WMU-Fall 2001   ☐ **You Must Go Through "Check-Out" With Dr. Phil**
Final Exam - 200,000 points + 40,000 ☆ points

12/05/2001•Rev.9

State Any Assumptions You Need To Make – Show All Work – Circle Any Final Answers
Use Your Time Wisely – Work on What You Can – Be Sure to Write Down Equations
Feel Free to Ask Any Questions   ☐☆2a ☐☆2b ☐☆2c ☐☆2e

"… And We're Carrying Unlicensed Particle Accelerators" GHOSTBUSTERS   (50,000 points)

1.) You all probably own a particle accelerator – it is the heart of every TV picture tube and every computer monitor (unless either is an LCD or plasma panel). Electrons are accelerated from rest to a kinetic energy of 25,000 eV. (It's really going to help if you can remember what an electron-volt, eV, is or this page is going to really hurt.) (a) What is the accelerating potential, ΔV, that is driving the electrons?

(b) How fast are the electrons traveling as they leave the accelerator and cross the expanse of the vacuum tube? Is this speed relativistic? $e = 1.602 \times 10^{-19}\ C$; $m_e = 9.11 \times 10^{-31}\ kg$

(c) The accelerated electrons are moving in the $+x$ direction. Draw a diagram using two parallel plates and showing the constant $\vec{E}$ field that makes up the particle accelerator, as well as the charges $\pm Q$ on the plates.

(d) The parallel plates are 6.25 mm (0.00625 m) apart. What is the magnitude of the constant electric field, E?

(e) The accelerator is basically a parallel plate capacitor. If the plates each have an area of 1.00 cm² (0.000100 m²), how much charge $\pm Q$ is on each plate?

***And Now, the Stars of Our Final Exam!*** **(50,000 points)**

2.) ☆(a) Find the magnetic flux, $\Phi_B = \int \vec{B} \cdot d\vec{A}$, in a square area of sides a in the xy plane, centered on the origin, for a magnetic field $\vec{B} = b\,x^3 y^2 z\,\hat{k}$, where b is an arbitrary constant.
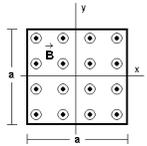

☆(b) Try out B = [B_1 sin (kx - ωt) + B_2 cos (kx - ωt)] in the wave equation for B, $\dfrac{\partial^2 B}{\partial t^2} = c^2 \dfrac{\partial^2 B}{\partial x^2}$, and see if it is a solution.

☆(c) A cylindrical insulator of radius R and length L (and $L >> R$) has a total charge Q evenly distributed throughout the cylinder. Use Gauss' Law to find the magnitude of the E-field at a radius r, where $r < R$, in the middle of the cylinder. *NOTE: You must do the integrals to get full credit.*

(d) A light ray in air comes in from the left and strikes a parallel-plano slab of glass A of thickness d. The dashed line shows the path the light ray would have gone if no glass is there. First, sketch in the way the transmitted rays are offset after passing through the glass A. Second, sketch whether or not the offset ray goes back to its original path if a second identical slab of glass B is set at an angle opposite to A. There are no numbers to calculate in this problem, but of course the index of refraction of the glass *is* higher than the index of refraction of air ($n = 1.00$). *Show all relevant lines in your sketches.*
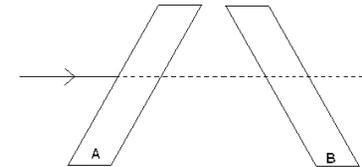

☆(e) A $\vec{B}$ -field in the xy plane forms closed circular lines of constant E point. Use Ampère's Law to find the current, I, if any, enclosed in the as the heavy dark line.
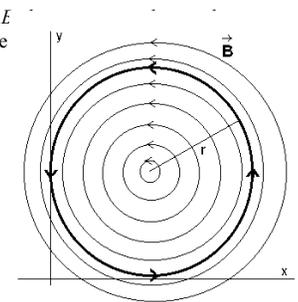
Fish Stories (50,000 points)

