Course Updates

http://www.phys.hawaii.edu/~varner/PHYS272-Spr10/physics272.html

Notes for today:

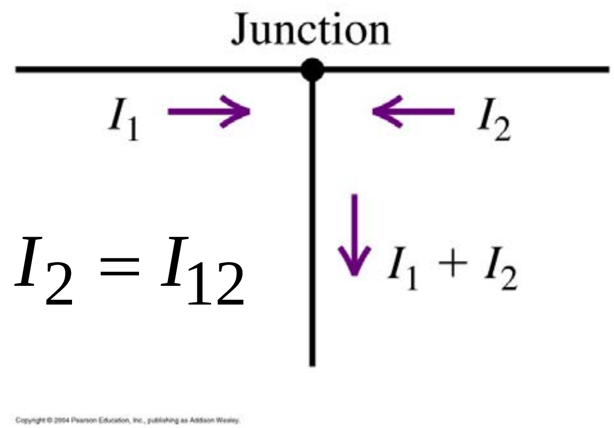
1) Complete Chap 26, Problem session Friday
2) Assignment 6 (Mastering Physics) online and separate, written problems due Monday
3) Quiz 3 on Friday
4) Review Midterm 1

Kirchhoff's Rules

Kirchhoff's rules are statements used to solve for currents and voltages in complicated circuits. The rules are

Rule I. Sum of currents into any junction is zero.

$$\sum_i I_i = 0$$

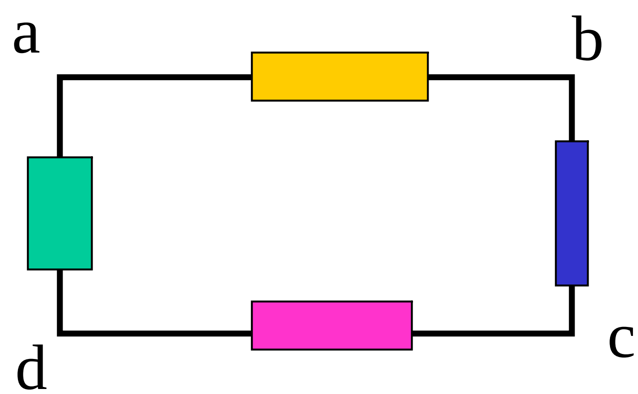


$$I_1 + I_2 = I_{12}$$

Why? Since charge is conserved.

Rule II. Sum of potential differences in any loop is zero. (This includes emfs)

