Waves

$$\upsilon = \lambda f = \frac{\omega}{k} = \frac{2\pi}{Tk} = \frac{\lambda\omega}{2\pi}; \quad k = \frac{2\pi}{\lambda}; \quad \omega = \frac{2\pi}{T} = \mathrm{k}\,\upsilon; \quad f = \frac{1}{T}$$

$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{\nu^2}\frac{\partial^2 y}{\partial t^2}$$

$$y = A\cos(\kappa x \pm \omega t)$$

$$\bar{P} = \frac{1}{2}\mu\omega^2 A^2 V$$

$$\nu = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{B}{\rho}}; \quad B = \rho\upsilon^2$$

$$\Delta p = -B\frac{\partial S(x)}{\partial x} = -\rho\nu^2\frac{\partial S(x)}{\partial x}$$

$$\Delta p_{max} = \rho\omega\upsilon S_{max}$$

$$I = \frac{1}{2}\rho\omega^2\ \upsilon\, S^2_{max} = \eta\upsilon = \frac{1}{2}\frac{p_0^2}{\rho\upsilon}; \qquad \eta = \frac{1}{2}\rho\omega^2 S_0^2$$

$$I_{sp} = \frac{\rho}{4\pi r^2}$$

$$\upsilon = 331\frac{m}{s}\sqrt{\frac{T}{273}}$$

$$\beta = 10\log\left(\frac{I}{I_0}\right) = 20\log\left(\frac{p}{p_0}\right) \qquad I_0 = 10^{12}\ W/m^2$$

$$f' = f\left[\frac{\upsilon - \upsilon_0}{\upsilon - \upsilon_s}\right]$$

$$A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos(\beta_2 - \beta_1)} = 2\left|A_1\right|\left|\cos\left(\frac{\beta_2 - \beta_1}{2}\right)\right|$$

$$\beta_2 - \beta_1 = 2n\pi \ (even)(constructive) \qquad \beta_2 - \beta_1 = (2n+1)\pi \ (odd)(destructive)$$

$$A = 2A_1\left|\sin(k(L-x))\right|$$

$$X_m = L - m\frac{\lambda}{2} \qquad X_{m+1} - X_m = \frac{\lambda}{2}$$

$$\lambda_n = \frac{2L}{n} \qquad f_n = n\,f_1$$

$$\lambda_n = \frac{4L}{2n-1} \qquad f_n = (2n-1)\,f_1$$

$$f_b = \left| f_2 - f_1 \right|$$

$$y_{net} = 2A\cos\left[\left(\frac{K_1 - K_2}{2}\right)x - \left(\frac{\omega_1 - \omega_2}{2}\right)t\right]\cos\left[\left(\frac{K_1 + K_2}{2}\right)x - \left(\frac{\omega_1 + \omega_2}{2}\right)t\right]$$

k : *wave number*

λ : *wave length*

υ : *wave velocity*

T : *Period*

f : *frequency*

ω : *angular frequency*

p : *change in pressure*

I : *Intensity*

η : *average energy density*

β : *intensity level* (db)

I_{sp} : *wave intensity*

Electric Charges and Fields

$$\vec{F} = k\frac{q_1 q_2}{r^2}\hat{e}_r = q\vec{E} \qquad \hat{e}_r = \frac{\vec{r}}{r}; \quad k = 8.99\times10^{9}\ Nm^2/C^2$$

$$\vec{F}_{12} = -\frac{G\,m_1 m_2}{r_{12}^2}\hat{r}_{12} = k\frac{q_1 q_2}{r_{21}^2}\hat{e}_{21} \qquad \hat{r}_{12} = \frac{\vec{r}}{r}; \quad G = 6.67\times10^{-11}\ Nm^2/kg^2$$

$$F = \frac{1}{4\pi\varepsilon_0}\frac{|q_1 q_2|}{r^2} = k\frac{|q_1||q_2|}{r^2} \qquad E = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}$$

$$\vec{E} = k\frac{q}{r^2}\hat{e}_r = \frac{\vec{F}}{q} \qquad \hat{e}_r = \frac{\vec{r}}{r}$$

$$\overrightarrow{E_p} = k\int\frac{dr}{r^2}\hat{e}_r = k\int\frac{\overrightarrow{r_p}\,\rho}{r^2}\,dV = -\frac{kQ}{a[a+L]}\hat{\imath} \qquad E_p = E_{px} = \frac{kQx}{\sqrt[3]{x^2+R^2}} = \frac{kQ}{a[a+L]}$$

$$d\phi_E = \vec{E}\cdot d\vec{A} = E\cdot dA\ \cos\theta$$

$$\phi_E = \int E\cos\theta\ dA = \int\vec{E}\cdot d\vec{A} = \frac{Q_{encl}}{\varepsilon_0} = EA\cos\theta = \vec{E}\cdot\vec{A} = E_n A = \vec{E}\cdot\hat{n}\ A$$

