Optics Review I

I. 1D Wave Motion
   a. Traveling waves $\psi(x,t) = f(x \pm vt)$
   b. Wave equation $\psi_{tt} = v^2 \psi_{xx}$
   c. Harmonic Waves - $\psi(x,t) = A\sin k(x - vt)$
   d. period, wavelength, frequency, wave number, phase velocity, wave speed
   e. Complex Representation $\psi(x,t) = Ae^{i\varphi}$

II. Maxwell's Equations
   a. Laws – Coulomb, Gauss, Faraday, Ampere, Maxwell-Ampere, Bio-Savart
   b. Differential and Integral Forms

Differential Form	Integral Form
$\nabla \cdot \mathbf{E} = \dfrac{\rho}{\varepsilon_0}$	$\oint_S \mathbf{E} \cdot \mathbf{n}\, da = \dfrac{q_{\text{enc}}}{\varepsilon_0}$
$\nabla \cdot \mathbf{B} = 0$	$\oint_S \mathbf{B} \cdot \mathbf{n}\, da = 0$
$\nabla \times \mathbf{E} = -\dfrac{d\mathbf{B}}{dt}$	$\oint_C \mathbf{E} \cdot d\mathbf{l} = -\dfrac{d}{dt}\int_S \mathbf{B} \cdot \mathbf{n}\, da$
$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \varepsilon_0 \dfrac{d\mathbf{E}}{dt}$	$\oint_C \mathbf{B} \cdot d\mathbf{l} = \mu_0 I_{\text{enc}} + \mu_0 \varepsilon_0 \dfrac{d}{dt}\int_S \mathbf{E} \cdot \mathbf{n}\, da$

   c. Wave equation – $\nabla^2 E - \mu_0 \varepsilon_0 \dfrac{\partial^2 E}{\partial t^2} = 0$,
   d. Polarization: $\mathbf{J} = \mathbf{J}_f + \mathbf{J}_{\text{p}} = \mathbf{J}_f + \dfrac{\partial \mathbf{P}}{\partial t}$ and $\rho = \rho_f + \rho_p = \rho_f - \nabla \cdot \mathbf{P}$.
   e. Material Properties

$$\mathbf{D} = \varepsilon_0 \mathbf{E} + \mathbf{P} = \varepsilon \mathbf{E},\ \mathbf{H} = \frac{1}{\mu_0}\mathbf{B} - \mathbf{M} = \frac{1}{\mu}\mathbf{B} \text{ for } \mathbf{P} = \varepsilon_0 \chi_e \mathbf{E} \text{ and } \mathbf{M} = \chi_m \mathbf{H}$$

III. Plane Wave Solutions - $\mathbf{E}(\mathbf{r},t) = \mathbf{E}_0 \cos(\mathbf{k} \cdot \mathbf{r} - \omega t)$
   a. Relations between **E** and **B**
   b. Waves in Dielectrics, Susceptibility $\mathcal{N} = n + i\kappa = \sqrt{1 + \chi}$
   c. Index of Refraction, Absorption ($z = \dfrac{c}{\kappa\omega}$), Wavelength ($\lambda = \dfrac{\lambda_{vac}}{n}$), Wavespeed
   d. Poynting Vector $S = \dfrac{1}{\mu_0}\mathbf{E} \times \mathbf{B}$
   e. Irradiance and Intensity $\langle \mathbf{S} \rangle_t = \dfrac{1}{2} n \varepsilon_0 c \mathbf{E}_0 \cdot \mathbf{E}_0^* \hat{\mathbf{u}} \equiv I\hat{\mathbf{u}}$

IV. Reflection and Refraction of Plane Waves
   a. Boundary Conditions: Parallel field components are continuous
   b. Angle Relations, $\theta_r = \theta_i,\ n_i \sin\theta_i = n_t \sin\theta_t$
   c. Brewster's Angle, $\theta_i + \theta_B = \dfrac{\pi}{2},\ \theta_B = \tan^{-1}\dfrac{n_t}{n_i}$

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d. Total Internal Reflection, $\sin\theta_c \frac{n_t}{n_i}$

V. Parallel Interfaces

a. $T^{tot} = \frac{T^{\max}}{1 + F\sin^2\frac{\Phi}{2}}$, $T^{\max} = \frac{T^{0\to1}T^{1\to2}}{\left(1-\sqrt{R^{1\to0}R^{1\to2}}\right)^2}$, $F = \frac{4\sqrt{R^{1\to0}R^{1\to2}}}{\left(1-\sqrt{R^{1\to0}R^{1\to2}}\right)^2}$

b. Fabry-Perot etalon/interferometer, $\Phi = \frac{4\pi n_1 d}{\lambda_{vac}}\cos\theta_1 + \delta_r$

VI. Propagation in Crystals

a. $\mathbf{P} = \varepsilon_0\chi_x E_x\hat{\mathbf{x}} + \varepsilon_0\chi_y E_y\hat{\mathbf{y}} + \varepsilon_0\chi_z E_z\hat{\mathbf{z}}$

b. $n_x = \sqrt{1+\chi_x}$, etc

c. Birefringence, ordinary-extraordinary waves, optic axis

VII. Rainbows

a. Primary, Secondary Rainbows

b. Minimum Deviation, Location as function of *n*.

c. Know answers to Dr. Lewin's 15 Questions, such as location of primary and secondary rainbows, color order, key angles, etc.