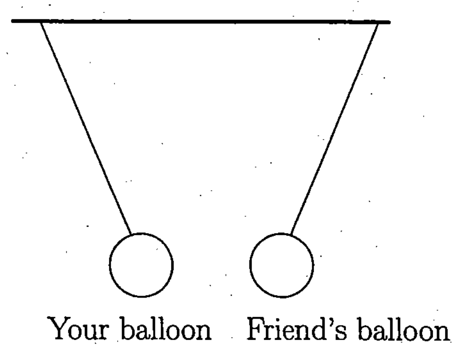
PHYS 212 First Hour Exam
February 15, 2005

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

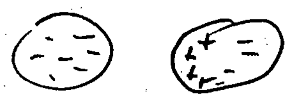
Show all work for full credit! Answers must have correct units and appropriate number of significant digits. For all the problems (except for multiple choice questions), start with some combination of (a) a fundamental equation (b) a sentence explaining your approach; or (c) a sketch.

$e = 1.6\times10^{-19}\,\mathrm{C}$ $k = 8.99\times10^{9}\,\mathrm{Nm^2/C^2}$ $\mu_0 = 4\pi\times10^{-7}\,\mathrm{N/A^2}$ $1\,\mathrm{eV} = 1.6\times10^{-19}\,\mathrm{J}$

1. (10 pts) You charge up a balloon by rubbing it on a sweater, and hang it by a thread from the ceiling. A friend of yours takes great care to hang another balloon nearby without rubbing it on her sweater, or charging it in any way. This means that there is *no net charge* on your friend's balloon. At equilibrium the balloons hang as illustrated. Explain the origin of the attractive force between the balloons.

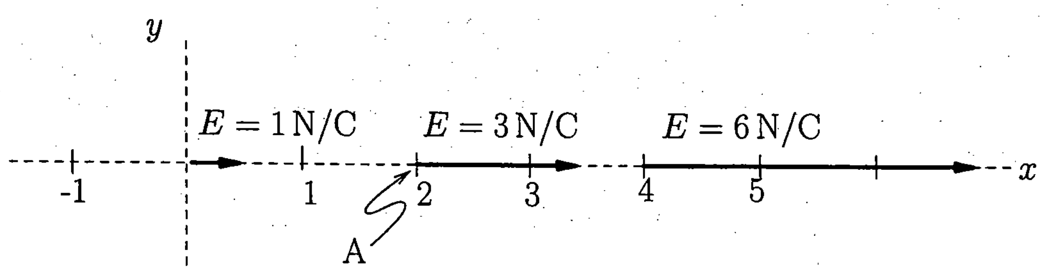


Your balloon induces charges to move in your friend's balloon → pulls opposite charges closer, pushes like charges farther away.



Attraction from closer, opposite charges is stronger than repulsion from farther like-sign charges

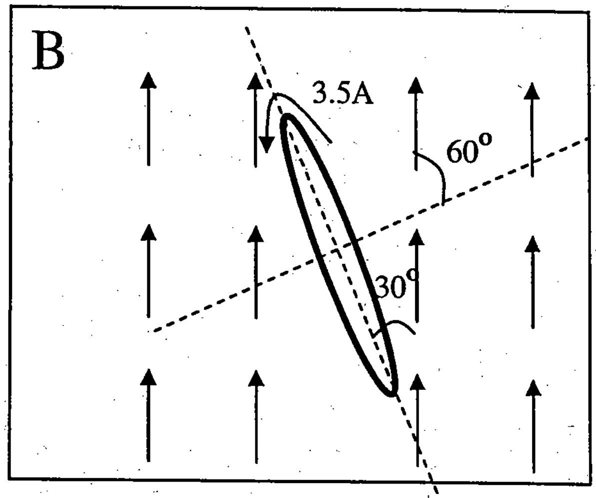
2. (10 pts) The electric field at several points along the x-axis is indicated in the diagram. (As is usual, the length of the vector corresponds to the magnitude of the field at the position of the tail of the vector.) The magnetic field is zero in this region. Calculate the magnitude and direction of the force on an electron traveling to the right (positive x) at a speed $v = 2.0\times10^{6}$ m/s at the instant that the electron is at point A at $x = +2\,\mathrm{m}$.



