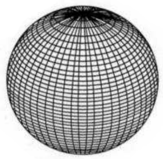
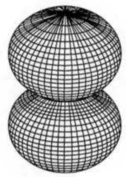
QM2 Concept Test 2.1

Which one of the following pictures represents the surface of constant $|\psi|^2$ for ψ_{200}?

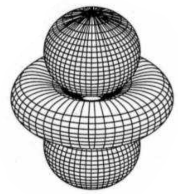
A.



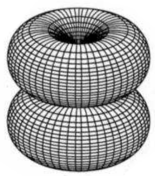
B.



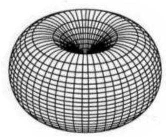
C.



D.



E.



1

QM2 Concept Test 2.2

Choose all of the following statements that are true about the quantum number m.

1. The quantum number m is determined by using separation of variables to solve for the angular wavefunction $Y(\theta, \phi) = \Theta(\theta)\Phi(\phi)$.
2. Using separation of variables to solve the angular equation $Y(\theta, \phi) = \Theta(\theta)\Phi(\phi)$ yields $\frac{d^2\Phi}{d\phi^2} = -m^2\Phi \rightarrow \ \Phi(\phi) \sim e^{im\phi}$.
3. The quantum number m must be an integer ($m = 0, \pm 1, \pm 2 \ldots$) because when ϕ advances by 2π, we return to the same point in space, i.e., $\Phi(\phi + 2\pi) = \Phi(\phi)$.

A. 1 only B. 3 only C. 1 and 2 only D. 1 and 3 only
E. All of the above

2

QM2 Concept Test 2.3

Choose all of the following statements that are true related to the quantum number l. The associated Legendre function is $P_l^{\ m}(x) = (1-x^2)^{|m|/2}\left(\frac{d}{dx}\right)^{|m|} P_l(x)$ and the lth Legendre polynomial is $P_l(x) = \frac{1}{2^l l!}\left(\frac{d}{dx}\right)^l (x^2-1)^l$.

1. We use separation of variables to solve for the angular wavefunction $Y(\theta, \phi) = \Theta(\theta)\Phi(\phi)$ which yields $\Theta(\theta) \sim \ P_l^{\ m}(\cos\theta)$.
2. Due to the definition of $P_l(x)$, l must be a nonnegative integer.
3. From the relation between $P_l^{\ m}(x)$ and $P_l(x)$, $P_l^{\ m}(x) = 0$ unless $|m| \leq l$. So for a normalizable wavefunction, for any given l, $m = -l, \ldots, -1, 0, 1, \ldots, l$.

A. 1 only B. 3 only C. 1 and 2 only D. 1 and 3 only
E. All of the above

3

QM2 Concept Test 2.4

Choose all of the following statements that are true about the radial equation and radial wavefunction $R(r)$ for spherically symmetric potential energy:

1. The radial wavefunction $R(r)$ cannot be found until a specific potential energy $V(r)$ is provided.
2. Solving for the radial wavefunction $R(r)$ determines the possible quantum number n and its relation to quantum number l
3. Solving the radial equation shows that the degeneracy of the n^{th} energy level E_n for hydrogen atom is $2n$.

A. 1 only B. 1 and 2 only C. 1 and 3 only D. 2 and 3 only
E. All of the above

4

QM2 Concept Test 2.5

A hydrogen atom is in the ground state $\psi_{100}(r) = \frac{1}{\sqrt{\pi a^3}} e^{-\frac{r}{a}}$, where a is the Bohr radius. What is the most probable value of r?

A. $r = 0$ m
B. $r = \frac{a}{2}$
C. $r = a$
D. $r = 2a$
E. None of the above

QM2 Concept Test 2.6

A hydrogen atom is initially in the state $\frac{1}{\sqrt{2}}(\psi_{200} + \psi_{210})$ at time $t = 0$. Choose all of the following statements that are correct about measurements performed on the atom <u>at time $t = 0$</u>:

1. If you make a measurement of the square of the magnitude of the angular momentum $\vec{L}^2$ immediately following a measurement of the z-component of the orbital angular momentum L_z of the electron at time $t = 0$, the measurement of $\vec{L}^2$ will yield $2\hbar^2$ or zero with 50% probability.
2. If you make a measurement of the z-component of the orbital angular momentum L_z immediately following a measurement of the x-component of the orbital angular momentum L_x of the electron at time $t = 0$, the measurement of L_z will yield zero with 100% probability.
3. If you make a measurement of the energy of the electron immediately following a measurement of the z-component of the orbital angular momentum L_z at time $t = 0$, the energy measurement will yield $\frac{-13.6eV}{4}$ with 100% probability.

