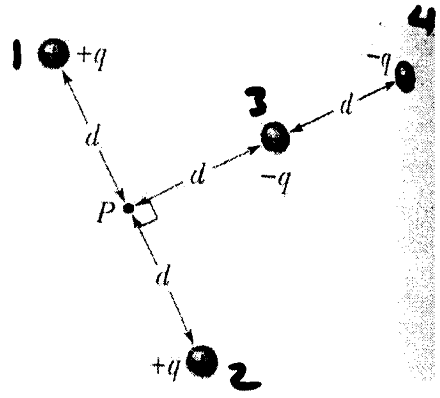
••15 In Fig. 24-33, what is the net electric potential at point P due to the four particles if $V = 0$ at infinity, $q = 5.00$ fC, and $d = 4.00$ cm? SSM



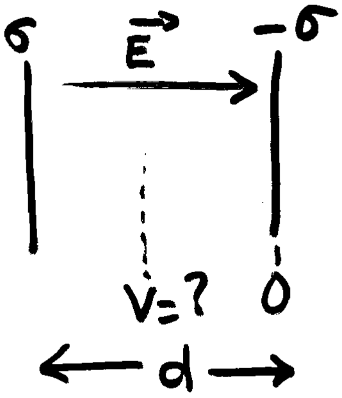
$$V_P = V_1 + V_2 + V_3 + V_4$$

$$= \frac{kq_1}{d} + \frac{kq_2}{d} + \frac{kq_3}{d} + \frac{kq_4}{2d}$$

$$= \frac{9\times10^9}{0.04}\left(5\times10^{-15} + 5\times10^{-15} - 5\times10^{-15} - \frac{5\times10^{-15}}{2}\right)$$

$$= 5.62\times10^{-4}\ \text{V}.$$

•30 Two large parallel metal plates are 1.5 cm apart and have charges of equal magnitudes but opposite signs on their facing surfaces. Take the potential of the negative plate to be zero. If the potential halfway between the plates is then +5.0 V, what is the electric field in the region between the plates?



$$\Delta V = -\int \vec{E}\cdot d\vec{s} = -\vec{E}\cdot\vec{d} = -Ed$$

$$|\Delta V| = E\,d$$

$$5 = E \times \frac{d}{2} = E \times 0.0075$$

$$\Rightarrow E = 667\ \text{N/C}$$

•31 The electric potential at points in an xy plane is given by $V = (2.0\ \text{V/m}^2)x^2 - (3.0\ \text{V/m}^2)y^2$. In unit-vector notation, what is the electric field at the point (3.0 m, 2.0 m)?

$V = V(x, y)$ two dimensions.

$$E_x = -\frac{\partial V}{\partial x} = -4x$$

$$E_y = -\frac{\partial V}{\partial y} = 6y$$

at $(3, 2) \Rightarrow E_x = -12$

$E_y = 12$

$$\vec{E} = -12\hat{i} + 12\hat{j}\ \text{N/C}$$

$$|\vec{E}| = 12\sqrt{2}\ \text{N/C}$$

$\theta = -45°$

(•37) How much work is required to set up the arrangement of Fig. 24-46 if $q = 2.30$ pC, $a = 64.0$ cm, and the particles are initially infinitely far apart and at rest? **SSM ILW WWW**

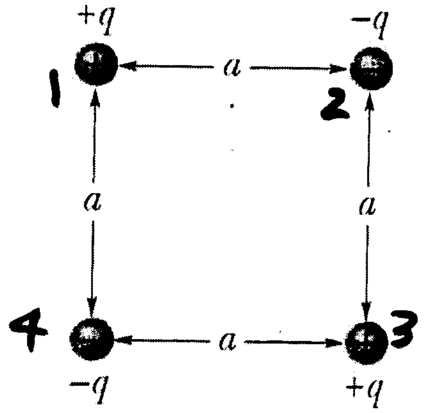


Fig. 24-46 Problem 37.

