PY208 section 012 Test 1, Monday 2002 Sep. 16

Name____ **Group** _________________________

- **Read all problems carefully before attempting to solve them.**
- **Your work must be legible, and the organization must be clear.**
- **Correct answers without adequate explanation will be counted wrong.**
- **Incorrect explanations mixed in with correct explanations will be counted wrong.**
- **Make explanations complete but brief. Do not write a lot of prose.**
- **Include diagrams!**
- **Show what goes into a calculation, not just the final number:** $\frac{(8\times10^{-3})(5\times10^{6})}{(2\times10^{-5})(4\times10^{4})} = 5\times10^{4}$
- **Give physical units with your results.**

Unless specifically asked to derive a result, you may start from the formulas given on the formula sheet.

If you cannot do some portion of a problem, invent a symbol for the quantity you can't calculate (explain that you're doing this), and do the rest of the problem.

Problem Score

1 (25 pts):_______

2 (20 pts):________

3 (20 pts):_______

4 (35 pts):________

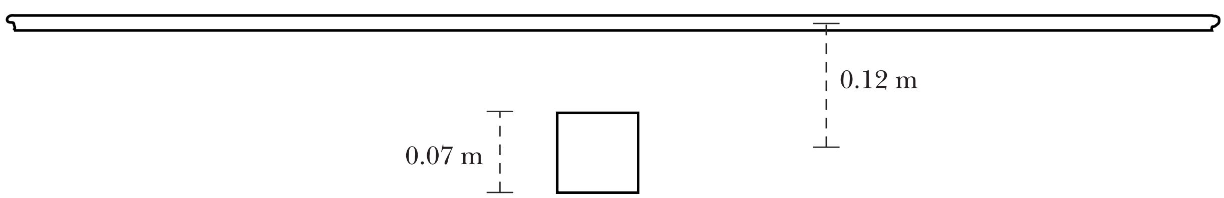
Total (100 pts): _______

Problem 1 (25 pts)

(a: 5 pts) A student claimed that the formula for the electric field outside a cube of edge length L, carrying a uniformly distributed charge Q, at a distance x from the center of the cube, was $E = \frac{Q}{\varepsilon_0}\frac{L}{\sqrt{x}}$. Explain how you know that this formula cannot be correct.

(b: 5 pts) A thin glass rod of length 5 m has been rubbed with a silk cloth, and has gained a net charge of -5×10^{-7} coulombs, distributed uniformly over its surface. A cubical block of copper with side length 0.07 m is placed with its center 0.12 m from the center of rod, as shown in the diagram below. Note that the rod is very long, and only part of it is shown on the diagram.

On the diagram, show the distribution of charges in and on the copper, using the conventions discussed in the textbook.



(c: 5 pts) On the diagram above draw an arrow representing the electric field at the center of the copper block, *due only to the charges in and on the copper.*

(d: 10 pts) What is the magnitude of the electric field vector you drew in part (c)? Show your work, and explain.

Problem 2 (20 points)

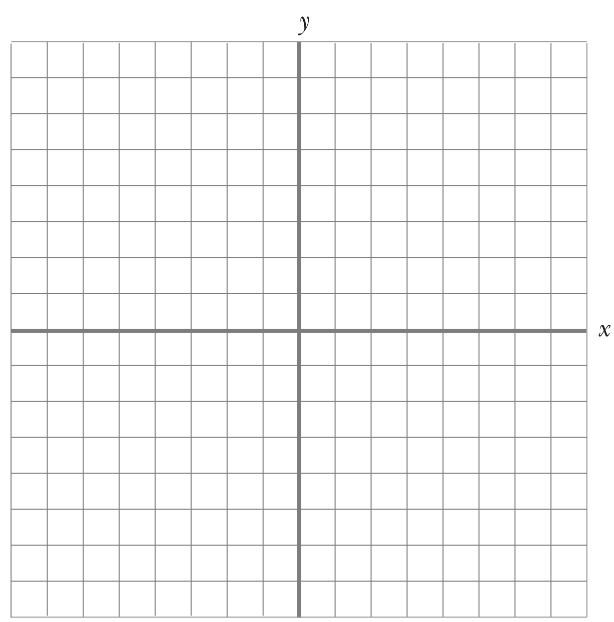
Your friend has missed class, and asks you to explain a program you have started to write (but not finished) , which will calculate the electric field of a dipole at various locations. Your program is shown below.

```
from visual import *
from __future__ import division
minus = sphere(pos=(0, -2e-10, 0), radius=.3e-10, color=color.green)
minus.charge = -1.6e-19
plus = sphere(pos=(0, 2e-10, 0), radius=.3e-10, color=color.magenta)
plus.charge = 1.6e-19
const = 9e9
scalefactor = 7e-20
pt = vector(-5e-10, 0, 0)
obs = arrow(pos=pt, shaftwidth = 2e-11, color=color.yellow)
rp = obs.pos - plus.pos
Ep = (const*plus.charge/mag(rp)**2)*norm(rp)
rm = obs.pos - minus.pos
Em = (const*minus.charge/mag(rm)**2)*norm(rm)
Enet = Ep + Em
obs.axis = Enet*scalefactor
```

Answer the following questions your friend asks about your program:

(a: 5 pts) On the diagram below, draw the positive and negative point charges at the locations specified in the program above. Label each one clearly with a "+" or a "-":

(b: 5 pts) On the diagram, draw an arrow with its tail at the observation location specified in the program, pointing in the direction the electric field at that location should point.



