1. (a) Write down Ohm's law and the differential forms of Maxwell's equations? (5 points)
   (b) Which Maxwell's equation leads to a discovery of electromagnetic fields propagating in free space with the speed of light? (3 points)
   (c) What does the linear, homogeneous, and isotropic medium mean? (3 points)
   (d) Under an assumption of the linear, homogeneous, isotropic, and source-free medium, derive the following general wave equation of the electric fields $\vec{\mathbf{E}}$ from Maxwell's equations: (8 points)

$$\nabla^2\vec{\mathbf{E}} = \mu\sigma\frac{\partial\vec{\mathbf{E}}}{\partial t} + \mu\epsilon\frac{\partial^2\vec{\mathbf{E}}}{\partial t^2}$$

   (Vector Identity: $\nabla\times\nabla\times\vec{\mathbf{F}} = \nabla(\nabla\cdot\vec{\mathbf{F}}) - \nabla^2\vec{\mathbf{F}}$; ϵ: dielectric constant; μ: magnetic permeability; σ: conductivity)
   (e) Under which conditions, the general wave equations will become time-dependent wave (or Helmholtz) equations? (3 points)
   (f) What will happen to a plane wave if the wave is propagating in a conducting medium? (3 points)

2. (a) Explain Coulomb's law and Gauss's law for the electric fields. (6 points)
   (b) Derive the electric field intensity at any point due to an infinite plane with a surface charge density ρ_s using **Coulomb's law.** (10 points)
   (c) Derive the electric field intensity at any point due to an infinite plane with a surface charge density ρ_s using **Gauss's law for the electric fields.** (9 points)

3. (a) Explain the Biot-Savart law and Ampère's circuital law. (6 points)
   (b) Derive the magnetic flux density at any point due to a very long, very thin, straight wire carrying a current I using **the Biot-Savart law.** (10 points)
   (c) Derive the magnetic flux density at any point due to a very long, very thin, straight wire carrying a current I using **Ampère's circuital law.** (9 points)

4. The motion of a charged particle is governed by the Lorentz Force equation. With the equation, discuss the possible trajectory and the energy change of a positive charge moving with a velocity $\vec{\mathbf{v}}$ under the following conditions of the electric and magnetic fields:
   (a) No electric and magnetic fields; (5 points)
   (b) Uniform electric fields; (5 points)
   (c) Uniform magnetic fields; (5 points)
   (d) Uniform electric and magnetic fields, but the electric fields are perpendicular to the magnetic fields; (5 points)
   (e) Nonuniform magnetic fields with a gradient perpendicular to the magnetic fields. (5 points)