Quiz 4: Modern Physics

Date: 5 **May** 2018

Useful Formulae

$$h = 6.63 \times 10^{-34}\ \text{Js} \qquad m_e = 9.11 \times 10^{-31}\ \text{kg}$$
$$k_B = 1.38 \times 10^{-23}\ \text{JK}^{-1} \qquad 1\text{eV} = 1.6 \times 10^{-19}\ \text{J}$$
$$c = 3 \times 10^{8}\,\text{ms}^{-1} \qquad a_0 = 5.29 \times 10^{-11}\ \text{m}$$

1. In the state $n = 3$, $\ell = 0$, at what distance from the nucleus, is their maximum probability of locating the electron in the Hydrogen atom? The radial wave function is

$$R_{10}(r) = 2\sqrt{\frac{1}{a_0^3}}\left(e^{-r/a_0}\right)$$ **(5 marks)**

2. Free electrons in a metal behave like a quantum gas. At what minimum temperature, would these electrons behave like a classical gas? The density of electrons is 1 per atom and atoms are roughly 0.3 nm apart. **(6 marks)**

3. In a liquid sample certain nuclei acts like spin$-\frac{1}{2}$ particles. They are modeled by two-state quantum levels (qubits). The energy separation between these levels is 1 μeV at a field of 1 Tesla. At what temperature, would 75% of the lower state and 25% of the upper state will be occupied? **(5 marks)**

4. ZnTe laser has a band gap of about 2.2 eV. What wavelength is this laser expected to produce? **(3 marks)**

5. Diamond is barely transparent at a UV wavelength of 250 nm. What is its approximate band gap? How can we predict transparency or opaqueness based on band gaps? **(4 marks)**