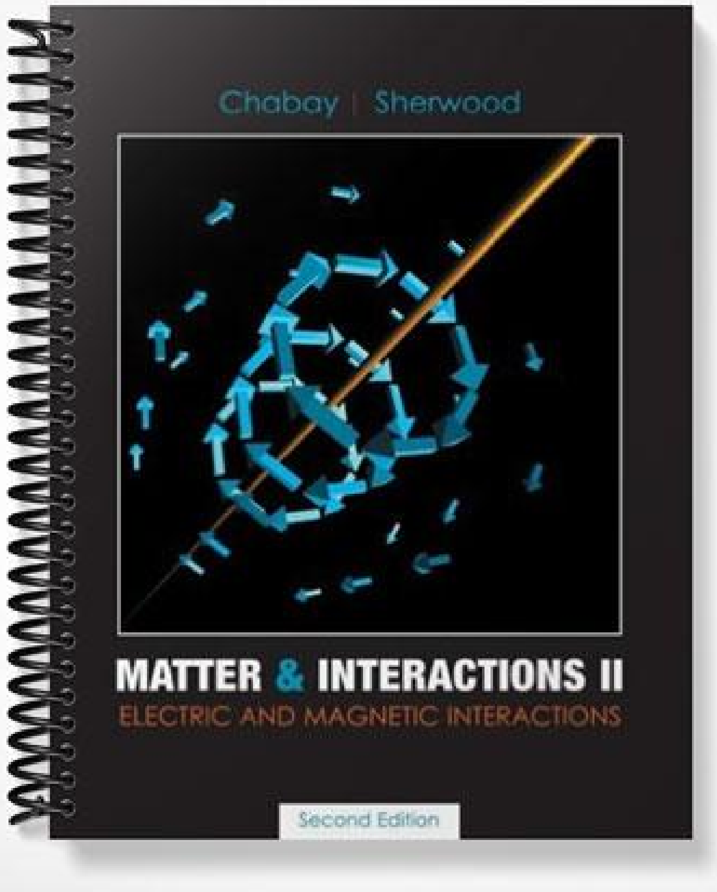
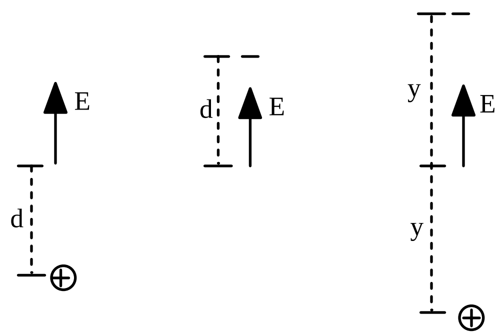
SOLUTIONS MANUAL



13.RQ.26 A proton should be south of the observation location, an electron north of the observation location, or you could put a proton south and an electron north of the location:



To find the distance d in the first two cases:

$$\frac{1}{4\pi\varepsilon_0}\frac{e}{d^2} = E = 10^6\,\mathrm{N/C}$$

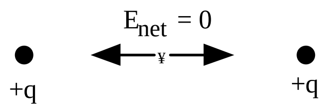
$$d = \sqrt{\frac{1}{4\pi\varepsilon_0}\frac{e}{E}} = \sqrt{\left(9\times10^9\,\mathrm{N\cdot m^2/C^2}\right)\frac{1.6\times10^{-19}\,\mathrm{C}}{10^6\,\mathrm{N/C}}} = 3.8\times10^{-8}\,\mathrm{m}$$

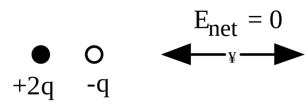
To find the distance y in the last case:

$$2\frac{1}{4\pi\varepsilon_0}\frac{e}{y^2} = E = 10^6\,\mathrm{N/C}$$

$$y = \sqrt{2\frac{1}{4\pi\varepsilon_0}\frac{e}{E}} = \sqrt{2}\,d = \sqrt{2}\times3.8\times10^{-8}\,\mathrm{m} = 5.4\times10^{-8}\,\mathrm{m}$$

13.RQ.28 Here are a couple of ways to arrange two point charges in order to make the electric field be zero at some location:

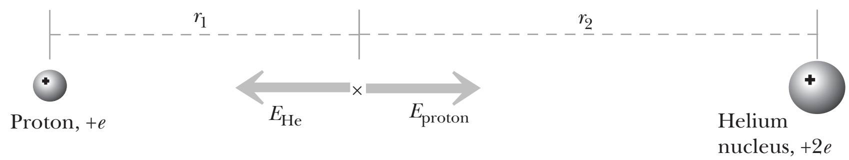




13.RQ.32 Force by permanent dipole on a distant point charge goes like $1/r^3$, so doubling the distance will reduce the force by a factor of $1/2^3 = 1/8$.

