HOMEWORK #1 SOLUTIONS

Chapter 17

C1. Polarization. Charged comb polarizes paper. Opposite charges in polarized paper are closer to comb than like charges. So, by Coulomb's Law, attractive force between comb and paper exceeds repulsive force.

C3. Similarities:

Electrical force is proportional to product of charges, and
gravitational force is proportional to product masses ("gravitational charges").

Both vary inversely with the square of the separation of particles.

Differences:

Gravitational force is much weaker.

Like masses attract, but like charges repel.

There are no negative masses, but there are negative charges.

Gravitational force is always attractive, but electrostatic force can be attractive or repulsive.

Acceleration of a charged particle is proportional to the electric force acting on it, but acceleration of a massive particle is *not* proportional to the gravitational force acting on it.

C6. Chain ensures that there is no potential difference between the gasoline tank and the ground. The eliminates any potential difference by allow charge to flow freely between the tank and the ground.

MC1. Acceleration each charge is proportional to the force acting on it ($F = ma$). Force is given by Coulombs law. Coulomb law says that force is inversely proportional to the separation of charges. Therefore for acceleration is inversely proportional to the separation of charges. Or

$$a = \text{constant x } \frac{1}{D^2}$$

Case 1: Separation = *D*

$$a_1 = \text{constant x } \frac{1}{D^2}$$

Case 2: Separation = *D/2*

$$a_2 = \text{constant x } \frac{1}{\left(\frac{D}{2}\right)^2} = \text{constant x } \frac{4}{D^2}$$

So $a_2 = 4a_1$

Answer: D. 4*a*.

MC3. In Region 1, magnitude of field from +4 charge is always greater than that of -2 charge. Therefore, no cancellation.

In Region 2, field from +4 charge is always in same direction as field from -2 charge. Therefore, no cancelation.

In Region 3, field from -4 charge and that from -2 charge are in different directions. Near -2 charge, magnitude of field of -2 charge exceeds that of field of +4 charge. Far from -2 charge, magnitude of field of +4 charge exceeds that of field of +2 charge. Therefore, there exists a point in Region 3 were magnitudes are equal and cancellation occurs (i.e. field = 0).

Answer: C. only in Region 3

MC5. Apply Gauss' Law. Imaginary surface is a sphere that encloses the balloon and is very slightly larger than the surface of the balloon. Because of the symmetry of the charge distribution, the electric field is perpendicular to the surface of the balloon and therefore also perpendicular to our imaginary surface. Using the formula for the area of our surface, $A = 4\pi\left(\frac{D}{2}\right)^2$, Gauss' Law becomes

$$E_1 \times 4\pi\left(\frac{D}{2}\right)^2 = 4\pi kQ$$ Case 1: Diameter = *D*.

or

$$E_1 = \frac{4kQ}{D^2}$$

[Where E_1 denotes the electrical field in "Case 1" in which the diameter of the sphere is *D*, and E_2 denotes the electric field in "Case 2" in which the diameter is 2*D*.]

Note that because our surface is a sphere whose diameter is infinitesimally larger than that of the balloon, its diameter is effectively the same as that of the balloon.

$$E_2 \times 4\pi\left(\frac{2D}{2}\right)^2 = 4\pi kQ$$ Case 2: Diameter = 2*D*

or

$$E_2 = \frac{kQ}{D^2}$$

So $E_2 = E_1/4$

Answer: E. $E/4$

MC7. If the electric field points downward, the force on a positively charged particle is downward. But the force on a negatively charged particle is just the opposite, i.e. upward.

Because the force acts perpendicularly to the horizontal momentum of the electron, it does not affect this momentum. So the electron now moves both horizontally and upward.

Answer: C.

Problems

17.6. Set Up: The total charge is the number if ions times the charge of each. $e = 1.60 \times 10^{-19}$ C.
Solve: $N = (5.6 \times 10^{11}/\text{m})(1.5 \times 10^{-2}\ \text{m}) = 8.4 \times 10^{9}$ ions

$$Q = Ne = (8.4 \times 10^{9})(1.60 \times 10^{-19}\ \text{C}) = 1.3 \times 10^{-9}\ \text{C} = 1.3\ \text{nC}$$

17.24. Set Up: In the O-H-N combination the O^- is 0.170 nm from the H^+ and 0.280 nm from the N^-. In the N-H-N combination the N^- is 0.190 nm from the H^+ and 0.300 nm from the other N^-. Like charges repel and unlike charges attract. The net force is the vector sum of the individual forces.

