This is a closed book, closed notes exam. An equation sheet (without any words) is allowed; please hand it in with your exam. Credit is assigned as noted. Partial credit will be awarded based on work shown.

Units

Resistance	Ω (Ohm)
Capacitance	F (Farad)
Charge	C (Coulomb)
Current	A (Amp)
Electric Potential, a.k.a Voltage	V (Volt)

Useful Constants

$k_c = 8.99\times10^{9}\ N\cdot m^2/C^2$

$e = 1.60\times10^{-19}$C

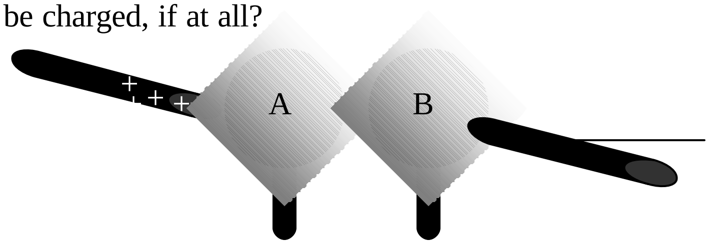
$\varepsilon_o = 8.85\times10^{-12} C^2/(N\cdot m^2)$

1) (4pts) A conducing sphere has a 5.6×10^{8} protons and 5.4×10^{8} electrons, what is the net charge on the sphere?

$$Q = e(N_p - N_e) = 1.6\times10^{-19}\,Coul\cdot\left(5.6\times10^{8} - 5.4\times10^{8}\right) = \boxed{3.2\times10^{-12}\,Coul}$$

2) (4pts) Two uncharged, conducting spheres, A and B, are held at very near, *but not touching*. A positively charged rod is brought in and touches sphere A and is removed. Then a neutral metal rod touches sphere B and is removed. How will the spheres be charged, if at all?

	Sphere A	Sphere B
a)	positive	positive
b)	**positive**	**negative**
c)	negative	positive
d)	negative	negative
e)	neutral	neutral

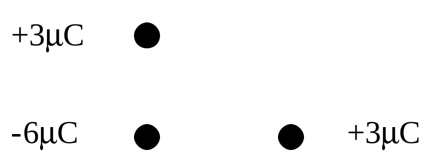


3) (4pts) A charge Q exerts a 12 N force on another charge, q. If the distance between the charges is cut in 1/2, what is the magnitude of the force between Q and q?

$$F_1 = 12N = k\frac{Qq}{r_1^2} \qquad r_2 = \tfrac{1}{2} r_1$$

$$F_2 = ? = k\frac{Qq}{r_2^2} = k\frac{Qq}{(\frac{1}{2}r_1)^2} = k\frac{Qq}{\frac{1}{4}(r_1)^2} = 4k\frac{Qq}{(r_1)^2} = 4F_1 = 4\cdot12N = \boxed{48N}$$

4) (4pts) If the 3μC charge gets 6 field lines, draw field lines for the collection of charge below. Don't forget to indicate their direction.



5) (4pts) Two positive point charges are separated by a distance *R*. This configuration is characterized by an electric potential energy $P.E._i$ If the distance between the charges is doubled, in terms of the initial electric potential energy of the system, what is its new potential energy?

$$P.E._i = k\frac{Qq}{r_i} \quad r_f = 2r_i \quad P.E._f = k\frac{Qq}{r_f} = k\frac{Qq}{2r_i} = \frac{1}{2}k\frac{Qq}{r_i} = \boxed{\frac{1}{2}P.E._i}$$

6) (4pts) The electric potential energy of a charge *decreases* by 0.003 J when moved through an electric potential difference (voltage) of +10 V. What must be the charge's *sign* and *magnitude*?

$$\Delta P.E._{elect} = -0.003J = q\Delta V = q\cdot 10Volts \qquad q = \frac{\Delta P.E._{elect}}{\Delta V} = \frac{-0.003J}{10Volts} = \boxed{-0.0003Coul}$$

7) (4pts) A parallel plate capacitor with plates of area *A* and pate separation d_i is charged so that the potential difference between its plates is DV_i. The capacitor is then isolated and its plate separation is increased to $d_f = 4d_i$. In terms of the old potential difference between the plates, DV_i , what is the new value?

