PHYS 301 - Tutorial 5

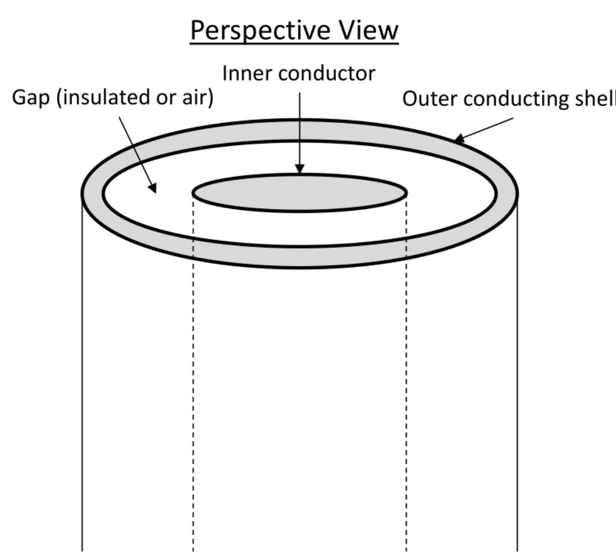
- Complete all problems and submit ONE set of answers as a group (max 4 students)
- One group member uploads a pdf to gradescope and specifies the other group members there.
- Upload is due by the end of the day of the tutorial. We will accept late submission till Thursday 11:59 pm, after which the submission will be closed.

Learning Goals:

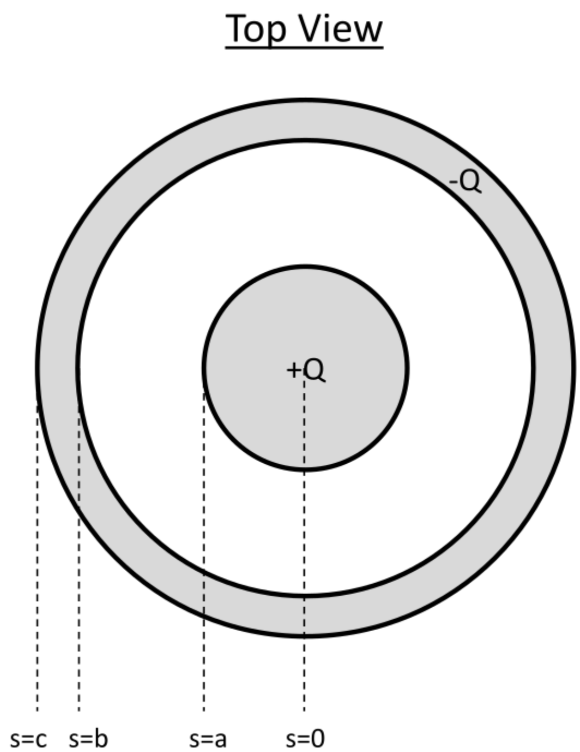
- Describe the behaviour of charges in a conductor in response to electric fields that arise outside the conductor or inside any cavity within the conductor.
- State that conductors are equipotentials, i.e. $E = 0$ inside a conductor, that $\mathbf{E}$ is perpendicular to the surface of a conductor (just outside the conductor), and that all charge resides on the surface of a conductor.
- Determine the surface charge distribution on a conductor in equilibrium.

Part 1 – Conceptually understanding conductors

A coaxial cable is essentially one long conducting cylinder surrounded by a conducting shell (the shell has some thickness). The two conductors are separated by a small distance. (Neglect all fringing fields near the cable's ends.)

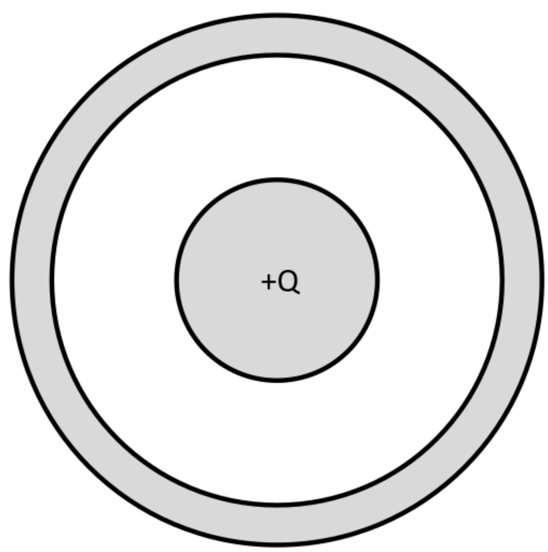


a) Draw the charge distribution (use + and − signs) if the inner conductor has a total charge $+Q$ on it, and the outer conductor has a total charge $-Q$. Be precise about exactly where the charge will be on the conductors, and how you know.

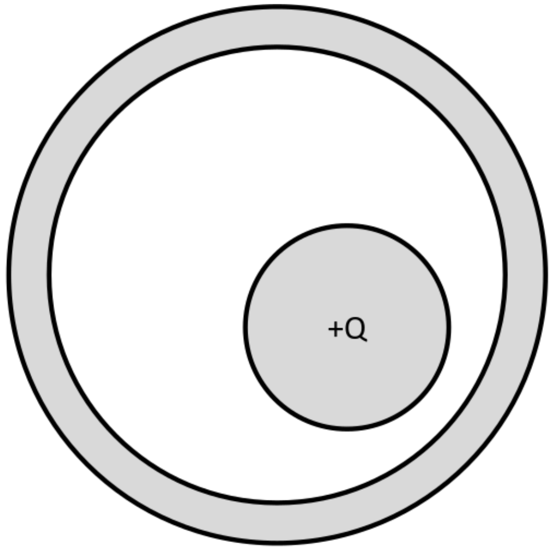


b) If you were calculating the potential difference ΔV between the centre of the inner conductor ($s = 0$) and infinitely far away ($s = \infty$), what regions of space would have a non-zero contribution to your calculation?

