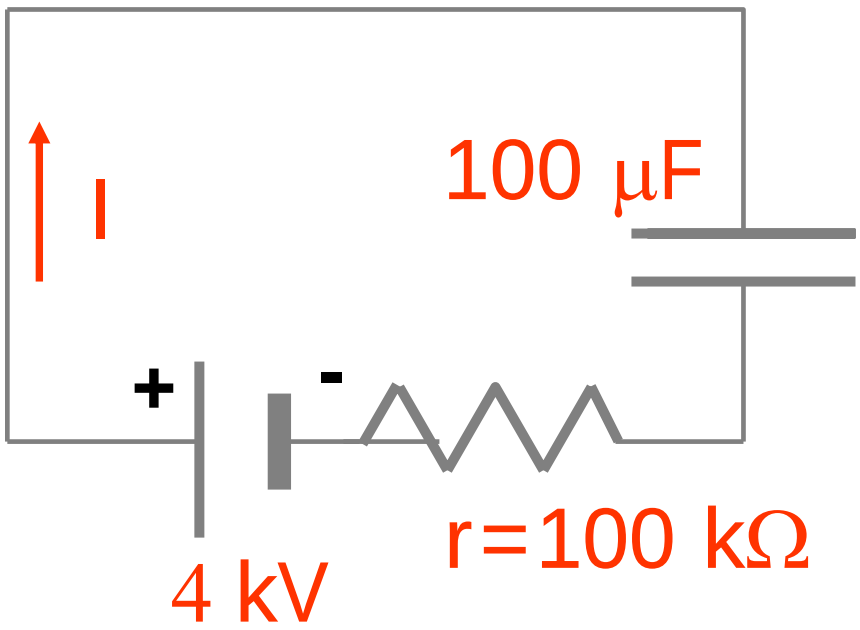
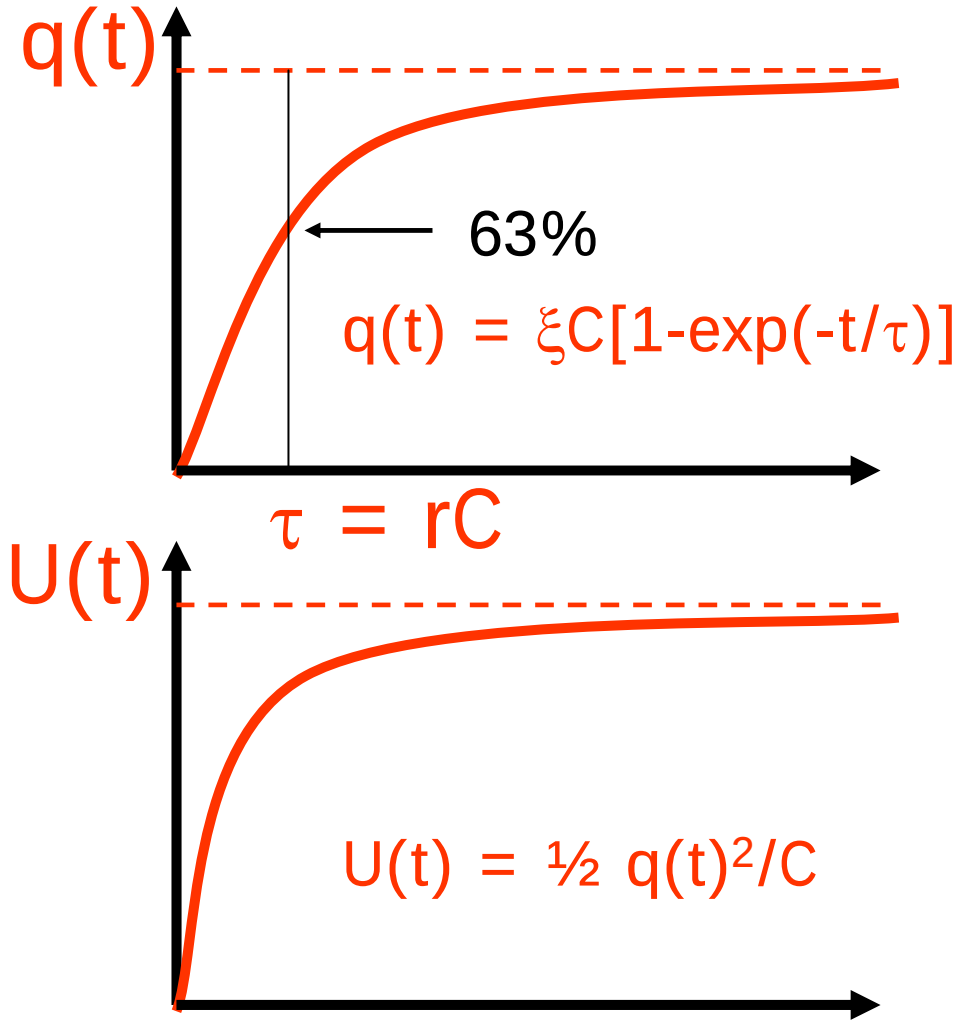
Electricity and Magnetism

