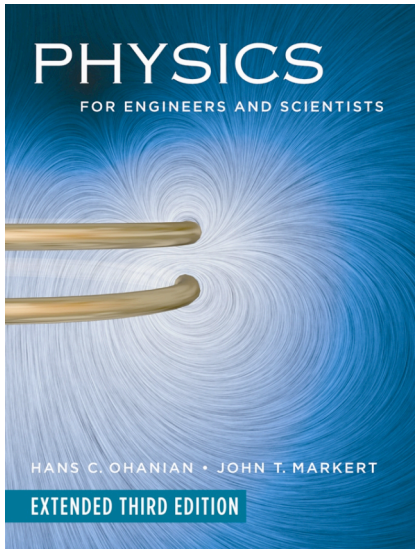
Chapter 22

Electric Force and Electric Charge



Physics for Engineers and Scientists

Third Edition

Checkup 22.1

Six electrons are added to 1.0 coulomb of positive charge. The net charge is approximately

a. 7.0 C
b. -5.0 C
c. 1.0 C
d. -6*e*
e. -5*e*

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Checkup 22.2

Two particles are separated by a distance of 3.0 m; each exerts an electric force of 1.0 N on the other. If one particle carries 10 times as much electric charge as the other, what is the magnitude of the smaller charge?

a. 10 pC
b. 10 μC
c. 10 C
d. 10 kC

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Checkup 22.3

Three identical point charges are at the vertices of an equilateral triangle. A fourth, identical point charge is placed at the midpoint of one side of the triangle. As a result of the three electric force contributions from the vertex charges, the fourth charge

a. Is in equilibrium and remains at rest
b. Is pushed toward the center of the triangle
c. Is pushed outside the triangle

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Checkup 22.4

Is it possible for a body to have an electric charge of 2.0×10^{-19} C? 3.2×10^{-19} C?

a. Yes; yes
b. Yes; no
c. No; yes
d. No; no

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Checkup 22.5

Suppose you have two metallic balls of equal size, one with a charge of $+1 \times 10^{-7}$ C, and the other with a charge of -3×10^{-7} C. If you touch them together, what will be the resulting charge on each ball?

a. There will remain $+1 \times 10^{-7}$ C on one and -3×10^{-7} C on the other

b. There will be 0 C on one and -2×10^{-7} C on the other

c. There will be -1×10^{-7} C on each

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PhysiQuiz 22-1

Case I: Distribute two positive charges q_1 and q_2, with $q_1 > q_2$, on two identical conducting spheres. Each sphere has a radius R. The separation between the centers of the two spheres is r, where $r >> R$. Denote the magnitude of the repulsive force between the two spheres by F_I.

Case II: Now let the two charged spheres from case I touch each other. While they are in contact, there is a charge flow. After an electric equilibrium is established, separate the two centers again by the same distance r. The magnitude of the force is now F_{II}. Compare F_I and F_{II}:

A	$F_I > F_{II}$
B	$F_I = F_{II}$
C	$F_I < F_{II}$

Hint: Express the force between the two charges as $F = kq_1(q_0 - q_1)/r^2 \geq 0$, where $q_0 = q_1 + q_2 = \text{Constant}$. Inspect how F varies as a function of q_1.

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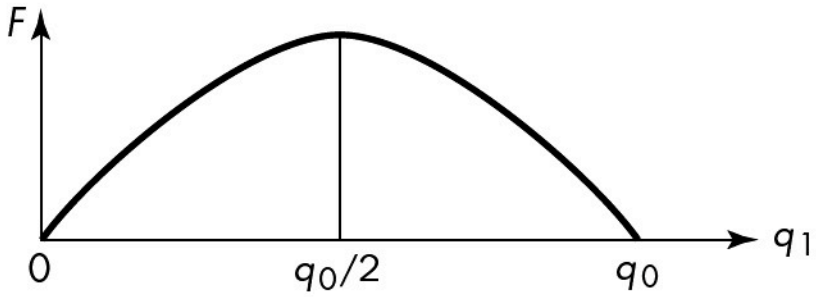
PhysiQuiz 22-1 answer

