The following questions are designed to give you some practice with concepts covered since the midterm (you should look at old practice midterms for sample problems covering the earlier course material!). Some are specifically designed to be difficult in order to make sure you can go beyond simple "plug and chug" problems. These problems will be gone over during the final exam review session. Note: Due to recently added problems (and follow-ons), there are now a total of 28 problems (25 plus 3 follow-ons).

1) An electron has a wavefunction $\Psi(r,\theta,\phi) = Cr^3e^{-r/a}$. At what radius is it most likely to find the electron?

A) r = a
B) r = 2a
C) r = 3a
D) r = 4a
E) r = 5a

2) An electron in an infinite square well of width L = 1 nm has the wavefunction:

$\Psi(x) = \text{sqrt}(2/L)*(\sin(3\pi x/L) + 2\sin(5\pi x/L) - \sin(\pi x/L))*1/\text{sqrt}(6)$.

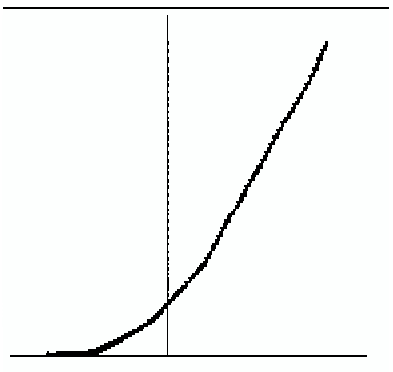
What is/are the possible result/results for a measurement of the electron's energy?

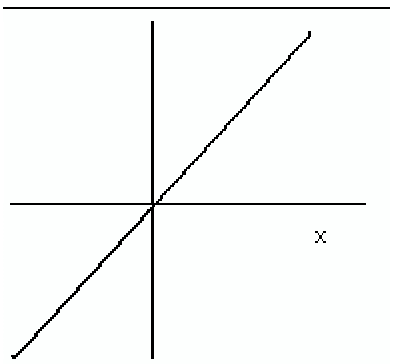
A) 4.39 eV
B) 6.90 eV
C) 0.38 eV, 3.39 eV, or 9.41 eV

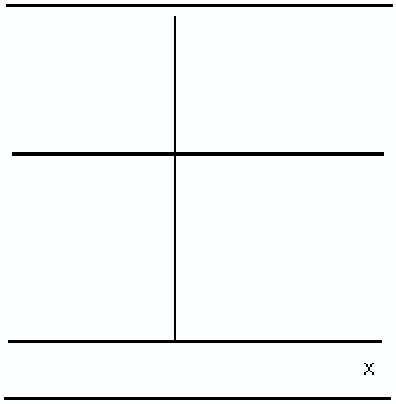
3) What is the probability of measuring the electron in problem 2 to have an energy of 9.41 eV?

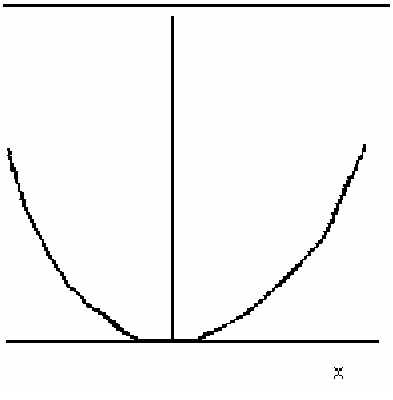
A) 0
B) .17
C) .41
D) .67
E) 1.0

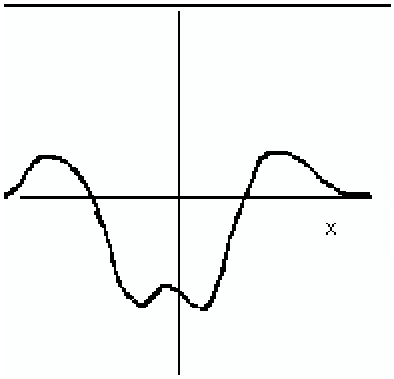
4) Which of the following pictures shows a valid wavefunction over the range $-\infty < x < \infty$?

