Applied Physics

BS Software Engineering/Information Technology

1st Semester

Lecture # 3

CHAPTER 21

Coulomb's Law

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Lecture # 3

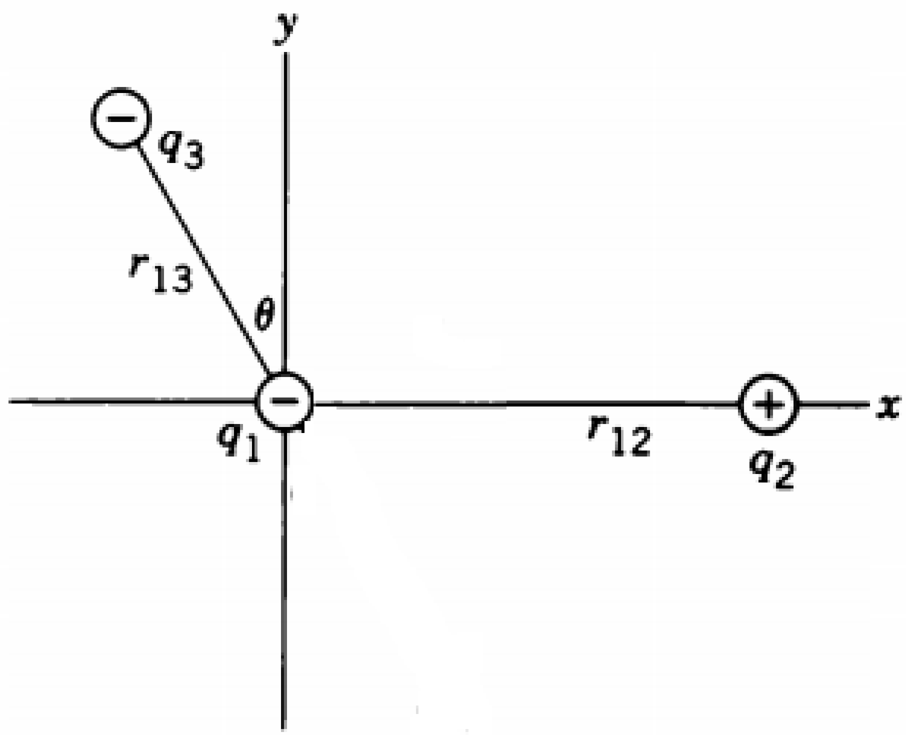
- Principle of Superposition
- Related problems
- Assignment # 1

Principle of superposition applied to electric forces

Multiple Forces. As with all forces in this book, the electrostatic force obeys the principle of superposition. Suppose we have n charged particles near a chosen particle called particle 1; then the net force on particle 1 is given by the vector sum

$$\vec{F}_{1,\mathrm{net}} = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \vec{F}_{15} + \cdots + \vec{F}_{1n},$$

Sample Problem Figure 6 shows three charged particles, held in place by forces not shown. What electrostatic force, owing to the other two charges, acts on q_1? Take $q_1 = -1.2\ \mu C$, $q_2 = +3.7\ \mu C$, $q_3 = -2.3\ \mu C$, $r_{12} = 15$ cm, $r_{13} = 10$ cm, and $\theta = 32°$.



Solution This problem calls for the use of the superposition principle. We start by computing the magnitudes of the forces that q_2 and q_3 exert on q_1. We substitute the magnitudes of the charges into Eq. 5, disregarding their signs for the time being. We then have

$$F_{12} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r_{12}^2}$$

$$= \frac{(8.99 \times 10^9\ \mathrm{N\cdot m^2/C^2})(1.2 \times 10^{-6}\ \mathrm{C})(3.7 \times 10^{-6}\ \mathrm{C})}{(0.15\ \mathrm{m})^2}$$

