Instructor: Tomoyuki Nakayama Wednesday, May 11, 2011

PHY 2005 Applied Physics 2 - Summer 2011
Solutions for Suggested Homework Problems (Chapter 19)

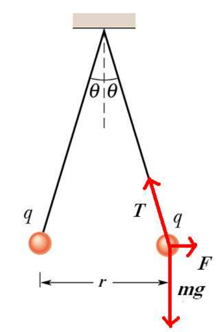
---

1. Each electron has a charge of $-e$, where $e = 1.6\times10^{-19}$ C. Thus in 1-C charge, there are 1 C/ (1.6×10^{-19} C/electron) = 6.25×10^{18} electrons.

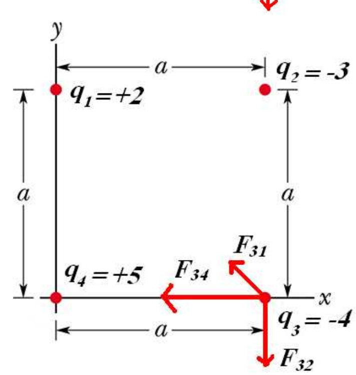
7. A proton has a charge $+e$ and an electron has a charge $-e$. They are unlike charges, thus the force on the electron is toward the proton. The magnitude of the force is given by Coulomb's law. Coulomb's law yields
$F = ke^2/r^2 = 8.20\times10^{-8}$ N

9. (a) Applying Coulomb's law, we obtain
$F = k|q_1||q_2|/r^2 = 4.32\times10^{-5}$ N,
where $q_1 = 0.3$ μC and $q_2 = -0.4$μC. The force is attractive because they have opposite signs.
(b) After the two *identical* spheres are touched together, the charge distributes itself so that each sphere has an equal amount of charge. Each sphere has a charge of $q = (q_1 + q_2)/2 = -0.05$ μC. Coulomb's law yields
$F = k|q|^2/r^2 = 9.00\times10^{-7}$ N.

11. (a) Electric force is proportional to $1/r^2$. We use the ratio of the force at $r_1 = 4$ m to the force at $r_2 = 3$ m to obtain
$F(r_2)/F(r_1) = (1/r_2^2)/(1/r_1^2) \Rightarrow F(r_2) = (r_2^2/ r_1^2)F(r_1) = 4.44\times10^{-8}$ N.
(b) Coulomb's law yields
$F = k|q_1||7q_1|/r^2 \Rightarrow q_1 = \pm r\sqrt{(F/7k)} = \pm2.52\times10^{-9}$ C.
Since $q_2 = 7q_1$, we get
$q_1 = +2.52\times10^{-9}$ C, $q_2 = +1.76\times10^{-8}$ C and $q_1 = -2.52\times10^{-9}$ C, $q_2 = -1.76\times10^{-8}$ C



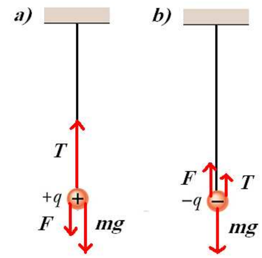
16. The angle between one of the threads and the vertical is $\theta = 14°$. Applying Newton's 2nd law in the vertical direction, we get
$T\cos\theta - mg = 0 \Rightarrow T = mg/\cos\theta$
Newton's 2nd law in the horizontal direction yields
$F - T\sin\theta = 0 \Rightarrow F = T\sin\theta = (mg/\cos\theta)\sin\theta = mg\tan\theta$.
We apply Coulomb's law to obtain
$k|q|^2/r^2 = T\tan\theta\ r \Rightarrow q = \pm r\sqrt{(T\tan\theta/k)} = \pm6.10\times10^{-8}$ C



