Exercise 1. Potential

If the potential energy due to the scalar potential V on a charge q is $U = qV$, what are the units of V?

Exercise 2. Speed I

Suppose that an electron of charge e is released from one side of a capacitor at potential V_i, and moves towards the other side of the capacitor at potential V_f. Draw a picture of the setup.

Exercise 3. Speed II

By the conservation of energy, what is the kinetic energy of the electron when it strikes the far side of the capacitor?

(a) $e(V_i - V_f)$ ***

(b) $e(V_f - V_i)$

(c) $mV_i^2/2$

(d) $mV_f^2/2$

Exercise 4. Speed III

If the electron has mass m, at what speed is it traveling when it strikes the far side of the capacitor?

(a) $\sqrt{2e(V_i - V_f)/m}$ ***

(b) $\sqrt{2e(V_f - V_i)/m}$

(c) V_i

(d) V_f

Exercise 5. Speed IV

In which scenario will the electron be moving fastest? (If more than one have in the same speed, select all that apply)

(a) $V_i = 10$ [V], $V_f = 0$ [V], separation $= 2$ [mm]

(b) $V_i = 20$ [V], $V_f = 5$ [V], separation $= 2$ [mm] ***

(c) $V_i = 100$ [V], $V_f = 90$ [V], separation $= 2$ [mm]

(d) $V_i = 10$ [V], $V_f = 0$ [V], separation $= 1$ [mm]

(e) $V_i = 20$ [V], $V_f = 5$ [V], separation $= 1$ [mm] ***

(f) $V_i = 100$ [V], $V_f = 90$ [V], separation $= 1$ [mm]

(g) $V_i = 10$ [V], $V_f = 0$ [V], separation $= 0.5$ [mm]

(h) $V_i = 20$ [V], $V_f = 5$ [V], separation $= 0.5$ [mm] ***

(i) $V_i = 100$ [V], $V_f = 90$ [V], separation $= 0.5$ [mm]

(j) $V_i = 10$ [V], $V_f = 0$ [V], separation $= 0.1$ [mm]

(k) $V_i = 20$ [V], $V_f = 5$ [V], separation $= 0.1$ [mm] ***

(l) $V_i = 100$ [V], $V_f = 90$ [V], separation $= 0.1$ [mm]

Exercise 6. Speed V

In which scenario will the electron accelerate fastest during its journey? Hint: $F = -\nabla U$. (If more than one have in the same acceleration, select all that apply)

(a) $V_i = 10$ [V], $V_f = 0$ [V], separation $= 2$ [mm]

(b) $V_i = 20$ [V], $V_f = 5$ [V], separation $= 2$ [mm]

(c) $V_i = 100$ [V], $V_f = 90$ [V], separation $= 2$ [mm]

(d) $V_i = 10$ [V], $V_f = 0$ [V], separation $= 1$ [mm]

(e) $V_i = 20$ [V], $V_f = 5$ [V], separation $= 1$ [mm]

(f) $V_i = 100$ [V], $V_f = 90$ [V], separation $= 1$ [mm]

(g) $V_i = 10$ [V], $V_f = 0$ [V], separation $= 0.5$ [mm]

(h) $V_i = 20$ [V], $V_f = 5$ [V], separation $= 0.5$ [mm]

(i) $V_i = 100$ [V], $V_f = 90$ [V], separation $= 0.5$ [mm]

(j) $V_i = 10$ [V], $V_f = 0$ [V], separation $= 0.1$ [mm]

(k) $V_i = 20$ [V], $V_f = 5$ [V], separation $= 0.1$ [mm] ***

(l) $V_i = 100$ [V], $V_f = 90$ [V], separation $= 0.1$ [mm]

Exercise 7. Electric Field

Given $F = qE$, $F = -\nabla U$, and $U = qV$, derive $E = -\nabla V$.

Exercise 8. Potential of a Point Charge

Draw some equipotential surfaces for a point charge q.

Exercise 9. Electric Potential

Given a square of charges q at $(0, a)$, $(a, 0)$, $(0, -a)$, and $(-a, 0)$, find the electric potential at $(0, 0)$. Hint: $V_{\text{point charge}} = kq/r$.

(a) 0

(b) kq/a

(c) $2kq/a$

(d) $4kq/a$ ***

Exercise 10. Hydrogen I

Find the electric potential energy of a dipole composed of an electron of charge $-e$ separated from a proton of charge $+e$ by a distance of r_0.

(a) $-ke^2/r_0$ ***

(b) $+ke^2/r_0$

(c) $-2ke^2/r_0$

(d) $+2ke^2/r_0$

Exercise 11. Hydrogen II

Now, if $k = 8.988 \times 10^9$ [N m^2/C^2], $e = 1.602 \times 10^{-19}$ [C], and $r_0 = 5.292 \times 10^{-11}$ [m], what is this energy in [J]?

(a) -4.85×10^{-28} [J]

(b) -4.36×10^{-18} [J] ***

(c) -3.02×10^{-9} [J]

(d) -27.2 J

Exercise 12. Hydrogen III

What is the answer to the last question in [eV] if 1 [eV] $= 1.602 \times 10^{-19}$ [J]? How does this compare to the electronic ground state energy of Hydrogen, 13.6 [eV]?

Exercise 13. Electric Field

What is the electric field at $(1, 2, 3)^T$, for $V(x, y, z) = x^2 + y^2 + z^2$? Hint: $E = -\nabla V$.

(a) $-(0, 0, 0)^T$

(b) $-(1, 2, 3)^T$

(c) $-(2, 4, 6)^T$ ***

(d) $-(1, 4, 9)^T$

Exercise 14. Electricity vs Gravity

The force for electricity and gravity are both proportional to $1/r^2$, so why is electricity dominant at short length scales and why is gravity dominant at long length scales?

Exercise 15. Atoms

Why electrons don't fall into and stay in atomic nuclei? Think about the conserved quantities: energy, momentum, angular momentum, charge, etc.