wave equation

$\frac{\partial^2\psi}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2\psi}{\partial t^2}$	$\psi = \sin(kx \pm \omega t)$	$k = \frac{2\pi}{\lambda}$	$\omega = \frac{2\pi}{T}$	$\frac{\omega}{k} = v$

Phasors and addition of waves

$y_1 = A_1 e^{i\phi_1}$	$y_2 = A_2 e^{i\phi_2}$	$\delta = \phi_2 - \phi_1$
$y_r = y_1 + y_2$	$y_r = \lvert y_r\rvert e^{i\phi}$	

$\lvert y_r\rvert = A_1^2 + A_2^2 + 2A_1A_2\cos\delta$	$\tan\phi = \frac{A_1\sin\phi_1 + A_2\sin\phi_2}{A_1\cos\phi_1 + A_2\cos\phi_2}$

Spherical waves	Cylindrical waves
$\vec{E}(x,y,z,t) = \frac{\overrightarrow{E_0}}{r} e^{(\vec{k}.\vec{r}-\omega t)}$	$\vec{E}(x,y,z,t) = \frac{\overrightarrow{E_0}}{\sqrt{r}} e^{(\vec{k}.\vec{r}-\omega t)}$

Electromagnetic theory

$\vec{\nabla}.\vec{D} = \rho$	$\vec{\nabla}\times\vec{E} = -\frac{\partial\vec{B}}{\partial t}$	$\vec{\nabla}.B = 0$	$\vec{\nabla}\times\vec{H} = \vec{J} + \frac{\partial\vec{D}}{\partial t}$

$\vec{D} = \epsilon_0\vec{E} + \vec{P} = \epsilon_0(1+x)\vec{E} = \epsilon\vec{E} = \epsilon_0 n^2\vec{E}$	$\vec{B} = \mu_0\vec{H} + \vec{M}$
$n = \sqrt{\frac{\epsilon}{\epsilon_0}}$	$\vec{J} = \sigma\vec{E}$

Electromagnetic wave equation

$$\nabla^2\vec{E} = \mu\epsilon\frac{\partial^2\vec{E}}{\partial t^2}$$

$v = \frac{1}{\sqrt{\mu\epsilon}} = \frac{c}{n}$	$\vec{k}.\vec{E} = 0$	$\vec{K}\times\vec{E} = w\vec{B}$	$\lvert\vec{B}\rvert = \frac{n}{c}\lvert\vec{E}\rvert$	$\frac{\lvert\vec{E}\rvert}{\lvert\vec{H}\rvert} = \sqrt{\frac{\mu}{\epsilon}} = Z$

Energy and momentum

$\vec{S} = \vec{E}\times\vec{H}$ pointing vector

$I = \lvert\langle\vec{S}\rangle\rvert = \frac{1}{2}E_0H_0 = \frac{1}{2}c\epsilon_0E_0^2 = c\langle u\rangle$ I: irradiance, $\langle u\rangle$: average energy density

$\langle\vec{F}\rangle = \langle\frac{d\vec{P}}{dt}\rangle = \hat{k}q\langle v_xB\rangle$	$\langle\frac{dU}{dt}\rangle = cq\langle v_xB\rangle$	$\langle\frac{d\vec{P}}{dt}\rangle = \frac{1}{c}\langle\frac{dU}{dt}\rangle$

Damped oscillator model

$m(\ddot{x} + \gamma\dot{x} + \omega_0^2x) = qE_0e^{i\omega t}$	$x_0 = \frac{qE_0}{m(\omega_0^2 - \omega^2 + i\gamma\omega)}$	$p = qx = \frac{Nq^2E_0e^{i\omega t}}{m(w_0^2 - w^2 + i\gamma\omega)}$

dipole moment for N oscillator per unit volume (macroscopic polarization)

$$n = 1 + \frac{Nq^2}{2m\epsilon_0(\omega_0^2 - \omega^2 + i\gamma\omega)} = n' + in''$$

