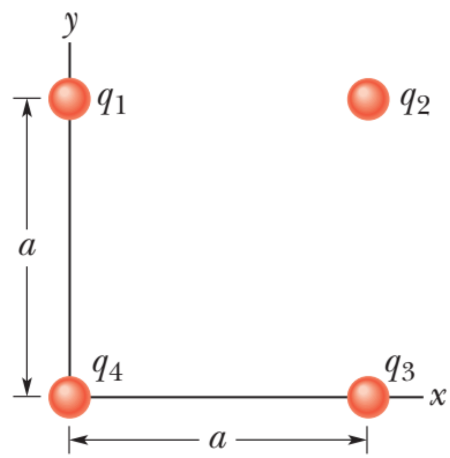
16. Question and Solution. There are some changes in the provided vales of the assignment. But the formula is same.

four particles form a square of edge length $a = 5.00$ cm and have charges $q_1 = +10.0$ nC, $q_2 = -20.0$ nC, $q_3 = +20.0$ nC, and $q_4 = -10.0$ nC. In unit-vector notation, what net electric field do the particles produce at the square's center?



7. **THINK** Our system consists of four point charges that are placed at the corner o: square. The total electric field at a point is the vector sum of the electric fields individual charges.

EXPRESS Applying the superposition principle, the net electric field at the center of t square is

$$\vec{E} = \sum_{i=1}^{4} \vec{E}_i = \sum_{i=1}^{4} \frac{1}{4\pi\varepsilon_0} \frac{q_i}{r_i^2} \hat{\mathrm{r}}_i .$$

With $q_1 = +10$ nC, $q_2 = -20$ nC, $q_3 = +20$ nC, and $q_4 = -10$ nC, the x component of t electric field at the center of the square is given by, taking the signs of the charges ir consideration,

$$E_x = \frac{1}{4\pi\varepsilon_0}\left[\frac{|q_1|}{(a/\sqrt{2})^2} + \frac{|q_2|}{(a/\sqrt{2})^2} - \frac{|q_3|}{(a/\sqrt{2})^2} - \frac{|q_4|}{(a/\sqrt{2})^2}\right]\cos 45°$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{1}{a^2/2}(|q_1| + |q_2| - |q_3| - |q_4|)\frac{1}{\sqrt{2}}.$$

Similarly, the y component of the electric field is

$$E_y = \frac{1}{4\pi\varepsilon_0}\left[-\frac{|q_1|}{(a/\sqrt{2})^2} + \frac{|q_2|}{(a/\sqrt{2})^2} + \frac{|q_3|}{(a/\sqrt{2})^2} - \frac{|q_4|}{(a/\sqrt{2})^2}\right]\cos 45°$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{1}{a^2/2}(-|q_1| + |q_2| + |q_3| - |q_4|)\frac{1}{\sqrt{2}}.$$

The magnitude of the net electric field is $E = \sqrt{E_x^2 + E_y^2}$.

ANALYZE Substituting the values given, we obtain

$$E_x = \frac{1}{4\pi\varepsilon_0}\frac{\sqrt{2}}{a^2}\left(|q_1|+|q_2|-|q_3|-|q_4|\right) = \frac{1}{4\pi\varepsilon_0}\frac{\sqrt{2}}{a^2}\left(10\text{ nC}+20\text{ nC}-20\text{ nC}-10\text{ nC}\right)=0$$

and

$$E_y = \frac{1}{4\pi\varepsilon_0}\frac{\sqrt{2}}{a^2}\left(-|q_1|+|q_2|+|q_3|-|q_4|\right) = \frac{1}{4\pi\varepsilon_0}\frac{\sqrt{2}}{a^2}\left(-10\text{ nC}+20\text{ nC}+20\text{ nC}-10\text{ nC}\right)$$

$$= \frac{\left(8.99\times10^9\text{ N}\cdot\text{m}^2/\text{C}^2\right)(2.0\times10^{-8}\text{ C})\sqrt{2}}{(0.050\text{ m})^2}$$

$$=1.02\times10^5\text{ N/C}.$$

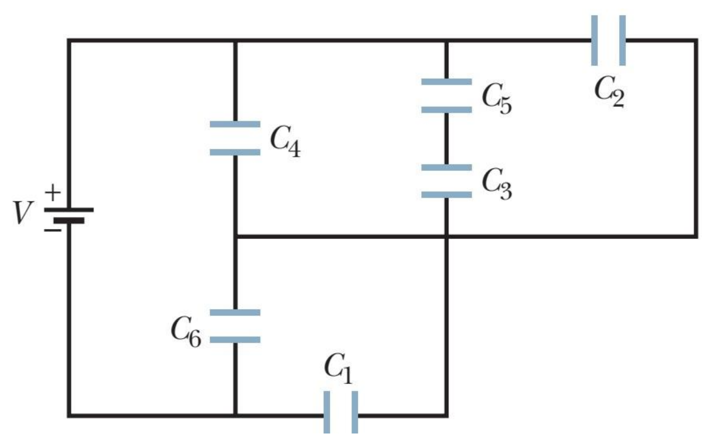
Thus, the electric field at the center of the square is $\vec{E}=E_y\hat{\text{j}}=(1.02\times10^5\text{ N/C})\hat{\text{j}}$.

