Coulomb's Law

① Original Force $F_e = \frac{kQq}{r^2}$

a) New Force $F_e' = \frac{k(2Q)(2q)}{r^2} = 4\,\frac{kQq}{r^2} = 4\,F_e$

$\therefore F_e' = 4(3.0\times10^{-6})$

$= \boxed{1.2\times10^{-5}\ N}$

b) New Force

$F_e' = \frac{kQ(0.5q)}{r^2} = 0.5\,\frac{kQq}{r^2} = 0.5\,F_e$

$\therefore F_e' = 0.5(3.0\times10^{-6})$

$= \boxed{1.5\times10^{-6}\ N}$

c) New Force

$F_e' = \frac{kQq}{(3r)^2} = \frac{1}{9}\cdot\frac{kQq}{r^2} = \frac{1}{9}\cdot F_e$

$\therefore F_e' = \frac{1}{9}(3.0\times10^{-6})$

$= \boxed{3.\bar{3}\times10^{-7}\ N}$

② Original Force $F_e = \frac{kQq}{r^2}$

a) New Force

$$F_e' = \frac{kQq}{(2r)^2} = \frac{1}{4} \cdot \frac{kQq}{r^2} = \frac{1}{4} F_e$$

$$\therefore F_e' = \frac{1}{4}(3.6 \times 10^{-5})$$

$$= \boxed{9.0 \times 10^{-6} \text{ N}}$$

b) New Force

$$F_e' = \frac{kQq}{(2.5r)^2} = \frac{1}{6.25} \cdot \frac{kQq}{r^2} = \frac{1}{6.25} F_e$$

$$\therefore F_e' = \frac{1}{6.25} \cdot (3.6 \times 10^{-5})$$

$$= \boxed{5.76 \times 10^{-6} \text{ N}}$$

c) New Force

$$F_e' = \frac{kQq}{(3r)^2} = \frac{1}{9} \cdot \frac{kQq}{r^2} = \frac{1}{9} \cdot F_e$$

$$\therefore F_e' = \frac{1}{9}(3.6 \times 10^{-5})$$

$$= \boxed{4.0 \times 10^{-6} \text{ N}}$$

③ $F_e = \frac{kQq}{r^2}$

$= \frac{(9\times10^9)(5\times10^{-8})(1\times10^{-7})}{(0.05)^2}$

$F_e = \boxed{0.018\ N}$

④ $F_e = \frac{kQq}{r^2}$

$= \frac{(9\times10^9)(1.5\times10^{-6})(3.2\times10^{-4})}{(1.5)^2}$

$F_e = \boxed{1.92\ N}$

⑤ $F_e = \frac{kQq}{r^2}$ $\qquad Q = 2q$

$1.2\times10^{-9} = \frac{(9\times10^9)(2q)(q)}{(0.04)^2}$

$1.2\times10^{-9} = 1.125\times10^{13}\ q^2$

$q^2 = 1.06\times10^{-22}$

$q = \boxed{1.03\times10^{-11}\ C}$

$Q = 2q = 2(1.03\times10^{-11}) = \boxed{2.06\times10^{-11}\ C}$

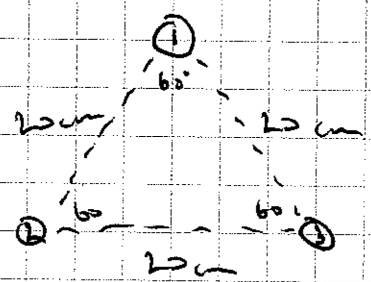
⑥ $F_e = \frac{kQq}{r^2}$

$r = \sqrt{\frac{kQq}{F_e}}$

$= \sqrt{\frac{(9\times10^9)(1.1\times10^{-7})(1.1\times10^{-7})}{(4.2\times10^{-4})}}$

$r = \boxed{0.51\ m}$

⑦



All 3 forces will be the same (since the charges are equal and so are the r values) so we will calculate one as an example.

$F_{21} = \frac{kQ_2Q_1}{r^2} = \frac{(9\times10^9)(4\times10^{-6})(4\times10^{-6})}{(0.2)^2} = 3.6\ N$ [30° E of N]

$F_{31} = \frac{kQ_3Q_1}{r^2} = \frac{(9\times10^9)(4\times10^{-6})(4\times10^{-6})}{(0.2)^2} = 3.6\ N$ [30° W of N]

Use vector addition to combine the forces.