$n' = 1 + \frac{Nq^2}{2m\epsilon_0}\frac{\omega_0^2 - \omega^2}{(\omega_0^2-\omega^2)^2 + \gamma^2\omega^2}$	$n'' = \frac{Nq^2}{2m\epsilon_0}\frac{\gamma\omega}{(\omega_0^2-\omega^2)^2 + \gamma^2\omega^2}$

For $\omega_0 \ll \omega$:

$n' = 1 + \frac{Nq^2}{2m\epsilon_0\omega_0}\frac{\omega_0 - \omega}{(\omega_0-\omega)^2 + (\frac{\gamma}{2})^2}$	$n'' = \frac{Nq^2}{8m\epsilon_0\omega_0}\frac{\gamma}{(\omega_0-\omega)^2 + (\frac{\gamma}{2})^2}$

Refraction

$r_\perp = \frac{E_{0r}}{E_{0i}} = \frac{n_i\cos\theta_i - n_t\cos\theta_t}{n_i\cos\theta_i + n_t\cos\theta_t}$	$t_\perp = \frac{E_{0t}}{E_{0i}} = \frac{2n_i\cos\theta_i}{n_i\cos\theta_i + n_t\cos\theta_t}$
$r_\parallel = \frac{E_{0r}}{E_{0i}} = \frac{n_i\cos\theta_t - n_t\cos\theta_i}{n_i\cos\theta_t + n_t\cos\theta_i}$	$t_\parallel = \frac{E_{0t}}{E_{0i}} = \frac{2n_i\cos\theta_i}{n_i\cos\theta_t + n_t\cos\theta_i}$

$\theta_{Broster} = \tan^{-1}\frac{n_t}{n_i}$	$\theta_{Critical} = \sin^{-1}\frac{n_t}{n_i}$

Reflected power	Transmittance power	
$R = \frac{I_rA_r}{I_iA_i} = r^2$	$T = \frac{I_tA_t}{I_iA_i} = \frac{n_t\cos\theta_t}{n_i\cos\theta_i}t^2$	$I = \frac{n\epsilon_0c_0}{2}\lvert E_0\rvert^2$

Lenses

Refracting prisms	Spherical	Convex lens
$\frac{n_{prism}}{n_0} = \frac{\sin\frac{1}{2}(A+D)}{\sin\frac{1}{2}A}$	$\frac{n_1}{s_{01}} + \frac{n_2}{s_{i1}} = \frac{n_2 - n_1}{R_1}$	$\frac{1}{s_{01}} + \frac{1}{s_{i1}} = \left(\frac{n_l}{n_m} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{f}$

Mirror

$-\frac{h_0}{h_i} = \frac{d_0}{d_i}$	$\frac{1}{d_0} + \frac{1}{d_i} = \frac{2}{R} = \frac{1}{f}$	$magnification = \frac{h_i}{h_0}$

Simple telescope	Compound lens
$M = \frac{\theta'}{\theta} = \frac{f_0}{f_e}$	$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$

Ray tracing

Translation	Refraction
$\begin{bmatrix} x_2 \\ \gamma_2 \end{bmatrix} = \begin{bmatrix} 1 & d \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ \gamma_1 \end{bmatrix}$	$\begin{bmatrix} x_2 \\ \gamma_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & \frac{n_2}{n_1} \end{bmatrix} \begin{bmatrix} x_1 \\ \gamma_1 \end{bmatrix}$

Curved lens

n_1 to n_2	n_2 to n_3
$\begin{bmatrix} x_2 \\ \gamma_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ \frac{n_1 - n_2}{n_2 R_1} & \frac{n_1}{n_2} \end{bmatrix} \begin{bmatrix} x_1 \\ \gamma_1 \end{bmatrix}$	$\begin{bmatrix} x_3 \\ \gamma_3 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ \frac{n_2 - n_3}{n_3 R_2} & \frac{n_2}{n_3} \end{bmatrix} \begin{bmatrix} x_2 \\ \gamma_2 \end{bmatrix}$

