Physics 143 - Second Quiz
November 5-15, 1999

I will abide by the Duke Honor Code  Name ________________________________

This is an open book, take home exam (you can use your notes, the two required texts of
the course, and any Introductory Physics text). Only work shown in the blue book will be
graded. However, please hand in these sheets with the blue book. **TOTAL POINTS: 21.**

1. Describe what is meant by the phase front (also known as the wave front) of a wave
propagating in three dimensional space.

2. A Martian-bound space ship consists of a space vessel that uses photons generated by
a laser as the propellant. (The rocket shoots photons out the back of the rocket to
move forward rather than gas as in standard rockets). The mass of the rocket is 1,000
kg (remains constant for the voyage), and the laser is able to produce a power of 1 MW
($10^6$ W). Estimate how long it will take for the craft to travel from Earth to Mars.
For this problem, ignore the force of Earth’s gravity or the gravitational force of any
other planets. **Hint:** The Mars-Earth distance is approximately $7.8 \times 10^7$ km.

3. Consider a plane electromagnetic wave of the form

$$\vec{E}(\vec{r}, t) = \vec{E}_o \cos(\vec{k} \cdot \vec{r} - \omega t) = \frac{\vec{E}_o}{2} \left[ e^{i(\vec{k} \cdot \vec{r} - \omega t)} + e^{-i(\vec{k} \cdot \vec{r} - \omega t)} \right].$$

Show explicitly that the field is transverse (that is, that $\vec{E}_o$ is always perpendicular to $\vec{k}$
for any $\vec{k}$). Make a sketch of the wave, carefully indicating the propagation direction
and the direction of the field. **Hint:** Use the differential form of Maxwell’s equations
for the first part of this question.

4. For the field given in the previous question, find the corresponding vector amplitude
of the magnetic induction $\vec{B}$ in terms of the vector amplitude of the electric field $\vec{E}_o$.

5. Consider the following wave function

$$\psi(x, t) = \frac{\psi_0}{\sqrt{[\pi \text{ m}^{-1}]x + (2\pi \text{ s}^{-1})t]^2 + 25 \cos[(2\pi \text{ m}^{-1})x + (2\pi \text{ s}^{-1})t]}.$$  

What is the approximate speed, direction of propagation, wavelength, and frequency
of the wave represented by this function?

6. Make a sketch of the function given in the previous problem at $t = 0$ and $t = 10$ s.
Explain to me how you came up with your sketch. (The use of a plotting program or
a graphing calculator is unacceptable for this problem. You will only receive credit if
you have a clear explanation as to how you went about plotting the function.)
7. An electron of momentum $p$ and mass $m_e$ is at a distance $r$ in a circular orbit around a stationary proton. The system has a kinetic energy $K = p^2/2m_e$ and a potential energy $U = -ke^2/r$. The average position of the electron is at the proton but the uncertainty in its position is approximately equal to the radius $r$ of its orbit. The electron’s average momentum will be zero, but the uncertainty in its momentum is approximately equal to the electron’s momentum $p$. Estimate the size and energy of the atom using Heisenberg’s uncertainty principle.  

*Hint:* Treat this as if it were a one-dimensional problem.