1.4 EXERCISES

Coulomb's Law

Ex 1.4.1. Two point particles with charges +2 μC and +5 μC are held in place by 3 N forces on each charge in appropriate directions. (a) Draw free-body diagram of each particle. (b) Find the distance between the charges. Ans: (b) 17.3 cm.

Ex 1.4.2. Two charges +3 μC and +12 μC are fixed one meter apart. Find the magnitude and direction of the net force on a -2 nC charge when placed at the following locations: (a) half-way between the two, (b) half a meter to the left of +3 μC while the other charge is to the right, (c) half a meter above the +12 μC charge in a direction perpendicular to the line joining the two fixed charges. Ans: (a) 6.5×10^{-7} N, (b) 3.1×10^{-7} N, (c) 8.84×10^{-7} N, 267°.

Ex 1.4.3. Two copper spheres of radius 2 cm are held 1 meter apart. If proton's charge were to be 1% greater than an electron's charge in magnitude, what will be the magnitude of force between the two spheres? Cu: density = 8.92 g/cc, atomic number=29, atomic weight = 63.54. Ans: 1.5×10^{20} N.

Ex 1.4.4. Evaluate the net Coulomb force on charge Q in each case shown in the figures. The charges are : A (+10 pC), B(-6 pC), C(+2 pC), D(-7 pC), and Q(100 pC). The distance are : AB = 1 μm, AC = 0.63 μm. Ans: (a) 12.5 N, 56° clockwise from the negative x-axis, (b) 56 N, 12.8° counterclockwise.

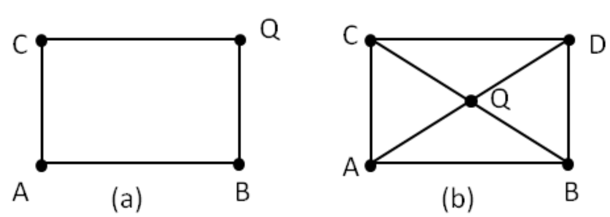
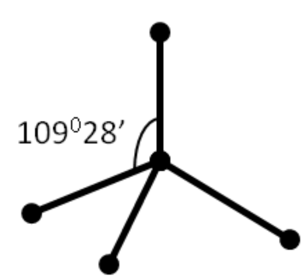


Figure 1.32: Exercise 1.4.4.

Ex 1.4.5. Find the direct distance vectors from P_1 to P_2 for the following points in space. (a) P_1(0,0,0), P_2(1,0,0); (b) P_1(0,1,0), P_2(1,0,1); (c) P_1(0,1,1), P_2(1,2,3); (d) P_1(1,2,4), P_2(1,0,0); (e) P_1(1,-3,8), P_2(-1,3,-4); (f) P_1(-1,-2,-3), P_2(0,-1,-1).



Ex 1.4.6. Find the direct vectors from the atom in the middle to the other four atoms in a diamond lattice where each bond is 10 nm long and the angle between bonds is 109°28′ as shown in Fig. 1.33.

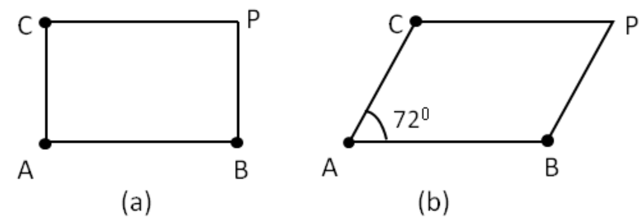


Figure 1.34: Exercise 1.4.9.

Electric Field of Discrete Charges

Ex 1.4.7. The electric force experienced by a -4 μC charge at some point P has a magnitude of 20 N and points due North. (a) What is the magnitude and direction of the electric field at P? (b) What is the force experienced by an electron if it is placed at the same spot? (c) What is the force experienced by a proton if it is placed at the same spot? (d) How do the accelerations of the electron and proton compare when they are subject to only the electric force? Compare both magnitude and direction. Ans: (a) 5×10^6 N/C, (b) 8.0×10^{-13} N.

Ex 1.4.8. The electric field of 25 N/C pointed due East at some point P. Find the forces experienced by the following two charges if placed at that point without disturbing any of the charges responsible for the electric field: (a) +2 C, and (b) -2 C. Ans: (a) 50 N, towards the East, (b) 50 N, towards the West.

