Print your full name: ________________________________

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Please fill in your Student ID number: __ __ __ __ __ __

IMPORTANT

Read these directions carefully:

• There are 9 problems totalling 200 points. Check your exam to make sure you have all the pages. Work each problem on the page the problem is on. You may use the back. If you need extra pages, I have plenty up front.

• **Indicate what you are doing!** We cannot give full credit for merely writing down the answer. **Neatness counts!** I will give generous partial credit if I can tell that you are on the right track. This means you must be *neat* and organized.

• Each problem with its associated figure is self explanatory. If you *must* ask a question, then come to the front, being as discrete as possible so as not to disturb others.

• Put your name on each page it is asked for. You will lose credit if you fail to print your name on each page it is asked for.
Problem 1. 25 points.

Two charges, $125 \, \mu\text{C}$ and $-64 \, \mu\text{C}$ respectively, are placed 3 cm apart. For the following, we are interested in the point $P$ which is 4 cm from the negative charge on a line perpendicular to the line between the charges.

Use the coordinate system shown in the following Figure for your calculations:

(a) (15 points) Calculate the $x$ and $y$ components of the electric field at the point $P$.

(b) (10 points) Calculate the electric potential at the point $P$, using zero potential infinitely far away as a reference.

Note: You may substitute the given values and calculate the numerical answers if you have a calculator, or you may express your answer as a simple expression involving $\varepsilon_0$. You must simplify your expressions for full credit. Simply put, this means: do the arithmetic.

Work neatly! I can find more partial credit if you are neat and organized.
Consider a nice round insulating sphere of radius $R$. Suppose this sphere is charged, but the charge density is not uniform and is given by the equation:

$$\rho(r) = \rho_0 \frac{r}{R}$$

where $\rho_0$ is the value of the charge density at the surface, and $r$ is the distance from the center of the sphere. (The charge density is spherically symmetric, meaning it only depends on the distance from the center of the sphere, not on the angular orientation of the sphere.)

(a) (10 points) Calculate the total charge of this sphere. Express your answer in terms of $\rho_0$ and $R$.

(b) (10 points) Calculate the electric field inside the sphere, as a function of the distance from the center of the sphere. Express your answer in terms of $\epsilon_0$, $\rho_0$, $R$, and $r$.

(c) (5 points) Calculate the electric field outside the sphere, as a function of the distance from the center of the sphere. Express your answer in terms of $\epsilon_0$, $\rho_0$, $R$, and $r$. 
Consider the circuit shown in the following Figure:

(a) (5 points) Calculate the equivalent resistance of the network of 4 resistors.

(b) (5 points) Calculate the equivalent capacitance of the network of 4 capacitors.

(c) (15 points) Suppose that the switch $S$ is open and the capacitors are uncharged. At $t = 0$ the switch is closed. Calculate how much current will be supplied by the battery $15 \, \mu s$ (fifteen microseconds) after the switch is closed.
Problem 4. 25 points.

Consider the DC circuit shown below:

Calculate the current in the upper loop. That is, calculate how much current is supplied by the 20V battery.

Be careful!.

If you write the equations neatly so I can tell what you are doing, I may be able to give you more points!
Problem 5. 25 points.

A wire, in a plane, has the shape shown in the Figure below: two arcs of a circle connected by radial lengths of wire. The wire carries a current $I$. The inner radius is $R_1$, the outer radius is $R_2$, and the angle subtended by the arc is $\theta$. Calculate the magnetic field $B$ at the point $C$ (the center of the circular arcs) in terms of $R_1$, $R_2$, $\theta$, and the current $I$. Be sure to indicate the direction of the field.

Remember to be NEAT!
A rectangular loop of wire has sides of length $a$ and $b$. The total resistance of the loop is $R$. The loop is initially in a uniform magnetic field $B$ with its plane perpendicular to $\vec{B}$. Suppose the magnetic field exists in a rectangular region aligned as shown with respect to the loop of wire. The loop is removed from the field at constant velocity $v$, in the direction shown in the Figure:

Calculate the electric energy dissipated in this process.
Problem 7. 25 points.

Consider a rectangular loop of wire of height $h$ and width $w$. The loop is at a distance $a$ from a very long straight wire which is aligned in the plane of the loop, and parallel to the height of the loop. The long straight wire carries a current $I$.

(a) (20 points) Calculate the magnetic flux through the loop, due to the magnetic field created by the straight wire.

(b) (5 points) Suppose that the current $I$ is changing with time in a given manner. What else would you need to calculate to find the EMF induced in the loop? (Very short answer, please.)

Note: You'll want to work neatly.
Problem 8. 15 points.

(a) (10 points) Suppose a radio station broadcasts EM waves with rms power $P$ uniformly in all directions. What is the rms voltage induced in a vertical car antenna of length $l$, if the car is a distance $r$ from the transmitter? (Assume that $r$ is much greater than the size of the transmitter or the size of the antenna.)

(b) (5 points) Suppose the volume of the car above is $V$. What is the average amount of energy inside the car due to the radio station?

*Hint* My favorite station here in Bryan is KEOS 89.1 FM. KEOS broadcasts with an rms power of 1 kW. When I am 10 km from the transmitter, the voltage induced in a 1 m antenna would be 17 mV with the conditions given above. That may not sound like much, but they are 17 really sweet millivolts!

*Note:* Organize your thoughts. Each part should only be a very few lines.
Problem 9. 10 points.

(a) An object is placed 4 cm in front of a concave spherical mirror. The focal length of the mirror is 5 cm. Calculate where the image is formed.

(b) An object is placed 4 cm in front of a convex spherical mirror. The focal length of the mirror is 5 cm. Calculate where the image is formed.

Note: Guess what! Work neatly!