AP Physics C: Chapter 25

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1 Intro to Electrodynamics

Electrostatics	Electrodynamics
Charge	✓
insulator vs. conductor	✓
F_E	✓
$\vec{E}$	✓
U_E	✓
V	ΔV or V
capacitors	batteries
	F_B
	inductor

- Circuit elements
  - battery or capacity ΔV
  - wire (charge carrier)
  - resistor
  - inductor
  - capacitor
- Equations
  - **current (I)**: the rate of electron flow
    * $I = \dfrac{\mathrm{d}Q}{\mathrm{d}t}$
    * $I = N_E \cdot ev_d \cdot A$
    * $I = \dfrac{\Delta V}{R}$ (for **ohmic materials**)
  - **resistance (R)**: the tendency to resist current
    * $R = \dfrac{\rho \ell}{A}$
    * $R_{\text{seq}} = \sum_i R_i$
    * $R_{\text{parallel}}^{-1} = \sum_i R_i$

        * $\rho = I\Delta V$
    - **electric field** ($\vec{E}$)
        * $\vec{E} = \rho\vec{J} = \rho\dfrac{I}{A}$

- **electrodynamics**: controlled movement of charge in a conductor due to an *internal* electic field

- the charge *carrier* is what moves
    - <u>metal</u>
        * e^- bound to the solid, not individual atoms
        * random thermal motion of e^-
        * collisions with lattice
        * net motion = 0
        * the electric field is like a push that causes all e^- to have a direction
        * **drift velocity** (v_d): $v_d = \dfrac{\Delta x}{\Delta t} = 10^{-4} m/s$
        * **electron current** (i_e): $i_e = \dfrac{n_e}{\Delta t}$
        * **number of electrons** (N_e): $N_e = \dfrac{n_e}{\text{volume}}$

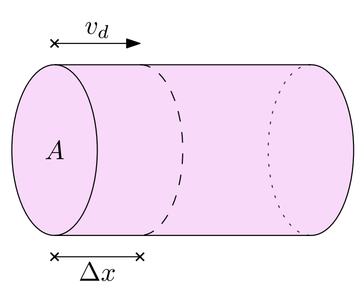


Figure 1: A labeled diagram of a charge capacitor

- **capacitive discharging**

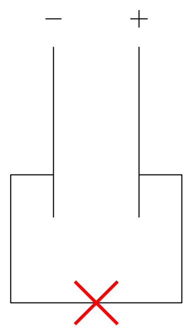


Figure 2: A diagram of a discharged capacitor

- discharge occurs immediately
- wire heats up

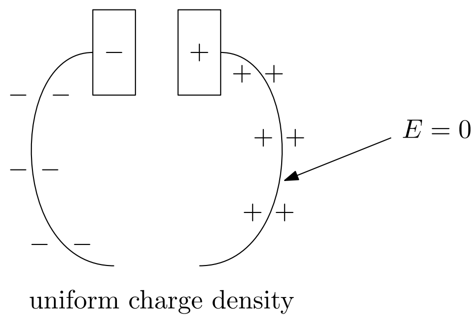


Figure 3: A discharged capacitor with uniform charge density

- **batteries**

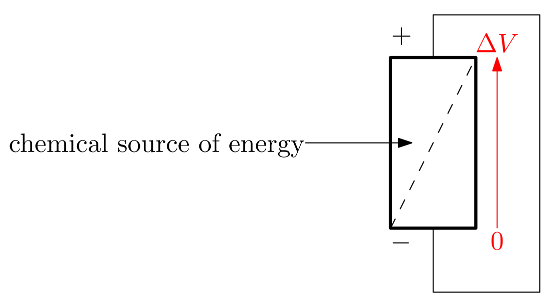


Figure 4: A diagram of how a battery changes voltage

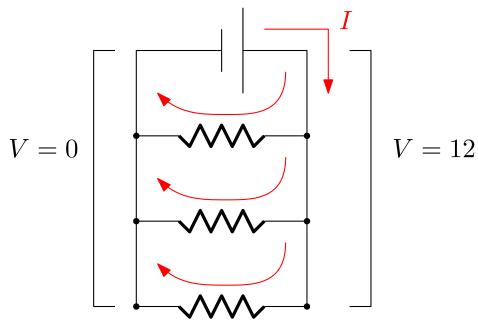


Figure 5: A circuit with a battery and resistors, demonstrating the change in V

- batteries work the same as capacitors
    - provide a "pathway back" to 0
- **ideal batteries** have no internal resistance
- **non-ideal batteries** have internal resistance

