9.26 Here $1.00 < 1.34 < 2.00$, hence from Eq. (9.36) with $m = 0$, 
\[ d = (0 + 1/2)(633 \text{ nm})/2(1.34) = 118 \text{ nm}. \]

9.27 (9.36) $d \cos \theta_t = (2m + 1)(\lambda_f)/4$ for a maximum at (near) normal incidence, and taking $m = D$ (lowest value) 
\[ d = \lambda_f/4 = \lambda_o/4n = (5.00 \times 10^{-7} \text{ m})/4(1.36) = 9.2 \times 10^{-6} \text{ m}. \]

9.28 (9.37) $d \cos \theta_t = 2m(\lambda_f/4)$ for minimum reflection $= 2m(\lambda_o/n)$ 
at $\theta \simeq 0$, $\lambda_o = nd/2m = [(1.34)(550.0 \text{ nm})]/2 \text{ m} = 368.5(1/m) \text{ nm}$, 
m = 1, 2, 3, . . . or $\lambda_o = 368.5 \text{ nm}$, 184.25 nm, 122.83 nm, . . .

9.29 Eq. (9.37) $m = 2n_f d/\lambda_0 = 10,000$. A minimum, therefore central dark region.

9.30 The fringes are generally a series of fine jagged bands, which are fixed with respect to the glass.

9.31 $x^2 = d_1[(R_1 - d_1) + R_1] = 2R_1d_1 - d_1^2$. Similarly $x^2 = 2R_2d_2 - d_2^2$. 
d = $d_1 - d_2 = (x^2/2)(1/R_1 - 1/R_2)$, $d = m\lambda_f/2$. As $R_2 \to \infty$, $x_m$ approaches Eq. (9.43).

9.32 (9.42) $x_m = [(m + 1/2)\lambda_f R]^{1/2}$, air film, $n_f = 1$, so $\lambda_f = \lambda_0$.
\[ R = x_m^2/(m + 1/2)\lambda_o = (0.01 \text{ m})^2/(20.5)(5 \times 10^{-7} \text{ m}) = 9.76 \text{ m}. \]

9.33 $\Delta x = \lambda_f/2\alpha$, $\alpha = \lambda_o/2n_f \Delta x$, $\alpha = 5 \times 10^{-5} \text{ rad} = 10.2 \text{ seconds}.$

9.34 (9.40) $\Delta x = \lambda_f/2\alpha$ for fringe separation where $\alpha = d/x$.
\[ \Delta x = \lambda_f/2(d/x) = x\lambda_f/2d. \text{ Number of fringes} = (\text{length})/(\text{separation}) = x/\Delta x \text{ so,} \]
\[ x/\Delta x = 2d/\lambda_f = [2(7.618 \times 10^{-5} \text{ m})]/(5.00 \times 10^{-7} \text{ m}). \]

9.35 A motion of $\lambda/2$ causes a single fringe pair to shift past, hence 
$92\lambda/2 = 2.53 \times 10^{-5} \text{ m}$ and $\lambda = 550 \text{ nm}$.

9.36 $\Delta d = N(\lambda_o/2) = (1000)(5.00 \times 10^{-7} \text{ m})/2 = 2.50 \times 10^{-4} \text{ m}$. 
9.37 \[ \Lambda = \Delta d = N(\lambda_o/2); \quad \Lambda = (n_{\text{air}}x - n_{\text{vacuum}}x); \]
\[ N = 2\Lambda/\lambda_o = [2(1.00029 - 1.00000)(0.10 \text{ m})]/(6.00 \times 10^{-7} \text{ m}) = 97. \]

9.38 Fringe pattern comes from the interference of two beams, one that passes through the lower medium \((n_1)\), and is reflected off its mirror, one that passes through the top medium \((n_2)\) and is reflected off its mirror. The two beams reflect off the front surface of the other medium.

It might be used to compare \(n_1\) and \(n_2\) (especially if one changes, such as due to pressure or temperature), or compare the flatness of one surface, to a known optically flat surface.

