Exam 3: Physics 2113 Spring 2015 **8:00 PM, Monday, 30 March 2015**

Last Name (print) KEY **First Name (print)**

Clearly circle your section:

MON/WEDS/FRI SECTIONS				TUES/THURS SECTIONS	
M. Gaarde 10:30 AM	J. Dowling 12:30 PM	J. Moreno 2:30 PM	D. Rupnik 3:30 PM	D. Rupnik 12:00 PM	R. Beaird 1:30 PM

Answer all 3 problems & all 4 questions.

Be sure to write your name. Please read the questions carefully.

You may use only scientific or graphing calculators. *In particular you may not use the calculator app on your phone or tablet!*

You may detach and use the formula sheet provided at the back of this test. No other reference materials are allowed.

You may not answer or use cell phones during the exam. Please note that the official departmental policy for exams is as follows:

> "During your test, the only electronic device you may have with you at your seat is a scientific or graphing calculator. You may not have your cell phone, tablet, smartphone, smart watch, PDA, pager, digital camera, computer, or any other device capable of taking pictures or video, sending text messages, or accessing the Internet. This means not just on your person, but close enough to you that you could reach it during the test. Any student found with such a device during a test will be assumed to be violating the LSU Honor Code and will be referred to the Dean of Students for Judicial Affairs."

The simplest remedy is to bring nothing to this test but the calculator, and leave your backpack or purse at home. *If you have brought your cell phone or tablet with you, please leave it at the front of the room under the watchful eye of your instructor.*

Some questions are multiple-choice. You should work these problems starting with the basic equation listed on the formula sheet and write down all the steps. Although the work will not be graded, this will help you make the correct choice and to determine if your thinking is correct.

On problems that are not multiple-choice, be sure to show all of your work, since no credit will be given for an answer without explanation or work. These will be graded in full, and you are expected to show all relevant steps that lead to your answer.

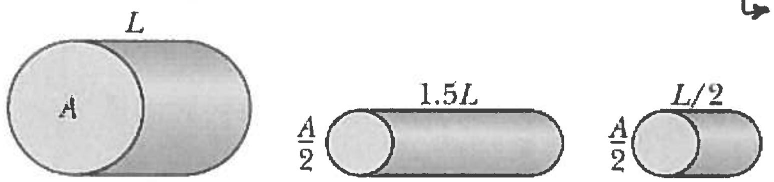
Please use complete sentences where explanations are asked for. For numerical answers that require units you must give the correct units for full credit.

YOU GET 60 min (1 hr) to complete the examination.

VERSION 1

1. (Question) [8 points] The figure below shows three cylindrical copper conductors along with their face areas and lengths. The same potential difference V is placed across their lengths.

$\hookrightarrow V_a = V_b = V_c = V$



(a) (b) (c)

$P = \frac{V^2}{R} \propto \frac{1}{R}$; $R = \rho \frac{L}{A}$

$\Rightarrow P \propto \frac{A}{L}$ ... V and ρ are the same

a) **[4 points]** Rank them according to their resistivity ρ, greatest first. (Circle one.)

$\rho_a > \rho_b > \rho_c$ $\qquad$ $\rho_b > \rho_a = \rho_c$ $\qquad$ $\rho_a = \rho_c > \rho_b$

$\rho_a = \rho_b > \rho_c$ $\qquad$ $\rho_a = \rho_b = \rho_c$ ... all 3 are of the same material (copper)

$\Rightarrow \rho$ is the same

b) **[4 points]** Rank them according to the power P dissipated by them, ***smallest first.*** (Circle one.)

$P_a < P_b < P_c$ $\qquad$ $P_b < P_a = P_c$ $\qquad$ $P_a = P_c < P_b$

$P_a = P_b < P_c$ $\qquad$ $P_a = P_b = P_c$

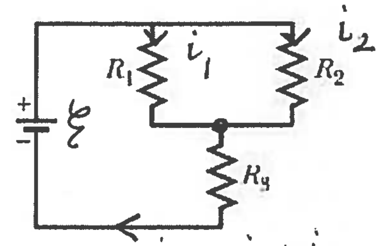
	a	b	c
"$\frac{A}{L}$"	$\frac{A}{L}$	$\frac{A}{3L}$	$\frac{A}{L}$

$a = c > b$

OR $b < a = c$

2. (Question) [8 points] The figure shows a circuit with three resistors, where $R_3 > R_2 > R_1$.

a) **[4 points]** Rank the resistors according to the net current through each of them. (Circle one.)



