PRINT Your Name: ______________________ Instructor:_________________

Louisiana State University Physics 2102, Exam 2,

March 5th, 2009.

• Please be sure to PRINT your name and class instructor above.

• The test consists of 4 questions (multiple choice), and 4 problems (numerical).

• For the problems: Show your reasoning and your work. Note that in many of the problems, you can do parts (b) or (c) even if you get stuck on (a) or (b).

• You may use scientific or graphing calculators, but you must derive and explain your answer fully on paper so we can grade your work.

• Feel free to detach, use, and keep the formula sheet pages. No other reference material is allowed during the exam.

• **May The Force Be With You!**

Question 1 [8 points]

A parallel plate capacitor has a dielectric material of dielectric constant $\kappa > 1$ between the plates. The capacitor is charged by first connecting it to a 12 V battery and then disconnecting it from the battery. After it is disconnected, the dielectric is pulled out. Compared to before the dielectric is removed, what happens after it is removed? (Circle the correct answer for each part.)

(i) The electric potential across the capacitor:

decreases stays the same increases

(ii) The charge on the capacitor:

decreases stays the same increases

(iii) The capacitance:

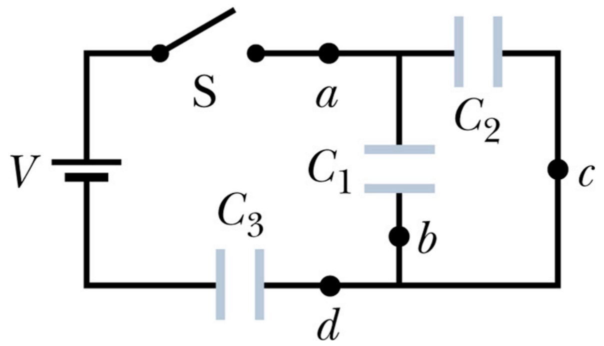
decreases stays the same increases

(iv) The potential energy stored in the capacitor:

decreases stays the same increases

Problem 1 [18 points]

Consider the circuit in the figure below. The capacitors have capacitance values C_1 = 0.75 pF, C_2= 0.50 pF, and C_3 = 1.00 pF. The battery voltage is 12 V.



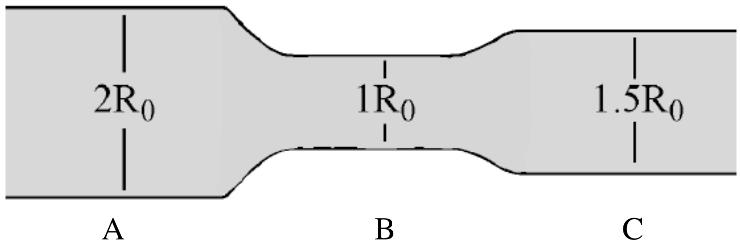
(a) (7 pts) What is the equivalent capacitance of this circuit?

(b) (6 pts) Long after the switch is closed, how many electrons have traveled through point *a*?

(c) (5 pts) After the capacitors are charged, what is the voltage drop across capacitor C_1?

Question 2 [9 points]

The figure shows a current-carrying wire consisting of three sections, which have different radii, as marked on the figure:



(a) (3 pts) Rank the sections according to the magnitude of the current, greatest first (circle one):

$i_A > i_B > i_C$ $\quad$ $i_C > i_B > i_A$ $\quad$ $i_B > i_C > i_A$

$i_A > i_C > i_B$ $\quad$ all tie

(b) (3 pts) Rank the sections according to the magnitude of the current density, greatest first (circle one):

$J_A > J_B > J_C$ $\quad$ $J_C > J_B > J_A$ $\quad$ $J_B > J_C > J_A$

$J_A > J_C > J_B$ $\quad$ all tie

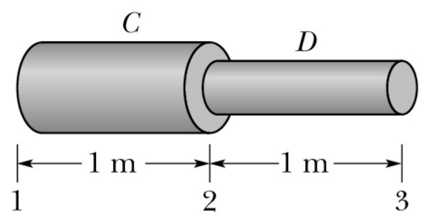
(c) (3 pts) Rank the sections according to the magnitude of the electric field, greatest first (circle one):

$E_A > E_B > E_C$ $\quad$ $E_C > E_B > E_A$ $\quad$ $E_B > E_C > E_A$

$E_A > E_C > E_B$ $\quad$ all tie

Problem 2 [18 points]

Wire C and wire D have lengths $L_C = L_D = 1.0$ m. Wire C is made of copper and has a resistivity of 1.69×10^{-8} Ω•m and a cross-sectional area of 4.50×10^{-6} m^2. Wire D is made of aluminum and has a resistivity of 2.75×10^{-8} Ω•m and a cross-sectional area of 1.33×10^{-6} m^2. The wires are joined as shown in the figure, and a current of 2.0 A is sent down the two wires.