- Today
  - RC Circuit Demos
  - Electric Breakdown Experiment
  - Ionization

RC Circuits

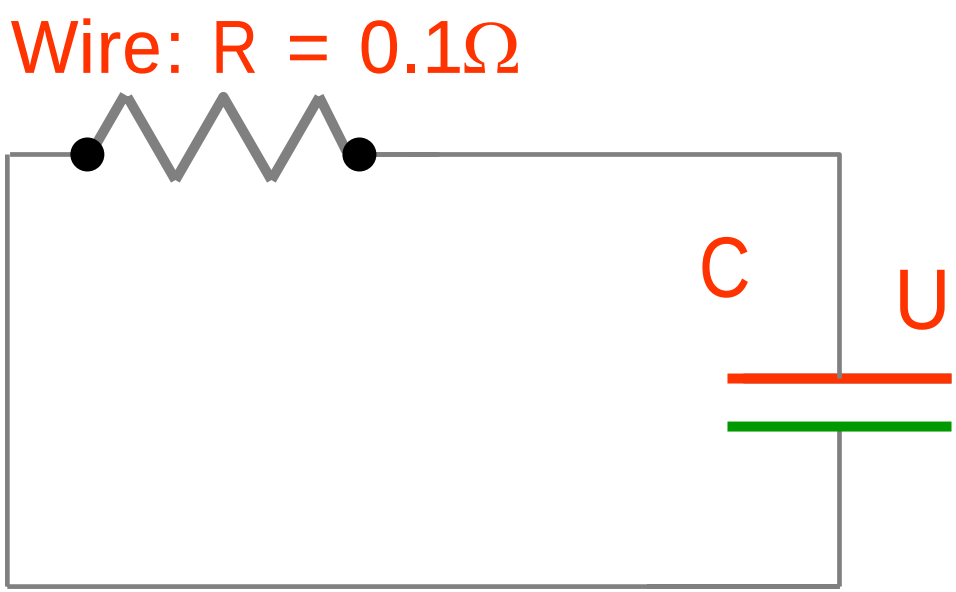
- First: Charging the capacitor

