3.6 EXERCISES

Electric Potential Energy

Ex 3.6.1. Consider a charge Q_1 (+5 μC) fixed at a site and another charge Q_2 (charge +3 nC, mass 6 μg) moves in the neighboring space. (a) Evaluate the potential energy of Q_2 when it is 4 cm from Q_1. (b) If Q_2 starts from rest from a point 4 cm from Q_1, what will be its speed when it is 8 cm from Q_1. (Note: Q_1 is held fixed in its place.) Ans: (a) 3.4×10^{-3} J (b) 750 m/s.

Ex 3.6.2. Consider a charge Q_1 (+5 μC) fixed at a site and another charge Q_2 (charge -3 nC, mass 6 μg) moves in the neighboring space. (a) Evaluate the potential energy of Q_2 when it is 4 cm from Q_1. (b) If Q_2 starts from rest from a point 4 cm from Q_1, what will be its speed when it is 2 cm from Q_1. (Note: Q_1 is held fixed in its place.) Ans: (a) 3.4×10^{-3} J (b) 1060 m/s.

Ex 3.6.3. Two charges Q_1 (+ 2 μC) and Q_2 (+2 μC) are placed symmetrically along the x-axis at $x = \pm$ 3 cm. Consider a charge Q_3 of charge +4 μC and mass 10 milligrams moving along the y-axis. If Q_3 starts from rest from $y = 2$ cm, what is its speed when it reaches $y = 4$ cm? Ans: 473 m/s.

Ex 3.6.4. To form a hydrogen atom, a proton was fixed at a point and an electron was brought from far away to a distance of 0.529×10^{-10} m, the average distance between proton and electron in hydrogen atom. How much work was done? Ans: 4.36×10^{-18} J.

Ex 3.6.5. To form a helium atom, an alpha particle which contains two protons and two neutrons was fixed at one place, and two electrons were brought from far away one at a time. The first electron was placed at 0.6×10^{-10} m from the alpha particle and held there while the second electron was brought to 0.6×10^{-10} m from the alpha particle on the other side of the first electron. (a) How much work was done in each step? (b) What is the electrostatic energy of the alpha particle and two electrons in the final configuration? Ans: (a) 7.68×10^{-18} J, 5.76×10^{-18} J; (b) 1.34×10^{-17} J.

Ex 3.6.6. Find the electrostatic energy of eight equal charges (+3 μC) each fixed at the corners of cube of side 2 cm. Ans: 92.3 J.

Ex 3.6.7. Six Na^+ and six Cl^- ions are placed alternately equispaced along a circle of radius 50 nm. Find the electrostatic energy stored. Ans: -7.38×10^{-20} J.

Electric Potential

Ex 3.6.8. (a) Evaluate the electric potential of a point charge +5 μC at a point 3 cm from the charge using reference zero potential at infinity. (b) Evaluate the electric potential of a point charge -5 μC at a point 3 cm from the charge using reference zero potential at infinity. Ans: (a) 1.5 MV, (b) $-$ 1.5 MV.

Ex 3.6.9. A proton moves from a spot where the potential is 200 V to another place where the potential is 500 V. What is the change in energy in eV and in Joules? Ans: 300 eV, 4.8×10^{-17} J.

Ex 3.6.10. A 5 nC point charge is brought from infinitely far away to a point P in the vicinity of some fixed charges. It is found that it took 10 J of energy. What is the potential at P? Ans: 2 GV.

Ex 3.6.11. An electron is brought from infinitely far away to a point P a distance of 3-cm from a fixed charge q. It is found that it took 100 eV of energy. (a) What is the potential at P? (b) Find the value of charge q. Ans: (a) -100 V, (b) -0.33 nC.

Ex 3.6.12. Find the potential at points P_1, P_2, P_3 and P_4 in the diagram from two fixed charges. Ans: $V_1 = 7.5$ GV, $V_2 = -3.75$ GV, V_3=V_4 = $-$ 900 MV.

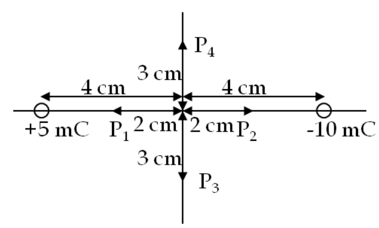


Figure 3.24: Ex. 3.6.12

Ex 3.6.13. Find all the places on the line joining the two given fixed charges in Fig. 3.25 (a) and (b) where the potential is zero. Take the reference for the zero of potential at ∞.

