PHYS 122: Homework Assignment #05

February 16, 2009

This homework due in Box outside of Rock 207: 5:00 PM Sharp, Monday, February 23, 2009

Announcements:

- Please pick up your graded First Hour Exam. See posting on web site under "Grades" for a distribution and interpretation of the scores. See Handout #14 for official policy on requesting re-grades on the exams.
- Due to research obligations, Mr. Covault will be out of the country for most of this week. Office hours are canceled (sorry). Prof. Gavin Buxton will give the lecture Wednesday, February 17th. Mr. Covault can be reached most easily by email during this time. **Important! Please put "Physics 122" in your email the subject header so I know that I am getting email from a student in the course!**
- Note that the lecture on Friday, February 19th is **postponed** to a time and date TBD.

Problem 1.

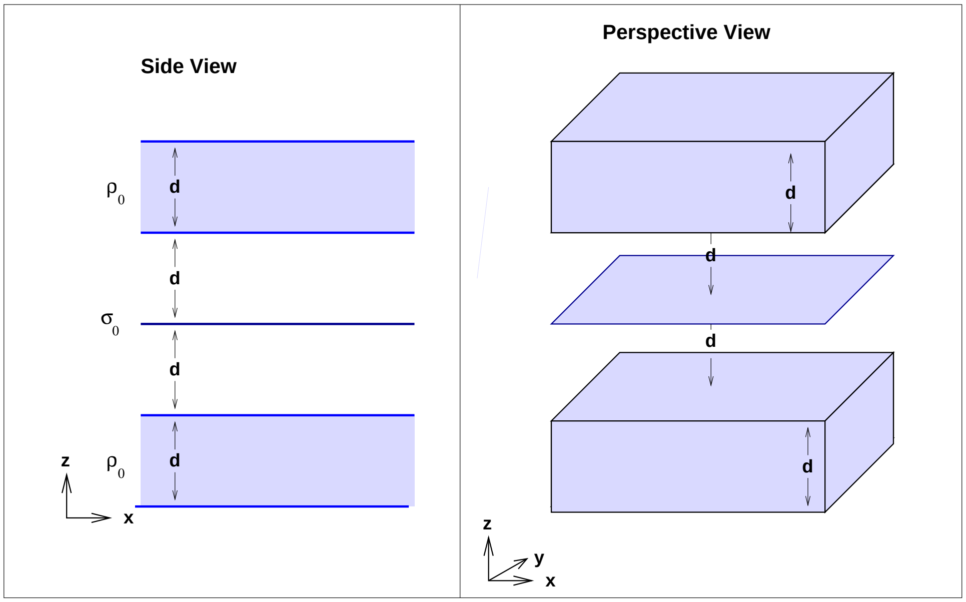
> *Note that the following problem will be graded for "effort" not content. Students who coherently address the following problem can expect to receive full credit.*

The First Hour Exam (with solutions) is posted online at:

`http://www.phys.cwru.edu/courses/p122/hour_01.pdf`

- Please compare carefully the work that you have done on the exam against the posted solutions. Do this first.
- For each problem where you earned less than 80% of the available points, re-work the assigned problem, and submit this re-work with your homework. For example, if you earned a score of 23 points or less on Problem 1, then take a blank sheet of paper and work Problem 1 on that blank sheet. Do this for each of the three problems.
- Be sure to check your new solution against the posted solution to be sure you have done the problem correctly. If not, correct your work.
- Write a **short** paragraph (200 words or less) addressing the following: if you performance on the exam was less than what you expected, please describe one or two things that could have been done to improve your score. This would include actions that could have been taken by you, or by the course staff. Alternatively, if you did as well or better than you expected, describe one or two things done that were most important for your success. This would include actions that could have been taken by you, or by the course staff. Possible subjects for discussion might include, for example, lectures (your attendence, my presentations), homeworks, practice problems, solution sets, clicker problems, SI sessions, review sheets, crib sheets, etc.