Thin lens

$$\begin{bmatrix} x_3 \\ \gamma_3 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ \frac{n_2-n_3}{n_3 R_2} + \frac{n_1-n_2}{n_3 R_1} & \frac{n_1}{n_3} \end{bmatrix} \begin{bmatrix} x_1 \\ \gamma_1 \end{bmatrix}$$

For $n_1 = n_3 = 1$ and $R_1 = -R_2$	$\begin{bmatrix} x_3 \\ \gamma_3 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ -\frac{1}{f} & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ \gamma_1 \end{bmatrix}$	$f = \frac{R}{2(n-1)}$

Imaging by thin lens

$$\begin{bmatrix} x_i \\ \gamma_i \end{bmatrix} = \begin{bmatrix} 1 - \frac{s_i}{f} & s_0 + s_i - \frac{s_0 s_i}{f} \\ -\frac{1}{f} & 1 - \frac{s_0}{f} \end{bmatrix} \begin{bmatrix} x_0 \\ \gamma_0 \end{bmatrix}$$

$$s_0 + s_i - \frac{s_0 s_i}{f} = 0 \rightarrow \frac{1}{s_0} + \frac{1}{s_i} = \frac{1}{f}$$

$magnification$	$angular\ magnification$
$\beta_l = 1 - \frac{s_i}{f}$	$\beta_\gamma = 1 - \frac{s_0}{f}$

$\beta_l \beta_\gamma = 1$	$x_i \gamma_i = x_0 \gamma_0$

Thick lens and lenses system

$$M = \begin{bmatrix} 1 & 0 \\ \frac{n_2 - n_3}{n_3 R_2} & \frac{n_2}{n_3} \end{bmatrix} \begin{bmatrix} 1 & d \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \frac{n_1 - n_2}{n_2 R_1} & \frac{n_1}{n_2} \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}$$

$A = 1 + \frac{n_1 - n_2}{n_2 R_1} d$	$D = \frac{n_1}{n_3}(1 + \frac{n_2 - n_3}{n_2 R_2} d)$
$B = \frac{n_1}{n_2} d$	$C = \frac{1}{n_3}(\frac{n_2 - n_3}{R_2} + \frac{n_1 - n_2}{R_1} + \frac{n_1 - n_2}{n_2 R_1}\frac{n_2 - n_3}{R_2} d)$

Thin lens

Take: $n_1 = n_3$ and $d = 0$

$A = 1$	$B = 0$	$C = \frac{1}{n_1}(\frac{n_2 - n_1}{R_2} + \frac{n_1 - n_2}{R_1})$	$D = 1$

At $-R_1 = R_2 = -R$	At $n_1 = 1$
$C = -\frac{2}{n_1}(\frac{n_2 - n_1}{R})$	$C = -\frac{1}{f}$

Furior optics

$$f(t) = \frac{a_0}{2} + \sum_1^\infty a_l \cos(l\omega t) + \sum_1^\infty b_l \sin l\omega t$$

$a_0 = \frac{2}{T}\int_{-\frac{T}{2}}^{\frac{T}{2}} f(t)dt$	$a_n = \frac{2}{T}\int_{-\frac{T}{2}}^{\frac{T}{2}} f(t)\cos(n\omega t)\, dt$	$b_n = \frac{2}{T}\int_{-\frac{T}{2}}^{\frac{T}{2}} f(t)\sin(n\omega t)\, dt$

$f(t) = \sum_{-\infty}^{\infty} \alpha_l e^{il\omega t}$	$\alpha_l = \frac{1}{T}\int_{-\frac{T}{2}}^{\frac{T}{2}} f(t) e^{-il\omega t} dt$

Fourier integral

$f(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} f(\omega) e^{i\omega t} d\omega$	$f(\omega) = \int_{-\infty}^{\infty} f(t) e^{-i\omega t} dt$

Dirac delta function

$\delta(t - t_0) = f(x) = \begin{cases} 0, & t \neq t_0 \\ \infty, & t = t_0 \end{cases}$	$\int_{-\infty}^{\infty} \delta(t - t_0) dt = 1$	$\int_{-\infty}^{\infty} f(t)\delta(t - t_0) dt = f(t_0)$