Explanation: Based on $F = kq_1(q_0 - q_1)/r^2$ and the slope $dF/dq_1 = k(q_0 - 2q_1)$, we see that at $q_1 = 0$, $F = 0$. The situation illustrated in the figure. As q_1 increases, at first F increases, until F rises to a peak at $q_1 = q_0/2$, where the slope $dF/dq_1 = 0$. As q_1 further increases, F is now on the downhill side: it decreases. Case I has $q_1 > q_2 = q_0 - q_1$, whereas case II has $q_1 = q_2 = q_0/2$. So F peaks at F_{II} and F_I is on the downhill side of the peak—that is, $F_I < F_{II}$. Answer = C.



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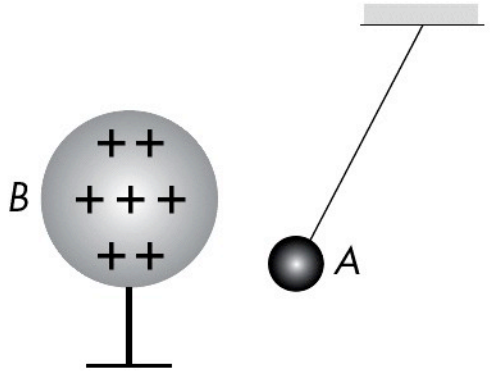
PhysiQuiz 22-2



Two conducting spheres *A* and *B* are shown here. The sphere labeled *B* is positively charged; sphere *A*, suspended by a string, is attracted to *B*. The setup is in equilibrium. What is the sign of the net charge on *A*?

A	B	C
Can only be negative	Can only be neutral	Can be either negative or neutral

Extra: Consider a new situation in which q_A is negative and $q_B >> |q_A|$. Now *A* swings upward and touches *B*. Do you expect that *A* will remain in contact with *B*?

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PhysiQuiz 22-2 answer

Explanation:

- When *A* carries a negative charge, of course an attraction is expected.
- When *A* is neutral, *B* causes *A* to be polarized. Negative charges are induced on the near surface, resulting in a positive charge of an equal magnitude on the far side. The force on the near side should be stronger because the charges are closer, so there is again an attraction.

Both cases lead to an attraction. Answer = C.

Explanation—extra: After *A* contacts *B*, the net charge is positive. Both *A* and *B* will be positively charged. So *A* will be repelled by *B*.

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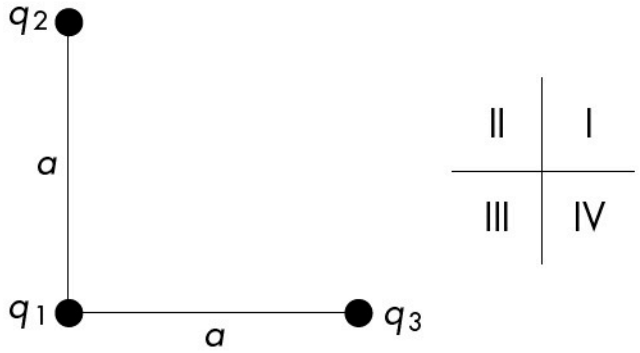
PhysiQuiz 22-3



We have three charged particles; $q_1 = q$, $q_2 = -3q$, and $q_3 = 4q$, where q is positive. Sketch a vector diagram to determine the direction of the electric force on q_1. Which quadrant should the force vector be in?

A	B	C	D
I	II	III	IV

Hint: Sketch the vector $\mathbf{F}_{12}$ (the force on q_1 due to q_2). Also sketch $\mathbf{F}_{13}$. Add the vectors: $\mathbf{F}_1 = \mathbf{F}_{12} + \mathbf{F}_{13}$.

Extra: Use Coulomb's Law to show that $F_1 = 5kq^2/a^2$.

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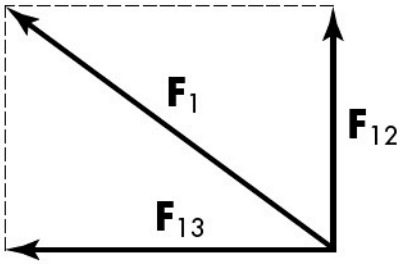
PhysiQuiz 22-3 answer

Explanation: By inspection we arrive at the following vector diagram:



So vector $\mathbf{F}_1$ is pointing in the second quadrant. Answer = B.

