PHYS 212E **Name ____________________**
Comprehensive Final Exam **May 6, 2004**

Scores: Comp ____ Lab _____

<u>Show all work for full credit</u>! Answers must have correct units and appropriate number of significant digits. For all the problems (except for multiple choice questions), start with either (a) a generally applicable equation or statement; (b) a sentence explaining your approach; or (c) a sketch.

<u>This final exam comes in two parts:</u>

- **A Comprehensive Final Exam worth 120 points**
- **A Laboratory Final Exam worth 60 points**

- **Constants and a Particle Data Table are included at the end of the Comprehensive Exam; feel free to remove this sheet at your convenience**
- **Equations for the Laboratory Exam are provided on the Laboratory Exam.**

<u>There are 13 questions on the Comprehensive Exam</u>:

- **For each of questions 1 – 6, choose ONE of the available questions to answer. Clearly indicate which question you want graded. If you neglect to indicate which question you want graded and you provide solutions to both, I will grade the "A" question by default.**
- **You must answer all of questions 7 – 13.**

<u>There are 11 questions on the Laboratory Exam</u>:

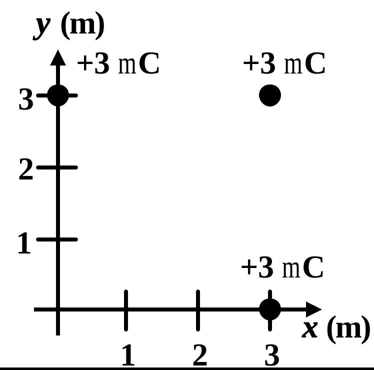
- **You must answer all 11 questions on the Laboratory Exam.**

PICK EITHER 1A OR 1B TO ANSWER. INDICATE YOUR CHOICE.

1A. (12 pts) Three identical point charges (all charge +3 μC) are held fixed as shown in the figure, at positions (0, 3), (3, 0) and (3, 3), with all distances in meters.

a) Determine the electric field $\vec{E}$ at the origin due to the three charges.

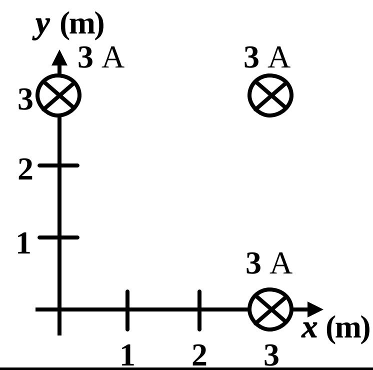
b) An electron is released from rest at the origin. Determine the acceleration $\vec{a}$ of the electron upon its release.



1B. (12 pts) Three infinitely long straight wires (parallel to the *z*-axis) all carry current 3 A going into the page as shown in the figure. The wires' locations in the *x*-*y* plane are (0, 3), (3, 0) and (3, 3), with all distances in meters.

a) Determine the magnetic field $\vec{B}$ at the origin due to the three wires.

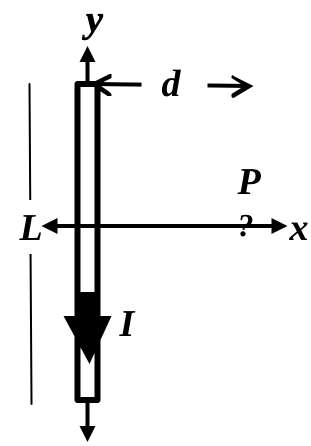
b) An electron is released from rest at the origin. Determine the acceleration $\vec{a}$ of the electron upon its release.



PICK EITHER 2A OR 2B TO ANSWER. INDICATE YOUR CHOICE.

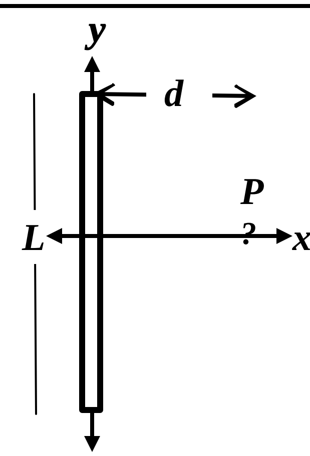
2A. (12 pts) Some piece of a wire, length L, lies along the y-axis, symmetric with respect to the x-axis, and carries current I in the negative $\hat{j}$ direction as shown in the figure. A field point P is located on the x-axis a distance d away from the wire.

Set up the integral(s) that will allow you to calculate the magnetic field $\vec{B}$ at the field point P due to the section of wire pictured. Your integral(s) should contain only physical constants, given quantities, and the integration variable. You do NOT need to evaluate the integral(s), but make sure that the only thing left to do would be to evaluate the definite integral(s).



