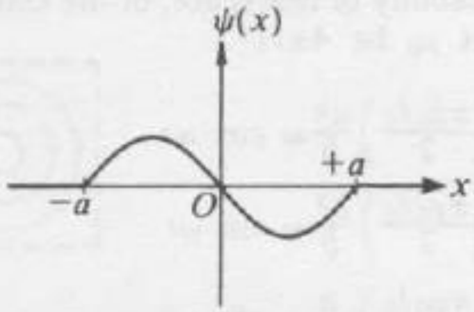
Physics 402
Spring 2019
Prof. Belloni
Discussion Worksheet for April 3, 2019



The figure above shows one of the possible energy eigenfunctions $\psi(x)$ for a particle bouncing freely back and forth along the x-axis between impenetrable walls located at $x = -a$ and $x = +a$. The potential energy equals zero for $|x| < a$. If the energy of the particle is 2 electron volts when it is in the quantum state associated with this eigenfunction, what is its energy when it is in the quantum state of lowest possible energy?

(A) 0 eV (B) $\frac{1}{\sqrt{2}}$ eV (C) $\frac{1}{2}$ eV

(D) 1 eV (E) 2 eV

The configuration of the potassium atom in its ground state is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$. Which of the following statements about potassium is true?

(A) Its $n = 3$ shell is completely filled.
(B) Its $4s$ subshell is completely filled.
(C) Its least tightly bound electron has $\ell = 4$.
(D) Its atomic number is 17.
(E) Its electron charge distribution is spherically symmetrical.

The hypothesis that an electron possesses spin is qualitatively significant for the explanation of all of the following topics EXCEPT the

(A) structure of the periodic table
(B) specific heat of metals
(C) anomalous Zeeman effect
(D) deflection of a moving electron by a uniform magnetic field
(E) fine structure of atomic spectra

Sodium has eleven electrons and the sequence in which energy levels fill in atoms is $1s$, $2s$, $2p$, $3s$, $3p$, $4s$, $3d$, etc. What is the ground state of sodium in the usual notation ${}^{2S+1}L_J$?

(A) ${}^1S_0$ (B) ${}^2S_{\frac{1}{2}}$ (C) ${}^1P_0$

(D) ${}^2P_{\frac{1}{2}}$ (E) ${}^3P_{\frac{1}{2}}$

Which of the following is NOT compatible with the selection rule that controls electric dipole emission of photons by excited states of atoms?

(A) Δn may have any negative integral value.
(B) $\Delta \ell = \pm 1$
(C) $\Delta m_\ell = 0, \pm 1$
(D) $\Delta s = \pm 1$
(E) $\Delta j = \pm 1$

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The mean kinetic energy of electrons in metals at room temperature is usually many times the thermal energy kT. Which of the following can best be used to explain this fact?

(A) The energy-time uncertainty relation
(B) The Pauli exclusion principle
(C) The degeneracy of the energy levels
(D) The Born approximation
(E) The wave-particle duality

In the Bohr model of the hydrogen atom, the linear momentum of the electron at radius r_n is given by which of the following? (n is the principal quantum number.)

(A) $n\hbar$
(B) $nr_n\hbar$
(C) $\frac{n\hbar}{r_n}$
(D) $n^2 r_n \hbar$
(E) $\frac{n^2\hbar}{r_n}$

The Fermi temperature of Cu is about 80,000 K. Which of the following is most nearly equal to the average speed of a conduction electron in Cu?

(A) 2×10^{-2} m/s
(B) 2 m/s
(C) 2×10^2 m/s
(D) 2×10^4 m/s
(E) 2×10^6 m/s

De Broglie hypothesized that the linear momentum and wavelength of a free massive particle are related by which of the following constants?

(A) Planck's constant
(B) Boltzmann's constant
(C) The Rydberg constant
(D) The speed of light
(E) Avogadro's number

An atom has filled $n = 1$ and $n = 2$ levels. How many electrons does the atom have?

(A) 2
(B) 4
(C) 6
(D) 8
(E) 10

Consider a set of wave functions $\psi_i(x)$. Which of the following conditions guarantees that the functions are normalized and mutually orthogonal? (The indices i and j take on the values in the set $\{1, 2, \ldots, n\}$.)

(A) $\psi_i^*(x)\psi_j(x) = 0$

(B) $\psi_i^*(x)\psi_j(x) = 1$

(C) $\int_{-\infty}^{\infty} \psi_i^*(x)\psi_j(x)dx = 0$

(D) $\int_{-\infty}^{\infty} \psi_i^*(x)\psi_j(x)dx = 1$

(E) $\int_{-\infty}^{\infty} \psi_i^*(x)\psi_j(x)dx = \delta_{ij}$

Consider a single electron atom with orbital angular momentum $L = \sqrt{2}\hbar$. Which of the following gives the possible values of a measurement of L_z, the z-component of L?

(A) 0

(B) $0, \hbar$

(C) $0, \hbar, 2\hbar$

(D) $-\hbar, 0, \hbar$

(E) $-2\hbar, -\hbar, 0, \hbar, 2\hbar$

Which of the following statements about bosons and/or fermions is true?

(A) Bosons have symmetric wave functions and obey the Pauli exclusion principle.
(B) Bosons have antisymmetric wave functions and do not obey the Pauli exclusion principle.
(C) Fermions have symmetric wave functions and obey the Pauli exclusion principle.
(D) Fermions have antisymmetric wave functions and obey the Pauli exclusion principle.
(E) Bosons and fermions obey the Pauli exclusion principle.

A quantum mechanical harmonic oscillator has an angular frequency ω. The Schrödinger equation predicts that the ground state energy of the oscillator will be

(A) $-\frac{1}{2}\hbar\omega$

(B) 0

(C) $\frac{1}{2}\hbar\omega$

(D) $\hbar\omega$

(E) $\frac{3}{2}\hbar\omega$

Characteristics of the quantum harmonic oscillator include which of the following?

I. A spectrum of evenly spaced energy states
II. A potential energy function that is linear in the position coordinate
III. A ground state that is characterized by zero kinetic energy
IV. A nonzero probability of finding the oscillator outside the classical turning points

(A) I only
(B) IV only
(C) I and IV only
(D) II and III only
(E) I, II, III, and IV