Standard Physics Equations and Laws

This document compiles fundamental physics equations and laws that will be redefined under the COM (Continuous Oscillatory Model) framework.

Classical Mechanics

Newton's Laws of Motion

- First Law (Inertia): An object at rest stays at rest, and an object in motion stays in motion with the same speed and direction unless acted upon by an unbalanced force.
- Second Law (Force): $F = ma$ (Force equals mass times acceleration)
- Third Law (Action-Reaction): For every action, there is an equal and opposite reaction.

Kinematics

- Position: $x = x \; + v t + (1/2)at^2$
- Velocity: $v = v \; + at$
- Acceleration: $a = dv/dt = d^2x/dt^2$
- Average velocity: $\bar{v} = \Delta x/\Delta t$
- Relative velocity: v_AB = v_A - v_B

Dynamics

- Momentum: $p = mv$
- Conservation of momentum: $p \; + p \; = p\,' + p\,'$ (in isolated systems)
- Impulse: $J = F \cdot \Delta t = \Delta p$
- Work: $W = F \cdot d = F \cdot d \cdot \cos(\;)$
- Kinetic energy: $KE = (1/2)mv^2$
- Potential energy (gravitational): $PE = mgh$
- Conservation of energy: $E \; = E$ (in isolated systems)
- Power: $P = dW/dt = F \cdot v$

Rotational Mechanics

- Angular position:
- Angular velocity: $= d\;/dt$
- Angular acceleration: $= d\;/dt$
- Torque: $= r \times F = r \cdot F \cdot \sin(\;)$
- Moment of inertia: $I = \Sigma m\, r\;^2$
- Angular momentum: $L = I$
- Rotational kinetic energy: KE_rot = $(1/2)I\;^2$

Gravitation

- Newton's law of universal gravitation: $F = G(m\; m\;)/r^2$

- Gravitational field: $g = GM/r^2$
- Gravitational potential energy: $U = -G(m\ m\ )/r$
- Kepler's laws:
  - Planets move in elliptical orbits with the Sun at one focus
  - A line joining a planet and the Sun sweeps out equal areas in equal times
  - The square of the orbital period is proportional to the cube of the semi-major axis: $T^2 \quad a^3$

Thermodynamics

Laws of Thermodynamics

- Zeroth Law: If two systems are in thermal equilibrium with a third system, they are in thermal equilibrium with each other.
- First Law (Energy Conservation): $\Delta U = Q - W$
- Second Law (Entropy): $\Delta S \quad 0$ for isolated systems
- Third Law: As temperature approaches absolute zero, entropy approaches a constant minimum.

Thermodynamic Quantities

- Ideal gas law: $PV = nRT$
- Internal energy: $U = (3/2)nRT$ (for monatomic ideal gas)
- Heat capacity: $C = \Delta Q/\Delta T$
- Entropy: $S = k \cdot \ln(\Omega)$ (Boltzmann's entropy formula)
- Gibbs free energy: $G = H - TS$
- Enthalpy: $H = U + PV$

Statistical Mechanics

- Maxwell-Boltzmann distribution: f(v) = (m/2 kT)^(3/2) · 4 v^2 · e^(-mv^2/2kT)
- Partition function: Z = Σ e^(-E /kT)
- Boltzmann factor: P   e^(-E/kT)

Electromagnetism

Electrostatics

- Coulomb's law: $F = k(q\ q\ )/r^2$
- Electric field: $E = F/q = k(Q)/r^2$
- Electric potential: $V = k(Q)/r$
- Gauss's law: $E \cdot dA = Q/$

Magnetism

- Magnetic field due to current: $B = (\ \ /4\ )(I \cdot dl \times \hat{r}/r^2)$

- Lorentz force: $F = q(E + v \times B)$
- Biot-Savart law: $dB = (\ /4\ )(I \cdot dl \times \hat{r}/r^2)$
- Ampere's law: $\ B \cdot dl = \ I$

Electromagnetic Induction

- Faraday's law: $\ = -d\Phi/dt$
- Lenz's law: Induced current flows to oppose the change that produced it
- Self-inductance: $\ = -L(dI/dt)$

Maxwell's Equations

- Gauss's law for electricity: $\ \cdot E = \ /\ $
- Gauss's law for magnetism: $\ \cdot B = 0$
- Faraday's law: $\ \times E = -\ B/\ t$
- Ampere-Maxwell law: $\ \times B = \ J + \ \ (\ E/\ t)$

Electromagnetic Waves

- Wave equation: $\ ^2E = (1/c^2)(\ ^2E/\ t^2)$
- Speed of light: $c = 1/\sqrt{(\ \ )}$
- Energy density: $u = (1/2)\ E^2 + (1/2)B^2/\ $
- Poynting vector: $S = (1/\ )(E \times B)$