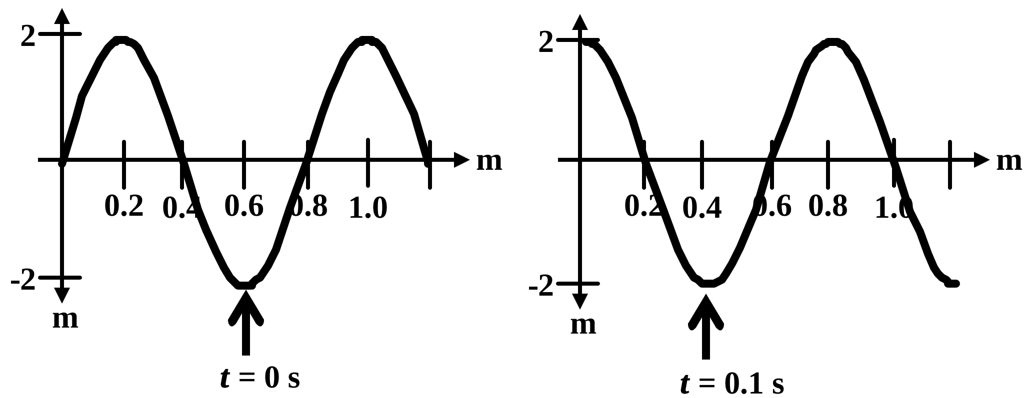
2B. (12 pts) A rod, of length L, lies along the y-axis, symmetric with respect to the x-axis, and has a uniform charge density λ distributed along its length. A field point P is located on the x-axis a distance d away from the rod.

Set up the integral(s) that will allow you to calculate the electric field $\vec{E}$ at the field point P due to the rod pictured. Your integral(s) should contain only physical constants, given quantities, and the integration variable. You do NOT need to evaluate the integral(s), but make sure that the only thing left to do would be to evaluate the definite integral(s).



PICK EITHER 3A OR 3B TO ANSWER. INDICATE YOUR CHOICE.

3A. (10 pts) The figures represent "snapshots" taken of a traveling wave at time $t = 0$ and at time $t = 0.1$ s. The arrow represents the same peak of the traveling wave that you were able to observe moving. Note that both the horizontal and vertical axes are in meters; call the horizontal axis the x-direction.



a) Estimate the velocity and wavelength of this wave from the two figures above.

b) Write down an equation that describes this traveling wave.

3B. (10 pts) A plane polarized electromagnetic wave travels in vacuum in the $+x$ direction with frequency 5×10^{14} Hz. The electric field component of the EM wave is polarized along the z-axis, with maximum amplitude 6×10^{-2} N/C. Write down an equation that describes the magnetic field part of this wave.

PICK EITHER 4A OR 4B TO ANSWER. INDICATE YOUR CHOICE.

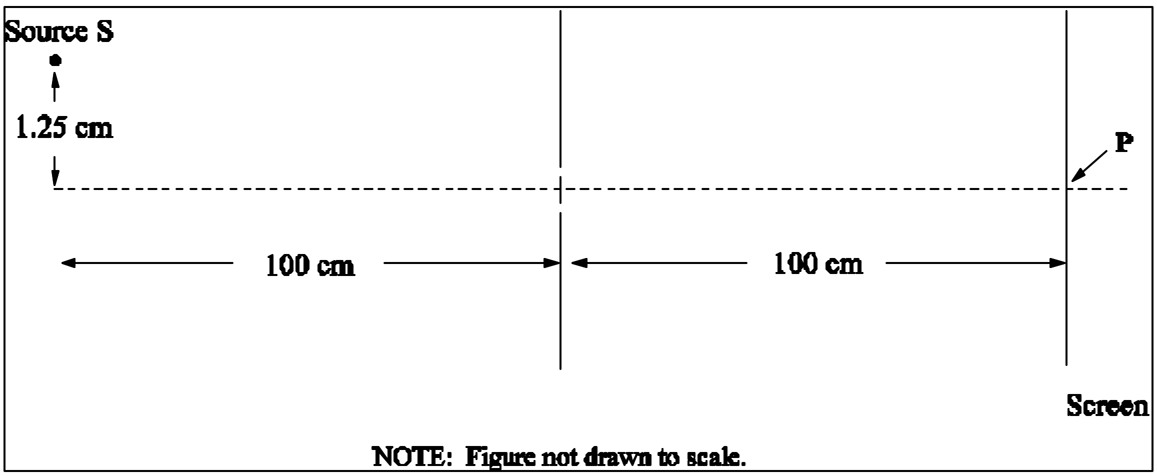
4A. (8 pts) An electron in the $n = 3$ state of an infinite square well has energy 1.51 eV. This electron absorbs a photon and makes a transition to a higher energy level. Determine the longest possible wavelength for a photon which could have caused this transition.	**4B.** (8 pts) An electron in the $n = 3$ state of hydrogen atom has energy –1.51 eV. This electron absorbs a photon and makes a transition to a higher energy level. Determine the longest possible wavelength for a photon which could have caused this transition.

