PHYS 212 First Hour Exam
February 17, 2004

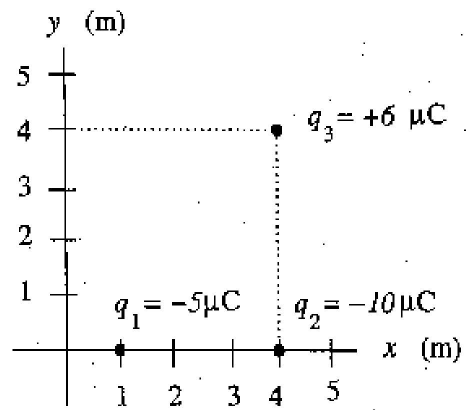
Name ______________
Problem Session:
Hr _____ **Instr** _____

<u>Show all work for full credit</u>! Answers must have correct units and appropriate number of significant digits. For all the problems (except for multiple choice questions), start with either (a) a fundamental equation (b) a sentence explaining your approach; or (c) a sketch.

$k=9.0\times10^{9}$ Nm^2/C^2 $\quad m_e=9.1\times10^{-31}$ kg = 511 keV/c^2 $\quad m_p=1.67\times10^{-27}$ kg = 938 MeV/c^2

$e = 1.6\times10^{-19}$ C $\quad$ 1 eV = 1.6×10^{-19} J $\quad \mu_o = 4\pi\times10^{-7}$ Tm/A $\quad m_{earth} = 5.98\times10^{24}$ kg

1. (12 pts) Consider charges $q_1 = -5\ \mu C$, $q_2 = -10\ \mu C$, and $q_3 = +6\ \mu C$ positioned as shown. Find the total electric force on q_2.



Force	Magnitude	x-comp.	y-comp.
$\vec{F}_{32}$	0.034 N	0	+.034 N
$\vec{F}_{12}$	0.050	+0.050N	0
$\vec{F}_{total}$		+0.05N	+0.034 N

$$F_{32} = k\frac{|q_3 q_2|}{r_{32}^2} = \frac{9\times10^9\times6\times10^{-6}\times10\times10^{-6}}{4^2} = 3.4\times10^{-2}\ N$$

$$F_{12} = k\frac{|q_1 q_2|}{r_{12}^2} = \frac{9\times10^9\times5\times10^{-6}\times10\times10^{-6}}{3^2} = 5.0\times10^{-2}\ N$$

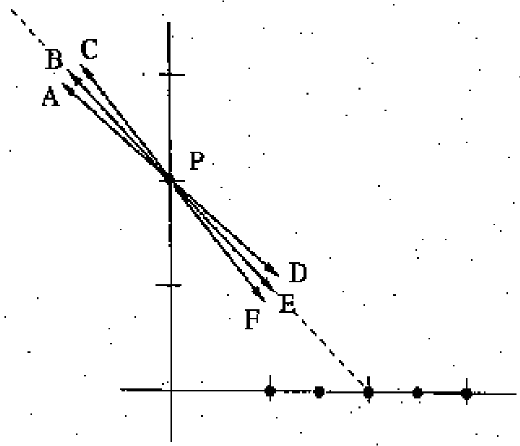
$$\vec{F}_{total} = 0.05\hat{i} + 0.034\hat{j}\ N$$

or

$$|F_{total}| = \sqrt{.05^2+0.034^2} = 0.060\ N$$

$$\theta = \tan^{-1}\frac{.034}{.050} = 34.2^\circ \text{ above } +x \text{ axis}$$

2. (8 pts) Consider five point charges arranged along the horizontal axis as illustrated. All the charges are negative, and they all have same magnitude. Which arrow best represents the electric field vector at the point **P**? (Circle one.)