13.P.37 Making a zero electric field

(a)



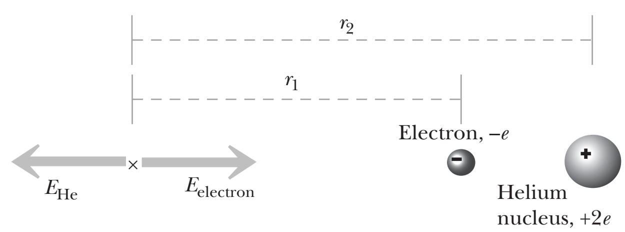
The diagram shows the electric fields contributed by each charge, labeled by their magnitudes. Reading off the diagram, because the two electric field vectors must add to zero, we have this:

$$\frac{1}{4\pi\varepsilon_0}\frac{e}{r_1^2} = \frac{1}{4\pi\varepsilon_0}\frac{2e}{r_2^2}$$

$$r_2^2 = 2r_1^2$$

$$r_2 = \sqrt{2}r_1$$

(b)



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38.P.38 Field and force with three charges

$Q_1 = 3\times10^{-6}$ **C;** $Q_2 = 8\times10^{-6}$ **C;** $Q_3 = -5\times10^{-6}$ **C**

(a) Remove Q_1, calculate electric fields due to Q_2 and Q_3:

$$\vec{E}_2 = \frac{1}{4\pi\varepsilon_0}\frac{Q_2}{r^2}\hat{r} = \left(9\times10^9\,\frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left(\frac{(8\times10^{-6}\text{ C})}{(0.04^2)\text{ m}^2}\right)\frac{<0, 0.04, 0>}{(0.04^2)^{1/2}} = <0, 4.5\times10^7, 0> \text{ N/C}$$

$$\vec{E}_3 = \frac{1}{4\pi\varepsilon_0}\frac{Q_3}{r^2}\hat{r} = \left(9\times10^9\,\frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left(\frac{(-5\times10^{-6}\text{ C})}{(0.03^2+0.04^2)\text{ m}^2}\right)\frac{<-0.03, 0.04, 0>}{(0.03^2+0.04^2)^{1/2}} = <1.08\times10^7, -1.44\times10^7, 0> \text{ N/C}$$

$$\vec{E} = \vec{E}_2 + \vec{E}_3 = <1.08\times10^7, 3.06\times10^7, 0> \text{ N/C}$$

(b) $\vec{F}_{\text{on }1} = Q_1\vec{E} = (3\times10^{-6}\text{ C})<1.08\times10^7, 3.06\times10^7, 0> \text{ N/C} = <32.4, 91.8, 0> \text{ N}$

(c) Calculate the fields due to each of the three charges:

$$\vec{E}_1 = \frac{1}{4\pi\varepsilon_0}\frac{Q_1}{r^2}\hat{r} = \left(9\times10^9\,\frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left(\frac{(3\times10^{-6}\text{ C})}{(0.03^2)\text{ m}^2}\right)\frac{<0.03, 0, 0>}{(0.03^2)^{1/2}}$$

$$\vec{E}_2 = \frac{1}{4\pi\varepsilon_0}\frac{Q_2}{r^2}\hat{r} = \left(9\times10^9\,\frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left(\frac{(8\times10^{-6}\text{ C})}{(0.03^2+0.04^2)\text{ m}^2}\right)\frac{<0.03, 0.04, 0>}{(0.03^2+0.04^2)^{1/2}}$$

$$\vec{E}_3 = \frac{1}{4\pi\varepsilon_0}\frac{Q_3}{r^2}\hat{r} = \left(9\times10^9\,\frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left(\frac{(-5\times10^{-6}\text{ C})}{(0.04^2)\text{ m}^2}\right)\frac{<0, 0.04, 0>}{(0.04^2)^{1/2}}$$

Add components:

$$E_x = \left(9\times10^9\,\frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left(\frac{(3\times10^{-6}\text{ C})(0.03\text{ m})}{(0.03^2)^{3/2}\text{ m}^3} + \frac{(8\times10^{-6}\text{ C})(0.03\text{ m})}{(0.03^2+0.04^2)^{3/2}\text{ m}^3}\right) = 4.73\times10^7 \text{ N/C}$$

$$E_y = \left(9\times10^9\,\frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left(\frac{(8\times10^{-6}\text{ C})(0.04\text{ m})}{(0.03^2+0.04^2)^{3/2}\text{ m}^3} + \frac{(-5\times10^{-6}\text{ C})(0.04\text{ m})}{(0.04^2)^{3/2}\text{ m}^3}\right) = -0.51\times10^7 \text{ N/C}$$

$$E_z = 0$$

$$\vec{E} = \langle 4.73\times10^7, -0.51\times10^7, 0\rangle \text{ N/C}$$

(d) Nonrelativistic approximation okay to get initial acceleration, because starting from rest:

$$\vec{F} = \frac{d\vec{p}}{dt} \approx \frac{d}{dt}(m\vec{v}) = m\frac{d\vec{v}}{dt} = m\vec{a}$$

$$\vec{a} = \frac{\vec{F}}{m} = \frac{(2e)\vec{E}_A}{m} = \frac{(3.2\times10^{-19}\text{ C})}{(4\times1.7\times10^{-27}\text{ kg})}<4.73\times10^7, -0.51\times10^7, 0> \text{ N/C}$$

$$\vec{a} = <2.22\times10^{15}, -0.24\times10^{15}, 0> \text{ m/s}^2$$

This is the instantaneous acceleration at the initial time. As the particle speeds up, the acceleration will decrease (and the non-relativistic approximation will no longer be valid).