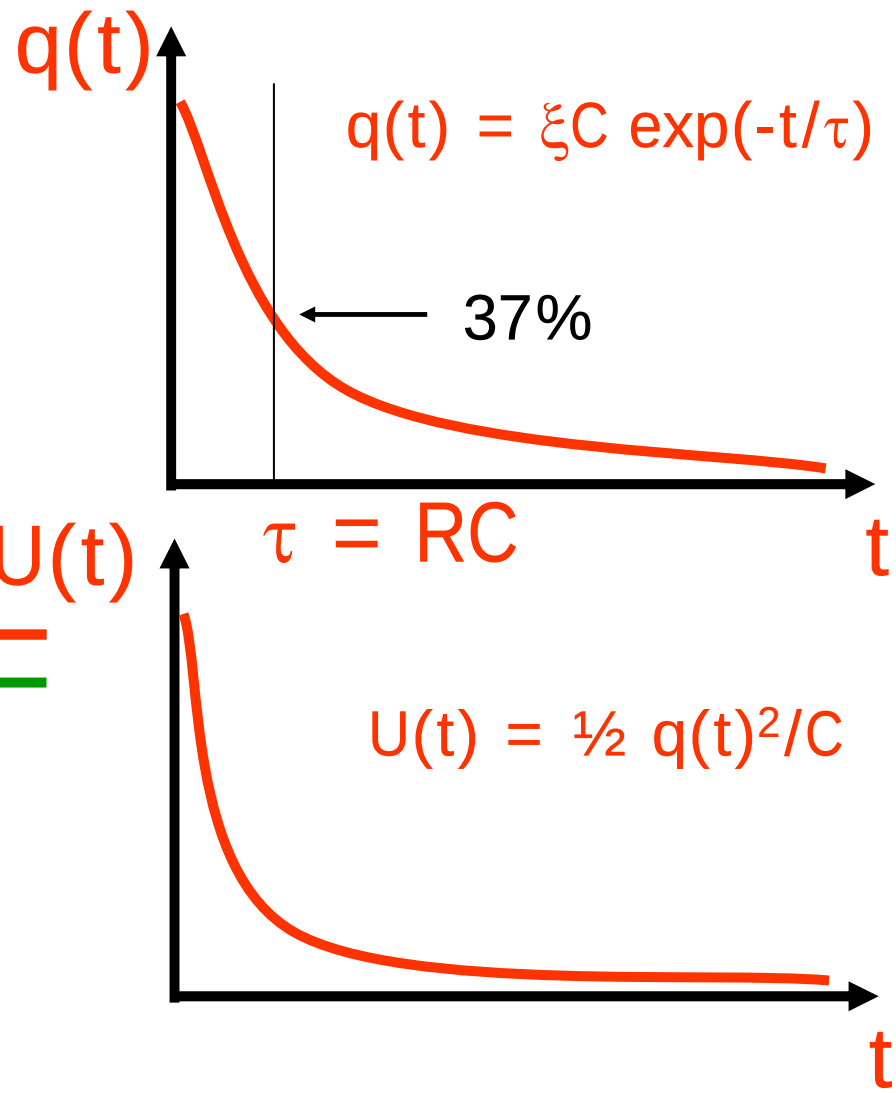




RC Circuits

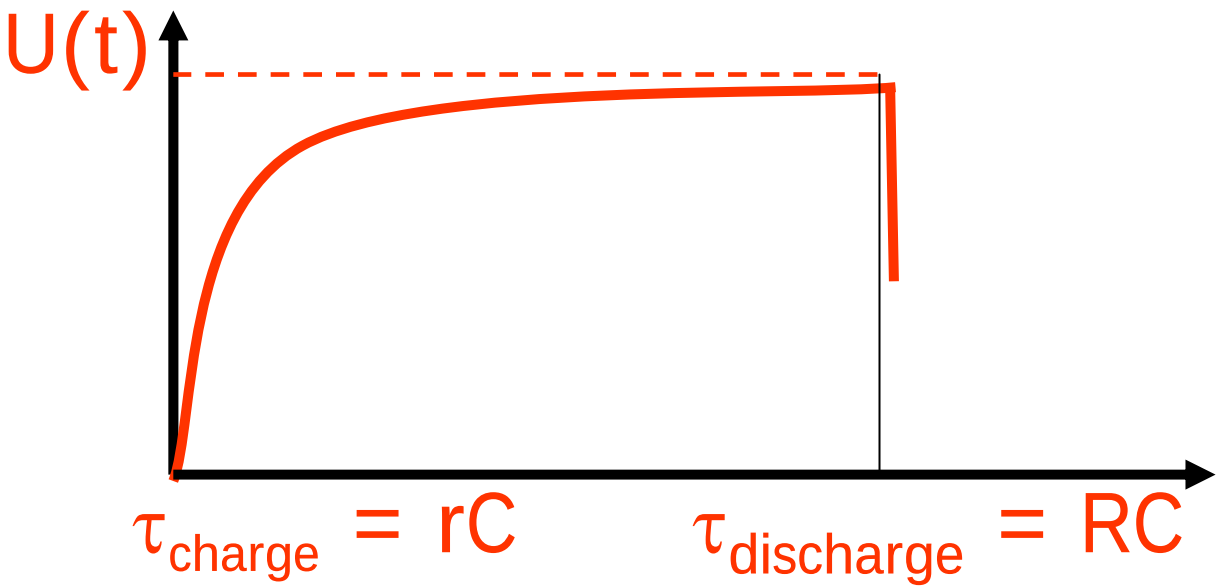
- Then: Discharging the capacitor