$i_1 = i_2 > i_3$ $\qquad$ $i_3 > i_1 = i_2$ $\qquad$ $i_3 > i_2 > i_1$

$i_3 > i_1 > i_2$ $\qquad$ $i_1 = i_2 = i_3$

$V_1 = V_2$

$i_1 R_1 = i_2 R_2$

$R_2 > R_1$

$\Rightarrow i_2 < i_1$

$i_3 = i_1 + i_2$

$\Rightarrow i_3 > i_1$, $i_3 > i_2$

b) **[4 points]** Rank the resistors according to the potential difference across each of them. (Circle one.)

$V_1 = V_2 > V_3$ $\qquad$ $V_3 > V_1 = V_2$ $\qquad$ $V_3 > V_2 > V_1$

$V_3 > V_1 > V_2$ $\qquad$ $V_1 = V_2 = V_3$

$V + V_3 = \mathcal{E}$

$V_1 = V_2 = V$

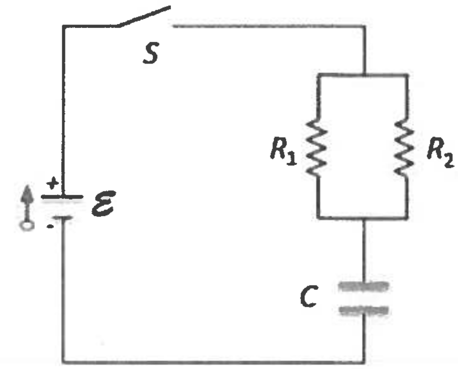
i_3 is the largest current

R_3 is the largest resistance

$\Rightarrow i_3 R_3 = V_3$ is the largest pot. diffr

$\Rightarrow V_3 > V_1 = V_2$

3. (Problem) [21 points] The figure below shows an RC circuit in which the battery has $\mathcal{E}$ = 12 V, the resistors $R_1 = R_2$ = 4.0 MΩ, and the capacitor C = 1.5 μF. Initially the capacitor is empty. The switch S is closed at time t = 0.



a) **[7 points]** Calculate the time constant. SHOW YOUR WORK!

$$\tau = RC = \left(\frac{R_1 R_2}{R_1 + R_2}\right) C = \frac{R}{2} C$$

$$\tau = \frac{(4\times10^6\,\Omega)}{2}(1.5\times10^{-6}F) = 3.0\ s$$

$$R_{eq} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} = \frac{R_1 R_2}{R_1 + R_2}$$

R_1, R_2... in parallel

b) **[7 points]** Find the maximum charge that will appear on the capacitor plates during charging. SHOW YOUR WORK!

$$q(t) = q_0(1 - e^{-t/RC}) \quad \text{where } q_0 = C\mathcal{E}$$

$$q_0 = C\mathcal{E} = (1.5\times10^{-6}F)(12V) = 18\,\mu C$$

c) **[7 points]** Find the time it takes for the charge on the capacitor to build up to 70% of this maximum charge. SHOW YOUR WORK!

$q(t) = 0.7C\mathcal{E}$; $q(t) = C\mathcal{E}(1 - e^{-t/RC})$; $RC = 3s$

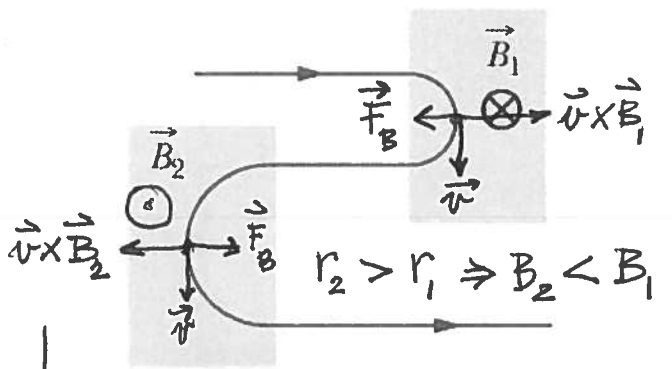
$$0.7\cancel{C\mathcal{E}} = \cancel{C\mathcal{E}} - \cancel{C\mathcal{E}}\, e^{-t/RC}$$

$$e^{-t/RC} = 1 - 0.7 = 0.3 \quad /\ln$$

$$t = -RC \ln 0.3 = -(3)\ln 0.3 = 3.61\,s$$

$$t \simeq 3.6\,s$$

4. (Question) [12 points] The figure shows the path of a charged particle that passes through two regions containing uniform magnetic fields of magnitudes B_1 and B_2. Its path in each region is a half-circle.



