Physics 208 Exam 2 Name________________________________

You are graded on your work, with partial credit. See the last pages of the exam for formula sheets.
Please be clear and well-organized, so that we can easily follow each step of your work.

1. A mass spectrometer is used to determine the atomic mass number of singly charged selenium ions.

(a) (7) The velocity of each ion is first determined by a velocity selector, in which the magnetic field is 1.08 T and the electric field is 2.24×10^5 V/m. What is the magnitude v of the velocity of each ion emerging from the velocity selector?

(b) (7) The ions then enter a region in which the electric field is zero and the magnetic field B is still 1.08 T. By setting the centripetal force equal to the magnetic force, derive the expression for R, the radius of the orbit of an ion, in terms of B, the mass m of an ion, the fundamental charge e, and the speed v of an ion.

(c) (7) R for these ions is measured and found to be 15.5 cm. Calculate the numerical value of the mass m.

(d) (7) Given that 1 u = 1 atomic mass unit = 1.66×10^{-27} kg, determine the atomic mass number for this isotope of selenium.

2. Electronic flash units for cameras contain a capacitor for storing the energy used to produce the flash.

(a) (9) Suppose that the charge stored on the capacitor is 0.5 C when the applied potential difference (across the capacitor) is 125 volts. What is the capacitance?

(b) (9) How much energy is stored in the capacitor when it is fully charged (with 0.5 C)?

(c) (9) If the flash lasts for 1/250 of a second, what is the power of the flash during that period (in watts)?

3. (20) A material of resistivity ρ is formed into a solid, truncated cone of height h. The radius r of a circular cross-section is given by $r = r_1 + \left(\frac{r_2 - r_1}{h}\right)x$, with $x = 0$ at the bottom of the cone and $x = h$ at the top. I.e., the radius at the bottom is r_1 and the radius at the top is r_2. Calculate the resistance of the cone between these two flat end faces.

(Hint: Imagine slicing the cone into very many thin disks. First calculate the resistance of one such disk, and then integrate over all the disks. As a check on your answer, you know that you should get an expression of the form $R = \rho L / A$ when $r_2 = r_1$ and the cone becomes a cylindrical conductor.)

4. Consider a circuit consisting of only a battery, a resistor, and a capacitor. The battery has an emf $\mathcal{E} = 12.0$ V, and its internal resistance is negligible. The resistor has a resistance $R = 5.0\,\Omega$. The capacitor has a capacitance $C = 6.0\ \mu\text{F}$.

The circuit is initially open, with no charge on the capacitor. At time $t = 0$, a switch is thrown to close the circuit, and charge begins to flow onto the capacitor. I.e., the time-dependent charge $q(t)$ on the capacitor has an initial value $q(0) = 0$.

(a) (5) Use Kirchhoff's second rule, for the voltage change around a closed loop, to write down the differential equation for $q(t)$ (which also, of course, involves dq/dt).

(b) (5) Show that this differential equation is satisfied by $q(t) = Q\left(1 - e^{-t/\tau}\right)$, and at the same time determine the characteristic time constant τ in terms of R and C.

(c) (5) What is the value of Q, in terms of $\mathcal{E}$ and C?

(d) (5) What is the charge on the capacitor at a time $t = 1.0 \times 10^{-6}$ s after the switch has been closed?

(e) (5) What is the current I through the circuit at this time?

5. (5 points extra credit) In a region enclosing a cubical volume, which is bounded by $x = \pm a$, $y = \pm a$, $z = \pm a$, someone claims to have used conventional magnets to have created a magnetic field $\vec{B} = \alpha x \hat{i}$, where α is a constant and $\hat{i}$ is the unit vector in the x direction. Is this possible? Explain. (The explanation is what counts.)