Modern Physics

Problem 1:

A spectral line is produced by a gas that is sufficiently dense that the mean time between atomic collisions is much shorter than the mean lives of the atomic states responsible for the line. Compared with the same line produced by a low-density gas, the line produced by the higher-density gas will appear

(A) the same
(B) more highly polarized
(C) broader
(D) shifted toward the blue end of the spectrum
(E) split into a doublet

Problem 2:

Which of the following properties of the hydrogen atom can be predicted most accurately from the simple Bohr model?

(A) Energy differences between states
(B) Angular momentum of the ground state
(C) Degeneracy of states
(D) Transition probabilities
(E) Selection rules for transitions

Problem 3:

The ratio of the nuclear radius to the atomic radius of an element near the middle of the periodic table is most nearly

(A) 10^{-2}
(B) 10^{-5}
(C) 10^{-8}
(D) 10^{-11}
(E) 10^{-14}

Problem 4:

The solution to the Schrödinger equation for a particle bound in a one-dimensional, infinitely deep potential well, indexed by quantum number n, indicates that in the middle of the well the probability density vanishes for

(A) the ground state ($n = 1$) only
(B) states of even n ($n = 2, 4, \ldots$)
(C) states of odd n ($n = 1, 3, \ldots$)
(D) all states ($n = 1, 2, 3 \ldots$)
(E) all states except the ground state

Problem 5:

The total energy necessary to remove all three electrons from a lithium atom is most nearly

(A) 2 MeV.
(B) 2 KeV.
(C) 200 eV.
(D) 20 eV.
(E) 2 eV.

Problem 6:

In the spectrum of hydrogen, what is the ratio of the longest wavelength in the Lyman series ($n_f = 1$) to the longest wavelength in the Balmer series ($n_f = 2$) ?

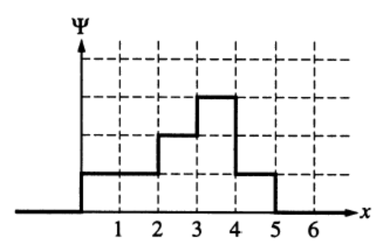
(A) 5/27
(B) 1/3
(C) 4/9
(D) 3/2
(E) 3

Problem 7:

Light of wavelength 500 nanometers is incident on sodium, with work function 2.28 electron volts. What is the maximum kinetic energy of the ejected photoelectrons?

(A) 0.03 eV
(B) 0.2 eV
(C) 0.6 eV
(D) 1.3 eV
(E) 2.0 eV

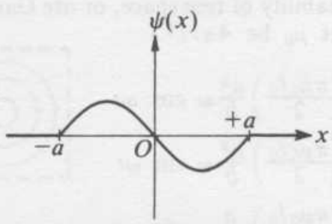
Problem 8:



The wave function for a particle constrained to move in one dimension is shown in the graph above ($\Psi = 0$ for $x \le 0$ and $x \ge 5$). What is the probability that the particle would be found between $x = 2$ and $x = 4$?

(A) 17/64
(B) 25/64
(C) 5/8
(D) $\sqrt{5/8}$
(E) 13/16

Problem 9:



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

Problem 10:

When a narrow beam of monoenergetic electrons impinges on the surface of a single metal crystal at an angle of 30 degrees with the plane of the surface, first-order reflection is observed. If the spacing of the reflecting crystal planes is known from x-ray measurements to be 3 ångstroms, the speed of the electrons is most nearly

(A) 1.4×10^{-4} m/s
(B) 2.4 m/s
(C) 5.0×10^{3} m/s
(D) 2.4×10^{6} m/s
(E) 4.5×10^{9} m/s

Problem 11:

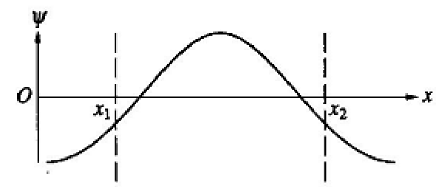
The Hamiltonian operator in the Schrödinger equation can be formed from the classical Hamiltonian by substituting

(A) wavelength and frequency for momentum and energy
(B) a differential operator for momentum
(C) transition probability for potential energy
(D) sums over discrete eigenvalues for integrals over continuous variables
(E) Gaussian distributions of observables for exact values

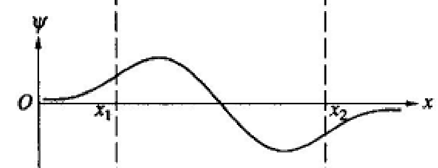
Problem 12:

An attractive, one-dimensional square well has depth V_0 as shown above. Which of the following best shows a possible wave function for a bound state?

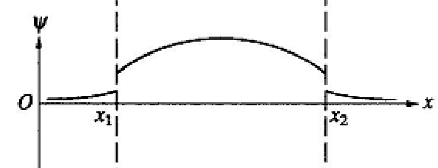
(A)



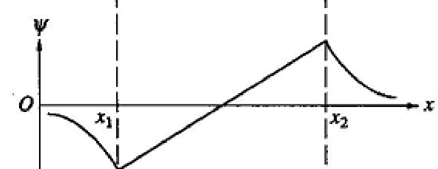
(B)



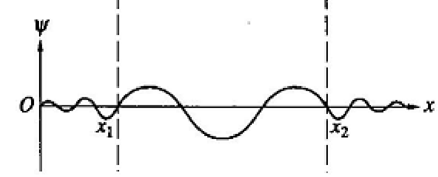
(C)



(D)



(E)



Problem 13:

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

Problem 14:

If ψ is a normalized solution of the Schrödinger equation and Q is the operator corresponding to a physical observable x, the quantity $\psi^* Q \psi$ may be integrated in order to obtain the

(A) normalization constant for ψ
(B) spatial overlap of Q with ψ
(C) mean value of x
(D) uncertainty in x
(E) time derivative of x

Problem 15:

Which of the following is an eigenfunction of the linear momentum operator $-i\hbar \frac{\partial}{\partial x}$ with a positive eigenvalue $\hbar k$; i.e., an eigenfunction that describes a particle that is moving in free space in the direction of positive x with a precise value of linear momentum?

(A) $\cos kx$ (B) $\sin kx$ (C) e^{-ikx}
(D) e^{ikx} (E) e^{-kx}