One small division represents 1e-10 m.

(continued on next page)

(c: 2 pts) Which line of code calculates the vector from the positive charge to the observation location? Copy the line of code here:

(d: 2 pts) Which line of code calculates the electric field due to the negatively charged object? Copy the line of code here:

(e: 4 pts) What is the purpose of the constant named “scalefactor”? What does it do?

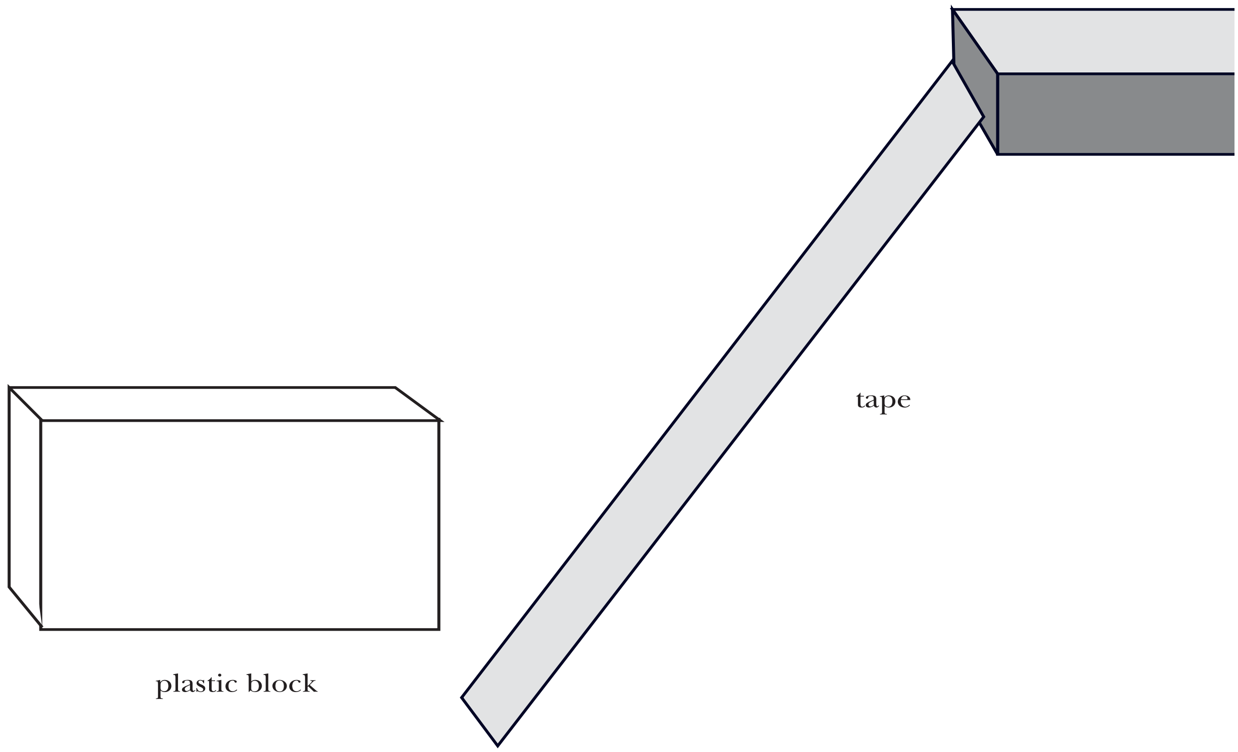
(f: 2 pts) What is the magnitude of `norm(rm)`?

Problem 3 (20 pts)

You pull a piece of magic tape off of a surface, and bring it near a plastic pen that has been rubbed with wool and has acquired a negative charge. You observe that the tape is repelled by the pen.

Next you bring the tape near a block of plastic, and discover that the tape is attracted to the plastic.

(a: 10 pts) On the diagram below, show the charges in and on the plastic.

