EA3 – Week 8
Electrical Systems

Spring 2017
1. The conserved quantity in an electrical system is
   A. voltage  
   B. charge  
   C. current  
   D. time
2. Voltage
   E. is a through variable  
   F. is measured with a two probed meter  
   G. is an “effort” variable analogous to force  
   H. is equal to electric potential when measured relative to “ground”
3. The convention for voltmeter polarities wrt current direction
   I. + is always “upstream” for batteries  
   J. + is always “upstream” for all elements except batteries
2. For a resistor:
   E. the constitutive law is given by V = i R
   F. the constitutive law is given by V = i/R
   G. the power flowing into it cannot be negative  
   H. the power flowing into it can be calculated by P = i^2R or P = V^2/R
Today’s Outline

• Electrical systems
  – Charge
  – Current
  – Batteries

• Resistors
  – Series and Parallel
  – Ohm’s Law

• Loops and Junctions
  – Kirchoff Current Law
  – Kirchoff Voltage Law
CQ 1

Flow variables: velocity, flux, current
Effort variables: force, concentration gradient, voltage

Do the following quantities act THROUGH or ACROSS an element?

(A) Force ___ a spring
(B) Velocity ___ a damper
(C) Force ___ a mass
(D) Flow ___ a pump
(E) Voltage ___ a light bulb
(F) Current ___ battery
A 1.5 volt battery is connected to a 3 Ω bulb for 10 seconds.

(A) 0.5 amperes of current flows

(B) The total charge that moves through the circuit in 10s is 5 coulombs.

(C) Electrons move up in the red wire.

(D) The balance of + and – charge in the battery shifts in favor of +.

(E) The balance of + and – charge in the battery shifts in favor of –.

(F) No current flows because the circuit is not grounded.
A bird (or cat) on a high-voltage wire does not get electrocuted because...

(A) Feathers & fur don’t conduct electricity.
(B) The potential of the bird is zero.
(C) The bird would be electrocuted if there were a current in the wire.
(D) The bird would be electrocuted if it also touched another wire of the same potential.
(E) The bird would be electrocuted if it also touched the ground.
(F) The bird would be electrocuted if it were carrying a metal object
(A) Current would flow if the battery were turned around so the + side were connected to the bulb.

(B) Current would flow if the wire from the battery connected to the end-terminal of the bulb.

(C) Current would flow if the + end of the battery were also grounded.

(D) Current would flow if the – end of the battery were also grounded.

(E) The potential of the horizontal wire is −1.5 volts

(F) The potential of the horizontal wire is zero
(A) If you remove one bulb from a series set, the others will go out too.
(B) If you remove one bulb from a parallel set, the others will go out too.
(C) If you connect a single bulb from a series set to 120 volts, it will flash brightly and burn out
(D) If you connect a single bulb from a series set to 120 volts, it will glow normally
(E) If you connect a single bulb from a series set to 120 volts, it will glow dimly
(F) If you wanted to make a "shortened" series set, with only 20 bulbs, you should use 1.5-volt bulbs.
CQ 6

With switch S1 open...

(A) L1 is lit
(B) L2 is lit
(C) L3 is lit

When switch S1 is closed...

(D) L1 will brighten
(E) L2 will brighten
(F) L3 will brighten
CQ 7

With switch S1 open...

(A) $V_B = V_1 = V_2$
(B) $V_B = V_1 + V_2$
(C) $i_B = i_1 + i_2$
(D) $i_1 = \frac{V_B}{R_1}$
(E) $i_1 = \frac{V_B}{(R_1 + R_2)}$
(F) $i_B = i_1 = i_2$
CQ 8

With switch S1 closed...

Label Current Arrows & Voltmeter Polarities
CQ 8

With switch S1 closed...
Let $R_1 = R_2 = R_3 = R$

(A) $V_B = V_1 = V_2$
(B) $V_B = V_1 + V_2$
(C) $V_B = V_1 + V_3$
(D) $V_2 = V_3$
(E) $V_1 = V_2$

(A) $i_1 = V_1/R$
(B) $i_B = i_1 + i_2$
(C) $i_1 = i_2 + i_3$
(D) $i_1 = V_B/R$
(E) $i_1 = V_B/2R$
(F) $i_1 = i_2$
Let \( R_1 = R_2 = R_3 = R = 5 \)

With switch S1 closed...

