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(name: PLEASE PRINT)

Physics 321 Spring 2009

First Hour Exam

This is an open-book exam. You may use your notes, anything I have put on the web, your homework, and your text but no other book. If you have any question, raise your hand.

1. (25) Consider the field

$$\mathbf{E} = (2x^2 - 2xy - 2y^2) \hat{\mathbf{i}} + (-x^2 - 4xy + y^2) \hat{\mathbf{j}}$$

a) (15) It is irrotational. Find a potential  $V(x, y)$  such that  $\mathbf{E} = -\nabla V$ .

b) (10) Calculate  $\nabla \cdot \mathbf{E}$ .

2. (30) First try at designing an ion channel designed to pull a charge through it. Consider a charged, hollow, cylinder of radius  $R$  and length  $L$ . For convenience, let the axis of the cylinder be the  $z$  axis and extend between  $-L/2 \leq z \leq L/2$ . The upper part of the cylinder,  $z > 0$  has a uniform charge per unit area of  $\sigma$ , while the lower part of the cylinder has a uniform charge per unit area of  $-\sigma$ .

a) (25) Calculate the magnitude and direction of the electric field on the  $z$  axis at an arbitrary value of  $z$ .

b) (5) The electric field is largest at  $z = 0$ . What is its value there?

3. (45) Consider the  $\text{CO}_2$  molecule which is linear; a carbon atom of charge  $+4e$  (at the origin of coordinates) an oxygen atom of charge  $-2e$  at  $x = d$ ,  $y = 0$  and another oxygen atom of charge  $-2e$  at  $x = -d$ ,  $y = 0$ .

a) (5) What is the dipole moment,  $\mathbf{p}$ , of this molecule?

b) (12) What is the potential energy,  $U$ , of this molecule?

c) (18) What is the potential,  $V(r, \theta)$ , at an arbitrary point  $x = r \cos \theta$ ,  $y = r \sin \theta$ ?

d) (10) Expand your result in c) for distances  $r$  such that  $d/r \ll 1$ . Recall that

$$(1 + \epsilon)^{1/2} = 1 + \frac{\epsilon}{2} - \frac{\epsilon^2}{8} + \dots +$$