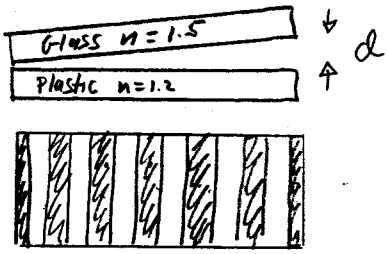
Physics 7C, Fall 2003, Section 1
Instructor: Adrian Lee

Final Examination, Thursday December 11

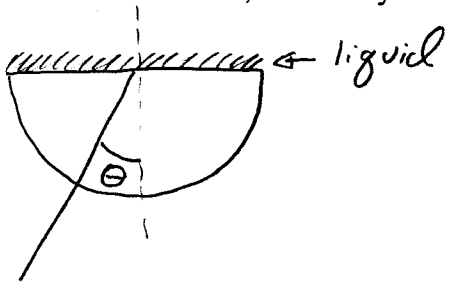
You may use three 3.5" x 5" cards of double-sided notes. GOOD LUCK!

1)



a) A flat piece of glass with n = 1.5 is placed over a flat piece of plastic with n = 1.2. They touch at the left edge and are separated by d on the right edge. Light with wavelength 600 nm is incident normally from above. Given the drawing of the dark fringes above (viewed from above), what is the value for d? The two pieces are thick enough that you can ignore any interference within the two pieces. (25 pts)

b) If the gap is filled with water with n = 1.33, how many dark fringes appear? (15 pts)



2) An apparatus to measure the index of refraction of small amounts of transparent liquid is shown in the figure above. It consists of a semicircular slab of glass on which a drop of liquid can be put to form a think layer covering the flat top. A light beam is directed upward along a radius at angle θ to the normal. For small angle θ a there are both reflected and refracted rays, but beyond a critical angle θ_c there is only the reflected ray (total internal reflection). Assume that only the reflection from the glass-liquid interface is important.

a) Show that the measurement of the angle θ_c allows a determination of the ratio of the index of refraction of the liquid to that of the glass. (30 pts)

b) When the liquid is absent, it is observed that θ_c = 45 deg, and when a certain liquid is present θ_c = 58 deg. What are the indices of refraction of the glass and liquid? (Assume that the index of refraction of air is 1.0). (10 pts

3) Consider an electron with a kinetic energy of 1 keV. The rest mass of an electron is 511 keV/c^2.

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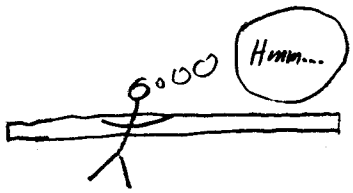
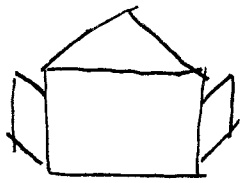
a) What is the momentum p of the electron? (15 pts)

b) A stream of such electrons diffracts through an aperture. What size does the aperture have to be to have the first minimum of the diffraction pattern at 10 deg from the original stream? What could be used to produce such apertures (a decent guess is enough)? (10 pts)

c) Do the electrons have relativisitic velocities, i.e. is the γ (gamma) factor appreciably different from 1? 10% would be appreciable. (15 pts)

4) The "Pole Vaulter" Paradox





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A pole vaulter is running with a pole at v = sqrt(3)/2 c. Her pole has a proper length of L. She runs into a barn with proper length L/2 with doors on the front and back. When the pole vaulter runs into the barn, a farmer tries to close both front and back doors at the same time, but only for an instant, and then reopens them.

a) What is the length of the pole from the farmer's perspective? What is the length of the Barn from the pole vaulter's perspective? From the farmer's perspective can he close the barn doors at the same time? (10 pts)

b) Are the doors closed at the same time for the pole vaulter? What is the expression for the time interval of the door closings in the pole vaulter's frame? What is the interpretation of the sign of the expression? (15 pts)

c) In the pole vaulter's frame give an expression for what the time interval would have to be to avoid an accident. Comparing the answers of (b) and (c), is there an accident? (15 pts)

5) The energy levels of a two-dimensional potential well with infinite sides can be written in the form $E = E_0(n_x^2 + n_y^2)$, where n_x and $n_y = 1,2,3,...$ If we place 7 electrons in the well and neglect coulomb repulsion between them,

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(a) What is the total energy of the ground state system? (25 points)

(b) What would be the ground state energy if the particles had zero spin (no pauli exclusion)? (15 points)

6) Consider an infinite well with sides at +L/2 and -L/2, that is the potential is equal to zero betweeen the two boundaries and equal to infinity beyond them. Hint: The physics of this problem are the same as a well that has boundaries at 0 and L. You have to derive everything here again, however, and the math is quite different.

a) What are the wavefunctions for the quantum states with the four lowest energies? They can be expressed in terms of normalization constants (see part d). (10 points)

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b) What are the energies of these four lowest energy states? (10 points)

c) Sketch the wavefunctions and probability densities for these four states. (10 points)

d) Write the equations necessary to normalize the energy wavefunctions with the lowest two energies, but you do notneed to evaluate the expressions. (10 points)

7) Particle Physics and Cosmology (5 points each)

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(a) The 2.7 K Cosmic Microwave Background is:

(i) The integrated starlight from all stars in the Universe.

(ii) Microwave photons emitted in the atmosphere due to Cosmic Rays interactions.

(iii) Radiation from the Big Bang that has cooled to 2.7K.

(iv) Diffuse emission from dust particles in our galaxy.

(b) The Hubble expansion is:

(i) The enlargement of stars before they go supernova.

(ii) The linear expansion of the universe as evidenced by galaxy motion.

(iii) The growth of a black hole due to accreting matter.

(iv) Ejection of matter from an exploding star.

(c) Which of the following is true?

(i) Current data show that the Universe is decelerating (slowing down) T F

(ii) Neutrons and Protons are made of elementary particles called Quarks T F

(iii) All the forces have been unifed into a grand unified theory T F

(iv) The study of the cosmic microwave background supports the Big Bang model T F

(v) There are three fundamental interactions electromagnetic, strong, and gravity T F