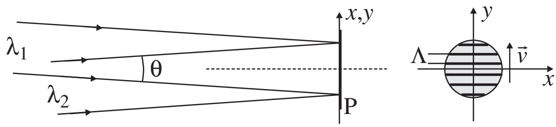
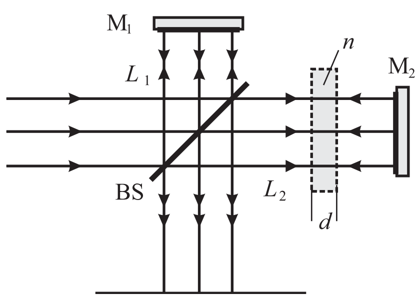
4.26 Two plane monochromatic waves with different wavelengths $\lambda_1 = 630$ nm and $\lambda_2 = 631.1$ nm are superimposed at angle $\theta = 0.05$ deg. Determine the frequency f of the intensity oscillations in a single point on the screen, the period Λ, and the velocity v of the motion of interference fringes observed on the screen P placed perpendicularly to the bisector of angle θ.



4.27 Two monochromatic waves with wavelengths $\lambda_1 = 633$ nm and $\lambda_2 = 650$ nm are superimposed on the aperture of a photodetector. Determine the response rate f_p or the response time $\tau_p = 1/f_p$ of the photodetector necessary to observe the interference signal (beating) of the waves.

4.2 Amplitude division interferometers: The Michelson and Mach–Zehnder interferometers

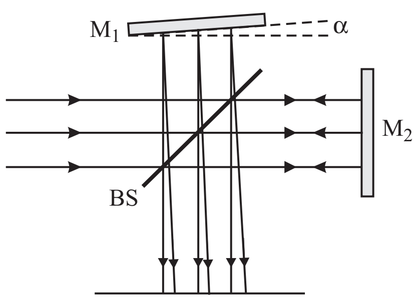
4.28 Determine the optical path difference Δ_{12} in an air-filled Michelson interferometer with arms having geometric lengths L_1 and L_2. What will be the variation $\delta\Delta_{12}$ of this path length difference if a glass plate with thickness d and refractive index n is placed inside one of the interferometer arms?



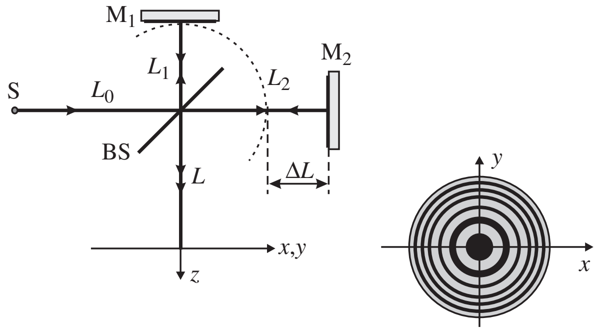
4.29 Arms 1 and 2 of a Michelson interferometer are filled with media having different refractive indices n_1 and n_2. A plane-parallel glass plate with thickness d and refractive index n is placed inside arm 2. What shift ΔL of the mirror in one of the interferometer arms will restore the initial optical path difference between the arms?

4.30 Determine the shift ΔL of a mirror in an air-filled Michelson interferometer needed to provide five periodic changes of the intensity of light with wavelength $\lambda_0 = 400$ nm in the center of the interference pattern observed in the output arm of the interferometer.

4.31 A plane monochromatic wave with wavelength λ_0 enters a Michelson interferometer. One of the interferometer mirrors is perpendicular to the direction of propagation of the illuminating wave, while the other mirror forms an angle (90 deg $+\alpha$) with this direction. Determine the period Λ of interference fringes at the output of the interferometer, provided that the inclination angle α of the mirror is small.



4.32 A monochromatic-light point source S with wavelength λ_0 is used in a Michelson interferometer. The distance between the source and the beam splitter BS is L_0. The distances between the beam splitter and the mirrors of the interferometer are L_1 and L_2. Write the equation for the phase difference $\Delta\phi_{12}(x, y)$ of the light waves as a function of the coordinates (x, y) at the output screen of the interferometer installed at distance L from the beam splitter. Use the paraxial approximation for the light rays that hit the screen.

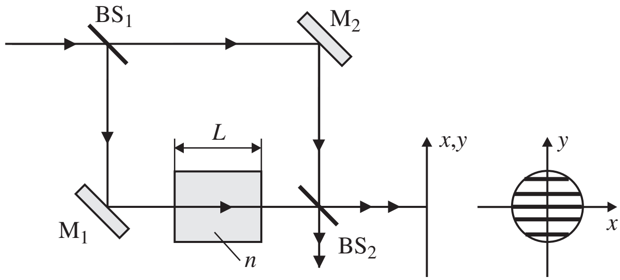


4.33 In a Michelson interferometer, one mirror moves with constant velocity $v = 2$ mm/s along the optical axis. Determine frequency f_S of the periodical variation of the light intensity $I(t)$ in the interference pattern at the output of the interferometer if the wavelength of the light is $\lambda_0 = 633$ nm.