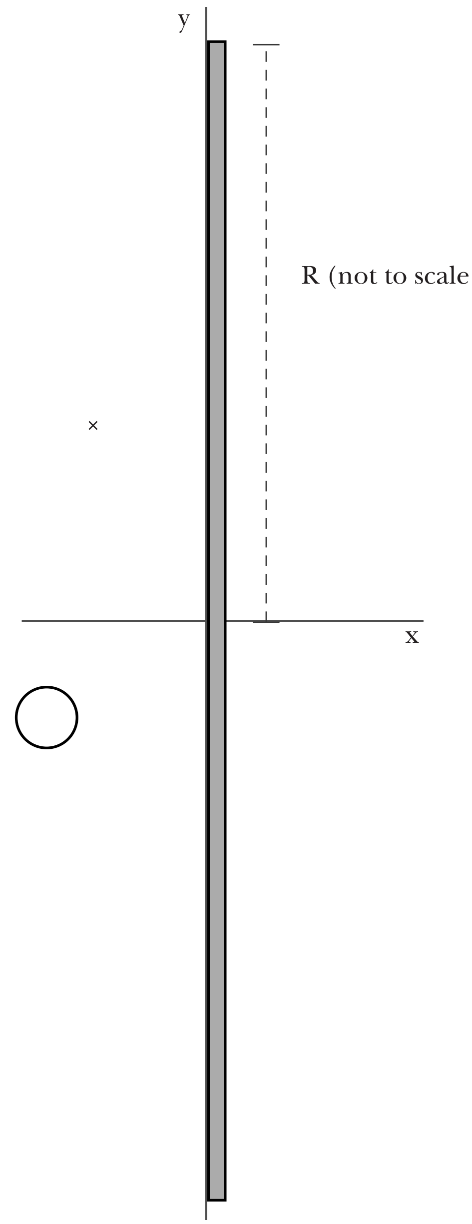


(b: 10 pts) Explain in detail why the tape is attracted to the plastic block. Draw field vectors and force vectors on the diagram to support your explanation.

Problem 4 (35 pts)

A plastic disk carries a negative charge of -3×10^{-6} C distributed uniformly over its surface. Its center is at the origin, and its radius is $R = 7$ m. A small hollow glass ball, of radius 0.02 m, carrying a charge of 2.5×10^{-8} C uniformly distributed over its surface, is located with its center at $\langle -0.07, -0.04, 0\rangle$ m.

(a: 23 pts) Calculate the net electric field at location $\langle -0.05, 0.1, 0\rangle$. Show every step in your calculation explicitly. Give your answer as a vector.



(b: 5 pts) Draw the electric field vector you calculated on the diagram, with its tail at the observation location.

(c: 2 pts) Explicitly state any approximations or assumptions you made in your calculation.

(c: 5 pts) What would be the force on an antiproton (whose charge is $-e$ and whose mass is the same as the mass of a proton) if it were located at $\langle -0.05, 0.1, 0\rangle$?

Fundamental Concepts

$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$ $\vec{F}_2 = q_2\vec{E}_1$

Conservation of charge the Superposition Principle

Specific results and data

$E_{rod} = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q}{r\sqrt{r^2+(L/2)^2}}\right]$ a perpendicular distance r from the center; $E_{rod} \approx \frac{1}{4\pi\varepsilon_0}\frac{2(Q/L)}{r}$ if $r << L$

$E_{ring} = \frac{1}{4\pi\varepsilon_0}\frac{qz}{(z^2+R^2)^{3/2}}$ a distance z along the axis $E_{solid\ sphere} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R^3}r$ inside solid sphere of radius R

$E_{disk} = \frac{Q/A}{2\varepsilon_0}\left[1 - \frac{z}{(z^2+R^2)^{1/2}}\right]$ a distance z along the axis; $E_{disk} \approx \frac{Q/A}{2e_0}\left[1 - \frac{z}{R}\right] \approx \frac{Q/A}{2e_0}$ if $z << R$

$E_{capacitor} \approx \frac{Q/A}{\varepsilon_0}$ for $+Q$ and $-Q$ disks; $E_{fringe} \approx \frac{Q/A}{\varepsilon_0}\left(\frac{s}{2R}\right)$ just outside capacitor

$E_{dipole,x} \approx \frac{1}{4\pi\varepsilon_0}\frac{2qs}{x^3}$ along axis, where $x >> s$; $E_{dipole,x} \approx -\frac{1}{4\pi\varepsilon_0}\frac{qs}{y^3}$ along perpendicular axis, for $y >> s$

$F \approx \frac{1}{4\pi\varepsilon_0}\frac{2\alpha Q^2}{r^5}$ for point charge acting on a neutral atom $p = qs = \alpha E$

Physical constants

$\frac{1}{4\pi\varepsilon_0} = 9\times10^9\frac{N\cdot m^2}{C^2}$ $\varepsilon_0 = 9\times10^{-12}\frac{C^2}{N\cdot m^2}$

$c = 3\times10^8$ m/s $e = 1.6\times10^{-19}$ coulomb

$m_{proton} \approx m_{neutron} \approx m_{hydrogen\ atom} = 1.7\times10^{-27}$ kg $m_{electron} = 9\times10^{-31}$ kg $g = 9.8$ N/kg

6×10^{23} molecules/mole Atomic radius $\approx 10^{-10}$ m Proton radius $\approx 10^{-15}$ m

Electric field necessary to ionize air, about 3×10^6 N/C

Geometry

area of circle = πr^2 circumference of circle = $2\pi r$ area of cylinder = $2\pi rL$

surface area of sphere = $4\pi r^2$ volume of sphere = $\frac{4}{3}\pi r^3$

arc length = $r\Delta\theta$