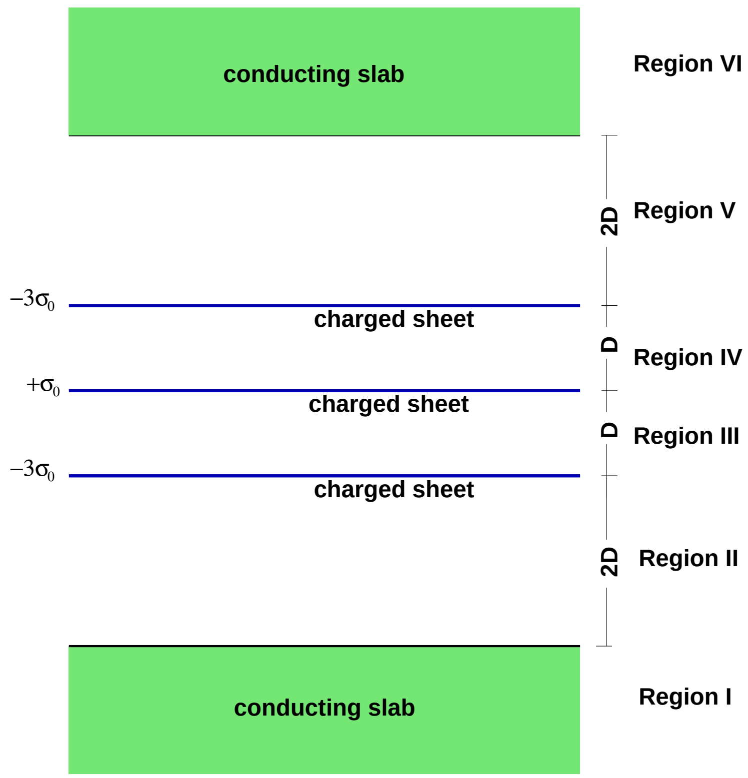
Problem 2.



Charge is arranged as shown above. A thin infinite sheet of charge with surface charges density (charge per unit area) is σ_0 is placed exactly half-way between two thick slabs of charge, where the charge density (charge per unit volume) is ρ_0. All charges are positive.

Using the coordinate system given, we define the position of the charge sheet as $z = 0$. Determine the electric field everywhere. Explain how you got your answer.

Problem 3:

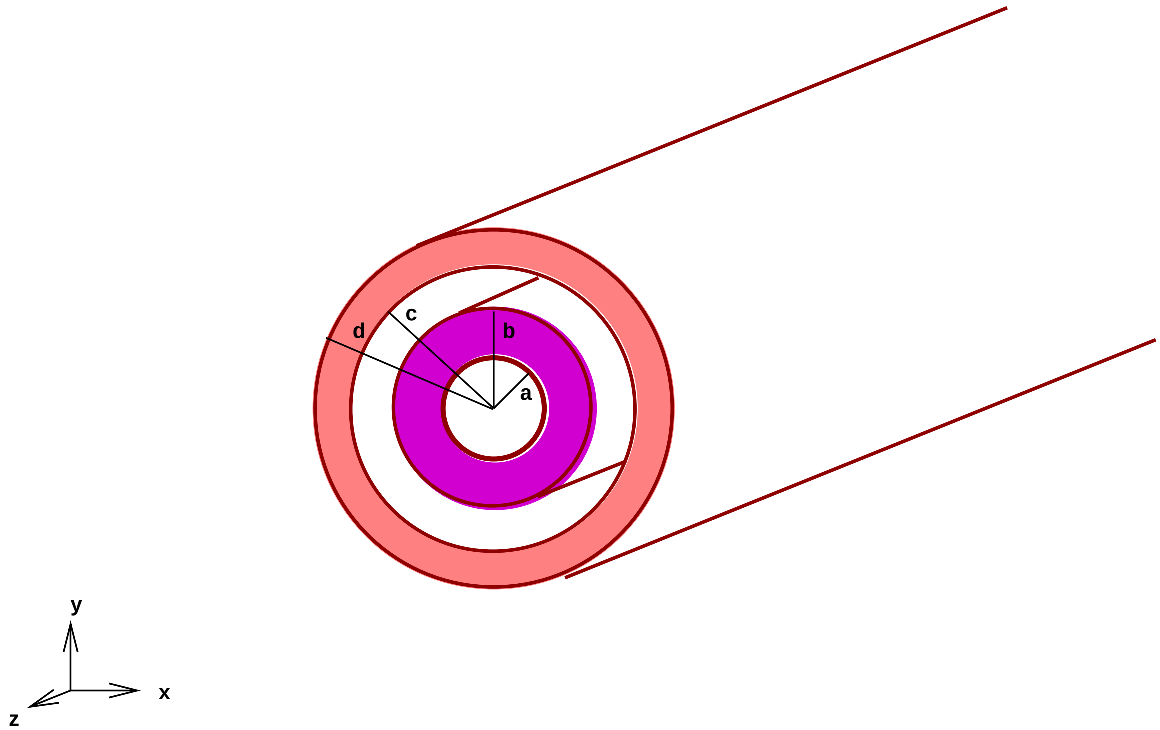


A set of three infinite thin charged sheets and and two semi-infinite conducting slabs are positioned as shown above. The sheets and the boundary of the slab divide space into six regions as shown. The central sheet has a given positive surface charge density $+\sigma_0$. The charge sheets above and below each have given surface charge densities $\sigma_D = -3\sigma_0$.

Part a) Suppose we define σ_{+s} σ_{-s} as the surface charge densities that are induced on the upper and lower conducting slabs? Use Gauss' Law to determine the values of σ_{+s} σ_{-s} in terms of the given parameters.

Part b) Use Gauss' Law to determine the electrica field *everywhere*. Specifically, what is the magnitude and direction of the field in each of the six regions?

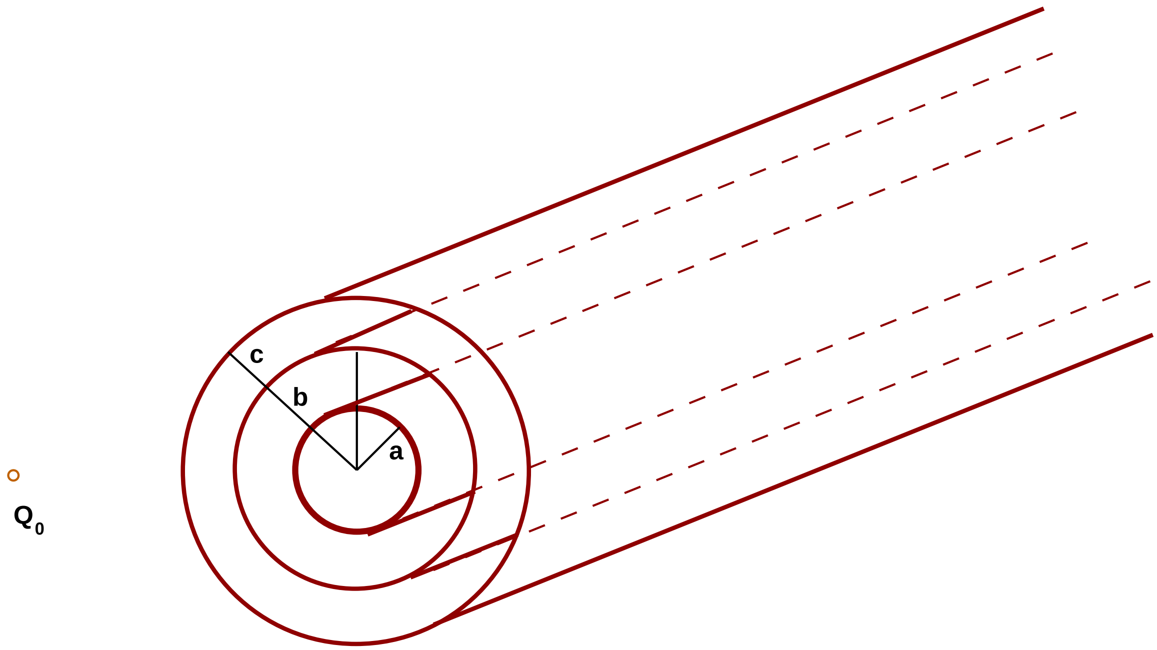
Problem 4:



Two infinitely long thick coaxial cylindrical sheaths are made of insulating materials. Each sheath has a uniform charge embedded in the material. The inner sheath has inner radius a and outer radius b. The outer sheath has inner radius c and outer radius d. The volume charge density ρ_i for the inner sheath and ρ_o for the outer sheath.

Use Gauss' to determine the electric field everywhere. Explain your work.

Problem 5:



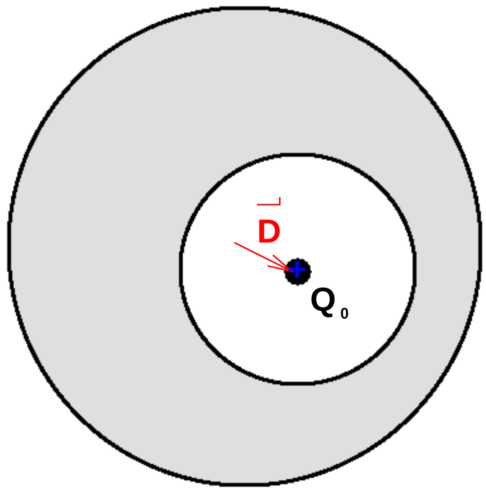
A system is made of three infinitely long thin cylindrical sheaths plus a point charge as shown above:

- The inner-most sheath at radius a is a neutral conductor.
- The sheath at radius b is an insulating layer with a fixed surface charge density of σ_0.
- The outer-most sheath at radius c is a neutral conductor.
- The point charge has a value Q_0 and is located at a distance R from the central axis of the sheathes.

Part (a): Determine the electric field at all positions for $r < c$.

Part (b): What is the voltage if measured between the inner conducting sheath and the outer conducting sheath?

Problem 6: Point Charge inside Conductor Off-center



A point charge of $+Q_0$ is placed inside a thick-walled hollow conducting sphere as shown above. The hollow cavity is spherical and *off-center* relative to the outer surface of the conducting sphere. The point charge is centered on the hollow cavity as shown. The radius of the inner surface (hollow volume) is a and the outer radius of the spherical conductor is b. The offset displacement between the position of the point charge and the center of the outer surface is given by the displacement vector $\vec{D}$ as shown.

