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PHYS2130 SAMPLE Midterm #2 –
note: these are some sample exam questions
Answers are not provided. They may be in the future.
You should be able to check your answers and your reasoning behind each question.

THIS EXAM WILL CONTAIN 18 MULTIPLE CHOICE PROBLEMS (1.67 POINT EACH) PLUS TWO ESSAY QUESTIONS (20 POINTS) FOR A RAW SCORE OF 50 POINTS.

IMPORTANT INFORMATION that you may need:

Speed of light in empty space (c)	3.0×10^{8} m/s
Planck's constant (h)	6.626×10^{-34} J-sec
$\hbar = h/2\pi$	
Coulomb's constant (k)	8.99×10^{9} N-m^2/C^2
Charge of an electron (e)	1.6×10^{-19} C
Ground state energy of electron in Hydrogen	-13.6 eV
Mass of electron (kg)	9.11×10^{-31} kg
Mass of proton or Mass of neutron (kg)	1.67×10^{-27} kg

hc = 1240 eV-nm
ke^2 = 1.440 eV-nm
1 electron – Volt (eV) = 1.602×10^{-19} Joules   1 MeV = 1×10^{6} eV
1 pm = 1×10^{-12} 1 nm = 1×10^{-9} m   1 μm = 1×10^{-6} m   1 mm = 1×10^{-3} m

Some Useful Equations:

$$-\frac{\hbar^2 \partial^2 \Psi(x,t)}{2m\partial x^2} + V(x,t)\Psi(x,t) = i\hbar \frac{\partial \Psi(x,t)}{\partial t}$$

$$-\frac{\hbar^2}{2m}\frac{d^2\psi(x)}{dx^2} + V(x)\psi(x) = E\psi(x)$$

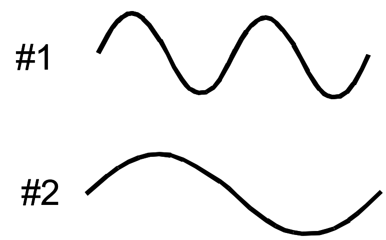
Honor Code Pledge

"On my honor as a University of Colorado at Boulder student I have neither given nor received unauthorized assistance on this work."

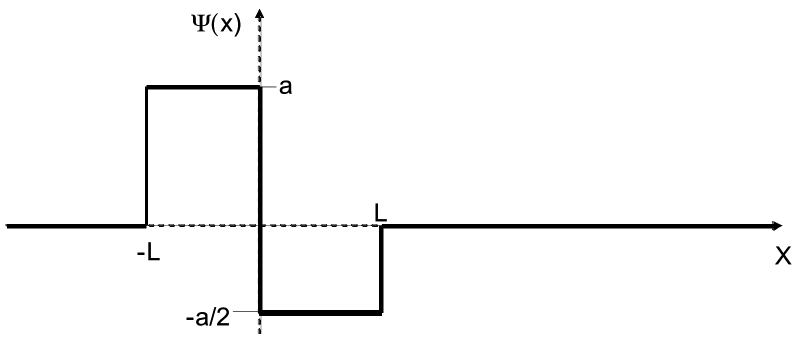
Student ID:___________________________ Name: ___________________________________

MULTIPLE CHOICE

1. Two electrons (1 and 2) are described by the wave functions shown at right. How does the momentum of electron #1 compare to electron #2?
a. momentum of #1 is greater than momentum of #2
b. momentum of #1 and #2 are the same
c. momentum of #2 is greater than momentum of #1
d. there is not enough information to compare the momentums.



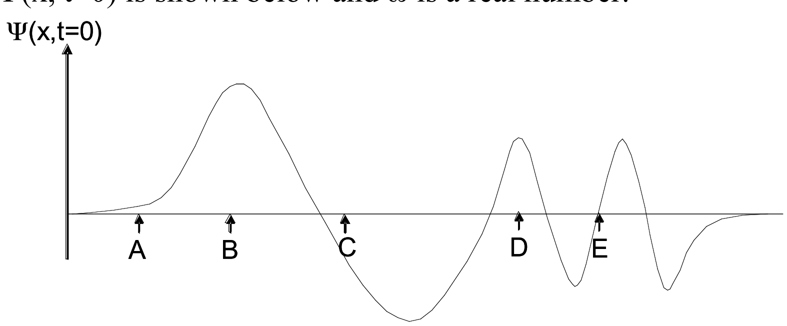
2. A particle is described by the wave function shown below where $\Psi(x) = 0$ for $x<-L$ and $x>L$



What does "a" need to be for this function so that the total probability of finding the electron anywhere between minus infinity and plus infinity is one?

