# Exam 2 (March 23, 2010)

Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary. Show your work where indicated.

Problem 1 (8 pts):

In each of the four sketches to the right, the specified electric charge (note the sign of each charge is given) is moving in the direction of the velocity vector in a region of uniform magnetic field. In each case clearly indicate the direction of the force on the charge due to the magnetic field. If there is no force write "no net force" next to the particular sketch.

No net force

F out of paper
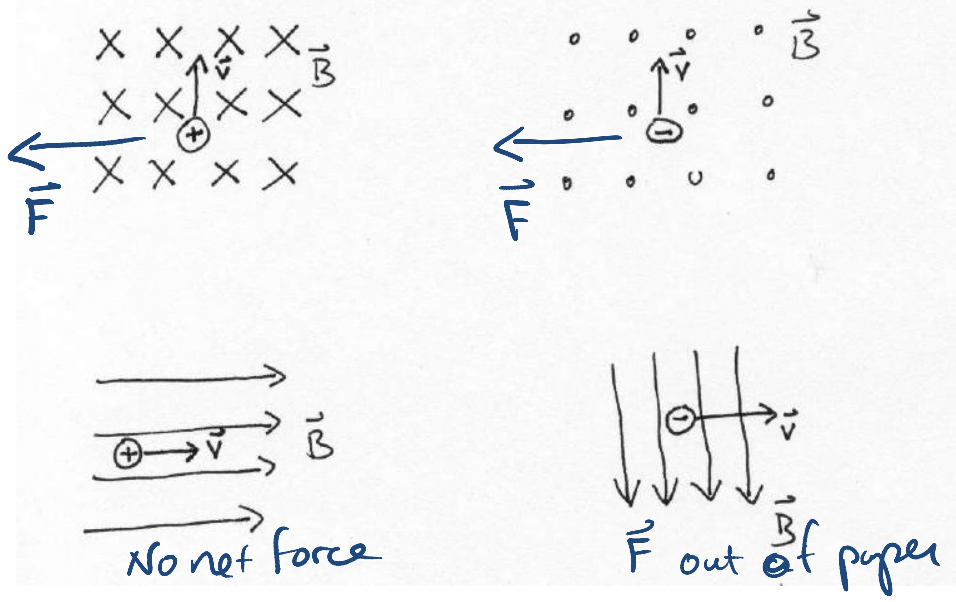
Problem 2 (6 pts):

In each of the three sketches below a positively charged particle moves in a uniform magnetic field in the direction specified by the velocity vector. Also shown is a vector representing the force on the moving charge due to the magnetic field through which it moves. Indicate the direction of the magnetic field in each case.

F (into paper)

(into paper)
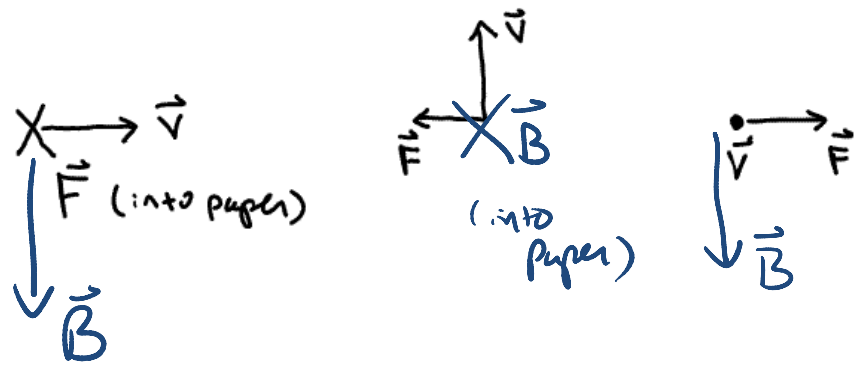
Problem 3 (6 pts):

Six separate situations are sketched below. In each case, electric charges are arranged equal distances from a point where the potential is specified. The charges in each situation have the same magnitude but the signs of the charges are not specified.

