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| $y(x,t) = A\cos\left(2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)\right)$ | sinusoidal wave moving to the right (change to positive sign for wave to the left) |
| $v = f\lambda$ | basic relationship between speed, frequency, and wavelength |
| $v_{\text{sound}} = \sqrt{\frac{\gamma k_B T}{m}} = \sqrt{\frac{\gamma RT}{M}}$ | $k_B = 1.38 \times 10^{-23}$ J/K, $R = 8.31$ J/K·mole, $\gamma = 3/2$ for monatomic gases, $5/2$ for diatomic |
| $v = \sqrt{\frac{T}{\mu}}$ | waves on a string, $T$ is tension, $\mu$ is *linear* density |
| $\beta = (10\text{ db})\log_{10}\left(\frac{I}{I_0}\right)$ | $I_0 = 1.0 \times 10^{-12}$ W/m$^2$ is the threshold of hearing |
| $f = \frac{1}{T} = \frac{\omega}{2\pi}$ | relationship between period, frequency, and radial frequency |
| $m\frac{\lambda_m}{2} = L \quad m = 1, 2, 3, \ldots$ | waves on string, closed-closed or open-open pipe, or deBroglie particles in a box (draw a picture!) |
| $(2m-1)\frac{\lambda_m}{4} = L \quad m = 1, 2, 3, \ldots$ | waves in open-closed pipe (draw a picture!) |
| $f_m = \frac{v}{\lambda_m}$ | changing resonant wavelengths to frequency |
| $f_{\text{beat}} = \lvert f_1 - f_2 \rvert$ | beats arise from a superposition of waves with nearly the same frequency |

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| $\Delta r = d\sin\theta_m = m\lambda$ | path length difference for constructive interference in Young's double slit, $m = \ldots -2, -1, 0, 1, 2, \ldots$ |
| $y_m = \frac{m\lambda L}{d}$ | bright fringes Young's double slit interference (small angle approximation) |
| $w = \frac{2\lambda L}{a}$ | width of diffraction maximum from single slit |
| $w \approx \frac{2.44\lambda L}{D}$ | width of diffraction maximum from circular aperature |
| $n = \frac{\text{speed of light in a vacuum}}{\text{speed of light in the material}} = \frac{c}{v}$ | index of refraction defined |
| $n_1 \sin\theta_1 = n_2 \sin\theta_2$ | Snell's law of refraction |
| $\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$ | critical angle for total internal reflection |
| $\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$ | thin lens law for image formation |
| $m = -\frac{s'}{s}$ | lateral magnification |

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| $\lvert \vec{F}_{1\text{ on }2} \rvert = \lvert \vec{F}_{2\text{ on }1} \rvert = \frac{K\lvert q_1\rvert\lvert q_2\rvert}{r_{12}^2}$ | magnitude of forces in Coulomb's law, $K = 8.99 \times 10^9$ N m$^2$/C$^2$ direction of force is along the line connecting the charges, attractive if charges have unlike signs, repulsive if they have like signs |
| $\vec{F}_{\text{elec on }q} = q\vec{E}$ | force on a charge, if a test charge can define $\vec{E}$ |
| $\vec{E}(x,y,z) = \left(\frac{K\lvert q}{r^2}, \begin{bmatrix} \text{away from } q \text{ if } q > 0 \\ \text{toward } q \text{ if } q < 0 \end{bmatrix}\right)$ | electric field of a point charge when distance $r$ from charge |

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| $\vec{E}_{\text{total}} = \vec{E}_1 + \vec{E}_2 + \ldots$ | total electric field from several charges, $r$ will be different for each and so will the direction! |
| $\vec{E} = \left(\frac{Q}{\epsilon_0 A}, \text{from positive to negative}\right)$ | electric field in parallel plate capacitor |
| $\epsilon_0 = \frac{1}{4\pi K} = 8.85 \times 10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2$ | |
| $\tau = qdE \sin\alpha$ | torque on an electric dipole with $q$ and $-q$ separated by $d$. $\alpha$ is the angle between the vector pointing from the negative to the positive charge and $\vec{E}$ |

