4.6 EXERCISES

Charge Distribution And Electric Field Lines In Metals

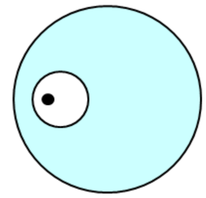
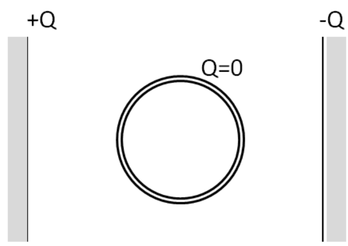


Figure 4.26: Exercise 4.6.1.

Ex 4.6.1. A negative charge $-q$ is fixed inside the cavity of a neutral spherical conductor. (a) Show any charge distributions schematically, and draw electric field lines. (b) Draw equipotential lines on the same diagram using either a different color ink or as dashed lines.

Ex 4.6.2. An uncharged metallic ring is placed between two charged parallel plates of a parallel plate capacitor with charges $\pm Q$. Draw electric field lines and equipotential surfaces.



Ex 4.6.3. An uncharged spherical conductor S of radius R has two spherical cavities A and B of radii a an b respectively as shown in Fig. 4.27. Two point charges $+q_a$ and $+q_b$ are placed at the center of the two cavities by using non-conducting supports. In addition, a point charge $+q_0$ is placed outside at a distance r from the center of the sphere. (a) Draw approximate charge distributions in the metal although metal sphere has no net charge. (b) Draw electric field lines. Draw enough lines to represent all distinctly different places.

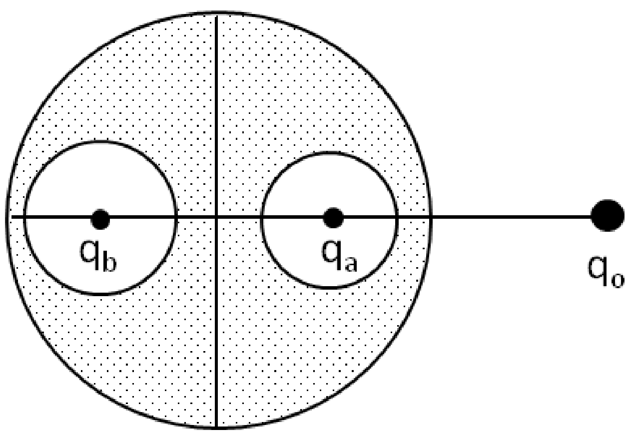


Figure 4.27: Exercise 4.6.3.

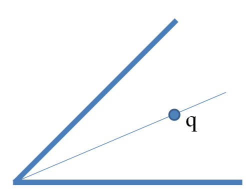


Figure 4.28: Exercise 4.6.4.

Ex 4.6.4. A positive point charge is placed at the angle bisector of two uncharged plane conductors which make an angle of 45°. Draw electric field lines and equipotential surfaces.

Electric Field Of Isolated Conductors

Ex 4.6.5. A long cylinder of copper of radius 3 cm is charged so that it has a uniform charge per unit length on its surface of 3 C/m. (a) Find the electric field inside and outside the cylinder. (b) Draw electric field lines in a plane perpendicular to the rod.

Ex 4.6.6. An aluminum spherical ball of radius 4 cm is charged with 5 μC of charge. A copper spherical shell of inner radius 6 cm and outer radius 8 cm surrounds it. A total charge of -8 μC is put on the copper shell. (a) Find the electric field at all points in space including points inside the aluminum and copper shell when copper shell and aluminum sphere are concentric. (b) Find the electric field at all points in space including points inside the aluminum and copper shell when the centers of copper shell and aluminum sphere are 1 cm apart.

Ex 4.6.7. Two large charged plates of charge density ± 30 mC/m^2 face each other at a separation of 5 mm. (a) Find the electric potential everywhere. (b) An electron is released from rest at the negative plate, with what speed will it strike the positive plate? Ans: (b) 5.7×10^7 m/s.

Ex 4.6.8. A small spherical pith ball of radius 0.5 cm is painted with a silver paint and then -10 μC of charge placed on it. The charged pith ball is put at the center of a gold spherical shell of inner radius 2 cm and outer radius 2.2 cm. (a) Find the electric potential of the gold shell with respect to zero potential at infinity. (b) How much charge should you put on the gold shell if you want to make its potential 100 V? Ans: (a) 4.1 MV, (b) $(10^{-5} + 2.4 \times 10^{-10})$ C.

Ex 4.6.9. A long cylinder of aluminum of radius R meters is charged so that it has a uniform charge per unit length on its surface of λ. (a) Find the electric field inside and outside the cylinder. (b) Find the electric potential inside and outside the cylinder. (c) Plot electric field and electric potential as a function of distance from the center of the rod.

Capacitors

Ex 4.6.10. A steel screw and a steel nut fixed to a dry wooden board at a distance of 1 cm from each other are connected to a 12 V battery. When they are fully charged, the screw has a charge of +10 pC and the nut a charge of -10 pC. What is the capacitance of the screw/nut? Ans: $\frac{5}{6}$ pF.

Ex 4.6.11. Two concentric spherical metal shells separated by non-conducting air have a capacitance of 300 pF. What are the charges on the two shells when the potential difference between them is 1.5 V? Ans: 450 pC.

Ex 4.6.12. A parallel plate capacitor is constructed from two aluminum foil sheets, each of dimensions 20 cm $\times$ 20 cm. The plates are separated by 2 mm with nothing between the plates. (a) Evaluate the capacitance of the capacitor. (b) What will be the capacitance if the distance between the sheets is increased to 4 mm? (c) What will be the capacitance if the foils are cut into half making the dimensions 20 cm $\times$ 10 cm each, but kept at a separation of 2 mm? Ans: (a) 180 pF, (b) 89 pF, (c) 89 pF.

Ex 4.6.13. You need a capacitor of capacitance 1.0 F. Find out the dimensions of an aluminum foil and their separation you will need to construct a capacitor with the desired capacitance. Ans: 1.1×10^{11} m.

Ex 4.6.14. A capacitor charged to 100 V stores $\pm 10\ \mu$C of charge on its plates. How much electrostatic energy is stored? Ans: 500 μJ.

The Method Of Images

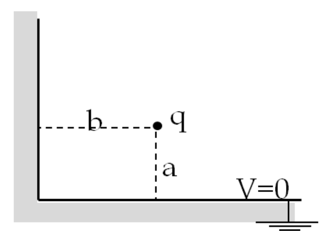


Figure 4.29: Exercise 4.6.15.

Ex 4.6.15. A point charge $+q$ is placed near a large grounded ($V = 0$) uncharged conductor which is bent at right-angle in the middle. The distance of $+q$ from the two sides are a and b. Find the force of attraction on $+q$ by the uncharged conductor.

Ex 4.6.16. A point charge $q = +2$ C is placed near a large grounded ($V = 0$) uncharged conductor which is bent at $\theta = 60°$ in the middle. The distance of q from the two sides is equal to $a = 1$ cm. Find the force of attraction on q by the uncharged conductor.

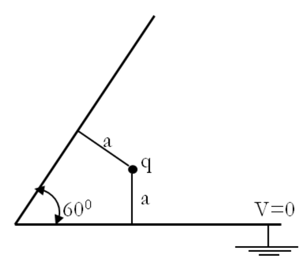


Figure 4.30: Exercise 4.6.16.

Ex 4.6.17. A point charge is brought from infinity to a distance h from a grounded plane conductor. Find the amount of work done.