Ask to mark charges too

In which of the six situations is the electric field zero at the point where the potential is specified? *(There might be more than one situation that satisfies this criterion.)*

B, C, D, E

In which of the six situations is the magnitude of the electric field greatest (relative to the other situations) at the point where the potential specified? *(There might be more than one situation with that maximum electric field magnitude.)*

A, F

A $V=0$

B $V=4V_o$

C $V=2V_o$

D $V=-4V_o$

E $V=-2V_o$

F $V=2V_o$
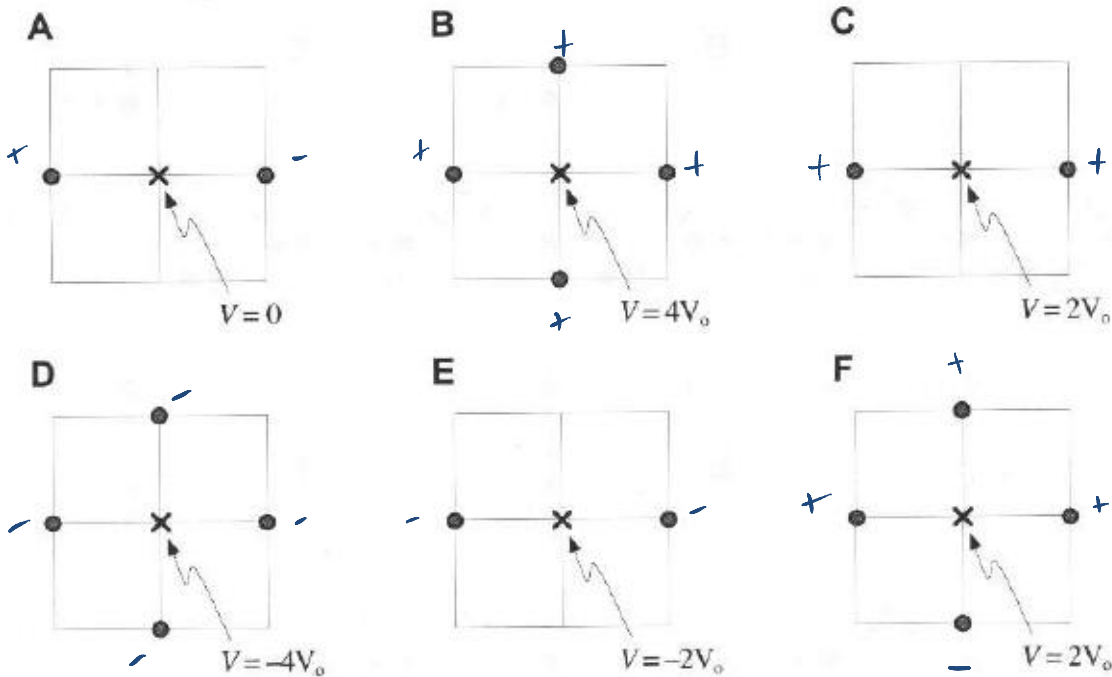
1)	8	/8
2)	6	/6
3)	6	/6
4)	8	/8
5)	10	/10
6)	10	/10
7)	10	/10
8)	11	/11
9)	11	/11
10)	10	/10
11)	10	/10

tot 100 /100

Problem 4 (8 pts):

A battery is connected to a series combination of a switch, a resistor, and an initially uncharged capacitor. The switch is closed at t=0. Which of the following statements is true? Give a brief explanation to justify your answer.

a) As the charge on the capacitor increases, the current increases.
b) As the charge on the capacitor increases, the voltage drop across the resistor increases.
c) As the charge on the capacitor increases, the current remains constant.
d) As the charge on the capacitor increases, the voltage drop across the capacitor decreases.
e) As the charge on the capacitor increases, the voltage drop across the resistor decreases.
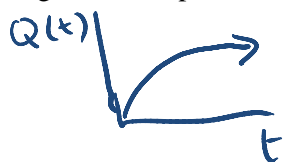
Q increases, $dQ/dt = i$ decreases

$V = iR$ across R also decreases

V across Capacitor increases

Problem 5 (10 pts):