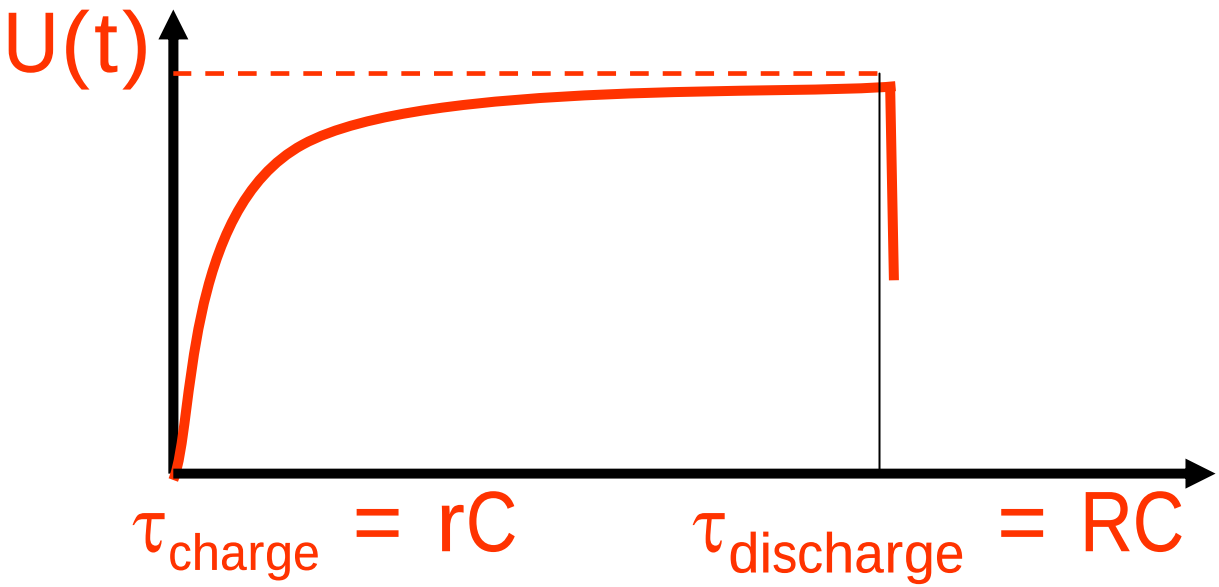
RC Circuits

- But
  - τ_{charge} = 100kΩ x 100μF = 10s
  - $\tau_{discharge}$ = 0.1Ω x 100μF = 10μs



