Recitation 7

•3 SSM The nucleus of a plutonium-239 atom contains 94 protons. Assume that the nucleus is a sphere with radius 6.64 fm and with the charge of the protons uniformly spread through the sphere. At the nucleus surface, what are the (a) magnitude and (b) direction (radially inward or outward) of the electric field produced by the protons?

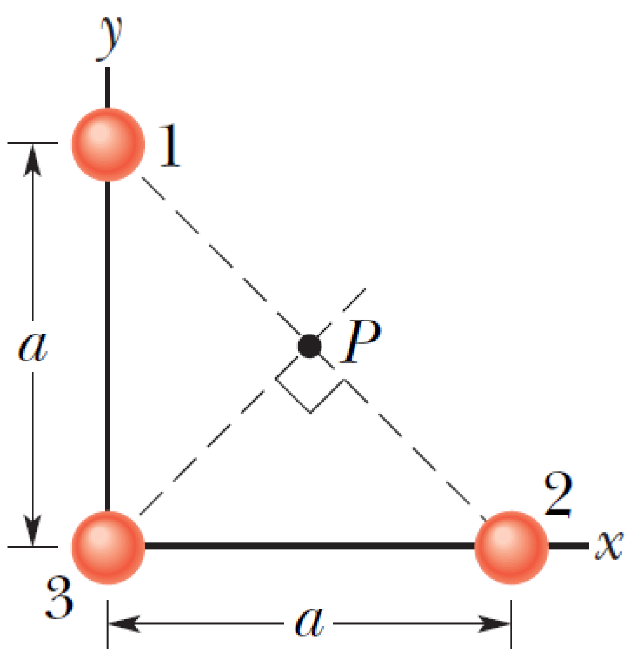
(a) By the shell theorem, the spherical nucleus can be replaced by a point charge at the center of the nucleus.

$$E = k\frac{Q}{r^2} = k\frac{94e}{r^2} = \left(8.99 \times 10^9 \frac{\mathrm{N \cdot m^2}}{\mathrm{C^2}}\right)\frac{94(1.60 \times 10^{-19}\ \mathrm{C})}{(6.64 \times 10^{-15}\ \mathrm{m})^2}$$

$$= 3.07 \times 10^{21}\ \mathrm{N/C}.$$

(b) Radially outward.

••15 In Fig. 22-37, the three particles are fixed in place and have charges $q_1 = q_2 = +e$ and $q_3 = +2e$. Distance $a = 6.00\ \mu$m. What are the (a) magnitude and (b) direction of the net electric field at point P due to the particles?



(a) We can see that $\vec{E}_1$ and $\vec{E}_2$ cancel at point P. Thus,

$$E_{net} = E_3 = k\frac{q_3}{r^2} = k\frac{2e}{\left(\frac{\sqrt{2}}{2}a\right)^2} = k\frac{4e}{a^2} = \left(8.99 \times 10^9\,\frac{\mathrm{N \cdot m^2}}{\mathrm{C^2}}\right)\frac{4(1.60 \times 10^{-19}\ \mathrm{C})}{(6.00 \times 10^{-6}\ \mathrm{m})^2}$$

$$= 160\ \mathrm{N/C}.$$

(b) 45° above the x-axis.

••55 ILW A uniform electric field exists in a region between two oppositely charged plates. An electron is released from rest at the surface of the negatively charged plate and strikes the surface of the opposite plate, 2.0 cm away, in a time 1.5×10^{-8} s. (a) What is the speed of the electron as it strikes the second plate? (b) What is the magnitude of the electric field $\vec{E}$?

(a)

$$x = \frac{1}{2}at^2$$

$$a = \frac{2x}{t^2} = \frac{2(2.0 \times 10^{-2}\ \text{m})}{(1.5 \times 10^{-8}\ \text{s})^2} = 1.78 \times 10^{14}\ \frac{\text{m}}{\text{s}^2}.$$

$$v = at = (1.78 \times 10^{14}\ \text{m/s}^2)(1.5 \times 10^{-8}\ \text{s}) = 2.7 \times 10^{6}\ \text{m/s}.$$

(b)

$$a = \frac{F}{m_e} = \frac{eE}{m_e}$$

$$E = \frac{m_e a}{e} = \frac{(9.11 \times 10^{-31}\ \mathrm{kg})\left(1.78 \times 10^{14}\ \frac{\mathrm{m}}{\mathrm{s}^2}\right)}{1.60 \times 10^{-19}\ \mathrm{C}} = 1.0 \times 10^{3}\ \frac{\mathrm{N}}{\mathrm{C}}.$$

83 **SSM** An electric dipole with dipole moment

$$\vec{p} = (3.00\hat{\mathrm{i}} + 4.00\hat{\mathrm{j}})(1.24 \times 10^{-30}\ \mathrm{C \cdot m})$$

is in an electric field $\vec{E} = (4000\ \mathrm{N/C})\hat{\mathrm{i}}$. (a) What is the potential energy of the electric dipole? (b) What is the torque acting on it? (c) If an external agent turns the dipole until its electric dipole moment is

$$\vec{p} = (-4.00\hat{\mathrm{i}} + 3.00\hat{\mathrm{j}})(1.24 \times 10^{-30}\ \mathrm{C \cdot m}),$$

how much work is done by the agent?

(a)

$$U = -\vec{p} \cdot \vec{E}$$

$$= -[(3.00\,\hat{\imath} + 4.00\,\hat{\jmath})(1.24 \times 10^{-30}\ \mathrm{C \cdot m})] \cdot [4000\ \mathrm{N/C}\,\hat{\imath}]$$

$$= -\left(12000\,\frac{\mathrm{N}}{\mathrm{C}}\right)(1.24 \times 10^{-30}\ \mathrm{C \cdot m}) = -1.49 \times 10^{-26}\ \mathrm{J}.$$

(b)

$$\vec{\tau} = \vec{p} \times \vec{E}$$

$$= [(3.00\,\hat{\imath} + 4.00\,\hat{\jmath})(1.24 \times 10^{-30}\ \mathrm{C \cdot m})] \times [4000\ \mathrm{N/C}\,\hat{\imath}]$$

$$= \left(-16000\,\frac{\mathrm{N}}{\mathrm{C}}\,\hat{\mathrm{k}}\right)(1.24 \times 10^{-30}\ \mathrm{C \cdot m})$$

$$= -1.98 \times 10^{-26}\ \mathrm{N \cdot m}\,\hat{\mathrm{k}}.$$

(c)

$$W_a = \Delta U = U_f - U_i$$

$$U_i = -\vec{p}_i \cdot \vec{E} = -1.49 \times 10^{-26}\ \mathrm{J}.$$

$$U_f = -\vec{p}_f \cdot \vec{E}$$

$$= -[(-4.00\ \hat{\imath} + 3.00\ \hat{\jmath})(1.24 \times 10^{-30}\ \mathrm{C \cdot m})] \cdot [4000\ \mathrm{N/C}\ \hat{\imath}]$$

$$= -\left(-16000\,\frac{\mathrm{N}}{\mathrm{C}}\right)(1.24 \times 10^{-30}\ \mathrm{C \cdot m}) = 1.98 \times 10^{-26}\ \mathrm{J}.$$

$$W_a = 1.98 \times 10^{-26}\ \mathrm{J} - (-1.49 \times 10^{-26}\ \mathrm{J}) = 3.47 \times 10^{-26}\ \mathrm{J}.$$