$$\phi_{net} = \oint\vec{E}\cdot\vec{n}\ dA = \frac{kq}{R^2}\oint dA = 4\pi kq$$

$$\oint\vec{E}\ d\vec{A} = \frac{q}{\varepsilon_0} \qquad \varepsilon_0 = \frac{1}{4\pi k}; \quad k = \frac{1}{4\pi\varepsilon_0}$$

$$E = \frac{2k\lambda}{r} = 2\pi k\sigma = \frac{\sigma}{2\varepsilon_0} = \frac{1}{4\pi\varepsilon_0}\frac{Qr}{R^3} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$

$$\rho = \frac{3Q}{4\pi R^3}$$

$$E = \frac{kq}{r^2} \quad for\ \ r > R \qquad E = \frac{kq}{R^3}r \quad for\ \ r < R$$

$\vec{F}$: *Force*	$\vec{E}$: *Electric field*
G: *Universal gravitational constant*	ε_0: *permittivity of free space* $= 8.85\times10^{-12}\ C^2/N\text{-}m^2$
q_*: *charge*	ϕ: *flux*
r: *distance*	σ: *charge density*
$\hat{e}_r$: *Unit vector*	$Q_{encl} = q_1 + q_2 + \cdots$: *total charge enclosed by the surface*

Electric Potential

$$w_e = -\Delta u = u_f - u_i = q\int_{\vec{r}_i}^{\vec{r}_f} \vec{E}\, d\vec{r} = q\vec{E}\cdot\Delta\vec{r} = q\Delta V = qEd\cos\theta$$

$$\frac{1}{2}mv_i^2 + u_i = \frac{1}{2}mv_f^2 + u_f$$

$$U = \frac{1}{4\pi\varepsilon_0}\frac{qq_0}{r}$$

$$W_e = \int dW_e = \int_{\overrightarrow{r_1}}^{\overrightarrow{r_2}} \overrightarrow{F_r}\cdot d\vec{r} = q\int_{\overrightarrow{r_1}}^{\overrightarrow{r_2}} \vec{E}\cdot d\vec{r} = q\vec{E}\cdot\Delta\vec{r} = qEd\cos\theta = q\times Ed$$

$$|\Delta u| = |q|Ed$$

$$\Delta v = \frac{\Delta u}{q} = -Ed$$

$$v(r) = \frac{kq}{r}$$

$$u = \frac{kq_1q_2}{r} = \frac{kq_1q_2}{r_{12}} + \frac{kq_2q_3}{r_{23}} + \frac{kq_1q_3}{r_{13}} = \frac{1}{2}\sum_{i=1}^{n}\sum_{i=j}^{n}\frac{kq_iq_j}{r_{ij}}$$

$$v_p = k\lambda\ln\left(\frac{a+L}{a}\right)$$

$$E = -\frac{v}{dx} = \frac{\sigma}{\varepsilon_0}$$

$$Q = c\Delta v$$

W : *Work*

U : *potential energy*

Electrical

$$I_{av} = \frac{Q}{\Delta t} \qquad I = \frac{d\theta}{dt} \qquad I(t) = I_{\max} e^{-\frac{1}{RC}t}$$

Ohm's Law: $V = I \cdot R$

Resistance of a wire: $R = \frac{\rho \cdot l}{A} = \frac{\Delta V}{I} = R_0 \left[1 + \alpha\left(T - T_0\right)\right]$

Power $P = I^2 \cdot R = I \cdot V = \frac{V^2}{R} = \frac{\Delta u}{\Delta t}$

$$P_S = \frac{W_S}{\Delta t} = I\varepsilon$$

$$P_d = P_S - P_r = \varepsilon I - I^2 r = \varepsilon I - I^2 r$$

$$P_R = \varepsilon I - I^2 r = I^2 r$$

$$\sum_{\textit{Around any loop}} \Delta V_i = 0$$

$$\sum_{\textit{At any node}} I_i = 0$$

Series Resistor $R_{eq} = R_1 + R_2 + R_3 + \cdots$ *Parallel Resistor* $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$

Series Capacitor $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_n}$ *Parallel Capacitor* $C_{eq} = C_1 + C_2 + C_3 + \cdots$

