Name:

Student Number:

Quiz 1 ELEC 4705

Tuesday Oct. 1 2019

1. (10 marks) Classical Physics.
   (a) What is the model used by classical physics of a particle? Contrast it with a classical field such as an electric field (**E**)
   (b) What are the equations that we use to describe the movement of a classical electron?
   (c) What is the classical model of light? Describe an experiment or phenomena that clear demonstrates why this model was developed.

   (a) A particle is distinct identifiable object with prescribed qualities such as mass, velocity, position, charge, etc. Its primary characteristic is that is a "lump" of matter that has unique position and follows a trajectory. A field by contrast is distributed has a magnitude (vector or scaler) and is described by a continuous functions such as $\mathbf{E}(x, y, z)$.

   (b) Newtons laws – $F = ma$, conservation of mass, conservation of momentum.

   (c) Maxwell's equations – a wave theory of coupled E and B fields. Interference, diffraction, thin slit experiments, thin film diffraction, etc.

2. (10 marks) QM electrons
   (a) Describe the dual nature of the QM model of the electron.
   (b) What is the motivation for using a wave packet description of an electron in QM?
   (c) Describe in words (possibly using an equation) what a wave packet is.
   (d) Describe the difference between the phase velocity and group velocity of a wave packet.

(a) The electron has both wave-like and particle like properties. It propagates like a wave and exhibits interference, dispersion and diffraction phenomena. However, it interacts with other "objects" like a particle with an energy $E = \hbar\omega$.

(b) An electron with single energy component will not be localized. A wave-packet allows for a distribution of possible energies and momentums to be present in the electron wave-function and a spacial localization.

(c) A wave-packet is formed by a superposition of phase components with each phase having a different wavelength (momentum) and allowing for a "pulse" of electron probability to be described. Formally this is done by using Fourier Transforms between the spatial domain and momentum domain.

(d) Phase velocity is the individual velocity of each phase (energy/momentum) of the wave function. Group velocity is the velocity at which the "center" of the wave-packet moves.

3. (10 Marks) QM electron in a well

   (a) What is the procedure for determining how an electron placed in potential well behaves.

   (b) Describe the distinction between a bound electron and free electron.

   (c) Sketch the E vs k dispersion relationship for a perfectly free electron.

   (d) On the same sketch add a E vs K dispersion relationship for an electron in a finite box.

(a) i. Write down the SCE for each region

ii. Write down the boundary and interface conditions between each region. Smooth continuous wave-function at all interfaces.

iii. Solve the system of equations – for bound electron this will produce the quantization condition.

iv. Extract the dispersion relationship $E(k)$.

(b) A bound electron has an energy less then the well depth, is confined to the well and has quantized energy levels. A free electron has an energy greater then the well depth a continuous energy spectrum and is free to be anywhere in space.