(a) (6 pts) Calculate the electric potential difference between points 1 and 3:

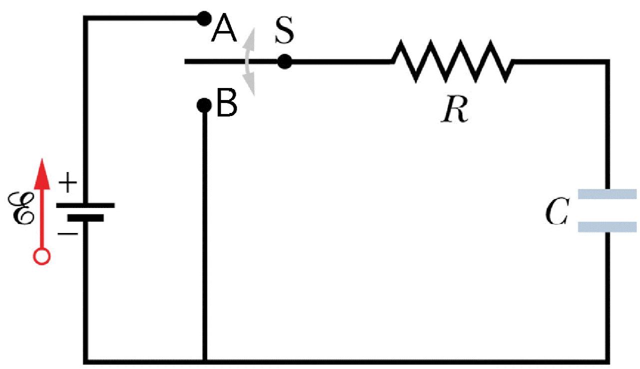
(b) (6 pts) Calculate the rate at which energy is dissipated between points 1 and 2:

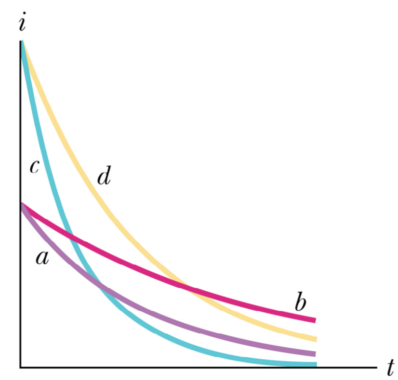
(c) (6 pts) Calculate the drift speed of the electrons in wire C, given that copper has a charge carrier density of 8.49×10^{28} m^{-3}:

Question 3 [8 points]

In the figure below to the left, the switch is closed to point *A* at time $t = 0$. After closing the switch, there is a current *i* through resistor *R*. In the figure below (to the right) it shows this current *i*, as a function of time *t*, for four sets of values of resistance *R* and capacitance *C*.

Set (1): $R = 2.5\ \Omega$ and $C = 3.0\ \mu F$
Set (2): $R = 5.0\ \Omega$ and $C = 3.0\ \mu F$
Set (3): $R = 2.5\ \Omega$ and $C = 6.0\ \mu F$
Set (4): $R = 5.0\ \Omega$ and $C = 6.0\ \mu F$





(a) (4 pts)

In set (1) above, the *R* and *C* values go with which curve (circle one):

(i) curve (a) (ii) curve (b)

(iii) curve (c) (iv) curve (d)

(b) (4 pts)

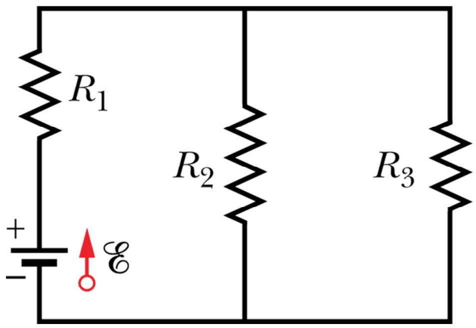
In set (4) above, the *R* and *C* values go with which curve (circle one):

(i) curve (a) (ii) curve (b)

(iii) curve (c) (iv) curve (d)

Problem 3 [18 points]

In the figure below, the resistors have resistance values of R_1 = 1.2 Ω, R_2 = 2.5 Ω, R_3 = 10.0 Ω, and the ideal battery has an EMF of $\mathcal{E}$=3.0 mV.



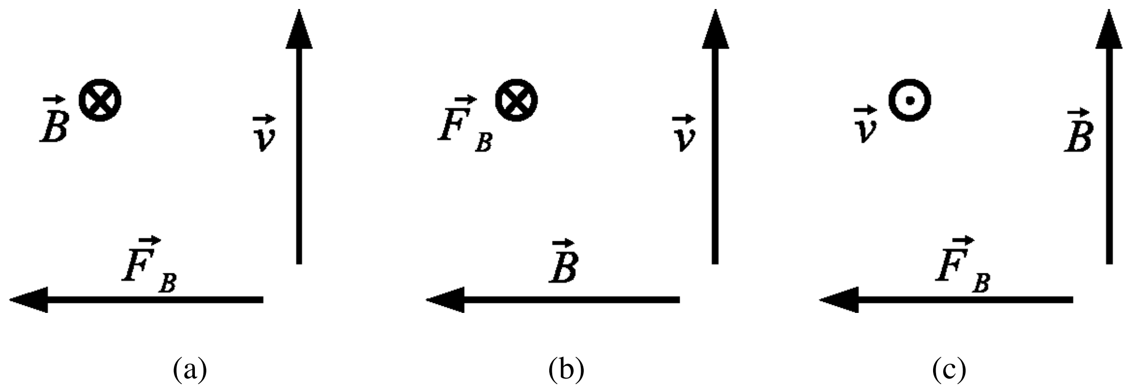
(a) (5 pts) Find the equivalent resistance for R_2 and R_3.