4.34 One mirror in a Michelson interferometer harmonically oscillates along the optical axis with amplitude $l = 1.5$ μm and frequency $f = 10^2$ Hz. Plot intensity $I(t)$ in the interference pattern at the interferometer output versus time, provided that the wavelength is $\lambda_0 = 0.63$ μm and the intensities of the interfering waves are $I_1 = I_2 = 0.5$ mW/mm^2. The initial phase difference between the waves is $\Delta\phi_0 = 0, \pi/2$, or π rad. For plotting, take the time interval $[0, t]$ equal to two periods of the mirror oscillation.

4.35 A mirror in a Michelson interferometer harmonically oscillates with frequency f_0 and amplitude l_0 along the optical axis, $\Delta z = l_0 \sin(2\pi f_0 t + \phi_0)$. Derive the expression for frequency f_S of the periodic variation of the light intensity in the interference pattern $I(t)$ at light wavelength λ_0; determine the maximal $f_{\max}$ and the minimal $f_{\min}$ values of the frequency f_S.

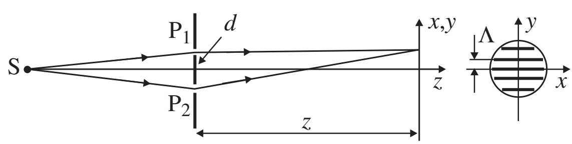
4.36 A cuvette with length $L = 100$ mm, filled with a liquid having refractive index n, is installed in one of the arms of a Mach–Zehnder interferometer. Heating the liquid causes the shift of interference fringes at the interferometer output by 2.5 pattern periods Λ. Determine the heat-induced increment of refractive index Δn if the wavelength is $\lambda_0 = 0.63$ μm.



4.37 The pressure of air in an airtight cell of length L = 70 mm, placed in one of the arms of a Mach–Zehnder interferometer, is increased by ΔP = 200 mm Hg, changing the refractive index of the air by Δn and, correspondingly, shifting the interference pattern observed at the output of the interferometer by Δm fringes. Determine the phase shift $\Delta\phi$ of the light wave passed through the cell and the relative pattern shift $\Delta m = \Delta y/\Lambda$, where Λ is the spatial period of the fringes and Δy is the linear shift of the pattern. The wavelength of light is λ_0 = 633 nm. The air refractive index linearly depends on pressure with proportionality coefficient $B \approx 2.4 \cdot 10^{-9}$ Pa^{-1}.

4.3 Wavefront division interferometers: The Young interferometer

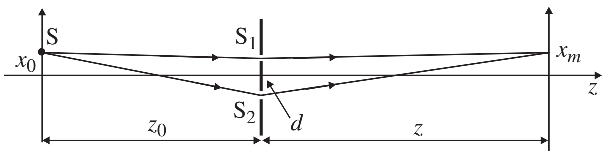
4.38 In a setup similar to that in Young's experiment, the interference fringes produced on a screen placed at distance z = 60 cm from a two-slit opaque screen have the period Λ = 0.6 mm. The separation between the slits is d = 0.55 mm. Determine the wavelength of light λ_0 used in the experiment.



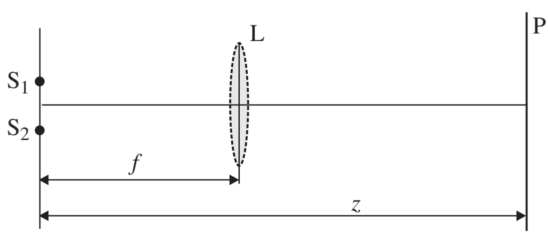
4.39 In a setup similar to that in Young's experiment, the distance from the central fringe to the fifth interference maximum is x = 0.3 cm. The distance between the two-slit opaque screen and the observation plane is $z = 5$ m, and the separation between the centers of the slits is $d = 0.5$ cm. Determine the wavelength of the incident monochromatic light λ_0.

4.40 Determine the period Λ of Young's interference fringes observed in the light from a semiconductor laser with $\lambda_0 = 650$ nm at a distance $z = 55$ cm from a two-slit opaque screen with narrow slits separated by $d = 1$ mm.

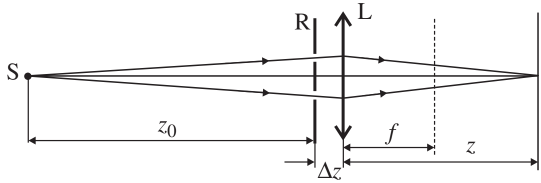
4.41 In Young's interferometer with two slits S_1 and S_2 in an opaque screen, the point light source S with $\lambda_0 = 0.6$ μm is separated by $z_0 = 1$ m from the screen and by $x_0 = 1$ mm from the optical axis, crossing the segment $d = 2$ mm between the slits. Determine the positions x_m of the centers of bright fringes in the interference pattern observed on the screen at distance $z = 2$ m from the slits.