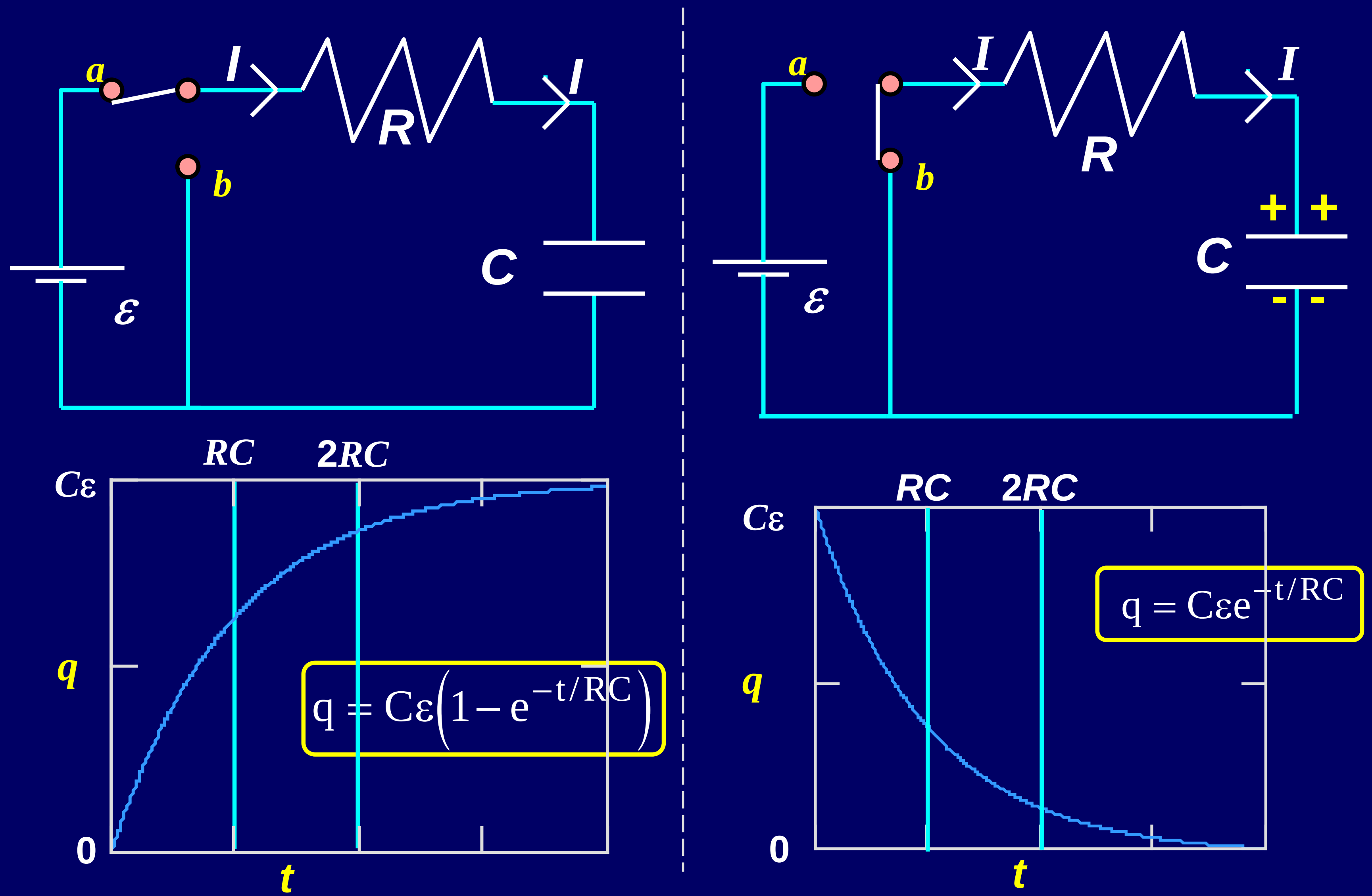
$$\sum_i V_i = 0$$



Why? Since potential (energy) is conserved

$$V_{ab} + V_{bc} + V_{cd} + V_{da} = 0$$

RC Circuits


a
I
R
I
b
C
ε
RC
2RC
Cε
q
0
t
$q = C\varepsilon\left(1 - e^{-t/RC}\right)$
a
I
R
I
b
+ +
C
- -
ε
RC
2RC
Cε
q
0
t
$q = C\varepsilon e^{-t/RC}$

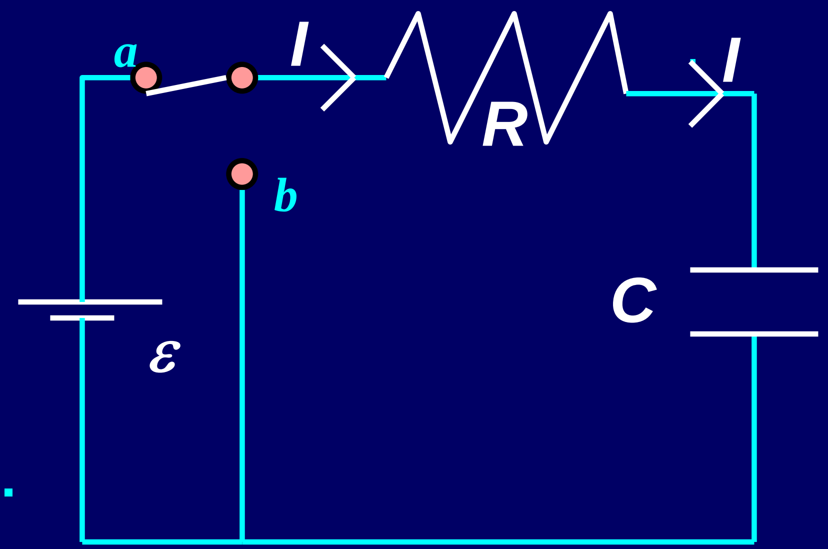
RC Circuits
(Time-varying currents, charging)

- **Charge capacitor:**

  C initially uncharged;
  connect switch to a at t=0

  Calculate current and

  charge as function of time.



