※ 注意：請於試卷內之「非選擇題作答區」依序作答，並應註明作答之部份及題號。

There are three parts of this exam.

Part I: Modern Physics I (35%)

1.(10%) For the infinite barrier quantum well problem with quantum well length L (From x=0 to x=L) . The electron energy will split into n states where the energy and wave function can be expressed as

$$E_n = \frac{n^2\pi^2\hbar^2}{2mL^2} \qquad \psi_n(x) = \sqrt{\frac{2}{L}}\sin\frac{n\pi x}{L}, n = 1,2,3 \ldots$$

Please calculate the following expectation value if the electron is in the ground state: (1) $<x>$ (2) $<x^2>$ (3) $<p>$ (4) $<p^2>$

2.(5%) If λ is the mean free path between the collisions of a free electron and the average time τ between collision is $\tau = \lambda/V_F$, where V_F is the Fermi velocity Calculate the resistivity ρ in terms of m, n, e, λ, and V_F . (m, n, and e are the electron mass, density, and charge, respectively.)

3. (5%) Please calculate the density of states *g(E)* of photons within the energy range of E and E+dE.

4. (10%) If a system has angular momentum of quantum number l=3, (1) what is the magnitude of **L**, and (2) what is the smallest possible angle between **L** and the *z* axis?

5.(5%) What is Rayleigh scattering?

Part II: Modern Physics II (40%)

Please find the answer of **(1)** to **(8)**, 5% each.

6. In a system of two particles with energies and momenta (E_1, P_1) and (E_2, P_2), respectively, the quantity, $S^2=(E_1+E_1)^2-C^2(p_1+p_2)^2$, is invariant; i.e., it has the same numerical value in all inertial frames.

(a) Consider a center-of-mass collision of proton and an antiproton (Mc^2=939.3 MeV). The minimum momentum required to produce a particle with mass Mc^2=91200 MeV is **(1)** GeV/c.

(b) In a fixed-target accelerator, an antiproton projectile collides with a proton target at rest. The minimum energy that the antiproton must have to create the new particle of part (a) is **(2)** TeV.

7. Assume that in a gas of H under normal conditions, the interatomic spacing is $1.6*10^{-8}$ m and the gas is made of atomic, not molecular, hydrogen. What n-value of the hydrogen atoms is the size of the atom comparable to the interatomic spacing: **(3)**.

8. Compton used photons of wavelength 0.0711 nm. (a) What is the energy of these photons: **(4)** eV; (b) What is the wavelength of the photons scattered at $\theta=180^o$: **(5)** nm; (c) What is the energy of the photons scattered at $\theta=180^o$: **(6)** eV; (d) What is the recoil energy of the electrons if $\theta=180^o$: **(7)** eV.

9. An excited state of a certain nucleus has a half-life of 0.85 ns. Taking this to be the uncertainty Δt for the emission of a photon, as λ=0.01 nm, $\Delta f/f$= **(8)**.

Part III: Microelectronics (25%)

10. Choose the correct description(s) about a p-n junction diode: (a) depletion region under forward-bias is wider than that under reverse-bias, (b) diffusion current (rather than drift current) dominants under forward bias, (c) junction capacitance increases with increasing reverse-bias, (d) Higher doping concentration results in larger junction built-in voltage. (12%)（每小題各三分，答錯不倒扣）

11. Consider a MOSFET with t_{ox} = 8 nm, W = 8 μm, L = 0.8 μm, μ_n = 450 cm^2/Vs, V_t = 0.7 V, ε_{ox} = 3.45x10^{-11} F/m:

(a) Find Cox. (3%)

(b) Calculate the values of V_{GS} and minimum V_{DS} needed to operate the transistor in the saturation region with a dc current I_D = 100 μA. (6%)

(c) Find the value of V_{GS} required to cause the device to operate as a 1000 Ω resistor for very small V_{DS}. (4%)