$$\vec{F} = q\vec{E} = (-1.6\times10^{-19}\,C)\cdot 3\,N/C\,\hat{i} = -4.8\times10^{-19}\,\hat{i}\ N$$

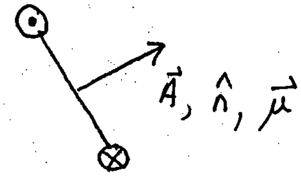
or you can say 4.8×10^{-19} N to the left

3. (12 pts) A simple motor consists of a circular coil of wire with 100 loops and a radius 2.0 cm. The coil carries a current of 3.5 A. At a particular moment in time, the coil is in a uniform magnetic field with magnitude 0.3T, as shown in the diagram.

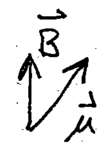


(a) Calculate the magnitude of the torque on the coil at this moment.

$$|\tau| = |\mu|\,|B| \sin\theta$$
$$= NIAB\sin\theta$$
$$= 100 \times 3.5\text{A} \times \pi \times (0.02\text{m})^2 \times 0.3\text{T} \times \sin 60^\circ$$
$$= 0.11 \text{ N-m}$$

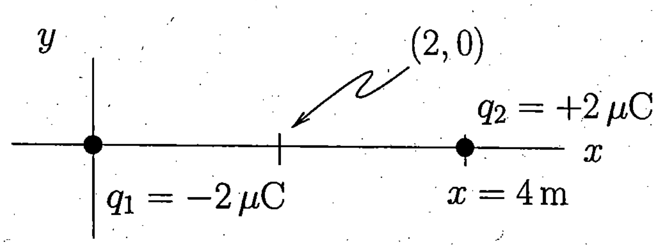


(b) Circle the choice below which best shows the direction of the torque at this moment.

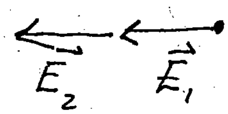


↑ ↓ ← → ↘ ↙ ↖ ↗ IN OUT

4. (10 pts) Two charges, $q_1 = -2\,\mu\text{C}$ and $q_2 = +2\,\mu\text{C}$ are located on the x-axis in the illustrated positions.



Calculate the magnitude and direction of the total electric field due to q_1 and q_2 at the point $x = 2\,\text{m},\ y = 0$.



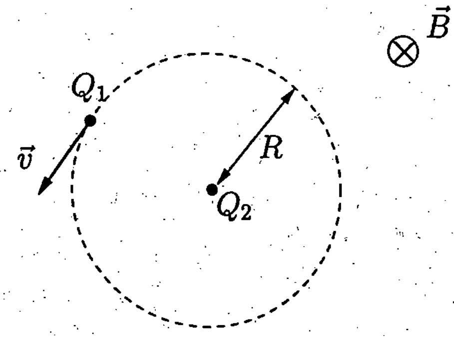
$$|E_1| = \frac{kq_1}{r_1^2}$$
$$= 8.99 \times 10^9 \frac{\text{Nm}^2}{\text{C}^2} \cdot \frac{2 \times 10^{-6}\text{C}}{(2\text{m})^2}$$
$$= 4.5 \times 10^3 \text{ N/C}$$
$$|E_2| = |E_1|$$
$$|E_{total}| = 2E_1 = 9.0 \times 10^3 \text{ N/C}$$, Direction: To the left

5. (8 pts) Copper has a resistivity of 1.7×10^{-8} Ωm. A 50-m long copper wire is used for a remote-controlled race-car. When a current of 1.3 A goes through this wire, there is a potential difference of 0.8 V across the wire. What is the resistance of the wire?

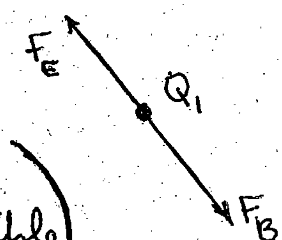
$$\Delta V = I R$$

$$\Rightarrow \quad R = \frac{\Delta V}{R} = \frac{0.8\,V}{1.3\,A} = 0.62\,\Omega$$

6. (12 pts) A positively charged particle with charge Q_1 travels in a circle of radius R around another positive charge Q_2 at a constant speed v. The charge Q_2 is held in place so that it cannot move. The entire illustrated region is in a uniform magnetic field $\vec{B}$ directed into the page.



a) Draw a force diagram showing ***all*** forces acting on the charge Q_1.



