$k = 9.0 \times 10^9$ N m^2 / C^2 $e = 1.60 \times 10^{-19}$ C $\varepsilon_o = 8.85 \times 10^{-12}$ C^2 / N m^2

Coulomb's law: $F = k\, q\, Q / r^2$ (unlike charges attract, like charges repel)

Electric field from a point charge : $E = k\, q / r^2$ (towards -, away from +)

Force on a charge in an electric field : $\mathbf{F} = q\mathbf{E}$

Potential energy of two charges : $U = k\, q\, Q / r$ Electric potential : $V = k\, q / r$

Potential energy of a charge in an electric potential : $U = qV$

Uniform field between two parallel plates a distance d apart : $E = V / d$

Accelerating a charge through a potential difference : $qV = 1/2\ mv^2$

Circuits

Capacitance of a parallel-plate capacitor : $C = \kappa\, \varepsilon_o\, A / d$

Charge on a capacitor : $Q = CV$ Energy in a capacitor : $U = 1/2\ CV^2$

Resistance : $R = \rho\, L / A$ (ρ = resistivity, L = length, A = cross-sectional area)

Ohm's Law : $V = I\, R$ Current : $I = \Delta Q / \Delta t$

Resistors in series : $R = R_1 + R_2 + R_3 + \ldots$

Resistors in parallel : $1/R = 1/R_1 + 1/R_2 + 1/R_3 + \ldots$

Electric power : $P = VI = I^2 R = V^2 / R$ 1 Watt = 1 J / s

Kirchoff's junction rule : current flowing in to a junction = current flowing away

Kirchoff's loop rule : the sum of the potential differences around a closed loop = 0

For an RC circuit, the time constant is $\tau = RC$

Current in an RC circuit: $I = I_o\, e^{-t/RC}$

Capacitor voltage (charging) : $V = V_o\, [\, 1 - e^{-t/RC}\,]$ V_o = battery voltage

Capacitor voltage (discharging) : $V = V_o\ e^{-t/RC}$

Magnetism

Magnitude of the force on a charged particle in a magnetic field : $F = qvB \sin\theta$

- force direction is perpendicular to **v** and **B**, by the right-hand rule

Radius of the circular path of a charged particle with **v** perpendicular to **B** : $r = mv / qB$

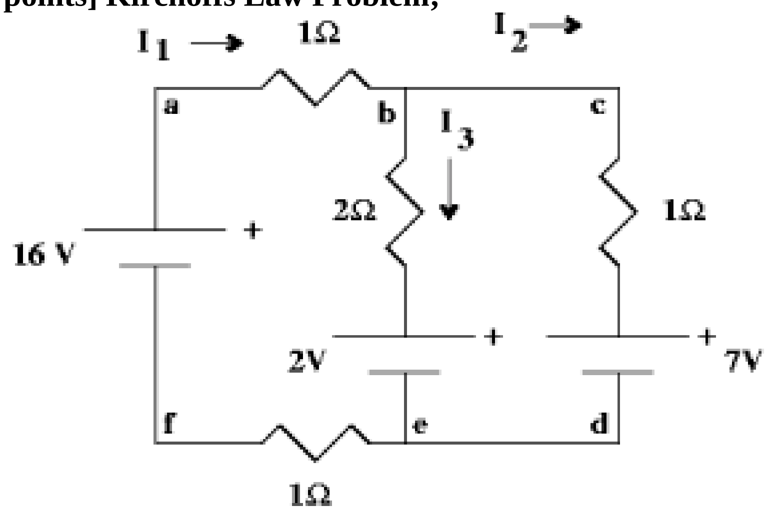
Magnetic field from a long straight wire : $B = \mu_o\, I / 2\, \pi\, r$ $\mu_o = 4\, \pi \times 10^{-7}$ T m / A

Magnetic field down the axis of a solenoid : $B = \mu_o\, NI / l$

Magnitude of the force on a current-carrying wire in a magnetic field : $F = I\, l\, B\ \sin\theta$

- force direction is perpendicular to I and **B**, by the right-hand rule

Problem 5: [15 points] Kirchoffs Law Problem;



a. [2 pts] Write down the junction rule for the currents as marked

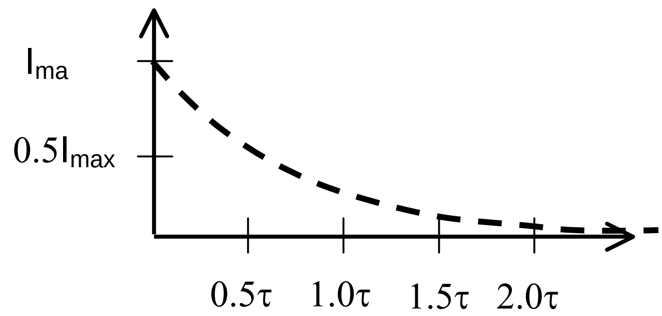
b. [4 pts] Write down the loop equations for ***abefa*** and ***bcdeb***

c. [6 pts] Use your equations to solve for the three unknown currents

d. [3 pts] What is the potential difference between the points ***e*** and ***f*** **(V_e-V_f**?

