Solutions to the Extra Practice Problems for Chapter 13

1. <u>0.141 m</u>. We can use Equation (13.1) to get the distance, since we have everything else in the equation. However, the first charges need to be converted to 3.50×10^{-5} C and -1.40×10^{-5} C.

$$F = \frac{k \cdot q_1 \cdot q_2}{r^2}$$

$$222\ \mathrm{N} = \frac{\left(8.99 \times 10^9 \frac{\mathrm{N}\cdot\mathrm{m}^2}{\mathrm{C}^2}\right)\cdot(3.50\times10^{-5}\ \mathrm{C})\cdot(1.40\times10^{-5}\ \mathrm{C})}{r^2}$$

$$r = \sqrt{\frac{\left(8.99 \times 10^9 \frac{\cancel{\mathrm{N}}\cdot\mathrm{m}^2}{\cancel{\mathrm{C}^2}}\right)\cdot(3.50\times10^{-5}\cancel{\mathrm{C}})\cdot(1.40\times10^{-5}\cancel{\mathrm{C}})}{222\cancel{\mathrm{N}}}} = 0.141\ \mathrm{m}$$

2. <u>0.410 m</u>. Circular motion requires a centripetal force, and in this case, the electrostatic force is supplying it. Our two equations are:

$$F_c = \frac{m \cdot v^2}{r} \text{ and } F = \frac{k \cdot q_1 \cdot q_2}{r^2}$$

Since the electrostatic force supplies the centripetal force, those two expressions must equal one another:

$$\frac{m \cdot v^2}{\cancel{r}} = \frac{k \cdot q_1 \cdot q_2}{\cancel{r^2}}$$

Recognizing that one of the r's cancel and converting the charges to Coulombs:

$$(6.11\ \mathrm{kg})\cdot\left(1{,}910\ \frac{\mathrm{m}}{\mathrm{s}}\right)^2 = \frac{\left(8.99\times10^9 \frac{\mathrm{N}\cdot\mathrm{m}^2}{\mathrm{C}^2}\right)\cdot(0.0631\ \mathrm{C})\cdot(0.0161\ \mathrm{C})}{r}$$

$$r = \frac{\left(8.99\times10^9 \frac{\frac{\cancel{\mathrm{kg}}\cdot\mathrm{m}}{\mathrm{s}^2}\cdot\cancel{\mathrm{m}^2}}{\cancel{\mathrm{C}^2}}\right)\cdot(0.0631\cancel{\mathrm{C}})\cdot(0.0161\cancel{\mathrm{C}})}{(6.11\cancel{\mathrm{kg}})\cdot\left(1{,}910\frac{\cancel{\mathrm{m}}}{\cancel{\mathrm{s}}}\right)^2} = 0.410\ \mathrm{m}$$

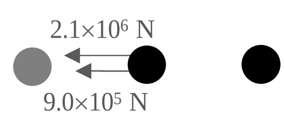
3. <u>3.0×10^6 N to the left</u>. First, we have to calculate the forces that are being exerted on the -15 mC charge, which is the one the question is asking about. The 15-mC charge exerts an attractive force:

$$F = \frac{k\cdot q_1\cdot q_2}{r^2} = \frac{\left(8.99\times10^9\frac{\mathrm{N}\cdot\cancel{\mathrm{m}^2}}{\cancel{\mathrm{C}^2}}\right)\cdot(0.015\cancel{\mathrm{C}})\cdot(0.015\cancel{\mathrm{C}})}{(1.5\cancel{\mathrm{m}})^2} = 9.0\times10^5\ \mathrm{N}$$

The -35 mC charge exerts a repulsive force:

$$F = \frac{k\cdot q_1\cdot q_2}{r^2} = \frac{\left(8.99\times10^9\frac{\mathrm{N}\cdot\cancel{\mathrm{m}^2}}{\cancel{\mathrm{C}^2}}\right)\cdot(0.015\cancel{\mathrm{C}})\cdot(0.035\cancel{\mathrm{C}})}{(1.5\cancel{\mathrm{m}})^2} = 2.1\times10^6\ \mathrm{N}$$

Taking direction into account, we get the diagram given on right. Defining motion to the left as positive, then, the sum of the forces would be:



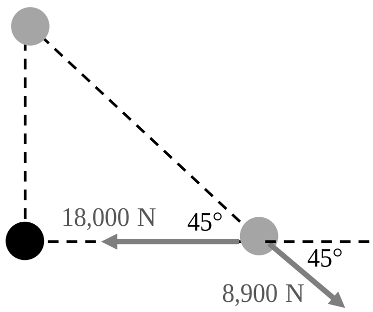
$$F = 9.0 \times 10^5\ \text{N} + 2.1 \times 10^6\ \text{N} = 3.0 \times 10^6\ \text{N}$$

Since this is addition, we look at decimal place. The first number has its last significant figure in the ten thousands place, and the second in the hundred thousands place. Since the latter is less precise, that means the answer must have its last significant figure in the hundred thousands place. Since motion to the left was defined as positive, that means the force is to the left.

