$2.5 - 2$.

Point charges $q_1$, $q_2$, and $q_3$ are at the corners of an equilateral triangle of side 2.5 m. Find the electrostatic potential energy of this charge distribution if (a) $q_1 = q_2 = q_3 = 4.2 \mu C$, (b) $q_1 = q_2 = 4.2 \mu C$ and $q_3 = -4.2 \mu C$, (c) $q_1 = q_2 = -4.2 \mu C$ and $q_3 = +4.2 \mu C$.

$$E = \frac{1}{2} \sum q_i V_i, \quad V_i = \frac{kq_i}{r_i}, \quad \frac{kq_0}{r}, \quad \text{etc.}$$

a) $q_1 = q_2 = q_3 = q_0 = 4.2 \mu C \quad V_1 = V_2 = V_3 = \frac{2kq_0}{r_0}$

$$E = \frac{1}{2} \left( 3q_0 \cdot \frac{2kq_0}{r_0} \right) = \frac{3 \times k \times q_0^2}{r_0} = \frac{3 \times 9 \times 10^9 \text{ Nm}^2 \times (4.2 \times 10^{-6} \text{ C})^2}{2.5 \text{ m}} = 0.19 \text{ J}$$

b) $q_1 = q_2 = +q_0 \quad q_3 = -q_0 \quad V_3 = \frac{2kq_0}{r_0}$

$$E = -\frac{1}{2} \frac{2kq_0^2}{r_0} = -\frac{kq_0^2}{r_0} = -0.063 \text{ J}$$

c) $q_1 = q_2 = -q_0 \quad q_3 = +q_0$ (same as b) \quad i.e., -0.063 J

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$25 - 11$

(a) If a parallel-plate capacitor has a 0.15-mm separation, what must its area be for it to have a capacitance of 1 F? (b) If the plates are square, what is the length of their sides?

$$C = \frac{\varepsilon_0 A}{d} = 1 \text{ F} \quad A = \frac{Cd}{\varepsilon_0} = \frac{1 \text{ F} \times 1.5 \times 10^{-4} \text{ m}}{8.85 \times 10^{-12} \text{ F/m}} = 1.7 \times 10^7 \text{ m}^2$$

$$A = L^2 \quad L = \sqrt{A} = \sqrt{1.7 \times 10^7 \text{ m}^2} = 4.1 \times 10^3 \text{ m}$$
Energy prospectors from a distant planet are inspecting the earth to decide if its electrical energy resources are worth stealing. Measurements reveal that earth’s electric field extends upward for 1000 m and has an average magnitude of 200 V/m. Estimate the electrical energy stored in the atmosphere. (Hint: You may treat the atmosphere as a flat slab with an area equal to the surface area of the earth. Why?)

\[
U = \frac{1}{2} CV^2
\]

\[
C = \frac{\varepsilon_0 A e}{d} = \frac{8.85 \times 10^{-12} \text{F/m}}{4.77 \times (6.4 \times 10^6 \text{m})^2} = 4.55 \text{ F}
\]

\[
V = E \cdot d = 200 \text{ V/m} \cdot 1000 \text{ m} = 2 \times 10^5 \text{ V}
\]

\[
U = \frac{1}{2} \times 4.55 \text{ F} \times (2 \times 10^5 \text{ V})^2 = 9.1 \times 10^{10} \text{ J} \quad \left\{ \begin{array}{l}
\text{About 10 seconds of output of a large power plant}
\end{array} \right. 
\]

A 3.0-\mu F capacitor and a 6.0-\mu F capacitor are connected in series, and the combination is connected in parallel with an 8.0-\mu F capacitor. What is the equivalent capacitance of this combination?

\[\begin{align*}
\text{1st combine } \frac{1}{3.0 \mu F} + \frac{1}{6.0 \mu F} &= \frac{6.0 + 3.0}{18.0 \mu F} = \frac{1}{2 \mu F} \\
\Rightarrow C_E &= 2.0 \mu F \\
\text{now add the two parallel capacitors} \\
C &= 2.0 \mu F + 8.0 \mu F = 10.0 \mu F
\end{align*}\]
A parallel-plate capacitor has rectangular plates of length $L = 10 \text{ cm}$ and width $W = 4 \text{ cm}$ (Figure 25-33). The region between the plates is filled with a dielectric slab of dielectric constant $\kappa = 4$ which can slide along the length of the capacitor. Initially, the slab completely fills the rectangular region, and the capacitor holds a charge of $0.2 \mu\text{C}$. How far should the dielectric slab be pulled so that the stored energy is double its initial value?

For $U = 2U_0$,

$$C = \frac{1}{2}C_0$$

$$\frac{\varepsilon_0 xL}{d} + \frac{\varepsilon_0 (L-x)L}{d} = \frac{1}{2} \frac{\varepsilon_0 L^2}{d}$$

$$xL + xL^2 - xx L = \frac{xL^2}{2}$$

$$x(1-x) = -\frac{xL}{2} = x(4-1) = \frac{4L}{2} \Rightarrow x = \frac{2}{3} L$$

$$= 2.67 \text{ cm}$$