Ex 1.4.9. Find the electric field (vector) at point P in the plane of the three charges A, B and C shown in Fig. 1.34. The charges are: A (+10 pC), B(-6 pC), and C(+2 pC). The distance are AB = 1 μm, AC = 0.63 μm. Ans: (a) 1.25×10^{11} N/C, 54.5° counterclockwise from $\overrightarrow{AB}$ direction.

Ex 1.4.10. Four charges A(+3 nC), B(-4 nC), C(+6 nC) and D(-9 nC) are fixed to the successive corners of a square of side 5 μm. A charge Q(-2 pC) is brought to the center of the square. Find the force on charge Q by using the method of electric field. Ans: 8.38 N, 149° counterclockwise from the D-to-B direction.

Ex 1.4.11. Two electric charges +2 μC and -2 μC are fixed on the x-axis at $x = 3$ cm and $x = -3$ cm respectively. (a) Find the electric field at point P(0,4 cm,0). (b) Is there a point on the x-axis where the electric field will be zero?

Ex 1.4.12. Two charges $+q$ and $-q$ are placed on the y-axis at $y = \frac{d}{2}$ and $y = -\frac{d}{2}$ respectively. Find the electric field at an arbitrary point P$(x, y, 0)$ in the xy-plane.

Electric Field of Continuous Charge Distributions

Ex 1.4.13. A 30-cm long thin nonconducting rod has a uniform charge density of 2.0×10^{-2}C/m. (a) Evaluate the electric field at a point 1 cm from the center of the rod on the axis of symmetry. (b) How different would the electric field be if the entire charge on the rod was placed at its center? (c) Repeat (a) and (b) for a field point that is 100 cm from the center of the rod. Ans: (a) 3.5×10^{9} N/C, directed away from the rod (b) % difference = 54%, (c) 5.34×10^{7} N/C, directed away from the rod.

Ex 1.4.14. A copper spherical ball of radius 2 cm contains -3 C charge spread over its surface. There are no excess charges inside the ball. (a) Find the surface charge density. (b) What is the electric field of the spherical charge distribution at a distance of 5 cm from the center of the sphere? Ans: (a) -5.97×10^{-4} C/m^2, (b) 1.1×10^{7} N/C, directed towards the center of the ball.

Ex 1.4.15. A nonconducting sphere of radius 3 cm has 10 mC of charge distributed uniformly in its body. (a) Find the electric charge density? (b) What is the electric field of the spherical charge distribution at a distance of 5 cm from the center of the sphere? (c) What is the electric field of the spherical charge distribution at a distance of 2 cm from the center of the sphere? Ans: (a) 88.4 C/m^3, (b) $E = 3.6 \times 10^{10}$ N/C, directed away from the center of the ball.

Ex 1.4.16. (a) Rewrite each function in terms of a variable, call it ϵ, whose value is much smaller than 1, and then perform a Maclaurin series expansion of the resulting expression about $\epsilon = 0$. (b) Finally, rewrite the answer in terms of x. (a) $\frac{1}{1+x}$ $(x << 1)$; (b) $\frac{1}{x+a}$ $(x << a)$; (c) $\frac{1}{\sqrt{1+x}}$ $(x << 1)$; (d) $\frac{1}{\sqrt{1+x^2}}$ $(x << 1)$; (e) $\frac{1}{\sqrt{a^2+x^2}}$ $(x << a)$; (f) $\frac{1}{(a^2+x^2)^{3/2}}$ $(x << a)$.

Ex 1.4.17. A very wide cloud has a charge density of -1.0×10^{-3} C/m^2 on the surface facing the earth. What electric field would you expect between the earth and the cloud? Make reasonable assumptions and state your assumptions. Ans: 4.65×10^{7} N/C, away from Earth towards the cloud.