A. $\sqrt{\frac{12}{5L^3}}$ B. $\frac{2L}{3}$ C. $\sqrt{\frac{3L}{2}}$ D. $\sqrt{\frac{4}{5L}}$ E. $\frac{2}{3L}$

3 A electron is bound in a potential well. The wave function of the electron is: $\Psi(x,t)=\psi(x)e^{-i\omega t}$ where $\Psi(x, t=0)$ is shown below and ω is a real number.



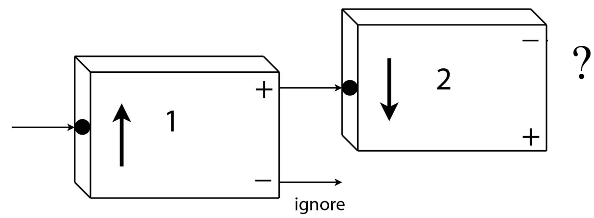
4. How do the probabilities of detecting the electron within a small distance (dx) of the positions (A-E) compare?
a. all probabilities are equal b. B>D>A>E>C c. B>D>A>C>E d. B>D>C>A>E
e. E>A>C>D>B

Student ID:___________________________ Name: __________________________________

5. A Plane Wave can be described by: $\Psi(x,t) = A\exp(i(kx-\omega t))$.
A Wave Packet can be described by: $\Psi(x,t) = \Sigma_n A_n \exp(i(k_n x-\omega_n t))$
For which type of wave are position x and momentum p most well-defined?

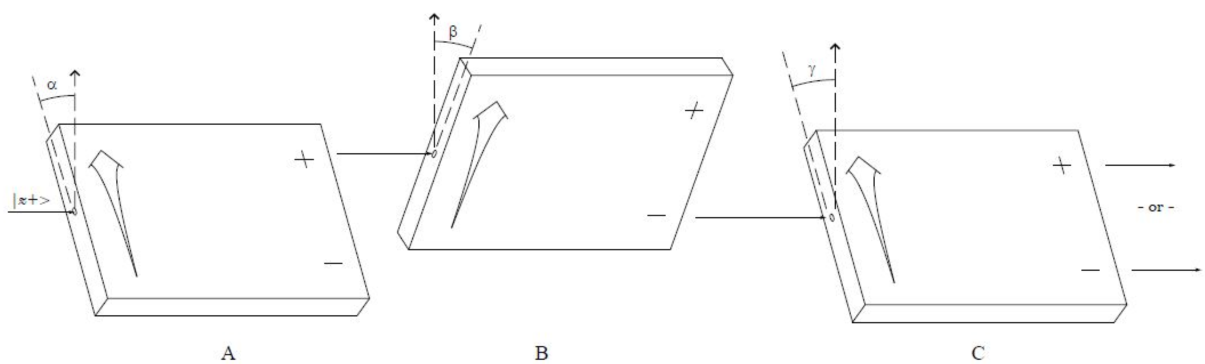
A. p most well-defined for plane wave, x most well-defined for wave packet.
B. x most well-defined for plane wave, p most well-defined for wave packet.
C. p most well-defined for plane wave, x equally well-defined for both.
D. x most well-defined for wave packet, p most well-defined for both.
E. p and x equally well-defined for both.

6. Atoms exiting from the plus-channel of Stern-Gerlach Analyzer 1 (oriented along the +z-axis) are fed into Analyzer 2 (oriented along the –z-axis). What is the probability for the atoms to exit from the plus-channel of Analyzer 2?



A) 0 B) 1/4 C) 1/2
D) 3/4 E) 1

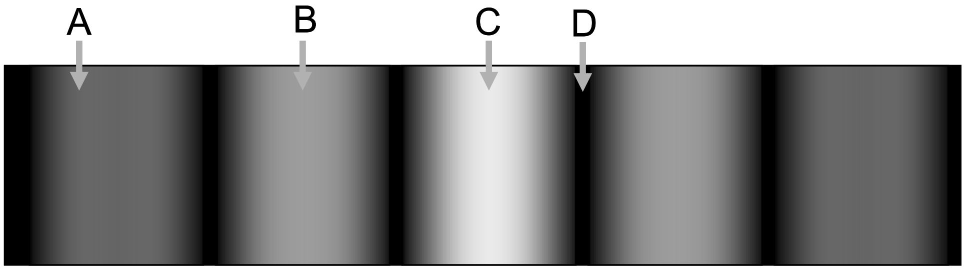
7. An atom in the state $|\Uparrow_z>$ is shot into the following line of three Stern-Gerlach analyzers. Analyzer A is tilted at an angle of $-\alpha$ from the vertical, Analyzer B at $+\beta$, and Analyzer C at $-\gamma$.