(F_{grav} is negligible)

F_E = electric force (repulsion from Q_2)
F_B = magnetic force (moving charge (Q_1) in a $\vec{B}$ field)

(a) Determine an expression for the magnitude of the magnetic field B in terms of the speed v, the radius R, and the charges Q_1 and Q_2.

For constant circular motion, $|F_{TOT}| = |ma| = \left|\frac{mv^2}{R}\right|$

$$\vec{F}_{TOT} = \vec{F}_B + \vec{F}_E$$

$$|F_B| = |q\vec{v} \times \vec{B}| = qvB\sin\theta \quad (\vec{v} \perp \vec{B}, \text{ so } \sin\theta = \sin 90° = 1)$$
$$= Q_1 v B$$

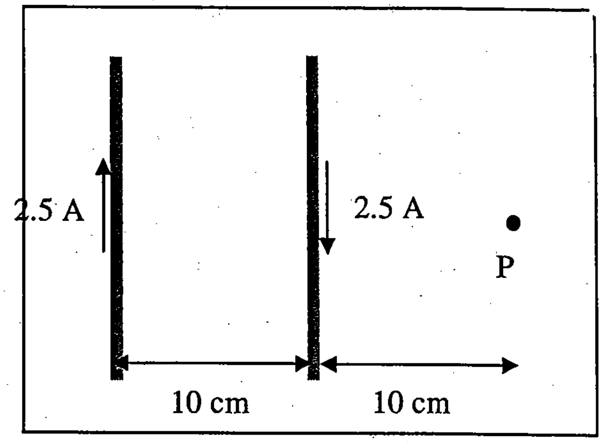
$$|F_E| = \frac{kq_1q_2}{r^2} = \frac{kQ_1Q_2}{R^2}$$

Choosing radially inward as the positive direction,

$$|F_{TOT}| = (Q_1 vB) - \left(\frac{kQ_1Q_2}{R^2}\right) = \frac{mv^2}{R}$$

Solving for B:
$$\boxed{B = \frac{\left(\frac{mv^2}{R}\right) + \left(\frac{kQ_1Q_2}{R^2}\right)}{Q_1 v} = \frac{mv^2R + kQ_1Q_2}{Q_1 vR^2}}$$

7. (12 pts) Two long wires lie in the plane of the paper and are separated by 10 cm. They each carry a current 2.5 A with one directed toward the top of the page and the other downward, as shown in the diagram.



(a) Determine the magnitude of the total magnetic field produced by these wires at the point P, a distance 10 cm to the right of the right-most wire.

Approximating these wires as infinitely long: $B_{wire} = \frac{\mu_0 I}{2\pi R}$

At point P,

$|\vec{B}_{left}| = \frac{\mu_0 I}{2\pi(0.20m)} = \frac{(4\pi\times10^{-7}N/A^2)(2.5A)}{2\pi(0.20m)} = 2.5\times10^{-6}T\ (\otimes)$

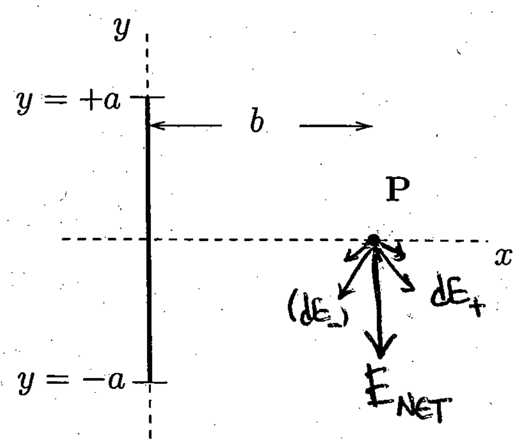
$|\vec{B}_{right}| = \frac{\mu_0 I}{2\pi(0.10m)} = \frac{(4\pi\times10^{-7}N/A^2)(2.5A)}{2\pi(0.10m)} = 5\times10^{-6}T\ (\odot)$

$\rightarrow |B_{NET}| = |B_{right}| - |B_{left}|$
$= 5\times10^{-6}T - 2.5\times10^{-6}T$
$\boxed{B_{NET} = 2.5\times10^{-6}T}$

(b) Circle the choice below which best shows the direction of the total magnetic field at the point P.