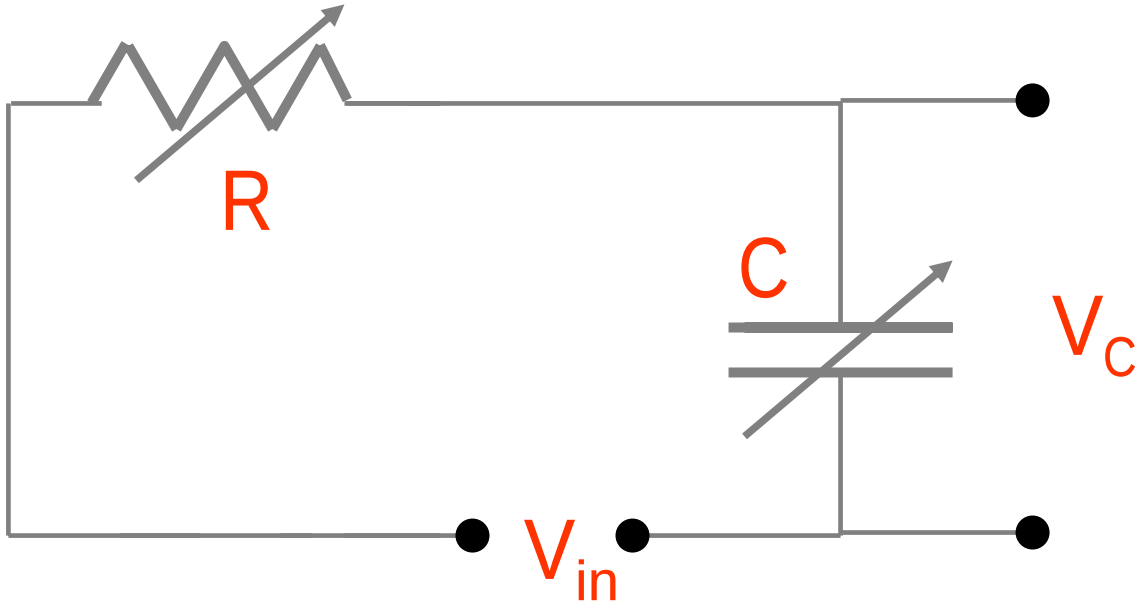
RC Circuits

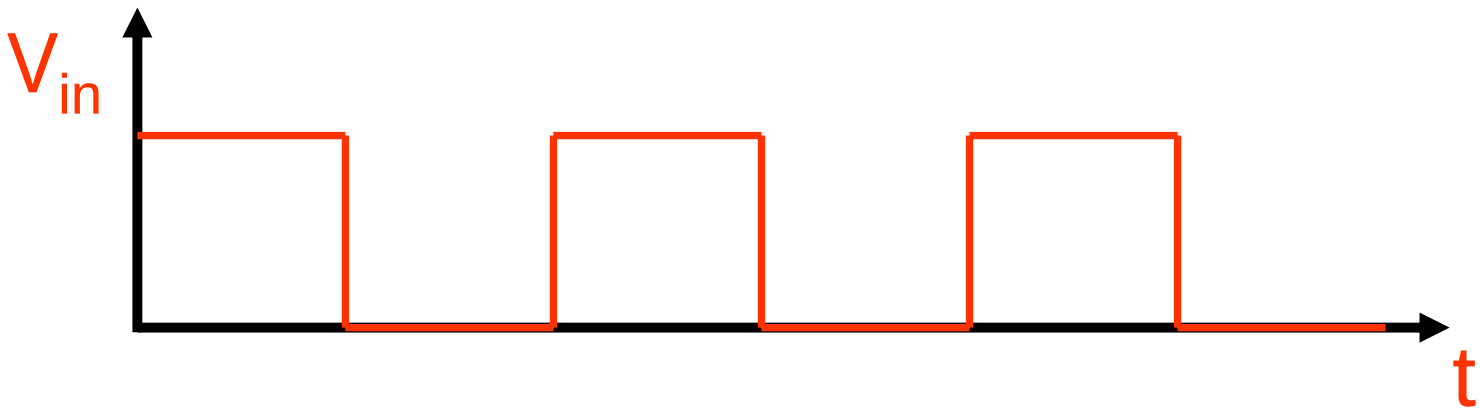
- Power?
  - Power = $\Delta U/\Delta t$ -> SLOPE!