PICK EITHER 5A OR 5B TO ANSWER. INDICATE YOUR CHOICE.

5A. (8 pts) You are given a polarizing sheet for Polarizing Sheet Day. You want to determine the transmission axis of your polarizing sheet, but you don't have access to any other polarizer. You also do not want to break the sheet you have. Describe a simple experiment or experiments you could do to determine the transmission axis of the polarizer, using things you might find in your dorm room, kitchen, or cafeteria.	**5B.** (8 pts) You are given a pen laser for Pen Laser Day. You want to determine the frequency of the light emitted from your pen laser. Describe a simple experiment or experiments you could do to determine the frequency of the light from the laser, using items you might find in the Physics 212 lab.

PICK EITHER 6A OR 6B TO ANSWER. INDICATE YOUR CHOICE.

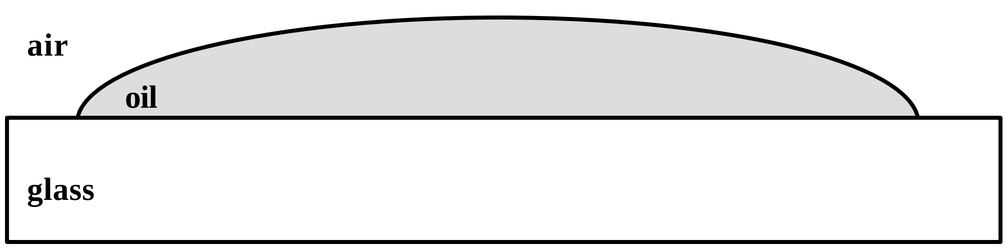
6A. (10 pts) A point source of monochromatic light S illuminates two slits separated by 0.02 mm. Note that the source is *not* on the centerline between the two slits. The wavelength of the light is 500 nm; other dimensions are indicated in the diagram.



a) Calculate the path length difference for the light that travels from the source to the upper slit and the light that travels from the source to the lower slit.

b) Is there a bright spot or a dark spot at the point **P** at the center of the screen? Justify your answer with quantitative calculations.

6B. (10 pts) A drop of oil (index of refraction 1.25) is sitting on a glass slide (index of refraction 1.5). The maximum thickness of the oil (at the center) is 1300 nm. The reflection of normally incident light of wavelength 500 nm is observed; consider only reflections from the air/oil interface and the oil/glass interface. At the center of the drop, do you observe a bright spot or a dark spot? Justify your answer with quantitative calculations.



MORE ROOM ON NEXT PAGE.

SHOW WORK FOR QUESTION 6A OR 6B ON THIS PAGE

7. (14 pts) The wavefunction of a particle is given as

$$|\psi\rangle = \frac{2}{3}|a\rangle + B|b\rangle - \frac{2}{3}|c\rangle,$$

where $|a\rangle$ is a state with energy $E_a = -4\text{eV}$, $|b\rangle$ is a state with energy $E_b = -1\text{eV}$, $|c\rangle$ is a state with energy $E_c = 3\text{eV}$, and B is some constant.

a) Determine a numerical value for the expectation value for the energy $\langle E \rangle$ of the particle prepared in state $|y\rangle$.

b) If you measure the energy of a particle prepared to be in the state $|y\rangle$ given above, what is the probability that you will find the energy to be equal to the expectation value $\langle E \rangle$ you calculated in part b)?

c) If you measure the energy of a particle prepared to be in the state $|y\rangle$ given above, what is the probability that you will find the energy to be 3 eV?

d) If you measure the energy of a particle prepared to be in the state $|y\rangle$ given above and find the energy to be 3 eV, what is the probability that a second measurement of the same particle's energy done immediately after the first will yield a value of -1 eV?

8. (10 pts) An alpha particle is composed of two protons and two neutrons and has a mass $m = 6.64 \times 10^{-27}$ kg $= 3.73 \times 10^{9}$ eV/c^2. The alpha particle is accelerated from rest through an electric potential difference of 10^6 V. Calculate the resulting de Broglie wavelength of the alpha particle.

