PHYS 272 - Fall 2010
Hand-Graded part of Exam 1

Name (Print):________________________________

Signature:__________________________________

PUID:______________________________________

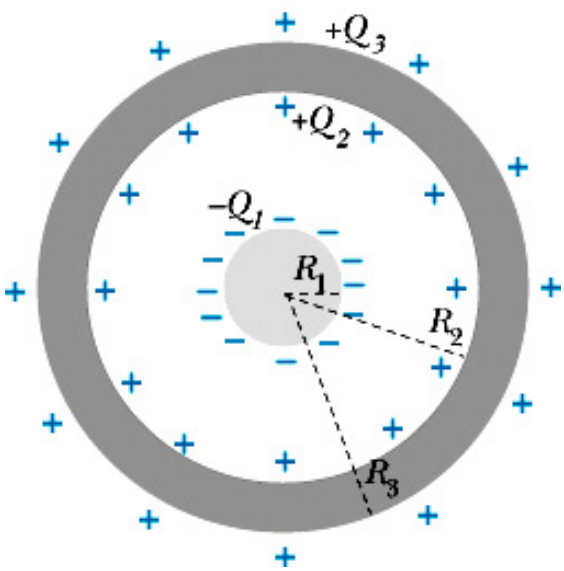
Circle your Recitation Section:

001 Tue	8:30	Nistor
002 Tue	8:30	Sheek
003 Tue	9:30	Nistor
004 Tue	9:30	Sheek
005 Tue	10:30	Deligkaris
006 Tue	11:30	Boomsma
007 Tue	12:30	Boomsma
008 Tue	1:30	Wolff
022 Tue	2:30	Wolff
023 Tue	3:30	Wolff

Note: In all the hand-graded problems below you **MUST explain your answer** in sufficient details, including all the major steps you used to arrive at your answer. Merely giving a final answer (even if correct) with no explanations will receive little or no points. There are 2 problems (total 40 points) in this test. Mark your name/ID at the bottom of each page. If you use any additional pages to enter your answers (additional/scarp pages are available from the proctors), please number them and also mark your name, PUID and the problem number on the page.

Problem 9 [20 points]

A solid plastic sphere of radius R_1 has a charge $-Q_1$ uniformly distributed on its surface. A concentric spherical metal shell of inner radius R_2 and outer radius R_3 carries a uniform charge Q_2 on the inner surface and a uniform charge Q_3 on the outer surface. Q_1, Q_2, and Q_3 are positive numbers. At an observation location a distance r from the center determine the magnitude and direction of the electric field for the cases $r < R_1$, $R_1 < r < R_2$, $R_2 < r < R_3$, and $r > R_3$ respectively.



[you can use this blank space to enter your answer for Problem 9]

Recall that a spherical shell of uniform charge (Q) generates zero E-field inside (E=0) [P1A=3, if student demonstrates knowing this fact in their answers]

and point-charge-like E-field outside ($E = \frac{Q}{4\pi\varepsilon_0 r^2}\hat{r}$).[P1B=3 for knowing this]

[Subtotal P1=P1A+P1B=6pts for knowing both]

Therefore for

(Case 1) $r < R_1$: since it's inside all spheres, $\vec{E} = 0$; [Subtotal P2=2pts]

(Case 2) $R_1 < r < R_2$: since it's outside spherical charge -Q1 but inside Q2 & Q3,

$\vec{E} = \frac{-Q_1}{4\pi\varepsilon_0 r^2}\hat{r} + 0 + 0 = -\frac{Q_1}{4\pi\varepsilon_0 r^2}\hat{r}$ [P3A=1 for knowing to apply superposition principle]

(magnitude= $\frac{Q_1}{4\pi\varepsilon_0 r^2}$ [P3B=1 for getting the right magnitude], direction is radially inward, ie., pointing toward the center) [P3C=1 for getting the right direction];

[Subtotal P3=P3A+P3B+P3C=3pts]

(Case 3) $R_2 < r < R_3$: since it's inside a metal, $\vec{E} = 0$. [Subtotal P4=3pts for knowing E inside metal is zero; if they attempt to calculate E by superposition from two inner spheres but not realizing E is zero, give up to 2 pts]

Another useful observation is that since now we are outside both -Q1 and Q2, but inside Q3, the E-field must also equal to $\frac{-Q_1}{4\pi\varepsilon_0 r^2} + \frac{Q_2}{4\pi\varepsilon_0 r^2}$, in order for this to be zero (as it must be inside a metal), we must have $Q_2 = Q_1$; [Subtotal P5=2pts for realizing this]