- **Loop theorem** $\Rightarrow$ $\varepsilon - IR - \dfrac{Q}{C} = 0$

Would it matter where R is placed in the loop??

- **Convert to differential equation for Q:**

$$I = \frac{dQ}{dt} \quad \Rightarrow \quad \boxed{\varepsilon = R\frac{dQ}{dt} + \frac{Q}{C}}$$

No!

Charging Capacitor

- **Charge capacitor:**

$$\varepsilon = R\frac{dQ}{dt} + \frac{Q}{C}$$

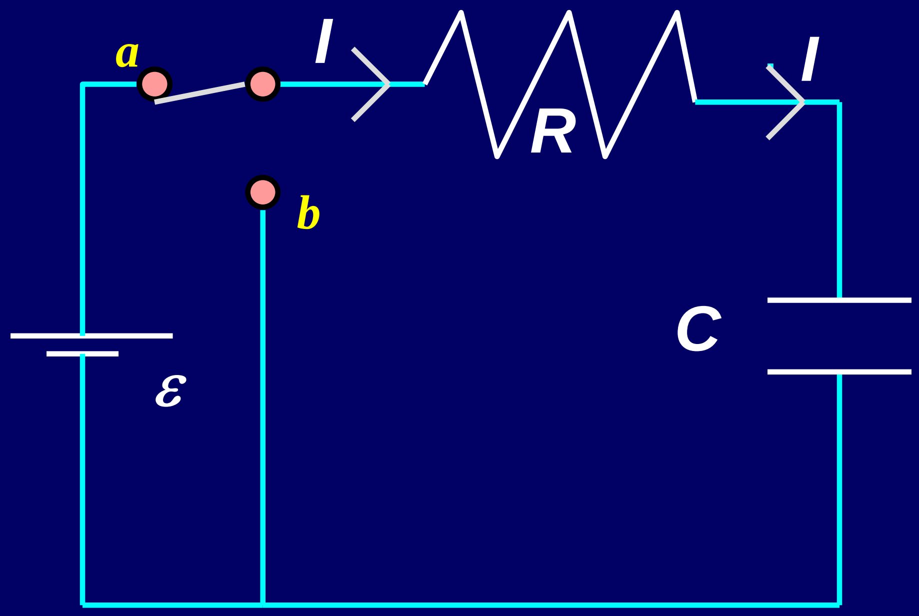
- **Guess solution:**

$$Q = C\varepsilon(1 - e^{-t/RC})$$

- **Check that it is a solution:**

$$\frac{dQ}{dt} = C\varepsilon e^{-t/RC}\left(-\frac{1}{RC}\right)$$

$$\Rightarrow \quad R\frac{dQ}{dt} + \frac{Q}{C} = -\varepsilon e^{-t/RC} + \varepsilon(1 - e^{-t/RC}) = \varepsilon \quad !$$



Note that this "guess" fits the boundary conditions:

$$t = 0 \Rightarrow Q = 0$$

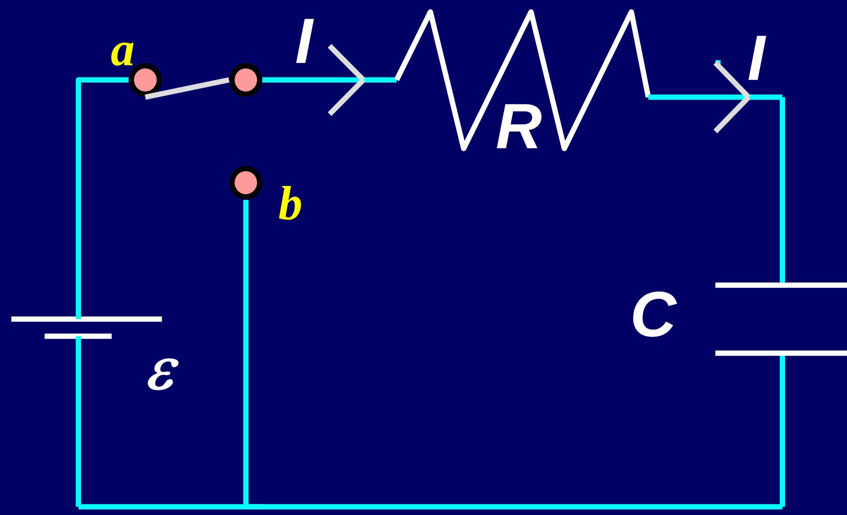
$$t = \infty \Rightarrow Q = C\varepsilon$$

