Key Concepts

Chapter 6

Coulomb's law

Vector addition

$F = \frac{kq_1q_2}{r^2}$

Takeaways

To find the net force on an object:

(1) Choose positive directions for your x- and y-axes.

(2) Break each of the individual forces on the object into **X** and **Y** components.

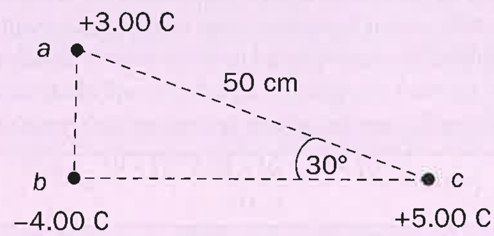
(3) Add the **X** components of the individual forces to obtain the **X** component of the net force on the object; add the **Y** components of the individual forces to obtain the **Y** component of the net force.

(4) To find the magnitude of the net force, apply the Pythagorean theorem to the **X** and **Y** components of the net force.

(5) To find the direction of the net force (measured as an angle from the x-axis), take the inverse tangent of the **Y** component of the net force divided by the **X** component of the net force.

Electric Force

Find the net force exerted on point charge a by the other two point charges depicted in the diagram below. ($k = 8.99 \times 10^9\ \mathrm{N \cdot m^2/C^2}$)



1) Find the distance from charge *a* to charge *b*.

$$\sin 30° = \frac{r_{ab}}{50\,\text{cm}}$$

$$r_{ab} = 50\ \text{cm} \times \sin 30°$$

$$r_{ab} = 25\ \text{cm}$$

To find the distance between points a and b, use sine. Sine of angle 30 is the hypotenuse over opposite.

---

2) Find the force exerted by charge *b* on charge *a*.

Start with Coulomb's law. Plug in the charges located at points a and b. r_{ab} is the distance between points a and b.

$$F = \frac{kq_1q_2}{r^2}$$

$$F_{ab} = \frac{kq_aq_b}{r_{ab}^2}$$

$$F_{ab} = \frac{(8.99 \times 10^9\ \mathrm{N \cdot m^2/C^2})(3.00\ \mathrm{C})(-4.00\ \mathrm{C})}{(0.250\ \mathrm{m})^2}$$

$$F_{ab} = -1.73 \times 10^{12}\ \mathrm{N}$$

Remember: *The negative sign for the force means that there is an attraction (unlike charges). Because point charge* a *is positive whereas* b *is negative, the direction is straight down toward charge* b.

---

3) Find the force exerted by charge *c* on charge *a*.
Start with Coulomb's law. Plug in the charges located at points *a* and *c*. r_{ac} is the distance between points *a* and *c*.

$$F = \frac{kq_1q_2}{r^2}$$

$$F_{ac} = \frac{kq_aq_b}{r_{ac}^2}$$

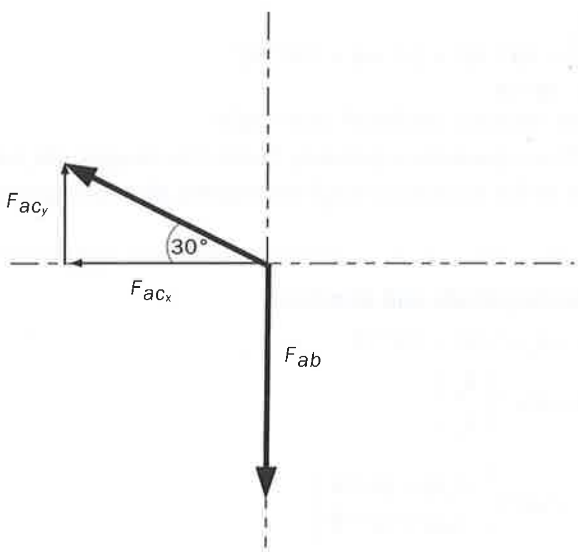
$$F_{ac} = \frac{(8.99 \times 10^9\ \text{N·m}^2/\ \text{C}^2)(3.00\ \text{C})(5.00\ \text{C})}{(0.500\ \text{m})^2}$$

$$F_{ac} = 5.39 \times 10^{11}\ \text{N}$$

***Remember:** The positive sign for the force means that there is repulsion (like charges). This means that the direction of the force is away from point charge c.*