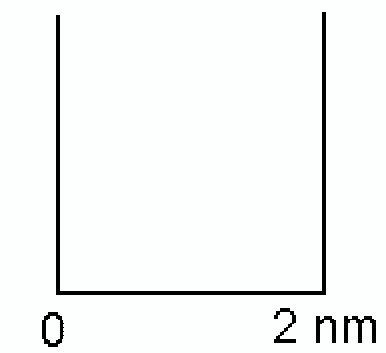
A) 

B) 

C) 

D) 

E) 



5) An electron is in the 3rd excited state of a 2 nm wide infinite square well. What is the probability of measuring the electron to be between x=0.4 nm and x=0.45 nm?

A) 0.04
B) 0.08
C) 0.16
D) 0.32
E) 0.64

6) An electron with total energy E approaches a barrier of height U_0 and width L. Assuming $E<U_0$, which one of the following changes will increase the probability for the electron to appear on the other side of the barrier?

A) increase L
B) increase E
C) increase U_0

7) An electron in a hydrogen atom is in a p state. Which of the following statements is true?

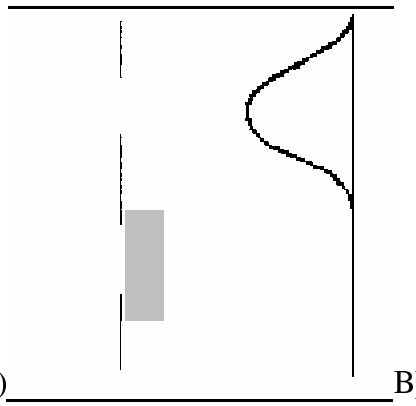
A) The electron has a total angular momentum of ħ.
B) The electron has an energy of -13.6 eV.
C) The probability to find the electron within 0.1 nm of the origin changes in time.
D) The electron's wavefunction has at least one node.
E) The electron has a z-component of angular momentum equal to sqrt(2)* ħ.

8) Which of the following normalized wavefunctions for the infinite square well has the shortest period of oscillation in time?

A) (sin(πx/L) + sin(2πx/L))/sqrt(L)
B) (sin(2πx/L) + sin(3πx/L))/sqrt(L)
C) (sin(πx/L) + sin(3πx/L))/sqrt(L)

9) Which of the following probability distributions will you observe from a beam of electrons passing through a double slit with one slit covered! (Note: you are to assume that the detection screen is far away from the slits, i.e, the diagrams are not drawn to scale)?

A)



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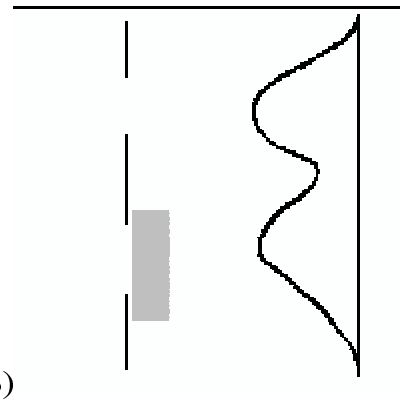
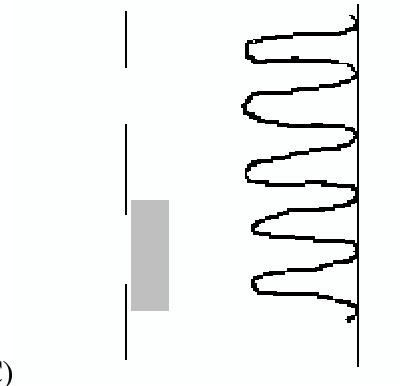


C)



9'(new) Now both slits are unblocked. However, we modify the experiment in the following way. We prepare the electrons incident on the slits so that they all have their spins "pointing up", i.e., so that $m_s = +1/2$. We install a tiny radio-coil near the top slit (this is only a thought experiment!), so that the spin of any electron that passes through the top slit is flipped (without affecting the spin of electron passing through the bottom slit). Now which pattern do we see?

A)
B)
C)

10) A photon has energy 3 eV. What is its momentum?