(continued on next page)

⑦

	N	E
F_{21}	$3.6 \cos 30$	$3.6 \sin 30$
F_{31}	$3.6 \cos 30$	$-3.6 \sin 30$
Total	6.235	0

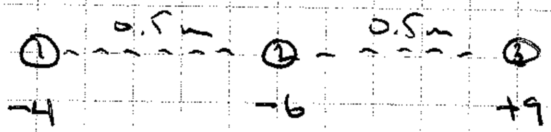
$\therefore$ Force on charge #1 = **6.2 N [N]**

Similarly, the force on:

charge # 2 = **6.2 N [30° S of W]**

charge # 3 = **6.2 N [30° S of E]**

⑧



$$F_{21} = \frac{kQ_1Q_2}{r^2} = \frac{(9\times10^9)(4\times10^{-6})(6\times10^{-6})}{(0.5)^2} = 0.864 \text{ N [left]}$$

$$F_{31} = \frac{kQ_3Q_1}{r^2} = \frac{(9\times10^9)(4\times10^{-6})(9\times10^{-6})}{1^2} = 0.324 \text{ N [right]}$$

$$F_1 = 0.324 - 0.864 = -0.54$$

or

0.54 N [Left]

(8) (continued)

$F_{12} = 0.864\ N$ [right]

$F_{32} = \frac{kQ_3Q_2}{r^2} = \frac{(9\times10^9)(6\times10^{-6})(9\times10^{-6})}{0.5^2} = 1.944\ N$ [right]

$F_2 = 0.864 + 1.944 = \boxed{2.81\ N\ [right]}$

$F_{13} = 0.324\ N$ [Left]

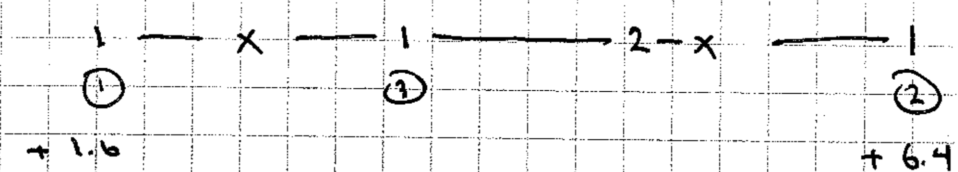
$F_{23} = 1.944\ N$ [left]

$F_3 = -0.324 - 1.944 = -2.27\ N$

or

$\boxed{2.27\ N\ [left]}$

(9)



$F_{13} = \frac{kQ_1Q_3}{x^2}$ [right]

$F_{23} = \frac{kQ_2Q_3}{(2-x)^2}$ [left]

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⑨ To produce a net force of zero, the 2 forces must be equal in magnitude.

$$\therefore \quad \frac{kQ_1Q_3}{x^2} = \frac{kQ_2Q_3}{(2-x)^2}$$

$$\frac{Q_1}{x^2} = \frac{Q_2}{(2-x)^2}$$

$$Q_1(2-x)^2 = Q_2 \cdot x^2$$

$$(1.6\times10^{-5})(4-4x+x^2) = (6.4\times10^{-5})\,x^2$$

$$6.4\times10^{-5} - 6.4\times10^{-5}x + 1.6\times10^{-5}x^2 = 6.4\times10^{-5}x^2$$

$$4.8\times10^{-5}x^2 + 6.4\times10^{-5}x - 6.4\times10^{-5} = 0$$

$$x = \frac{-6.4\times10^{-5} \pm \sqrt{(6.4\times10^{-5})^2 - 4(4.8\times10^{-5})(-6.4\times10^{-5})}}{2(4.8\times10^{-5})}$$

$$x = \frac{-6.4\times10^{-5} \pm 1.28\times10^{-4}}{9.6\times10^{-5}}$$

$$x = \boxed{0.67\ m} \quad \text{or} \quad \cancel{-2\ m}$$

The third charge should be 0.67 m from charge 1, on the line joining the 2 charges.