---

4) Draw the force diagram and separate into vectors.



$$F_{ab,\,x} = 0\ \text{N}$$

$$F_{ab,\,y} = -1.73 \times 10^{12}\ \text{N}$$

$$F_{ac,\,x} = F_{ac} \times (-1)\cos 30°$$

$$= (5.39 \times 10^{11}\ \text{N}) \times (-0.866) = -4.67 \times 10^{11}\ \text{N}$$

$$F_{ac,\,y} = F_{ac} \times \sin 30° = (5.39 \times 10^{11}\ \text{N}) \times (0.5)$$

$$= 2.70 \times 10^{11}\ \text{N}$$

F_{ab} points toward point *b*, which is straight down. Thus, F_{ab} has no **X** component—only a **Y** component.

Things to Watch Out For

This problem shows the nature of the coulomb. One coulomb is a huge charge. Usually you will deal with microcoulombs. Even when you solve for inverse tangent, be sure the angle measurement is pointing in the right direction. Draw force diagrams to confirm.

Similar Questions

1) Two point charges, the first with a charge of $+1.97 \times 10^{-6}$ C and the second with a charge of -5.01×10^{-6} C, are separated by 25.5 cm. Find the magnitude of the electrostatic force experienced by the positive charge.
2) Point charge *a* has a charge of 3.693×10^{-7} C, whereas point charge *b* has a charge of 1.75×10^{-6} C. They exert an electrostatic force of magnitude 36.1×10^{-3} N on each other. Find the separation between the point charge *a* and point charge *b*.
3) Point charge *a* has a charge of 3.693×10^{-7} C and exerts a force of 36.1×10^{-3} N on point charge *b*. If the two charges are separated by a distance of 0.025 m, find the charge of point charge *b*.

F_{ac} points away from point *c*, which is 30° above the horizontal to the left. F_{ac} has both a horizontal and vertical component. Find the **X** and **Y** components by using the cosine and sine of 30°, respectively.

Remember: *F_{ab} is pointing down, so the x-vector component should be 0 while the y-vector component should be negative. F_{ac} is pointing up and to the left, so the x-vector component should be negative while the y-vector component should be positive.*

---

5) Add the vector components.

X components:

$$F_x = F_{ab,x} + F_{ac,x} = 0 + -4.67 \times 10^{11}\ \text{N}$$
$$= -4.67 \times 10^{11}\ \text{N}$$

Y components:

$$F_y = F_{ab,y} + F_{ac,y} = -1.73 \times 10^{12}\ \text{N} + 2.70 \times 10^{11}\ \text{N}$$
$$= -1.46 \times 10^{12}\ \text{N}$$

$$F_a^2 = F_x^2 + F_y^2$$
$$F_a^2 = (-4.67 \times 10^{11}\ \text{N})^2 + (-1.46 \times 10^{12}\ \text{N})^2$$
$$F_a = 1.53 \times 10^{12}\ \text{N}$$

Add the **X** and **Y** components separately. To find the magnitude, take the square root of the sum of the squares of each component (the Pythagorean theorem).

---

6) Solve for the magnitude and direction.

$$\text{Magnitude} = F_a = 1.53 \times 10^{12}\ \text{N}$$

$$\text{Direction} = \tan^{-1}\left(\frac{F_y}{F_x}\right)$$
$$= \tan^{-1}\left(\frac{-1.46 \times 10^{12}\ \text{N}}{-4.67 \times 10^{11}\ \text{N}}\right)$$
$$= 72.3°$$

The magnitude of F_a was determined in step 5. To solve for direction, take the inverse tangent of the **Y** component over the **X** component. The net force exerted on point charge *a* is 1.53×10^{12} N exerted at 72.3° south of west.