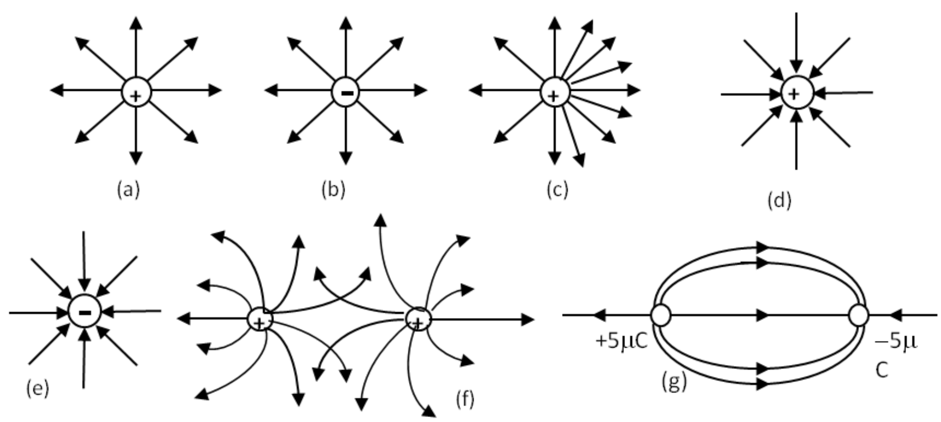
Ex 1.4.18. Two identical plastic disks of radius 5 cm face each other with a separation of 6 mm. Equal amount of charge of opposite types, ± 10 μC, are placed on the two disks. Assume the charges are uniformly spread over the surfaces of the two disks and reside on the surface of each disk that faces the other disk. Compare the electric field at a point on the axis 4 mm from positively charged plate by two methods: (a) by using charged disk formula, and (b) by using the large sheet approximation. (c) What is the physical reason for the difference? Ans: (a) (2.8×10^8 N/C, directed from + to − plate), (b) (2.9×10^8 N/C, directed from + to − plate).

Ex 1.4.19. An infinite line of charge placed along the y-axis carries a charge density of 2.5 μC/m. Find the electric field at a point P on the x-axis that has $x = 0.2\ m$.

Ex 1.4.20. Two charges $\pm q$ are separated by a distance d. What is the electric field at a point along the line joining the two charges? Give the answer for three types of points on the line joining the two charges: one on the left of the two charges, one between the two charges and the third to the right of the second charge. You may place $-q$ to the left of $+q$ when drawing the configuration for the solution.

Electric Field Lines And Electric Field Line Maps

Ex 1.4.21. Which of the following electric field lines are incorrect? Explain why.



Ex 1.4.22. In this exercise you would practice drawing electric field lines. Make sure you represent both the magnitude and direction of the electric field adequately. Note that the number of lines into or out of charges is proportional to the charges. (a) Draw the electric field lines map for two charges +20 μC and −20 μC situated 5 cm from each other. (b) Draw the electric field lines map for two charges +20 μC and +20 μC situated 5 cm from each other. (c) Draw the electric field lines map for two charges +20 μC and −30 μC situated 5 cm from each other.

Ex 1.4.23. Draw electric field lines map for four equal charges +10 μC at the corner of a square of side 2 cm. Make sure you represent both the magnitude and direction of the electric field adequately. Note that the number of lines into or out of charges is proportional to the charges.

Ex 1.4.24. Draw electric field vectors and lines maps for a system of three particles of charges $+1\ \mu$C, $+2\ \mu$C and $-3\ \mu$C fixed at the corners of an equilateral triangle of side 2 cm. Make sure you represent both the magnitude and direction of the electric field adequately. Note that the number of lines into or out of charges is proportional to the charges.

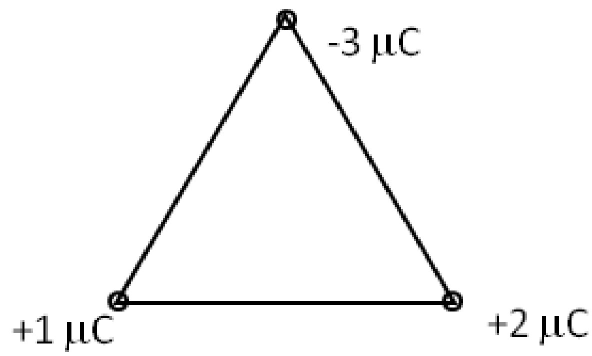


Figure 1.35: Exercise 1.4.24.

Ex 1.4.25. Two charges of equal magnitude but opposite types make up an electric dipole. Two electric dipoles are placed anti-parallel at two edges of a square as shown in Fig. 1.36. Draw the electric field lines map of the charge distribution.

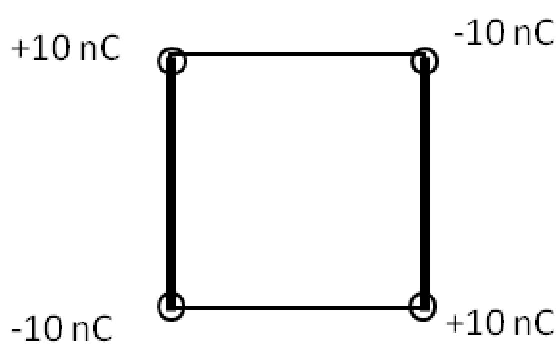


Figure 1.36: Exercise 1.4.25.