Charging Capacitor

- **Charge capacitor:**

$$Q = C\varepsilon\left(1 - e^{-t/RC}\right)$$

- **Current is found from differentiation:**

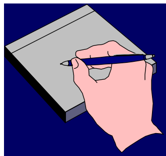


$$I = \frac{dQ}{dt} = \frac{\varepsilon}{R} e^{-t/RC}$$

$\Rightarrow$

Conclusion:

- **Capacitor reaches its final charge($Q=C\varepsilon$) exponentially with time constant $\tau = RC$.**
- **Current decays from max ($=\varepsilon/R$) with same time constant.**



Charging Capacitor

Charge on C

$$Q = C\varepsilon\left(1 - e^{-t/RC}\right)$$

Max = $C\varepsilon$

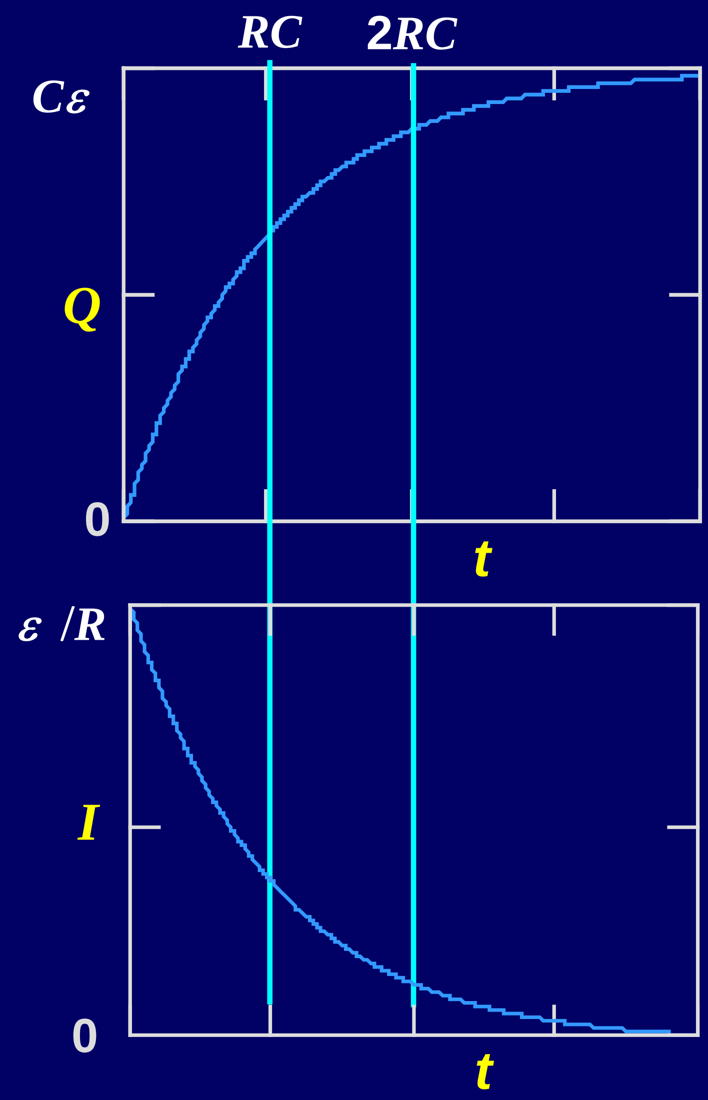
63% Max at $t = RC$

Current

$$I = \frac{dQ}{dt} = \frac{\varepsilon}{R} e^{-t/RC}$$

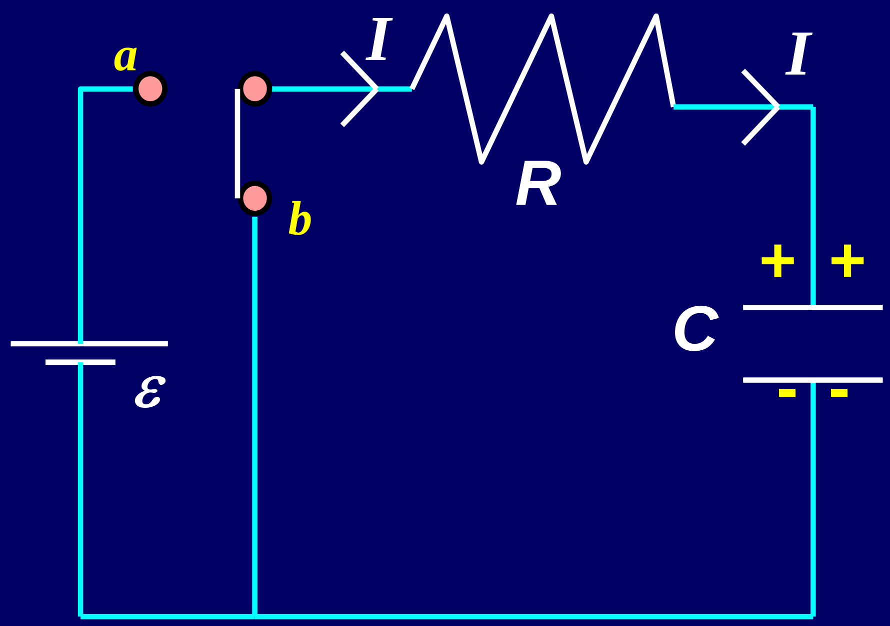
Max = ε / R

37% Max at $t = RC$



Discharging Capacitor

$$R\frac{dQ}{dt}+\frac{Q}{C}=0$$