(Case 4) $r > R_3$: Since now we are outside all three spherical charges,

$\vec{E} = \frac{-Q_1}{4\pi\varepsilon_0 r^2}\hat{r} + \frac{Q_2}{4\pi\varepsilon_0 r^2}\hat{r} + \frac{Q_3}{4\pi\varepsilon_0 r^2}\hat{r}$ [P6A=1 for superposition]; but since $Q_2 = Q_1$, [P6B=1]

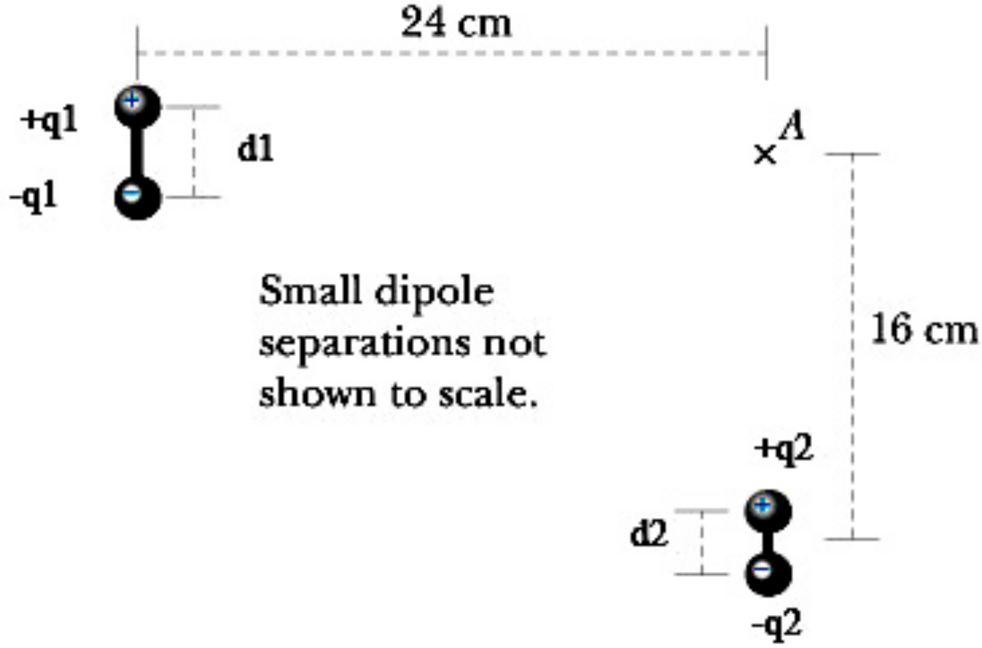
therefore $\vec{E} = \frac{Q_3}{4\pi\varepsilon_0 r^2}\hat{r}$ (magnitude= $\frac{Q_3}{4\pi\varepsilon_0 r^2}$ [P6C=1], direction is radially outward, ie, pointing away from the center [P6D=1])

[Subtotal P6=P6A+P6B+P6C+P6D=4pts]

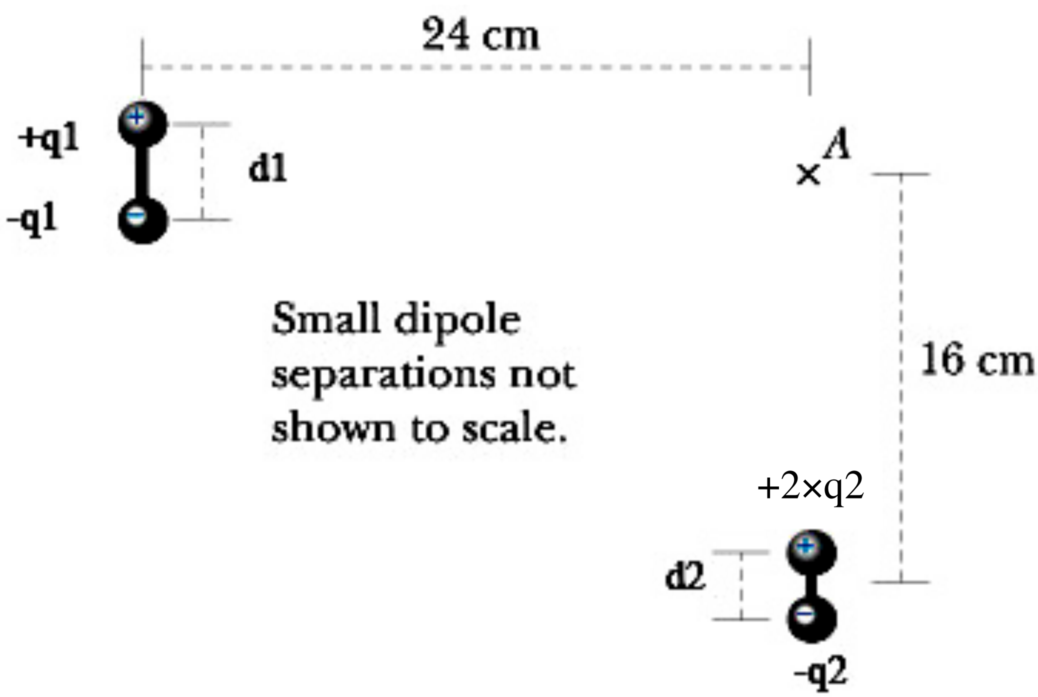
[Total=P1+P2+P3+P4+P5+P6=6+2+3+3+2+4=20pts]