\[
V_B = V_1 + V_2 \quad V_1 = i_1 R \\
V_2 = V_3 \quad V_2 = i_2 R \\
i_1 = i_2 + i_3 \quad V_3 = i_3 R
\]

(A) \( V_1 = 3 \)
(B) \( V_2 = 3 \)
(C) \( V_3 = 3 \)
(D) \( i_1 = 6/5 \)
(E) \( i_2 = 3 \)
(F) \( i_3 = 3/5 \)
Electrical Systems – Capacitors & RC Circuits
RQ (T/F)

1. A capacitor...
   A. stores energy.
   B. allows electrons to pass across the gap
   C. is analogous to a spring

2. The constitutive law for the capacitor is
   D. $V = iC$
   E. $V = qC$
   F. $V = i/C$
   G. $V = q/C$

3. The energy stored in a capacitor may be evaluated by
   H. the area under the curve of the $V$-$vs$-$q$ constitutive law.
   I. integrating $iV$ over time
   J. voltage * time
Outline

• Rates and Reactions review example

• Capacitors
  – Capacitance
  – Parallel and Series
  – Energy

• RC Circuits
  – Time Constant
  – Charging a capacitor

• The first instant...

• Steady State

\[ V = \frac{q}{C} \]
\[ V' = \frac{i}{C} \]
Which circuits are equivalent to (A)?

(A)

(B)

(C)

(D)
Which circuits are equivalent to A?

(A)  
(B)  
(C)  
(D)  
(E)  

Which of the above diagrams are equivalent to the circuit labeled A?
What is the steady-state current $i$ long after the switch is closed?

(A) Positive  
(B) Zero  
(C) Negative  
(D) It cannot be determined
C1 is initially charged to 10v, while C2 & C3 are uncharged.

After S1 is closed, what are the voltages across C1 and C2?

(A) C1: 0  (D) C2: 0
(B) C1: 5v  (E) C2: 5v
(C) C1: 10v  (F) C2: 10v
Now S1 is opened and S2 is then closed.

After S2 is closed, what are the voltages across C2 and C3?

(A) C2: <2.5v  (D) C3: <2.5v
(B) C2: =2.5v  (E) C3: =2.5v
(C) C2: >2.5v  (F) C3: >2.5v
After $S1$ is closed, in steady state, what is the voltage across $R3$?

(A) 6v
(B) 4v
(C) 3v
(D) 2v
(E) 0
(F) It cannot be determined
Charging a capacitor

Close S1:

\[ V_{c1} = 9 \text{V} \]
\[ q_{c1} = 0.9 \text{coulombs} \]

Open S1, Close S2:

\[ V_{c1} = V_{c2} = 4.5 \text{V} \]
\[ q_{c1} = q_{c1} = 0.45 \text{coulombs} \]

→ Charge is conserved: \( \frac{1}{2} q_{c1} \) flows from C1 to C2

Is the energy before and after the same?
When S1 is first closed, which are zero?

(A) $V_{S1}$  
(B) $i_{R1}$  
(C) $i_{C1}$  
(D) $V_{R1}$  
(E) $V_{C1}$  
(F) $V_{R2}$
What is the time constant for the charging of C1?

(A) \(0.000022\) sec = \(2.2\) μsec
(B) \(0.00022\) sec = \(22\) μsec
(C) \(0.0022\) sec = \(220\) μsec
(D) \(0.022\) sec = \(2.2\) msec
(E) \(0.022\) sec = \(22\) msec
(F) \(0.22\) sec
In **steady state**, which are zero?

(A) $V_{S1}$  
(B) $i_{R1}$  
(C) $i_{C1}$  
(D) $V_{R1}$  
(E) $V_{C1}$  
(F) $V_{R2}$
Which is the qualitative shape of the charging of C1?

- $i_{C1}$
  - (A)
  - (X)
  - (B)
  - (C)

- $V_{C1}$
  - (D)
  - (X)
  - (E)
  - (F)
When S2 is first closed, which are zero?

(A) $i_{R4}$

(B) $i_{C2}$

(C) $i_{C3}$

(D) $V_{R4}$

(E) $V_{R3}$

(F) $V_{C3}$
In steady state, which are zero?

(A) $i_{R4}$
(B) $i_{C2}$
(C) $i_{C3}$
(D) $V_{R4}$
(E) $V_{R3}$
(F) $V_{C3}$