Comb function

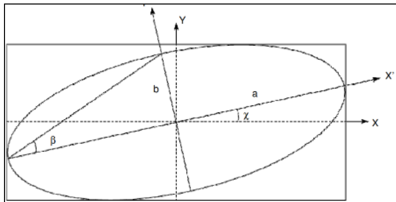
$comb(t) = \sum_{-N}^{N} \delta(t - t_n)$	$t_n = nt_0$

$$F(\omega) = \int_{-\infty}^{\infty} comb(t) e^{-i\omega t} = \sum_{-N}^{N} e^{-i\omega t_n}$$

Polarization

$E_x(z,t) = E_{0x}\cos(\tau + \delta_x)$	$E_y(z,t) = E_{0y}\cos(\tau + \delta_y)$
$\frac{E_x^2}{E_{0x}^2} + \frac{E_y^2}{E_{0y}^2} - 2\frac{E_x}{E_{0x}}\frac{E_y}{E_{0y}}\cos(\delta) = \sin^2(\delta)$	$I = I_0\cos^2\theta$
Linear ($\boldsymbol{\delta = 0\ or\ \pi}$)	**Right/left circular ($\boldsymbol{\delta = \frac{\pi}{2}\ or\ \frac{3\pi}{2}, E_{0x} = E_{0y} = E_0}$)**
$\left(\frac{E_x}{E_{0x}} + \frac{E_y}{E_{0y}}\right)^2 = 0$	$\left(\frac{E_x}{E_{0x}}\right)^2 + \left(\frac{E_y}{E_{0y}}\right)^2 = 1$

General elliptical polarization

	$E'_x = E_x\cos(\aleph) + E_y\sin(\aleph)$	$E'_y = -E_x\sin(\aleph) + E_y\cos(\aleph)$
	$\tan(2\aleph) = \frac{2E_{0x}E_{0y}\cos\delta}{E_{0x}^2 + E_{0y}^2}$	$\tan(\beta) = \pm\frac{b}{a}$
$\widetilde{E_x}(z,t) = E_{0x}e^{i(kz-\omega t+\delta_x)}$	$\widetilde{E_y}(z,t) = E_{0y}e^{i(kz-\omega t+\delta_y)}$	
$\tilde{E} = \left[E_{0x}e^{i(\delta_x)}\hat{x} + E_{0y}e^{i(\delta_y)}\hat{y}\right]e^{i(kz-\omega t)} = \widetilde{E_0}e^{i(kz-\omega t)}$	$\widetilde{E_0} = \begin{bmatrix}\widetilde{E_{0x}}\\ \widetilde{E_{0y}}\end{bmatrix} = \begin{bmatrix}E_{0x}e^{i\delta_x}\\ E_{0y}e^{i\delta_x}\end{bmatrix}$	
Transformation of polarization	$\begin{pmatrix}E'_x\\ E'_y\end{pmatrix} = \begin{pmatrix}\cos^2\theta & \sin\theta\cos\theta\\ \sin\theta\cos\theta & \sin^2\theta\end{pmatrix}\begin{pmatrix}E_x\\ E_y\end{pmatrix}$	

Jones vector	$\begin{pmatrix}E_{0x}\\ E_{0y}\end{pmatrix} = \begin{pmatrix}\lvert E_{0x}\rvert e^{i\phi_x}\\ \lvert E_{0y}\rvert e^{i\phi_y}\end{pmatrix} = \begin{pmatrix}\lvert E_{0x}\rvert\\ \lvert E_{0y}\rvert e^{i\delta}\end{pmatrix}$	$\begin{pmatrix}E_{0x}\\ E_{0y}\end{pmatrix} = \frac{1}{\sqrt{E_{0x}^2 + E_{0y}^2}}\begin{pmatrix}\lvert E_{0x}\rvert\\ \lvert E_{0y}\rvert e^{i\delta}\end{pmatrix}$