Relativity

Special Relativity

- Time dilation: $\Delta t = \Delta t\ /\sqrt{(1-v^2/c^2)}$
- Length contraction: $L = L\ \sqrt{(1-v^2/c^2)}$
- Relativistic momentum: $p = mv/\sqrt{(1-v^2/c^2)}$
- Mass-energy equivalence: $E = mc^2$
- Relativistic energy: $E = mc^2/\sqrt{(1-v^2/c^2)}$
- Lorentz transformation:
  - $t' = \ (t - vx/c^2)$
  - $x' = \ (x - vt)$
  - $y' = y$
  - $z' = z$
  - where $\ = 1/\sqrt{(1-v^2/c^2)}$

General Relativity

- Einstein field equations: $G\ \ = (8\ G/c\ )T$
- Geodesic equation: $d^2x\ /d\ ^2 + \Gamma\ \ (dx\ /d\ )(dx\ /d\ ) = 0$
- Schwarzschild metric: $ds^2 = (1\text{-}2GM/rc^2)c^2dt^2 - (1\text{-}2GM/rc^2)\ ^1dr^2 - r^2d\Omega^2$
- Gravitational time dilation: $\Delta t = \Delta t\ /\sqrt{(1\text{-}2GM/rc^2)}$

Quantum Mechanics

Wave-Particle Duality

- De Broglie wavelength: $\ = h/p$
- Heisenberg uncertainty principle: $\Delta x\Delta p \ \ \hbar/2$

Quantum State

- Schrödinger equation: $i\hbar(\Psi/ t) = \hat{H}\Psi$
- Time-independent Schrödinger equation: $\hat{H}\Psi = E\Psi$
- Probability density: $|\Psi|^2$
- Normalization: $|\Psi|^2dx = 1$
- Expectation value: $A = \Psi^*\hat{A}\Psi dx$

Quantum Operators

- Position operator: $\hat{x} = x$
- Momentum operator: $\hat{p} = -i\hbar(/ x)$
- Energy operator (Hamiltonian): $\hat{H} = -\hbar^2/(2m)(^2/ x^2) + V(x)$
- Angular momentum operator: $\hat{L} = r \times \hat{p}$

Quantum Systems

- Particle in a box: $E = (n^2 \ ^2\hbar^2)/(2mL^2)$
- Quantum harmonic oscillator: $E = \hbar (n + 1/2)$
- Hydrogen atom energy levels: $E = -13.6$ eV/n^2

Quantum Field Theory

Quantum Electrodynamics

- Dirac equation: $(i \ \ - m) = 0$
- Feynman propagator: D_F(x-y) = (d k/(2))(e^(-ik · (x-y))/(k^2 - m^2 + i))

Standard Model

- Lagrangian density of quantum field theory
- Higgs mechanism: $v = \sqrt{(- ^2/)}$
- Weak interaction: W and Z bosons
- Strong interaction: Quantum Chromodynamics (QCD)

Statistical and Thermal Physics

Statistical Distributions

- Fermi-Dirac distribution: f(E) = 1/(e^((E-)/kT) + 1)
- Bose-Einstein distribution: f(E) = 1/(e^((E-)/kT) - 1)

Phase Transitions

- Clausius-Clapeyron equation: dP/dT = L/(T(V -V))
- Critical exponents: various power laws near critical points

Wave Mechanics

Wave Properties

- Wave equation: ^{2}y/ t^2 = v^2(^{2}y/ x^2)
- Wave speed: v = f
- Superposition principle: y = y + y
- Standing waves: y(x,t) = 2A · sin(kx) · cos(t)
- Doppler effect: f' = f((v ± v_observer)/(v v_source))

Acoustics

- Sound intensity: I = P/A
- Sound intensity level: = 10 · log(I/I) dB
- Speed of sound: v = √(B/) (in fluids)

Fluid Dynamics

Fluid Statics

- Pressure: P = F/A
- Pascal's principle: Pressure applied to an enclosed fluid is transmitted undiminished to all parts of the fluid
- Archimedes' principle: Buoyant force equals weight of displaced fluid

Fluid Dynamics

- Continuity equation: A v = A v
- Bernoulli's equation: P + (1/2) v ^{2} + gh = P + (1/2) v ^{2} + gh
- Viscous flow: Poiseuille's law: Q = (r ΔP)/(8 L)

Optics

Geometric Optics

- Snell's law: n sin( ) = n sin( )
- Lens equation: 1/f = 1/s + 1/s
- Magnification: M = -s /s

Wave Optics

- Interference: I = I + I + 2√(I I)cos( )
- Diffraction: sin( ) = m /d (for diffraction grating)
- Polarization: Malus's law: I = I cos^2( )