$\Rightarrow$ $\vec{v}\times\vec{B}$ is in the opposite direction to $\vec{F}_B$ $\Rightarrow$ charge is negative

to get $\vec{v}\times\vec{B}$ in opposite direction to $\vec{F}_B$, $\vec{B}_2$ has to be $\odot$

a) [4 points] What is the sign of the charge of the particle? (Circle one.)

Positive Negative Neutral

b) [4 points] Which field is stronger? $|\vec{v}|$ does not change, $r = \frac{mv}{qB} \propto \frac{1}{B}$

$B_1 > B_2$ $B_2 > B_1$ $B_1 = B_2$

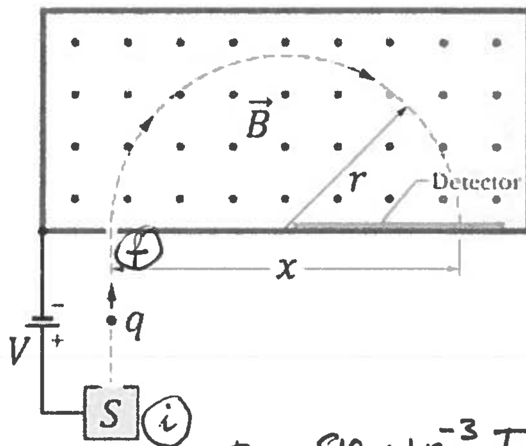
• larger the radius r weaker the field B

c) [4 points] What is the direction of the field B_2? (Circle one.)

Into the page ⊗ Out of the page ⊙ Up ↑

Down ↓ Not enough info to decide

5. (Problem) [21 points] The figure shows a mass spectrometer, which can be used to measure the mass m of an ion with charge q. The initially stationary ion is accelerated from source S through a potential difference V. In the separator chamber, a uniform magnetic field $\vec{B}$ causes the ion to move in a semi-circle and strike the detector along the bottom wall of the chamber, at distance x from the entrance slit. Suppose that B = 80.0 mT, V = 1000 V, and ions have charge $q = +1.60\times10^{-19}$ C and mass $m = 1.244 \times 10^{-25}$ kg.



$$F_B = F_{cp} \quad q\cancel{v}B = \frac{mv^{\cancel{2}}}{r} \Rightarrow r = \frac{mv}{qB}$$

$B = 80\times10^{-3}$ T
$q = +1.6\times10^{-19}$ C
$m = 1.244\times10^{-25}$ kg
$V = 1000$ V

a) **[7 points]** Calculate the speed of an ion as it is entering the separator chamber. SHOW YOUR WORK!

$$(K+U)_i = (K+U)_f \quad K_i = 0,\ U_f = 0,\ U = qV$$

$$qV = \tfrac{1}{2}mv^2$$

$$v = \sqrt{\frac{2qV}{m}} = \sqrt{\frac{2(1.6\times10^{-19})(1000)}{1.244\times10^{-25}}} = 5.07\times10^{4}\ m/s$$

b) **[7 points]** Calculate the distance x, from the entrance slit to the point that the ion strikes the detector. SHOW YOUR WORK!

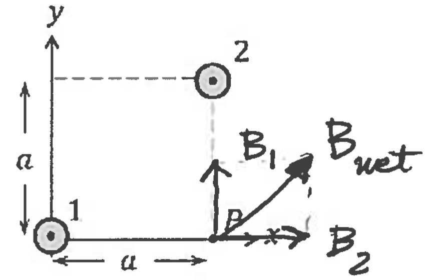
$$\left.\begin{aligned} x &= 2r \\ r &= \frac{mv}{qB} \end{aligned}\right\} \quad x = \frac{2mv}{qB} = \frac{2(1.244\times10^{-25})(5.07\times10^{4})}{(1.6\times10^{-19})(80\times10^{-3})}$$

$$x = 9.85\times10^{-1}\ m = 98.5\ cm$$

c) **[7 points]** How long does it take for an individual ion to reach the detector after entering the separator chamber? SHOW YOUR WORK!

$$t = \frac{T}{2} = \frac{\pi m}{qB} = \frac{\pi(1.244\times10^{-25})}{(1.6\times10^{-19})(80\times10^{-3})} = 3.05\times10^{-5}\ s = 30.5\ \mu s$$

6. (Problem) [20 points] Two long straight wires are located at two out of four corners of a square of edge length a = 8.50 cm. The wires carry currents $i_1 = i_2$ = 15.0 A which are both directed out of the page.