Referring to the figure to the right, determine the current through the circuit
(with the direction of positive current flow defined by the direction of I in the
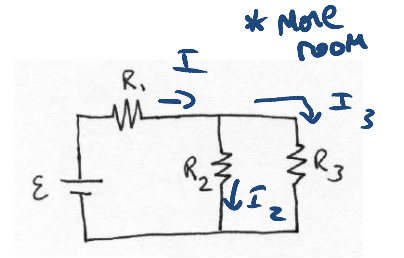figure. Show your work.
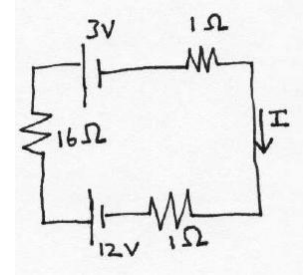
a) +0.83 A
b) -0.50 A
c) +0.5 A *(circled)*
d) +0.55 A
e) -0.92 A

$$\sum V = 0$$
$$-I + 12 - 16I - 3 - I = 0$$
$$-18I = -9$$
$$I = 0.5 \text{ A}$$

Problem 6 (10 pts):

Find the ratio of the power dissipated in resistor 1 to that in resistor 2 to that in
resistor 3, $P_1:P_2:P_3$, for the circuit sketched to the right. Assume $R_1=R_2=R_3$.
Show your work.

$R_{eq} = R$ for Parallel part $\quad \frac{1}{R_{eq}} = \frac{1}{R_2} + \frac{1}{R_3} = \frac{2}{R}$

$$R_{eq} = R/2$$

$$\mathcal{E} = I R_{TOT} = I(R + R/2) \quad P_1 = I^2 R \quad P_2 = \left(\frac{I}{2}\right)^2 R$$

$$P_3 = \left(\frac{I}{2}\right)^2 R$$

$R_1 = R_2 = R_3 = R$

$I_2 = I_3 = \frac{1}{2}I$

so, $P_1 : P_2 : P_3$
$\quad = 4 : 1 : 1$

Problem 7 (10 pts):

Consider two parallel plate capacitors that are identical in every way except that one (capacitor
A) has air between the plates while the other (capacitor B) has a dielectric material between the
plates which has a dielectric constant of 2.

(a) If each capacitor is fully charged by a battery with a potential difference of V, how does
the energy stored in capacitor A compare to that in capacitor B?

$$U = \tfrac{1}{2} C V^2 \quad V \text{ is SAM}$$

$$C \to KC \quad U_A = \tfrac{1}{2} C V^2 \quad U_B = \tfrac{1}{2} K C V^2 \quad U_B = 2U_A$$

(b) Suppose the fully charged capacitors in part (a) are discharged separately through the
same resistor. When capacitor A is discharging through the resistor, it is observed that it
takes 20 seconds for the charge on the capacitor to drop by half. How long will it take for
the charge on capacitor B to drop by half when it is discharging through the resistor?
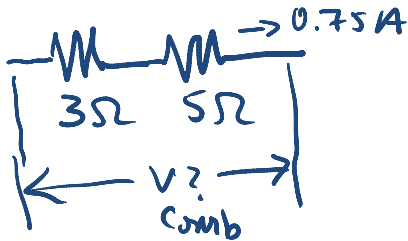
time constant goes as RC

$$q_A(t) = \tfrac{1}{2} q_{init} = q_{init_A} e^{-t_A/RC}$$

$$\tfrac{1}{2} q_{init_B} = q_{init_B} e^{-t_B/RKC}$$

$$e^{-t_A/RC} = e^{-t_B/RKC}$$

$$-\frac{t_A}{RC} = -\frac{t_B}{RKC}$$

$$\frac{t_B}{t_A} = K = 2$$

Will TAKE 40 seconds
for chg on Cap B
to Drop factor of TWO

Problem 8 (11 pts):

Two resistors, 3.0 Ω and 5.0 Ω, are connected in series. The current through the 5.0 Ω resistor is 0.75 A. What is the potential difference across the series combination?
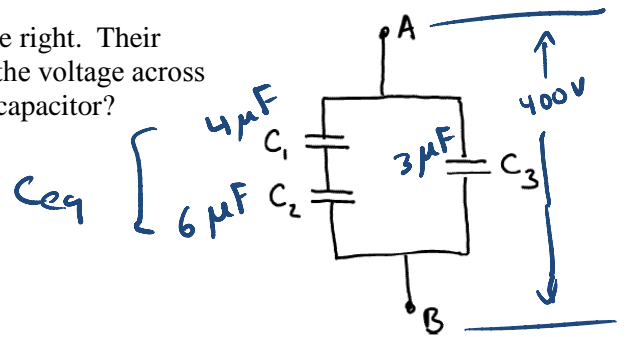
I Thru 3Ω Resistor is Also .75 A

