1. [20 pts] Charge $q$ is uniformly distributed on a straight line of length $l$ along the $z$ direction. Choose the middle point of the line charge as the origin.
   
   (a) Compute the electric dipole and quadrupole moments of the line charge.
   
   (b) Find the scalar potential $\Phi(r, \theta, \phi)$ for $r \gg l$ to the order of $1/r^3$.

2. [20 pts] The top surface of a cubic box is maintained at constant potential $V$, while all other surfaces are grounded at potential zero. The side length of the box is $a$.
   
   (a) Write down the differential equation for the potential $\Phi(x, y, z)$ inside the cube and its boundary conditions in cartesian coordinate system.
   
   (b) Solve for $\Phi(x, y, z)$. You may express the answer as a series sum.

3. [30 pts] A spherical thin shell of radius $R$ is made of ideal conductor and initially charge neutral. Then it is placed in a uniform electric field $E_0 \hat{z}$.
   
   (a) Find the scalar potential $\Phi$ outside the shell.
   
   (b) Find the surface charge density $\sigma(\theta)$ at the outer surface of the shell, where $\theta$ is the polar angle defined respect to $\hat{z}$.
   
   (c) Suppose the shell now cracks into two equal halves along the plane perpendicular to $\hat{z}$ and going through the center of the shell. How much external force is required to prevent the two halves from separating from each other?

4. [30 pts] A circular loop of radius $R$ carries current $I$. It is within the $xy$ plane and centered at the origin. The current flows counterclockwise when viewed from above the $xy$ plane.
   
   (a) Find the magnetic induction $B(z)$ on the $z$ axis.
   
   (b) Find the vector potential $A(r)$ off axis for $r \gg R$, show your steps.
   
   (c) Suppose the current decays over time, $I(t) = I_0 e^{-t/\tau}$. In what direction does the electromagnetic energy flow near the origin?