Physics 208 – Comprehensive Exam

Fall 2018 (all sections) - November 30, 2018.

Please fill out the information and read the instructions below, but
do not open the exam until told to do so.

Rules of the exam:

1. You have 120 minutes (2.0 hrs.) to complete the exam.
2. Formulae are provided to you with the exam on a separate sheet. Make sure you have one before the exam starts. You may not use any other formula sheet.
3. Check to see that there are 8 numbered (4 double-sided) pages plus a blank page for additional work if needed, in addition to the scantron-like cover page. Do not remove any pages.
4. If you run out of space for a given problem, the last page has been left blank and may be used for extra space. **Be sure to indicate at the problem under consideration that the extra space is being utilized so the graders know to look at it!**
5. You will be allowed to use only non-programmable calculators on this exam.
6. **NOTE** that you **must** show your work clearly to receive full credit.
7. Cell phone use during the exam is strictly prohibited. Please turn off all ringers as calls during an exam can be distracting.
8. Be sure to put a box around your final answer(s) and clearly indicate your work. Credit can be given only if your work is legible, clearly explained, and labelled.
9. All of the questions require you show your work and reasoning.
10. Have your TAMU ID ready when submitting your exam to the proctor.

Fill out the information below and sign to indicate your understanding of the above rules

Name:______________________________ UIN:__________________

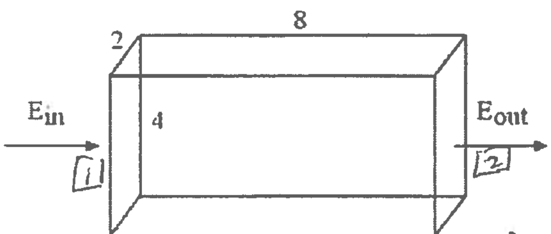
(please print legibly)

Signature:___________________________ Section Number:______________

Instructor: **Webb** **Kocharovskaya**
(circle one)

A. A rectangular box is in a horizontal E-Field, where the field is in the direction of the long side of the box as shown in the figure. The sides are 4.0 cm by 8.0 cm (along the direction of the field) with a height of 2.0 cm (out of the page). The field is 90.0 V/m entering on the left and 50.0 V/m leaving on the right.

i.) Find the total flux of this E-field passing through the surface of the box.
ii.) Find the charge enclosed in the box.



LO	P	F
7.1		
15.1		
16.1		
3.1		

2.1

A) $\Phi_E = \oint \vec{E} \cdot d\vec{A} = \int_1 + \int_2 + \underbrace{\int_3 + \int_4 + \int_5 + \int_6}_{\text{all other fluxes } 0 \text{ since } d\vec{A} \perp \vec{E}} = -\int_1 E_{in} dA + \int_2 E_{out} dA$

$= (50-90)[.02 \times .04] m^2$

$= 3.2 \times 10^{-2}$ Vm

B) From Gauss's Law $\quad \Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{q_{enc}}{\epsilon_0}$

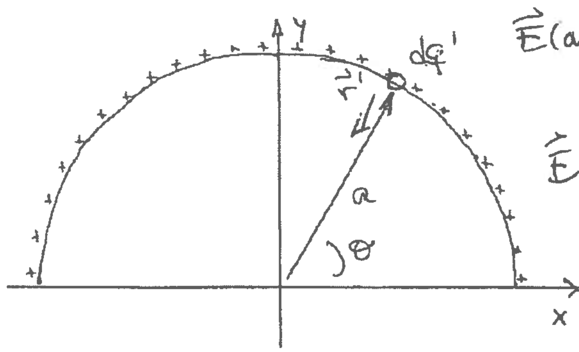
so $q_{enc} = \epsilon_0 \Phi_E = (8.9 \times 10^{-12})(3.2 \times 10^{-2}) \simeq 28 \times 10^{-14}$ Coul

B. A uniform positive line charge, λ, is distributed on a semicircle of radius a in the upper half-plane as shown. Find the electric field due to this charge distribution at the origin.

