PHYS-115(3) (Kaldon-16406) **Name** ____________________
WMU - Winter 2001
Exam 2 - 100,000 points **Book Title** ____________________
Section: **3a** A to F **3b** G to M **3c** N to S **3d** T to Z
Sample Exam Rev. 2/08/01

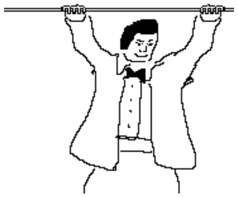
State Any Assumptions You Need To Make -- Show All Work -- Circle Any Final Answers
Use Your Time Wisely - Work on What You Can - Be Sure to Write Down Equations
BOLDFACE Variables Are Vectors - Feel Free to Ask Any Questions

"Good Evening, Mister Bond." (30,000 points)

1.) (a) "You cannot escape, Mr. Bond," said the evil Dr. Megaohm. "Your shackles are held in place electronically. Only a precise current of 1.000 amps through this copper wire ($\rho_{Cu} = 1.8 \times 10^{-7}\ \Omega \cdot m$), which is 8 1/3 m long and has a square cross-section of 1.00 mm × 1.00 mm, will set you free." Find the voltage drop, V, of this copper wire.

(b) Bond pulls out a battery from his pocket flashlight. "I'll turn the power back on with this battery." "But how can you Mr. Bond? The internal resistance of your battery is too high because it is old and weak." "Nonsense, this is a Bunny Brand ™ Battery, and it keeps going and going and going, and always delivers 1½ volts." And with that, he frees himself. What is the internal resistance of this special battery?

(c) James Bond has a resistance of .007 x $10^8\ \Omega$ (that's 7.00 x $10^5\ \Omega$). To escape, he hangs onto a wire carrying 1500 A of current and has a potential difference of 100,000 V from the ground. His hands are 85 cm apart and the cable has a resistance per length of 1.00 Ω/m. Mr. Bond is <u>not</u> touching the ground. Find the current that goes through Mr. Bond. *Hint: Redraw this picture as if it were part of a resistor circuit.*

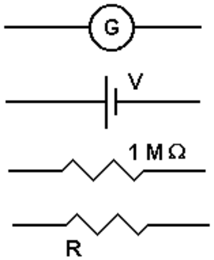


Shaken, But Not Stirred (continued.)

(d) James Bond's nemesis Dr. Megaohm, as are all villains, is not as smart as Mr. Bond. So Dr. Megaohm grabs onto two wires, which have a potential difference of 100,000 V between them. Dr. Megaohm's resistance is 1.00 MΩ. Find the current that goes through Dr. Megaohm.

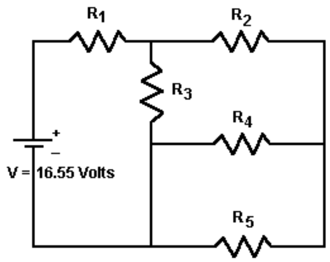
(e) If we wanted to measure the current going through Dr. Megaohm, using the galvanometer (generic meter) shown here, how would we hook up the meter so that it will read full-scale deflection? Draw the appropriate circuit either in series or parallel with the galvanometer, G, using all the components below. (f) Find R.

The galvanometer has a full-scale deflection current of 4.72×10^{-4} A.

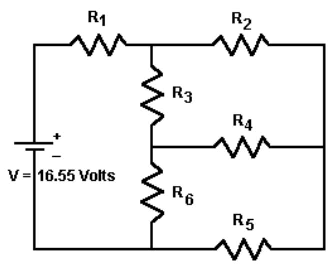


"We are the Borg. Resistance is Irrelevant" The Borg -- Star Trek: Next Generation **(20,000 points)**

2.) Circuit 1 can be solved by network reduction, as usual. Circuit 2 is the same as Circuit 1, except that there is a new resistor at R_6. Circuit 2 is redrawn as Circuit 3 for clarity. You'd *think* that you could solve Circuit 2 using network reduction, but trust Dr. Phil, you can't. Given that all the resistors are 100 Ω, however, you can find an equivalent resistance if you realize that the current, I_4, through R_4, must be zero. (a) Find R_{TOTAL} and (b) I_{TOTAL} for Circuit 2. *Assume, since $I_4 = 0$, that R_4 and its wire don't exist.*

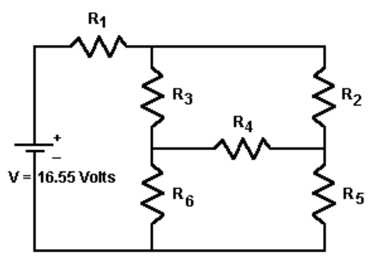


Circuit 1



Circuit 2

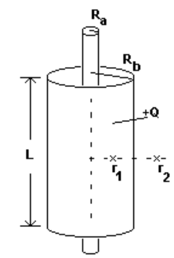
(c) Treating all the currents through the resistors (I_1, I_2, I_3, I_4, I_5 and I_6) as unknowns, write down *but do not solve* all the equations you need to solve this circuit as a multi-loop circuit (Kirchhoff's Laws). (d) Note which ones would show that $I_4 = 0$, by putting a ✰ next to those equations.