(a) [10 points] What is the magnitude of the net magnetic field at point P? SHOW YOUR WORK!

$$\vec{B}_1 \perp \vec{B}_2 \Rightarrow \vec{B}_{net} = \vec{B}_1 + \vec{B}_2, \quad B_{net} = \sqrt{B_1^2 + B_2^2}$$

$$B_1 = B_2 = \frac{\mu_0 i}{2\pi a}$$

$$B_{net} = \frac{\mu_0 i}{2\pi a}\sqrt{2} = \frac{(\cancel{4}^{2}\cancel{\pi}\times10^{-7})(15)}{\cancel{2\pi}(0.085)}\sqrt{2}$$

$$B_{net} = 4.99\times10^{-5}\ T \simeq 5.0\times10^{-5}\ T$$

$i_1 = i_2 = i = 15A$

$a = 0.085$ m

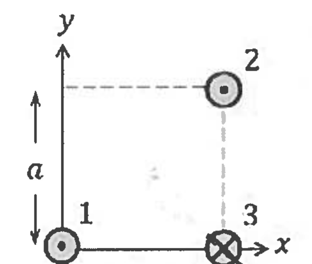
$B = \frac{\mu_0 i}{2\pi r}$

$r = a$

(b) [4 points] Circle the arrow that *best* represents the direction of the net magnetic field at P.

see the figure

(c) [6 points] A third wire is now placed parallel to the other two wires so that it passes through point P and carries a current i_3 = 12.0 A directly into the page. What is the magnitude of the net magnetic force per unit length on wire 3? SHOW YOUR WORK!



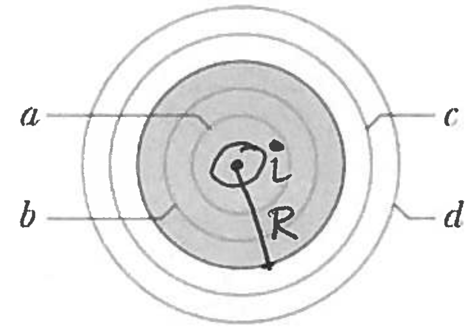
$i_3 = 12A$, into the page

$$F_3 = i_3 L B_{net}, \quad \theta_{L, B_{net}} = 90°, \quad \sin 90° = 1$$

$$\frac{F_3}{L} = i_3 B_{net} = (12)(5.0\times10^{-5}) = 6.0\times10^{-4}\ N/m$$

$$\frac{F_3}{L} \simeq .6\ mN/m$$

7. (Question) [10 points] The figure shows four circular Amperian loops (*a*, *b*, *c*, and *d*) concentric with a wire whose current is directed **out of the page**. The current is **uniform** across the wire's circular cross section (the shaded region).



a) **[5 points]** Rank the loops according to the magnitude of $\oint \vec{B} \cdot d\vec{s}$ around each, greatest first. (Circle one.)

$a = b = c = d$

$a = b > c > d$

$c > d > a = b$

$c = d > b > a$

$c = d > a > b$

$\oint \vec{B} \cdot d\vec{s} = \mu_0 i_{enc}$

$c = d > b > a$ $\quad i_{enc} = i$ for loops c and d

$(i_{enc})_b < i$ because the area of loop b is smaller than $R^2\pi$

$(i_{enc})_a < (i_{enc})_b$

b) **[5 points]** Which statement is true for the loops *c* and *d*? (Circle one.)

$|\vec{B}_c| > |\vec{B}_d|$ and both fields are clockwise (CW)

$|\vec{B}_c| > |\vec{B}_d|$ and both fields are counterclockwise (CCW)

$|\vec{B}_d| > |\vec{B}_c|$ and both fields are clockwise (CW)

$|\vec{B}_d| > |\vec{B}_c|$ and both fields are counterclockwise (CCW)

$|\vec{B}_c| > |\vec{B}_d|$ and field B_c is clockwise (CW) and field B_d is counterclockwise (CCW)

B outside of a long wire (cylindrical symmetry) is $B = \frac{\mu_0 i}{2\pi r} \propto \frac{1}{r} \Rightarrow B_c > B_d$ because $r_c < r_d$

RHR: $\left.\begin{array}{l}\text{thumb} \equiv \text{dir. of } i \\ \text{fingers} \equiv \text{dir. of } B\end{array}\right\}$ $\vec{B}$ is CCW