- **Guess solution:**

$$Q = Q_0 e^{-t/\tau} = C\varepsilon e^{-t/RC}$$

- **Check that it is a solution:**

$$\frac{dQ}{dt} = C\varepsilon e^{-t/RC}\left(-\frac{1}{RC}\right)$$

$$\Rightarrow R\frac{dQ}{dt}+\frac{Q}{C} = -\varepsilon e^{-t/RC} + \varepsilon e^{-t/RC} = 0 \; !$$

Note that this "guess" fits the boundary conditions:

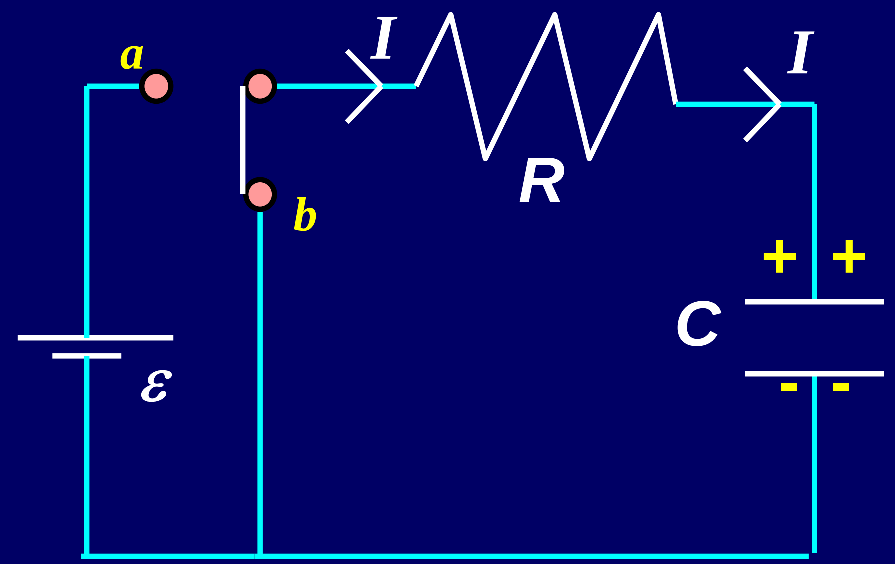
$$t=0 \Rightarrow Q=C\varepsilon$$

$$t=\infty \Rightarrow Q=0$$

Discharging Capacitor

- **Discharge capacitor:**

$$Q = Q_0 e^{-t/\tau} = C\varepsilon e^{-t/RC}$$



- **Current is found from differentiation:**

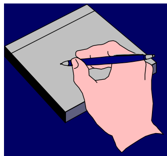
$$I = \frac{dQ}{dt} = -\frac{\varepsilon}{R} e^{-t/RC}$$

$\Rightarrow$

Minus sign:
Current is opposite to original definition, i.e., charges flow *away* from capacitor.