$$d_f = 4d_i \qquad C_i = \frac{Ae}{d_i} \qquad C_f = \frac{Ae}{d_f}$$

$$Q = C_i\Delta V_i = C_f\Delta V_f$$

$$\frac{Ae}{d_i}\Delta V_i = \frac{Ae}{d_f}\Delta V_f$$

$$\frac{Ae}{d_i}\Delta V_i = \frac{Ae}{4d_i}\Delta V_f$$

$$\Delta V_i = \frac{1}{4}\Delta V_f$$

$$\boxed{\Delta V_f = 4\Delta V_i}$$

8) (4pts) A capacitor is initially charged to an electric potential difference of $DV_{batt.1} = 2$ V. It is then disconnected and connected to a different battery. If the ratio of the *final* to the *initial* energy stored in the capacitor is $\frac{P.E._f}{P.E._i} = 4$, what must be the voltage of the second battery?

$$P.E._i = \tfrac{1}{2}C(\Delta V_{batt.1})^2 \qquad P.E._f = \tfrac{1}{2}C(\Delta V_{batt.2})^2 \qquad \frac{P.E._f}{P.E._i} = 4 \qquad DV_{batt.1} = 2\text{ V}$$

$$\frac{P.E._f}{P.E._i} = 4 = \frac{\tfrac{1}{2}C(\Delta V_{batt.1})^2}{\tfrac{1}{2}C(\Delta V_{batt.2})^2} = \frac{(\Delta V_{batt.1})^2}{(\Delta V_{batt.2})^2}$$

$$\sqrt{4} = \sqrt{\frac{(\Delta V_{batt.1})^2}{(\Delta V_{batt.2})^2}} \Rightarrow 2 = \frac{(\Delta V_{batt.1})}{(\Delta V_{batt.2})} \Rightarrow \Delta V_{batt.2} = 2\Delta V_{batt.1} = 2\cdot 2Volts = \boxed{4Volts}$$

9) (4pts) Which one of the following situations results in a conventional electric current that flows *west*ward?

a) a beam of *electrons* moves *west*ward
b) an *electric dipole* moves *east*ward
c) a beam of *protons* moves *east*ward
d) a beam of *protons* moves *west*ward
e) a beam of *neutral atoms* moves *west*ward

10) (4pts) When a light bulb is connected to a 9 Volt battery, a current of 0.3 A passes through the bulb filament. What is the resistance of the filament?

$$\Delta V = IR \Rightarrow R = \frac{\Delta V}{I} = \frac{9Volts}{0.3Amps} = \boxed{30\Omega}$$

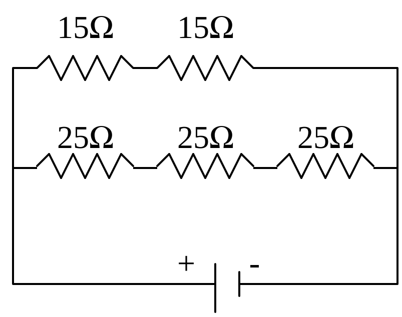
11) (4pts) What is the resistivity of a wire with radius 5.04 ×10^{-4}m , length 3.00m, and resistance 0.1Ω?

$$A = pr^2 \qquad R = r\frac{L}{A} \Rightarrow r = R\frac{A}{L} = R\frac{pr^2}{L} = 0.1\Omega\frac{p\left(5.04\times10^{-4}m\right)^2}{3.00m} = \boxed{2.6\times10^{-8}\,\Omega\cdot m}$$

12) (4pts) A 10 Ω resistor dissipates 1.5 Watts when it is connected to a battery. What is the batteries voltage?

$$P = \frac{(\Delta V)^2}{R} \Rightarrow (\Delta V)^2 = PR$$
$$\Delta V = \sqrt{PR} = \sqrt{1.5Watts\cdot10\Omega} = \boxed{3.9Volts}$$

13) (4pts) Two 15 Ω and three 25 Ω light bulbs and a 24 Volt battery are connected as shown. What is the current that passes one of the 25 Ω bulbs?