(b) (6 pts) What is the current through the battery?

(c) (7 pts) What is the power being dissipated in the resistor R_2?

Question 4 [8 points]

In the figure you see three situations in which a *negatively* charged particle moves at velocity $\vec{v}$ through a uniform magnetic field $\vec{B}$ and experiences a force $\vec{F}_B$.



Which of the depicted situations are correct? Circle one:

(i) (a)

(ii) (b)

(iii) (c)

(iv) (a) and (b)

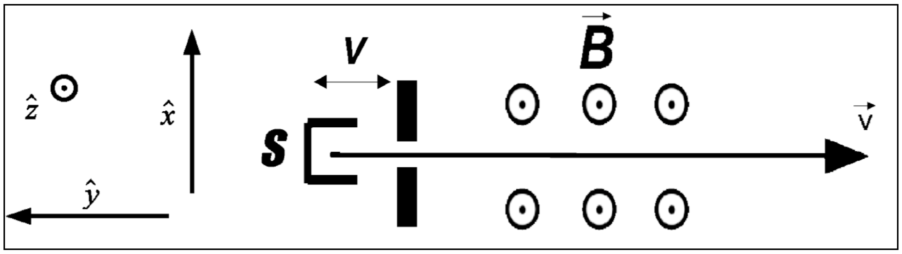
(v) (b) and (c)

(vi) (a) and (c)

(vii) (a) and (b) and (c)

Problem 4 [13 points]

An ion source S is producing positively charged ^{6}Li ions, which have a charge $+e$ and a mass of 9.99×10^{-27} kg, as shown in the figure.



(a) (3 pts) The ions are accelerated by a potential difference of V = 10 kV. What is their final speed?

(b) (5 pts) The ^{6}Li ions enter horizontally a region in which there is a uniform magnetic field with magnitude B = 1.2 T, pointing out of the page as shown. What is the direction and magnitude of the force $\vec{F}_B$ on the ions due to the magnetic field? (Draw the direction on the figure or use the coordinate system to specify it.)

(c) (5 pts) What is the direction and magnitude of an electric field necessary to create a force, which balances $\vec{F}_B$ such that the ^{6}Li ions pass un-deflected through region with the two fields? (Draw the direction on the figure or use the coordinate system to specify it.)

PHYS 2102 Formula Sheet   Spring 2009.

- **Constants, definitions:**

  $\epsilon_o = 8.85 \times 10^{-12}\ \mathrm{C^2/Nm^2}$ $k = \dfrac{1}{4\pi\epsilon_o} = 8.99\ \times 10^9\ \mathrm{Nm^2/C^2}$

  $\mu_0 = 4\pi \times 10^{-7} \frac{\mathrm{T\cdot m}}{\mathrm{A}}$ c $= 3.00\ \times 10^8$ m/s

  $e = 1.60 \times 10^{-19}$ C   1 eV = e(1V) = 1.60 $\times 10^{-19}$ J

  dipole moment: $\vec{p} = q\vec{d}$ charge densities: $\lambda = \dfrac{Q}{L}$, $\sigma = \dfrac{Q}{A}$, $\rho = \dfrac{Q}{V}$

  $m_e = 9.11 \times 10^{-31}$kg $m_p = 1.67 \times 10^{-27}$kg   gravity $g = 9.81$ m/s^2

  Area of circle: $A = \pi r^2$ Area of sphere: $A = 4\pi r^2$ Volume of sphere: $V = \frac{4}{3}\pi r^3$

- **Kinematics (constant acceleration) :**

  $v = v_0 + at$ $x - x_0 = \frac{1}{2}(v_0 + v)t$ $x - x_0 = vt - \frac{1}{2}at^2$