Conclusion:

- **Capacitor discharges exponentially with time constant $\tau = RC$**
- **Current decays from initial max value (= $-\varepsilon/R$) with same time constant**



Discharging Capacitor

Charge on C

$$Q = C\varepsilon e^{-t/RC}$$

Max = $C\varepsilon$

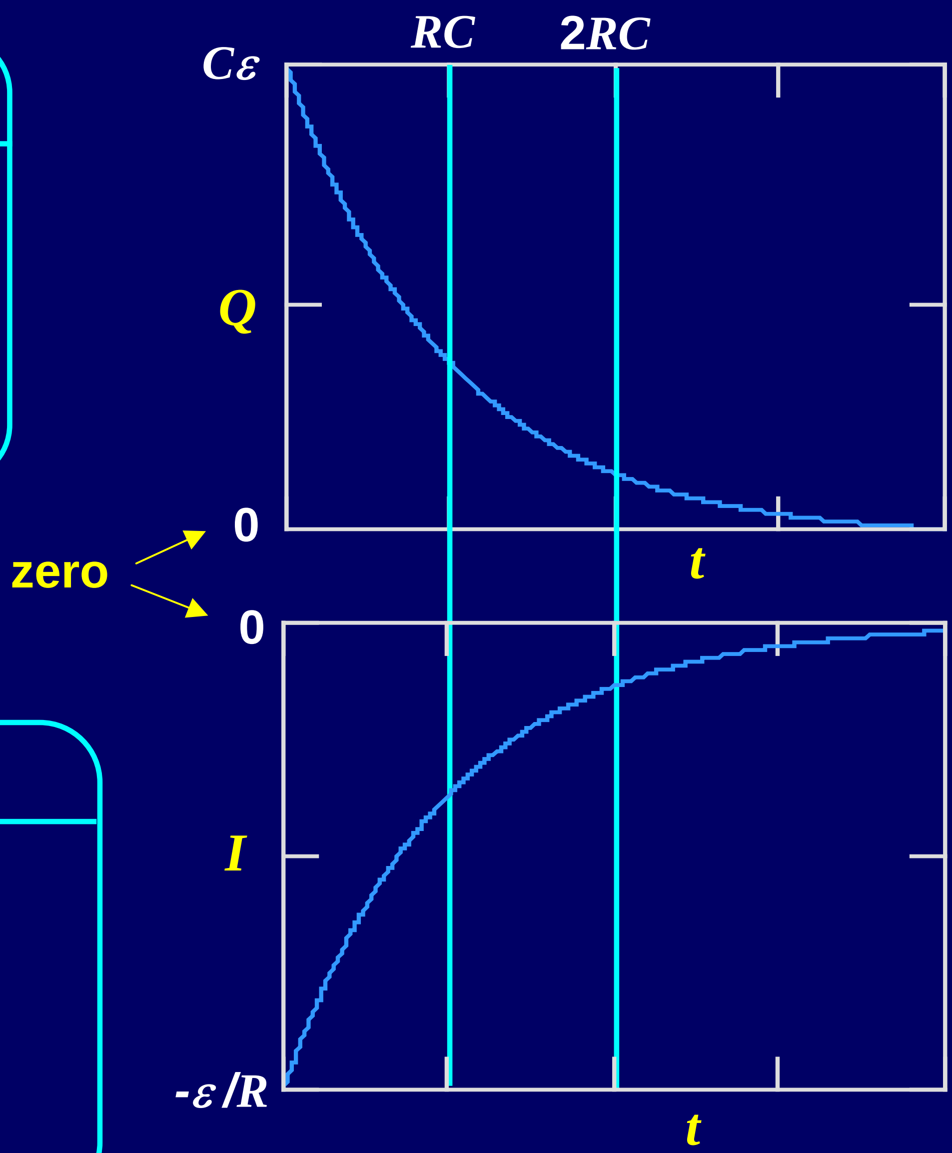
37% Max at $t = RC$

Current

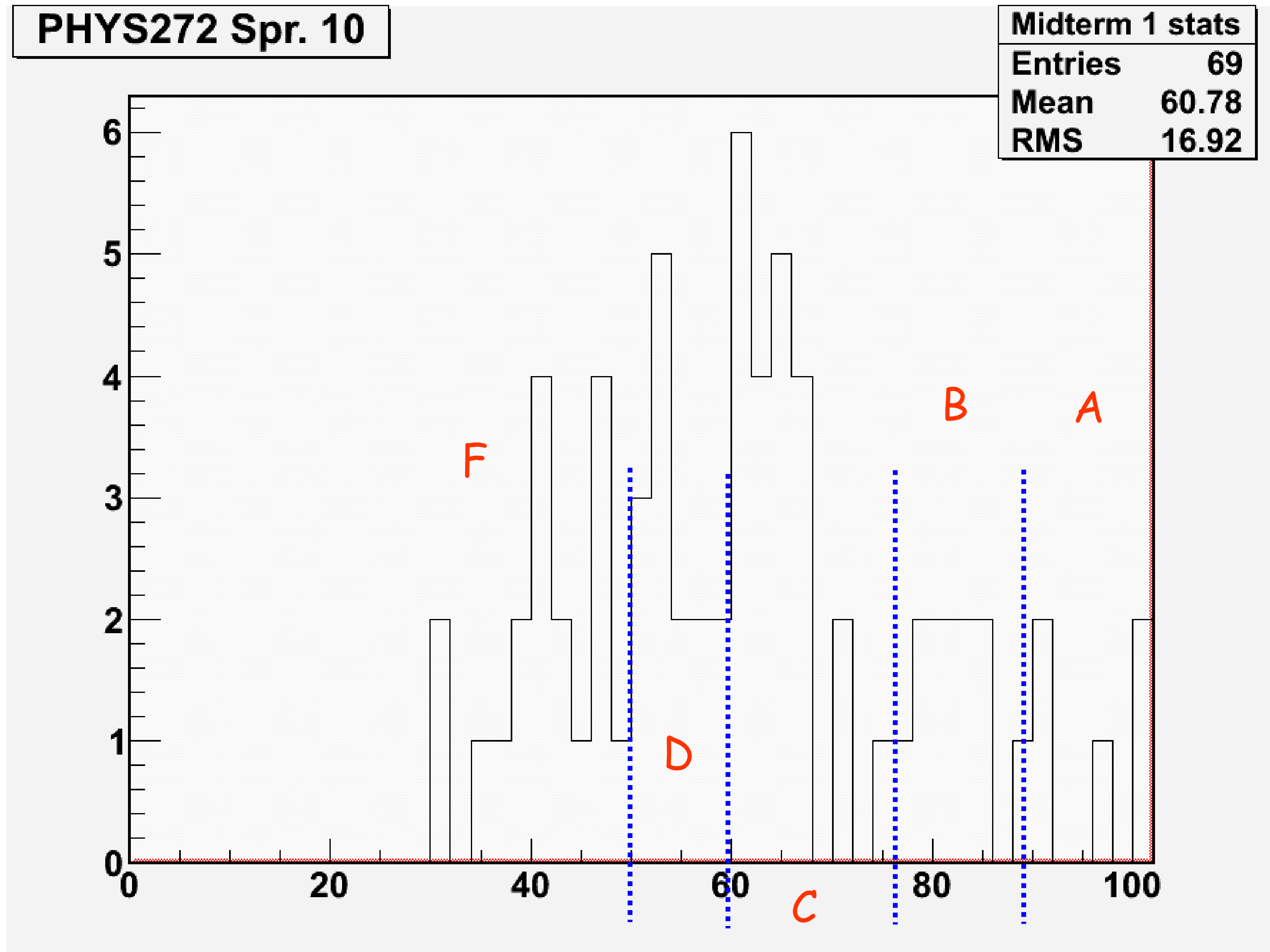
$$I = \frac{dQ}{dt} = -\frac{\varepsilon}{R}e^{-t/RC}$$

