Exercise 1. Square I

Find the electric field at the center of a square of side length a with charges q fixed on each corner.

(a) 0 ***

(b) $8k/a^2$

(c) $2k/a^2(\hat{\boldsymbol{x}} + \hat{\boldsymbol{y}})$

(d) $4k/a^2(\hat{\boldsymbol{x}} + \hat{\boldsymbol{y}})$

Exercise 2. Square II

Describe the subsequent motion for a charge q released anywhere in the square. I.e. does the charge stay in the square, move to the center, move towards a fixed charge, head to infinity, oscillate, etc. Hint: there are two regions.

Exercise 3. Line

Suppose two charges of $-q$ are separated by a distance $2a$, and a charge q is placed equally spaced between the two. If the charge is then pushed perpendicular to the line, describe its subsequent motions.

Exercise 4. Sheet of Charge

A sheet of charge of infinite extent is spread on the xy plane. At $z = 1$ the electric field is E. What is the electric field at $z = 100$?

(a) $10000E$

(b) $100E$

(c) E ***

(d) $E/100$

(e) $E/10000$

(f) 0

Exercise 5. Charged Sphere

A sphere is covered by a uniform surface charge. At $z = 1$ which is greater than the radius of the sphere, the electric field is E. What is the electric field at $z = 100$?

(a) $10000E$

(b) $100E$

(c) E

(d) $E/100$

(e) $E/10000$ ***

(f) 0

Exercise 6. Lightbulb I

What is the net charge of a gas in a fluorescent lightbulb? Assume t is the time since turning the bulb on, ω is the frequency of AC current, P is the power dissipated, and V is the voltage.

(a) 0 [C] ***

(b) $(P/V)t$ [C]

(c) $-(P/V)t$ [C]

(d) $-(P/V)te^{-i\omega t}$ [C]

Exercise 7. Lightbulb II

A typical plasma in a lightbulb may have a pressure of 1 [kPa], and have singly ionized mercury ions at a density of 0.01 to the total number. Assuming that the ions are uniformly spaced in say a square arrangement, calculate the distance between nearest neighboring ions in [m]. Hint: $n = PV/RT$, where $R = 8.314$ [L kPa/K mol], and you may assume $T = 300$ [K]. Hint: 1 L $= 0.001$ [m^3], and 1 [mol] $= 6.022 \times 10^{23}$.

(a) 7.46×10^{-9} [m]

(b) 7.46×10^{-8} [m] ***

(c) 7.46×10^{-7} [m]

(d) 7.46×10^{-6} [m]

Exercise 8. Lightbulb III

Calculate the strength of the coulomb interaction per mass between nearest neighbor ions. You may assume that the mass of each ion is 3.33×10^{-25} [kg].

(a) 8.06×10^{12} [N/kg]

(b) 1.24×10^{11} [N/kg] ***

(c) 1.24×10^{-11} [N/kg]

(d) 8.06×10^{-12} [N/kg]

Exercise 9. Fusion

Suppose that two tritium nuclei (two neutrons and one proton), are brought together to fuse into a Helium nucleus. The nuclei need to be brought to within 10^{-15} m to fuse. Calculate the strength of the coulomb interaction per mass at this distance in newtons per kilogram. You may assume that the mass of each nucleon is 1.67×10^{-27} [kg].

(a) 1.38×10^{29} [N/kg]

(b) 4.61×10^{28} [N/kg] ***

(c) 1.54×10^{19} [N/kg]

(d) 5.13×10^{18} [N/kg]

Exercise 10. Gravitational Charge I

Compare the strength of gravitational to electric attraction, F_g/F_q, in a Hydrogen atom where the nucleus has a mass 1.67×10^{-27} [kg], and the electron has a mass 9.11×10^{-31} [kg]. Both have a charge of 1.62×10^{-19} [C]. Assume that $k_q = 8.988 \times 10^9$ [N m^2/C^2], and $k_g = 6.674 \times 10^{-11}$ [N m^2/kg^2].

(a) 1.35×10^{20}

(b) 1

(c) 0.00743

(d) 4.30×10^{-40}

Exercise 11. Gravitational Charge II

The electronic attraction of charges is often linked to gravity, and while this analogy holds well for two bodies, the analogy breaks down for more bodies. Through a suitable example, show that for gravitational attraction, only the magnitude of the charge matters, and not the sign. Viz, gravitational charge comes in one "flavor".

Exercise 12. Gravitational Charge III

In our universe, electrons e^-, and their anti-particles positrons e^+ exist, both with mass m. What is the total force experienced by an electron and a positron separated by r? Assume that the force constant for charges is k_q and the force constant for masses is k_g.

(a) $-k_q e^2/r^2$

(b) $k_g m^2/r^2$

(c) $-k_q e^2/r^2 + k_g m^2/r^2$

(d) $-k_q e^2/r^2 - k_g m^2/r^2$ ***

Exercise 13. Gravitational Charge IV

Suppose we lived in a universe, where in addition to electronic charges, $\pm e$, there were positive and negative masses, $\pm m$, so there would be four species of electrons: e^+_+, e^+_-, e^-_+, and e^-_-. If the total force is given by $F = k_q(q_1 q_2)/r^2 + k_g(g_1 g_2)/r^2$ for constants k_q and k_g, where the sign of g_1 and g_2 now matter, what is the force experienced by a e^+_+ particle r away from a e^-_- particle?

(a) $k_q e^2/r^2$

(b) $-k_q e^2/r^2 - k_g m^2/r^2$

(c) $k_g m^2/r^2$

(d) $-k_q e^2/r^2 + k_g m^2/r^2$ ***

Exercise 14. Gravitational Charge V

What would it mean for there to be negative mass? Think about acceleration and momentum. If you're interested, look at "negative effective mass" for electrons in solids.

Exercise 15. Halogens

Fluorine, Chlorine, Bromine, and Iodine are gas, gas, liquid, and solid at STP. These elements have the same outer electron configurations of p^5, yet their states of matter are due to electronic behavior how can this be?

Exercise 16. Potential

If $V = k(x^2 + y^2 + z^2)$, calculate the electric field. Which direction/to what point does the E-field point? Hint: $E = -\nabla V$.

Exercise 17. Induced Polarization

Qualitatively, what is the polarization that results in a metal needle placed in line with an electric field?

Exercise 18. Space Quantization I

Suppose that we have a crystal of say, HCl (at low temperature/high pressure). Quantum mechanics says that angular momentum in a system like this is quantized by a number n as $L = \sqrt{l(l+1)}\hbar$. There are then possible observed momenta, $\ell\hbar$ where $m \in \{-l, -l+1, \ldots, l\}$. We find that the allowed angles of rotation are $\phi = \sin^{-1}(m/\sqrt{l(l+1)})$. Calculate this angle for $l = 3$ and $m = \{-1, 0, 1\}$.

Exercise 19. Space Quantization II

Find an expression for the magnitude of the torque in terms of electric field strength E, and the quantum numbers l, and m.

Exercise 20. Space Quantization III

Now, suppose we turn on an electric field 120 [V/m]. Calculate the magnitude of torque experienced by the molecule in each m configuration if the dipole moment is 1.03 [D], where 1 [D] $= 3.34 \times 10^{-30}$ [C m].