  $x - x_0 = v_0 t + \frac{1}{2}at^2$ $v^2 = v_0^2 + 2a(x - x_0)$

- **Coulomb's law:** $F = k\dfrac{\mid q_1 \mid\mid q_2 \mid}{r^2}$
- **Force on a charge in an electric field:** $\vec{F} = q\vec{E}$
- **Electric field of a point charge:** $E = k\dfrac{\mid q \mid}{r^2}$
- **Electric field of a dipole on axis, far away from dipole:** $E = \dfrac{2kp}{z^3}$
- **Electric field of an infinite line charge:** $E = \dfrac{2k\lambda}{r}$
- **Torque on a dipole in an electric field:** $\vec{\tau} = \vec{p} \times \vec{E}$
- **Potential energy of a dipole in electric field:** $U = -\vec{p} \cdot \vec{E}$
- **Electric flux:** $\Phi = \int \vec{E} \cdot d\vec{A}$
- **Gauss' law:** $\epsilon_o \oint \vec{E} \cdot d\vec{A} = q_{enc}$
- **Electric field of an infinite non-conducting plane with charge density σ:** $E = \dfrac{\sigma}{2\epsilon_o}$
- **Electric field of infinite conducting plane, or close to the surface of a conductor:** $E = \dfrac{\sigma}{\epsilon_o}$
- **Electric potential, potential energy, and work:**

  $V_f - V_i = -\int_i^f \vec{E} \cdot d\vec{s}$,   **In a uniform field:** $\Delta V = -Ed\cos\theta$

  $\vec{E} = -\vec{\nabla} V$, $E_x = -\dfrac{\partial V}{\partial x}$, $E_y = -\dfrac{\partial V}{\partial y}$, $E_z = -\dfrac{\partial V}{\partial z}$

  Potential of a point charge q: $V = k\dfrac{q}{r}$

  Potential of n point charges: $V = \sum_{i=1}^{n} V_i = k \sum_{i=1}^{n} \dfrac{q_i}{r_i}$

  Electric potential energy: $\Delta U = q\Delta V$ $\Delta U = -W_{field}$

  Potential energy of two point charges: $U_{12} = W_{ext} = q_2 V_1 = q_1 V_2 = k\dfrac{q_1 q_2}{r_{12}}$

- **Capacitance** definition: $q = CV$

  Capacitor with a dielectric: $C = \kappa C_{air}$

  Parallel plate: $C = \varepsilon_\circ \dfrac{A}{d}$

  Potential Energy in Cap: $U = \dfrac{q^2}{2C} = \dfrac{1}{2}qV = \dfrac{1}{2}CV^2$ Energy density of electric field: $u = \dfrac{1}{2}\kappa\varepsilon_0 E^2$

  Capacitors in parallel: $C_{eq} = \sum C_i$ Capacitors in series: $\dfrac{1}{C_{eq}} = \sum \dfrac{1}{C_i}$

- **Current:** $i = \dfrac{dq}{dt}$ **Current density:** $J = \dfrac{i}{A}$

- **Drift speed of the charge carriers:** $\vec{v}_d = \dfrac{\vec{J}}{ne}$

- **Definition of resistance:** $R = \dfrac{V}{i}$ **Definition of resistivity:** $\rho = \dfrac{E}{J}$

- **Resistance in a conducting wire:** $R = \rho \dfrac{L}{A}$

- **Power in an electrical device:** $P = iV$ **Power in a resistor:** $P = i^2 R = \dfrac{V^2}{R}$

- **Definition of** emf**:** $\mathcal{E} = \dfrac{dW}{dq}$

- **Resistors in series:** $R_{eq} = \sum R_i$ **Resistors in parallel:** $\dfrac{1}{R_{eq}} = \sum \dfrac{1}{R_i}$

- **Loop rule in DC circuits:** the sum of changes in potential across any closed loop of a circuit must be zero.

- **Junction rule in DC circuits:** the sum of currents entering any junction must be equal to the sum of currents leaving that junction.

- **Charging a capacitor in a series RC circuit:** $q(t) = C\mathcal{E}(1 - e^{-t/\tau})$, time constant $\tau = RC$

  Discharging: $q(t) = q_0 e^{-t/\tau}$

- **Magnetic Fields**

  Magnetic force on a charge q: $\vec{F} = q\vec{v} \times \vec{B}$ Lorentz force: $\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$

  Circular motion in a magnetic field: $qvB = \dfrac{mv^2}{r}$ with period: $T = \dfrac{2\pi m}{qB}$

  Magnetic force on a length of wire: $\vec{F} = i\vec{L} \times \vec{B}$

  Magnetic Dipole: $\vec{\mu} = Ni\vec{A}$

  Torque on a Magnetic Dipole: $\vec{\tau} = \vec{\mu} \times \vec{B}$

  Energy of a Magnetic Dipole: $U = -\vec{\mu} \cdot \vec{B}$