The potential energy of the system of particles is

$$U = U_{12} + U_{13} + U_{14} + U_{23} + U_{24} + U_{34}.$$

$$U = kq^2\left(-\frac{1}{a} + \frac{1}{a\sqrt{2}} - \frac{1}{a} - \frac{1}{a} + \frac{1}{a\sqrt{2}} - \frac{1}{a}\right)$$

$$= \frac{2kq^2}{a}\left(\frac{1}{\sqrt{2}} - 2\right) = -\frac{2 \times 9\times10^{9} \times (2.3\times10^{-12})^2 \times 1.3}{0.64}$$

$$= -1.9 \times 10^{-13}\ \text{J}$$

The amount of work done is $W = \Delta U = U_f - U_i$.

$$W = U = -1.9\times10^{-13}\ \text{J}$$

••41 In the rectangle of Fig. 24-49, the sides have lengths 5.0 cm and 15 cm, $q_1 = -5.0$ μC, and $q_2 = +2.0$ μC. With $V = 0$ at infinity, what is the electric potential at (a) corner A and (b) corner B? (c) How much work is required to move a charge $q_3 = +3.0$ μC from B to A along a diagonal of the rectangle? (d) Does this work increase or decrease the electric potential energy of the three-charge system? Is more, less, or the same work required if q_3 is moved along a path that is (e) inside the rectangle but not on a diagonal and (f) outside the rectangle? **SSM**

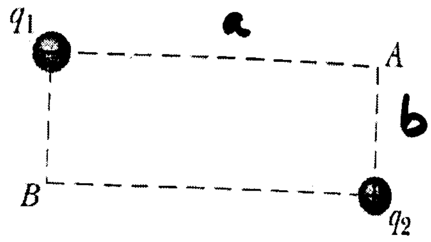


Fig. 24-49 Problem 41.

a) $V_A = k\left(\frac{q_1}{a} + \frac{q_2}{b}\right) = 6 \times 10^4 \text{ V}$

b) $V_B = k\left(\frac{q_1}{b} + \frac{q_2}{a}\right) = -7.8 \times 10^5 \text{ V}$

c) $W = q_3 \Delta V = q_3 (V_A - V_B) =$

$= 3 \times 10^{-6} (6 \times 10^4 + 7.8 \times 10^5) = 2.5 \text{ J}$

d) $W > 0 \Rightarrow$ increase in P.E. of the system $[W = \Delta PE > 0]$

e) and f) Electric force is conservative $\Rightarrow$ Work is the same (remember Phys 101)

••46 In Fig. 24-50, a charged particle (either an electron or a proton) is moving rightward between two parallel charged plates separated by distance $d = 2.00$ mm. The plate potentials are $V_1 = -70.0$ V and $V_2 = -50.0$ V. The particle is slowing from an initial speed of 90.0 km/s at the left plate. (a) Is the particle an electron or a proton? (b) What is its speed just as it reaches plate 2?

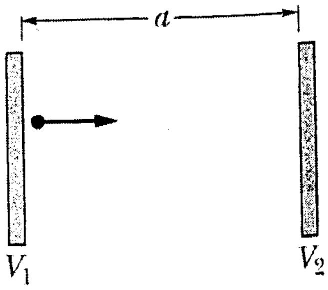
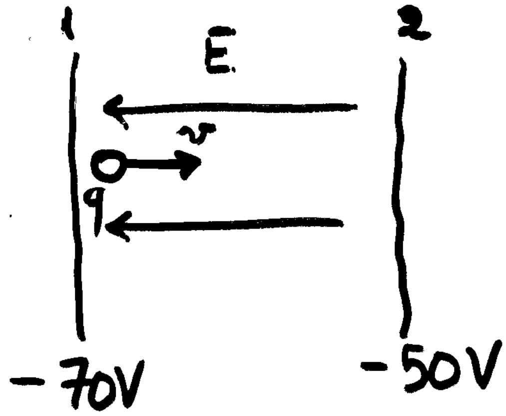


Fig. 24-50 Problem 46.

a) The particle is deceleration while moving to the right
⇒ it is a proton ($q>0$).



b) Conservation of energy

$$\Delta K + \Delta U = 0$$

$$K_f - K_i = -\Delta U = -q\,\Delta V$$

$$K_f = K_i - q\,\Delta V$$

$$\frac{1}{2} m v_f^2 = \frac{1}{2} m v_i^2 - q\,\Delta V$$

$$v_f^2 = v_i^2 - \frac{2q\,\Delta V}{m}$$

$$v_f = 6.5 \times 10^4 \text{ m/s}$$

(•53) What is the excess charge on a conducting sphere of radius $r = 0.15$ m if the potential of the sphere is 1500 V and $V = 0$ at infinity? SSM

$$V_{surface} = \frac{kq}{R} \Rightarrow q = \frac{V \times R}{k} = 2.5 \times 10^{-8}\,C$$

(•54) A hollow metal sphere has a potential of +400 V with respect to ground (defined to be at $V = 0$) and a charge of 5.0×10^{-9} C. Find the electric potential at the center of the sphere.

