A solid sphere of radius $a$ is inside of a spherical shell of inner radius $b$ and outer radius $c$. The sphere has a charge $+Q$ uniformly distributed on its surface and the shell has charges $-3Q$ and $+5Q$ uniformly distributed on its inner and outer surfaces, respectively.

(a) Is the outer shell a conductor or an insulator?

Insulator

(b) What is the magnitude of the electric field at a point $r$ between the sphere and the shell? Draw and label an arrow on the diagram to indicate the direction of the field.

$$E = \frac{+Q}{4\pi \varepsilon_0 r^2} \text{ radially outward} \quad \varepsilon_{enc} = +Q$$

$$E = \frac{kQ}{4\pi \varepsilon_0 r^2} \quad f = \frac{Q}{\varepsilon_0}$$

(c) What is the potential difference between the inner and outer surface of the shell?

$$V_b = \left[ \frac{Q}{r} + \frac{5Q}{c} - \frac{3Q}{r} \right] \frac{1}{4\pi \varepsilon_0} \quad r = b$$

$$V_c = \left[ \frac{Q}{r} + \frac{5Q}{c} - \frac{3Q}{c} \right] \frac{1}{4\pi \varepsilon_0} \quad r = c$$

$$\pi \varepsilon_0 (V_c - V_b) = -\left( \frac{2Q}{b} + \frac{5Q}{c} \right) + \frac{3Q}{c} = +\frac{2Q}{b} - \frac{2Q}{c}$$

$$V_c - V_b = -\frac{2Q}{4\pi \varepsilon_0} \left( \frac{1}{b} + \frac{1}{c} \right) = \frac{2a}{4\pi \varepsilon_0} \left( \frac{1}{b} - \frac{1}{c} \right)$$