Physics 212 : Fifteenth week assignment:

Reading: Study sections 7-8, 11, 13, 16 -18 of chapter 25 and the lecture notes for doing the problems.
The handout by Brian Greene should be interesting also and fun to read.

Tues, Dec 5: Lecture. There will also be a short quiz duringthe period.

Homework problems to be handed in at the beginning of the Workshop on Wed, Dec 6: problems 12, 17 and 26 of chapter 25.

Wed, Dec 6: In this Workshop you will consider questions 8 and 10 on page 1194 as well as problems 14, 19 and 38 of chapter 25.

Thurs, Dec 7: Lecture.

Homework problems to be handed in at the beginning of the Workshop on Fri, Dec 8: problems 49, 50, 58 and 59 of chapter 25.

Fri, Dec 8: In this Workshop you will consider question 12 on page 1194 as well as problems 39, 64 and 66 of chapter 25.

Remember that the final exam is scheduled for ~~Fri~~, Dec 12, 7:15-9:15 pm in Stolkin.
Tues.

SAMPLE FINAL EXAM

1. (24 points). Multiple choice questions.

(a) The Earth's magnetic field is 5.5×10^{-5} T and is directed at an angle of 40° below the horizontal at a site in the continental USA. A 15 ampere current flows downward through a straight, vertical wire at this location. What is the *direction* of the force exerted upon a 0.10 m segment of this wire?

A. Horizontally and to the east.

B. Horizontally and to the west.

C. Upward and at an angle of 40° north of the perpendicular.

D. Downward and at an angle of 50° east of the perpendicular.

E. None of these.

(b) An electric field has been established between two parallel metal plates by placing opposite charges upon the plates. The two plates are 0.001 m apart and a 6.0 volt potential difference exists between them. If the left plate is – and the right plate is +, what is E at a point between the plates and 0.0002 m away from the negative plate?

A. 1.2×10^3 V/m toward the – plate.

B. 1.2×10^3 V/m toward the + plate.

C. 4.8×10^3 V/m toward the + plate.

D. 6.0×10^3 V/m toward the – plate.

E. None of these.

(c) A battery has a terminal potential of V_0 if no current flows through it. Assuming that this battery has an internal resistance r, what will be its terminal potential difference when connected to a load whose resistance is R?

A. V_0.

B. V_0 (1-r/R).

C. V_0 (1-R/(R+r)).

D. V_0 (1-r/(R+r)).

E. V_0 (1+R/(R+r)).

(d) The difference between the electric field of a point charge and an electric field induced by a changing magnetic field is:

A. There is none.

B. The flux of a point charge electric field through a closed surface must be zero.

C. The flux of an induced electric field through a closed surface must be zero.

D. Induced fields can vary in magnitude while the point charge electric field must have a constant value.

E. You can have an induced field without a static field but you can not have a static field without an induced field.

(e) A spaceship is traveling rapidly through space toward a distant star. How will the speed with which a stationary astronomer contends the spaceship approaches the star compare with the speed with which the spaceship pilot observes the star to be "coming toward them"?

A. The speeds would be the same.

B. The pilot would report the larger speed due to time dilation.

C. The pilot would report the smaller speed due to time dilation.

D. The pilot would report the smaller speed due to length contraction.

E. Both C and D.

(f) Electromagnetic radiation provides an indication that Galilean relativity is not completely satisfactory. Relative to an observer this is shown by:

A. The very large value for c, the speed of light.

B. The ability to polarize electromagnetic radiation.

C. That the speed of light does not depend on the source speed.

D. A moving charged particle can be deflected as it passes through a magnetic field.

E. All of these are problems for Galilean relativity.

(g) With two reference frames, where one frame is moving at speed v with respect to the first:

A. No event can occur simultaneously in *both* frames.

B. Two events cannot be simultaneous in *both* frames.

C. No event can occur at both x=0, t=0 and x'=0, t'=0.

D. Both A and C.

E. Both B and C.

(h) At what speed will the relativistic *kinetic* energy of a particle, defined as:

$$\frac{mc^2}{\sqrt{1-v^2/c^2}} - mc^2,$$

be equal to its *rest* energy?

A. 0.560 c.

B. 0.750 c.

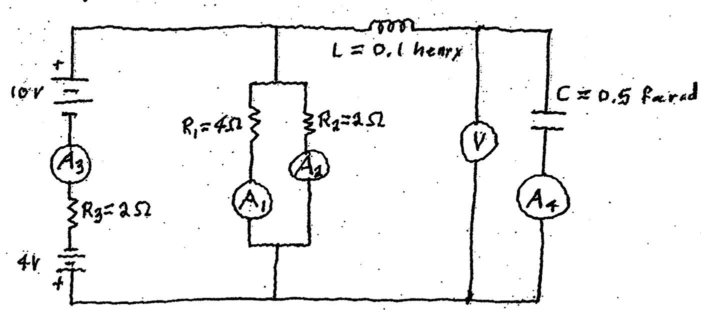
C. 0.866 c.

D. 1.15 c.

E. None of these.

2. (26 points). An electric circuit.