A) $1.6*10^{-27}$ kg m/s
B) $4.5*10^{-27}$ kg m/s
C) $5.3*10^{-26}$ kg m/s
D) $6.0*10^{-25}$ kg m/s
E) $9.4*10^{-25}$ kg m/s

11) A laser with wavelength 300 nm illuminates a metal in a photoelectric effect experiment. It takes a stopping potential of 2 Volts to halt the ejected electrons. What is the work function of the metal?

A) 1 eV
B) 2 eV
C) 3 eV
D) 4 eV
E) 5 eV

12) An electron is confined to a rectangular region in space with sides L_x =2 nm, L_y = 3 nm, L_z = 4 nm. What is the energy of the ground state?

A) 0.04 eV
B) 0.16 eV
C) 0.56 eV

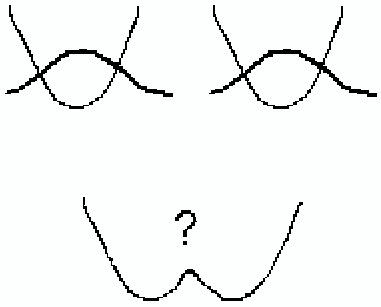
13) What is the degeneracy of the 1st excited state for the electron in problem 12?

A) 1
B) 3
C) 6

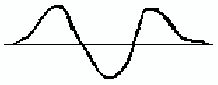
NOTE: We no longer cover Fermi energy in Physics 214!

14) Sodium has an atomic weight of 23 g/mole and a density of 970 kg/m3. What is its Fermi energy?

A) 0.2 eV
B) 0.6 eV
C) 1.3 eV
D) 2.5 eV
E) 3.1 eV

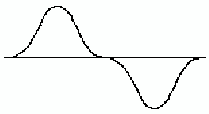


15) Two harmonic oscillators in their ground states are brought near each other. Which of the following pictures shows the correct 1st excited state for the combined system?



A)_____

B)_____



C)

15' (new)

Assume there is one electron from each harmonic oscillator (and neglect electrostatic interactions between the electrons).

If the "molecule" is in its lowest energy state, one of the electrons is in state (B) above. Which of the above pictures is appropriate for the wavefunction of the second electron?

A)

B)

C)

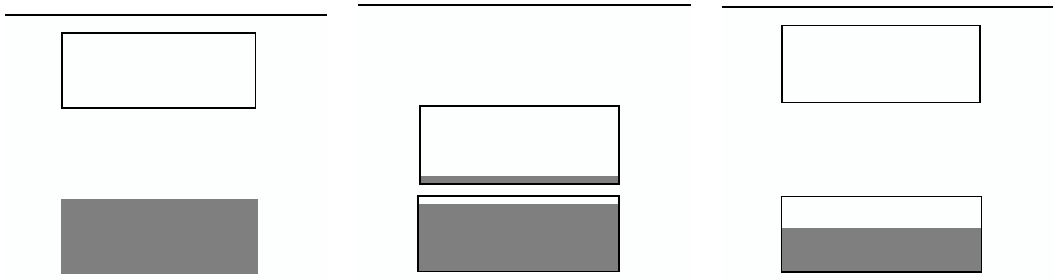
16) What are the quantum numbers n and l of the outermost electron of a Br atom? Br has 35 electrons.

A) n=3, l=0
B) n=3, l=1
C) n=4, l=0
D) n=4, l=1
E) n=4, l=2

16' (new)
If the outermost electron is now excited (e.g., by a collision) to the n = 5, l = 1 state, to which final state could the electron fall back down by emitting a photon?

A) n=4, l=3
B) n=4, l=2
C) n=5, l=0
D) n=4, l=1
E) n=3, l=2

17) Which of the following energy band pictures corresponds to a conductor?



A) B) C)

18) What frequency of electromagnetic radiation will flip a "spin up" electron to a "spin down" electron in a magnetic field of 2.0 T?