Circuit 3

Like Totally Tubular, Man (25,000 points)

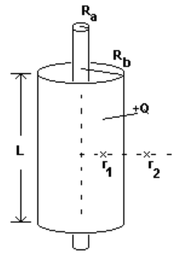
3.) A long, thin rod (radius R_a = 5.00 cm = 0.0500 m) has a charge q = - 3.14 × 10^{-3} C and a length of 0.730 m. (a) Find the charge density, ρ , and the charge per unit length, λ , of the rod of charge.



(b) Wrapped around the rod of charge is a sheet of charge (radius R_b = 25.00 cm = 0.2500 m; and length L = 0.500 m), which has a charge +Q equal in magnitude to L × λ (where λ is from the rod of charge). Find the charge, +Q, and the surface charge, σ , of the sheet of charge.

"I Had To Invent the Flux Capacitor!" **Doc Brown --** ***Back to the Future!*** **(continued)**

(c) Use Gauss' Law to find the electric field vector, **E**, at a point r_1 that is 0.1500 m from the co-axial center of the rod and the wrapped sheet of charges, on the positive x-axis.



(d) Use Gauss' Law to find the electric field vector, **E**, at a point r_2 that is 0.3500 m from the co-axial center of the rod and the wrapped sheet of charges, on the positive x-axis.

(e) How is this device like a capacitor? *Short answer. List three things for full credit.*

You Are My Sunshine, My Only Sunshine... (25,000 points)

4.) Mrs. Dr. Phil has a alarm lamp/clock, the Bio Brite Sunrise Clock ™, that works by slowly turning on a 60 watt halogen light bulb, thus simulating the brightening of Dawn -- even in the winter when it is still dark at 6am. (a) If the lamp works on 120 V, then what is the resistance of this 60 W bulb at full brightness?

(b) Imagine that the bulb is a simple resistor, and that in conjunction with a capacitor, this makes an RC circuit that allows the bulb to slowly come on. One half-life gets the brightness up to 0.5 (or 1 minus ½), two half-lives is 0.75 (or 1 minus ¼). How many half-lives will get the brightness up to at least 95% of the full brightness? How many time constants τ will get the brightness up to at least 95% of the full brightness? *NOTE: A half-life is DIFFERENT than the RC time constant.*

(c) If we want the light to go from dark to approximately full light in half-an-hour, find the value of τ.

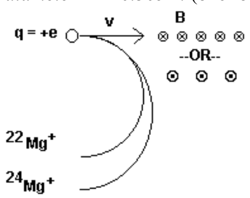
(d) Given τ , find the time constant RC and the value of the capacitor, C.

(e) Actually, the timing circuit isn't likely to use the bulb itself as the resistor. Why? *Short answer!*

Magnesium Hits On The Ol' Mass Spectrometer (25,000 points)

5.) A desktop mass spectrometer is going to be used to separate two magnesium isotopes. (a) Mg^+ ions, moving at $\vec{v} = 125\ m/s\ \hat{i}$, safely pass through two velocity selectors. The first has $\vec{B} = -1500\ T\ \hat{k}$, the second has
$\vec{E} = +1500\ N/C\ \hat{k}$. Find the $\vec{E}$ and $\vec{B}$, respectively, of the two velocity selectors.

(b) We design the mass spectrometer so that $^{22}Mg^+$ ions (mass = $22 \times 1.7 \times 10^{-27}\ kg$) will travel in a semi-circle of *diameter* D = $0.305\ m$ (one foot). Find the magnetic field vector, $\vec{B}$, that will do this.

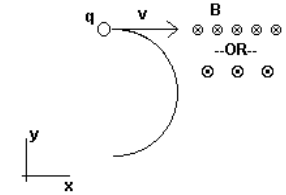


(c) Use the magnetic field vector, $\vec{B}$, from (b) to determine the *diameter* of the path of any $^{24}Mg^+$ ions that happen to enter the mass spectrometer.

(d) What is the separation distance, *d*, between the $^{22}Mg^+$ and $^{24}Mg^+$ ions after they have traveled around their semi-circles? Is this separation large enough to measure on film, filter paper or electronic detector?

(e) If a trillion Mg^+ ions go through the mass spectrometer every second, what current, i, does this represent?

***The Empire Strikes Back* (50,000 points)**



6.) In the *Star Wars* movies, as well as *Star Trek*, the big starships have something called *deflectors*, which are designed to keep the ship from running into things. We can make a *deflector*, or something that works like one, by first shooting some electrons at the object, and then applying a large magnetic field. (a) Identify the directions that $\vec{F}_B$ and $\vec{B}$ must point in this problem.

(b) Given that $q = -1.25\ C$, $v_{0x} = 19{,}500\ m/s$, $m = 125\ kg$, $r = 125\ m$, find the magnitude of *B*.

(c) The time it takes for the charged object to go halfway around is half the period, *T*, of the whole orbit. Since we have a *charge* moving in a certain *time*, then this defines a current, *I*. Find *I*.

(d) What electric field vector, $\vec{E}$, would cause this charged object to continue on in a straight line?