"Max" = $-\varepsilon/R$

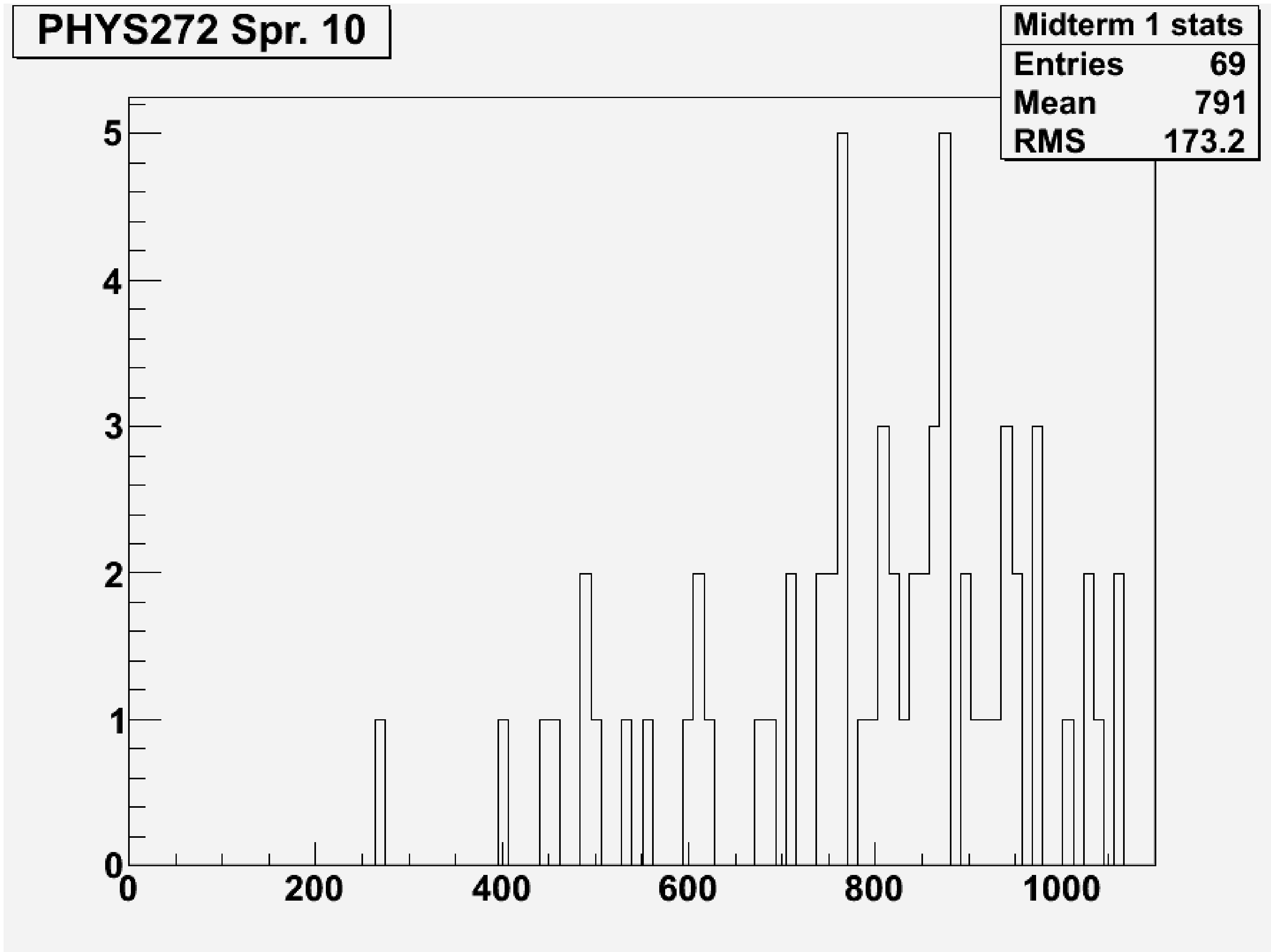
37% Max at $t = RC$



Midterm 1 statistics



Cumulative statistics



Midterm Review

- Not many systematic, consistent problems

- However, some recurrent themes:
  - Electric Potential (V) vs. Potential Energy (U)
  - Electric field sums as vector quantity
  - Potential field (V) sums as a scaler
  - Area of a circle is πr^2

- Detailed points breakdown (by roster ID) linked from course webpage
- Will go over in outline form problems next…

For next time

- HW #6 Assigned → due next Monday
- Quiz #3 on Friday
- Problem session Friday prior to quiz