$V_{at\ the\ center}$ is the same as V on the surface

$$V_{surface} = +400\,V = V_{center}$$

$= V$ everywhere inside the sphere.

(•53) What is the excess charge on a conducting sphere of radius $r = 0.15$ m if the potential of the sphere is 1500 V and $V = 0$ at infinity? **SSM**

$$V_{surface} = \frac{kq}{R} \Rightarrow q = \frac{V \times R}{k} = 2.5 \times 10^{-8} C$$

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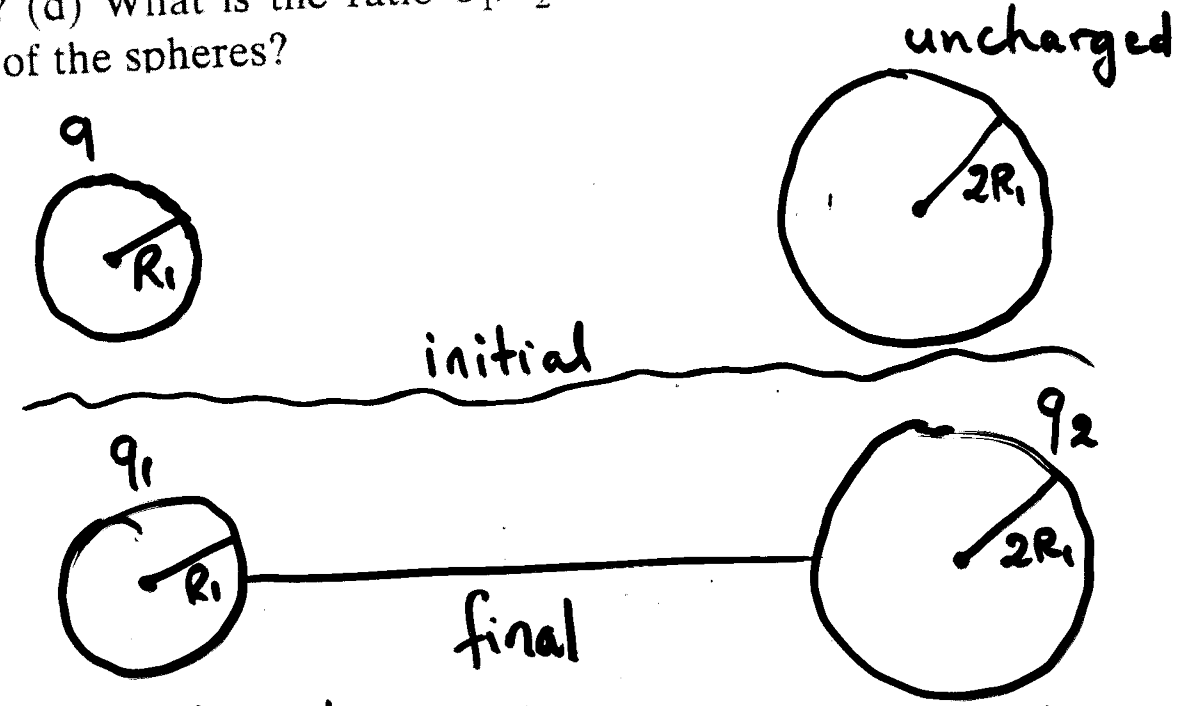
$V_{at\ the\ center}$ is the same as V on the surface

$$V_{surface} = +400V = V_{center}$$

$= V$ everywhere inside the sphere.

•56 Sphere 1 with radius R_1 has positive charge q. Sphere 2 with radius $2.00R_1$ is far from sphere 1 and initially uncharged. After the separated spheres are connected with a wire thin enough to retain only negligible charge, (a) is potential V_1 of sphere 1 greater than, less than, or equal to potential V_2 of sphere 2? What fraction of q ends up on (b) sphere 1 and (c) sphere 2? (d) What is the ratio σ_1/σ_2 of the surface charge densities of the spheres?



a) When the two spheres are connected they will have the same potential.