The circuit shown below contains two batteries, three resistors, a capacitor and an inductor. Currents through the resistors are being measured by the ammeters A_1, A_2 and A_3. The voltage across the capacitor is being measured by voltmeter, V and the current going to the capacitor by the ammeter, A_4. Assume that the ammeters and voltmeter do not affect the operation of the circuit in any way. Consider the situation when the circuit has been on for a long enough time so that any "transients" have already died out.



(a) What is the effective resistance of R_1 and R_2 in parallel?

(b) What is the reading of ammeter A_4 ?

(c) What is the reading of ammeter A_3 ?

(d) What is the reading of ammeter A_1?

(e) What is the reading of ammeter A_2?

(f) How much power is being dissipated as heat in each of the three resistors?

(g) How much power is being supplied by the 10 volt battery? How much by the 4 volt battery? Is all the power properly accounted for?

(h) What is the potential difference across the capacitor C ? How much charge is being stored in the capacitor?

(i) Now suppose we replace the two batteries by a single alternating current source, having frequency, v. At which frequency might you expect the current measured by A_4 to be greatest?

3. (25 points) Waves and relativity.

(a) A plane, sinusoidal wave of frequency 1×10^6 Hz and amplitude 3×10^{-3} v/m is polarized in the x direction while propagating in the positive z direction. First sketch the electric and magnetic field vectors. Then give the mathematical expression for $E_x(z,t)$ with appropriate numbers.

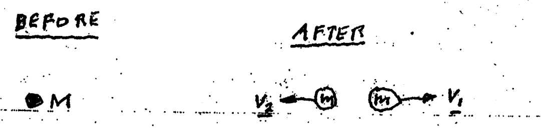
(b) Remember that in Relativity the momentum of a particle with rest mass, m and velocity, v is:

$$\underline{p} = \frac{m\underline{v}}{\sqrt{1 - |\underline{v}|^2/c^2}}$$

while the energy is:

$$E = \frac{mc^2}{\sqrt{1 - |\underline{v}|^2/c^2}}$$

Both p and E are conserved in any microscopic collision. (In other words, the sum of all initial particle momenta (energies) equals the sum of all the final particle momenta (energies). Now suppose an unstable particle of mass M, in its rest frame, decays into two identical particles which each have mass, m.



What is the initial momentum? Show that momentum conservation in the form,

$$\underline{p}_{initial} = \frac{m\underline{v}_1}{\sqrt{1 - |\underline{v}_1|^2/c^2}} + \frac{m\underline{v}_2}{\sqrt{1 - |\underline{v}_2|^2/c^2}}$$

requires $v_1 = -v_2$.

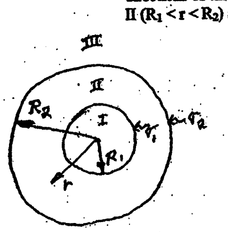
(c) What is the initial energy of the decaying particle at rest? Use energy conservation to derive a formula for $|v_1|$ in terms of M, m and c (the velocity of light).

(d) If the lifetime in its rest frame of the unstable particle above is τ_0, what would an observer moving at speed u with respect to the rest frame measure its lifetime to be? Express your answer in terms of symbols.

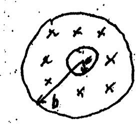
(e) A space ship having the *proper* length 250m passes by a technician on Earth. This person notices that it has taken 1.2×10^{-6} sec for the space ship to pass by her check point. What does she write down in her log for the speed of the space ship?

4. (25 points) Calculating E and B fields using "Maxwell's equations". In these problems express your answers in terms of algebraic symbols.

(a) Two, infinitely long concentric, plastic cylindrical shells each carry a different but uniform electric charge density (charge/area in this case). Referring to the illustration, $R_2 > R_1$ while the charge densities satisfy $\sigma_1 = \sigma$ = positive and $\sigma_2 = -\sigma$ = negative. Find the magnitudes and directions of the electric fields in each of the three regions: I ($r < R_1$), II ($R_1 < r < R_2$) and III ($r > R_2$). [Hint: this is a Gauss's law problem].



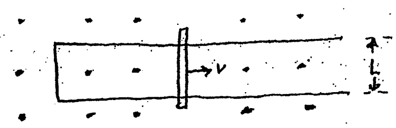
(b) An Ampere's law problem: As shown, current is flowing (into the page) in a long cylindrical copper wire having inner radius a and outer radius b. Note that the center of the wire has been hollowed out. The current density j (or current/area) is assumed to be known.



i. What is the total current flowing through the wire?

ii. What are the magnitudes and directions (sketch them) of the magnetic field vectors at distance r from the axis of the wire? Consider separately the three cases: $r < a$, $a < r < b$ and $r > b$.

(c) A Faraday's law problem: As shown, a conducting rod is being pulled along a pair of rails with constant velocity v. A constant magnetic field B, out of the page, exists everywhere in the vicinity of the rails. The rails are electrically connected together at the left end. Also, the spacing between the two rails is L



i. What is the magnetic flux cutting the loop when the rod is a distance x from the left end?

ii. What is the magnitude of the emf generated for this loop?

iii. What is the direction of the induced current in the loop?