1. A satellite that orbits Earth (the radius of 6400km) in a circle with a period of 12 hours, the height of its orbit is 20200km and emits radio waves at a frequency of 1.5GHz. The angle between the direction of the motion of the satellite and the direction from it to a receiver is 90degrees.

   (a) If the receiver is fixed on the ground. What frequency change is found by the receiver? (5%)

   (b) If the receiver on car moving at 200km/hour. What frequency change is found by the receiver? (5%)

   (c) What is the time difference between a clock in the satellite and one on the ground after 7200 circulations of the satellite? (5%)

   (d) What is the phase difference between the emitted radio waves and the received waves after 2 circulations of the satellite? (5%)

   (e) The satellite has a mass of 200kg on the ground. What is the angular momentum of the satellite? (5%)

2. Photometers measure light by counting individual photons. Does the principle of photometers associate with the photon process of

   (a) the photoelectric effect? Why? (5%)

   (b) the Compton effect? Why? (5%)

   (c) the pair production? Why? (5%)

3. A particle has momentum $p = mv$ with the relativistic mass m. We describe its state by using a de Broglie wave.

   (a) What the group velocity is it associated with the velocity? (5%)

   (b) What the phase velocity is it associated with the velocity? (5%)

   (c) How can the phase velocity physically be greater than the speed of light c? (5%)

4. In one-dimensional space, a particle having energy E approaches a potential barrier of width L and height V.

   (a) Draw the wave function distribution for $E > V$. (5%)

   (b) Is there a situation in which the transmission probability is 1? Why? (5%)

   (c) Why the tunneling effect is observed only on the atomic scale? (5%)

5. A quantum particle of mass m moves in a circle of radius a.

   (a) What is its wave equation? (5%)

   (b) Find the possible energies of the particle. (5%)

   (c) Find the possible angular momentum of the particle. (5%)

6. A hydrogen atom is in a state with quantum numbers, the principal quantum number $n = 4$ and the orbital quantum number $l = 3$.

   (a) What are the possible values of the total angular momentum quantum number j? (5%)

   (b) What are the possible z components of the total angular momentum? (5%)

7. Why does the total energy of a Fermi-Dirac system not approach zero as temperature $T \to 0$? (5%)