九題全答

（一）電磁學部份（1-4，共四題）

[1] 20% A long two-wire transmission line of length s is placed in a medium of permeability \( \mu \), permittivity \( \varepsilon \), and conductivity \( \sigma \). The wires are parallel to each other and carry currents in opposite directions.
(A) Find the total inductance and the total leakage resistance of the line if the distance D between centers of wires is much larger than the wire radius b. The internal inductance should be included.
(B) How can the signal frequency affects the total inductance of the line if b is not small compared with D?

[2] 7% Explain the magnetic hysteresis loop of ferromagnetic material which is good for use in electric transformers.

[3] 7% A homogenous isotropic dielectric sphere of radius \( r \) and relative permittivity \( \varepsilon_r = 5 \) is placed in an initially uniform electric field \( \mathbf{E}_0 \). The medium outside the sphere is air. Draw qualitatively the equipotential curves and the directions of electric fields inside and outside the sphere.

[4] 16% A circular disk of radius \( R \), conductivity \( \sigma \), and thickness t (t<\( \varepsilon \)) is placed in a magnetic field \( \mathbf{B}_0 \), where \( \mathbf{B} \) is the unit vector in the z direction. The axis of the disk is in the z direction. Discuss and find
(A) the voltage which can be generated in the disk if \( \mathbf{B} \) is constant and the disk is rotating about the z-axis with a constant angular velocity \( \omega \);
(B) the eddy current which can be generated in the disk if the disk is fixed in space and \( \mathbf{dB}/\mathbf{dt} = \mathbf{b}_0 \), where \( \mathbf{b}_0 \) is a constant.
(二) 固態電子學部份 (5-9, 共五題)

[5] 7% Calculate the approximate donor ionization energy for a semiconductor with relative permittivity $\varepsilon_r = 15$, conductivity effective mass $m_e^* = 0.1m_0$, and density of state effective mass $m_v^* = 0.6m_0$, where $m_0$ is the free electron mass.

[6] 7% Sketch qualitatively and compare the temperature dependences of Fermi levels $E_F$ in (A) the Si sample with donor impurity of $10^{16}$ cm$^3$ and (B) the Si sample with donor impurity of $10^{18}$ cm$^3$ for the temperature (T) range from T=50K to T=700K.

[7] 6% A Si sample is doped with Boron (硼) impurity of $10^{16}$ cm$^3$. Sketch qualitatively the distributions of electron and hole concentrations as functions of energy at room temperature. The corresponding formula should be written. The positions of Fermi level, the conduction and valence band edges should be shown on the energy axis.

[8] 14% Draw the energy-band diagrams for the following structures:
(A) a p-n junction under a reverse bias; (The electron and hole quasi-Fermi levels should be shown in the figure.)
(B) an Al-Si-Al structure (n-type Si sample sandwiched between two pieces of Al(鋁)) with a temperature $T_L$ at the left-hand-side Al and a temperature $T_H$ at the right-hand-side Al, $T_H > T_L$. Assume that the work function of Si is larger than that of Al.

[9] 16% Consider a Ge p-n step junction diode with permittivity $\varepsilon$ and doping concentrations $N_s$ and $N_d$ in the p- and n-regions, respectively. Find the total current density of the diode illuminated uniformly by light so that the carrier generation rate $g$(m$^{-3}$s$^{-1}$) is steady and uniform in the whole diode. Given that $V=$ the voltage across the diode under low injection, $T=$ temperature, $k=$ Boltzmann constant, $q=$ electron charge, $n_i =$ intrinsic carrier concentration, $\tau_e =$ electron lifetime, $\tau_p =$ hole lifetime, $D_n =$ electron diffusion coefficient, and $D_p =$ hole diffusion coefficient.