HW 13 - Solutions

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Chapter 21, Question 9:

a) ***The magnitudes are the same.*** The two "source" charges have equal magnitudes (you know this because it's the same variable; if they were different magnitudes, we'd call them q_1 and q_2 or something). We are told that the two source charges are equidistant from the y-axis, therefore they are equidistant from the central charge. When we use Coulomb's Law, the only difference will be direction: magnitudes will be the same.
b) ***The magnitude of the net force is less than 2F.*** The two source charges both exert a force of F on the central charge. If these forces were in the same direction, the magnitude of the net force would be simply F + F = 2F. But they are not in the same direction.
c) ***The x-components cancel.*** Both source charges will repel the central charge (since their signs are all the same). The force from the left charge will push the central charge up-right. The force from the right charge will push the central charge up-left. The left & right x-components will cancel.
d) ***The y-components will add.*** From the logic used in explanation c above, we can see that both charges will exert an upward force (one up-left, the other up-right). The upward y-components will add.
e) This is sort of a silly question. The cancelling x-components components cancel out to nothing, so ***the net force is the combination of the adding y-components***: upwards.
f) ***See explanation e.***
g) ***Downward***. Both charges attract the central charge: one pulls it down-left, the other pulls it down-right. Again, the x-components cancel, the y-components add, and we get a downward net force.
h) ***To the right***. The left-hand charge will push the central charge up-right (same signs repel). The right-hand charge will pull the central charge down-right (opposite signs attract). The up and down y-components will cancel. The rightward x-components will combine.
i) ***To the left***. This is just the exact opposite of the previous scenario.

Chapter 21, Question 10:

The force on the central charge from all the point charges ***cancel out*** except the force from the +3q charge on the left side of the square. If you look at the others, they all have an identical pair on the exact opposite side of the square. The trick is to understand that "opposite" doesn't mean across left-right. It means 180 degrees in the other direction.

The +3q charge will attract the -2q charge, so the force will be to the left.

This appears to be a d/2 distance. So, for ***magnitude*** (ignoring signs & r-hats), we have:

$$F = \frac{k(2q)(3q)}{d^2} = -\frac{6kq^2}{d^2}$$

Chapter 21, Problem 3:
A μC is a micro-coulomb, equal to 0.000001 Coulombs. So

$26.0\ \mu C = 2.6\times10^{-5} C$, and

$-47.0\ \mu C = -4.7\times10^{-5} C$.

By Coulomb's Law, we have:

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

$$5.7 = \frac{(8.99\times10^9)(2.6\times10^{-5})(4.7\times10^{-5})}{r^2}$$

(We're ignoring signs, because we don't care about direction. The problem only gave us the magnitude of the force, and that's all we need to find distance, which is a scalar.)

$$r = \sqrt{\frac{(8.99\times10^9)(2.6\times10^{-5})(4.7\times10^{-5})}{5.7}} \approx 1.4\ m$$

Chapter 21, Problem 13:
It turns out this is very hard—harder than what would be the on exam. We know that:

$\vec{F}_1 = \frac{k(10^{-6})q_3}{{r_1}^2}\hat{r}_1$ and

$\vec{F}_2 = \frac{k(-3\times10^{-6})q_3}{{r_2}^2}\hat{r}_2$.

We also know that the forces cancel, so $\vec{F}_1$ and $\vec{F}_2$ are equal and opposite. If we did not have the intuition from the hint on the website, we could still solve algebraically using components, but this would be very involved. We'll assume the hint: q_3 lies on the x-axis. It's y-component is zero. So we're looking for the x-component, call it x'.

q1 lies at the origin, so r_1=x'.

q2 lies at x = 10cm, so r_2 = x' – 0.1 m. (r is always from the source to the receiver)

So we have:

$\vec{F}_{1x} + \vec{F}_{2x} = 0 \rightarrow \vec{F}_{1x} = -\vec{F}_{2x}$ and substituting, we get:

$\frac{k(10^{-6})q_3}{{r_1}^2} = -\frac{k(-3\times10^{-6})q_3}{{r_2}^2}$. Substituting our expressions for r_1 and r_2, we get:

$\frac{k(10^{-6})q_3}{(x\prime)^2} = -\frac{k(-3\times10^{-6})q_3}{(x'-0.1)^2}$. Cancelling we have: $\frac{1}{(x\prime)^2} = \frac{3}{(x'-0.1)^2}$

Which we can rearrange to $\frac{1}{3} = \frac{(x\prime)^2}{(x'-0.1)^2} \rightarrow \frac{(x\prime)}{(x'-0.1)} = \sqrt{\frac{1}{3}} \approx 0.58$

$x' = 0.58(x' - 0.1)$ Distributing & solving, we get:

$x' - 0.58x' = -0.058 \rightarrow x' = \frac{0.058}{0.42} \approx 0.138\ m = 13.8\ cm$