Problem 10 [20 points]

(a) [10 points] Two dipoles are oriented as shown in the figure below. Each dipole consists of charges held apart by a short rod (not shown to scale). If $q1$ = **25** nC, $q2$ = **12** nC, $d1$ = **0.43** mm, and $d2$ = **0.38** mm what is the electric field at the location A. Consider $+x$ to the right, $+y$ upwards, and $+z$ coming out of page.



(b) [10 points] If the positive charge in the previous 2nd dipole is doubled (becomes +2×q2, while the negative charge –q2 remains the same), and an electron is placed at location A. What will be the direction of the force on the electron?



[you can use this blank space to enter your answer for Problem 10]

(a) At location A, the E-field due to dipole#1 is

$$\vec{E}_1 \approx -\frac{1}{4\pi\varepsilon_0}\frac{q_1 d_1}{(24\text{cm})^3}\hat{y} \approx -9\times10^9\frac{\text{Nm}^2}{\text{C}^2}\times\frac{(25\times10^{-9}\text{C})\times(0.43\times10^{-3}\text{m})}{(24\times10^{-2}\text{m})^3}\hat{y} \approx -7\hat{y}[\frac{\text{N}}{\text{C}}]$$

[P1=4 pts: 1 for applying the right formula, 1 for getting the correct magnitude, 1 for correct direction, 1 for correct unit]

and the E-field due to dipole#2 is

$$\vec{E}_2 \approx +\frac{1}{4\pi\varepsilon_0}\frac{2\times q_2 d_2}{(16\text{cm})^3}\hat{y} \approx 9\times10^9\frac{\text{Nm}^2}{\text{C}^2}\times\frac{2\times(12\times10^{-9}\text{C})\times(0.38\times10^{-3}\text{m})}{(16\times10^{-2}\text{m})^3}\hat{y} \approx 20\hat{y}[\frac{\text{N}}{\text{C}}]$$

[P2=4 pts: 1 for applying the right formula, 1 for getting the correct magnitude, 1 for correct direction, 1 for correct unit]

Therefore the total E-field at A is

$\vec{E} = \vec{E}_2 + \vec{E}_2 \approx 13\hat{y}[\frac{\text{N}}{\text{C}}]$ [P3=2pts]

[Total: 10pts]

(b) If the positive charge in dipole#2 is doubled (from $+q_2$ to $+2q_2$), applying superposition principle for E-field, the new E-field at location A would be the previously calculated E-field in (a) plus the E-field generated by the extra point charge $+q_2$ (whose distance from A is 16cm-0.19mm≈16cm). [P1=3 for realizing the total E-field is superposition of that calculated in (a) and that due to extra point charge]

This extra E-field is

$\vec{E}_3 \approx +\frac{1}{4\pi\varepsilon_0}\frac{q_2}{(16\text{cm})^2}\hat{y} \approx 9\times10^9\frac{\text{Nm}^2}{\text{C}^2}\times\frac{(12\times10^{-9}\text{C})}{(16\times10^{-2}\text{m})^2}\hat{y} \approx 4219\hat{y}[\frac{\text{N}}{\text{C}}]$, which is in fact much larger (one can in fact see this even without detailed calculations, from the different distance-dependence in the E-field formula for dipole vs point charge) than the previously calculated E-field. Thus the new total E-field is dominated by $\vec{E}_3$ [P2=4 for arriving at this conclusion either by full calculation as done here or by correct argument] and is pointing along +y direction [P3=1]. Thus for a negatively charged [P4=1] electron, the force would point in –y direction [P5=1].

[Total: 10 pts]