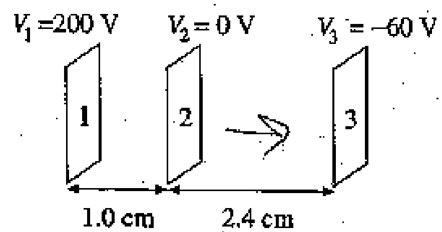
A **B** **C** **D** **E** **F**

Briefly explain your reasoning:

(1) Charges are negative, $\vec{E}$ generally points toward ⊖ so Not A, B, C

(2) Closer charges produce bigger $\vec{E}$'s $\left(E = \frac{kq}{r^2}\right)$ so Result tipped down from E to F

3. (12 pts) Three infinite parallel plates are arranged as shown. The electric potential for each plate is shown in the figure. Determine the magnitude and direction of the electric field in the region between plates 2 and 3.



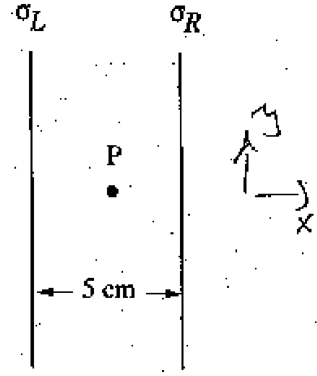
Infinite plates $\Rightarrow \vec{E} = \text{const}$ between each pair

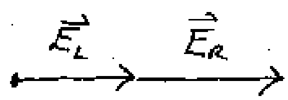
Then $\Delta V = -\vec{E} \cdot \vec{\Delta x}$

and $E = \left|\frac{\Delta V}{\Delta x}\right| = \left|\frac{60\,V}{0.024\,m}\right| = \boxed{2500\ N/C \text{ to the right}}$

$\vec{E}$ points to lower V

4. (12 pts) Determine the electric field vector $\vec{E}$ at the point P midway between two infinite uniformly charged plates as shown. The charge density on the left plate is $\sigma_L = 3\,\mu C/m^2$, and the charge density on the right plate is $\sigma_R = -5\,\mu C/m^2$.



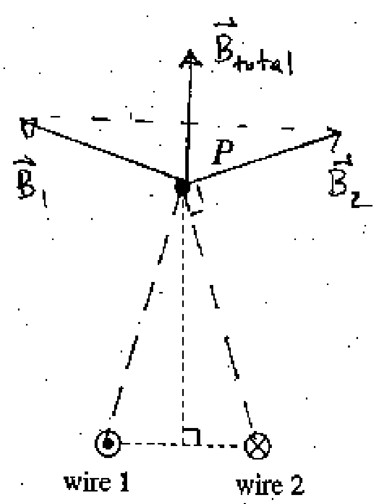


$$|E_L| = 2\pi k|\sigma_L| = 2\pi \times 9\times10^9 \times 3\times10^{-6}\ N/C$$
$$= 1.7\times10^5\ N/C$$

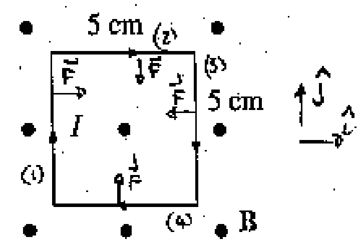
$$|E_R| = 2\pi k|\sigma_R| = 2\pi \times 9\times10^9 \times 5\times10^{-6}\ N/C$$
$$= 2.8\times10^5\ N/C$$

$$\vec{E}_{total} = (1.7\times10^5\ N/C + 2.8\times10^5\ N/C)\,\hat{i} = 4.5\times10^5\,\hat{i}\ N/C$$

5. (9 pts) Two infinite wires are positioned perpendicular to the page, as shown. They carry equal and opposite current I. The point P is equidistant from the two wires. Carefully sketch and label at point P all of the following: $\vec{B}_1$, the magnetic field vector due to wire 1, $\vec{B}_2$, the magnetic field vector due to wire 2, and $\vec{B}_{total}$, the total field at P. Be especially careful with directions and relative lengths of your vectors.



6. (12 pts) A 5 cm by 5 cm square loop of wire lies in the plane of the page, and a uniform magnetic field of 2×10^{-5} T points out of the page. A current $I = 3$ A flows clockwise around the loop. Determine the torque on the loop about its center.



