PHYS 212E **Name ____________________**
Third Hour Exam **April 21, 2005**

<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>electron</u>	<u>proton</u>
$m = 9.11\times10^{-31}\,\text{kg} = 511\,\text{keV}/c^2$	$m = 1.67\times10^{-27}\,\text{kg} = 938\,\text{MeV}/c^2$
$\mu_z = 9.27\times10^{-24}\,\text{J/T} = 5.8\times10^{-5}\,\text{eV/T}$	$\mu_z = 1.41\times10^{-26}\,\text{J/T} = 8.8\times10^{-8}\,\text{eV/T}$

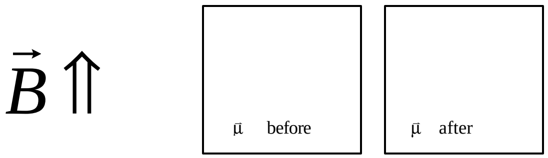
$c = 3.0\times10^{8}\,\text{m/s} = 3.0\times10^{17}\,\text{nm/s}$ $hc = 1240\,\text{eV}\cdot\text{nm}$ $1\,\text{eV} = 1.6\times10^{-19}\,\text{J}$

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

Integral table provided on back of exam.

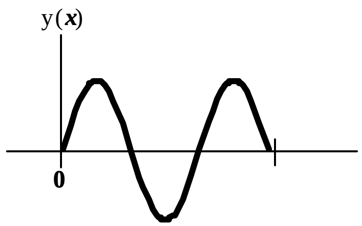
1. (10 points) An electron in a magnetic field $\vec{B}$ flips its spin as it emits a photon of wavelength 21 cm.

a) On the diagram, sketch arrows showing the direction of the (z-component of the) electron magnetic moment before and after the photon emission.



b) Determine the magnitude of the magnetic field experienced by the electron.

2. (15 points) A particle is trapped in an infinite square well potential of width L. The particle's wave function is sketched as shown; the wave function is described by the function $\psi(x) = \sqrt{\frac{2}{L}}\sin\frac{3\pi x}{L}$.



a) Determine the magnitude of the momentum of the particle using givens from the sketch and any fundamental constants.

b) On the sketch, carefully indicate regions where you would be ***most likely*** to find the particle.

c) Determine a numerical value for the probability of finding the particle in the region $0 \le x \le L/4$.

3. (20 points) Many identical particles are each prepared in the superposition state $|\psi\rangle = \frac{2}{3}|a\rangle + B|b\rangle - \frac{2}{3}|c\rangle$, 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 particles prepared in this state $|\psi\rangle$.

b) You measure the energy of a particle prepared to be in the state $|\psi\rangle$ given above. Determine the numerical probability that you will find the energy to be $3\,\text{eV}$.

c) Let's say that you *do* find an energy of $3\,\text{eV}$ for the particle. Consider the following statements about the particle's energy. Circle any statements which are true.

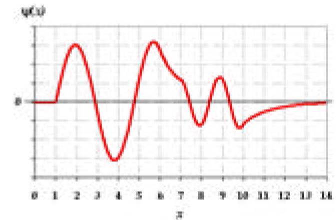
(i) Before the measurement was made, the energy of the particle was the expectation value from part (a).

(ii) Before the measurement was made, the energy of the particle was definitely one of the three possibilities $-4\,\text{eV}$, $-1\,\text{eV}$, or $3\,\text{eV}$, although you didn't know which one.

(iii) Before the measurement was made, the energy of the particle was $3\,\text{eV}$.

(iv) Another measurement of the energy immediately after the first will definitely come up with a value of $3\,\text{eV}$.

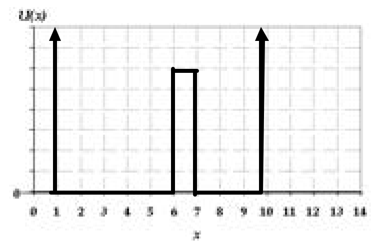
4. (10 points) A particle of mass m and total energy E is placed in a region of varying potential energy. Consider the one dimension wave function plotted to the right ($\psi(x)$ vs. x).



a) Which of the six graphs below represents a possible potential energy curve ($U(x)$ vs. x) that could give rise to this wave function? Write your choice in this box: $\boxed{}$

b) On the graph you chose, draw a line that represents the total energy E of the particle. Your line should be qualitatively correct.

