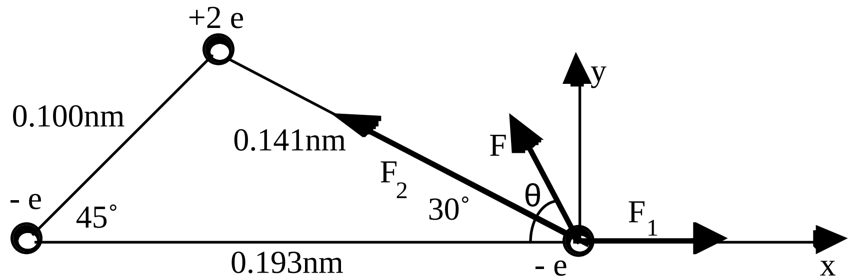
Physics 4B FINAL EXAM Chapters 22 - 34 Spring 1997

Name:____ Posting Code _____ _____ _____

Solve the following problems in the space provided. Use the back of the page if needed. Each problem is worth 10 points. You must show your work in a logical fashion starting with the correctly applied physical principles which are on the last page. Your score will be maximized if your work is easy to follow because partial credit will be awarded.

1. At some instant the nucleus of a helium atom and its orbiting electrons are oriented as shown. Find the electric force (magnitude and direction) felt by the electron at the bottom right.



The electric forces due to the point charges are given by Coulomb's Rule:

$$F_1 = k\frac{(e)(e)}{r_1^2} = (9x10^9)\frac{(1.6x10^{-19})^2}{(0.193x10^{-9})^2} = 6.19x10^{-9}N$$

$$F_2 = k\frac{(2e)(e)}{r_2^2} = (9x10^9)\frac{2(1.6x10^{-19})^2}{(0.141x10^{-9})^2} = 2.32x10^{-8}N$$

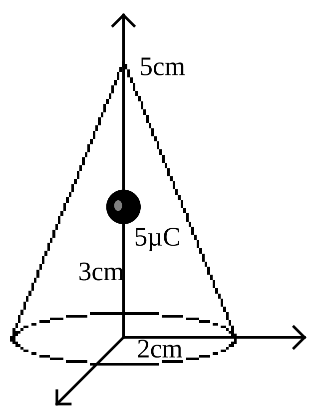
Adding the vector components:

$F_x = F_1 - F_2\cos30^\circ = -1.39x10^{-8}N$ and $F_y = F_2\sin30^\circ = 1.16x10^{-8}N$

The magnitude and direction are:

$\boxed{F = \sqrt{F_x^2 + F_y^2} = 1.81x10^{-8}N}$ and $\boxed{\theta = \arctan\frac{F_y}{F_x} = 40^\circ}$ above the -x axis.

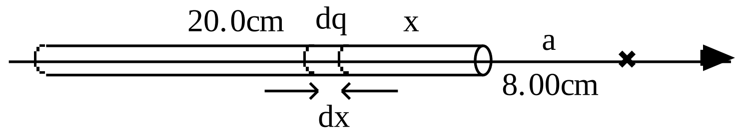
2. A 5.00μC charge is located 3.00cm upward from the center of the base of a cone of radius 2.00cm and height 5.00cm. Find the total electric flux leaving the cone.



Applying Gauss's Law to the entire cone,

$$\oint \vec{E}\cdot d\vec{A} = \frac{q_{enclosed}}{\varepsilon_o} \qquad \Phi_{total} = \frac{q_{enclosed}}{\varepsilon_o} \qquad \Phi_{total} = \frac{5.00x10^{-6}}{8.85x10^{-12}} = \underline{\underline{5.65x10^5\ V\ m}}\ .$$

3. Find the potential due to a 20.0cm long rod that has a linear charge density of 2.00μC/m at a point 8.00cm from the end of the rod along the same axis as the rod.

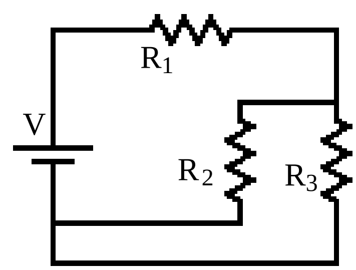


The potential due to the point charge dq is, $dV = k\frac{dq}{r}$.
The charge dq can be written in terms of the charge density, $dq = \lambda dx$.
The distance between dq and the point where we need the field is, $r = x + a$.

