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

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) $\dfrac{n\hbar}{r_n}$

(D) $n^2 r_n \hbar$

(E) $\dfrac{n^2\hbar}{r_n}$

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) $-\dfrac{1}{2}\hbar\omega$

(B) 0

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

(D) $\hbar\omega$

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

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

The lifetime for the $2p \rightarrow 1s$ transition in hydrogen is 1.6×10^{-9} s. The natural line width for the radiation emitted during the transition is approximately

(A) 100 Hz
(B) 100 kHz
(C) 100 MHz
(D) 100 GHz
(E) 100 THz

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

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

Which of the following expressions is proportional to the total energy for the levels of a one-electron Bohr atom? (m is the reduced mass, Z is the number of protons in the nucleus, $-e$ is the charge on the electron, and n is the principal quantum number.)

(A) $\frac{mZe^2}{n}$
(B) $\frac{mZe^2}{n^2}$
(C) $\frac{mZ^2e^4}{n^2}$
(D) $\frac{m^2Z^2e^2}{n^2}$
(E) $\frac{m^2Z^2e^4}{n^2}$

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.

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A

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C

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(B) $0, \hbar$
(C) $0, \hbar, 2\hbar$
(D) $-\hbar, 0, \hbar$
(E) $-2\hbar, -\hbar, 0, \hbar, 2\hbar$

D

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

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IV. A nonzero probability of finding the oscillator outside the classical turning points

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

C

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D