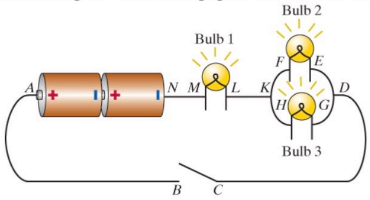
Three bulbs

A circuit is made of two 1.7 volt batteries and three light bulbs as shown in the figure. When the switch is closed and the bulbs are glowing, bulb 1 has a resistance of 7 ohms, bulb 2 has a resistance of 38 ohms, bulb 3 has a resistance of 30 ohms, and the copper connecting wires have negligible resistance. You can also neglect the internal resistance of the batteries.



(a) With the switch open, indicate the approximate surface charge on the circuit diagram.(Do this on paper. Your instructor may ask you to turn in this work.) Refer to your diagram to decide which of the following statements about the circuit (with the switch open) are true:

- [x] The electric field in the filament of bulb 3 is zero.
- [x] The surface charge on the wire at location B is positive.
- [ ] There is a large gradient of surface charge between locations M and L.
- [ ] The electric field in the air between locations B and C is zero.
- [ ] There is no excess charge on the surface of the wire at location C.

(b) With the switch open, find these potential differences:

$V_B - V_C =$ ______ V

$V_D - V_K =$ ______ V

(c) After the switch is closed and the steady state is established, the currents through bulbs 1, 2, and 3 are I_1, I_2, and I_3 respectively. Which of the following equations are correct loop or node equations for this steady state circuit?

- [x] $I_1 = I_2 + I_3$
- [ ] $+3.4\text{V} + -I_1*(7\ \Omega) + I_3*(7\ \Omega) = 0$
- [x] $+3.4\text{V} + -I_1*(7\ \Omega) + -I_2*(38\ \Omega) = 0$
- [x] $-I_2*(38\ \Omega) + I_3*(30\ \Omega) = 0$
- [ ] $-I_1*(7\ \Omega)-I_2*(38\ \Omega) + I_3*(30\ \Omega) = 0$
- [ ] $I_2 = I_3$

(d) In the steady state (switch closed), which of these are correct?

- [ ] $V_C - V_F = 0$
- [ ] $V_C - V_F = +I_1*(7\ \Omega)$
- [x] $V_C - V_F = +I_3*(30\ \Omega)$
- [x] $V_C - V_F = +I_2*(38\ \Omega)$
- [x] $V_L - V_A = -3.4\text{V} + I_1*(7\ \Omega)$

(f) Now find the unknown currents, to the nearest milliampere. (I.e. enter your answer to three decimal places.)

$I_1 =$ ______ A

$I_2 =$ ______ A

$I_3 =$ ______ A

(g) How many electrons leave the battery at location N every second?

______ electrons/s

(i) What is the numerical value of the power delivered by the batteries?

P = ______ W

(j) The tungsten filament in the 38 ohm bulb is 12 mm long and has a cross-sectional area of 2×10^{-10} m^2. What is the magnitude of the electric field inside this metal filament?

$|\vec{E}| =$ ______ V/m

Part One

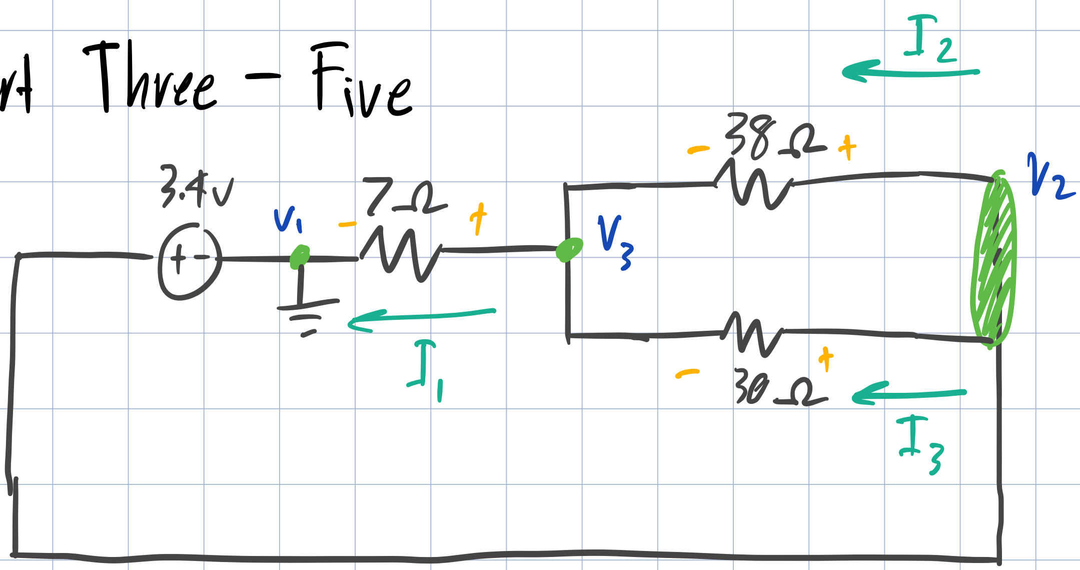
$V_B - V_c = 1.7 \cdot 2$

$= 3.4\ \text{V}$

Part Two

$V_D - V_k = 0\,v$

Part Three - Five



Node Voltage

$V_1 = 0$

$V_2 = 3.4v$

KCL at V_3

$I_1 = I_2 + I_3$

$$\frac{V_3 - V_1}{7} = \frac{V_2 - V_3}{38} + \frac{V_2 - V_3}{30}$$

$V_2 = 1.601\,v$

Find currents

$$I_1 = \frac{V_3 - V_1}{7}$$

$$= 0.143\,A$$

$$I_2 = \frac{V_2 - V_3}{38}$$

$$= 0.063\,A$$

$$I_3 = \frac{V_2 - V_3}{30}$$

$$= 0.080\,A$$

Part Five

$$I_1 = 0.143\,\frac{c}{s}$$

$$A = \frac{c}{s}$$

$$= \frac{0.143\,c}{s} \cdot \frac{1 \text{ electron}}{1.6e{-}19\,c} = 894.375e15\,\frac{\text{electron}}{s}$$

Part Six

$$P = IV$$

$$= 0.486\,W$$

Part Seven

$$E = \frac{RI}{L}$$

$$= 199.88 \, V/m$$