A) $2.4*10^{9}$ Hz
B) $4.1*10^{9}$ Hz
C) $5.6*10^{10}$ Hz
D) $7.1*10^{11}$ Hz
E) $8.8*10^{12}$ Hz

A calcium ion (charge |e|, mass = 6.65×10^{-26} kg) is trapped in an electromagnetic potential that approximates a harmonic oscillator. The frequency associated with the oscillation of the ion in the trap is 100 kHz.

19. If one wanted to excite the ion from the ground state of the trap *directly* to the *second excited state*, one might shine on radio waves with frequency:

A. 100 kHz
B. 200 kHz
C. 800 kHz

20. At time t = 0, the ion is prepared into an equal superposition of the ground state and the *second* excited state, $\psi = \frac{1}{\sqrt{2}}(\psi_0 + \psi_2)$. Which of the following describes the likely location of the ion:

A. The ion is more likely to be found in the left-hand side of the trap.
B. The ion is more likely to be found in the right-hand side of the trap.
C. The ion is equally likely to be found in either half of the trap.

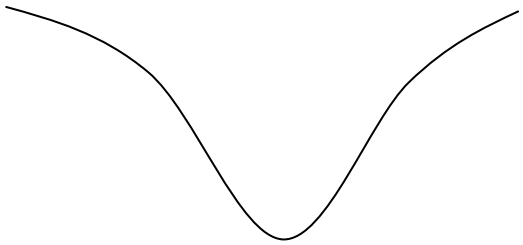
21. We now let the system evolve in time. Which of the following best describes the future behavior of the ion:

A. The ion will "slosh" back and forth from the left-hand side of the well to the right-hand side.
B. The ion will "slosh" back and forth from being mostly located near the center of the well to being mostly located away from the center (i.e., nearer the "edges" of the well).
C. The probability density of the ion will not change over time.

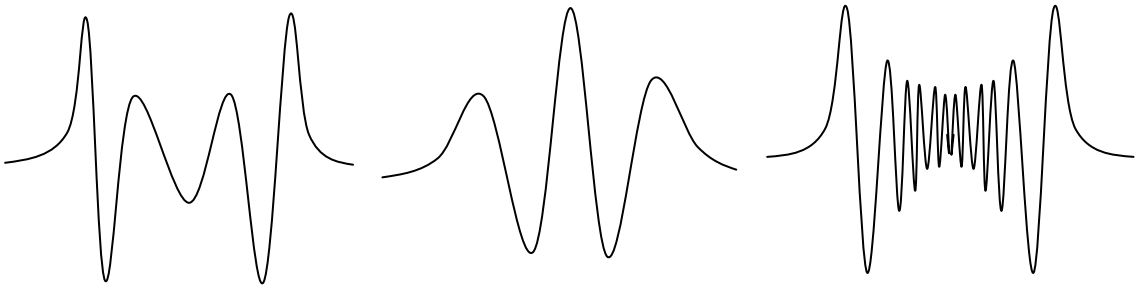
22. A hydrogen atom in its ground state is passed through a Stern-Gerlach apparatus, producing a set of peaks. The uppermost peak only is then passed through *another* Stern-Gerlach apparatus (with the same magnetic field gradient dB/dz as the first). How many peaks are observed in the output of the second Stern-Gerlach apparatus?

A. 0
B. 1
C. 2
D. 3
E. 4

23. For an electron trapped in a potential energy well that looks like this,



which one of the following wave functions is possible?



A. B. C.

24. In which state (if the ground state is n = 1) is an electron described by the wavefunction for choice A?

A. n = 2
B. n = 4
C. n = 7
D. n = 9
E. n = 10

25. A beam of electrons is sent toward a potential barrier (height = 2 eV, width = 0.5 nm) with velocity 6 x 10^5 m/s. What fraction of the incident beam is reflected?

A. 0.6 %
B. 12%
C. 98%
D. 99.4%
C. 100% (all of it)

Answers:
1) D
2) C
3) D
4) E
5) A
6) B
7) D
8) C
9) A

9') B

10) A
11) B
12) B
13) A
14) E
15) C

15') B

16) D

16') B&C

17) C
18) C

19) B
20) C
21) B
22) B
23) C
24) C
25) D