$$= 1.77\ \mathrm{N}.$$

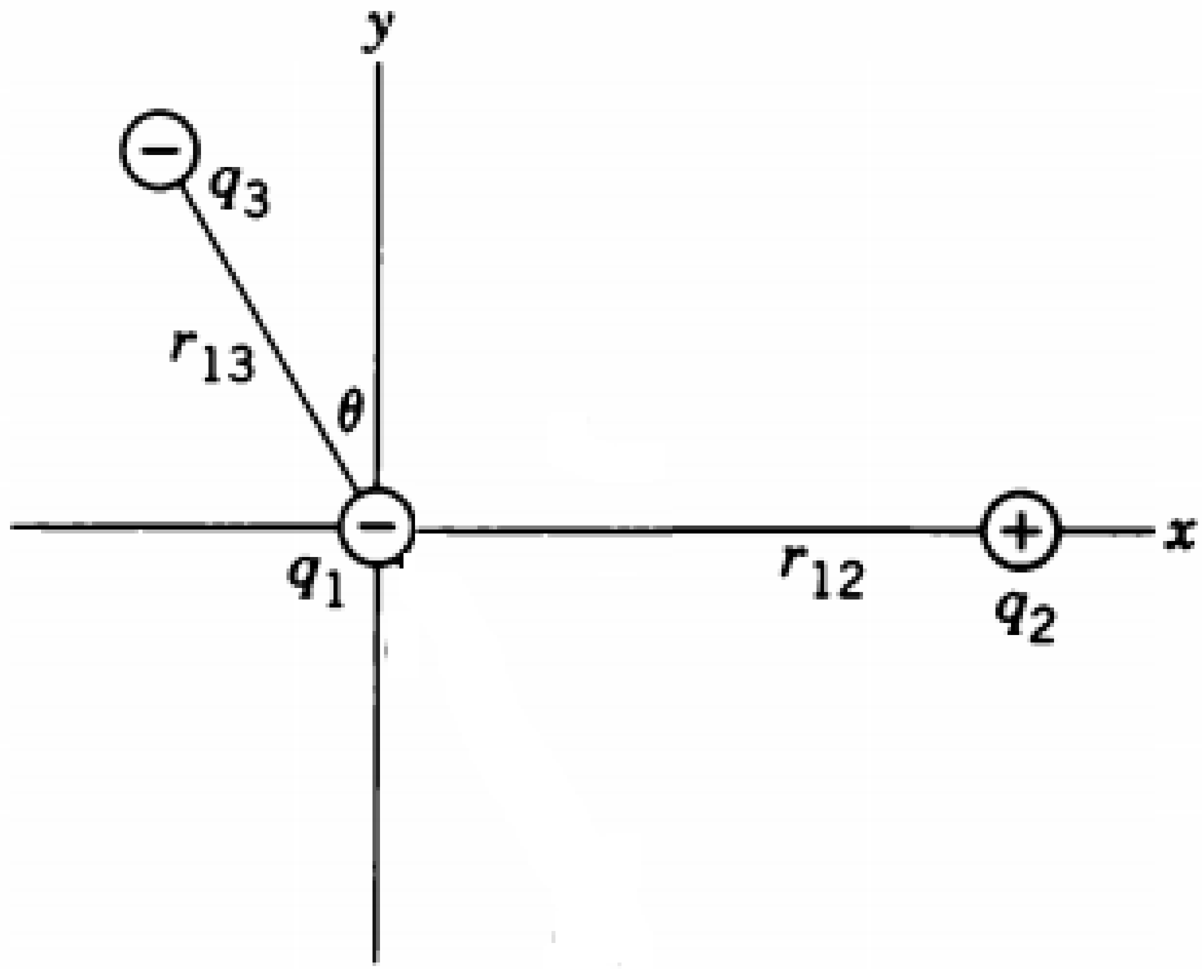
The charges q_1 and q_2 have opposite signs so that the force between them is attractive. Hence $\mathbf{F}_{12}$ points to the right in Fig. 6.