A



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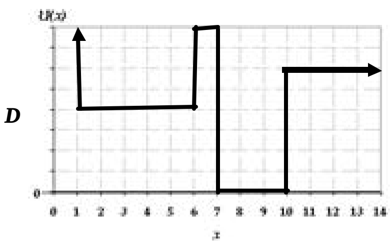
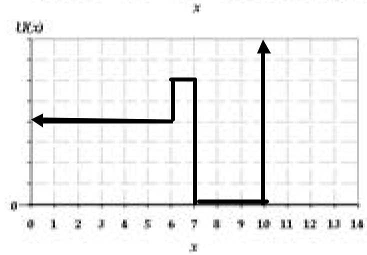
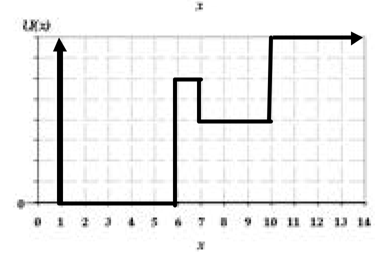


B



E



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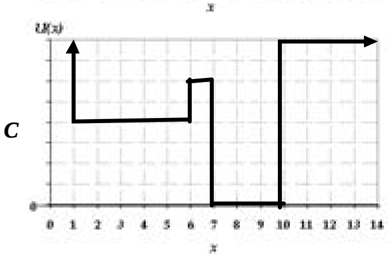

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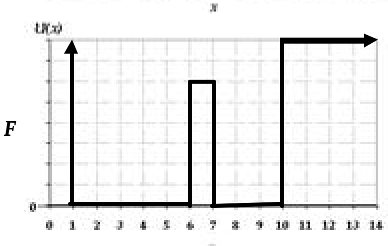

5. (15 points) Given that the x-components of the spin angular momentum of a proton can be written as a superposition of the definite z-component states as follows:

$$|+x\rangle = \sqrt{\frac{1}{2}}|+z\rangle + \sqrt{\frac{1}{2}}|-z\rangle \qquad \text{and} \qquad |-x\rangle = \sqrt{\frac{1}{2}}|+z\rangle - \sqrt{\frac{1}{2}}|-z\rangle$$

A proton is prepared in the superposition spin state $|\psi\rangle = \frac{5}{13}|+z\rangle - i\frac{12}{13}|-z\rangle$.

a) Calculate the numerical probability that a proton prepared in the superposition state $|\psi\rangle$ as given above will be measured to have its ***x*-component** of spin to be $+\hbar/2$.

b) Say that you did find the x-component of spin for this protons to be $+\hbar/2$. You then measure the z-component of spin for this proton, and also find it to be $+\hbar/2$. Finally, you measure the x-component of spin **again**. What will be the result of this final measurement? (Circle one).

$-\hbar/2$	0	$+\hbar/2$	either $-\hbar/2$ or $+\hbar/2$	both $-\hbar/2$ and $+\hbar/2$

6. (20 points) The state of an electron in a hydrogen atom can be fully described by its quantum numbers n, ℓ, m_ℓ, and m_s. Consider an electron that is in the partially described state $n=2$, $\ell=1$.

a) What result(s) might you obtain from a measurement of this electron's energy?

b) What result(s) might you obtain from a measurement of this electron's z-component of orbital angular momentum?

c) This electron (still in $n=2$, $\ell=1$) absorbs a photon of wavelength 656 nm. What is/are the energy/energies of the electron after it absorbs this photon?

d) Write down a set of four quantum numbers that could describe the state of the electron after it absorbed the photon from part c).

7. (10 points) Please choose ***one*** of the following short answer questions. Note that ***each question has two parts***. Please indicate which question you wish me to grade; in the absence of any indication, I will grade **neither** question.

<table>
<tr>
<td>Identical bosons "like" to be in the same state. Identical fermions can never be in the same state.

a) Briefly describe (don't just name!) one application/device or physical phenomena or consequence that relies on the fact that bosons "like" to be in the same state.

b) Briefly describe (don't just name!) one application/device or physical phenomena or consequence that relies on the fact that fermions can never be in the same state.</td>
<td>We've discussed the fact that quantum spin (such as the intrinsic spin of an electron) is very different from classical spin (such as the earth rotating about its axis).

a) Briefly escribe (don't just name!) two things about quantum spin that are different from classical spin.

b) Even though quantum spin and classical spin are so different, we still call it spin because it "acts like" classical spin in some ways. Briefly describe (don't just name!) one way in which quantum spin "acts like" classical spin.</td>
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a)

b)