Rutgers University – Physics Graduate Qualifying Exam
Electricity and Magnetism – August 31, 2009

Work problems A and B and (C1 or C2) and (D1 or D2).
Work each problem in a separate blue book.
Each problem is worth a total of 10 points.

EM - A

A spherical solid conductor of radius R has several cavities in its volume, as shown in the figure below. A net charge $+q$ resides on the outer surface of the conductor. Cavities A and C contain point charges $+q$ and $-q$, respectively.

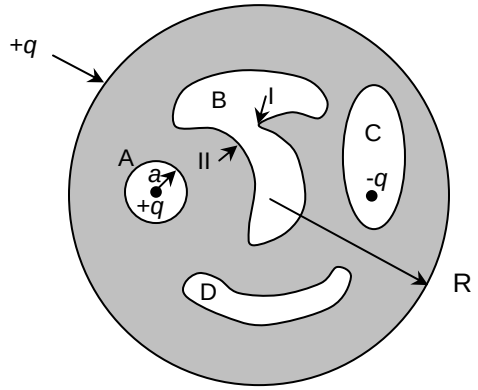
(a) What is the net charge on the surface of each cavity?

(b) Determine the charge *density* on the surface of cavity A, or give a brief argument as to why you need more information to answer this question.

(c) Repeat (b) for cavity C.

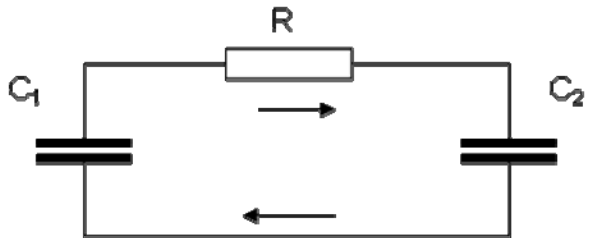
(d) In cavity B, how does the electric field at point I compare to that at point II? Explain your answer.

(e) Determine the charge density on the outer surface of the sphere, or give a brief argument as to why you need more information to answer this question.



EM - B

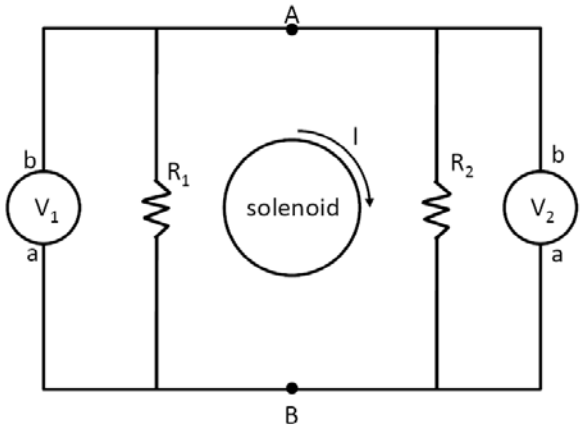
A capacitor with capacitance C_1 is charged up to a voltage V_0 and then connected to an uncharged capacitor with capacitance C_2 using wires that have total resistance R (see figure). Find the time dependence of the current in the circuit, $I(t)$.



EM - C1

The current in a long solenoid is increasing linearly with time, so that the flux is proportional to t: $\Phi = \alpha t$. Two voltmeters are connected to diametrically opposite points (A and B), together with resistors (R_1 and R_2), as shown in the figure. What is the reading on each voltmeter?

Assume these are *ideal* voltmeters that draw negligible current (they have huge internal resistance), and that a voltmeter registers $\int_a^b \boldsymbol{E} \cdot d\boldsymbol{l}$ between the terminals and through the meter.



EM - C2

A uniform wire of resistance per unit length ρ is formed into a circular hoop. It is rotated with an angular acceleration α about an axis perpendicular to the hoop passing through its center. Find the magnetic induction at the center of the hoop.

EM - D1

An insulated, spherical conducting shell of radius a is in a uniform electric field E_o. If the sphere is cut into two hemispheres by a plane perpendicular to the field, find the force required to prevent the hemispheres from separating

(a) if the shell is uncharged
(b) if the total charge of the shell is Q.

EM - D2

A relativistic particle of charge e and mass m is moving in a uniform constant magnetic field $\boldsymbol{H}$. At $t = 0$ the particle has momentum $\boldsymbol{p}_o$ and is at a point with radius vector $\boldsymbol{r}_o$. Determine the subsequent motion of the particle (coordinates as functions of time for $t > 0$.