We also have

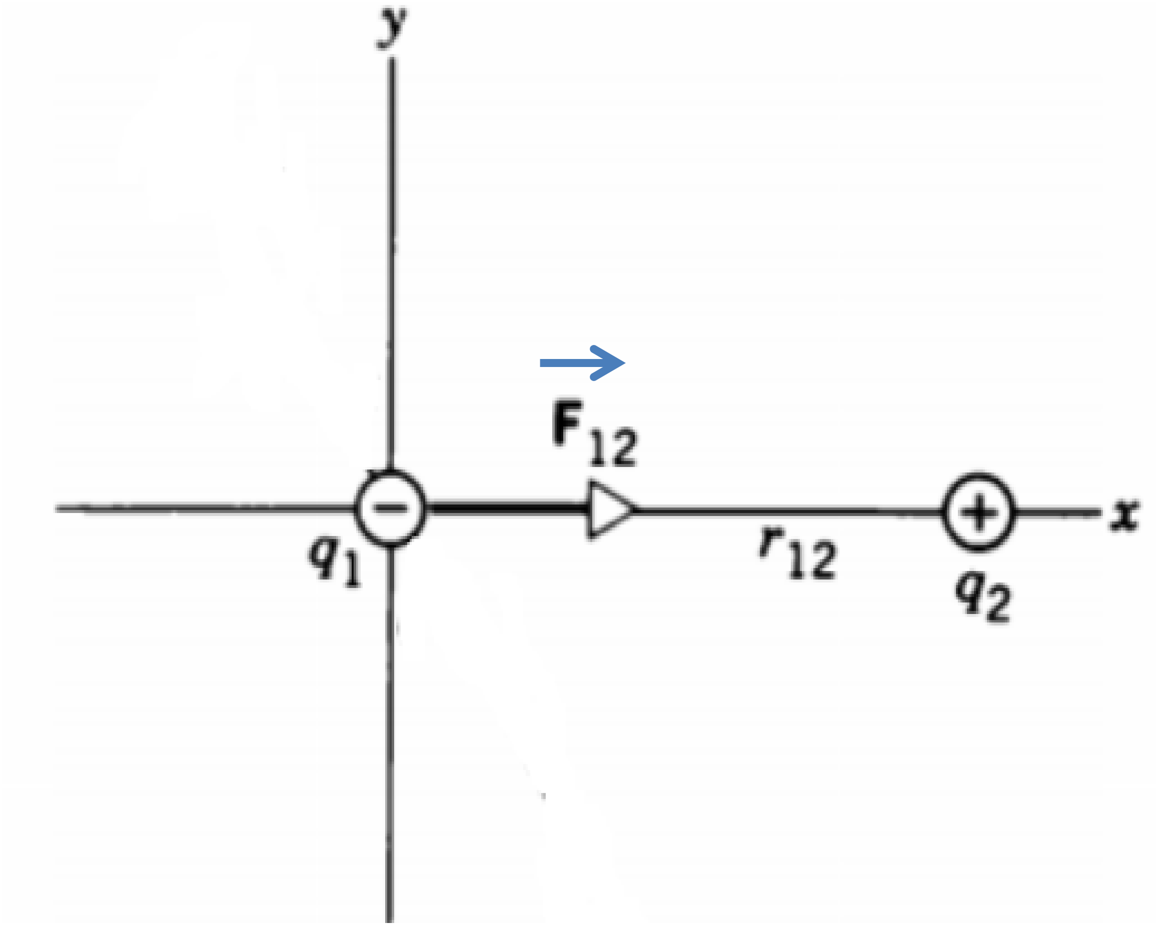
$$F_{13} = \frac{(8.99 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)(1.2 \times 10^{-6} \text{ C})(2.3 \times 10^{-6} \text{ C})}{(0.10 \text{ m})^2}$$

