Flipping Physics Lecture Notes:
Equations to Memorize for
AP Physics C: Electricity and Magnetism
http://www.flippingphysics.com/apcem-equations.html

I am definitely not a fan of rote memorization, however, sometimes there are good reasons to memorize equations. Here are my suggestions for AP Physics C: Electricity and Magnetism memorization

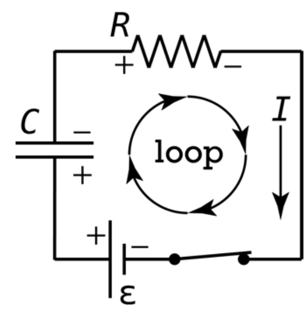
- Quantization of charge: $Q = ne$
  - e = elementary charge: $e = 1.60 \times 10^{-19} C$
- The Law of Charges:
  - Two charges with opposite signs attract one another.
  - Two charges with the same sign repel one another.
- The electric field around a point charge:
  - $$\vec{E} = \frac{\vec{F}_e}{q} \;\&\; F_e = \frac{kq_1q_2}{r^2} \Rightarrow E_{\text{point charge}} = \frac{\frac{kqQ}{r^2}}{q} = \frac{kQ}{r^2}$$
- You do not have to memorize it, it is on the Table of Information, however, it seems to come up quite often. The relationship between the Coulomb's law constant and vacuum permittivity:
  - $$k = \frac{1}{4\pi\varepsilon_0}$$
- Electric field around a continuous charge distribution: (memorize and know how to derive)
  - $$\vec{E}_{\text{point charge}} = \frac{kQ}{r^2}\hat{r} \Rightarrow d\vec{E} = \frac{k(dq)}{r^2}\hat{r} \Rightarrow \int d\vec{E} = \int \frac{k(dq)}{r^2}\hat{r}$$
  - $$\Rightarrow \vec{E}_{\text{continuous charge distribution}} = k\int \frac{dq}{r^2}\hat{r}$$
- The charge densities:
  - linear charge density, $\lambda = \frac{Q}{L} = \frac{dq}{dL}$ in $\frac{C}{m}$
  - surface charge density, $\sigma = \frac{Q}{A} = \frac{dq}{dA}$ in $\frac{C}{m^2}$
  - volumetric charge density, $\rho = \frac{Q}{V} = \frac{dq}{dV}$ in $\frac{C}{m^3}$
- The symbol for electric flux of Gauss' law never appears on the equation sheet and it does not clarify that the charge is the charge enclosed in the Gaussian surface:
  - $$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{enclosed}}}{\varepsilon_0}$$
- If the net charge inside a closed Gaussian surface is zero, then the net electric flux through the Gaussian surface is zero. $$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{enclosed}}}{\varepsilon_0} = \frac{0}{\varepsilon_0} = 0$$
- Equation for electric flux for a flat surface in a uniform electric field is not on the equation sheet:
  - $$\Phi_E = \vec{E} \cdot \vec{A} = EA\cos\theta$$
- The electric potential difference across a uniform electric field. Remember d is the straight-line distance parallel to the electric field.
  - $$\Delta V = -\int \vec{E} \cdot d\vec{r} = -\int_a^b E\cos(0°)\,dr = -E\int_a^b dr \Rightarrow \Delta V_{\text{uniform } E} = -Ed$$
- They only have 2 out of the 3 energy stored in a capacitor equations:

- $$U_C = \frac{1}{2}Q\Delta V = \frac{1}{2}C\Delta V^2 = \frac{Q^2}{2C}$$

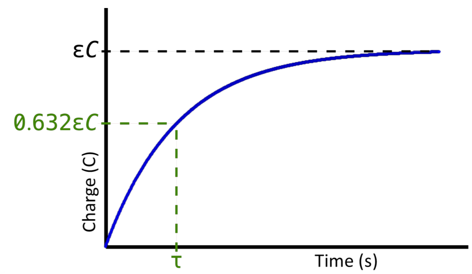
- Only 1 of the equations for electric power is on the equation sheet:

$$P = I\Delta V = I^2 R = \frac{\Delta V^2}{R}$$

- When we add a resistor in series, the equivalent resistance increases.
- When we add a resistor in parallel, the equivalent resistance decreases.
  - $$R_{\text{eq series}} = \sum_n R_n \;\; \& \;\; \frac{1}{R_{\text{eq parallel}}} = \sum_n \frac{1}{R_n}$$

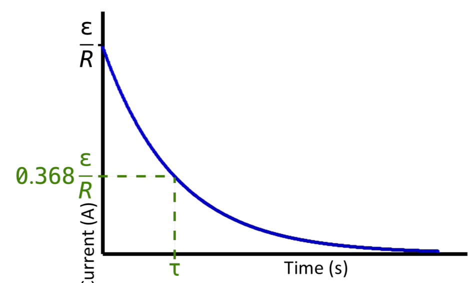


- When we add a capacitor in series, the equivalent capacitance decreases.
- When we add a capacitor in parallel, the equivalent capacitance increases.
  - $$\frac{1}{C_{\text{eq series}}} = \sum_n \frac{1}{C_n} \;\; \& \;\; C_{\text{eq parallel}} = \sum_n C_n$$
  - We can see the relationships from the equations provided on the equation sheet, however, it comes up often enough that it is good to memorize and, if you need to confirm what you memorized, just look at the equation sheet.
- None of the equations for RC or LR circuits are on the equation sheet, however, I do not suggest you memorize them. Instead, I suggest you know how to find their limits, know their general shapes, memorize the time constants, and memorize that one time constant represents the time for a 63.2% change.



