Simple Harmonic Motion

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

Period $= T$
Frequency $= f$

Angular frequency $w = \frac{2\pi}{T}$ or $w = 2\pi f$

Period: $T = \frac{1}{f} = 2\pi\sqrt{\frac{m}{k}}$

Maximum velocity of a wave $= v_{max} = \frac{2\pi A}{T} = 2\pi f A = wA$

Maximum acceleration of a wave $= -w^2 A = (2\pi f)^2 A$

General formulas:

$x(t) = A\cos(wt + \phi_0)$

$v_x(t) = \frac{dx}{dt} = -wA\sin(wt + \phi_0) = -v_{max}\sin(wt + \phi_0)$

$a_x(t) = \frac{d^2x}{dt^2} = -w^2 A\cos(wt)$

Energy: $E = K + U = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$

Traveling Waves

Linear Density

$\mu = \frac{m}{L}$

$T_s =$ tension

Wave speed: $v = f\lambda = \sqrt{\frac{T_s}{\mu}} = \frac{w}{k}$

Note: $v = f\lambda$ is from $v = \frac{\text{distance}}{\text{time}}$

Velocity

$v_{sound} = \sqrt{\frac{B}{\rho}}$

$B =$ Bulk moduliPa

$\rho =$ density kg/m^3

Dry air at 20degC $\approx 343\ m/s$

Beat Frequency $= |f_1 - f_2|$

Phase

$\phi_1 = kx_1 - wt + \phi_0$

$\phi_2 = kx_1 - wt + \phi_0$

Phase difference $\Delta\phi = 2\pi\frac{\Delta X}{\lambda}$

Superposition

$D(x,t) = a\sin(kt - \omega t) + a\sin(kt + \omega t) = sin(\alpha)\cos(\beta) \pm \cos(\alpha)\sin(\beta)$

or

$D(x,y) = 2a\sin(kx)cos(\omega t)$

$f_m = \frac{v}{\lambda_m} = \frac{v}{2L/m} = m\frac{v}{2L} \quad m = 1, 2, 3, 4...$

Fundamental frequency: $f_1 = \frac{v}{2L}$

Allowed frequencies: $f_m = mf_1 \quad m = 1, 2, 3, 4$

$m = 1$	$\lambda_1 = \frac{2L}{1}$	$f_1 = \frac{v}{2L}$
$m = 2$	$\lambda_2 = \frac{2L}{2}$	$f_2 = 2\frac{v}{2L}$
$m = 3$	$\lambda_3 = \frac{2L}{3}$	$f_3 = 3\frac{v}{2L}$

Open-open or closed-closed tubes:

$m = 1, 2, 3, 4...$

$\lambda_m = \frac{2L}{m}$

$f_m = m\frac{v}{2L} = mf_1$

Open-closed tubes:

$m = 1, 3, 5, 7$

$\lambda_m = \frac{4L}{m}$

$f_m = m\frac{v}{4L} = mf_1$

Maximum interference

Maximum constructive:

$\Delta\phi = 2\pi\frac{\Delta x}{\lambda} + \Delta\phi_0 = m \cdot 2\pi \text{ rad},\ m = 0, 1, 2, 3...$

or

$\Delta x = |x_2 - x_1| = n\lambda \quad n = 0, 1, 2, \ldots$

Maximum destructive:

$\Delta\phi = 2\pi\frac{\Delta x}{\lambda} + \Delta\phi_0 = (m + \frac{1}{2}) \cdot 2\pi \text{ rad},\ m = 0, 1, 2, 3...$

or

$\Delta x = |x_2 - x_1| = (n + \frac{1}{2})\lambda \quad n = 0, 1, 2, \ldots$

Electric Field of Line of Charge:

Finite: $E = k\frac{Q}{r(r^2+(\frac{L}{2})^2)^{\frac{1}{2}}}$

Infinite: $E = \frac{\lambda}{2\pi\epsilon_0 r}$ or $k\frac{2|\lambda|}{r}$

$\lambda = \frac{C}{L}$

Electric Field of Disk of Charge

$\eta = \frac{Q}{\text{area}} = \frac{Q}{\pi R^2}$

Finite: $E = \frac{\eta}{2\epsilon_0}(1 - \frac{x}{\sqrt{x^2+R^2}})$, where R is radius of disk and x is distance from the disk.

Infinite (plane): $E = \frac{\eta}{2\epsilon_0}$

Electric Field of Capacitor

$E_{cap} = \frac{\eta}{\epsilon_0}$

Force of a capacitor plate on the other:

$F = E_{cap} \times q_{other\ plate}$

Electric Field of Ring of Charge

$\vec{E} = k\frac{Qx}{(x^2+a^2)^{\frac{3}{2}}}$

Where

- x is the distance from the center of the ring
- a is the radius of the ring

Electric Field of a Dipole

$\vec{E}_{dipole} = k\frac{2\vec{p}}{r^3}$ (On axis)

$\vec{E}_{dipole} = -k\frac{\vec{p}}{r^3}$ (Bisecting plane)

Where: the direction of $\vec{p}$ identifies the orientation of the dipole

Sphere of Charge

$\vec{E}_{sphere} = k\frac{Q}{r^2}$ for $r \leq R$

Motion in a Uniform Field

$a = \frac{qE}{m} = \text{constant}$

Constants

Elementary Charge: $e = 1.602 \times 10^{-19}\text{C}$

Mass of Electron: $m = 9.109 \times 10^{-31}\text{kg}$

Mass of Proton: $m = 1.672 \times 10^{-27}\text{kg}$

Vacuum Permittivity: $\epsilon_0 = 8.854 \times 10^{-12}$

Coulomb Constant: $k = 9.0 \times 10^9 \frac{Nm^2}{C^2}$