$$= 2.48 \text{ N}.$$

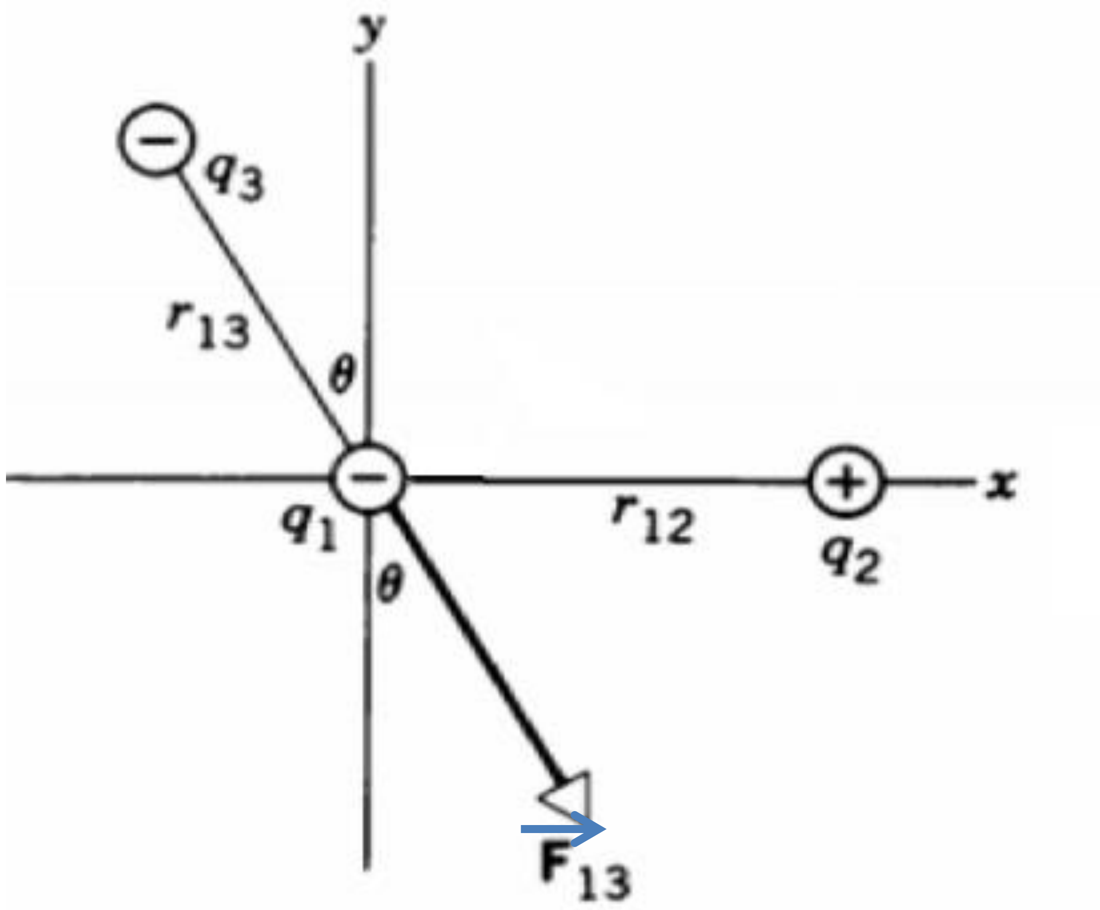
Now draw force vectors



Force vector: 1st pair F_{12}



Force vector: 2^{nd} pair F_{13}



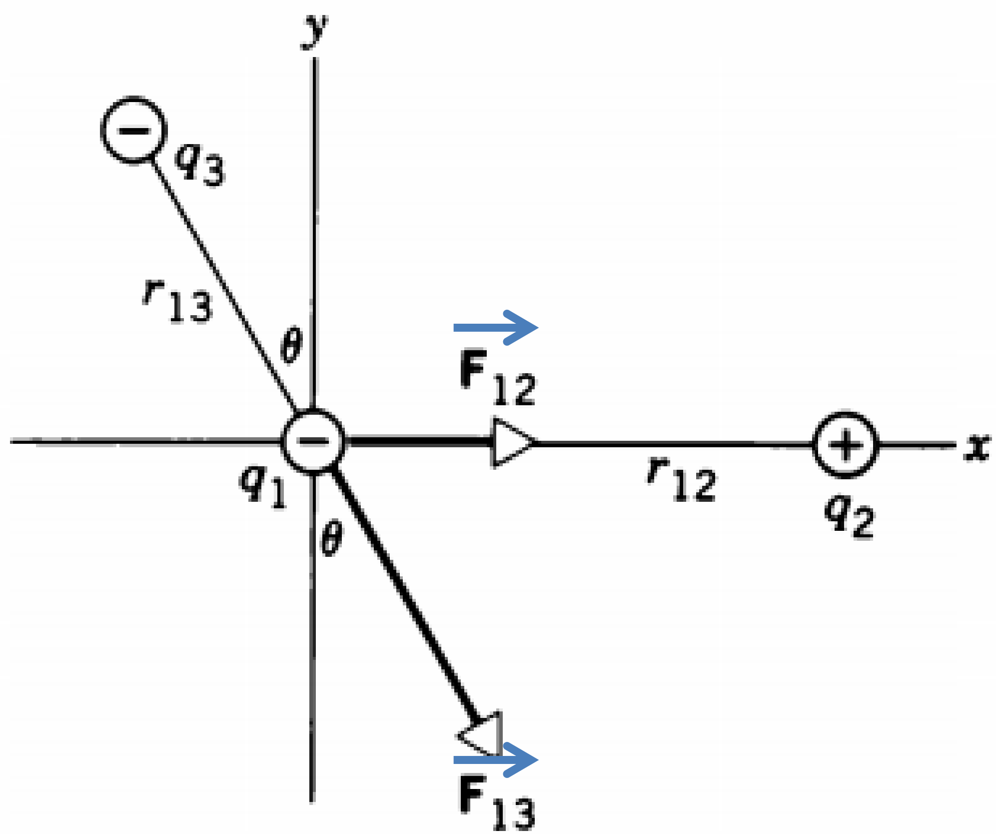
