1. Three identical point charges of \(-q\) are placed at three corners of a square of side \(L\).

(a) (15 points) Find the magnitude and the direction of the total electric force on a point charge \(2q\) placed at the “vacant” corner of the square.

(b) (15 points) Find the work done by the total electric force on the point charge \(2q\) when it is moved from the “vacant” corner to the center of the square.

2. (15 points) A uniformly charged line of 4L carries a positive charge \(Q\). It is folded into a square and placed on the x-y plane, with the z-axis passing through the center of the square (the origin of the coordinate system). Find the direction and magnitude of the electric force on a negative point charge \(-q\) on the z-axis as a function of z coordinate.
3. A thin spherical shell of radius $R$ carries a positive charge $Q$ that spreads uniformly over the shell. It is enclosed by a thick conducting shell with inner radius $2R$ and outer radius $3R$. The conducting shell carries a total charge of $3Q$.

(a) (10 points) Find the magnitude and the direction of the electric field between the thin spherical shell and the thick conducting shell, i.e., $R < r < 2R$;

(b) (15 points) Find the electric potential inside the thick conducting shell, $2R < r < 3R$, when the electric potential at infinity is chosen to be zero;

(c) (10 points) If the thin spherical shell of $R$ is now removed from the inside of the thick conducting shell, what is the electric potential inside the conducting shell again with $2R < r < 3R$.

![Diagram](image)

4. (20 points) A spaceship is shaped like a solid conducting sphere with radius $R = 10$ km, and its outside surface can be charged at will by its operator. A small missile of $m = 9$ kg carrying a net electric charge $q = 0.5$ C travels directly towards the spaceship from a distance much larger than $R$ with an initial speed of $v_0 = 1000$ m/s. In order to build an electrostatic “shield” to stop the missile from striking the ship surface, what is the minimum charge $Q_{\text{min}}$ that the ship operator must put on the surface of the ship for such a shield to be effective?

(Constants: $k = 1/4\pi\varepsilon_0 = 8.99\times10^9$ Nm$^2$/C$^2$).