Name:____________________________

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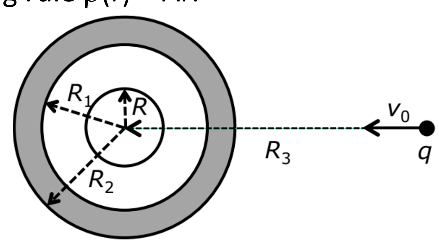
Physics 7B Final – Fall 2020
Professor A. Lanzara

TOTAL POINTS: 100

Show all work, and take particular care to explain what you are doing. Partial credit is given. Please use the symbols described in the problems, define any new symbol that you introduce and label any drawings that you make. All answers should be in terms of given variables or numbers. If you get stuck, skip to the next problem and return to the difficult section later in the exam period.

Problem 1 (15pts):

Consider the conducting sphere of radius R and charge Q_0 shown in the figure below. The conducting sphere is located in the interior of a spherical shell of internal radius R_1 and external radius R_2, $R_2 > R_1$. The inside of the spherical shell has a charge $Q = -Q_0/2$, whose charge distribution obeys the following rule $\rho(r) = Ar$.



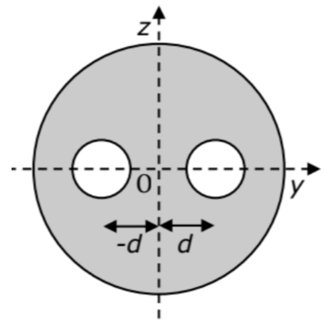
Find:

a) (5pts) The value of the constant A
b) (5pts) The electric field as a function of distance from the center of the conducting sphere.
c) (5pts) Consider a point like particle of charge q, mass m located at a distance $R_3 > R_2$ from the center of the sphere. If the particle is moving with initial velocity v_0, directed toward the center of the sphere, find the minimum value of v_0 that will allow the particle to reach the center of the sphere.

Problem 2 (15pts):

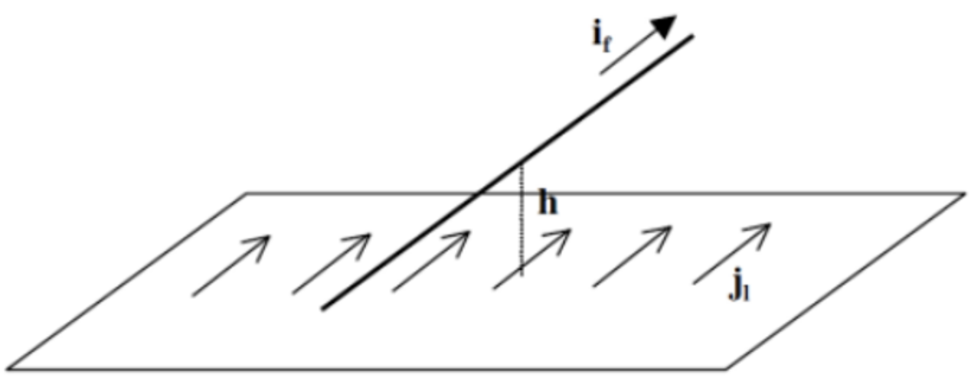
A sphere of radius R is uniformly charged. The sphere contains two spherical holes of radius R_1 centered on the y axis at y=+d and y=-d (see figure below). If the flux of the electric field through a closed surface that includes all the sphere is ϕ, find:

a) (4pts) The charge density ρ in terms of the quantities above and fundamental constants. Assume that $\rho>0$.
b) (6pts) The electric field at z=aR (magnitude and direction)
c) (5pts) The value of the potential with respect to infinity at the point z=R



Problem 3 (15pts):

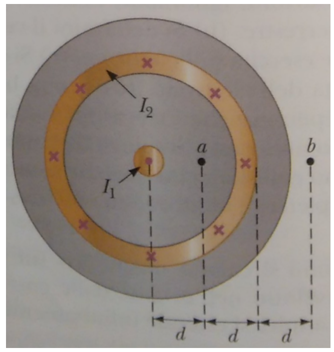
A current of uniform linear density J_S passes through a thin infinite sheet, as shown in the figure below. An infinite long wire is placed at a distance h from the sheet. A current i_f flows through the wire.