$\vec{E}(\text{origin}) = \int \frac{k\,dq'}{r^2} (-\cos\theta' \hat{i} - \sin\theta' \hat{j})$

$= \frac{k}{r^2} \int_0^\pi \lambda R\,d\theta (-\cos\theta' \hat{i} - \sin\theta' \hat{j})$

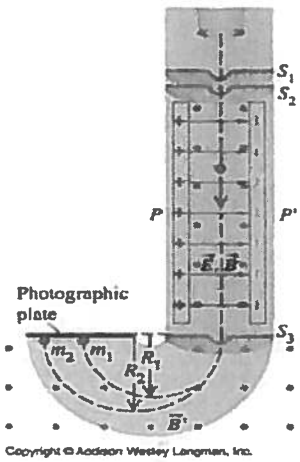
LO	P	F
12.1		
7.2		
1.1		
3.2		



$\vec{E}(\text{origin}) = \frac{k\lambda}{R} \left\{ -\sin\theta \Big|_0^\pi \hat{i} + \cos\theta \Big|_0^\pi \hat{j} \right\}$

$\vec{E}(\text{origin}) = \frac{k\lambda}{R} (-2) \hat{j}$

C. A mass spectrometer (a device for measuring the mass of the an ion) is pictured in the Figure below. What are the charge signs of two ions which paths are plotted? If these two ions have the same charge, which mass m_1 or m_2 is bigger? Explain your results using words and supporting equations.



a) $\vec{F}_{mag} = q\vec{v}\times\vec{B}$ force to the left F with B out of page

from cross product $q = +$

b) $\frac{MV}{qB} = R$ so if $R_2 > R_1$ then $M_2 > M_1$ for same velocity and charge

LO	P	F
2.2		
3.3		
46.1		
48.1		

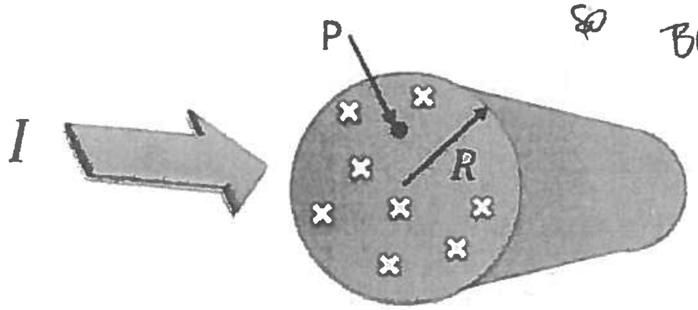
D. A long, straight, solid wire has radius *R*. A cross-sectional view is shown here. A current *I* is flowing down the wire, into the page, and the current is distributed uniformly over the cross-section of the wire. Find the magnitude and the direction of the magnetic field at the point P shown (inside the wire), which is **half way** (R/2) between the center line of the wire and the top edge of the wire.

using Ampere's Law

$\oint \vec{B}\cdot d\vec{\ell} = \mu_0 I_{through}$

so $B(r)(2\pi r) = \mu_0\left(\frac{I}{\pi R^2}\right)\pi r^2$

LO	P	F
2.3		
5.1		
7.3		
54.1		
55.1		



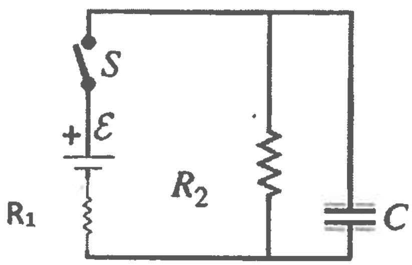
Solving for $B(r) = \frac{\mu_0 I}{\pi R^2}\left(\frac{\pi r^2}{2\pi r}\right)$

$= \frac{\mu_0 I r}{2\pi R^2}$

with B-field clockwise

E. In the circuit below, the capacitor is initially uncharged. The switch **S** is closed at t=0. Answer the following in terms of the quantities, R_1, R_2, $\mathcal{E}$ and C.