What is the probability that it emerges from the plus-channel of Analyzer C? From the minus-channel of Analyzer C? Why don't these probabilities sum to one? What would be the probability for the two above cases if $\alpha = 15^0$, $\beta = 35^0$ & $\gamma = 20^0$?

Student ID:___________________________ Name: __________________________________

8-10. Below you see the pattern on a screen created by a yellow laser shining through 2 slits.



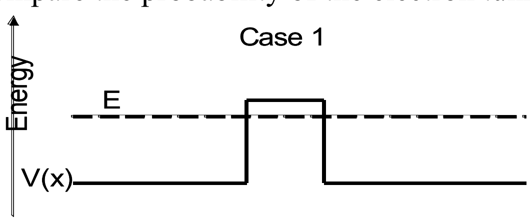
8. A photon is passing through the 2 slits. Rank the probability that the photon will be detected at locations A-D. (Below the letter "C" for instance means "probability of detecting photon at location C")
a. C>D>B>A b. C>B>A>D c. A=B=C>D
d. A=B=C=D e. D>A>B>C

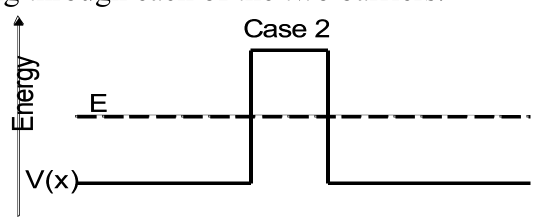
9. How would this pattern change if I were to shoot electrons through a double slit?

10. How would this change if I were to shoot small pebbles through two slits?

11. You have two wire-gap-wire situations as shown below. In each case, the gap between the wires forms a potential energy barrier that severely limits the current flow. An electron, with total energy shown as the dashed line, is traveling through the wire from left to right.

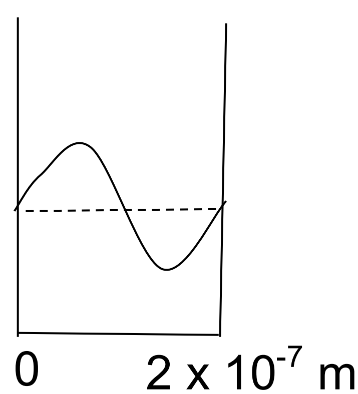
Compare the probability of the electron tunneling through each of the two barriers.





a. The tunneling probabilities for case 2 and case 1 will be the same.
b. The probability in case 2 will be greater than in case 1.
c. The probability in case 2 will be less than in case 1.
d. There is not enough information to compare the probabilities.

12. An electron is confined in a thin piece of metal that is 2×10^{-7} m thick, so it has energy levels similar to those of an infinite square well. The electron is in the second energy state with a wave function as shown. If you gently and smoothly squeeze the wire down so that the electron stays in the second energy state, but the wire is squished down to a thickness of 1×10^{-7} m, the uncertainty in the momentum of the electron will have
a. increased, b. decreased, c. remained the same.
HINT: think about where you can potentially find (measure) the electron in each case, and what does this say about the uncertainty of position.



13. (a) True (b) False. In the above problem potential energy of the electron changes as the wire is squished.

Student ID:_____________________________ Name: ____________________________________

LONG ANSWER SECTION:

THERE WILL BE 4 Long Answers.. You will be **required to answer two of them**.
These are not the questions but they'll involve ideas including but not limited to:

1) What do the terms ***locality***, ***completeness & realism*** mean? Are there experiments that demonstrate these properties for atoms, electrons or photons? That demonstrate that this perspective does not hold?

2) How does the double slit experiment work for electrons? What is observed? What are the implications?

3) When does light behave light a wave and when does it behave light a particle. Describe an experiment that would provide evidence of this behavior and how it shows this?

4) Work through solutions to the Schrodinger equation for V=0. What scenario(s) would this represent? Do you get quantized energies? What are the conditions when you get quantized energy levels?

5) Review the first three parts of the Tutorial from Tuesday's class.