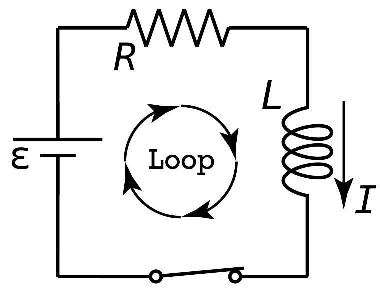
  - $$\Delta V_{\text{loop}} = 0 = \varepsilon - \Delta V_C - \Delta V_R \Rightarrow \varepsilon = \frac{Q}{C} + IR$$
  - $$\Rightarrow Q_i = 0 \rightarrow I_i = \frac{\varepsilon}{R}$$

$$\& \;\; I_f = 0 \rightarrow Q_f = \varepsilon C$$



  - $$y = (1 - e^{-x}) \Rightarrow q(t) = \varepsilon C\left(1 - e^{-\frac{t}{RC}}\right)$$

- $$y = e^{-x} \Rightarrow i(t) = \frac{dq}{dt} = \frac{\varepsilon}{R} e^{-\frac{t}{RC}}$$
- $\tau_{RC} = RC$
- $$y = 1 - e^{-x} \Rightarrow 1 - e^{-1} = 0.632$$
  - One time constant represents the time for a 63.2% change.



- We can do the same thing for an LR circuit:
  - $$\Delta V_{\text{loop}} = 0 = \varepsilon - \Delta V_R - \Delta V_L \Rightarrow \varepsilon = IR + L\frac{dI}{dt}$$
  - $$\Rightarrow I_i = 0 \rightarrow \left(\frac{dI}{dt}\right)_{\text{initial}} = \frac{\varepsilon}{L} \;\&\; \left(\frac{dI}{dt}\right)_{\text{final}} = 0 \rightarrow I_f = \frac{\varepsilon}{R} \;\&\; \tau_{LR} = \frac{L}{R}$$
  - $$y = (1 - e^{-x}) \Rightarrow I(t) = \frac{\varepsilon}{R}\left(1 - e^{\left(-\frac{Rt}{L}\right)}\right) \;\&\; y = e^{-x} \Rightarrow \frac{dI}{dt}(t) = \frac{\varepsilon}{L} e^{\left(-\frac{Rt}{L}\right)}$$

- For Ampère's law, the equation sheet does not identify it is the current inside the Amperian loop:
  - $$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{\text{in}}$$
- Motional emf. But of course, you need to know how to derive this motional emf equation and remember this assumes the velocity and magnetic field are at right angles relative to one another.
  - $\varepsilon = vBL$
    - In this motional emf equation, "L" stands for the length of the conductor.
- The inductance of an ideal solenoid (and how to derive it). Mostly so you remember what inductance does and does not depend on:
  - $$L_{\text{solenoid}} = \frac{\mu_0 N^2 A}{\ell}$$
  - The inductance of an ideal solenoid is determined by:
    - N, the number of turns: A, the cross-sectional area: ℓ, solenoid length.
    - μ, the magnetic permeability of the space inside the solenoid. For an ideal solenoid with nothing inside it, that equals the magnetic permeability of free space.
    - μ, the magnetic permeability of the core material, replaces μ_0 when the solenoid has a core material such as iron.
      - Inductance does *not* depend on current through the solenoid!
        - Resistance does *not* depend on current.
        - Capacitance does *not* depend on charge on the plates or ΔV across the plates.
- The angular frequency of LC circuits, and therefore, all the simple harmonic motion equations for LC circuits.
  - Energy oscillates back and forth between electric potential energy stored in the electric field of the capacitor and magnetic potential energy stored in the magnetic field of the inductor.
  - $$\omega_{LC} = \frac{1}{\sqrt{LC}} = 2\pi f = \frac{2\pi}{T} \Rightarrow T_{LC} = 2\pi\sqrt{LC}$$
  - $$q(t) = Q_{\max}\cos(\omega t + \phi) \Rightarrow i(t) = \frac{dq}{dt} = -I_{\max}\sin(\omega t + \phi)$$
    - (The above Simple Harmonic Motion equations did not make the video. It's *probably* not worth memorizing them.)