

Electrodynamics, Physics 321
Autumn 2004**First midterm**
Instructor: David Cobden**8.20 am, November 1, 2004**

You have 60 minutes. End on the buzzer at 9.20. Answer all 13 questions.

Write your name on every page and your ID on the first page.

Write all your working on these question sheets. Use this cover page for extra working (you might get credit for it.)

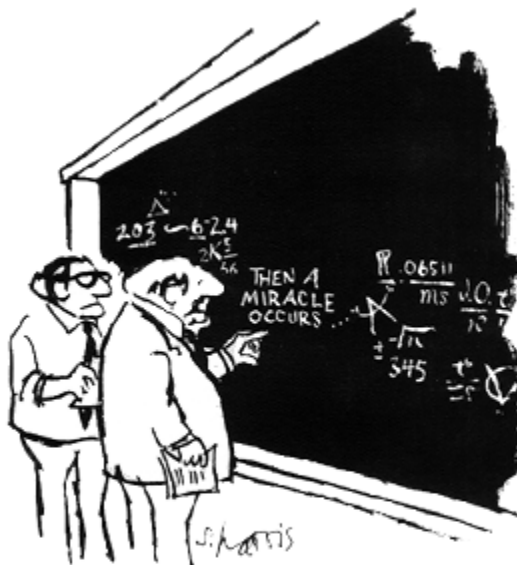
It is important to show your calculation or derivation. You won't get full marks just for stating the correct answer if you don't show how you get it.

Watch the blackboard for corrections or clarifications during the exam.

This is a **closed book** exam. **No notes allowed. No calculators!**

This exam contains 100 points, divided into four sections (one per page) each worth 25 points. Be sure to attempt all the questions, and *spend no more than 15 minutes on each section before moving on!*

Do not turn this page until I say 'go'!



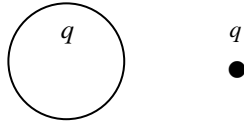
"I think you should be more explicit here in step two."

1. [8] State carefully *both* the general differential relationship *and* the integral relationship between the charge density $\rho(\mathbf{r})$ and the electric potential $V(\mathbf{r})$ over all space.

3. [12] Illustrate the validity of both the relationships in question 1 using the results for the point charge in question 2. You may use the result that $\nabla \cdot (\mathbf{r}/r^3) = 4\pi\delta^3(\mathbf{r})$.

II. A *nonconducting* sphere of radius R containing a fixed uniform positive charge density ρ_0 and total charge $q = (4/3)\pi R^3 \rho_0$ is centered at the origin. A particle with the same charge q is initially located at a distance $3R$ from the origin.

4. [6] Sketch the electric field lines (solid lines) and equipotentials (dashed lines) in this configuration.



5. [7] Find the force on the particle. Take care to specify the direction.

6. [12] Find the change in potential energy of the particle if it is moved from its initial position to the origin (the center of the sphere).

III. A circle of radius R has a fixed line charge density λ along its circumference. Take it to lie in the plane $z = 0$ centered on the z axis.

7. [15] Find the electrostatic potential $V(z)$ along the axis. Indicate your choice of a reference. Show that its form in the limit of large z is what you would expect.

8. [10] A particle of charge q and mass m moves freely along the axis, subject only to electrostatic forces, and has velocity v_0 just when it passes through the center of the circle (ie, the origin). Find an expression for its velocity as a function of z .

IV. A particle with positive charge q is located a distance D from the flat surface of a large piece of metal which is grounded (ie, $V = 0$ on the metal).

9. [6] Sketch the electric field (solid lines) and equipotential surfaces (dashed).



10. [3] State the relationship between the electric field and the surface charge density σ on the metal.

11. [7] What is the force exerted on the particle? Indicate the key principles at work.

12. [4] By how much does the force on the particle change if the potential of the metal is increased to V_0 by connecting it to a battery?

13. [5] If the particle were replaced by a charged wire, oriented parallel to the surface, having the same total charge q at the same distance D from the surface, would the force on the wire be greater than, equal to, or less than the force on the point particle? (A sketch might help you decide).