4. <u>13,000 N at 208°</u>. We can get the magnitudes of the forces acting on the 19 mC charge:

$$F = \frac{k \cdot q_1 \cdot q_2}{r^2} = \frac{(8.99 \times 10^9 \frac{\text{N} \cdot \cancel{\text{m}^2}}{\cancel{\text{C}^2}}) \cdot (0.015\ \cancel{\text{C}}) \cdot (0.019\ \cancel{\text{C}})}{(12\ \cancel{\text{m}})^2} = 18{,}000\ \text{N}$$

$$F = \frac{k \cdot q_1 \cdot q_2}{r^2} = \frac{(8.99 \times 10^9 \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}) \cdot (0.015\ \text{C}) \cdot (0.019\ \text{C})}{(17\ \text{m})^2} = 8{,}900\ \text{N}$$



Now we have to figure out the geometry of the situation, which is given in the diagram below. The top charge exerts a repulsive force directly away from it. Since this right triangle has equal sides, its two non-right angles are 45°. Since vertical angles are congruent, that means the repulsive force is directed 45° below the horizontal, making its physics angle 315°. The attractive force points directly left, meaning the angle is 180°. These angles are exact, since they come from the definition of a right triangle.

$$A_x = A \cdot \cos(\theta) = (18{,}000\ \text{N}) \cdot \cos(180^o) = -18{,}000\ \text{N}$$

$$A_y = A \cdot \cos(\theta) = (18{,}000\ \text{N}) \cdot \sin(180^o) = 0\ \text{N}$$

$$B_x = A \cdot \cos(\theta) = (8.900\ \text{N}) \cdot \cos(315^o) = 6{,}300\ \text{N}$$

$$B_y = A \cdot \sin(\theta) = (8{,}900\ \text{N}) \cdot \sin(315^o) = -6{,}300\ \text{N}$$

Now we can add the x-components and y-components. The results will be the x- and y-components of the vector sum:

$$C_x = A_x + B_x = -18{,}000\ \text{N} + 6{,}300\ \text{N} = -12{,}000\ \text{N}$$

$$C_y = A_y + B_y = 0\ \text{N} + -6{,}300\ \text{N} = -6{,}300\ \text{N}$$

Now that we have the x- and y-components of the vector sum, we can use Equations (4.4) and (4.3) to get the magnitude and direction:

$$C = \sqrt{C_x^2 + C_y^2} = \sqrt{(-12{,}000\ \text{N})^2 + (-6{,}300\ \text{N})^2} = 13{,}000\ \text{N}$$

Now for the angle:

$$\tan(\theta) = \frac{C_y}{C_x}$$

$$\tan(\theta) = \frac{-6{,}300\ \cancel{\text{N}}}{-12{,}000\ \cancel{\text{N}}}$$

$$\tan(\theta) = 0.525$$

$$\theta = \tan^{-1}(0.525) = 28^{o}$$

Note that I didn't round after dividing, since that's an intermediate step. However, I had to round the value of the angle, since the components have only two significant figures. Since both components are negative, it is in quadrant III, meaning we must add exactly 180°:

$$28° + 180° = 208°$$

5. They are positive. The electric field lines point away from both of them.

6. 4 mC, because three times as many lines point away from the left particle it as compared to the right particle.

7. Up and to the left, since negative charges accelerate opposite the direction of the field lines.

8. 0.89 N. The force comes from Equation (13.2), but nice the electric field has C in it, the charge must be converted to 0.115 C. Also, the question asks only about magnitude, so we don't have to worry about signs.

$$F = q \cdot E = (0.115\ \mathrm{C}) \cdot \left(7.7\ \frac{\mathrm{N}}{\mathrm{C}}\right) = 0.89\ \mathrm{N}$$

9. Smaller than, since there are fewer lines in the vicinity.

10. Yes. If you look at the blank spot in the middle, you will see the four curves all point in opposite directions, so the net force would be zero in the middle of that blank spot.