Stoke's parameters

$\vec{E} = \hat{\imath}E_{0x}\cos(kz - \omega t + \phi_x) + \hat{\jmath}E_{0y}\cos(kz - \omega t + \phi_y)$		
$S_0 = \langle E_{0x}^2\rangle + \langle E_{0y}^2\rangle$	$S_1 = \langle E_{0x}^2\rangle - \langle E_{0y}^2\rangle$	$S_2 = 2\langle E_{0x}E_{0y}\cos\delta\rangle$
$S_3 = 2\langle E_{0x}E_{0y}\sin\delta\rangle$	$\boldsymbol{S_0^2 = S_1^2 + S_2^2 + S_3^2}$ $(for\ \delta\ time\ independent)$	
Degree of polarization	$m = \frac{\sqrt{S_1^2 + S_2^2 + S_3^2}}{S_0}$	

Interference

Two point sources	$\overrightarrow{E_1} = \overrightarrow{E_{01}}e^{i(\vec{k}.\vec{r_1}-\omega t+\phi_1)}$	$\overrightarrow{E_2} = \overrightarrow{E_{02}}e^{i(\vec{k}.\vec{r_2}-\omega t+\phi_2)}$	$\overrightarrow{E_p} = \overrightarrow{E_1} + \overrightarrow{E_2}$
$I_p\ \alpha\ \langle\lvert\overrightarrow{E_p}\rvert^2\rangle$	$I_p = I_1 + I_2 + 2\langle\sqrt{I_1I_2}\cos\alpha\rangle, \alpha = \vec{k}.(r_2 - r_1) + (\phi_2 - \phi_1)$		

Young's Experiment

Maxima	Two adjacent maxima	
$\delta_m = 2m\pi$	$X_m - X_{m-1} = \frac{\lambda D}{h}$	$\delta = k(r_2 - r_1) = \frac{2\pi}{\lambda}\frac{xh}{D}$

Multiple sources

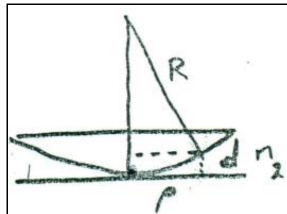
$\overrightarrow{E_p} = E_0e^{i(\vec{k}.\vec{r}-\omega t+\phi_1)}\frac{\sin(\frac{N}{2}\phi)}{\sin\frac{\phi}{2}}$	$r = r_1 + \frac{N-1}{2}\phi$	$\phi = \frac{2\pi}{\lambda}d\sin\theta$
Total phase difference	$\Phi = \frac{2\pi}{\lambda}a\sin\theta = (N-1)\phi \cong N\phi\ (constant)$	
$\lvert E_p\rvert = NE_0\frac{\sin\alpha}{\alpha}$	$\alpha = \frac{\pi}{\lambda}a\sin\theta$	$I_p = N^2E_0^2\frac{\sin^2\alpha}{\alpha^2}$

Minimum	$\alpha = m\pi$	$a\sin\theta = m\lambda$	$a\frac{X}{D} = m\lambda$	$X_m = m\frac{\lambda D}{a}$
Maximum	**Width of central maxima**		**Maxima**	
	$w = 2X_1 = \frac{2\lambda D}{a}$		$\frac{dI_p}{d\alpha} = 0, \tan\alpha = \alpha$	

Interference in thin films

Brightness at $\boldsymbol{\delta = 2m\pi}$	Brightness at normal incident ($\boldsymbol{\theta_t = 0}$)	Darkness at normal incident ($\boldsymbol{\theta_t = 0}$)
$2n_2d\cos\theta_t = m\lambda_0$	$d = \frac{m\lambda_0}{2n_2} = \frac{m\lambda_n}{2}$	$d = (2m+1)\frac{\lambda_0}{4n_2}$
If equal amount of light is reflected on both sides of the film		$\frac{n_2-n_1}{n_2+n_1} = \frac{n_3-n_2}{n_3+n_2} \to n_2 = \sqrt{n_3}$