i.) What is the initial voltage across the capacitor?
ii.) What are the initial currents through each resistor and the capacitor?
iii.) What are currents through each resistor and the capacitor after the switch is closed for a long time?
iv.) What is the voltage across the capacitor in the long time limit?
v.) Considering R_1 as the internal resistance of the battery, find the terminal voltage of the battery in the long time limit.
vi.) Considering R_1 as the internal resistance of the battery, find the power output of the battery in the long time limit.



i) $V_{cap}(t=0) = 0$ since $q(t=0) = 0$

ii) $i(t=0)$ through $R_1 = \mathcal{E}/R_1$
through $R_2 = 0$
through $C = \mathcal{E}/R_1$

iii) $i(t=\infty)$ through $R_1 = \mathcal{E}/R_1+R_2$
through $R_2 = \mathcal{E}/R_1+R_2$
through $C = 0$

iv) voltage across C at $t=\infty$
$V_c = \left(\frac{\mathcal{E}}{R_1+R_2}\right) R_2$

v) terminal voltage of battery
$V_{terminal} = \mathcal{E} - \left(\frac{\mathcal{E}}{R_1+R_2}\right) R_1$

vi) Power delivered to the circuit
$P = I V_{terminal} = \left(\frac{\mathcal{E}}{R_1+R_2}\right)\left(\frac{\mathcal{E} R_2}{R_1+R_2}\right) = \frac{\mathcal{E}^2}{(R_1+R_2)^2} R_2$

LO	P	F
43.1		
45.1		
43.2		
45.2		
43.3		
45.3		
43.4		
45.4		
39.1		
43.5		
40.1		
43.6		
3.4		

F. You are given a series R-L-C with R = 60.0 Ω, L = 0.40 H, and C = 4.00 X 10 $^{-4}$ F. The AC source has a voltage amplitude of 90.0 V and an angular frequency of 240 rad/sec.

i.) Find the impedance of this circuit.

ii.) What is the maximum current that flows in this circuit?

iii.) What is the maximum energy stored in the inductor?

iv.) When the energy in the inductor is at its maximum value, how much energy is stored in the capacitor?

v.) What is the maximum energy stored in the capacitor?

LO	P	F
68.1		
36.1		
36.2		
64.1		
67.1		
31.1		

i) $Z = \sqrt{R^2 + \left(L\omega - \frac{1}{C\omega}\right)^2} = \sqrt{(60)^2 + \left(.4(240) - \frac{1}{4\times10^{-4}(240)}\right)^2}$

$= 104.5\Omega$

ii) $I_{max} = \frac{\mathcal{E}_{max}}{Z} = 90V / 104.5\Omega = 0.86A$

iii) Energy stored in the inductor $= \frac{1}{2} L I_{max}^2$

$E_{max} = \frac{1}{2}(.4)(.86)^2 = .15$ joules

iv) when energy in the inductor is maximum energy in the capacitor is minimum, so $U_{cap} = 0$.

v) $U_{max\ capacitor} = U_{max\ inductor} = 0.15$ joules.

Problem 1.

A very long conducting wire of length L and radius R is uniformly charged with a total positive charge Q that is placed inside a concentric conducting tube of same length. The tube has an inner radius of $2R$ and an outer radius of $3R$, and has the same charge Q. The setup is shown in the figure below. In terms of R, Q, L, d and other known and given constants, answer the following:

a) Sketch the distribution of the electric field lines at equilibrium as viewed from above in the z-direction.

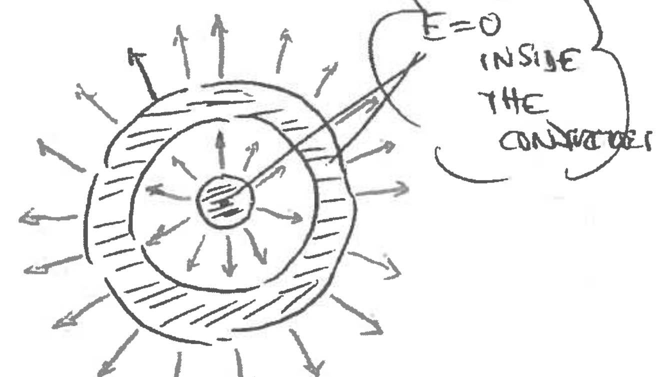
b) Find the electric flux passing through an external concentric cylindrical surface T of radius $4R$ and height h shown in the figure.

