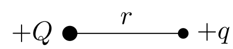
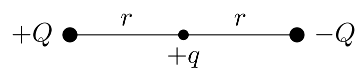
Problem 1. (20 Points)

I. (6 Points)

(a) A positive charge $+q$ is a distance r from a point charge $+Q$. What is the potential energy of $+q$? (3 points)

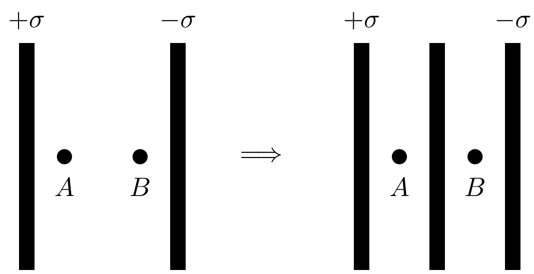


(b) If I add a second charge (value $-Q$) a distance r on the other side of the charge $+q$, the force of $+q$ increases. What is the potential energy of $+q$? (3 points)



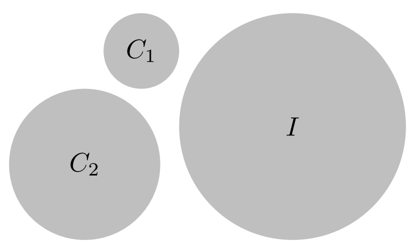
II. (5 points)

Points A and B lie in between two large conducting plates. If I insert a slab of conducting material as shown below, what happens to the potential difference between A and B? (5 points)



III. (9 points)

There are three balls as shown. There are two conductors with radii a and $2a$ and charges $-Q$ and $4Q$ respectively, and one insulator of radius $3a$ and surface charge $3Q$. If we let them touch each other at the same time and then separate them simultaneously, what are the charges on C_1 (3 points), C_2 (3 points), and I (3 points)?



Problem 2. (20 Points)

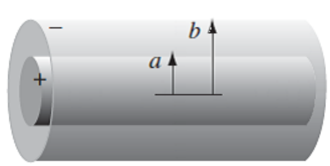
A long coaxial cable carries a volume charge density ρ_0 on the inner cylinder of radius a, and a uniform surface charge density σ on the outer cylinder of radius b. This surface charge is negative, and is of just the right magnitude that the cable as a whole is electrically neutral.

(a) Find the electric field for $r < a$ (5 points)

(b) Find the electric field for $a < r < b$ (5 points)

(c) Find the electric field for $b < r$ (5 points)

(d) Plot $|\boldsymbol{E}|$ as a function of r (5 points)



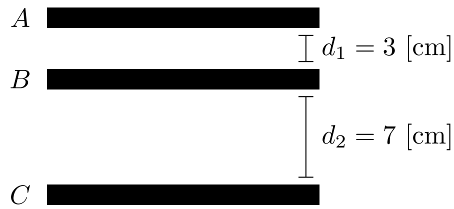
Problem 3. (25 Points)

Three large conducting plates A, B, and C are placed parallel to each other. A and C are connected using a conducting wire. The inner plate is isolated and carries a total surface charge of $\sigma = 1$ [μC/cm^2]. The charge on plate B will divide itself into a surface charge σ_t on the top and σ_b on the bottom surface.

(a) What is the potential difference between A and B? B and C? (express it using σ_t and σ_b) (10 points)

(b) What is the relationship between these two potential differences? (5 points)

(c) In what proportion must this charge divide itself into a surface charge σ_t on one face of the inner plate and a surface charge σ_b on the other side of the same plate? (10 points)



Problem 4. (35 Points)

A hollow conducting spherical shell B of inner radius R_0 and outer radius R_1 is positively charged with a charge $+Q$. A positive charge A of magnitude $+Q$ is placed in the center of the hollow sphere, and an insulating shell C with inner radius R_2 and outer radius R_3 surrounds the hollow sphere which has a charge distribution $\rho(r) = -Q/r^3$.

(a) What charges are on the inner (2 points) and outer (3 points) surfaces of the conducting sphere B?

(b) Find the electric field at all points in space: $0 < r < R_0$, $R_0 < r < R_1$, $R_1 < r < R_2$, $R_2 < r < R_3$ and $R_3 < r$. (10 points)

(c) Plot the electric field lines on the figure. (2 points)

(d) Plot the electric field as a function of r. (3 points)

(e) Find the electric potential V at all points in space: $0 < r < R_0$, $R_0 < r < R_1$, $R_1 < r < R_2$, $R_2 < r < R_3$ and $R_3 < r$. (V is 0 at infinity). (10 points)

(f) Plot this as a function of r. (5 points)