$DV_{battery}$ = 24Volts

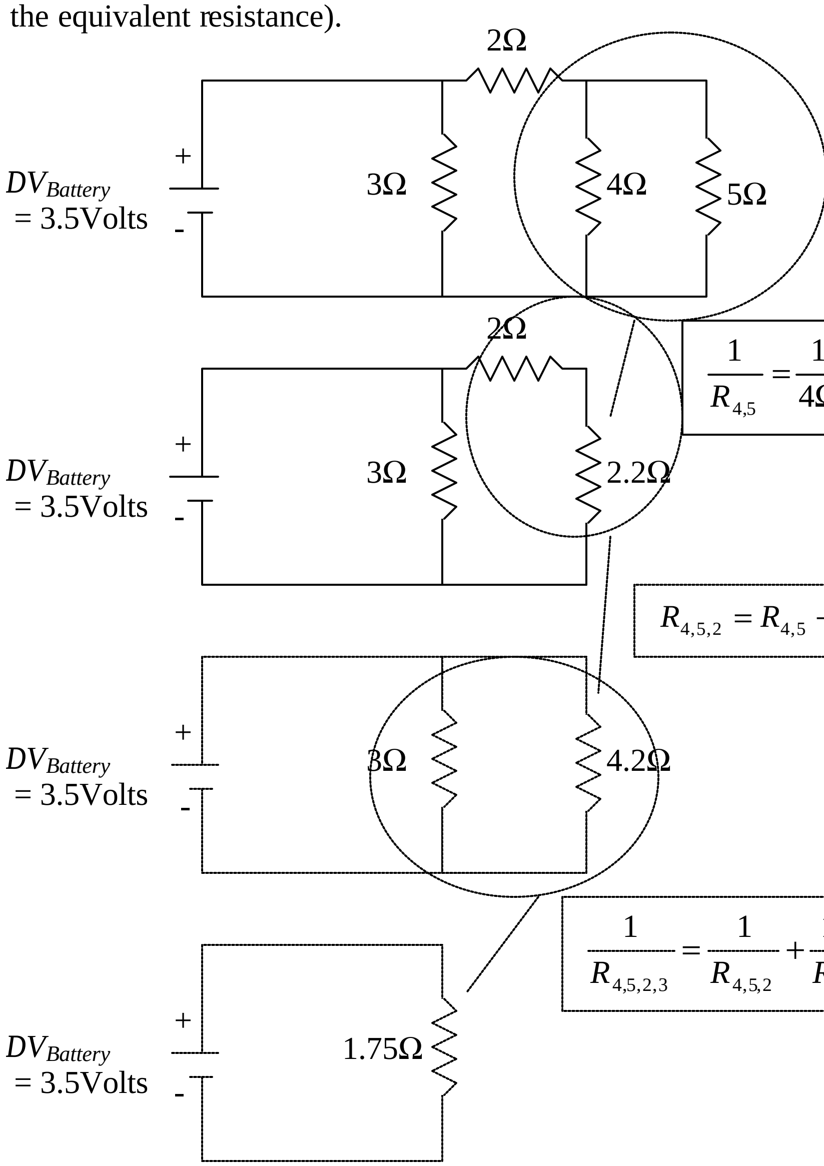
What current passes through one of the 25Ω resistors passes through that whole lower branch of the circuit.
$I_{25} = I_{bottom}$
The resistance of the lower branch of the circuit is
$R_{bottom} = 25\Omega + 25\Omega + 25\Omega = 75\Omega$
The bottom branch has the voltage of the batter applied across it
$\Delta V_{bottom} = \Delta V_{battery} = 24Volts$
Applying Ohm's law gives

$$I_{25} = I_{bottom} = \frac{\Delta V_{bottom}}{R_{bottom}} = \frac{24Volts}{75\Omega} = \boxed{0.32Amps}$$

14) (4pts) Three resistors, 6.0 Ω, 9.0 Ω, 15 Ω, are connected in *series* in a circuit. What is the equivalent resistance of this combination of resistors?

$$R_{series} = R_1 + R_2 + R_3 = 6.0\Omega + 9.0\Omega + 15\Omega = \boxed{30\Omega}$$

15) (12 pts) Given the circuit bellow, how much current is drawn out of the battery? (It would help to find the equivalent resistance).