A. 1 only B. 3 only C. 1 and 2 only D. 1 and 3 only E. None of the above

QM2 Concept Test 2.7

A hydrogen atom is initially in the state $\frac{1}{\sqrt{2}}(\psi_{200} + \psi_{210})$ at time $t = 0$. Choose all of the following statements that are correct about measurements performed on the atom <u>after a long time t</u>:

1. If you make a measurement of the square of the magnitude of the angular momentum $\vec{L}^2$ immediately following a measurement of the z-component of the orbital angular momentum L_z, the measurement of $\vec{L}^2$ will yield $2\hbar^2$ or zero with 50% probability.
2. If you make a measurement of the z-component of the orbital angular momentum L_z immediately following a measurement of the x-component of the orbital angular momentum L_x , the measurement of L_z will yield zero with 100% probability.
3. If you make a measurement of the energy of the atom immediately following a measurement of the z-component of the orbital angular momentum L_z at time, the energy measurement will yield $\frac{-13.6eV}{4}$ with 100% probability.

A. 1 only B. 3 only C. 1 and 2 only D. 1 and 3 only E. None of the above

QM2 Concept Test 2.8

A hydrogen atom is initially in the state $\frac{1}{\sqrt{2}}(\psi_{\mathbf{100}} + \psi_{\mathbf{210}})$ at time $t = 0$. Choose all of the following statements that are correct about measurements performed on the atom <u>after a long time t</u>:

1. If you make a measurement of the square of the magnitude of the angular momentum $\vec{L}^2$ immediately following a measurement of the z-component of the orbital angular momentum L_z, the measurement of $\vec{L}^2$ will yield $2\hbar^2$ or zero with 50% probability.
2. If you make a measurement of the z-component of the orbital angular momentum L_z immediately following a measurement of the x-component of the orbital angular momentum L_x , the measurement of L_z will yield zero with 100% probability.
3. If you make a measurement of the energy of the electron immediately following a measurement of the z-component of the orbital angular momentum L_z, the energy measurement will yield $\frac{-13.6eV}{4}$ with 100% probability.

A. 1 only B. 3 only C. 1 and 2 only D. 1 and 3 only E. None of the above

QM2 Concept Test 2.9

A hydrogen atom is initially in the state ψ_{200} at time $t = 0$. Choose all of the following statements that are correct.

1. The expectation value of the distance of the electron from the nucleus $\langle r \rangle$ depends on time.
2. The expectation value of the x-component of angular momentum of the electron $\langle L_x \rangle$ depends on time.
3. The expectation value of the z-component of angular momentum of the electron $\langle L_z \rangle$ depends on time.

A. 1 only B. 2 only C. 1 and 2 only D. 1 and 3 only E. None of the above

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QM2 Concept Test 2.10

A hydrogen atom is initially in the state $\frac{1}{\sqrt{2}}(\psi_{200} + \psi_{210})$ at time $t = 0$. Choose all of the following statements that are correct.

1. The expectation value of the distance of the electron from the nucleus $\langle r \rangle$ depends on time.
2. The expectation value of the x-component of angular momentum of the electron $\langle L_x \rangle$ depends on time.
3. The expectation value of the z-component of angular momentum of the electron $\langle L_z \rangle$ depends on time.

A. 1 only B. 2 only C. 1 and 2 only D. 1 and 3 only E. None of the above

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QM2 Concept Test 2.11

A hydrogen atom is initially in the state $\frac{1}{\sqrt{2}}(\psi_{100} + \psi_{210})$ at time $t = 0$. Choose all of the following statements that are correct.

1. The expectation value of the distance of the electron from the nucleus $\langle r \rangle$ depends on time.
2. The expectation value of the x-component of angular momentum of the electron $\langle L_x \rangle$ depends on time.
3. The expectation value of the z-component of angular momentum of the electron $\langle L_z \rangle$ depends on time.

A. 1 only B. 2 only C. 1 and 2 only D. 1 and 3 only E. None of the above

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QM1 Concept test 2.12

$\hat{H}$ is the Hamiltonian for the electron in a Hydrogen atom with Coulomb potential energy only. Choose all of the following statements that are correct.

1. $[\hat{H}, \hat{L}_z] = 0$
2. $[\hat{H}, \hat{L}^2] = 0$
3. In spherical polar coordinates, the potential energy V of the Hydrogen atom is independent of the angular variables θ and ϕ.

A. 3 only B. 1 and 2 only C. 1 and 3 only D. 2 and 3 only
E. all of the above

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QM1 Concept test 2.13

The stationary states of a hydrogen atom are ψ_{nlm}. Choose all of the following statements that are correct.

1. $\hat{L}^2\psi_{nlm} = l(l+1)\hbar^2\psi_{nlm}$
2. $\hat{L}_z\psi_{nlm} = m\hbar\psi_{nlm}$
3. $\hat{H}\psi_{nlm} = \frac{-13.6eV}{n}\psi_{nlm}$, where $\hat{H}$ is the Hamiltonian of the system.

A. 1 only B. 2 only C. 1 and 2 only D. 2 and 3 only
E. all of the above