Circuits I: (without inductance):

Resistors (Ohm's Law): $V = IR$ Power: $\text{Power} = VI = I^2 R$

Kirchhoff's Rules:

1. *Junctions:* "$\sum I_{in} = \sum I_{out}$", 2. Loops: $\sum voltages = 0$

Resistors in parallel: $\frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{R_{\text{TOTAL}}}$ …in series: $R_1 + R_2 = R_{\text{TOTAL}}$

Capacitors: $Q = C\,\Delta V$

Capacitors in parallel: $C_1 + C_2 = C_{\text{TOTAL}}$ … in series: $\frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{C_{\text{TOTAL}}}$

RC Circuits: Time constant: $\tau = RC$

Discharging or charging: $f(t) = f_1\, e^{-t/\tau} + f_2$

Often: $f(t) = f_0\, e^{-t/\tau}$ or $f(t) = f_\infty\left(1 - e^{-t/\tau}\right)$

Magnetism: Forces: $\vec{F}_{magnetic} = q\vec{v} \times \vec{B} = \ell \vec{I} \times \vec{B}$ or $\vec{F}_{EM} = q\left[\vec{E} + \left(\vec{v} \times \vec{B}\right)\right]$

Magnetic fields from currents: A distance r from a straight wire: $\left|\vec{B}\right| = \frac{\mu_0}{2\pi}\frac{I}{r}$

At the center of a loop of wire of radius R: $\left|\vec{B}\right| = \frac{\mu_0}{2}\frac{I}{R}$

In a cylindrical coil (or inductor): $\left|\vec{B}\right| = \frac{\mu_0\, N\, I}{length}$

Torque on a loop of wire: $\vec{\tau} = \vec{\mu} \times \vec{B}$ where $\mu = N\, I\, Area$

Inductance: $EMF = -L\frac{dI}{dt}$, and for a cylindrical inductor $\left|\vec{B}\right| = \frac{\mu_0\, N\, I}{length}$

For an LC circuit (capacitor and inductor):

$q = q_{\max}\sin\left(\omega_0 t - \phi\right)$, $I = \dot{q}$, $EMF_L = -L\ddot{q}$, and $\omega_0 = \sqrt{\frac{1}{LC}}$

Maxwell's equations: $\epsilon_0 = 8.854 \times 10^{-12}\ C^2/(N\,m^2)$ $\mu_0 = 4\pi \times 10^{-7}\ T\,m/A$

Gauss' law (for $\vec{E}$ and $\vec{B}$) $\int_{\substack{closed\\surface}} \vec{E} \cdot d\vec{A} = \frac{Q}{\epsilon_0}$ **and** $\int_{\substack{closed\\surface}} B \cdot d\vec{A} = 0$

Faraday's law: $\mathcal{E}mf = -\frac{d\Phi_B}{dt}$ or $\int_{loop} \vec{E} \cdot d\vec{\ell} = -\frac{d}{dt}\int \vec{B} \cdot d\vec{A}$

Ampere-Maxwell law: $\int_{loop} \vec{B} \cdot d\vec{\ell} = \mu_0 I_{encloed} + \mu_0\, \epsilon_0\, \frac{d}{dt}\int \vec{E} \cdot d\vec{A}$

Harmonic oscillators:

Angular frequency: $\omega = 2\pi f = \frac{2\pi}{T}$

SHO Equation: $\ddot{x} = -\omega^2 x$

Solution to SHO Equation:

$$x - x_{eq} = A\sin(\omega_0 t - \varphi)$$

where ω_0 is the natural *angular* frequency of the oscillator

Mass on a spring: $\omega_0 = \sqrt{\frac{k}{m}}$ Simple pendulum: $\omega_0 = \sqrt{\frac{g}{\ell}}$

Wave kinematics:

Traveling wave: $f(x,t) = f(x \pm vt)$

Standing wave: $f(x,t) = f(x+vt) \pm f(x-vt)$

Sinusoidal wave: $f(x,t) = A\sin(kx \pm \omega t \pm \varphi)$

$$or \;\; A\sin(kx + \omega t + \varphi) \pm A\sin(kx - \omega t + \varphi)$$

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

Wave dynamics:

The wave equation: I forget…

The wave equation is either $\frac{\partial^2 f}{dx^2} = v^2 \frac{\partial^2 f}{dt^2}$ or $\frac{\partial^2 f}{dt^2} = v^2 \frac{\partial^2 f}{dx^2}$

I can't remember which it is, but you ought to be able to figure it out.

Velocities:

strings: $v = \sqrt{\frac{\tau}{\mu}}$ sound: $v = \sqrt{\frac{B}{\rho}} = \sqrt{\frac{\gamma P}{\rho}}$ light: $v = c = \sqrt{\frac{1}{\mu\varepsilon}}$

Interference:

Interference for two sources:

Constructive interference when $\Delta d = n\lambda$ $(n = 0, \pm 1, \pm 2, \dots)$

Double slit interference for light (distances >> λ, separation of slits = *d*):

Interference pattern = $\cos^2\left(\frac{1}{2} k\, d \sin\theta\right)$

Constructive interference when: $d\sin\theta = n\lambda$ $(n = 0, \pm 1, \pm 2, \dots)$