22. Coulomb's law yields the forces on the -4-μC charge from the other individual charges.
$F_{31} = k|q_3||q_1|/(a\sqrt{2})^2 = 0.400$ N
$F_{32} = k|q_3||q_2|/a^2 = 1.20$ N
$F_{34} = k|q_3||q_4|/a^2 = 2.00$ N
According to the superposition principle, the net force is given by the vector sum of these three forces. The x component of the net force is
$F_{3,x} = F_{31}\cos135° - F_{34} = -2.28$ N
The y component of the net force is
$F_{3,y} = F_{31}\sin135° - F_{32} = -0.917$ N
We apply Pythagorean theorem to obtain
$F_3 = \sqrt{(F_{3,x}^2 + F_{3,y}^2)} = 2.46$ N

23. (a) The magnitude of the force is $F = |q|E = 1.5\times10^{-2}$ N. The direction of the force is the same as the direction of the field.
(b) The magnitude of the force is $F = |q|E = 1.5\times10^{-2}$ N. The direction of the force is opposite the direction of the field.

28. The magnitudes of the electric forces on ±9μC charges are both



$F = |qE| = 5.4\times10^{-3}$ N
(a) The electric force on the ball is directed downward. Apply Newton's 2nd law to obtain
$T-F-mg = 0 \Rightarrow T = F + mg = 3.48\times10^{-2}$ N
(b) The electric force on the ball is directed upward. Newton's 2nd law yields
$T+F-mg = 0 \Rightarrow T = -F + mg = 2.40\times10^{-2}$ N

31. The electric field due to q_1 = -2μC and that due to q_2 = -3μC are in the same directions in the region to left of q_1 and to the right of q_2. The fields due to q_1 and q_2 are in the opposite directions between the two charges. Therefore, the location where the electric field vanishes must be between the two charges.
$k|q_1|/x^2 - k|q_2|/(0.5-x)^2 = 0 \Rightarrow (0.5-x)^2/x^2 = |q_2|/|q_1| \Rightarrow (0.5-x)/x = \pm\sqrt{(|q_2|/|q_1|)}$
Only the positive root yields the desired result x = 0.225 m

34. Electric field due to a uniformly charged sphere is the same as the field due to an equal charge placed at the center of the sphere. Therefore, the field strength just outside of the sphere is
$E = k|q|/r^2 = 5.63\times10^6$ N/C

36. The electric force on the electron is
$F = eE = 3.20\times10^{-16}$ N
Newton's 2nd law yields the acceleration of the electron:
$a = F/m = 3.52\times10^{14}$ m/s^2
Since the acceleration is constant, we can use the kinematics equations. One of them yields
$v^2-0^2 = 2ax \Rightarrow v = \sqrt{(2ax)} = 2.37\times10^7$ m/s

37. (a) By definition, the potential difference is ΔV = 10 J/C. (b) A proton has a charge of e $=1.6\times10^{-19}$ C. Therefore, the work needed to carry a proton through a potential difference ΔV is $W = e\Delta V = 1.6\times10^{-18}$ J.

44. The potential energy lost in one second is
$|\Delta E_p| = q\Delta V = 4.4$ J
1 calorie = 4.18 J. Therefore, the generated heat in one second is
4.4 J × (1 cal/4.18 J) = 1.05 cal

48. (a) The energy conservation equation yields
$\Delta E_k + \Delta E_p = 0 \Rightarrow (1/2)mv^2 - q|\Delta V| = 0 \Rightarrow v = \sqrt{(2q|\Delta V|/m)} = 1.31\times10^7$ m/s,
(b) The kinetic energy gained by an alpha particle is
$\Delta E_k = -E_p = q\Delta V = 5.76\times10^{-13}$ J
Converting its unit to eV, we get
5.76×10^{-13} J × (1 eV/(1.6×10^{-19} J)) = 3.6×10^6 eV

49. We apply the energy conservation equation to obtain
$\Delta E_k + \Delta E_p = 0 \Rightarrow (1/2)mv_f^2 - (1/2)mv_i^2 + q\Delta V \Rightarrow \Delta V = m(v_f^2 - v_i^2)/(2q) = -11.4$ V