Newton's rings

	Minimum (Dark)	Maxima (Bright)
	$2kd = 2m\pi$	$\rho_m = \sqrt{\frac{\left(m+\frac{1}{2}\right)\lambda_0R}{n_2}}$
$d = \frac{\rho^2}{2R}$	$\rho_m = \sqrt{\frac{m\lambda_0R}{n_2}}$	

Michelson interferometer

Total phase difference	Circular symmetric ($\boldsymbol{\delta = 2\pi m}$)		
$\delta = \frac{2\pi}{\lambda_0}.2d\cos\theta_t$	$m = \frac{2d}{\lambda_0}\cos\theta_t$	**Normal incidence**	$m = \frac{2d}{\lambda_0}$
Intensity	$I = 2I_0\cos^2kd$	**At $\boldsymbol{I = \frac{I_{max}}{2}}$**	$\delta_{\frac{1}{2}} = \frac{\pi}{2}$

Fabri-Perot (multi reflection)

$\overrightarrow{E_i} = \overrightarrow{E_0}e^{i(\vec{k}.\vec{r}-\omega t)}$	$E_t = \frac{E_1(1 - r^2\cos\delta + ir^2\sin\delta)}{1 - 2r^2\cos\delta + r^4}$
$\overrightarrow{E_1} = \overrightarrow{E_0}t_1t_2e^{i(\vec{k}.\vec{r}-\omega t)}$	

$I_t = E_t.E_t^* = \frac{E_1^2}{1-2r^2\cos\delta + r^4} = \frac{E_1^2}{(1-r^2)^2 + 4r^2\sin^2\frac{\delta}{2}}$		
At $\delta = 2m\pi$	$I_t = I_{max} = \frac{E_1^2}{(1-r^2)^2}$	$I_t = \frac{I_{max}}{1 + \frac{4r^2}{(1-r^2)^2}\sin^2\frac{\delta}{2}}$
At $\delta = (2m+1)\pi$	$I_t = I_{min} = \frac{E_1^2}{(1+r^2)^2}$	

Visibility (v)	$v = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} = \frac{2r^2}{1+r^4}$	**Contrast (F)**	$F = \frac{4r^2}{(1-r^2)^2}$
$\frac{I_t}{I_{max}} = \frac{1}{1 + F\sin^2\frac{\delta}{2}}$			
Maximum trans		**At $I = \frac{I_{max}}{2}$**	
$\frac{\delta}{2} = m\pi$	$2n_2 d\cos\theta_t = \frac{m\lambda_0}{2}$	$\delta_{\frac{1}{2}} = 2\sin^{-1}\frac{1}{\sqrt{F}}$	**Half width (γ)** $\gamma = 2\delta_{\frac{1}{2}}$

Resolving power

$RB = \frac{\lambda}{\lvert\Delta\lambda\rvert} = \frac{\omega}{\Delta\omega} = \frac{\omega d}{2c}\sqrt{F} = \frac{\omega d}{\pi c} f$	$f = \frac{\pi}{2}\sqrt{F}$
Maxima, at ($\boldsymbol{\delta = 2m\pi}$), ($\boldsymbol{\frac{\omega d}{c} = m\pi}$)	$RB = mF$

Multilayer

For 3 regions n_0, n_1, n_3		
$\begin{pmatrix} E_1 \\ H_1 \end{pmatrix} = \begin{pmatrix} \cos\delta_1 & -\frac{i\sin\delta_1}{\beta_1} \\ -i\beta_1\sin\delta_1 & \cos\delta_1 \end{pmatrix}\begin{pmatrix} E_2 \\ H_2 \end{pmatrix}$	$\delta_1 = n_1 k_0 d\cos\theta_t$ $\beta_1 = \sqrt{\frac{\epsilon_0}{\mu_0}}n_1\cos\theta_t$	
For multi periodic layers		
$\begin{pmatrix} E_1 \\ H_1 \end{pmatrix} = M_1 M_2 \dots M_n \begin{pmatrix} E_{n+1} \\ H_{n+1} \end{pmatrix}$	$M = M_1 M_2 \dots M_n = \begin{pmatrix} M_{11} & -iM_{12} \\ -iM_{21} & M_{22} \end{pmatrix}$	
Reflectivity R	$r = \frac{(\beta_0 M_{11} - \beta_s M_{22}) - i(\beta_0\beta_s M_{12} - M_{21})}{(\beta_0 M_{11} + \beta_s M_{22}) - i(\beta_0\beta_s M_{12} + M_{21})}$	$R = rr^*$
Transitivity T	$t = \frac{2\beta_0}{(\beta_0 M_{11} + \beta_s M_{22}) - i(\beta_0\beta_s M_{12} + M_{21})}$	$T = tt^*$

