# Introductory Physics

U.C. Berkeley
Physics 8B, Fall 2011
Section II
Exam 1
October 6, 2011

Notes: Correct answers without supporting derivations will not receive credit. You **must** show your work, and partial credit will be given. Answer the questions in your blue book. Please be clear and neat, and **indicate your final answer**. Ask for assistance if any problem is unclear.

*No electronics aids of any type are permitted on this exam. Electronic aids include calculators, computers, cell phones, etc.*

**Make sure you list your Name, SID, Section Number and Section Time in your Blue Book.**

Possibly Useful Formulas

| | | |
|---|---|---|
| Force on a charged particle $\mathbf{F} = q\mathbf{E} + q\mathbf{v}\times\mathbf{B}$ | Electric field from a plane $E = \frac{\sigma}{2\varepsilon_0}$ | Electric Field from a point $E = \frac{q}{4\pi\varepsilon_0 r^2}$ |
| Gauss's Law $\varepsilon_0 \int \mathbf{E}\cdot d\mathbf{A} = q_{\text{enc}}$ | Potential difference $\Delta V = -\int \mathbf{E}\cdot d\mathbf{x}$ | Electric field from a line charge $E = \frac{\lambda}{2\pi\varepsilon_0 r}$ |
| Electric field between two oppositely charged planes $E = \frac{\sigma}{\varepsilon_0}$ | Power $P = IV$ | Ohm's Law $V = IR$ |
| Electric energy density $U = \frac{1}{2}\varepsilon_0 E^2$ | Resistance $R = \frac{\rho L}{A}$ | Microscopic Resistance $\rho = \frac{2mv}{e^2 n\lambda}$ |
| Capacitor formula $Q = CV$ | Energy in a capacitor $U = \frac{1}{2}CV^2$ | Parallel place capacitance $C = \varepsilon_0 \frac{A}{d}$ |
| Resistors in series $R = R_1 + R_2$ | Resistors in parallel $R = \frac{R_1 R_2}{R_1 + R_2}$ | $RC$ time constant $\tau = RC$ |
| Discharge of a capacitor $Q(t) = Q_0 e^{-t/\tau}$ | Capacitor charging $Q(t) = Q_0\left(1 - e^{-t/\tau}\right)$ | Biot-Savart law $\mathbf{B} = \frac{\mu_0 I}{4\pi}\int \frac{d\mathbf{l}\times\mathbf{r}}{r^3}$ |
| Ampere's law $\oint \mathbf{B}\cdot d\mathbf{l} = \mu_0 I + \mu_0\varepsilon_0 \frac{d\Phi_E}{dt}$ | Field from a straight wire $\mathbf{B} = \frac{\mu_0 I}{2\pi r}\hat{\theta}$ | Radius of orbit in uniform magnetic field $r = \frac{mv}{qB}$ |
| Force on a wire $\mathbf{F} = I\mathbf{L}\times\mathbf{B}$ | Magnetic Moment $\mu = NIA$ | Torque on a magnetic moment $\tau = \mu\times\mathbf{B}$ |
| Field in a solenoid $B = \mu_0 nI$ | Field at the center of a loop of radius $R$ $B = \frac{\mu_0 I}{2R}$ | Magnetic energy density $U = \frac{1}{2\mu_0}B^2$ |
| Lenz's law $\mathcal{E} = -\frac{d\Phi_B}{dt}$ | Faraday's law $\oint E\cdot d\mathbf{l} = -\frac{d\Phi_B}{dt}$ | Inductive EMF $V = -L\frac{dI}{dt}$ |
| Inductance of a solenoid $L = \mu_0 n^2 Al$ | $RL$ time constant $\tau = \frac{L}{R}$ | Flux in an inductor $\Phi = LI$ |

| Discharge of an inductor | Inductor charging | Transformer ratio |
|---|---|---|
| $I(t) = I_0 e^{-t/\tau}$ | $I(t) = I_0\left(1 - e^{-t/\tau}\right)$ | $I_2 = \frac{N_1}{N_2} I_1 \quad V_2 = \frac{N_2}{N_1} V_1$ |

| | | |
|---|---|---|
| $c = 3\times10^{8}\,\text{m/s}$ | $\varepsilon_0 = 8.85\times10^{-12}\,\text{F/m}$ | $\mu_0 = 4\pi\times10^{-7}\,\text{H/m}$ |
| $e = 1.6\times10^{-19}\,\text{C}$ | $m_{\text{electron}} = 9.11\times10^{-31}\,\text{kg}$ | $m_{\text{proton}} = 1.67\times10^{271}\,\text{kg}$ |
| $k = 1.38\times10^{-23}\,\text{J/K}$ | $h = 6.63\times10^{-34}\,\text{J}\cdot\text{s}$ | $1\,\text{eV} = 16\ \times10^{-19}\,\text{J}$ |