↑ ↓ ← → IN OUT

8. (8 pts) A straight line of charge lies on the y-axis between $y = -a$ and $y = +a$. The charge density on the line is $\lambda = 4y$. Note that this charge density is a function of position – **it is not uniform.** Indicate the direction of the total electric field at point **P** due to the line of charge. Explain your reasoning. (Qualitative reasoning and diagrams are sufficient to answer this question.)



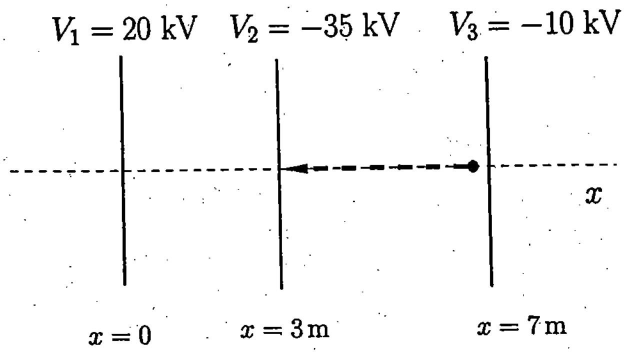
$\lambda = 4y$ → positive when $y>0$; negative when $y<0$

$dE = \frac{k\,dq}{r^2} = \frac{k\lambda\,dy}{r^2}$, pointing away from (+) charge, toward (−) charge

⇒ dE: points down and to the right for (dq) at $y>0$
points down and to the left for (dq) at $y<0$

⇒ by symmetry, $E_x = 0$; $\boxed{E_{NET} \text{ points in the } -\hat{j}\ (-y) \text{ direction}}$

9. (8 pts) A proton is ejected from the large flat conducting surface on the right in the figure. This plates is maintained at a potential of $V_3 = -10{,}000$ Volts. The proton starts from rest and is accelerated toward the middle large flat conducting plated that is maintained at a potential of $V_2 = -35{,}000$ Volts.



Calculate the kinetic energy of the electron immediately before it slams into the plate maintained at $V_2 = -35{,}000$ Volts.

Conservation of energy:

$$\Delta K + \Delta U = 0$$

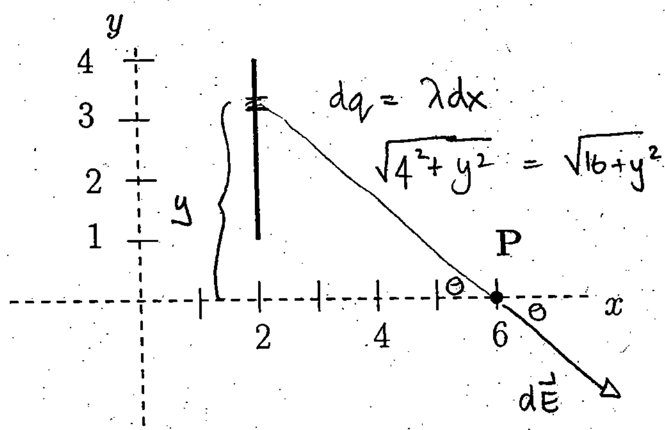
But $\Delta U = q\Delta V$

$$\Rightarrow \Delta K = -q\Delta V$$

$$= -1.6\times10^{-19}\,C \times -25\times10^{3}\,V$$

$$= 4\times10^{-15}\,J$$

10. (10 pts) The illustrated line of charge lies parallel to the y-axis and has constant linear charge density 2 μC/m. Fill in the 4 boxes in the following expression for the x-component of the electric field at point **P**. Leave your answer in a form that could be evaluated by a computer or calculator to give the correct answer. (You may use extra space elsewhere on the page if necessary.)



From segment

$$dE_x = +\cos\theta\, dE$$

$$= \frac{4}{\sqrt{16+y^2}}\frac{k\,dq}{r^2}$$

$$= \frac{4\lambda k\,dy}{(16+y^2)^{3/2}}$$

$$E_x = \int_{\boxed{1}}^{\boxed{4}} \boxed{\frac{8k}{(16+y^2)^{3/2}}}\, d\boxed{y}$$

But $\lambda = 2\mu C/m$.