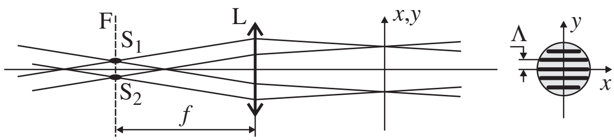
4.42 The light from two mutually coherent sources S_1 and S_2 gives rise to a system of interference fringes on the screen P, separated from the plane of the sources by the distance $z = 2.5$ m. By how many times β will the spatial period Λ of the interference fringes change if between the sources and the screen P a focusing lens L with focal length $f = 50$ cm is placed so that the sources will appear in the front focal plane of the lens?



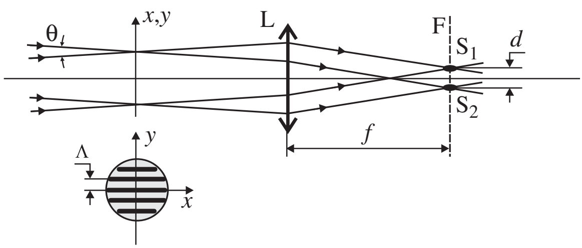
4.43 Young's interference fringes are observed using a converging lens L in the image plane P of the source S having the light wavelength $\lambda_0 = 600$ nm. Determine the period Λ of the fringes if a screen R with pinholes is placed before the lens at distance $\Delta z = 10$ mm from the lens and $z_0 = 100$ mm from the light source. The focus length of the lens is $f = 25$ mm, and the separation between the pinholes is $d = 0.3$ mm.



4.44 Two mutually coherent laser beams with wavelength $\lambda_0 = 0.6328$ μm are focused onto the front focal plane F of focusing lens L. Determine the separation d between the centers of the focal spots S_1 and S_2 of these beams if the interference fringes, arising in the domain of superposition of the beams behind the lens, have period $\Lambda = 1$ mm and the focal length of the lens is $f = 120$ mm.



4.45 Two collimated, mutually coherent beams of light with wavelength $\lambda_0 = 0.532$ μm overlap, forming a certain angle θ between the directions of their propagation and producing an interference pattern with fringe period $\Lambda = 5$ mm. Both beams enter an objective L with focal length $f = 110$ mm and are focused onto the back focal plane F of objective L. Determine the separation d between the foci of these beams.



4.24 $D \approx 17$ mm
4.25 $\Delta I = 2\sqrt{I_1 I_2}$,
$E_1(r,t) = E_{01}\exp(i2\pi\nu_1 t + \phi_1(r))$,
$E_2(r,t) = E_{02}\exp(i2\pi\nu_2 t + \phi_2(r))$,
$I \sim \langle |E_1 + E_2|^2\rangle_\tau \approx I_1 + I_2 + 2E_{01}E_{02}\cos(2\pi\Delta\nu_{12}t + \Delta\phi_{12}(r))$,
if $\tau \ll 1/\Delta\nu_{12}$
4.26 $f \approx 7.6 \cdot 10^4$ MHz, $\Lambda \approx 0.723$ mm, $v \approx 5.5 \cdot 10^7$ m/s
4.27 $f_p \geq 2 \cdot 0.124 \cdot 10^{14}$ Hz, $\tau_p \leq 4 \cdot 10^{-14}$ s

4.2 Amplitude division interferometers: The Michelson and Mach–Zehnder interferometers

4.28 $\Delta_{12} = 2(L_1 - L_2)$, $\delta\Delta_{12} = 2d(1-n)$
4.29 $\Delta L = d(n_2 - n)/n_2$ or $\Delta L = d(n_2 - n)/n_1$
4.30 $\Delta L = 1$ µm
4.31 $\Lambda \approx \lambda_0/2\alpha$
4.32 $\Delta\phi_{12}(x,y) \approx \frac{2\pi}{\lambda}2\Delta L + \frac{\pi}{\lambda}\left(\frac{1}{L_0+2L_2+L} - \frac{1}{L_0+2L_1+L}\right)(x^2+y^2)$
4.33 $f_s \approx 6.32$ kHz
4.34 $I(t) = 2I_1\left[1 + \cos\left(\frac{2\pi}{\lambda_0}2l\sin(2\pi f t) + \Delta\phi_0\right)\right]$
4.35 $f_S = (4\pi l_0 f_0/\lambda_0)\cos(2\pi f_0 t + \phi_0)$, $f_{\max} = 4\pi l_0 f_0/\lambda_0$,
$f_{\min} = 0$
4.36 $\Delta n \approx 0.000016$
4.37 $\Delta\phi \approx 14\pi$, $\Delta m = 7$

4.3 Wavefront division interferometers: The Young interferometer

4.38 $\lambda_0 = 0.55$ µm
4.39 $\lambda_0 = 0.6$ µm
4.40 $\Lambda \approx 0.36$ mm
4.41 $x_m \approx m\lambda_0 z/d - x_0 z/z_0 \approx (0.6m - 2)$ mm
4.42 $\beta = \Lambda_1/\Lambda_2 = 5$
4.43 $\Lambda \approx 0.059$ mm
4.44 $d \approx 76$ µm
4.45 $d \approx 12$ µm