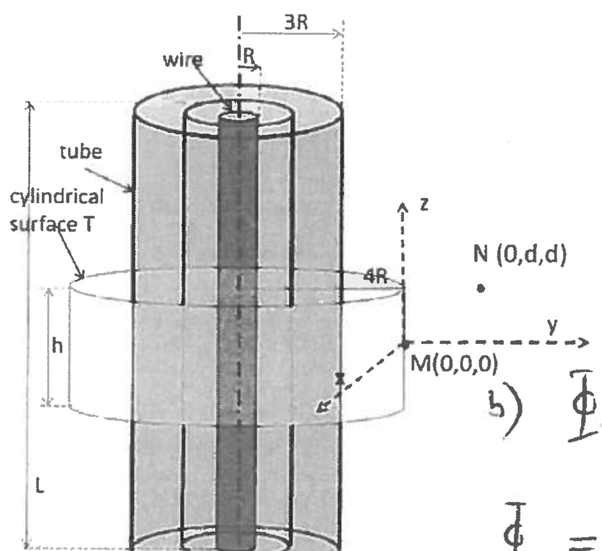
c) Find the electric field at the point M on the cylindrical surface T.

d) A point charge $+q$ is released at rest at point M. What work does the electric field of the cylinders do on the point charge q as it moves a distance d radially outward from point M?

e) What work does the electric field do on the charge as it is moved from point M to the point N with coordinates (x = 0, y = d, z = d)? The z-axis is the direction parallel to the axis of the cylinders.

a)





b) $\Phi_E = \int_T \vec{E}\cdot d\vec{A} = \oint_{\text{cylinder}} \vec{E}\cdot d\vec{A} = \frac{q_{en}}{\epsilon_0}$

(since ϕ through top and bottom = 0!)

$\Phi_E = \frac{\lambda h}{\epsilon_0} = \frac{2Qh}{L\epsilon_0}$

c) $\Phi_E = \oint \vec{E}\cdot d\vec{A} = \frac{q_{en}}{\epsilon_0} = E(4R)\left(2\pi(4R)h\right)$

$E(4R) = \frac{2Qh}{L\epsilon_0}\left(\frac{1}{8\pi Rh}\right) = \frac{2Q}{8\pi\epsilon_0 RL}$ outward

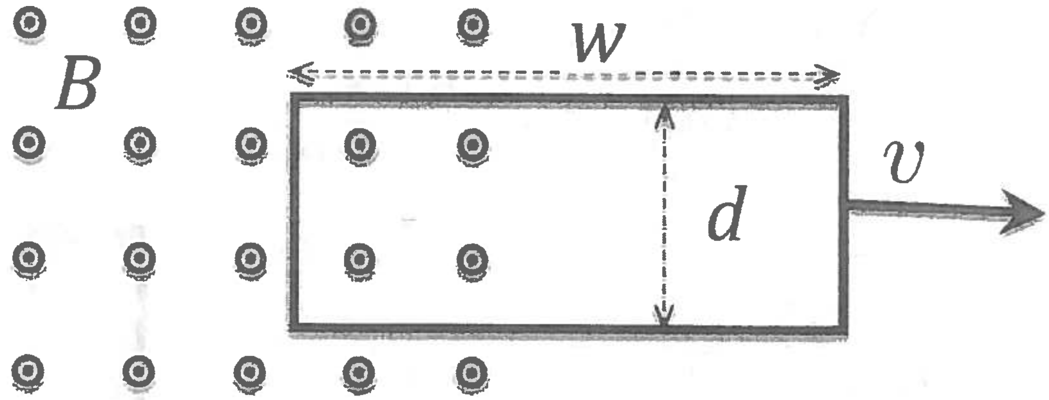
d) Work done $= q\Delta V = q\left(-\int_{4R}^{4R+d} \vec{E}\cdot d\vec{r}\right) = -q\left(\frac{2Q}{2\pi\epsilon_0}\int \frac{1}{r}dr\right) = \frac{q2Q}{2\pi\epsilon_0}\ln\left(\frac{4R+d}{4R}\right)$

e) Work done only depends on the radial displacement so Work done is the same as for part (d).