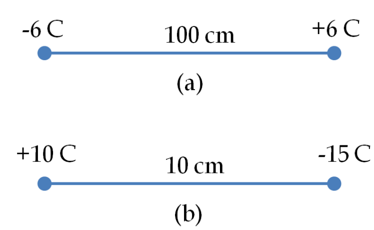


Figure 3.25: Ex. 3.6.13

Ex 3.6.14. Two charges, $q_1 = +6$ μC and $q_2 = -6$ μC are separated by a distance 100 cm. Place them along x-axis symmetrically about origin and find the loci of all points in the xy-plane where the potential is 1 V. Express x and y in meters.

Ex 3.6.15. Electric potentials at points A and B in space are 12 V and 5 V respectively. (a) What is the change in the potential energy of a point charge -3C when it moves from B to A? (b) What is the change in the potential energy of a point charge +3 C when it goes from B to A? Ans: (a) -21 J, (b) +21 J.

Ex 3.6.16. Two charges -2 μC and $+2$ μC are separated by 4 cm on the z-axis symmetrically about origin. Two space points of interest P_1 and P_2 are located 3 cm and 30 cm from origin at an angle 30° with respect to the z-axis. Evaluate electric potentials at P_1 and P_2 in two ways: (a) Using the exact formula for point charges, and (b) using the approximate dipole potential formula. Ans: (a) 267 kV and 4 kV, (b) 3,810 kV and 38.1 kV.

Electric potential of continuous charges

Ex 3.6.17. (a) Plot the potential of a uniformly charged 1 meter rod with 1 C/m charge as a function of the perpendicular distance from the center. show your graph from $s = 0.1$ m to $s = 1.0$ m. (b) On the same graph plot the potential of a point charge with 1 C charge at the origin. (c) Which potential is stronger near the rod? (d) What happens to the difference as the distance increases? Interpret your result.

Ex 3.6.18. (a) Find $x >> L$ limit of the potential of a uniformly charged rod ad show that it coincides with that of a point charge formula as expected. (b) Why would you expect this result?

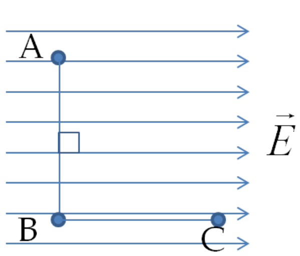
Ex 3.6.19. A uniformly charged ring of radius 10 cm is cut into two equal parts and one-half is placed on a nonconducting table. It is found that 3 cm above the center of the half-ring the potential is -3 V with respect to zero potential at infinity. How much charge is in the half-ring? Ans: 3.5×10^{-11} C.

Ex 3.6.20. A glass ring of radius 5 cm is painted with a charged paint such that the charge density around the ring varies continuously given by the following function of the polar angle θ, $\lambda = (3 \times 10^{-6} C/m)\ \cos^2\theta$. Find the potential at a point 15 cm above the center. Ans: 26.8 kV.

Ex 3.6.21. A CD disk of radius ($R = 3$ cm) is sprayed with a charged paint so that the charge varies continually with radial distance r from the center in the following manner: $\sigma = -(6\ \mathrm{C/m^2})r/R$. Find the potential at a point 4 cm above the center. Ans: 48 GV.

Relation between electric field and electric potential

Ex 3.6.22. In a region of space, electric field is uniform, meaning same magnitude and same direction. (a) Two points A and B are located at a distance d from each other and the line joining them makes an angle of 90^{circ} with the direction of the electric field. What is the difference in electric potential between the points A and B? If the potential difference is not zero, which point is at higher potential and why? (b) Points B and C are located at a distance d from each other and the displacement vector from B to C is parallel to the direction of the electric field. What is the difference in electric potential between the B and C? Which point is at higher potential?



Ex 3.6.23. Electric field of a large sheet of charges with a charge density 20 $\mu C/m^2$ is constant. (a) Find the electric field at an arbitrary point. (b) What is the potential difference between two points A and B which are located 3 cm and 7 cm respectively from the sheet. Ans: (b) 45.2 kV.

Ex 3.6.24. Two large metal plates separated by 4 mm have equal magnitude and opposite type charges with charge densities $\pm 5\mathrm{C/m}^2$. Find the potential difference between the plates. Ans: 2.26 GV.

Ex 3.6.25. Use the definition of potential difference in terms of electric field to deduce the formula for potential difference between $r = r_a$ and $r = r_b$ for a point charge located at the origin. Here r is spherical radial coordinate. Ans: $\frac{q}{4\pi\epsilon_0}\left(\frac{1}{r_b} - \frac{1}{r_a}\right)$