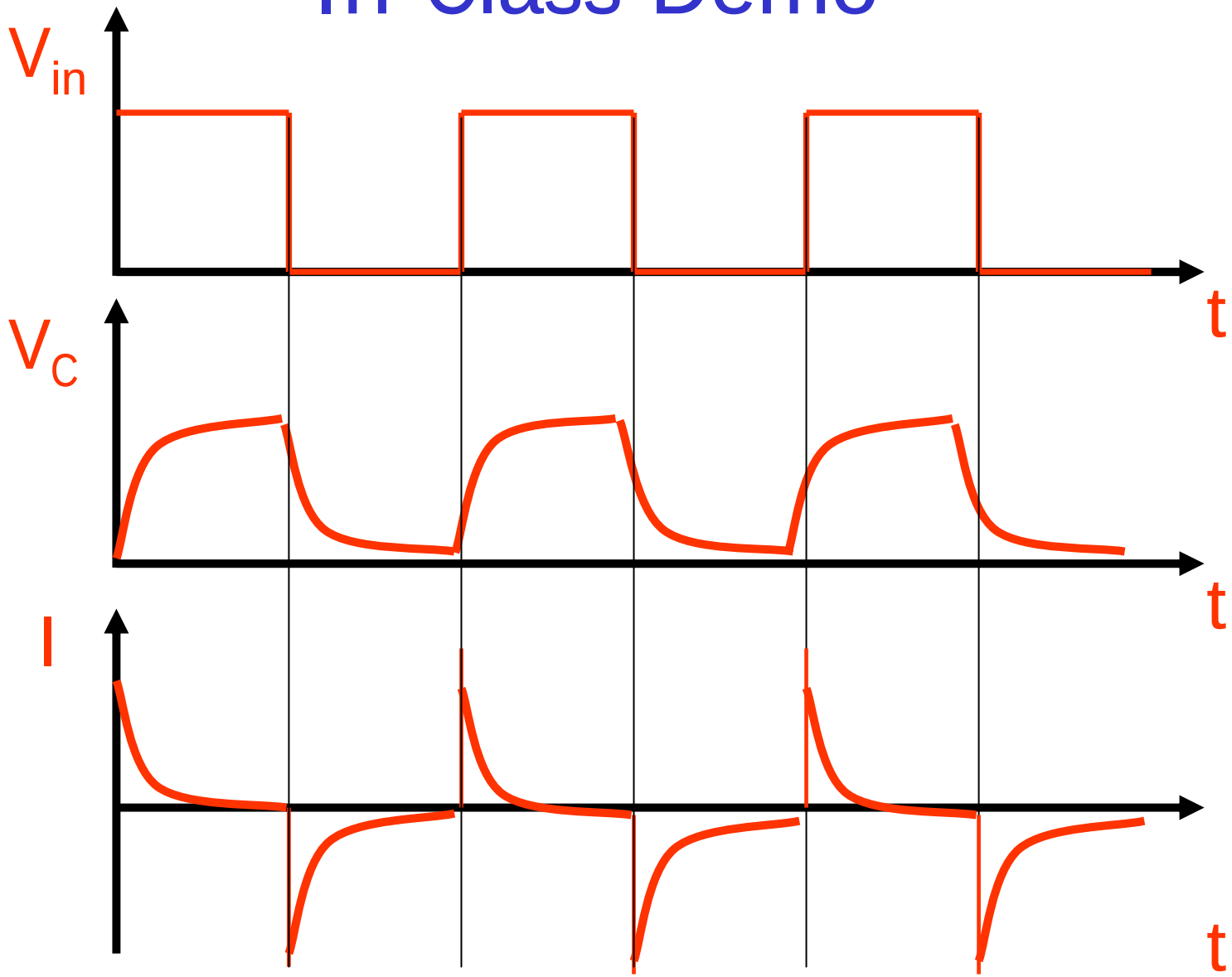
In-Class Demo

Variable time constant $\tau = RC$

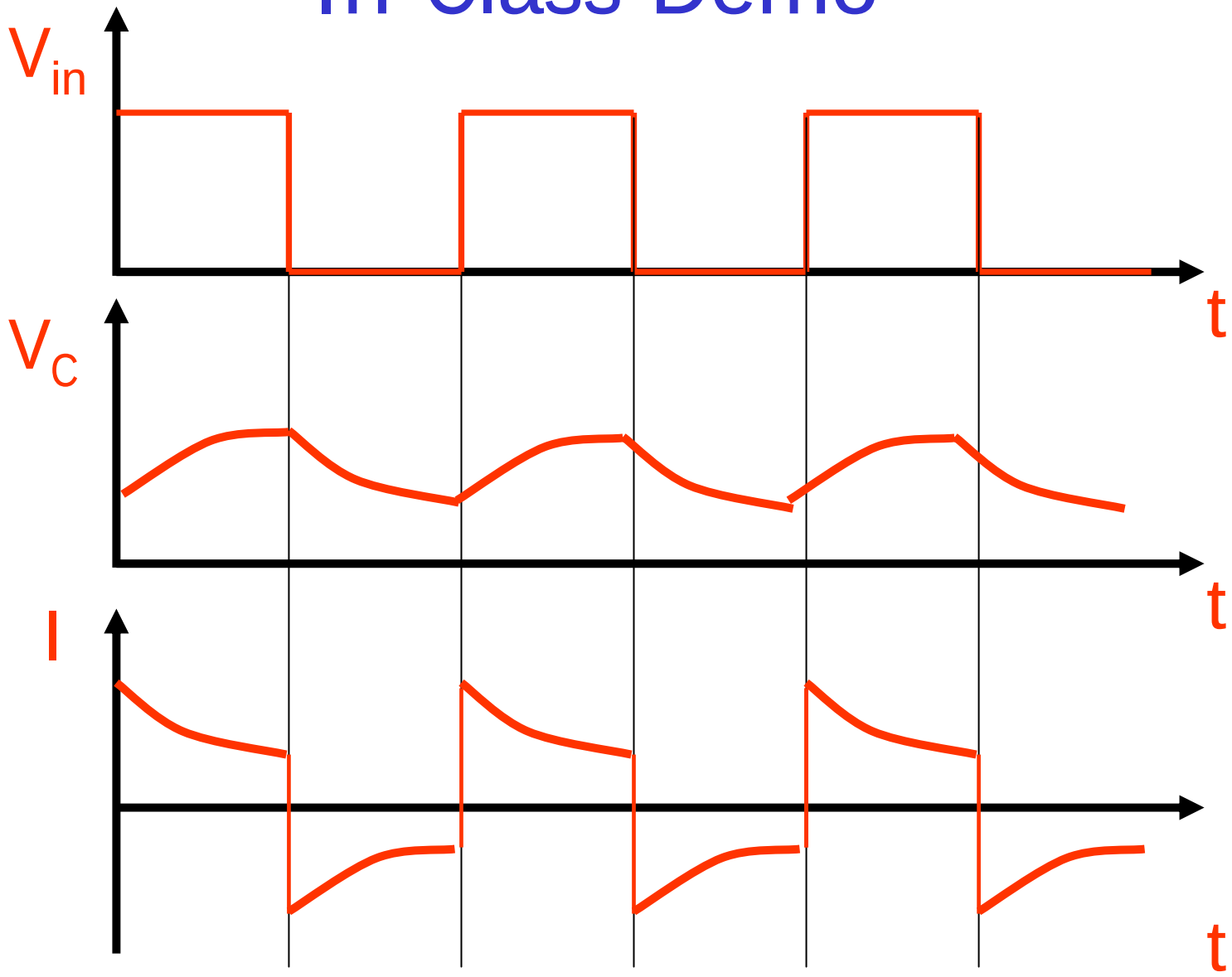




In-Class Demo



In-Class Demo



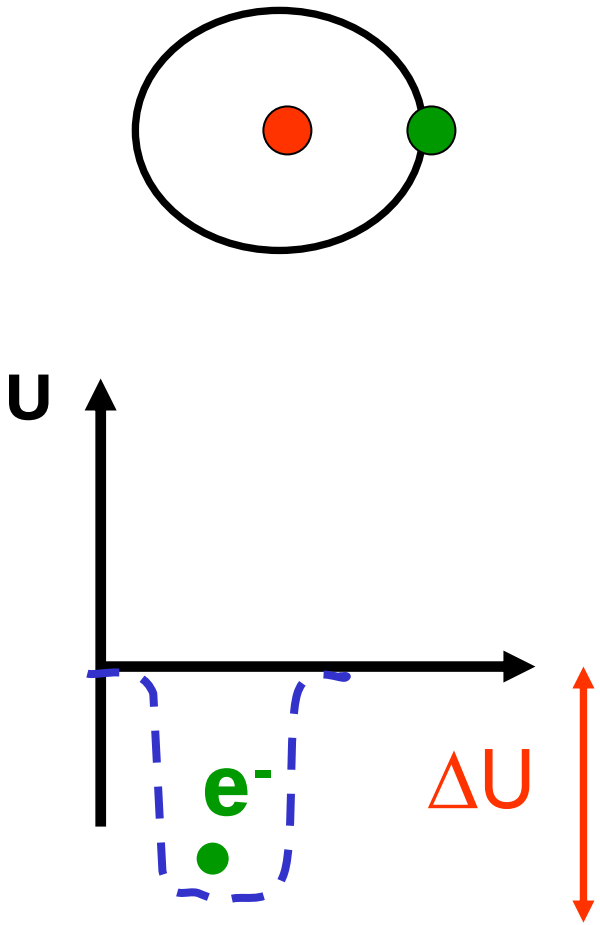
In-Class Demo

- Changes in R or C change τ
- Large τ smoothes out signals
- Sharp edges/rapid changes get removed
  - high frequencies are suppressed
- RC circuits are low-pass filters

