※ 注意：請於試卷內之「非選擇題作答區」作答，並應註明作答之題號。

1. The Schrödinger equation is widely used to solve energy problem. Consider the step potential

$V(x) = V_0 \cdot \theta(x) = 0$ in region 1 ($x < 0$)

$V(x) = V_0 \cdot \theta(x) = V_0$ in region 2 ($x > 0$)

a) What type of force does this potential describe? (2 pts)

b) Show that $\psi(x) = e^{\pm ikx}$ are solutions of the Schrödinger equation for this potential in both regions. (4 pts)

c) Calculate ki in regions $i = 1, 2$ in terms of the total energy E. (4 pts)

2. While the spins of the two electrons in a hydrogen molecule must be antiparallel in the the ground state, there is a degeneracy due to the spin of the two protons, $s_1=1/2$ and $s_2= 1/2$.

a) Why doesn't the Pauli exclusion principle apply to the protons? In other words, why can the two protons have arbitrary m_s, while the electrons must occupy different states? (3 pts)

b) List the possible combinations of quantum numbers (ms1, ms2). What is the degeneracy of the ground state? (3 pts)

c) Ortho-hydrogen (triplet) is 15 meV higher in energy than the ground state of para-hydrogen E =0 (singlet). For which value of s is it possible to have ($m_{s1} = m_{s2}$) = 1/2 (the spins aligned)? (4 pts)

3. If a particle is deflected by 0.01° (degree) in each collision, about how many collisions would be necessary to produce an rms deflection of 10°? What is the rms deflection angle for a gold foil of thickness 10^{-6} m, assuming that the thickness of each atom is 0.1 nm. (10 pts)

(Hint: Use the result from the one-dimensional random walk problem in statistics stating that the rms deflection equals the magnitude of the individual deflections times the square root of the number of deflections.)

4. The wavelengths of visible light range from about 380 nm to about 750 nm.

a) What is the range of photon energies (in eV) in visible light? (2 pts)

b) A typical FM radio station's broadcast frequency is about 100 MHz. What is the energy of an FM photon of the frequency? (2 pts)

c) The work function for cesium is 1.9 eV, the lowest of any metal. Find the threshold wavelength for the photoelectric effect. (3 pts)

d) Flowing the question above, find the stopping potential in voltage if the wavelength of the incident light is 300 nm. (3 pts)

5. A container at 300 K contains H_2 gas at a pressure of one atmosphere. At this temperature H_2 obeys the Boltzmann distribution. To what temperature must H_2 gas be cooled so that the quantum effects can be observed? In other words, the use of the Boltzmann distribution is no longer appropriate. (10 pts)

(Hint: Equate the de Broglie wavelength at the average energy to the average spacing between molecules, using the ideal gas law to compute the density.)

6.

a) Please draw a half-wave rectifier using a diode and other passive component(s). (5 pts)

b) Assuming the diode composed of an ideal diode in series with a DC voltage source (V_{DO}) and a resistor (r_D), and assuming a sinusoidal input source voltage waveform, please draw the input and output voltage in time domain. The peak amplitude difference between input and output voltage needs to be marked with proper parameters. (5pts)

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7. For the MOSFET,

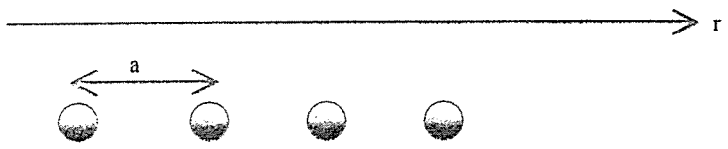
a). please draw a cross-section of a CMOS integrated circuit, assuming a p-type body. (5%)

b). please draw a common source amplifier circuit. The transistor is an n-channel MOS. The DC bias voltage, current source, input voltage, output voltage, bypass capacitors and coupling capacitors, load resistance, gate and drain resistance must be included and labeled in the circuit. (10%)

8. How many independent standing waves with wavelengths between 95 and 10.5 mm can occur in a cubical cavity 1 m on a side? How many with wavelengths between 99.5 and 100.5 mm? (Hint: First show that $g(\lambda)d\lambda = 8\pi L^3 d\lambda/\lambda^4$.) (10 pts)

9. For Kronig-Penney Model,

a) Given a one-dimensional lattice below, assuming the distance between two ions is a, please draw the potential "V(r) v.s. r". (5pts)



b) Please draw the potential "V(r) v.s. r" based on the Kronig-Penney Model. (5pts)

c) For a nearly free electron in the one-dimensional periodic potential, please draw the E-K (energy- momentum) diagram based on the Kronig-Penney Model. (5pts)

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