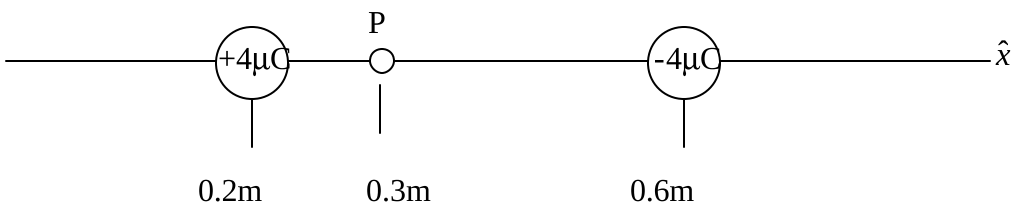
$$\frac{1}{R_{4,5}} = \frac{1}{4\Omega} + \frac{1}{5\Omega} = \frac{1}{2.2\Omega}$$

$$R_{4,5,2} = R_{4,5} + R_2 = 2.2\Omega + 2\Omega = 4.2\Omega$$

$$\frac{1}{R_{4,5,2,3}} = \frac{1}{R_{4,5,2}} + \frac{1}{R_3} = \frac{1}{4.2\Omega} + \frac{1}{3\Omega} = \frac{1}{1.75\Omega}$$

$$I_{Battery} = \frac{\Delta V_{battery}}{R} = \frac{3.5 Volts}{1.75\Omega} = 2 Amps$$

16)



a) (4 pts) Sketch enough Electric Field Lines to represent the character of the field everywhere.
b) (4 pts) Sketch enough Equipotential lines to represent the character of the voltage everywhere.
c) (16 pts) Evaluate the Electric Field at point P, magnitude and direction.

$$\vec{E}_{net}(p) = \vec{E}_{+4}(p) + \vec{E}_{-4}(p) = |\vec{E}_{+4}(p)|\,\hat{x} + |\vec{E}_{-4}(p)|\,\hat{x}$$

$$|\vec{E}_{+4}(p)| = \left|k_C \frac{q_{+4}}{r^2_{+4\to p}}\right| = \left|8.99\times10^9\, N\, {}^{m^2}\!/_{C^2} \frac{4\times10^{-6}\,Coul}{(0.1m)^2}\right| = 35.6\times10^5\ {}^{N}\!/_{C}$$

$$|\vec{E}_{+4}(p)| = \left|k_C \frac{q_{-4}}{r^2_{-4\to p}}\right| = \left|8.99\times10^9\, N\, {}^{m^2}\!/_{C^2} \frac{-4\times10^{-6}\,Coul}{(0.3m)^2}\right| = 4.00\times10^5\ {}^{N}\!/_{C}$$

$$\vec{E}_{net}(p) = |\vec{E}_{+4}(p)|\,\hat{x} + |\vec{E}_{-4}(p)|\,\hat{x} = 35.6\times10^5\ {}^{N}\!/_{C}\,\hat{x} + 4.00\times10^5\ {}^{N}\!/_{C}\,\hat{x} = 39.6\times10^5\ {}^{N}\!/_{C}\,\hat{x} = \boxed{4.0\times10^6\ {}^{N}\!/_{C}\,\hat{x}}$$

d) (12 pts) Evaluate the Electric Potential (voltage) at point P.

$$\Delta V_{net}(p) = \Delta V_{+4}(p) + \Delta V_{-4}(p) = k_C \frac{q_{+4}}{r_{+4\to p}} + k_C \frac{q_{-4}}{r_{-4\to p}}$$

$$\Delta V_{net}(p) = 8.99\times10^9\, N\, {}^{m^2}\!/_{C^2} \frac{4\times10^{-6}\,Coul}{0.1m} + 8.99\times10^9\, N\, {}^{m^2}\!/_{C^2} \frac{-4\times10^{-6}\,Coul}{0.3m}$$

$$\Delta V_{net}(p) = 3.596\times10^5\,Volts - 1.199\times10^5\,Volts = \boxed{2.4\times10^5\,Volts}$$