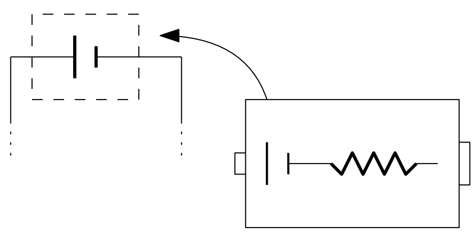
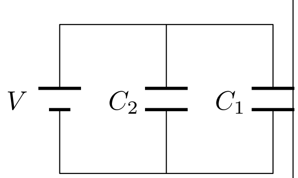
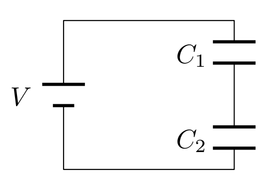
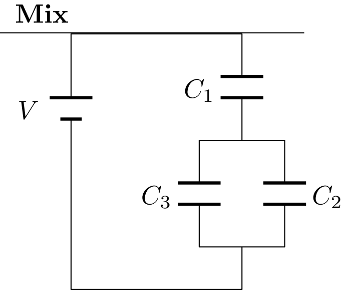
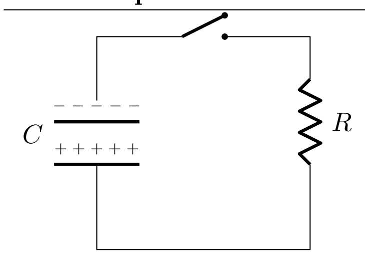
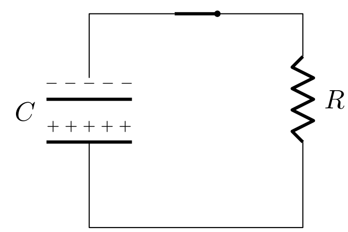


Figure 6: A battery with internal resistance (non-ideal)

2 Capacitors, cont.

Parallel	**Series**	**Mix**
		

2.1 Discharging a Capacitor

Switch open	**Right after switch is closed**
 	
$Q_0 = Q_{\max}$ $I_0 = 0$ $V_0 = V_c = \max = \dfrac{Q_0}{C}$	i Q leaving C get $i = -\dfrac{\mathrm{d}Q}{\mathrm{d}t}$ As $V_C \downarrow Q \downarrow I \downarrow$ $I_0 = \max$ $V_C = \dfrac{Q}{C}$

- **loop rule**

$$
\begin{aligned}
V_c - IR &= 0 \\
V_c - \left(-\frac{\mathrm{d}Q}{\mathrm{d}t}\right) R &= 0 \\
\frac{1}{R}\left(\frac{Q}{C} + \frac{\mathrm{d}Q}{\mathrm{d}t}R\right) &= 0 \\
\frac{Q}{RC} + \frac{\mathrm{d}Q}{\mathrm{d}t} &= 0 \\
\frac{\mathrm{d}Q}{Q} &= -\frac{1}{RC}\,\mathrm{d}t
\end{aligned}
$$

then integrate...

$$
\begin{aligned}
\int_{Q_{\max}}^{Q} \frac{1}{Q}\,\mathrm{d}Q &= -\frac{t}{RC} \\
\ln(Q)\Big|_{Q_{\max}}^{Q} &= -\frac{t}{RC} \\
\ln(Q) - \ln(Q_{\max}) &= \quad \wedge
\end{aligned}
$$

then simplify...

$$
\begin{aligned}
\ln\left(\frac{Q}{Q_{\max}}\right) &= -\frac{t}{RC} \\
\cancel{\ln}\left(\frac{Q}{Q_{\max}}\right) &= e^{-t/RC} \\
Q &= Q_{\max} \cdot e^{-t/RC}
\end{aligned}
$$

$$\boxed{RC = \tau}$$

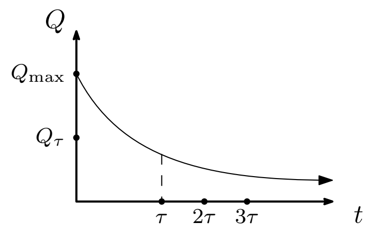


Figure 7: Charge over time in an RC circuit