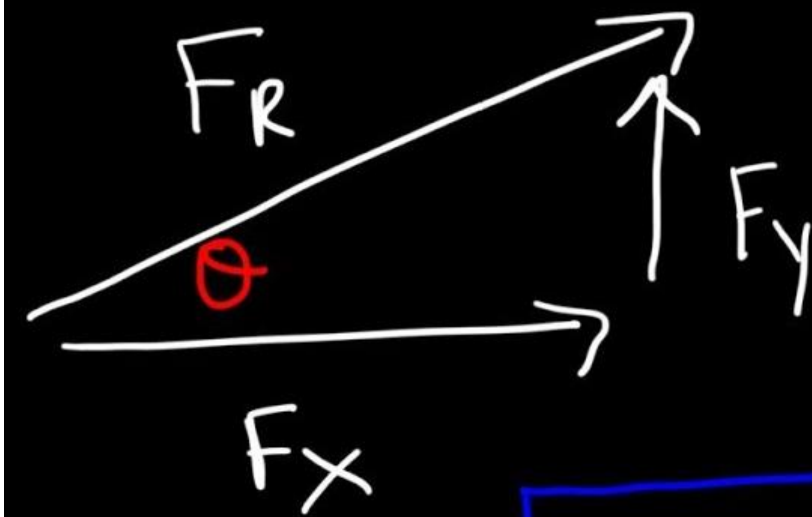


Figure 6 Sample Problem 1. The three charges exert three pairs of action – reaction forces on each other. Only the two forces acting on q_1 are shown here.



