$k = 9.0 \times 10^{9}\ N\ m^2 / C^2$ $e = 1.60 \times 10^{-19}\ C$ $\varepsilon_o = 8.85 \times 10^{-12}\ C^2 / N\ m^2$

Coulomb's law: $F = k\ q\ Q / r^2$ (unlike charges attract, like charges repel)

Electric field from a point charge : $E = k\ q / r^2$ (towards -, away from +)

Force on a charge in an electric field : $\mathbf{F} = q\mathbf{E}$

Potential energy of two charges : $U = k\ q\ Q / r$ Electric potential : $V = k\ q / r$

Potential energy of a charge in an electric potential : $U = qV$

Uniform field between two parallel plates a distance d apart : $E = V / d$

Accelerating a charge through a potential difference : $qV = 1/2\ mv^2$

Circuits

Capacitance of a parallel-plate capacitor : $C = \kappa\ \varepsilon_o\ A / d$

Charge on a capacitor : $Q = CV$ Energy in a capacitor : $U = 1/2\ CV^2$

Resistance : $R = \rho\ L / A$ (ρ = resistivity, L = length, A = cross-sectional area)

Ohm's Law : $V = I\ R$ Current : $I = \Delta Q / \Delta t$

Resistors in series : $R = R_1 + R_2 + R_3 + ...$

Resistors in parallel : $1/R = 1/R_1 + 1/R_2 + 1/R_3 + ...$

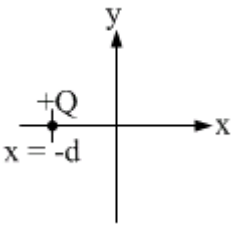
Electric power : $P = VI = I^2\ R = V^2 / R$ 1 Watt = 1 J / s

PROBLEM 1 – 20 points

A point object with a positive charge +Q is placed on the x-axis at x = -d. A second point object of unknown charge is placed at an unknown location on either the x-axis or the y-axis.

The potential energy associated with the charges is $U = +\frac{2kQ^2}{d}$

The potential at the origin due to the charges is $V = +\frac{4kQ}{d}$



The net electric field at the origin due to the two charges points in the negative x direction. Assume the electric potential is zero at infinity.

[8 points] (a) Before solving for the unknown charge and location answer these questions.

(i) What is the sign of the unknown charge?

[ ] positive [ ] negative [ ] can not be determined

How do you know?

(ii) Where is the unknown charge located?

[ ] positive x-axis [ ] negative x-axis [ ] positive y-axis [ ] negative y-axis

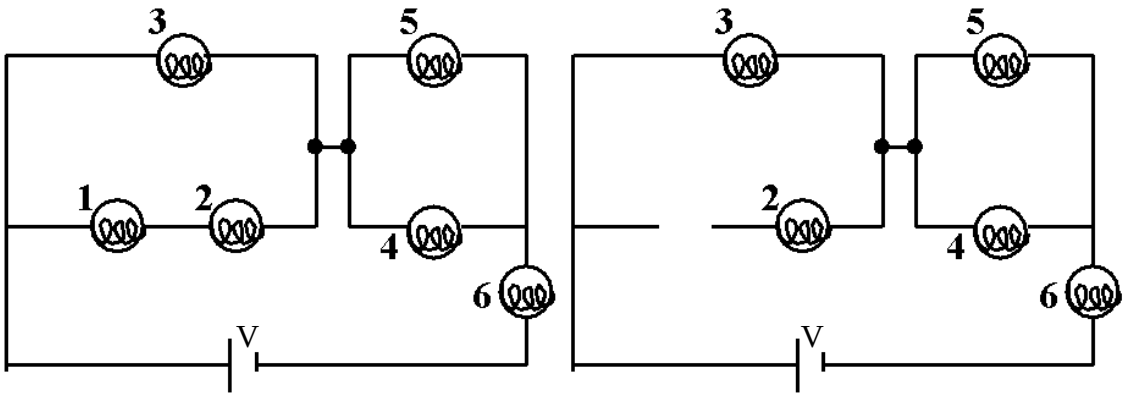
How do you know?

[8 points] (b) Determine the value (sign and magnitude) of the unknown charge and state its location.

[4 points] (c) What is the magnitude of the electric field at the origin?

PROBLEM 2. [20 points] – Light bulbs

The bulbs in the circuit are identical.



(1) [6 points] In the circuit on the left, rank bulbs 1-6 in order of **decreasing** brightness. Briefly explain your answers.

(2) [6 points] If each bulb has a resistance of 12 ohms, what is the equivalent resistance of the circuit on the left?

(3) [8 points] When bulb 1 is removed, leaving a break in the circuit….

a) The brightness of bulb 3 _____

[ ] increases [ ] decreases [ ] stays the same

Briefly explain your answer:

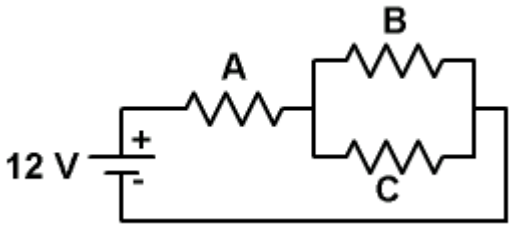
b) The brightness of bulb 6 _____

[ ] increases [ ] decreases [ ] stays the same

Briefly explain your answer:

PROBLEM 3 – 20 points

Three resistors are connected as shown in a circuit with a 12 volt battery. The resistances are:
For resistor A, $R_A = 4\ \Omega$
For resistor B, $R_B = 3\ \Omega$
For resistor C, R_C is an unknown value



[3 points] (a) Which resistor has the most current passing through it?

[ ] A [ ] B [ ] C [ ] It depends on the value of R_C

Briefly justify your answer:

[5 points] (b) Rank the resistors based on the potential difference across them, from largest to smallest.

[ ] A > B > C [ ] A > B = C [ ] B > C > A [ ] B = C > A
[ ] It depends on the value of R_C

Briefly justify your answer:

[8 points] (c) If R_C, the resistance of resistor C, is increased, what happens to the currents through the different elements in the circuit?

i) The current through the battery: [ ] increases [ ] decreases [ ] stays the same

ii) The current through A: [ ] increases [ ] decreases [ ] stays the same

iii) The current through B: [ ] increases [ ] decreases [ ] stays the same

iv) The current through C: [ ] increases [ ] decreases [ ] stays the same

[4 points] (d) If the current through the battery is 2.0 amps, what is R_C, the resistance of resistor C?