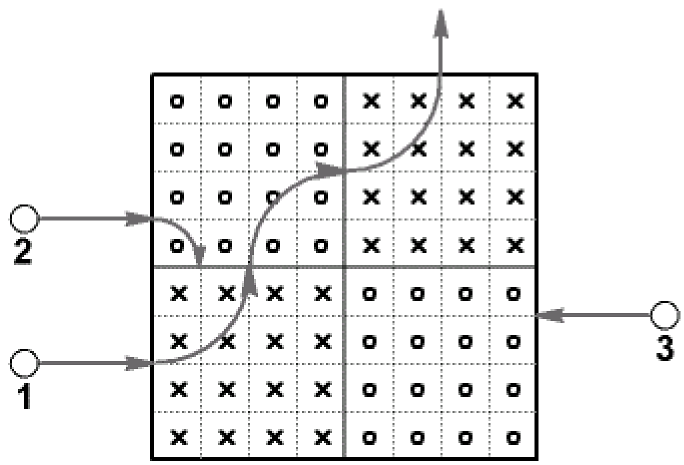
Problem 2 – 10 points

A battery, a resistor $\mathbf{R_0}$ and a switch are placed in series with a capacitor. When the switch closes, the battery charges the capacitor through the resistor. In the following graph, the dashed line plots the current across the resistor as a function of time following the closing of the switch. Now, the resistor is doubled to a value of $\mathbf{2R_0}$**. Plot on the same graph, what the current through the new resistor as a function of time would be.**



Justify your answer.

PROBLEM 3 - 25 points



In the square region at right the magnetic field is uniform and directed out of the page in the upper left and lower right quadrants, and uniform and into the page in the upper right and lower left quadrants. The magnetic field has the same magnitude in all quadrants, and there is no magnetic field outside the square region. Three objects (1, 2, and 3) are fired into the square region – the objects travel on paths that are entirely in the plane of the page. The objects have equal masses and their charges have equal magnitudes. The path followed by object 1 is shown, and the quarter-circle path object 2 takes through the upper left quadrant is also shown.

[2 points] (a) What is the sign of the charge on object 1?

[ ] positive [ ] negative [ ] the charge is zero [ ] insufficient data to determine

[3 points] (b) On the diagram above, carefully complete the path followed by object 2 through the square region. Make sure the radius of curvature, and the point where the object exits the square region, are accurately drawn.

[2 points] (c) How do the signs of objects 1 and 2 compare?

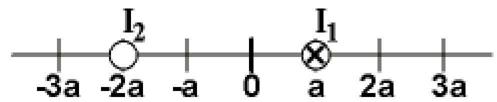
[ ] they have the same sign [ ] they have opposite signs

[3 points] (d) How do the speeds of objects 1 and 2 compare?

[ ] $v_1 = 4v_2$ [ ] $v_1 = 2v_2$ [ ] $v_1 = v_2$ [ ] $2v_1 = v_2$ [ ] $4v_1 = v_2$

[3 points] (e) Object 3 has the same speed as object 1 but the sign of its charge is opposite to that of object 1. On the diagram above carefully sketch the path followed by object 3 through the square region. Make sure the radius of curvature, and the point where the object exits the square region, are accurately drawn.

Two very long straight wires carry currents perpendicular to the page. The x axis is in the plane of the page. Wire 1, which carries a current I_1 into the page, passes through the x axis at x = +a. Wire 2, located at x = -2a, carries an unknown current.



The net field at the origin (x = 0) due to the current-carrying wires is:
$B = 2\ \mu_o\ I_1 / (2\pi a)$

[6 points] (f) I_2 has two possible values.

(i) Determine one of the possible values of I_2, stating both its magnitude and direction. You should be able to express the magnitude of I_2 in terms of I_1.

(ii) Determine the other possible value of I_2, stating both its magnitude and direction.

[3 points] (g) Set I_2 equal to the value you found in part (i) above. What direction is the force experienced by wire 1 because of wire 2?

[ ] left [ ] right [ ] up [ ] down [ ] into the page [ ] out of the page

[3 points] (h) Again set I_2 equal to the value you found in part (i) above. Without changing anything about wire 1, where on the x-axis would you position wire 2 to give a net magnetic field of zero at the origin? Briefly explain your reasoning.