Explanation—extra: From Coulomb's Law, $|\mathbf{F}_{12}| = k|q_1 q_2|/r^2 = 3kq^2/a^2 = 3kq^2/a^2$. Also, $|\mathbf{F}_{13}| = 4kq^2/a^2 = 4kq^2/a^2$. Because these vectors are perpendicular to each other, we have the following:

$$F_1 = \sqrt{F_{12}^2 + F_{13}^2} = \sqrt{(3kq^2/a^2)^2 + (4kq^2/a^2)^2} = 5kq^2/a^2$$

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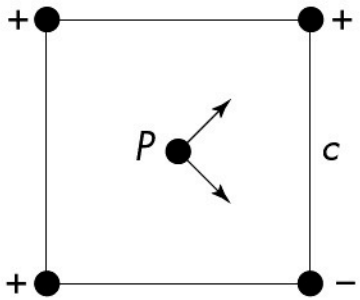
PhysiQuiz 22-4



What is the direction of the electric force at P on a negative charge $-Q$? Assume the magnitudes of the charges at the corners have the same value q.

A	B	C	D
↘	↖	↗	↙

Extra: Show that the magnitude of the electric force at P is $F = 4kqQ/c^2$, where c is the side of the square.

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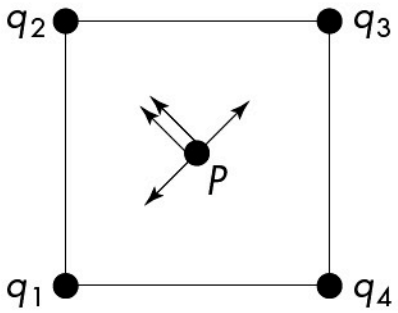
PhysiQuiz 22-4 answer

Explanation:



Explanation—extra: From the sketch in the explanation, the force contributions at P from q_3 and q_1 cancel each other. Thus the magnitude of the resultant force at P is $F = 2(kqQ/r^2)$. Because the distance from corner to the center is $r = \frac{\sqrt{2}}{2}c$, the magnitude of the force can be written as $F = 4kqQ/c^2$.

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PhysiQuiz 22-5

In an enclosed region of space with charges moving inside, some of the charges are positive and the rest are negative. There are forces among the charges, so they are constantly interacting with each other. Assume the region specified is an isolated system in the sense that no external force is acting on the system and no charge is flowing into or coming out of the system. Which items of the system listed here are conserved?

(1) Total momentum
(2) Net charge = $q_1 + q_2 + \ldots$
(3) Sum of the magnitudes of charges = $|q_1| + |q_2| + \ldots$

A	(1) only
B	(1) and (2) only
C	(1) and (3) only
D	All of them

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PhysiQuiz 22-5 answer

Explanation:
In the absence of external force, the total momentum is conserved. Conservation of charge implies that net charge is also conserved. However, (3) is not necessarily correct. So Answer = B.

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PhysiQuiz 22-6

Elementary particles that are strongly interacting with each other are referred to as *hadrons* (examples include the proton and the neutron). Hadrons have integer or zero charges. They are made out of quarks. Consider some hypothetical hadronic states made out u-quarks and d-quarks. The charge of a u-quark is $q_u = +2e/3$, and that of a d-quark is $q_d = -e/3$. Consider the following four-quark states:

(1) uddd
(2) uudd
(3) uuud
(4) dddd

Which states can carry an integer charge in units of e?

A	(1) only
B	(1) and (2) only
C	(1), (2), and (3) only
D	All four states
E	None of the states

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PhysiQuiz 22-6 answer

Explanation: From the quark charges specified, the charges of states (1), (2), (3), and (4) are respectively $-e/3$, $2e/3$, $5e/3$, and $-4e/3$. Answer = E. This exercise illustrates that conservation of charge together with the quantization of hadronic charge implies that hadrons cannot be made out of four-quark states with quarks having charges of either $2e/3$ or $-e/3$.

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