Heat of a phase $Q = m \cdot L$

$$C = \frac{Q}{V} = \frac{\kappa \varepsilon_0 A}{l} = \frac{\varepsilon_0 A}{d} = \frac{L}{2k \ln\left(\frac{b}{a}\right)} = \frac{ab}{k(b-a)} = kC_0$$

$$V_c = V_0 \, e^{-t/RC}$$

$$V_c - IR = 0$$

$$E = \rho J = -\frac{dV}{dr}$$

$$J = \sigma E = \frac{I}{A_\perp}; \qquad \rho = \frac{1}{\sigma}$$

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

$$\varepsilon = -L\frac{dI}{dt} = -\frac{d\phi_m}{dt}$$

$$\phi_m = \int B \cdot dA$$

$$\Delta v = \frac{\Delta v_0}{k} = kQ\left(\frac{1}{a} - \frac{1}{b}\right)$$

$$|\Delta v| = 2k\lambda \ln\frac{b}{a}$$

$$u = \frac{1}{2}C\Delta v^2 = \frac{1}{2}Q\Delta v = \frac{1}{2}\frac{Q^2}{C}$$

$$\frac{1}{2}\varepsilon_0 E^2 = u_E$$

$$k = \frac{E_0}{E}$$

$$\Delta\rho = \alpha\rho_0\Delta T \quad \rightarrow \quad \rho = \rho_0\left[1 + \alpha\ (T - T_0)\right]$$

V : *voltage*	ε : *emf*
I : *current*	ϕ_m : *magnetic flux*
R : *resistance*	B : *magnetic field*
C : *Capacitance*	$\Delta\rho = \rho - \rho_0$: Change in resistivity
L : *Inductance*	ρ_0 : Initial resistivity
Q : *charge*	$\Delta T = T - T_0$: Change in temperature
P : *power*	α: Temperature coefficient of resistivity
ρ : *resistivity of wire material*	P_S : Power of a source
σ : *conductivity*	W_S : Work done by a source in transporting charges from one to the other in a time Δt
r : *distance*	P_d : Power delivered to the external resistance
J : *current density*	P_R : Power dissipated in the external resistance
l : *length of wire*	
A : *cross-sectional area of the wire*	
U : *potential or stored energy*	
κ : *dielectric constant*	

$$\vec{F}_B = I\ \Delta\vec{\ell} \times \vec{B} \qquad F_B = |q| VB \sin\theta$$

$$\vec{\tau} = I\left(\vec{A} \times \vec{B}\right) \quad \rightarrow \quad \tau = IAB\sin\theta$$

$$\vec{\mu} = I\vec{A} \qquad u = -\vec{\mu} \bullet \vec{B}$$

$$\vec{F}_{em} = q\vec{E} + q\vec{v} \times \vec{B}$$

$$v = \frac{qRB}{m}$$

$$E = \frac{1}{2m} q^2 R^2 B^2$$

$$B = \frac{\Delta V_H}{v_d d} = \frac{nqt\Delta V_H}{I} = \frac{I\mu_0}{2\pi r_\perp} = \frac{\mu_0 NI}{\ell}$$

$$d\vec{B} = \frac{\mu_0 I\, d\vec{s} \times \vec{r}_p}{4\pi r_p^3} \qquad \vec{B} = \frac{\mu_0}{4\pi} I \frac{d\vec{s} \times \left(\vec{r} - \vec{r}'\right)}{\left|\vec{r} - \vec{r}'\right|^3} = \frac{\mu_0 I\ R^2}{2\left(a^2 + R^2\right)^{3/2}}\ \hat{k} = \frac{\mu_0 NI}{2R}\ \hat{k}$$

$$\frac{F_{12}}{\ell} = \frac{\mu_0 I_1 I_2}{2\pi d}$$

$$\oint_{\substack{closed\\ path}} \vec{B} \bullet d\vec{s} = \mu_0 I = \mu_0 NI = \mu_0\left(I + I_0\right) = \mu_0\left(I + \varepsilon_0 \frac{d\phi_E}{dt}\right)$$

$$B = \frac{\mu_0 I}{2\pi r_\perp} \quad if \quad r_\perp > R \qquad B = \frac{\mu_0 r_\perp I}{2\pi R^2} \quad if \quad r_\perp < R$$

F_B : Magnitude of magnetic force

V: Magnitude of velocity

B: Magnitude of magnetic field

$\vec{\tau}$: Magnetic torque

$\vec{\mu}$: Magnetic moment

$d\vec{B}$ → Magnetic field due to current I in a small path element $d\vec{s}$

$\vec{r}_p$ → Position vector of the point (P) with respect to the path element $d\vec{i}$

r_p → Distance between path element and the point.

$\mu_0 = 4\pi \times 10^{-7}\ \frac{Tm}{A}$ → A universal constant called magnetic permeability in vacuum.

$r_\perp$ → ⊥ distance between the wire and the point

$\frac{F_{12}}{\ell}$ → Force (magnetic) per unit length exerted by wire 2

$\vec{B}$ → Magnetic field at the location of $d\vec{s}$

I → Current crosses the closed path

N → Number of turns

ℓ → Length of solenoid