1. Given the electric potential $\Phi(r,\theta,\phi) = -Ar\cos\theta + \dfrac{B}{4\pi\varepsilon_0}(\dfrac{1}{r}-\dfrac{1}{R}) + \dfrac{AR^3}{r^2}\cos\theta$ in spherical coordinates (r,θ,ϕ) with constants A, B, R, and the permittivity of free space ε_0,
   (a) Determine the electric field　(5%)
   (b) Sketch the electric field lines.　(5%)
   (c) Find the charge distribution that given rise to the potential.　(5%)
   (d) Find the electric interaction energy of the system.　(5%)

2. A point charge q is placed at a point P in medium 1, which is at a distance d from the boundary of two semi-infinite homogeneous linear dielectrics of permittivities ε_1 and ε_2.
   (a) What are the boundary conditions for the potential and the electric field?　(5%)
   (b) Find the image charges.　(5%)
   (c) Find the potential in region 1 of permittivity ε_1.　(5%)
   (d) Find the polarization in region 2 of permittivity ε_2.　(5%)

3. A small current circular coil of radius R lies in x-y plane with its center at the origin. It carries a stationary current I running counterclockwise as viewed from the positive z-axis. There is an external uniform magnetic field $\vec{B} = \dfrac{B_0}{\sqrt{2}}(\hat{x}+\hat{y})$ that is not generated by the coil of the current I. Where B_0 is a constant and $\hat{x}, \hat{y}$ are unit vectors along the x-axis and y-axis, respectively.
   (a) Find the magnetic field at points along z-axis.　(5%)
   (b) Find the magnetic moment of the coil and express the result in (a) in terms of the magnetic moment.　(5%)
   (c) Find the force acting on the coil.　(5%)
   (d) Find the torque acting on the coil.　(5%)

4. A uniformly magnetized sphere of radius R with the magnetization $\vec{M} = M_0\hat{z}$ in z direction.
   (a) Find the vector potential of the magnetic field outside the sphere.　(5%)
   (b) Find the magnetic field outside the sphere.　(5%)
   (c) Find the current distribution of a conducting sphere of radius R that produces the identical magnetic field in (b).　(5%)

5. A rectangular wire of width w and length l in x-y plane is moving parallel to its width at a uniform velocity $\vec{v}$ in y direction. An infinite long wire, carrying a stationary current I in x direction, coplanar with the wire, and parallel to its length is at a distance d from the nearest long side.
   (a) Determine the electromotive force induced in the rectangular wire.　(5%)
   (b) Determine the mutual inductance of the system.　(5%)
   (c) If the current carried in the infinite long wire is time dependent $I(t)$, determine the electromotive force induced in the rectangular wire.　(5%)

6. For the electromagnetic waves confined to the interior of a hollow pipe (or wave guide),
   (a) Give the reasons for the fields inside the material of a hollow pipe are $\vec{E}=0$ and $\vec{B}=0$.　(5%)
   (b) Find the boundary conditions for the fields at the inner wall of a hollow pipe.　(5%)