Magnetic dipole for loop:

$$\vec{\mu} = IA\hat{n} = 3 \times 0.05 \times 0.05\ (-\hat{k})$$

Torque exerted by constant field on dipole:

$$\vec{\tau} = \vec{\mu} \times \vec{B}$$

But $\vec{B}$ is in the $\hat{k}$ direction. Thus

$$\vec{\tau} = 0.$$

Force calculation:

$$\vec{F} = I\vec{l} \times \vec{B}$$

$$= 3 \times 2 \times 10^{-5} \times 0.05\ \text{N}$$

$$= 3 \times 10^{-6}\ \text{N} \begin{pmatrix} \hat{i} \\ -\hat{j} \\ -\hat{i} \\ \hat{j} \end{pmatrix} \begin{matrix} \text{for (1)} \\ (2) \\ (3) \\ (4) \end{matrix}$$

$$\vec{\tau} = \vec{r} \times \vec{F}$$

But $\vec{r}$, $\vec{F}$ are parallel

$$\Rightarrow \vec{\tau} = 0$$

7. (12 pts) An electron moves with velocity $\vec{v} = (2\hat{i} - 3\hat{j})\times10^{6}$ m/s in a uniform magnetic field $\vec{B} = (4\hat{i} + 5\hat{j})\times10^{-2}$ T. Calculate the magnetic force on the electron.

$$\vec{F} = q\, \vec{v} \times \vec{B}$$

$$= -1.6\times10^{-19}\ (2\hat{i} - 3\hat{j}) \times (4\hat{i} + 5\hat{j}) \times 10^{4}\ \text{N}$$

$$= -1.6 \times [10\ \hat{i}\times\hat{j} - 12\ \hat{j}\times\hat{i}] \times 10^{-15}\ \text{N}$$

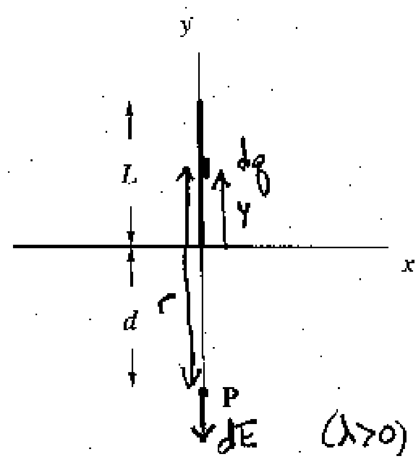
$$= -1.6 \times [10\ \hat{k} + 12\hat{k}] \times 10^{-15}\ \text{N}$$

$$\vec{F} = -35.2 \times 10^{-15}\ \hat{k}\ \ \text{N}$$

8. (6 pts) An 8 inch length of scotch tape is pressed sticky side down on a table. A second identical piece of tape is pressed down on the table beside the first piece of tape. The two pieces of tape are then ripped quickly from the table. The strips of tape are allowed to hang vertically, and brought next to each other. Do the strips of tape attract, repel, or hang unaffected by each other? Explain your reasoning.

Pulling a piece of tape off the table leaves some charge on the tape. The second piece of tape is prepared the same way, so it has the same charge. Like charges $\boxed{\text{repel}}$.

9. (15 pts) A line of charge with positive linear charge density λ and length *L* is located on the *y* axis with one end at the origin as shown Set up the integral that you would evaluate to determine the *y* component of the electric field E_y at the point **P** on the *y* axis a distance *d* below the origin, as shown. **You do not need to evaluate the integral.** Your expression should contain only given quantities, physical constants, and your integration variable.



$dq = \lambda dy \qquad r = d + y$

limits of y are 0 to L

$dE = \frac{k\,dq}{r^2} = \frac{k\lambda\,dy}{(y+d)^2}$ (magnitude)

$dE_y = -dE \Rightarrow E_y = \int dE_y = \boxed{-\int_0^L \frac{k\lambda\,dy}{(d+y)^2}}$