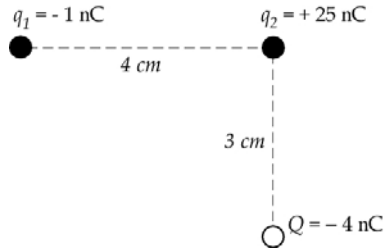
1. Two point charges $q_1 = -1$ nC and $q_2 = +25$ nC are held 4 cm apart.

(a) (**10 points**) Now another point charge $Q = -4$ nC is added at 3 cm below q_2 (see below). Find the magnitude and direction of the total electric force on Q in the coordinate frame of your choice.



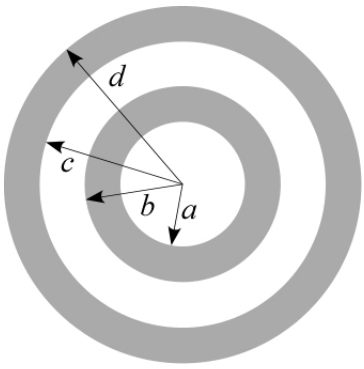
(b) (**10 points**) Find the electric potential energy U_Q for Q in the electric field produced by q_1 and q_2 referenced to infinity. (Useful constant: $k = 1/4\pi\varepsilon_0 = 9.0 \times 10^9$ $N \cdot m^2/C^2$)

2. A small conducting spherical shell with inner radius *a* and outer radius *b* is concentric with a large conducting spherical shell with inner radius *c* and outer radius *d*. The small shell has net charge *+4q*, and the large shell has net charge *-4q*.

(a) (**10 points**) Find the electric charge on each of the four surfaces with $r = a, b, c, d$ and make sure to explain how you arrive at the answers;

(b) (**10 points**) Find the electric field for (i) $r < a$; (ii) $r > d$ with details;

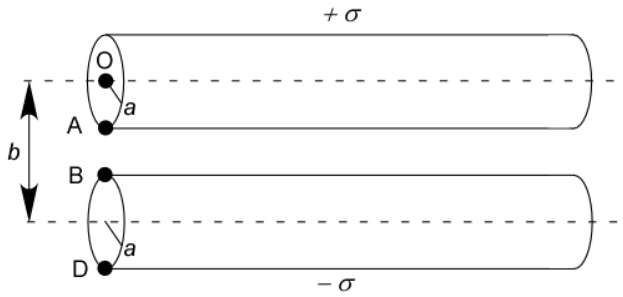
(c) (**10 points**) Find the electric potential *referenced to infinity* for $b < r <$ c.



3. Two long **cylindrical insulating thin shells** (both of radius ***a***) are parallel to each other. The cylindrical axes separated by ***b*** > *2**a***. One shell is uniformly charged with a surface charge density + σ, the other is uniformly charged with a surface charge density - σ.

(a) (**10 points**) Find the electric field at point *O* on the axis of the positively charged shell (Hint: the superposition principle);

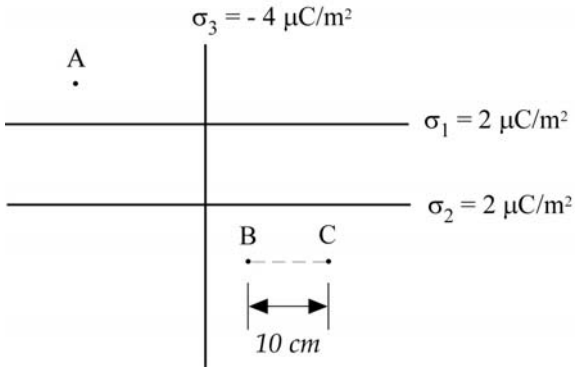
(b) (**15 points**) Find the electric potential difference $V_A - V_B$ (Hint: the superposition principle)



4. Three infinitely large sheets of uniformly distributed charges are shown below. The line connecting B and C is parallel to the charged sheets of σ_1 and σ_2. The third sheet of charge distribution σ_3 is perpendicular to the first two sheets.

(a) (**15 points**) Find the total electric field at points A in a suitably chosen coordinate system;.

(b) (**10 points**) Find the electric potential at point C relative to that point B, $V_C - V_B$.



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