The potential is, $dV = k\frac{\lambda dx}{x+a}$ $\quad V = k\lambda\int_0^L \frac{dx}{x+a} = k\lambda \ln\left(\frac{L+a}{a}\right)$.

Plugging in the numbers, $V = (9x10^9)(2x10^{-6})\ln\left(\frac{28}{8}\right) = \underline{\underline{2.25x10^4 V}}$.

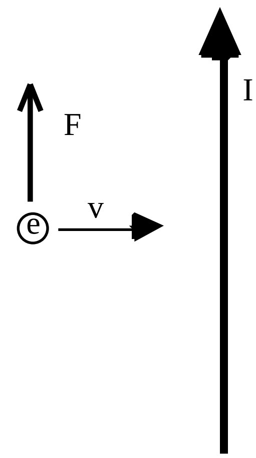
4. For the circuit shown the potential difference across R_2 is measured to be 12.0V. Find (a)the potential difference across each resistor, (b)the current through each resistor, (c)the current supplied by the battery and (d)the battery voltage. R_1=300Ω, R_2=900Ω and R_3=1800Ω.



V(V)	I(mA)	R(Ω)
6.00	20.0	300
12.0	13.3	900
12.0	6.67	1800
18.0	20.0	battery

(a)&(b)R_2 and R_3 are in parallel so by the loop theorem they have the same potential difference of 12.0V.
The current in R_1 and R_2 can each be found using Ohm's Rule,
$V = iR \quad i = \frac{V}{R_2} = \frac{12}{900} = 13.3mA$ and $V = iR \quad i = \frac{V}{R_3} = \frac{12}{1800} = 6.67mA$.
By the junction theorem, the current through R_1 must be $i_1 = i_2 + i_3 = 13.3 + 6.67 = 20.0mA$.
The voltage across R_1 can be found from Ohm's Rule, $V = iR = (20.0m)(300) = 6.00V$.
(c)Since R_1 is in series with the battery, the current through it is the same as the battery.
(d)Using the loop theorem, the voltage the battery must equal the voltage on R_1 plus the voltage across either R_2 or R_3. $V = V_1 + V_2 = 6.00 + 12.0 = 18.0V$.

5. A electron moves at 750km/s toward a wire carrying 150A as shown at the right. When the electron is 15.0cm from the wire, find the magnitude and direction of the force on the electron. If you want full credit on the direction, explain your reasoning.



The electron is in the magnetic field of the wire which is,

$$B = \frac{\mu_o I}{2\pi r} = (2.00\text{x}10^{-7})\frac{150}{0.15} = 200\mu T.$$

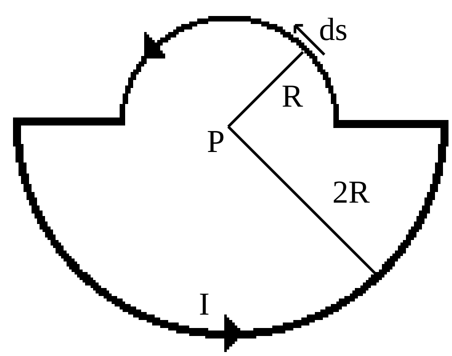
The force on the moving charge is,

$$\vec{F} = q\vec{\upsilon} \times \vec{B} \qquad F = q\upsilon B = (1.6\text{x}10^{-19})(750\text{x}10^{3})(200\text{x}10^{-6}) = \underline{\underline{2.40\text{x}10^{-17}\text{ N}}}$$

since the field is perpendicular to the velocity.

The magnetic field is out of the page so $\vec{\upsilon} \times \vec{B}$ is down the page. Since the charge is negative, the force must be up the page as shown at the right.

6. Find the magnitude and indicate the direction of the magnetic field at the point P which is at the common center of the semi-circular arcs carrying a current I shown in the sketch.



Use the Biot-Savart Rule $\vec{B} = \frac{\mu_o}{4\pi}\int \frac{Id\vec{s} \times \hat{r}}{r^2}$.

Along the top arc, ds is always perpendicular to R so, $B_t = \frac{\mu_o}{4\pi}\int \frac{Ids}{R^2}$.

