5.4 EXERCISES

Electric dipoles

Ex 5.4.1. Find the force on a dipole of dipole moment $\vec{p}$ from a fixed charge q in each of the cases shown in the figure.

Figure 5.14: Exercise 5.4.1.

Ex 5.4.2. Find the electrostatic energy of the configurations in Figs. 5.14(a) and 5.14(b). Ans: (a) $-\frac{pq}{4\pi\epsilon_0 d^2}$, (b) 0.

Ex 5.4.3. Find the force on dipole p_2 from dipole p_1. Ans: (a) $\frac{2p_1p_2}{4\pi\epsilon_0}\frac{6}{d^4}$.

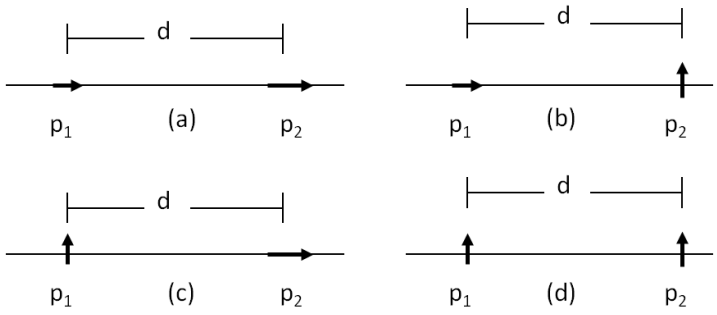

Figure 5.15: Exercise 5.4.3

Ex 5.4.4. Evaluate the electrostatic energy of the dipole configurations in Fig. 5.15(a) - (d). Ans: (a) $-\frac{2p_1p_2}{4\pi\epsilon_0 d^3}$.

Ex 5.4.5. The dipole moment of a carbon atom in an external electric field is found to have the magnitude 2.5×10^{-33} C.m. (a) What is the magnitude of the applied electric field? (b) What is the orientation of the dipole moment vector compared to the direction of the applied electric field? Ans: (a) 1.25×10^7 N/C.

Ex 5.4.6. (a) Evaluate the magnitude of the dipole moment of a sodium atom induced when the atom is between two large parallel aluminum plates separated by 3 mm where a potential difference of 100 V is maintained. (b) Draw a diagram showing the plates, the potentials of the two plates, the electric field direction at the site of the atom, and the direction of the dipole moment. Ans: (a) 9×10^{-35} C.m.

Ex 5.4.7. The water molecule has electric dipole moment of 6.1×10^{-30} C.m and the H−O−H angle is 104.5°. (a) What is the dipole moment in each OH bond? (b) If the O−H bond distance is 0.0965 nm, how much net charges reside on hydrogen and oxygen atoms written in terms of charge on one electron? Ans: (a) 5.0×10^{-10} C.m, (b) 0.323 e.

Ex 5.4.8. An ammonia molecule has an electric dipole moment of 5.0×10^{-30} C.m. It is placed in an external electric field of $1,000$ V/m. (a) What is the torque on it at the time the dipole is pointed at a 60° angle with respect to the electric field? (b) Once aligned, how much energy will it take to flip the orientation of the dipole by 180°? Write your answer in the electron volt (eV) unit. The unit 1 eV $= 1.6 \times 10^{-19}$ J. Ans: (a) 4.3×10^{-27} N.m, (b) 6.3×10^{-8} eV.

Ex 5.4.9. The dipole moment of a water molecule between two large copper plates separated by a distance of 5 mm in the north-south direction is pointed due east. Find the torque on the molecule, when a voltage of 150 V is applied across the plates so that electric field is pointed due north. (Use only the permanent dipole moment of water molecule.) Ans: 1.8×10^{-25} N.m.

Ex 5.4.10. A water molecule is 500 nm from a point charge A (2 fC). (a) Find the electric force on the water molecule when the dipole moment of the water molecule is pointed towards the charge. (b) How much energy will it take to rotate the water molecule so that dipole moment faces away?

Ex 5.4.11. Find the electrostatic force on the point charge by first finding the electric field of the dipoles at the location of the point charge.

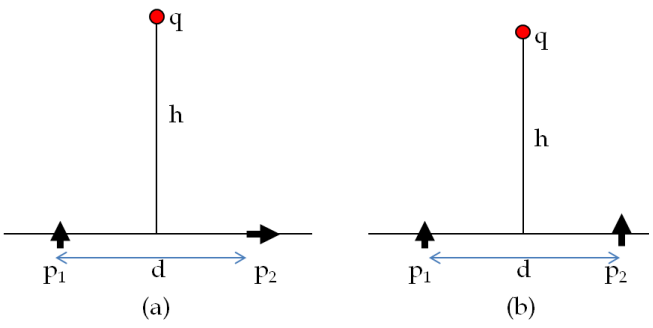

Figure 5.16: Exercise 5.4.11.

Linear dielectrics

Ex 5.4.12. The space between two copper plates of dimensions 20 cm × 30 cm separated by 4 mm is filled with mica. (a) Evaluate the capacitance. (b) What is the percent by which the capacitance increased ($\Delta C/C_0$) due to filling the space with mica? Ans: (a) 0.93 nF, (b) 600%.

Ex 5.4.13. Two pieces of aluminum foil of dimensions 25 cm × 25 cm is separated by a piece of paper of thickness 0.2 mm. (a) Find the capacitance. (b) If the foils are oppositely charged with $\pm 50\mu$C, what is the polarization of paper? Ans: (a) 10.2 nF, (b) 1.6×10^{-4} C/m^2.

Ex 5.4.14. A steel ball of radius 2 cm is charged with -10 μC. The charged steel ball is surrounded by plastic spherical shell of thickness 3 cm. (a) Find electric field at a point in the plastic at a distance 4 cm from the center of the ball. (b) Find the polarization of the plastic. Ans: (a) 2×10^{13} N/C, (b) 320 C/m^2.

Ex 5.4.15. The space between two charged gold foil sheets, 10 cm × 10 cm, separated by a 0.3 mm is filled with a sheet of mica of thickness 0.1 mm. Find the capacitance. Ans: 6.2 nF.

Ex 5.4.16. The space between two charged aluminum foils, 15 cm × 15 cm, separated by 2 mm is filled with 1 mm thick mica and 1 mm paper. The foils are oppositely charged with charges ± 10 μC. (a) Find the capacitance. (b) Find the electric field in the mica and in the paper. (c) Evaluate the polarization of mica. Ans: (a) 0.48 nF, (b) $|\vec{E}_{\text{mica}}| = 7.14 \times 10^6$ N/C, $|\vec{E}_{\text{paper}}| = 1.35 \times 10^7$ N/C, (c) 4.4×10^{-4} C/m^2.

Ex 5.4.17. The space between two long concentric cylindrical metal shells is filled with glass of the dielectric constant ϵ_r. Find the capacitance per unit length.

Forces on Dielectrics

Ex 5.4.18. Find the force on a mica slab 25 cm × 25 cm × 4.9 mm when quarter of it between two parallel metal plates of dimensions 25 cm × 25 cm separated by 5 mm and containing charges ± 30 μC. Ans: 7.8 N.

Ex 5.4.19. Half of a 1-mm thin paper of mass 15 g is between two metal plates separated by 2 mm. What should be the voltage difference between the plates so that the electric force just balances the force of gravity on the paper?