20. Question: In figure, a 24 V battery is connected across capacitors of capacitances $C_1 = C_6 = 3.00\ \mu F$ and $C_3 = C_5 = 2.00\ C_2 = 2.00 C_4 = 4.00\ \mu F$.

i). What is the equivalent capacitance Ceq of the Capacitors and energy stored by Ceq?

ii). What are the V_1 and q_1 for capacitor 1?

iii). What are the V_2 and q_2 for capacitor 2?



Sol^n

First, the equivalent capacitance of the two 4.00 μF capacitors connected in series is given by 4.00 μF/2 = 2.00 μF. This combination is then connected in parallel with two other 2.00-μF capacitors (one on each side), resulting in an equivalent capacitance C = 3(2.00 μF) = 6.00 μF. This is now seen to be in series with another combination, which

consists of the two 3.0-μF capacitors connected in parallel (which are themselves equivalent to C' = 2(3.00 μF) = 6.00 μF). Thus, the equivalent capacitance of the circuit is

$$C_{eq} = \frac{CC'}{C+C'} = \frac{(6.00\,\mu\text{F})\,(6.00\,\mu\text{F})}{6.00\,\mu\text{F}+6.00\,\mu\text{F}} = 3.00\,\mu\text{F}.$$

(b) Let V = 20.0 V be the potential difference supplied by the battery. Then

$$q = C_{eq}V = (3.00\ \mu\text{F})(20.0\ \text{V}) = 6.00 \times 10^{-5}\ \text{C}.$$

(c) The potential difference across C_1 is given by

$$V_1 = \frac{CV}{C+C'} = \frac{(6.00\,\mu\text{F})\,(20.0\text{V})}{6.00\,\mu\text{F}+6.00\,\mu\text{F}} = 10.0\text{V}.$$

(d) The charge carried by C_1 is $q_1 = C_1V_1$= (3.00 μF)(10.0 V) = 3.00 × 10^{-5} C.

(e) The potential difference across C_2 is given by $V_2 = V - V_1$ = 20.0 V – 10.0 V = 10.0 V.

(f) The charge carried by C_2 is $q_2 = C_2V_2$ = (2.00 μF)(10.0 V) = 2.00 × 10^{-5} C.

(g) Since this voltage difference V_2 is divided equally between C_3 and the other 4.00-μF capacitors connected in series with it, the voltage difference across C_3 is given by V_3 = V_2/2 = 10.0 V/2 = 5.00 V.

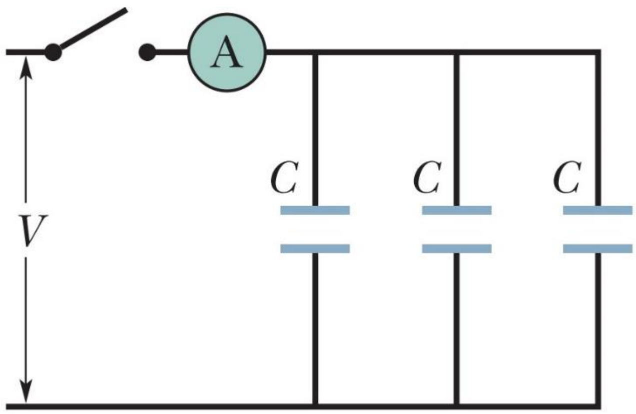
(h) Thus, $q_3 = C_3V_3$ = (4.00 μF)(5.00 V) = 2.00 × 10^{-5} C.

19. Question and Solution

The ammonia molecule NH_3 has a permanent electric dipole equal to 1.47 D, where 1D= 1 debye unit = 3.34 × 10^{-30} C.m. Calculate the electric potential due to an ammonia molecule at a point 52.0 nm away along the axis of the dipole. (set V= 0 at infinity)

$$V = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2} = \frac{(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)\,(1.47\times3.34\times10^{-30}\ \text{C}\cdot\text{m})}{(52.0\times10^{-9}\ \text{m})^2} = 1.63\times10^{-5}\ \text{V}.$$

21. Each of the uncharged capacitors has a capacitance of 25 μF. When the switch is closed the potential is set to be 4200 V. How many coulombs of charge then pass-through A?



The charge that passes through meter *A* is

$$q = C_{eq}V = 3CV = 3(25.0\ \mu\text{F})(4200\ \text{V}) = 0.315\text{C}.$$