Solve: (a) $F = k\dfrac{|q_1q_2|}{r^2} = k\dfrac{e^2}{r^2}$

O-H-N

$$O^-\text{-}H^+ \quad F = (8.99 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)\frac{(1.60 \times 10^{-19}\ \text{C})^2}{(0.170 \times 10^{-9}\ \text{m})^2} = 7.96 \times 10^{-9}\ \text{N, attractive}$$

$$O^-\text{-}N^- \quad F = (8.99 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)\frac{(1.60 \times 10^{-19}\ \text{C})^2}{(0.280 \times 10^{-9}\ \text{m})^2} = 2.94 \times 10^{-9}\ \text{N, repulsive}$$

N-H-N

$$N^-\text{-}H^+ \quad F = (8.99 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)\frac{(1.60 \times 10^{-19}\ \text{C})^2}{(0.190 \times 10^{-9}\ \text{m})^2} = 6.38 \times 10^{-9}\ \text{N, attractive}$$

$$N^-\text{-}N^- \quad F = (8.99 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)\frac{(1.60 \times 10^{-19}\ \text{C})^2}{(0.300 \times 10^{-9}\ \text{m})^2} = 2.56 \times 10^{-9}\ \text{N, repulsive}$$

The total attractive force is 1.43×10^{-8} N and the total repulsive force is 5.50×10^{-9} N. The net force is attractive and has magnitude $1.43 \times 10^{-8}\ \text{N} - 5.50 \times 10^{-9}\ \text{N} = 8.80 \times 10^{-9}$ N.

(b) $F = k\dfrac{e^2}{r^2} = (8.99 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)\dfrac{(1.60 \times 10^{-19}\ \text{C})^2}{(0.0529 \times 10^{-9}\ \text{m})^2} = 8.22 \times 10^{-8}\ \text{N}$

The bonding force of the electron in the hydrogen atom is a factor of 10 larger than the bonding force of the adenine-thymine molecules.

17.25. Set Up: In the O-H-O combination the O^- is 0.180 nm from the H^+ and 0.290 nm from the other O^-. In the N-H-N combination the N^- is 0.190 nm from the H^+ and 0.300 nm from the other N^-. In the O-H-N combination the O^- is 0.180 nm from the H^+ and 0.290 nm from the other N^-. Like charges repel and unlike charges attract. The net force is the vector sum of the individual forces.

Solve: $F = k\dfrac{|q_1q_2|}{r^2} = k\dfrac{e^2}{r^2}$. The attractive forces are: O^--H^+, 7.10×10^{-9} N; N^--H^+, 6.37×10^{-9} N; O^--H^+, 7.10×10^{-9} N. The total attractive force is 2.06×10^{-8} N. The repulsive forces are: O^--O^-, 2.74×10^{-9} N; N^--N^-, 2.56×10^{-9} N; O^--N^-, 2.74×10^{-9} N. The total repulsive force is 8.04×10^{-9} N. The net force is attractive and has magnitude 1.26×10^{-8} N.

17.39. Set Up: If the axon is modeled as a point charge, its electric field is $E = k\dfrac{q}{r^2}$. The electric field of a point charge is directed away from the charge if it is positive.

Solve: (a) 5.6×10^{11} Na^+ ions enter per meter so in a 0.10 mm $= 1.0 \times 10^{-4}$ m section, 5.6×10^7 Na^+ ions enter. This number of ions has charge $q = (5.6 \times 10^7)(1.60 \times 10^{-19}\ \text{C}) = 9.0 \times 10^{-12}\ \text{C}$.

(b) $E = k\dfrac{|q|}{r^2} = (8.99 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)\dfrac{9.0 \times 10^{-12}\ \text{C}}{(5.00 \times 10^{-2}\ \text{m})^2} = 32\ \text{N/C}$, directed away from the axon.