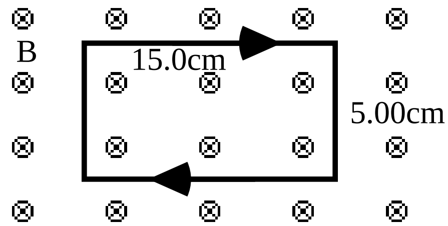
Since I and R are constant, $B_t = \frac{\mu_o I}{4\pi R^2}\int ds = \frac{\mu_o I}{4\pi R^2}\pi R = \frac{\mu_o I}{4R}$.

Along the straight sections ds is always parallel to R so they create no field at P.

The contribution of the bottom arc is the same as the top except the radius is twice as big, $B_b = \frac{\mu_o I}{8R}$.

The total field is $\boxed{B = B_t + B_b = \frac{\mu_o I}{4R} + \frac{\mu_o I}{8R} = \frac{3\mu_o I}{8R}}$. This field is out of the page by the right hand rule.

7. A plane rectangular loop of wire has 12 turns. It is 15.0cm wide and 5.00cm tall. It has a total resistance of 2.00Ω. A magnetic field of 2.50T is directed perpendicular to the plane of the loop as shown. This field is reduced to 1.00T at a uniform rate in 3.00ms. Find the current induced in the loop and indicate its direction in the sketch.



Apply Faraday's Law $\oint \vec{E}\cdot d\vec{s} = -\frac{d\Phi_B}{dt}$ $\quad V = N\frac{\Delta\Phi_B}{\Delta t}$.

Using the definition of flux and the fact that the field is constant and perpendicular to the plane of the loop,

$\Phi_B \equiv \int \vec{B}\cdot d\vec{A} = Bwh \qquad \Delta\Phi_B = \Phi_f - \Phi_i = B_f wh - B_f wh = wh\Delta B$

The voltage is now, $V = Nwh\frac{\Delta B}{\Delta t}$.

Using Ohm's Rule, $IR = Nwh\frac{\Delta B}{\Delta t} \qquad I = \frac{Nwh\Delta B}{R\Delta t}$.

Putting in the numbers, $I = \frac{Nwh\Delta B}{R\Delta t} = \frac{(12)(0.15)(0.050)(2.50-1.00)}{(2.00)(0.003)} = \underline{\underline{22.5A}}$

Since the field into the page is decreasing, the field caused by the induced current will try to make up for the loss and point into the page as well. Therefor, the current will be clockwise. This is Lenz's Rule.

8. A 28.0μH inductor is used in an FM radio tuner. Find the capacitance of the tuner circuit when it is receiving at station at 106.7Mhz.

The resonance frequency of an LC circuit is $\omega = \frac{1}{\sqrt{LC}} \qquad 2\pi f = \frac{1}{\sqrt{LC}} \qquad C = \frac{1}{4\pi^2 f^2 L}$.

Plugging in the numbers, $C = \frac{1}{4\pi^2(106.7x10^6)^2(28.0x10^{-6})} = \underline{\underline{7.95x10^{-14}F}}$

9. A 20.0μF capacitor is connected to a 60.0Hz - 15.0V rms power supply. Find the rms current through the capacitor.

Using the definition of impedance and the impedance of a capacitor,

$$V_{C,rms} = i_{C,rms}\chi_C \qquad i_{C,rms} = \frac{V_{C,rms}}{\chi_C} = 2\pi f C V_{C,rms}$$

Putting in the numbers, $\boxed{i_{C,rms} = 2\pi(60)(20x10^{-6})(15) = 113mA}$.

10. The peak electric field 10.0m away from a small light bulb is 2.00N/C. Find (a)the peak magnetic field and (b)average intensity of the light 10.0m away. (c)Find the total power radiated by the light bulb.

(a)The ratio of the peak fields is, $B_m = \frac{E_m}{c} = \frac{2.00}{3.00x10^8} = \underline{\underline{6.67nT}}$.

(b)The average intensity is related to the peak fields, $\bar{I} = \frac{E_m^2}{2\mu_o c} = \frac{(2.00)^2}{2(4\pi x10^{-7})(3.00x10^8)} = \underline{\underline{5.31\,\tfrac{mW}{m^2}}}$.

(c)Using the definition of intensity, $I \equiv \frac{P}{A} = \frac{P}{4\pi r^2} \qquad P = 4\pi r^2 I = 4\pi(10.0)^2(0.00531) = \underline{\underline{6.67W}}$.