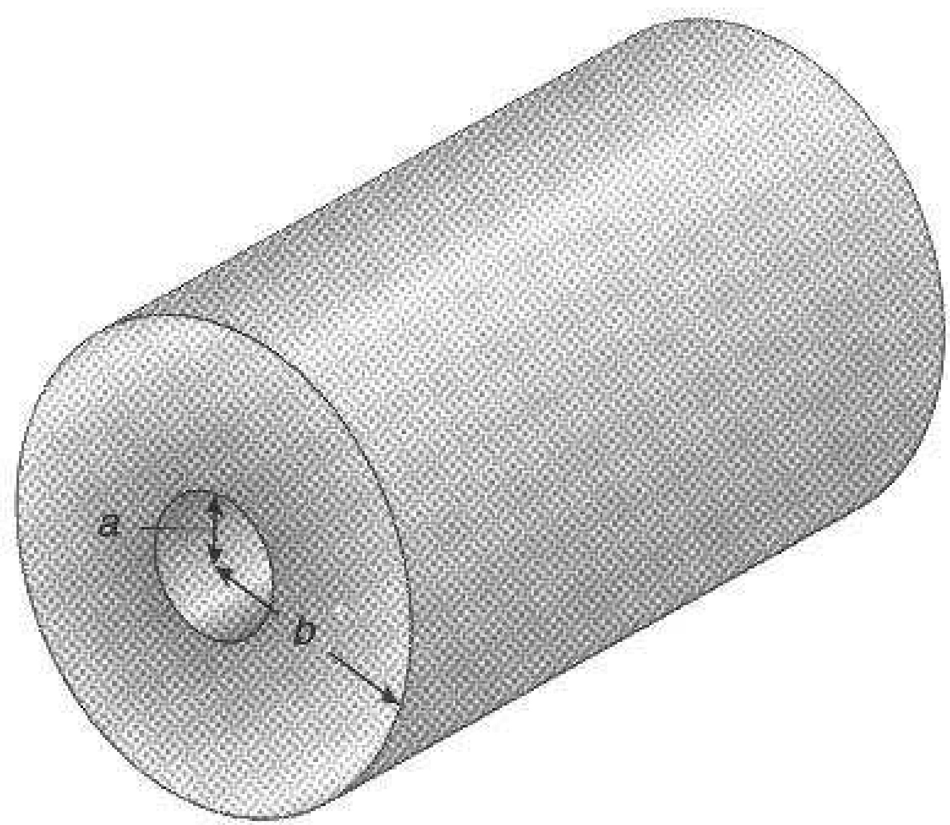
a) What is the total charge that must be on the inner surface of the conductor? Explain how you know this. Is the charge distributed with uniform density on the inner surface? If so, what is this density? If not, explain how you might expect the charge density to vary around the surface.

b) What is the total charge that must be on the outer surface of the conductor? Explain how you know this. Is the charge distributed with uniform density on the outer surface? If so, what is this density? If not, explain how you expect the charge density to vary around the surface.

c) Is it possible to write down a *vector expression* for the electric field at all positions in space? If so, it's up to you to define a coordinate system and spell it all out. Can you draw a simple sketch showing what the field lines look like qualitatively?

d) e) and **f)** Now suppose we replace the perfect conductor with a perfect (neutral) insulator. How does this change your answers to parts (a), (b) and (c) above?

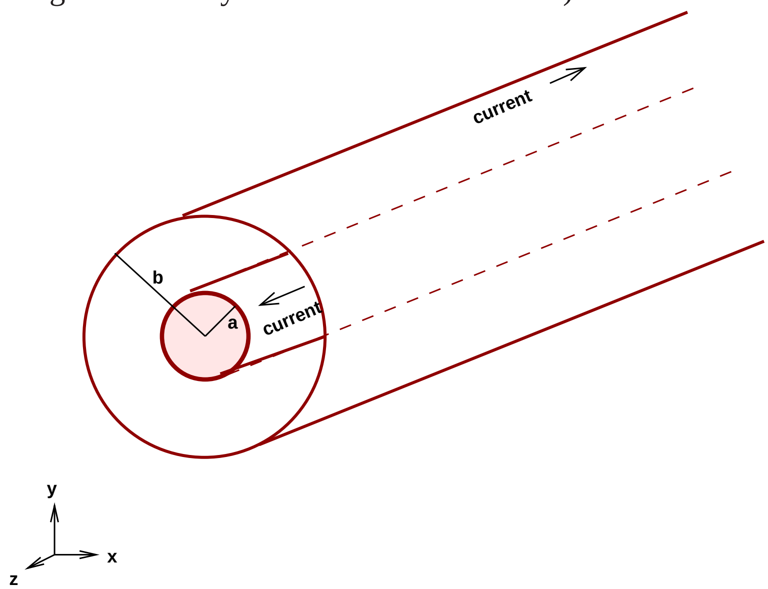
Problem 7:



An infinitely long conducting cable carries a total current of I_0. The cable has a hollow section as shown above. Assume that the current is *uniformly distributed throughout the conducting material*. Note that the conductor is *not* a perfect conductor.