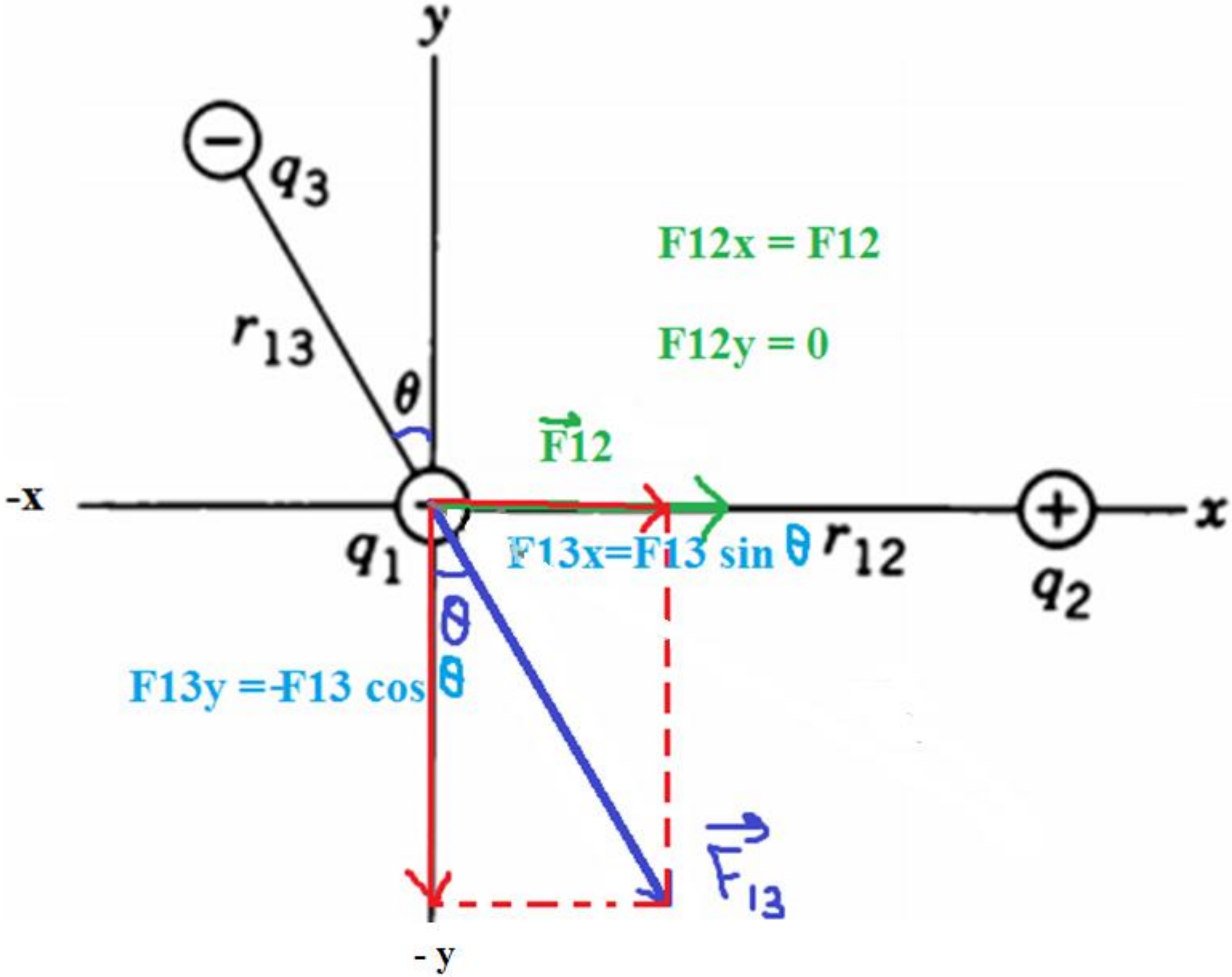
$$\boxed{\begin{aligned} F_x &= F\cos\theta \\ F_y &= F\sin\theta \end{aligned}}$$

$$\theta = \tan^{-1}\left(F_y / F_x\right)$$

$$\boxed{F_R = \sqrt{F_x^2 + F_y^2}}$$

$$F_{1x} = F_{12x} + F_{13x}$$

$$F_{1y} = F_{12y} + F_{13y}$$



y
q_3
r_{13}
θ
F12x = F12
F12y = 0
$\vec{F}12$
-x
x
q_1
F13x=F13 sin θ
r_{12}
q_2
θ
F13y = ~~-~~F13 cos θ
$\vec{F}_{13}$
- y