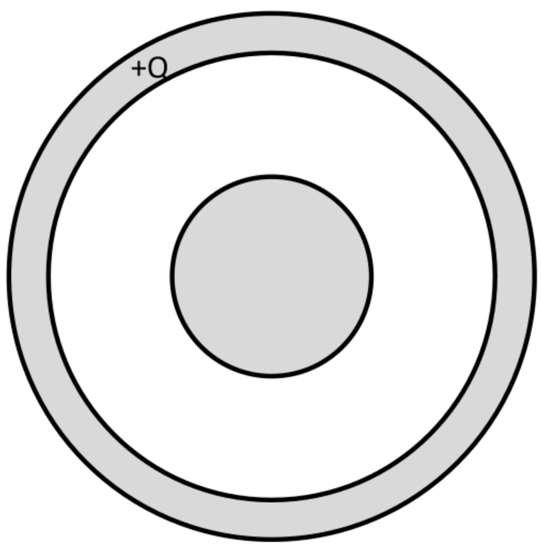
c) Now, draw the new charge distribution if the inner conductor has a total charge $+Q$ on it, and the outer conductor is electrically neutral. Explain how you know where the charge is located. Be precise.



d) Consider how the charge distribution would change if the inner conductor is shifted off-center, but still has $+Q$ on it, and the outer conductor remains electrically neutral. Draw the new charge distribution and be precise about how you know.



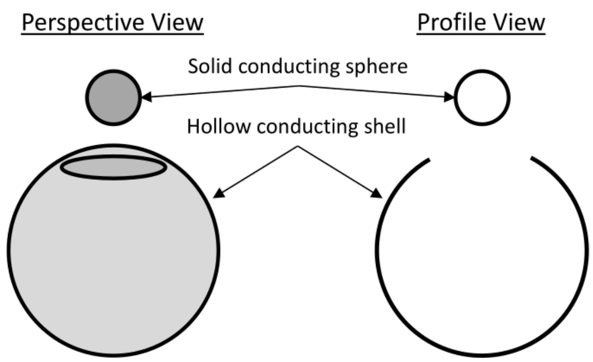
e) Now, instead of the total charge $+Q$ being on the inner conductor, sketch the charge distribution if the outer conductor has a total charge $+Q$ on it, and the inner conductor is electrically neutral. Be precise about exactly where the charge will be on these conductors, and how you know.



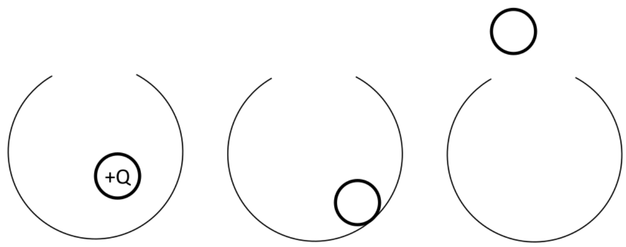
f) For the configuration in part e), what is the potential difference between the centre of the inner conductor ($s = 0$) and the outer conductor ($s = c$)?

Part 2 – Faraday's ice pail

Faraday's ice pail – originally a metal pail and suspended metal ball – helped early physicists understand conductors and shielding. It consists of a hollow conducting shell, with a hole cut out to allow a smaller conducting sphere to fit inside.

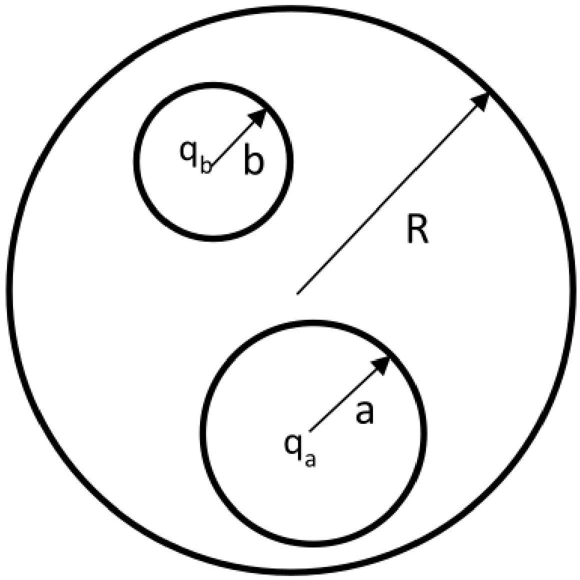


Consider this: the conducting shell starts out electrically neutral, but the small sphere inside of it has a total charge $+Q$. Based on your previous answers, what does the charge distribution look like before, during, and after, if the small solid sphere makes contact with the inside surface of the conducting shell (the "ice pail")



Part 3 – More on cavities

Consider the following configuration in which two spherical cavities of radii a and b are hollowed out from the inside of a neutral conducting sphere of radius R. At the centre of each cavity are point charges q_a and q_b.



a) Find the surface charges $\sigma_a, \sigma_b, \sigma_R$.

b) What is the field outside the conductor?

c) What is the field inside the conductor and in the cavities?

d) What are the forces on q_a and q_b?

e) Which of these answers would change if a third charge were brought near the conductor?