Find:

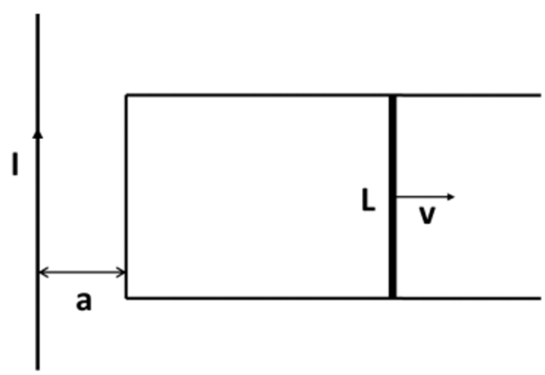
a) (5pts) The magnetic field generated by the infinite sheet
b) (5pts) The force per unit length exerted on the wire
c) (5pts) The distance y above the infinite sheet where the total magnetic field is zero

Problem 4 (10pts):
Consider the co-axial cable shown in the figure below. The space between the exterior and interior cylinders is filled with rubber and the external conductor is surrounded by another layer of rubber. The current in the internal conductor is I_1 and is coming out of the paper, while the current in the external conductor is $I_2 = 3I_1$ and is coming inside the paper. If *d* is the distance between the two center and the outer cylinder, find the magnetic field (vector and magnitude) at points *a* and *b*.



Problem 5 (15pts):
A metallic rod of length L can slide right and left on two conducting tracks of a circuit as shown in the figure below. The rod moves with velocity **v** in the presence of a magnetic field **B**. The field **B** is generated by an infinitely long vertical wire placed at a distance *a* from the circuit. A constant current I passes through the wire.

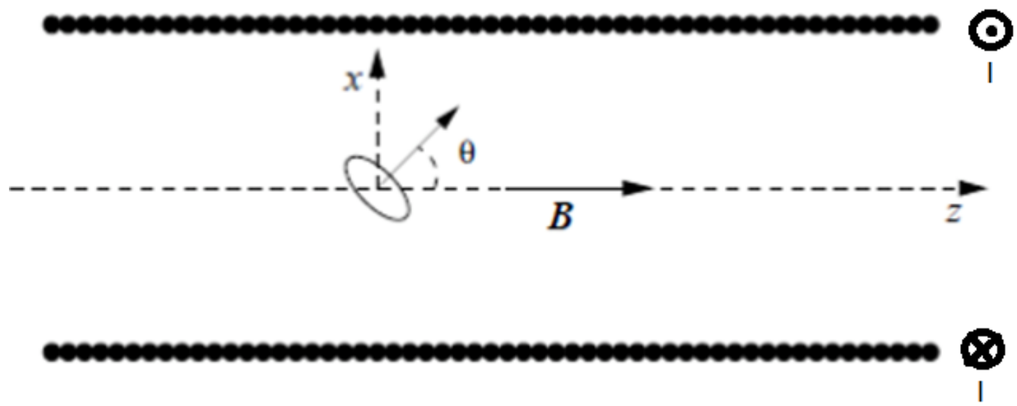
The rod and the tracks of the circuit have a resistance R. Neglect the friction between the rod and the track and the inductance of the circuit. At t=0 the rod is located on the left side of the circuit at a distance *a* from the infinitely long wire. The rod moves with constant velocity **v**.



Find:

a) (6pts) The direction and magnitude of the current in the rod at time Δt.
b) (4pts) The total energy dissipated in the resistance of the circuit at time Δt.
c) (5pts) An expression for the force required to maintain the uniform motion.

Problem 6 (15pts):
Consider a circular loop or radius $\boldsymbol{a}$, resistance **R** and negligible inductance. The loop is located in the middle of a long solenoid with n number of turns. The center of the loop is located at the center of the axis of the solenoid, see figure below. The loop forms an angle θ with the main axis of the solenoid. A current $I(t) = I(0)t/\tau$ passes through the solenoid.



Find:
a). (5pts) The induced current in the loop
b). (6pts) The total magnetic field at the center of the loop
c). (4pts) The torque $\boldsymbol{\tau}$ on the loop.

Problem 7 (15pts):
An adiabatic container of volume V is divided into two equal parts by a wall of area **A** and negligible volume. The wall can slide, without friction, in between the two sides of the container. Also assume that no heat can be transferred through the movable wall.

At time t=0, the left side of the container contains **n** moles of ideal monoatomic gas, while the right side is empty. In this initial situation, the wall is kept at a fixed position by a spring of elastic constant **k** and compressed by **Δx**. The spring volume and its thermal capacity are negligible. At time t, a valve is open allowing the gas to expand on the right side of the container. In terms of the above quantities, find:

a) (3pts) The pressure and temperature of the gas at t=0
b) (4pts) The change in internal energy of the gas after the valve is opened.
c) (4pts) The final pressure and temperature of the gas when it has expanded to fill the container.
d) (4pts) The change in entropy of the gas after the valve is opened.