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| $U_{\text{elec}} = qV$ | the electric potential energy for a charge $q$ at a location with electric potential $V$ |
| $V(x,y,z) = \frac{Kq}{r} = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$ | electric potential at a point $(x,y,z)$ if a point charge is distance $r$ away (assumes $V = 0$ at infinity) (can also be used for a conducting sphere if $r \geq R$ |
| $V_{\text{total}}(x,y,z) = \sum_i \frac{1}{4\pi\epsilon_0}\frac{q_i}{r_i}$ | electric potential is the sum of electric potential for a set of $i$ point charges |
| $V(x,y,z) = \frac{x}{d}\Delta V_C$ | electric potential between plates of a parallel plate capacitor *if* the $x$ direction is normal to the plates and the plate at $x = 0$ is set to $V = 0$ |
| $K_f + qV_f = K_i + qV_i$ | kinetic energy for a charged particle moving in a region with an electric potential (no "external" forces) |
| 1 eV$=1.60 \times 10^{-19}$ J | electron-Volt - Joules conversion |
| $\vec{E} = \left(\frac{\Delta V}{d}, \text{from high potential to low potenial}\right)$ | |
| $Q = C\Delta V_C$ | definition of capacitance |
| $C = \frac{\epsilon_0 A}{d} = \frac{\kappa\epsilon_0 A}{d}$ | capacitance for a parallel plate capacitor, $\kappa$ used if the capacitor is filled with a dielectric |
| $U_C = \frac{1}{2}C(\Delta V_C)^2$ | electrical energy stored in a capacitor |
| $u_E = \frac{1}{2}\kappa\epsilon_0 E^2$ | energy density in an electric field |

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| $I = \frac{\Delta q}{\Delta t}$ | definition of current. Signs of charge with direction of motion are included in $\Delta q$ so positive charges going to the right and negative charges going to the left would both contribute to current going to the right. |
| $\Delta V = IR$ | Ohm's law for a resistor, **remember** an ideal wire has $R = 0$ so $\Delta V = 0$ no matter the current |
| $\Delta V_{\text{battery}} = \text{emf}$ | a battery provides a constant electric potential difference through its emf. *It does not* provide constant current. |

$$I_{\text{battery}} = \frac{\Delta V_{\text{battery}}}{R_{\text{equiv}}}$$

Current through a battery is determined by the external elements (light bulbs, resistors, and how they are connected).

$$\frac{1}{R_{\text{equiv}}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$$

resistances in parallel add in this "reciprocal manner". Note: $R_{\text{equiv}}$ will end up being smaller than any of the individual resistances. The $R$ values may already be combinations of other resistors. If in parallel the same potential difference must be across all the resistances (or equivalents).

$$R_{\text{equiv}} = R_1 + R_2 + \ldots$$

resistances in series add. The $R$ values here may already be combinations of other resistors. If in series the same current must go through all the resistances (or equivalents).

$$R = \frac{\rho L}{A}$$

$\rho$ is the resistivity of the material

$$\sum I_i = 0$$

Kirchhoff's current law. At any junction if you give currents "in" a positive sign and currents "out" a negative sign then the sum of the currents is equal to zero.

$$\sum \Delta V_i = 0$$

Kirchhoff's voltage law. For any loop if you look at the sum potential differences around the loop they must be zero. (in class I joked that this is the same as when you go to the Cape Breton Highlands and back you have gone "up" just as much as you have gone "down".)

$$P = I\Delta V$$

the power dissipated/gained in an electric circuit element

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$$F_{\text{mag}} = |q|vB\sin\alpha$$

magnetic force of charged particle, direction of force is given by right-hand rule: $\vec{B}$ along index finger, $\vec{v}$ along thumb, and force on a *positive* charge is along middle finger when held perpendicular to palm. $\alpha$ is the angle between $\vec{B}$ and $\vec{v}$

$$F_{\text{mag}} = ILB\sin\alpha$$

magnetic force on a current carrying wire. Thumb points along direction of current and use right-hand rule