$V_{combination} = (0.75)(3+5)$

$V_{comb} = 6 Volts$

Problem 9 (11 pts):

Three capacitors are connected as shown in the sketch to the right. Their capacitances are $C_1=4.0$ μF, $C_2=6.0$ μF, and $C_3=3.0$ μF. If the voltage across the combination, V_{AB}, is 400V, what is the charge on each capacitor?

$Q_{TOT} = C_{TOT} V$

$C_{TOT} = C_3 + C_{eq}$

$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{4\times10^{-6}} + \frac{1}{6\times10^{-6}}$

$C_{eq} = 2.4$ μF

$\begin{cases} C_{TOT} = 3\times10^{-6} + 2.4\times10^{-6} \\ C_{TOT} = 5.4\times10^{-6} F \\ Q_{TOT} = (5.4\times10^{-6}) 400 \\ Q_{TOT} = 2.2\times10^{-3} Coul \end{cases}$

This part NOT necessary but can be used to check Ans.

in // geom
$Q_1 = Q_2$

$Q_1 = Q_2 = C_{eq} V$

$Q_1 = Q_2 = 2.4\times10^{-6}(400)$

$Q_1 = Q_2 = 9.6\times10^{-4} Coul$

$Q_3 = (3\times10^{-6}) 400 = 1.2\times10^{-3} Coul$

Problem 10 (10 pts):

An infinitely long, straight wire carrying a current I_1 is partially surrounded by a loop as shown in the sketch to the right. The loop has a length L and radius R, and it carries a current I_2. The axis of the loop coincides with the wire. Calculate the force exerted on the loop. (*If it is not obvious from the sketch, each of the semicircular parts of the loop are in a plane that is perpendicular to the long, straight wire and the linear parts of the loop are parallel to and on opposite sides of the long straight wire.*)
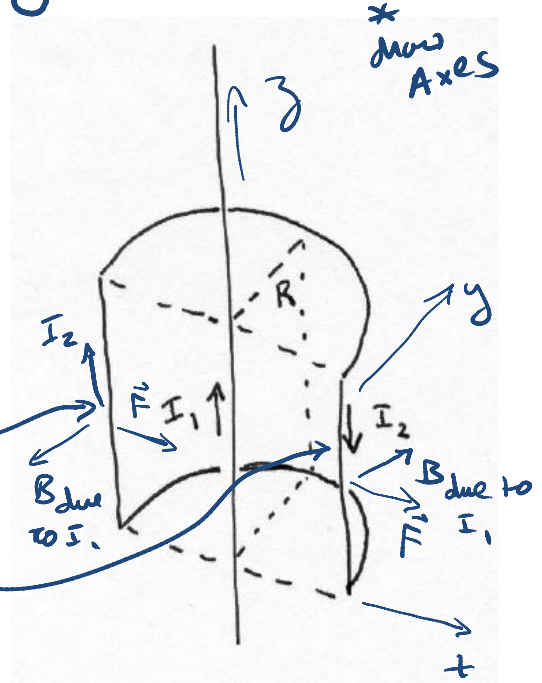
$\vec{B}$ due to I_1 is parallel to $d\vec{i}$ for semicircles

so $\vec{F}_{semicircles} = \ell d\vec{i} \times \vec{B} = 0$

only force comes from straight sides

$\vec{F}$ will be in $\hat{x}$ direction as shown

$\vec{F}_{TOTAL} = 2 L I_2 B = 2 L I_2 \dfrac{\mu_0 I_1}{2\pi R}$

2 straight sides

$$\boxed{\vec{F}_{TOT} = \mu_0 \dfrac{L I_1 I_2}{\pi R} \hat{x}}$$

*show Axes

at Radius R

B_{wire} is ?