Experiment EB

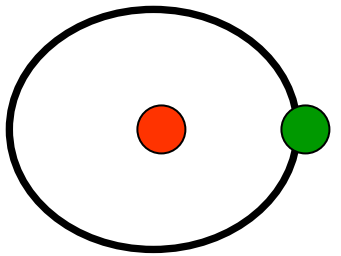
- Electrical Breakdown
  - You have seen many examples
    - Lightning!
    - Sparks (e.g. Faraday Cage Demo!)
    - Fluorescent tubes
  - Study in more detail
  - Reminder: Ionization

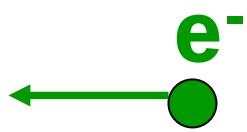
Ionization



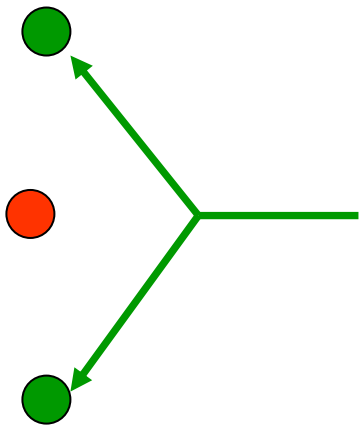
- Electrons and nucleus bound together
- Electrons stuck in potential well of nucleus
- Need energy ΔU to jump out of well
- How to provide this energy?

Impact Ionization





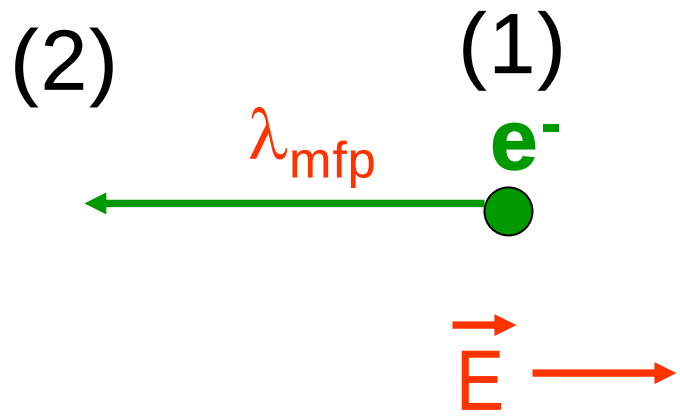
$U_{kin} > \Delta U$



- Define $V_{ion} = \Delta U/q$
- Ionization potential

- One e^- in, two e^- out
- Avalanche?

Impact Ionization



λ_{mfp} : Mean Free Path

- To get avalanche we need:

  ΔU_{kin} between collisions (1) and (2) $> V_{ion} * e$
- Acceleration in uniform Field

  $\Delta U_{kin} = V_2 - V_1 = e\ E\ d_{12}$
- Avalanche condition then

  $E > V_{ion} / \lambda_{mfp}$

Impact Ionization

How big is Mean Free Path?

(i) If Density n is big -> λ_{mfp} small

(ii) If size σ of molecules is big -> λ_{mfp} small

Effective cross-section

$$\lambda_{mfp} = 1/(n\,\sigma)$$

Impact Ionization

Avalanche condition $E > V_{ion} / \lambda_{mfp} = V_{ion}\, n\, \sigma$

Experiment EB: Relate E, V_{ion}, σ

Example: Air

$n \sim 6 \times 10^{23} / 22.4\ 10^{-3}\ m^3 = 3 \times 10^{25}\ m^{-3}$

$\sigma \sim \pi\ r^2 \sim 3 \times (10^{-10} m)^2 = 3 \times 10^{-20}\ m^2$

$V_{ion} \sim 10\ V$

Need $E > 3 \times 10^{25}\ m^{-3} \times 3 \times 10^{-20}\ m^2 \times 10\ V \sim 10^7\ V/m$

For $V \sim 800\ V$: $V = E\, d \rightarrow d = 800/10^7\ m \sim 0.1\ mm$

Experiment EB