3.) (a) A fish lives in fresh water, $n = 1.33$, in a fish tank made of glass, $n = 1.50$, that has an acrylic coating on the inside, $n = 1.25$. The fish tank is lit with a sodium light, whose wavelength in air is $\lambda = 555\ nm = 5.55 \times 10^{-7}\ m$. If the acrylic coating is a half-wave coating, will the fish see its reflection from the inside surface of the glass?

coating
n = 1.25

glass
n = 1.50

water
1.33
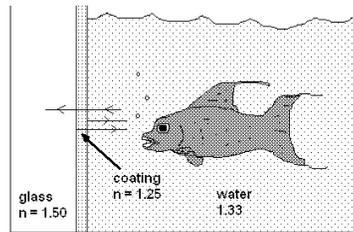
(b) If a second acrylic coating is applied to the *outside* of the glass, where it meets the air, should this coating be quarter-wave or half-wave, if the fish is going to NOT see its reflection from the outside surface of the glass?

air
n = 1.00

glass
n = 1.50

coating
n = 1.25

water
1.33
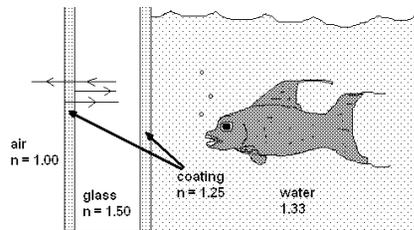
(c) An electric eel provides a shock of some *450. Volts* to *600. Volts*. My encyclopedia says that the electric cells are some sort of specialized muscle cells. But I also remember reading that the cells act like many thousands of small capacitors. How would you connect the capacitors to maximize voltage? How would connect the capacitors to maximize the charge Q ? *Short answer!*

(d) A long straight wire has a current i that is going to the right along positive x-axis. At a point $y = 0.150\ m$ above the wire the magnetic field has a magnitude $B = 0.450\ T$. Find i.

$-e \circ \xrightarrow{v}$

$i \longrightarrow$
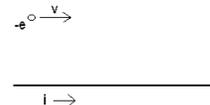
(e) An electron starts out at $y = 0.150\ m$ above the wire with an initial velocity $\vec{v}_0 = +525\ m/s\ \hat{i}$. Find the vector force, $\vec{F}_B$, acting on the electron.

Early Christmas Presents – Or Else Your Own Personalized Lump of Coal (50,000 points)

4.) (a) You are first told that two resistors, R_1 and R_2, when put in series are 65.0 Ω. You are then told that when these same two resistors are put in parallel, you get 131 Ω. If the first statement is TRUE, why must the second statement be FALSE? *Do not write a LONG answer!*

(b) Eight identical resistors, each $R = 100.\ \Omega$, are put in the arrangement shown. This is another circuit that technically requires Kirchhoff's Laws to solve, but because the resistors are identical, you can find the equivalent resistance, R_{eq} , of this circuit. What is R_{eq} ? *Sketch the intermediate circuits and circle the resistors you combining, indicating if they are in series or parallel, if you want any credit for this problem.*

R_1 R_2
R_3
R_4 R_6
V = 16.55 Volts
R_5
R_7 R_8
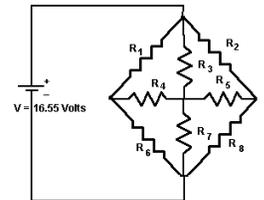
You're standing in the middle of a giant solenoid electromagnetic that at 4.00 meters in diameter is roughly twice at tall as you are, and is 15.0 meters long with 125,000 windings. As you look down the length of the coil (+x-axis), a current, $I = 155\ A$, goes above your head from left to right (and around to under your feet from right to left). (c) Find the inductance L of the solenoid.

(d) The copper wire that makes up the solenoid is 1571 kilometers long (that's not a typo – it's 2πr × 125,000 windings). To support 155 A, the wire has a diameter of 0.500 cm and a cross-sectional area of $6.25 \times 10^{-6}\ m^2$. How much energy is being lost per second in the coil due to Joule heating? *The resistivity of copper is $\rho_{Cu} = 1.7 \times 10^{-8}\ \Omega \cdot m$.*

(e) If the current is switched to 60.0 Hz A.C., $\omega = 377\ rad/sec$, find the impedance Z of this giant solenoid.