LO	P	F
13.1		
19.1		
15.2		
18.1		
18.2		
21.1		
24.1		
21.2		
24.2		

Problem 2.
A rectangular loop of wire with dimensions d and w has electrical resistance R. The loop of wire is being pulled to the right at constant velocity v out of a magnetic field $\mathbf{B}$. The normal to the plane of this loop is parallel to the magnetic field. Assume that part of the loop is still inside the field as shown. Express each answer in terms of $\mathbf{B}$, v, w, d, R, and known physical constants and numerical factors.

a) Calculate the induced current in the loop. Indicate whether it is clockwise or counter-clockwise. Show your work and reasoning.
b) Calculate the force necessary to make the loop move at the given constant velocity v.
c) Calculate the electrical power dissipated in the loop.



a) $\mathcal{E}mf = -\frac{d\Phi_M}{dt} = -\frac{d}{dt}(Bwd) = -Bd\frac{dw}{dt} = -Bdv$

direction CCW as loop pulled ~~to right~~

b) Force needed $d\vec{F} = I d\vec{l} \times \vec{B}$

$I = \frac{Bdv}{R}$ so force needed

$d\vec{F} = \left(\frac{Bdv}{R}\right) dB = \frac{B^2 d^2 v}{R}$

c) power dissipated during this motion,

$P = \vec{F}\cdot\vec{v} = I^2 R = \frac{B^2 d^2 v^2}{R}$

LO	P	F
56.1		
57.1		
58.1		
7.4		
40.2		
49.1		
3.5		

Problem 3. A local radio station broadcasts at a frequency of 104.7 MHz. Further, this station transmits a total of 50 kW of radio power uniformly in all directions **above** the Earth's surface.

a) What is the wavelength associated with this broadcast station?

b) Find the intensity at a distance of 2.5 km from the antenna.

c) Find the amplitude of the E-field at this distance.

d) For radiation traveling upward along the y-axis, the instantaneous electric field is at a maximum and points along the z-direction. Find the magnitude and direction of the instantaneous magnetic field.

e) After 5.0 ns, how far upward, along the y axis, does the wave travel?

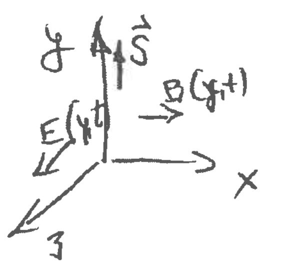
a) $c = \lambda f = \lambda(1.047\times10^{8}\,Hz) \Rightarrow \lambda = 3\times10^{8}/1.047\times10^{8} \approx 3\,m$

b) $I = S_{ave} = \dfrac{E_{max}B_{max}}{2\mu_0} = \dfrac{\text{Total Power}}{\text{Total Area @ 2.5 km}}$

$= \dfrac{50\ kW}{2\pi(2.5\times10^{3})^{2}} = 1.27\times10^{-3}\ Watt/m^{2}$

c) Find E_{max} from I; $E_{max} = \sqrt{2\mu_0 c I}$

$E_{max} = 0.978\ V/m$

d) 

$\vec{E}(y,t) = E_{max}\sin(ky-\omega t)\hat{k}$

$\vec{B}(y,t) = \dfrac{E_{max}}{c}\sin(ky-\omega t)\hat{i}$

e) distance traveled $= v\Delta t = c\Delta t = (3\times10^{8})(5.0\times10^{-9}\,s)$

$= 1.5\,m$

LO	P	F
71.1		
5.2		
73.1		
73.2		
3.6		
71.2		
71.3		
71.4		
3.7		