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

magnetic field from a current carrying wire. If current points along the direction of thumb on right hand then the the field points in the direction of the "curled" fingers. $\mu_0 = 4\pi \times 10^{-7}$ T·m/A

$$B = \mu_0 \frac{NI}{2R}$$

field at the centre of $N$ coils of wire. If current is counterclockwise then $\vec{B}$ points "out of the page".

$$B = \mu_0 \frac{IN}{L}$$

field inside a solenoid with $N$ coils over a length $L$

$$\tau = NIAB\sin\theta = |\vec{m}|B\sin\theta$$

the torque on a magnetic dipole moment $\vec{m}$ in magnetic field. A coil of wire has $|\vec{m}| = NIA$. Angle $\theta$ is measured between the magnetic field and a line normal to the coil/ parallel to the dipole moment. This allows you to use a compass to find the direction of the magnetic field.

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| $\text{emf} = vLB$ | motional emf for a conductor moving transversely through $\vec{B}$ |
| $\text{emf} = -\frac{\Delta\Phi_B}{\Delta t}$ | Faraday's law of induction, the negative sign is for Lenz' Law which states the response will oppose the change that causes it |
| $\Phi_B = BA_{\text{eff}}$ | magnetic flux, $\Phi_B$ can change because $B$ changes or $A_{\text{eff}} = A\sin\alpha$ changes |
| $c = \frac{1}{\sqrt{\epsilon_0\mu_0}} = 3.00 \times 10^8$ m/s | speed of light/EM wave in vacuum |
| $E_0 = cB_0$ | amplitudes of fields in an EM wave |
| $I = \frac{P}{A} = \frac{1}{2}c\epsilon_0 E_0^2$ | intensity of an EM wave, $P$ is power, energy per unit time |
| $I(r) = \frac{P_{\text{source}}}{4\pi r^2}$ | inverse square law for intensity from a point source |
| $E = hf = \frac{hc}{\lambda}$ | energy of a photon, Planck's constant $h = 6.63 \times 10^{-34}$ J·s |
| $K_{\text{max}} = eV_{\text{stop}} = hf - E_0$ | Einstein's photoelectric effect expression, $E_0$ is the work function |
| $\lambda = \frac{h}{mv} = \frac{h}{p}$ | the deBroglie wavelength of a particle |
| $E_n = \frac{h^2}{8mL^2}n^2 \quad n = 1, 2, 3, \ldots$ | energy levels of a particle of mass $m$ in a box of size $L$ |
| $m = 9.11 \times 10^{-31}$ kg | the mass of an electron |
| $m = 1.67 \times 10^{-27}$ kg | the mass of a proton |
| $f_{\text{photon}} = \frac{\Delta E}{h}$ | frequency of a photon coming from a transition between quantum levels |
| $r_n = \frac{h^2}{4\pi^2 Kme^2}n^2 = n^2 a_B$ | the allowed radii for a Bohr hydrogen atom. $K$ is the constant from Coulomb's law. $a_B = 0.0529$ nm is the *Bohr radius* |
| $E_n = -\frac{Ke^2}{2a_B}\frac{1}{n^2} = -\frac{E_1}{n^2}$ | the energy levels of a hydrogen atom $E_1 = 13.60$ eV |
| $L = mvr$ | angular momentum of an object in circular motion |
| $F_{\text{centri}} = \frac{mv^2}{r}$ | the centripetal force for circular motion |
| $E_K = K = \frac{1}{2}mv^2 = \frac{p^2}{2m}$ | kinetic energy of a particle (with different symbols for kinetic energy) |
| $v = \sqrt{\frac{3k_BT}{m}}$ | the average velocity of an atom in a gas at temperature $T$. $k_B = 1.38 \times 10^{-23}$ J/K. Can find $m$ from molecular weight (in kg) divided by $6.02 \times 10^{23}$. |