1. Please describe below in brief. **(20%)**
(a) uncertainty principle, (b) tunnel effect, (c) ultraviolet catastrophe, (d) Lamb shift, (e) Compton effect, (f) density of states, (g) Zeeman effect, (h) Raman effect, (i) Fermi energy, (j) Thomson's model, Rutherford's model, and Bohr's model (Hint: These models are models of the atom).

2. Consider a particle of mass m which can move freely along the x axis anywhere from $x = -a/2$ to $x = +a/2$, but which is strictly prohibited from being found outside this region. The particle bounces back and forth between the walls at $x = -a/2$ and $x = +a/2$ of a one-dimensional box. The walls are assumed to be completely impenetrable, no matter how energetic is the particle. **(20%)**
(a) Find the wave functions and determine the values of energy for different states of this particle. (8%)
(b) Evaluate the expectation values of x, p, x^2, and p^2 for the lowest energy state (ground state). (8%)
(c) Find the probability that the particle can be found between $x = -a/10$ and $x = +a/10$ for the lowest energy state (ground state) and the first excited state. (4%)

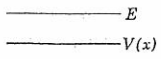
3. The light of wavelength 193 nm and intensity 1 W/cm^2 is directed at gold with work function 4.8 eV. **(10%)**
(a) Find the maximum kinetic energy (in eV) of the photoelectrons. (5%)
(b) If the quantum efficiency is 2%, how many photoelectrons per 1 cm^2 area are emitted per second? (5%)

4. For a hydrogen atom, the wave function can be assumed in the form of $\psi(r,\theta,\phi) = R(r)\Theta(\theta)\Phi(\phi)$ and the Schrödinger equation can be simplified with the method of separation of variables. (Hint: The wave function of a 1s electron (ground state) is $\psi = \frac{e^{-r/a_0}}{\sqrt{\pi a_0^{3/2}}}$.) **(20%)**
(a) Derive the electron energies and the wave functions for different states that correspond to n (principal quantum number) and l (orbital quantum number). (10%)
(b) Find the average value of 1/r for an electron in 1s state. (5%)
(c) Find the position where possibility is the highest to find the 1s electron. (5%)

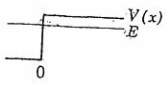
5. (a) Write down the quantum numbers for the states described in spectroscopic notation as $^2S_{3/2}$, $^3D_2$, $^5P_3$. **(9%)**
(b) Determine if any of the states in (a) are impossible, and if so, explain why. **(5%)**

6. Sketch the probability density ($\psi^*\psi$) as a function of x for the cases in below. **(16%)**

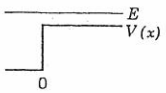
(a) zero potential



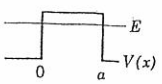
(b) step potential (energy below top)



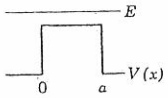
(c) step potential (energy above top)



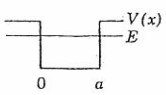
(d) barrier potential (energy below top)



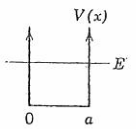
(e) barrier potential (energy above top)



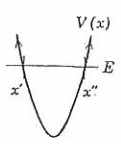
(f) finite square well potential



(g) infinite square well potential



(h) simple harmonic oscillator potential



試題隨卷繳回