13.P.39 Electric field of two objects

(a) The vector $\vec{r}_{ball}$ from the center of the hollow sphere to the observation location is:

$$\vec{r}_{ball} = \langle 0, 6, 0\rangle - \langle -3, 0, 0\rangle = \langle 3, 6, 0\rangle$$, and its magnitude is: $r_{ball} = [3^2 + 6^2]^{1/2} = 6.71$

$$\vec{E}_{ball} = \frac{1}{4\pi\varepsilon_0}\frac{Q_{ball}}{r_{ball}^2}\hat{r}_{ball} = \frac{1}{4\pi\varepsilon_0}\frac{Q_{ball}}{r_{ball}^3}\vec{r}_{ball} = \left(9e9\frac{\text{Nm}^2}{\text{C}^2}\right)\frac{(-3\times 10^{-9}\,C)}{(6.71\,\text{m})^3}\langle 3, 6, 0\rangle$$
$$= \langle -0.268, -0.536, 0\rangle \text{N/C}$$

The vector $\vec{r}_{pt}$ from the point charge to the observation location is:

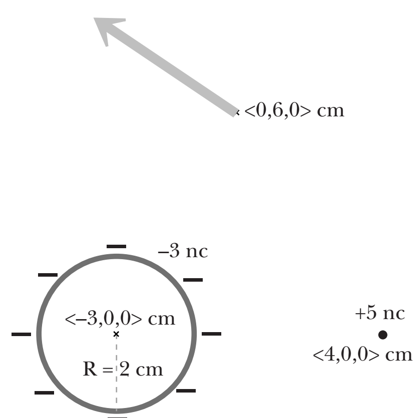
$$\vec{r}_{pt} = \langle 0, 6, 0\rangle - \langle 4, 0, 0\rangle = \langle -4, 6, 0\rangle$$, and its magnitude is: $r_{pt} = [(-4)^2 + 6^2]^{1/2} = 7.21$

$$\vec{E}_{pt} = \frac{1}{4\pi\varepsilon_0}\frac{q_{pt}}{r_{pt}^2}\hat{r}_{pt} = \frac{1}{4\pi\varepsilon_0}\frac{q_{pt}}{r_{pt}^3}\vec{r}_{pt} = \left(9e9\frac{\text{Nm}^2}{\text{C}^2}\right)\frac{(5\times 10^{-9}\,C)}{(7.21\,\text{m})^3}\langle -4, 6, 0\rangle$$
$$= \langle -0.480, 0.720, 0\rangle \text{N/C}$$

The net electric field is the sum of the contributions of the two objects:

$$\vec{E}_{net} = \vec{E}_{ball} + \vec{E}_{pt} = \langle -0.268, -0.536, 0\rangle\frac{\text{N}}{\text{C}} + \langle -0.480, 0.720, 0\rangle\frac{\text{N}}{\text{C}} = \langle -0.748, 0.184, 0\rangle\frac{\text{N}}{\text{C}}$$

(b)



13.P.43 (Grading key: 20 pts) Electric field of a dipole (computer program)

(a) Field vectors (8 pts)

(b) Field graphs (4 pts)

(c) Proton trajectory (5 pts)

(d) Energy graphs (3 pts)

13.P.44 (Grading key: 20 pts) Motion of charges without friction

(a, 5 pts) Screen print of level 5 solution

(b, 5 pts) Screen print of level 5 with extra charge that has a big effect

(c, 2 pts) Points where acceleration is large
–1 if errors
–1 if don't explain (correctly) how you can tell from looking at trail

(dot spacing changes, trajectory curves)

("large force" is not ok)

(d, 2 pts) Points where acceleration is small
–1 if errors
–1 if don't explain (correctly) how you can tell from looking at trail

(dot spacing constant, straight line motion)

("small force" is not ok)

(e, 2 pts) Point where force & velocity differ in direction

(all or nothing)

(f, 2 pts) How do answers to (c) & (d) illustrate rapid falloff of Coulomb force

(should say large acceleration only very near a charge)

(g, 2 pts) Why did distant charge have an effect

(very small force, but acting over sufficient time/distance to produce an effect)

–2 if think charge had an effect only when particle got near it