9.39 \[ E_t^2 = E_t I_t = E_0^2 [(tt')^2/(1 - r^2 e^{-i\delta})(1 - r^2 e^{i\delta})], \]
\[ I_t = I_t (tt')^2/(1 - r^2 e^{-i\delta} - r^2 e^{i\delta} + r^4). \]

9.40 (a) \( R = 0.80 \), therefore \( F = 4R/(1 - R)^2 = 80 \).
(b) \( \gamma = 4 \sin^{-1} 1/\sqrt{F} = 0.448 \).
(c) \( F = 2\pi/0.448 \).
(d) \( C = 1 + F \).

9.41 \[ 2/[1 + F(\Delta \delta/4)^2] = 0.81[1 + 1/(1 + F(\Delta \delta/2)^2)], \]
\[ F^2(\Delta \delta)^4 - 15.5F(\Delta \delta)^2 - 30 = 0. \]

9.42 \( I = I_{\text{max}} \cos^2 \delta/2, \) \( I = I_{\text{max}}/2 \) when \( \delta = \pi/2 \), therefore \( \gamma = \pi \). Separation between maxima is \( 2\pi \). \( F = 2\pi/\gamma = 2 \).

9.43 (4.47) \( r_{\theta=0} = (n_t - n_i)/(n_t + n_i) \). Bare substrate: \( r = (n_s - 1)/(n_s + 1) \).
Substrate with film: \( r' = t_{o-f} r_{f-o} \). (4.48) \( t_{\theta=0} = 2n_i/(n_i + n_t) \), so, \( r' = [2/(1 + n_f)][(n_s - n_f)/(n_s + n_f)][2n_f/(n_f + 1)] \), where \( n_f = n \). Note that for \( n_s > n_f > 1 \), both \( r \) and \( r' \) are positive. But, with thickness \( \lambda_f/4 \), a \( \pi \) phase shift occurs due to the OPD in the \( r' \) beam, so \( r_{\text{net}} = r - r' \). Thus, the \( r' \) beam (partially) cancels the \( r \) beam.

9.44 At near normal incidence \((\theta_i \approx 0)\) the relative phase shift between an internally and externally reflected beam is \( \pi \) rad. That means a total relative phase difference of \( (2\pi/\lambda_f)[2(\lambda_f/4)] + \pi \) or \( 2\pi \). The waves are in phase and interfere constructively.
Solution to HW 4-4.

From
\[ a_1 e^{i \omega t} + a_2 e^{i \omega t} + \ldots = (a_1 \cos \omega t + a_2 \cos \omega t + \ldots) \]
\[ + i (a_1 \sin \omega t + a_2 \sin \omega t + \ldots) \]

We have
\[ e^{-i \omega t} + ae^{-i \omega t + i \phi} + a^2 e^{-i \omega t + 2i \phi} + \ldots \]
\[ = \cos (\omega t) + a \cos (\phi - \omega t) + a^2 \cos (2\phi - \omega t) + \ldots \]
\[ + i \left[ \sin (\omega t) + a \sin (\phi - \omega t) + a^2 \sin (2\phi - \omega t) + \ldots \right] \]

Since
\[ e^{-i \omega t} + ae^{-i \omega t + i \phi} + a^2 e^{-i \omega t + 2i \phi} + \ldots \]
\[ = e^{-i \omega t} \left( 1 + ae^{i \phi} + (ae^{i \phi})^2 + \ldots \right) \]
\[ = \frac{e^{-i \omega t}}{1 - ae^{i \phi}} = e^{-i \omega t} \frac{e^{i \arctan \left( \frac{a \sin \phi}{1 - a \cos \phi} \right)}}{\sqrt{(1 - a \cos \phi)^2 + a^2 \sin^2 \phi}} \]
\[ = e^{i \left( \arctan \left( \frac{a \sin \phi}{1 - a \cos \phi} \right) - \omega t \right)} \]