$B \, 2\pi R = \mu_0 I_1$

$B_{at\,R} = \dfrac{\mu_0 I_1}{2\pi R}$

Problem 11 (10 pts):

Liquid dielectrics having polar molecules (such as water) always have dielectric constants that decrease with increasing temperature. Why?

* More room ↓

The dilution of the Electric field strength in a Polar dielectric comes about from the degree of alignment of the natural dipoles in the dielectric. As the temperature increases, thermal vibrations will knock the dipoles around reducing the net dipole alignment and reducing the dilution of the field strength. Thus the dielectric constant – which is a measure of that dilution – is reduced.

$E' = \dfrac{E_0}{K}$

Exam 2 Formulas

$$\vec{F} = q\vec{E}$$

$$|e| = 1.6 \times 10^{-19} \text{ coulombs}$$

$$k = 8.99 \times 10^{9} \ \frac{N m^2}{C^2}$$

$$\vec{F} = \frac{k q_1 q_2}{r_{12}^2} \hat{r}_{12} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r_{12}^2} \hat{r}_{12}$$

$$\epsilon_0 = 8.85 \times 10^{-12} \ C^2/N m^2$$

$$\mu_0 = 4\pi \times 10^{-7} \ \frac{Tm}{A}$$

$$\phi_E = \oint \vec{E} \cdot d\vec{A}$$

$$E = E_0 / \kappa$$

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{enclosed}}{\epsilon_0}$$

$$C = \kappa C_0$$

$$Q(t) = C\varepsilon(1 - e^{-t/RC})$$

$$\vec{E} = \int_{vol} \frac{k \, dQ}{r^2} \hat{r}$$

$$Q(t) = Q_0 e^{-t/RC}$$

$$R_{eq} = \sum r_i \left.\right\} \text{For series}$$

$$V = \text{work}/\text{charge}$$

$$1/C_{eq} = \sum \frac{1}{C_i} \left.\right\} \text{geometry}$$

$$V_{POINT \ charge} = \frac{kQ}{r}$$

$$\vec{F} = q\vec{V} \times \vec{B} = \ell \vec{i} \times \vec{B}$$

$$\vec{\mu} = nI A$$

$$V = \int_{vol} \frac{k \, dQ}{r}$$

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

$$E_s = -dV/ds$$

$$B_{solenoid} = \mu_0 n I$$

$$V = I R$$

$$Q = CV$$

$$\vec{B} = \frac{\mu_0}{4\pi} \int \frac{i \, d\vec{\ell} \times \hat{r}}{r^2}$$

$$U = \tfrac{1}{2} C V^2$$

$$\oint_{curve} \vec{B} \cdot d\vec{\ell} = \mu_0 I_{encl}$$

$$P = IV = I^2 R = \frac{V^2}{R}$$

$\sin\theta = \dfrac{o}{h}$ $\cos\theta = \dfrac{a}{h}$

$\tan\theta = \dfrac{o}{a}$
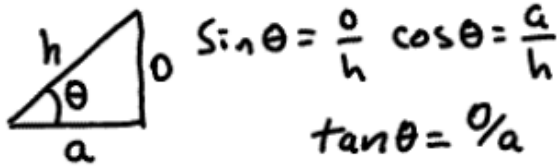
Sphere: $A = 4\pi r^2$ $V = \dfrac{4}{3}\pi r^3$

cylinder: $A = 2\pi r L + 2\pi r^2$

$V = \pi r^2 L$

$a_c = \dfrac{mv^2}{r}$

$S = r\theta$

$KE = \frac{1}{2} mv^2$

$PE_{spring} = \frac{1}{2} k x^2$

$V = V_0 + at$

$x = x_0 + V_0 t + \frac{1}{2} a t^2$

$V^2 = V_0^2 + 2a(x - x_0)$

$x = x_0 + \frac{1}{2}(V + V_0)t$

$\displaystyle\int u^n du = \dfrac{u^{n+1}}{n+1}$

$\displaystyle\int \dfrac{du}{u} = \ln|u|$

$\displaystyle\int e^u du = e^u$

$\displaystyle\int \dfrac{x\,dx}{(x^2+a^2)^{1/2}} = \sqrt{x^2+a^2}$