Physical constants:

Speed of light: $c = 3.00 \times 10^8$ m/s

Planck's constant: $h = 6.6 \times 10^{-34}$ J·s

Fundamental Charge: $e = 1.60 \times 10^{-19}$ C

Mass of electron: $m_e = 9.1 \times 10^{-31}$ kg

Mass of unit: $u = 1.66 \times 10^{-27}$ kg

Coulomb's law constant $1/4\pi\varepsilon_0 = 9 \cdot 10^9$ N·m^2/C^2

$c^2 = 931.5$ MeV/u

1. (20%) Briefly describe the following terms:
   (a) Pair production and Dirac's interpretation.
   (b) Fine structure and hyperfine splitting.
   (c) Normal and Anomalous Zeeman effect.
   (d) Neutrino and antineutrino.

2. (10%) Explain if an electron can be confined in an atomic nucleus by applying the uncertainty principle. The diameter of an atomic nucleus is on the order of magnitude of 10^{-15} m.

3. (10%) An electron-positron pair at rest annihilate, creating two photons. Find the wavelength and the momentum of the photon.

4. (20%) A particle of mass m is moving in a one-dimensional infinite square well of width a. The potential energy function V(x) is given as the following:

$$V(x) = 0 \quad \text{for } 0 < x < a$$
$$= \infty \quad \text{elsewhere}$$

   Find the possible allowed kinetic energies of the particle by using two different methods.
   (a) By using the Wilson-Sommerfeld quantization rules.
   (b) By using the Schrödinger equation.

（背面仍有題目，請繼續作答）

5. (10%) (a) Describe the forms of eigenfunctions for an atom with 2 electrons in the triplet state and the singlet state.

(b) What is the exchange force? Also compare the energy levels of the triplet state and the singlet state. Which is lower?

6. (20%) (a) ^6C atoms are placed in a weak external field B=0.2 T. Construct a diagram to show the transitions allowed by the selection rules between the states 2p3s $^1P_1$ and 2p^2 $^1D_2$. How many spectral lines will be produced in these transitions?

(b) Redraw the transition diagram and determine the number of spectral lines when the atoms are placed in a strong external field B>>1 T.

7. (10%) What are the Einstein A and B coefficients? Why are they important to be applied in the principle of Laser?