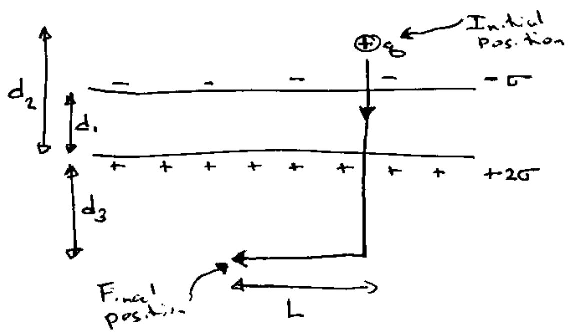
Note that all constants are given just for reference; you need not plug in the numeric values of the constants unless you are explicitly directed to give a purely numeric answer.

Kirchhoff's Rules

1. Wires carry currents without changing potentials
2. Traversing a battery increases the potential by the EMF of the battery.
3. Resistors decrease the potential by $IR$.
4. Current is conserved at a junction
5. The net potential difference along any closed circuit is zero.

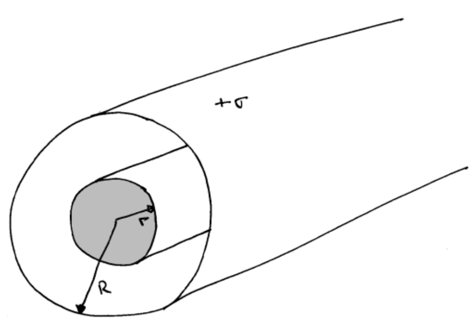
## Problem 1: [25 points]

A distance $d_1$ above an infinite plane of uniform surface charge $+2\sigma$ there is a second infinite plane with uniform surface charge $-\sigma$. A test charge $+q$ is moved from a distance $d_2$ above the first plane to distance $d_3$ below the first plane. The test charge is also moved a distance $L$ to the left. How much does the potential energy of the test charge change?



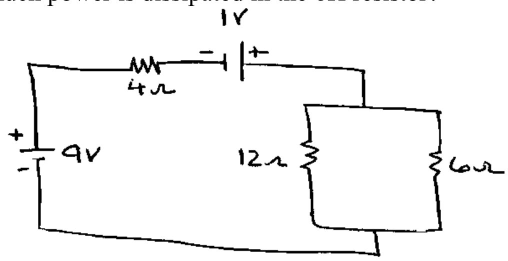

## Problem 2: [25 points]

An infinite, very thin, hollow cylinder of radius $R$ has a uniform surface charge density of $+\sigma$ (coul/m$^2$). Inside the cylinder there is an infinite, solid metal rod of radius $r$. Everywhere outside the hollow cylinder, the electric field is zero. Determine and draw the electric fields inside the hollow cylinder. Are there any charges on the solid rod? If there are, where are they and how big are they? How big is the electric field everywhere inside?



Problem 3: [25 points]

In the circuit below, how much power is dissipated in the 6Ω resistor?




Problem 4: [25 points]

Consider the arrangement of an ion source and electric fields plates shown below. The ion source sends positive ions with charge $q$ with velocity $v$ along the positive $x$ axis. They encounter electric fields plates a distance $d$ apart that generate a uniform electric field. This fields comes from the uniform surface charges of $+\sigma$ on the top plate and $-\sigma$ on the bottom plate. To cancel the resulting electric force with a magnetic force, so that the ion travels in a straight line, a magnetic field (not shown) is added. If this magnetic field is designed to be as small as possible, what is its magnitude and direction? If the constraint that the magnetic field be as small as possible is removed, are other values of the field allowed? If so, give an example, describing the magnitude and direction.