Final Examination, Physics 7C, Spring 2007
Instructor: Prof. Adrian Lee, Thursday May 17

3 double-sided 3.5" x 5" cards of notes and calculators permitted. Good Luck!

1) Consider an object to the left of a convex spherical mirror with radius R. The distance from the mirror to the object is s_0.

a) Make a drawing and show where the image is. What is the distance from the mirror to the image s_i in terms of R and s_0? (15 pts)

b) Show that the magnification is $M = R/(2s_0 + R)$. (15 pts)

2)An observer in S' places two clocks at points A' and B' with a distance L' = 100 light-minutes between the clocks and places a flashbulb at the midpoint C' between the two clocks. She arranges for the bulb to flash and for clocks at A' and B' to be started at zero when the light from the flash reaches them. Frame S' is moving to the right with speed 0.6c relative to an observer C in S who is at the midpoint between A' and B' when the bulb flashes. At the instant he sees the flash, observer C sets his clock to zero.

a) What is the separation distance between the clocks A' and B' according to the observer in S? (10 pts)
b) Calculate the time difference between the arrival of the flashes at A' and B' by working in the S frame. Calculate the travel time for each pulse taking into account the apparent distance, the speed of S', and the fact that the flashes travel with speed = c. (10 points)
c) Calculate the time difference between the arrival of the flashes at A' and B' in S by working in the S' frame. That is, calculate the time difference in S' and then use that to get the time in S. Compare your answers to (b) and (c). Does the comparison make sense? Why? (10 points)

3) An electron moves in an infinite two-dimensional well defined by $0 < x < L$ and $0 < y < 2L$.
a) Find the wave functions $\Psi(x,y)$ satisfying Schrodinger's equation. These can be stated in terms of arbitrary multiplicative constants i.e. you don't have to normalize or eliminate solutions here. (10 pts)
b) Apply boundary conditions to find the energy levels of this well in terms of the quantum numbers n_1 and n_2. Please show your work here. (15 points)
c) What are the quantum numbers for the two lowest energy states? (5 points)
d) Find the lowest two energy states that are degenerate and give the quantum numbers for these states (10 points)

4) Particles are incident on a potential step. The particles are initially moving from left to right and the potential drops from 0 to $-U_0$ (the particles fall off a cliff). The total energy of the particles at the start is $E > 0$.

a) Write down the solutions to schrodinger's eqns in the two regions. (10 points)
b) What are the k values for both regions? Does the wavelength of the particles increase or decrease as they pass the step? (10 points)
b) Solve for the reflection and transmission coefficients R and T. (15 points)
d) How is this behavior different from that for a classical system? (5 points)

5) Consider a finite well with potential equal to zero for $0 < x < L$ and equal to U_0 outside of that region. The energy of an electron is $0 < E < U_0$.

a) Write down the solutions of the (1-dimensional) Schrodinger equation for an electron in the region inside and outside the well. These can be in terms of arbitrary multiplicative constants i.e. you don't have to eliminate any particular solutions or normalize here. (10 pts)
b) What are the boundary conditions that you can apply at $x = 0$ and $x = L$, and conditions at $x = +/-$ infinity? Do these conditions eliminate any parts of the solutions? (10 pts).
c) Sketch the wavefunction and probability density for the lowest three energy states (5 points).
d) Roughly what are the energy levels of this well? You can approximate by analogy to an infinite well rather than solve. (You can use the energy levels of an *infinite* well from your notes or from analogy to the solutions to problem 3) (5 points)

6) Solid State Physics, Particle Physics, and Cosmology (2 points each)

Answer True or False:
a) Conductors have a conduction band that is only partly filled.
b) Semiconductors can be doped with impurities that reduce their effective gap and increase conduction.
c) Insulators and semiconductors both have a gap (forbidden region) in their energy band structure.
d) Insulators can be made to conduct if a strong enough field is applied.
e) Transistors use 3 regions of doped semiconductor in a sandwich

f) Dark Energy has the following property (choose one):
- i) It binds galaxies together.
- ii) It accelerates the expansion of the Universe.
- iii) It started the Hubble expansion.
- iv) It is responsible for the Big Bang

Answer True or False:
g) There are three fundamental forces according to the standard model of High Energy Physics.
h) Nuclei are made of elementary particles called quarks.
i) quarks are made up of mesons.
j) The cosmic microwave background is leftover radiation from the Big Bang.

Planck constant $h = 6.6260755 \cdot 10^{-34}$ J·s
$h\_bar = h / (2\pi) = 1.05457266 \cdot 10^{-34}$ J·s
Boltzmann constant $k_B = 1.380658 \cdot 10^{-23}$ J/K ($= 8.617385 \cdot 10^{-5}$ eV/K)
Elementary charge $e = 1.60217733 \cdot 10^{-19}$ C
Speed of light $c = 2.99792458 \cdot 10^{8}$ m/s
Electron rest mass $m_e = 9.1093897 \cdot 10^{-31}$ kg=511 keV/c^2
Proton rest mass $m_p = 1.6726231 \cdot 10^{-27}$ kg=928MeV/c^2
Neutron rest mass $m_n = 1.6749286 \cdot 10^{-27}$ kg=940 Mev/c^2
Charge-to-mass ratio for the electron $e / me = 1.75880 \cdot 10^{11}$ C/kg
Atomic mass unit amu$= 1.66057 \cdot 10^{-27}$ kg
Compton wavelength of the electron $= h / (me\ c) = 2.42631 \cdot 10^{-12}$ m