Calculate the magnetic field "everywhere". Clearly indicate both the magnitude and "direction" of the field.

Problem 8. (This straight from last year's Second Hour Exam:)



A horizontal coaxial cable is made from a central conducting core (radius a) surrounded by a thin conducting sheath at radius b. A constant current $+I_0$ flows in the z-direction through the core and a current of $-I_0$ flows through the outer sheath. Assume that the current in the core is uniformly distributed throughout the cross-sectional area of the core.

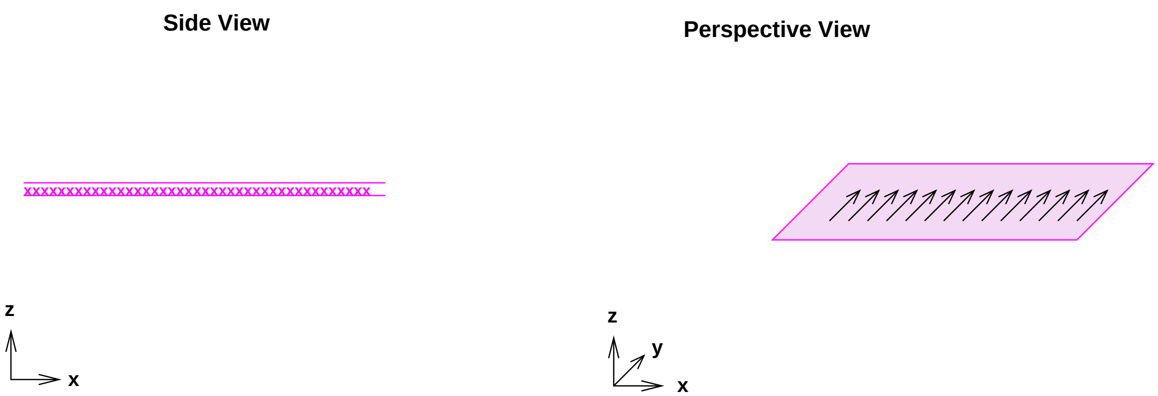
Use Ampere's Law to calculate the magnetic field everywhere as a function of radius. Determine the value of the *magnitude* of the field in each region as a function of radial distance from the center of the core. Also clearly indicate that you understand the *direction* of the magnetic field in each region.

Problem 9: Ampere's Law for a New Concept:

This was the "hard problem" on last year's Second Hour Exam:

Suppose we extend (somewhat) our development of Ampere's Law so that we can apply it to a system with planar geometry. Here we are rather deliberately asking you to *stretch* what you have learned about Ampere's Law to a geometry that you have probably not seen before.

We define a concept called a *current sheet*. The sheet is a infinitesimally thin flat plane that extends infinitely in each direction. A uniform *surface current density* is defined on the sheet with value J and direction $\hat{\boldsymbol{\jmath}}$ corresponding to a flow of current in the positive-y direction as shown:



Use **Ampere's Law** to determine both the *magnitude* and the *direction* of the magnetic field in all regions of space. For convenience, define the position of the plane as $z = 0$. To solve this problem, you will need to clearly define an "Amperian Loop" with a geometry and symmetry appropriate to the situation. It's up to you to try to figure out what this looks like for this problem. You also know from other examples – such a the straight line of current, and the solenoid – that the magnetic field will be *perpendicular* to both the direction of the current *and* the direction radial (directly away from) the current. Explain your work carefully. A possibly useful hint: the SI unit for surface current density is "amps per meter". Another hint: This example is somewhat *analogous* to the example of an electric field from a uniform infinite charge sheet. Final hint: The solution to the problem is quite simple, once you have applied Ampere's Law correctly; there is not much algebra to do here.