(c) $r = \sqrt{\dfrac{k|q|}{E}} = \sqrt{\dfrac{(8.99 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(9.0 \times 10^{-12}\ \text{C})}{1.0 \times 10^{-6}\ \text{N/C}}} = 280\ \text{m}$

17.76. Set Up: When the forces balance, $a = 0$ and the molecule moves with constant velocity.

Solve: (a) $F = F_D$ so $qE = KRv$ and $\frac{q}{R} = \frac{Kv}{E}$

(b) $v = \frac{Eq}{KR}$ and is constant. $x = vt = \left(\frac{Eq}{KR}\right)T = \left(\frac{ET}{K}\right)\frac{q}{R}$

(c) $x = \left(\frac{ET}{K}\right)\frac{q}{R}$, where $\frac{ET}{K}$ is constant. $\left(\frac{q}{R}\right)_2 = 2\left(\frac{q}{R}\right)_1$ and $\left(\frac{q}{R}\right)_3 = 3\left(\frac{q}{R}\right)_1$

$$x_2 = \left(\frac{ET}{K}\right)\left(\frac{q}{R}\right)_2 = 2\left(\frac{ET}{K}\right)\left(\frac{q}{R}\right)_1 = 2x_1;\ x_3 = \left(\frac{ET}{K}\right)\left(\frac{q}{R}\right)_3 = 3\left(\frac{ET}{K}\right)\left(\frac{q}{R}\right)_1 = 3x_1$$

Chapter 18

C1. Electric field lines must be perpendicular to equipotential surfaces so that there is no component of the electric field parallel to the surface. Were there such a parallel component, it would mean that a charge moving along the surface would experience a force. If that were true, it would require work to move a charge along the surface. That is, different points on the surface would be at different potentials. This violates the assumption that the potential is the same at every point on the surface.

C3. If the electric field is zero in a region, the potential is not necessarily zero there. But the potential is *constant* there. The electric E_x in the x-direction field related to the potential V by

$$E_x = -\frac{\Delta V}{\Delta x}$$

i.e. it's the rate at which V changes in the x-direction. [Similar equations apply for the y and z directions.] So $E_x = 0$ ➔ $\Delta V = 0$. But V can be nonzero.

MC7. Charge is same on each capacitor. Charge that appears on left side of 5 μF capacitor is the negative of the charge that is on its right side. Charge on right side of 5 μF appears there by leaving the left side of 10 μF capacitor. So charge on left side of 10 μF is the the negative of charge on right side of 5 μF capacitor. Similarly, charge on right side of 10 μF capacitor is the negative of the charge on the left side of 15 μF capacitor. And charge on the right side of 10 μF capacitor is the negative of charge on the left side of this capacitor. In short, capacitors all have the same magnitude of charge on their sides, because they are connected in series.

$$C_{equiv} = \frac{1}{\frac{1}{5\mu F} + \frac{1}{10\mu F} + \frac{1}{15\mu F}} = \frac{1}{\frac{6}{30} + \frac{3}{30} + \frac{2}{30}} = \frac{30}{11}\mu F < 30\mu F$$

Answer: B & D

MC9. $U = \frac{kq_1q_2}{r}$

Case 1: $r = d$

$$U_1 = \frac{kq_1q_2}{d}$$

Case 2: $r = 2d$

$$U_2 = \frac{kq_1q_2}{2d}$$

So $U_2 = U_1/2$

Answer: B. $U/2$

Problems

18.14. Set Up: For two oppositely charged sheets of charge, $V_{ab} = Ed$. The positively charged sheet is the one at higher potential.

Solve: **(a)** $E = \frac{V_{ab}}{d} = \frac{70 \times 10^{-3}\ \text{V}}{7.5 \times 10^{-9}\ \text{m}} = 9.3 \times 10^{6}\ \text{V/m}$. The electric field is directed inward, toward the interior of the axon, since the outer surface of the membrane has positive charge and $\vec{E}$ points away from positive charge and toward negative charge. Section 18.9 explores the effects of a material other than air between the plates.

(b) The outer surface has positive charge so it is at higher potential than the inner surface.

18.48. Set Up: For capacitors in series the voltage across the combination equals the sum of the voltages in the individual capacitors. For capacitors in parallel the voltage across the combination is the same as the voltage across each individual capacitor.

Solve: **(a)** Connect the capacitors in series so their voltages will add.

(b) $V = V_1 + V_2 + V_3 + \cdots = NV_1$, where N is the number of capacitors in the series combination, since the capacitors are identical.

$$N = \frac{V}{V_1} = \frac{500\ \text{V}}{0.10\ \text{V}} = 5000.$$