$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$v = \frac{c}{n}$$

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

$$m = -\frac{d_i}{d_o}$$

thin lens

$$v = \lambda f \qquad k = \frac{2\pi}{\lambda} \qquad \omega = \frac{2\pi}{T}$$

$$f = \frac{1}{T}$$

$$v = \sqrt{\frac{T_s}{\mu}}$$ wave on a string

$$\frac{I_1}{I_2} = \frac{r_2^2}{r_1^2}$$

$$D(x,t) = A \sin\left(\frac{2\pi}{\lambda}x - \frac{2\pi}{T}t + \phi_0\right)$$

sinusoidal wave in +x direction

open-open (fixed-fixed)

$$f_m = \frac{v}{2L} m$$

$$\lambda_m = \frac{2L}{m}, \quad m = 1, 2, 3, \dots$$

$$f_m = m f_1$$

open-closed (fixed-free)

$$f_m = \frac{v}{4L} m$$

$$\lambda_m = \frac{4L}{m}, \quad m = 1, 3, 5$$

$$f_m = m f_1$$

$$\Delta\phi = \frac{2\pi}{\lambda}\Delta r + \Delta\phi_0$$

phase differen

$$\Delta\phi = m \cdot 2\pi, \quad m = 0, 1, 2, \dots$$

if $\Delta\phi_0 = 0$

$$\Rightarrow \Delta r = m\lambda$$

maximum construc interference

$$\Delta\phi = \left(m + \frac{1}{2}\right) 2\pi \quad m = 0, 1$$

if $\Delta\phi_0 = 0$

$$\Rightarrow \Delta r = \left(m + \frac{1}{2}\right)\lambda$$

perfect destructive interference

double slit & diffraction grating bright fringes

$$d \sin\theta_m = m\lambda, \quad m = 0, 1, 2, \dots$$

$$x_m = L \tan\theta_m$$

maxima for single slit

$$D \sin\theta_p = p\lambda, \quad p = 1, 2, 3, \dots$$

$$x_p = L \tan\theta_p$$

$$\vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \hat{r}$$ point charge

$$\vec{F} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \hat{r}$$ Coulomb's Law

$$\frac{1}{4\pi\varepsilon_0} = K \approx 9 \times 10^9 \frac{N\,m^2}{C^2}$$

$$e = 1.6 \times 10^{-19} C$$

$$V = \frac{1}{4\pi\varepsilon_0} \frac{q_1}{r}$$ point charg

$$\vec{E} = -\vec{\nabla} V \qquad V = -\int \vec{E} \cdot d\vec{r} \qquad \vec{F} = q\vec{E}$$

$$\boxed{\vec{\nabla} = \frac{\partial}{\partial x}\hat{i} + \frac{\partial}{\partial y}\hat{j} + \frac{\partial}{\partial z}\hat{k}}$$

$$\boxed{\begin{array}{l} \Delta U + \Delta K = 0 \\ \text{or } U_i + K_i = U_f + K_f \end{array}}$$

conserv. of energy

$$K = \frac{mv^2}{2}$$

$$\Delta U = q\Delta V$$

$$\boxed{\oint \vec{E} \cdot d\vec{A} = \frac{q_{encl}}{\varepsilon_0} = \Phi_E}$$

Gauss's Law

$$\boxed{\begin{array}{l} \Phi_E = \int \vec{E} \cdot d\vec{A} \\ \Phi_E = \vec{E} \cdot \vec{A} \quad \text{for } \vec{E} \text{ uniform} \end{array}}$$

$$E = \frac{\sigma}{\varepsilon_0}$$ el. field between capacitor plates

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

$$E = \frac{1}{4\pi\varepsilon_0} \frac{Qx}{(x^2+a^2)^{3/2}}$$ on axis of a charged ring

$$C = \frac{Q}{V} \qquad E = \frac{Q}{\varepsilon_0 A}$$

$$C = \frac{\varepsilon_0 A}{d}$$ parallel plate

$$U = \frac{1}{2} \frac{Q^2}{C}$$

$$C = KC_0$$

$I = \frac{dQ}{dt}$ $\quad R = \rho \frac{\ell}{A}$ $\quad I = \frac{V}{R}$ $\quad P = IV$ $\quad j = \frac{I}{A}$ $\quad j = nev_d$

$R_{eq} = R_1 + R_2 + \dots$ (in series)

$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$ (in parallel)

$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$ (in series)

$C_{eq} = C_1 + C_2 + \dots$ (in parallel)

Kirchhoff's Loop Law:

$$\sum_i \Delta V_i = 0$$

Kirchhoff's Junction Law:

$$\sum I_{in} = \sum I_{out}$$

$\tau = RC$ $\quad I = I_0 e^{-\frac{t}{\tau}}$ $\quad Q = C\Delta V$

$d\vec{F} = I d\vec{\ell} \times \vec{B}$ $\quad \vec{F} = I\vec{\ell} \times \vec{B}$ $\quad \vec{F} = q\vec{v} \times \vec{B}$ $\quad \vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$

$f = \frac{qB}{2\pi m}$ $\quad r = \frac{mv}{qB}$ $\quad \mathcal{E}_H = E_H d = v_d B d$

$B = \frac{\mu_0}{2\pi} \frac{I}{r}$ $\quad \oint \vec{B} \cdot d\vec{\ell} = \mu_0 I_{encl}$

$B = \mu_0 n I = \mu_0 \frac{N}{L} I$

solenoid

$B = \frac{\mu_0 N I}{2\pi r}$

toroid

$d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{d\vec{\ell} \times \hat{r}}{r^2}$

$dB = \frac{\mu_0 I}{4\pi} \frac{d\ell \sin\theta}{r^2}$

$\mathcal{E} = -N \frac{d\Phi_B}{dt}$ $\quad \Phi_B = \vec{B} \cdot \vec{A}$ $\quad d\Phi_B = \vec{B} \cdot d\vec{A}$

$V_s = V_p \frac{N_s}{N_p}$ $\quad I_p V_p = I_s V_s = P$