Anti-reflecting film

For normal incidence			
$\delta = kd$	$\beta_1 = \sqrt{\frac{\epsilon_0}{\mu_0}}n_1$	$R = \frac{(n_s - n_1^2)^2}{(n_s + n_1^2)^2}$	$M = \begin{pmatrix} \cos\delta & -\frac{i\sin\delta}{\beta_1} \\ -i\beta_1\sin\delta & \cos\delta \end{pmatrix}$
$\beta_0 = \sqrt{\frac{\epsilon_0}{\mu_0}}$	$\beta_s = \sqrt{\frac{\epsilon_0}{\mu_0}}n_s$	$R = 0$ For $n_1 = \sqrt{n_s}$	

High-reflecting films

Alternate layers of high index n_h and low n_l with thickness $d = \frac{\lambda}{4n_{h,l}}$		
$M = \begin{bmatrix} -\frac{n_h}{n_l} & 0 \\ 0 & -\frac{n_l}{n_h} \end{bmatrix}$	**For 2N layers (films)**	
	$M_t = M^n = \begin{bmatrix} \left(-\frac{n_h}{n_l}\right)^N & 0 \\ 0 & \left(-\frac{n_l}{n_h}\right)^N \end{bmatrix}$	$R = \left(\frac{\left(\frac{n_h}{n_l}\right)^{2N} - n_s}{\left(\frac{n_h}{n_l}\right)^{2N} + n_s}\right)^2$

Diffraction

$r = r_0 + y\sin\theta$	$u_p = \int e^{ikr}ds$

Single and double slits

$\alpha = \frac{\pi}{\lambda}b\sin\theta$		$\beta = k\frac{a}{2}\sin\theta$	$C' = aLCe^{ikr_0}$	$I = \lvert u_p\rvert^2 = I_m\left(\frac{\sin\beta}{\beta}\right)^2$	
Single slit	$u_p = C'\frac{\sin\beta}{\beta}$		Double slits	$u_p = C'\frac{\sin\beta}{\beta}\cos\alpha$	
minima		**maxima**	**Minima**		**Maxima**
$\beta = m\pi$		$\frac{dI}{d\beta} = 0$	$m\pi = \frac{\pi}{\lambda}b\sin\theta$	$X_m = \frac{m\lambda D}{b}$	$w_c = \frac{2\lambda D}{a}$
$\frac{\pi}{\lambda}a\sin\theta = m\pi$		$\tan\beta = \beta$	#of fringes under central max		
$X_m = \frac{m\lambda D}{a}$	$width_{central} = \frac{2\lambda D}{a}$		$n = \frac{w}{\Delta x} - 1 = 2\frac{b}{a} - 1$		

Multi slits (diffraction grating)

$u_p = C'\frac{\sin\beta}{\beta}\frac{\sin N\alpha}{\sin\alpha}$		$I = N^2 I_0\left(\frac{\sin\beta}{\beta}\frac{\sin N\alpha}{\sin\alpha}\right)^2$	I_0: *intensity from one slit*
Maxima	$\alpha = m\pi$	$m\lambda = b\sin\theta$	**Resolving power:** $RB = \frac{\lambda}{\Delta\lambda} = Nm$

Circular aperture

$u_p = Ce^{ikr_0}2\frac{J_1(p)}{p}$	$I = I_0\left(2\frac{J_1(p)}{p}\right)^2$	$p = kR\sin\theta$
Airy disk	$\sin\theta = \frac{1.22\lambda}{D} = \theta$	$D = 2R$