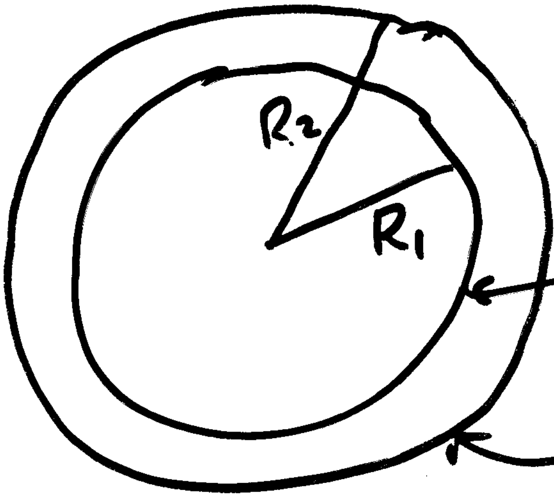
b) c) $V_1 = \dfrac{k q_1}{R_1}$ $\quad V_2 = \dfrac{k q_2}{2R_1}$ and $q_1 + q_2 = q$

but $V_1 = V_2 \Rightarrow q_2 = 2q_1 \Rightarrow \boxed{q_1 = \dfrac{q}{3}}$

and $\boxed{q_2 = \dfrac{2q}{3}}$

d) $$\frac{\sigma_1}{\sigma_2} = \frac{\dfrac{q_1}{4\pi R_1^2}}{\dfrac{q_2}{4\pi R_2^2}} = \frac{q_1}{q_2}\left(\frac{R_2}{R_1}\right)^2 = \frac{1}{2} \times 4 = \boxed{2}$$

(••58) Two isolated, concentric, conducting spherical shells have radii $R_1 = 0.500$ m and $R_2 = 1.00$ m, uniform charges $q_1 = +2.00\ \mu C$ and $q_2 = +1.00\ \mu C$, and negligible thicknesses. What is the magnitude of the electric field E at radial distance (a) $r = 4.00$ m, (b) $r = 0.700$ m, and (c) $r = 0.200$ m? With $V = 0$ at infinity, what is V at (d) $r = 4.00$ m, (e) $r = 1.00$ m, (f) $r = 0.700$ m, (g) $r = 0.500$ m, (h) $r = 0.200$ m, and (i) $r = 0$? (j) Sketch $E(r)$ and $V(r)$.



$R_1 = 0.5$ m

$R_2 = 1$ m

$q_1 = 2\ \mu C$

$q_2 = 1\ \mu C$

V at

$r = 4$ m $\quad V = \frac{k(q_1 + q_2)}{r} = 6.7 \times 10^3$ V

$r = 1$ m $= R_2$ $\quad V = \frac{kq_1}{R_2} + \frac{kq_2}{R_2} = 2.7 \times 10^4$ V

$r = 0.7$ m $\quad V = \frac{kq_1}{r} + \frac{kq_2}{R_2} = 3.5 \times 10^4$ V

$r = 0.5$ m $= R_1$ $\quad V = \frac{kq_1}{R_1} + \frac{kq_2}{R_2} = 4.5 \times 10^4$ V

$r = 0.2$ m $\quad V = \frac{kq_1}{R_1} + \frac{kq_2}{R_2} = 4.5 \times 10^4$ V

(89) Two charges $q = +2.0\ \mu C$ are fixed a distance $d = 2.0$ cm apart (Fig. 24-69). (a) With $V = 0$ at infinity, what is the electric potential at point C? (b) You bring a third charge $q = +2.0\ \mu C$ from infinity to C. How much work must you do? (c) What is the potential energy U of the three-charge configuration when the third charge is in place?

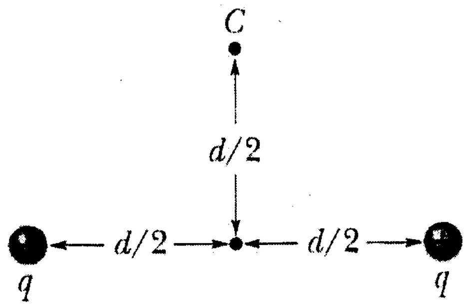


Fig. 24-69 Problem 89.

Solve it yourself!