9. (7 pts) The cosmic microwave background radiation is made up of photons that stopped interacting with matter at some point after the Big Bang.

a) What was the approximate scale of the photons' energy at the time that they stopped interacting with matter? (Circle one)

10 eV 10^6 eV 10^8 eV 10^{11} eV 10^{23} eV

b) Calculate the approximate time after the Big Bang when this occurred.

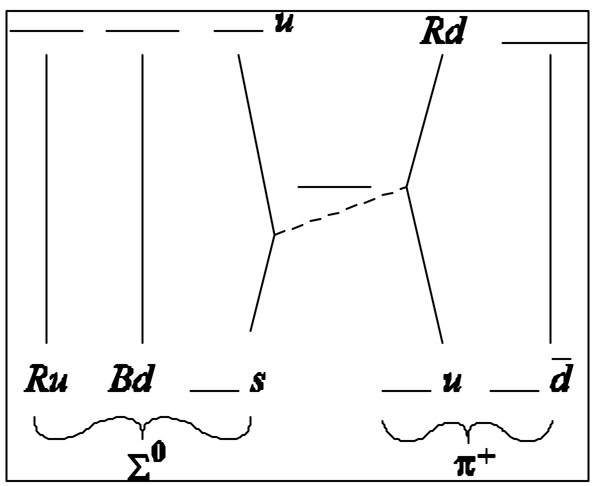
10. (6 pts) Determine the quark content of the following particles.

a) ? ^{0}

b) T^{+} pentaquark, with $Q = 1$, $B = 1$, and $S = 1$

11. (10 pts) Consider a collision between a Σ^0 and a π^+ that results in the formation of two unknown particles: $\Sigma^0 + \pi^+ \rightarrow ? + ??$

a) Fill in the missing parts of the following reaction diagram. Include all information necessary to specify fully the particles, including color where appropriate.



b) What force is involved in the illustrated interaction? (Circle one.)

Strong Nuclear　　Electromagnetic　　Weak Nuclear　　Gravitational

c) Identify a possible baryon produced in this reaction.

12. (5 pts) The following three decays all occur. Order them from fastest to slowest.

(A) $\pi^+(\bar{d}u) \to \mu^+ + \nu_\mu$
(B) $\Sigma^{*0}(sud) \to \Sigma^+(suu) + \pi^-(\bar{u}d)$
(C) $\Sigma^+(usu) \to n(udd) + \pi^+(\bar{d}u)$

Fastest _______ ________ ________ Slowest

13. (8 pts) For each of the reactions below list all of the conservations laws that are **violated,** and determine if the reaction can occur**.**

Reaction	Violated Conservation Laws	Can Occur? (Yes/No)
$\Delta^+ \to n + \mu^+ + \bar{\nu}_\mu$		
$\Sigma^- \to \pi^- + n$		

Constants

$k = \frac{1}{4\pi\varepsilon_0} = 9.0\times10^{9}\ \mathrm{Nm^2/C^2}$ $\frac{\mu_0}{4\pi} = 10^{-7}\ \mathrm{Tm^2/A} = 10^{-7}\ \mathrm{N/A^2}$ $1\ \mathrm{eV} = 1.6\times10^{-19}\ \mathrm{J}$

$e = 1.6\times10^{-19}\ \mathrm{C}$ $1\ \mathrm{eV} = 1.6\times10^{-19}\ \mathrm{J}$ $G = 6.67\times10^{-11}\ \mathrm{Nm^2/kg^2}$ $g = 9.8\ \mathrm{m/s^2}$

$c = 3.0\times10^{8}\ \mathrm{m/s} = 3.0\times10^{17}\ \mathrm{nm/s}$ $hc = 1240\ \mathrm{eV\cdot nm}$

$h = 6.626\times10^{-34}\ \mathrm{J\cdot s} = 4.136\times10^{-15}\ \mathrm{eV\cdot s}$ $\hbar = 1.05\times10^{-34}\ \mathrm{J\cdot s} = 6.585\times10^{-16}\ \mathrm{eV\cdot s}$

<u>electron</u>

$m = 9.11\times10^{-31}\ \mathrm{kg} = 511\ \mathrm{keV/c^2}$

$\mu_z = 9.27\times10^{-24}\ \mathrm{J/T} = 5.8\times10^{-5}\ \mathrm{eV/T}$

<u>proton</u>

$m = 1.67\times10^{-27}\ \mathrm{kg} = 938\ \mathrm{MeV/c^2}$

$\mu_z = 1.41\times10^{-26}\ \mathrm{J/T} = 8.8\times10^{-8}\ \mathrm{eV/T}$