

$$\mathbf{P} = \chi_e \epsilon_0 \mathbf{E} \quad (1)$$

$$\mathbf{P} = \frac{N}{V} q \delta = \frac{N}{V} \mathbf{p} \quad (2)$$

$$\chi_e = \epsilon - 1 \quad (3)$$

$$\mathbf{p} = \alpha \mathbf{E} \quad (4)$$

$$\mathbf{P} = (\epsilon - 1) \epsilon_0 \mathbf{E}_{\text{ext}} = \frac{N}{V} \mathbf{p} = \frac{N}{V} \alpha \mathbf{E} \quad (5)$$

$$\alpha = \frac{(\epsilon - 1) \epsilon_0 V}{\epsilon N} \quad (6)$$

$$\mathbf{E}_{\text{loc}} = \frac{1}{3} (\epsilon + 2) \mathbf{E}_{\text{ext}} \quad (7)$$

$$\mathbf{P} = \frac{N}{V} \alpha \mathbf{E}_{\text{loc}} = \frac{N \alpha}{3V} (\epsilon + 2) \mathbf{E}_{\text{ext}} \quad (8)$$

$$\alpha = \frac{\epsilon - 1}{\epsilon + 2} \frac{3 \epsilon_0 V}{N} \quad (9)$$

$$\frac{d^2 x}{dt^2} + \eta \frac{dx}{dt} + \omega_0^2 x = \frac{eE}{M} e^{-i\omega t} \quad (10)$$

$$x = A e^{-i\omega t} \quad (11)$$

$$A = \frac{eE}{M} \frac{1}{\omega_0^2 - \omega^2 - i\eta\omega} \quad (12)$$

$$A = \frac{eE}{M} \left(\frac{\omega_0^2 - \omega^2}{(\omega_0^2 - \omega^2)^2 + \eta^2 \omega^2} + \frac{i\eta\omega}{(\omega_0^2 - \omega^2)^2 + \eta^2 \omega^2} \right) \quad (13)$$

$$P = P_i + P_e = \frac{N}{V} e A e^{-i\omega t} + \frac{N}{V} \alpha E e^{-i\omega t} \quad (14)$$

$$\epsilon = \frac{P}{\epsilon_0 E e^{-i\omega t}} + 1 = \frac{NeA}{V \epsilon_0 E} + \frac{N\alpha}{V \epsilon_0} + 1 \quad (15)$$

$$\epsilon_{\text{opt}} = \frac{N\alpha}{V \epsilon_0} + 1 \quad (16)$$

$$\epsilon(\omega) = \frac{NeA}{V \epsilon_0 E} + \epsilon_{\text{opt}} \quad (17)$$

$$\epsilon_r(\omega) = \frac{Ne^2}{V \epsilon_0 M} \frac{\omega_0^2 - \omega^2}{(\omega_0^2 - \omega^2)^2 + \eta^2 \omega^2} + \epsilon_{\text{opt}} \quad (18)$$

$$\epsilon_i(\omega) = \frac{Ne^2}{V \epsilon_0 M} \frac{\eta\omega}{(\omega_0^2 - \omega^2)^2 + \eta^2 \omega^2} \quad (19)$$

$$P(t) = j(t) E(t) \quad (20)$$

$$j(t) = \frac{\partial D}{\partial t} = \frac{\partial}{\partial t} \epsilon \epsilon_0 E(t) = \epsilon_0 E(t) \left(-i\omega \epsilon_r + \omega \epsilon_i \right) \quad (21)$$