1. This problem is about α decay of ^{238}U.
   (a) ^{238}U is known to undergo α decay and the kinetic energy of α particles emitted is 4.2 MeV. Draw roughly to scale the potential energy V acting on a α particle as a function of r, the distance from the center of a ^{238}U nucleus. Please include V=8.8 MeV at $r = 3.0 \times 10^{-14} m$ in your plot and also indicate other r values that might be important. If the potential has more than one component, you should label the potential curve clearly. $k = \frac{1}{4\pi\varepsilon_0} = 8.988 \times 10^9 nt - m^2 / coul^2$ (5%)
   (b) According to classical mechanics α decay is not possible for ^{238}U. Then, how would you explain the experimental fact? State your approach to the problem. Give necessary equations but don't have to solve the equations. (5%)
   (c) What property or quality you can use to compare your theory to experiment? How would you express it theoretically? (4%)

2. Suppose you are going to perform a double-slit experiment with light. You hope to determine through which slit each photon passes without destroying the double-slit pattern.
   (a) Can you set up an experiment that meets the conditions? Please show your reasons. (6%)
   (b) Summarize what you learn from such an experiment. (4%)

3. Questions related to important experiments in the history of modern physics.
   (a) What can we learn from the Stern-Gerlach experiment? (5%)
   (b) Davisson and Germer confirmed de Broglie's hypothesis that the dual, wave-particle behavior of radiation applies equally well to matter. Please write out the key points of this experiment. (5%)

4. The wave lengths of the lines of the K series of an atom X are (ignoring fine structure): K_α: λ=0.312Å, K_β: λ=0.276Å, and K_γ: λ=0.265Å. The M absorption edge is λ=3.10Å.
   (a) Construct the X-ray energy level diagram based on the information provided. (7%)
   (b) Indicate the mentioned transitions in your diagram. (3%)

5. To solve the eigenfunctions for hydrogen atom we use Coulomb potential in the Schroedinger equations. Then we examine the probability density function for hydrogen atom and find that there is nodal surfaces at certain values of r and θ. Suppose now we have a collection of hydrogen atoms isolated from the environment. Can we locate the nodal surface of a quantum state with a particular set of quantum numbers n, ℓ, m_ℓ? (7%)

6. Please answer the following questions with a brief statement.
   (a) How is intensity of radiation defined in Einstein's quantum theory of light? (3%)
   (b) Why does a γ ray creates an electron-positron pair only in the presence of a third body? No need to prove it. (3%)

7. Suppose a bunch of 1,000,000 muons are formed in the cosmic rays with a speed of 0.999 c at the top of the atmosphere. Muons are unstable and will decay. A man at earth counts the number of muons in the bunch when it reaches the surface of the earth. Suppose the man can observe every muon that originally belongs to the bunch and does not decay after the journey. The number he gets is 686,000. The "survived" muons feel that they have traveled a distance of 360 m.
   (a) What is the height of the atmosphere? (4%)
   (b) What is the half life of the muons as measured by the man on earth? (4%)

8. In an experiment we measure the thermal radiation of two blackbodies R and K. In the plots of spectral radiancy vs frequency we find that the spectral radiancy has a maximum value at $\nu = 2\times10^{14}\,Hz$ and $3\times10^{14}\,Hz$, respectively for R and K. Please answer the following questions with a brief reason.
   (a) What is the ratio of the temperature of R and K?(3%)
   (b) What is the ratio of the power radiated by R and K if they have the same shape and size? (3%)
   (c) Now we plot energy density as a function of wavelength. What is the ratio of λ_{max} for R and K? (3%)
   (d) What is the ratio of the energy density at λ_{max} for R and K in the plot of (c)? (3%)

9. An external magnetic field of 100 tesla is applied to potassium atoms. Let's focus on the energy levels that are originated from the ground state configuration and first excited configuration of potassium atoms.
   (a) Draw the energy levels to scale in the absence of an external magnetic field. Label the levels with spectroscopic term. Indicate allowed transitions in your plot. (5%)
   (b) Draw the energy levels to scale in the presence of an external magnetic field. Label the levels with proper quantum numbers. Indicate allowed transitions in your plot. (5%)
   (c) Draw an emission spectrum for the allowed transitions in (b). Use the transitions in (a) as the reference in the spectrum. (5%)

10. The existence of deuterium was first demonstrated by observation of the isotope shift in spectral lines emitted by samples of natural hydrogen. Please show that it is possible experimentally by comparing the first line of the Balmer series. $m_e = 9.11\times10^{-31}\,kg$, $m_p = 1.673\times10^{-27}\,kg$, $m_n = 1.675\times10^{-27}\,kg$, $R_H = 109{,}678\ cm^{-1}$. (8%)