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Physics 2710 – Example Exam II

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Please **circle the letter corresponding to the *best* answer.**

Questions 1-4 refer to: An electron confined within an infinite cubical well has energy eigenvalues equal to $E_{n_x n_y n_z} = (1\text{ eV})(n_x^2 + n_y^2 + n_z^2)$.

1. The ground state energy is
(a) 0 eV
(b) 2 eV
(c) 3 eV
(d) 6 eV

2. The first excited state is
(a) nondegenerate
(b) 2-fold degenerate
(c) 3-fold degenerate
(d) 6-fold degenerate

3. The electron undergoes a transition from the first excited state to the ground state. The emitted photon is in which region of the electromagnetic spectrum?
(a) X-ray
(b) ultraviolet
(c) infrared
(d) visible

4. Suppose instead of a cubical well, the electron is in a quantum wire with y and z sides 1/10 as long as the x side. Its energy eigenvalues are now $E_{n_x n_y n_z} = (1\text{ eV})(an_x^2 + bn_y^2 + cn_z^2)$. What are the possible values of $a, b,$ and c?
(a) 1, 100, 100
(b) 1, 10, 10
(c) 1, 1/100, 1/100
(d) 1, 1/10, 1/10

Questions 5-19 refer to: The "sanitized" hydrogen atom problem.

5. The Schrödinger equation is expressed in spherical coordinates because
(a) electrons and protons are spheres
(b) the electron orbits the proton in circles
(c) electrons and protons have spin
(d) the electron-proton potential energy is spherically symmetric

6. The orbital angular momentum of the electron
(a) is conserved because the force of the proton on the electron points toward the proton
(b) has a magnitude of $\frac{1}{2}\hbar$
(c) has a magnitude of $\sqrt{2}\hbar$
(d) is not defined because the electron does not orbit the proton in a circle

7. How many different m_l values are possible for $l = 3$?
(a) 7
(b) 4
(c) 3
(d) 1

8. How many different l values are possible for $n = 3$?
(a) 7
(b) 4
(c) 3
(d) 1

9. The magnitude of the orbital angular momentum of the electron in a $3p$ state is
(a) $\hbar$
(b) $3\hbar$
(c) $7\hbar$
(d) $\sqrt{2}\hbar$

10. The electron is in an $l = 1, m_l = 1$ state. The angle the total orbital angular momentum vector makes with respect to a $z-$axis is
(a) 0°
(b) 45°
(c) 90°
(d) 135°

11. The minimum energy required to excite a $2s$ electron to an unbound state is
(a) 0 eV
(b) 1.5 eV
(c) 3.4 eV
(d) 13.6 eV

12. Violet photons are produced in the transition
(a) $n = 6$ to $n = 2$
(b) $n = 6$ to $n = 1$
(c) $n = 3$ to $n = 2$
(d) $n = 3$ to $n = 1$

13. Electric dipole transitions to the $1s$ electronic state can only occur from
(a) s states
(b) p states
(c) d states
(d) f states

14. The electron undergoes an electric dipole transition starting in an $(nlm_l) = (531)$ state. Which *one* of the following is a possible end state?
(a) $(42-1)$
(b) (211)
(c) (310)
(d) (322)

15. The electron undergoes an electric dipole transition starting in an $(nlm_l) = (210)$ state. Which *one* of the following is *not* a possible end state?
(a) (421)
(b) (500)
(c) (200)
(d) $(32-1)$

16. What is the degeneracy of the $n = 5$ level *if electron spin is included*?
(a) 50
(b) 25
(c) 10
(d) 5

17. How many $5d$ states are there *if electron spin is ignored*?
(a) 50
(b) 25
(c) 10
(d) 5

18. The dimensions of $k_E e^2$ are
(a) energy-length
(b) energy-length^2
(c) energy^2-length
(d) energy^2-length^2

19. The dimensions of $(\hbar c)^2 / mc^2$ are
(a) energy-length
(b) energy-length^2
(c) energy^2-length
(d) energy^2-length^2

20. The Stern-Gerlach experiment shows that
(a) electrons have spin ½
(b) photons have spin ½
(c) electrons have spin 1
(d) photons have spin 1

21. A hydrogen $1s$ electron with spin "up" has a slightly different energy from a $1s$ electron with spin "down" because of magnetic interaction with the nuclear proton. Which *one* of the following is true? A transition between these two states
(a) is forbidden by the electric dipole Δn rule
(b) is forbidden by the electric dipole Δl rule
(c) is associated with a UV photon with wavelength equal to 100 nm
(d) is associated with a radio wave photon with wavelength equal to 21 cm

22. Two identical, noninteracting *bosons* in a 1D infinite square well have quantum states s_1 and s_2. The proper wavefunction for this system (where A is a normalization constant) is

(a) $A\Psi_{s_1}(x_1)\Psi_{s_2}(x_2)$

(b) $A\Psi_{s_2}(x_1)\Psi_{s_1}(x_2)$

(c) $A[\Psi_{s_1}(x_1)\Psi_{s_2}(x_2)+\Psi_{s_2}(x_1)\Psi_{s_1}(x_2)]$

(d) $A[\Psi_{s_1}(x_1)\Psi_{s_2}(x_2)-\Psi_{s_2}(x_1)\Psi_{s_1}(x_2)]$

23. Neutral Ag has 47 protons and 61 neutrons. A $5s$ electron in neutral Ag is effectively bound to only about 3.7 protons. This is most directly due to

(a) inner electrons screening the nucleus

(b) magnetic interactions between the neutrons and electrons

(c) the fact that Ag has several nuclei orbiting one another

(d) the weak nuclear interaction

24. The ground state electronic configuration of Rb ($Z = 37$) is

(a) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^1$

(b) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 4d^1$

(c) $1s^1 2s^2 3s^2 2p^6 3p^6 4s^2 4p^6 3d^{10} 5s^2$

(d) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 5s^2 4p^5$

25. The first excited state of Rb is

(a) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^1$

(b) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 4d^1$

(c) $1s^1 2s^2 3s^2 2p^6 3p^6 4s^2 4p^6 3d^{10} 5s^2$

(d) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 5s^2 4p^5$