)^2} = I_0\cdot 0.2008\cdot\frac{0.0666}{8.298} = 0.001612\cdot I_0 = 8.06\cdot 10^{-7}\ W/m^2$$

36.29 • If a diffraction grating produces its third-order bright band at an angle of 78.4° for light of wavelength 681 nm, find (a) the number of slits per centimeter for the grating and (b) the angular location of the first-order and second-order bright bands. (c) Will there be a fourth-order bright band? Explain.

a) $d\sin\theta = m\lambda \Rightarrow N = \frac{10^{-2}}{d} = \frac{10^{-2}\cdot\sin\theta}{m\lambda} = 4790$ ritsar/cm

$d = \frac{m\lambda}{\sin\theta} = 2.0856\ \mu m$

b) $\theta_1 = \sin^{-1}\frac{\lambda}{d} = 19.1°;\quad \theta_2 = \sin^{-1}\frac{2\lambda}{d} = 40.8°;$

c) $\theta_4 = \sin^{-1}\frac{4\lambda}{d}\ men\ \frac{4\lambda}{d} = 1.31 > 1, d.v.s. 4{:}\ de\ ordningen\ syns\ inte$

36.30 • If a diffraction grating produces a third-order bright spot for red light (of wavelength 700 nm) at 65.0° from the central maximum, at what angle will the second-order bright spot be for violet light (of wavelength 400 nm)?

$$d \sin\theta = m\lambda \Rightarrow d = \frac{3\lambda_1}{\sin\theta_1}$$

$$\sin\theta_2 = \frac{2\lambda_2}{d} = \frac{2\lambda_2 \sin\theta_1}{3\lambda_1} = 0.3453 \Rightarrow \theta_2 = 20.2°$$

36.37 • A typical laboratory diffraction grating has 5.00×10^3 lines/cm, and these lines are contained in a 3.50-cm width of grating. (a) What is the chromatic resolving power of such a grating in the first order? (b) Could this grating resolve the lines of the sodium doublet (see Section 36.5) in the first order? (c) While doing spectral analysis of a star, you are using this grating in the *second* order to resolve spectral lines that are very close to the 587.8002-nm spectral line of iron. (i) For wavelengths longer than the iron line, what is the shortest wavelength you could distinguish from the iron line? (ii) For wavelengths shorter than the iron line, what is the longest wavelength you could distinguish from the iron line? (iii) What is the range of wavelengths you could *not* distinguish from the iron line?

a) $R_1 = mN = 1 \cdot 3.50 \cdot 5.00 \cdot 10^3 = 17500$

b) $\lambda_1 = 589.00\, nm; \quad \lambda_2 = 589.59\, nm; \quad \Delta\lambda = 0.59\, nm$

$\frac{\lambda}{\Delta\lambda} = \frac{589}{0.59} = 998 \ll 17500 \quad \textit{Gittret löser lätt upp linjerna}$

c) $R_2 = 2 \cdot R_1 = 35000; \quad \Delta\lambda = \frac{\lambda}{R_2} = 0.0168\, nm$

$\lambda + \Delta\lambda = 587.8170\, nm\, (i); \qquad \lambda - \Delta\lambda = 587.7834\, nm\, (ii)$

$587.7834\, nm < \lambda < 587.8170\, nm\, (iii)$

36.38 • The light from an iron arc includes many different wavelengths. Two of these are at $\lambda = 587.9782$ nm and $\lambda = 587.8002$ nm. You wish to resolve these spectral lines in first order using a grating 1.20 cm in length. What minimum number of slits per centimeter must the grating have?

$\frac{\lambda}{\Delta\lambda} = \frac{587.8892}{0.1780} = 3303\ d.v.s.\ gittret\ måste\ ha\ en\ upplösningsförmåga\ på\ minst\ 3303$

$R = mN \Rightarrow gittret\ måste\ ha\ minst\ 3303\ ritsar \Rightarrow \frac{3303}{1.20} = 2752\ ritsar/cm$

$Det\ behövs\ minst\ 2752 ritsar/cm$

36.47 • **Observing Jupiter.** You are asked to design a space telescope for earth orbit. When Jupiter is 5.93×10^8 km away (its closest approach to the earth), the telescope is to resolve, by Rayleigh's criterion, features on Jupiter that are 250 km apart. What minimum-diameter mirror is required? Assume a wavelength of 500 nm.

$\theta = \frac{1.22\lambda}{D};\ \theta \approx tan\theta = \frac{x}{R} \Rightarrow D = \frac{1.22\lambda R}{x} = 1.45\ m$