1. [30] A line charge with uniform charge density lies along the $z$-axis between $z = 0$ and $z = b$ and has total charge $Q$.
   a) [10] Find an exact expression for the electrostatic potential $\Phi(r, z)$ in cylindrical coordinates.
   b) [5] Show that your result in part (a) has the correct asymptotic form as $\sqrt{r^2 + z^2} / b \to \infty$.
   c) [10] Find the potential $\Phi(r, \theta)$ in spherical coordinates $(r, \theta, \phi)$ as a series involving Legendre polynomials and powers of $r$, for $r > b$.
   d) [5] Show that your results in parts (a) and (c) are equivalent for observation points on the $z$-axis with $z > b$. Recall the Taylor series
   \[
   \ln(1 - x) = -\sum_{n=0}^{\infty} \frac{x^{n+1}}{n+1} .
   \] (1)

2. [25] In this problem, you will find the electrostatic potential $\Phi(r, z)$ inside a circular cylinder with radius $a$ and height $L$, adopting cylindrical coordinates $(r, \phi, z)$. The bottom of the cylinder is at $z = 0$ and the cylinder’s axis is the $z$-axis. The potential is zero on the surface at $z = 0$ and on the curved surface and is a constant $V_0$ on the surface at $z = L$.
   a) [15] Show that the potential inside the cylinder can be expressed in the form
   \[
   \Phi(r, z) = \sum_{n=1}^{\infty} A_n \sinh \left( \frac{x_{0n} z}{a} \right) J_0 \left( \frac{x_{0n} r}{a} \right)
   \] (2)
   where $x_{0n}$ is the $n$th zero of the Bessel function $J_0(x)$.
   b) [10] Find the coefficients $A_n$. Recall that
   \[
   \frac{d}{du} [u^\nu J_\nu(u)] = u^\nu J_{\nu-1}(u)
   \] (3)

3. [15] A sphere has radius $a$, is centered on the origin, and is made up of a uniform, linear dielectric material with dielectric constant $\varepsilon/\varepsilon_0$. A point charge $q$ is located at the origin. Find the surface and volume bound charge densities.

4. [30] An infinite, conducting plane at $z = 0$ carries a uniform current per unit transverse length, $K \hat{y}$.
   a) [10] Find the magnetic induction $\vec{B}$ everywhere outside of the plane.
   b) [10] A second infinite, conducting plane at $z = -d$ carries a uniform current per unit transverse length, $-K \hat{y}$. Use the Lorentz force law to find the pressure that the first plane exerts on the second. Is it attractive or repulsive?
   c) [10] Repeat part (b), this time using the Maxwell stress tensor.