Notre Dame Physics Department Qualifying Examination

SAMPLE (not for distribution)

Part II

Each problem will be graded on a scale of 0-4 points. You are asked to do any 8 of the problems.

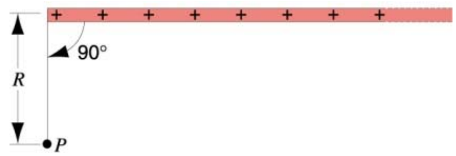
Clearly indicate your choices, by listing here the two problems that you are not going to attempt:
a) ________ b) _______.

Show all your work on separate pages for each problem. Please use only one side of the paper to work the problems!
Collect your work together in numerical order (number each page) by problem when you finish, including your equation sheet at the end, use the envelope provided to store your work and the exam. Good luck!

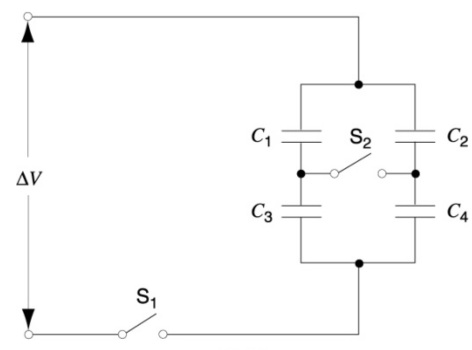
Please confirm your student ID number: **Master.**

DO NOT WRITE YOUR NAME!

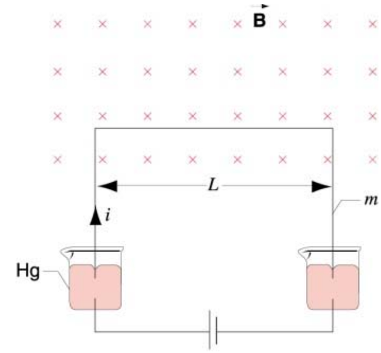
1. A "semi-infinite" insulating rod carries a constant charge per unit length of λ. Show that the electric field at the point P makes an angle of 45° with the rod and that this result is independent of the distance R.



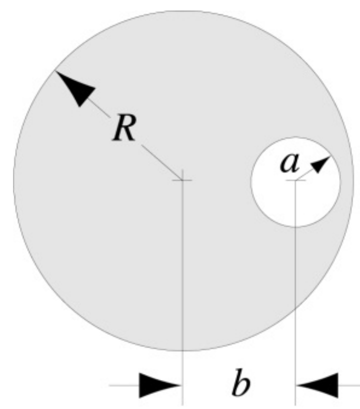
2. In the figure below, a battery supplies a potential difference ΔV of 12 V. (a) Find the charge on each capacitor when switch S_1 is closed and (b) when (later) switch S_2 is also closed, in terms of ΔV, C_1, C_2, C_3, C_4.



3. A U-shaped wire of mass m and length L is immersed with it two ends in mercury (see figure). The wire is in a homogeneous magnetic field $\vec{B}$. If a charge — that is, a current pulse $q = \int idt$—is sent through the wire, the wire will jump up. Calculate, from the height h that the wire reaches, the size of the charge or current pulse, assuming that the time of the current pulse is very small in comparison with the time of flight. Make use of the fact that impulse of force equals $\int Fdt$, which equals mv. (Hint: Relate $\int idt$ to $\int Fdt$.) Evaluate q for B = 0.12 T, m = 13 g. L = 20 cm, and h = 3.1 m.

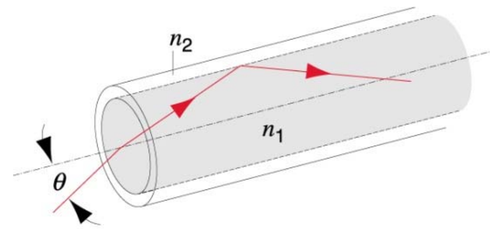


4. The figure shows a cross section of a long, cylindrical conductor of radius R containing a long, cylindrical hole of radius a. The axes of the two cylinders are parallel and are a distance b apart. A current i is uniformly distributed over the shaded area in the figure. (*a*) Use superposition ideas to find an expression for the magnetic field at the center of the hole. (*b*) Discuss the two special cases a = 0 and b = 0. (*c*) Can you use Ampère's law to show that the magnetic field in the hole is uniform? (Hint: Regard the cylindrical hole as filled with two equal currents moving in opposite directions, thus canceling each other. Assume that each of these currents has the same current density as that in the actual conductor. Thus we superimpose the fields due to two complete cylinders of current, of radii R and a, each cylinder having the same current density.)



5. A thin, plastic disk of radius R has a charge q uniformly distributed over its surface. If the disk rotates at an angular frequency ω about its axis, find an expression the magnetic dipole moment of the disk.

6. A particular optical fiber consists of a nongraded glass core (index of refraction $n_2 < n_1$). Suppose a beam of light enters the fiber from air at an angle θ with the fiber axis as shown below. (*a*) Find an expression for the greatest possible value of θ for which a ray can be propagated down the fiber. (*b*) Assume that the glass and coating indices of refraction are 1.58 and 1.53 respectively, and calculate the value of this angle.



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7. The two headlights of an approaching automobile are 1.42 m apart. At what (*a*) angular separation and (*b*) maximum distance will the eye resolve them? Assume a pupil diameter of 5.00 mm and a wavelength of 562 nm. Also assume that diffraction effects alone limit the resolution.

8. A stack of polarizing sheets is arranged so that the angle between any two adjacent sheets is α. The sheets are arranged so that *N* sheets rotate the plane of polarization by θ, where $\theta = N\alpha$. Calculate the fraction of light that will pass through the stack in the limit as $N \to \infty$. Assume that θ is fixed, so $\alpha \to 0$.

9. Two electrons in lithium (Z = 3) have as their quantum numbers n, l, m_l, m_s, the values 1, 0, 0, $\mp\frac{1}{2}$, respectively. (*a*) What quantum numbers can the third electron have if the atom is to be in its ground state? (*b*) If the atom is to be in its first excited state?

10. An electron is emitted from a middle-mass nuclide (A = 150, say) with a kinetic energy of 1.00 MeV. (*a*) Find its de Broglie wavelength. (*b*) Calculate the radius of the emitting nucleus. (*c*) Can such an electron be confined as a standing wave in a "box" of such dimensions? Show your work.