$$F_{1x} = F_{12x} + F_{13x}$$

$$= F_{12} + F_{13} \sin\theta$$

$$= 1.77\ \text{N} + (2.48\ \text{N})(\sin 32°) = 3.08\ \text{N}$$

$$F_{1y} = F_{12y} + F_{13y}$$

$$= 0 - F_{13} \cos\theta$$

$$= -(2.48\ \text{N})(\cos 32°) = -2.10\ \text{N}.$$

$$F_{1x} = 3.08N$$
$$F_{1y} = -2.10N$$

$$F_1 = (F_{1x}^2 + F_{1y}^2)^{1/2}$$
$$=3.73N$$

$$\text{Angle} = \tan^{-1}(F_{1y} / F_{1x})$$
$$= -34^0$$

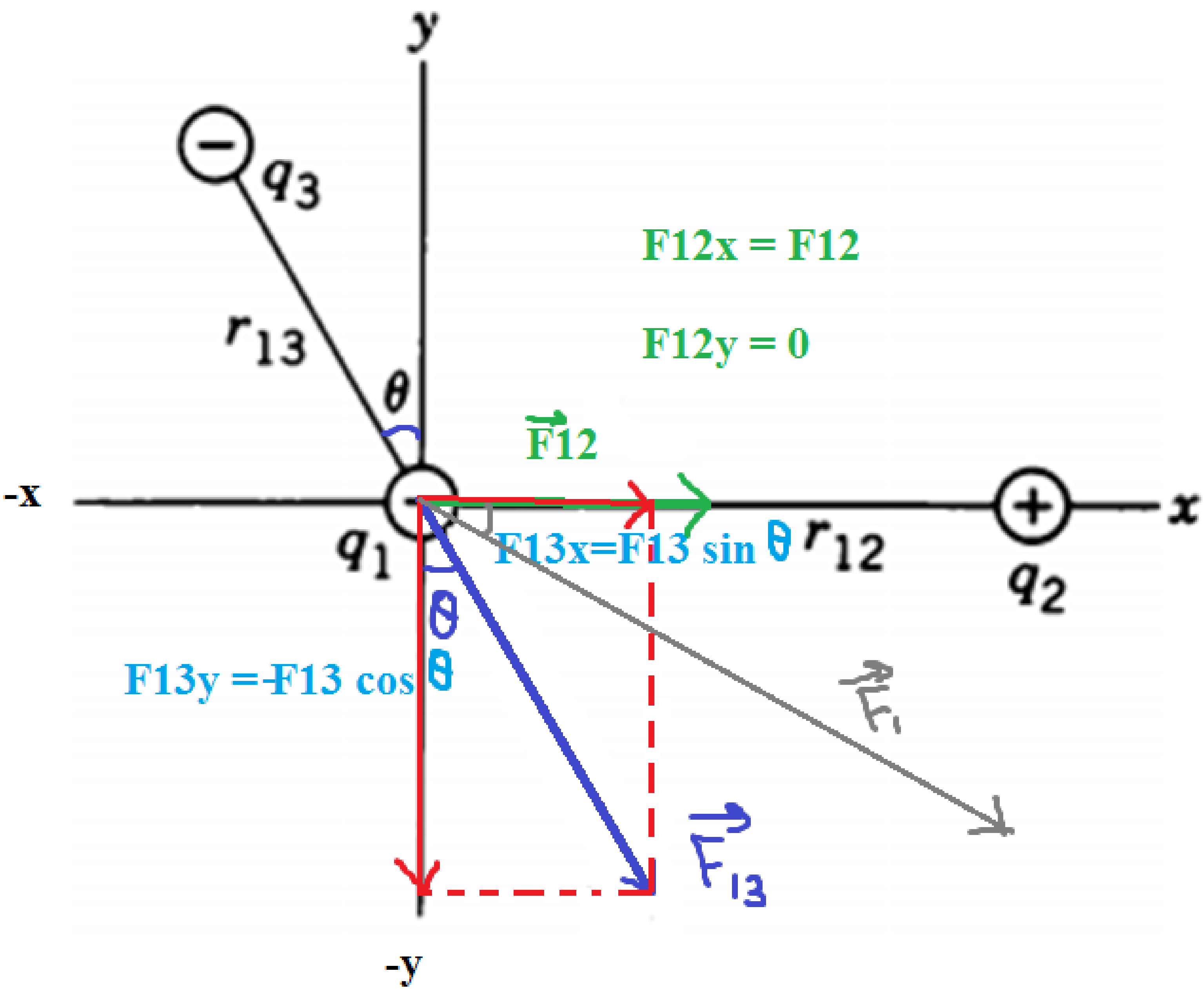
The components of the resultant force $\mathbf{F}_1$ acting on q_1 are determined by the corresponding components of Eq. 8, or

$$F_{1x} = F_{12x} + F_{13x} = F_{12} + F_{13} \sin\theta$$
$$= 1.77\text{ N} + (2.48\text{ N})(\sin 32°) = 3.08\text{ N}$$

and

$$F_{1y} = F_{12y} + F_{13y} = 0 - F_{13} \cos\theta$$
$$= -(2.48\text{ N})(\cos 32°) = -2.10\text{ N}.$$

From these components, you can show that the magnitude of $\mathbf{F}_1$ is 3.73 N and that this vector makes an angle of $-34°$ with the x axis.


y
q_3
r_{13}
θ
F12x = F12
F12y = 0
$\vec{F}12$
-x
x
q_1
F13x=F13 sin θ
r_{12}
q_2
θ
F13y =-F13 cos θ
$\vec{F}_{13}$
-y

8. In Fig. 13, find (*a*) the horizontal and (*b*) the vertical components of the resultant electric force on the charge in the lower left corner of the square. Assume that $q = 1.13\ \mu C$ and $a =$ 15.2 cm. The charges are at rest.

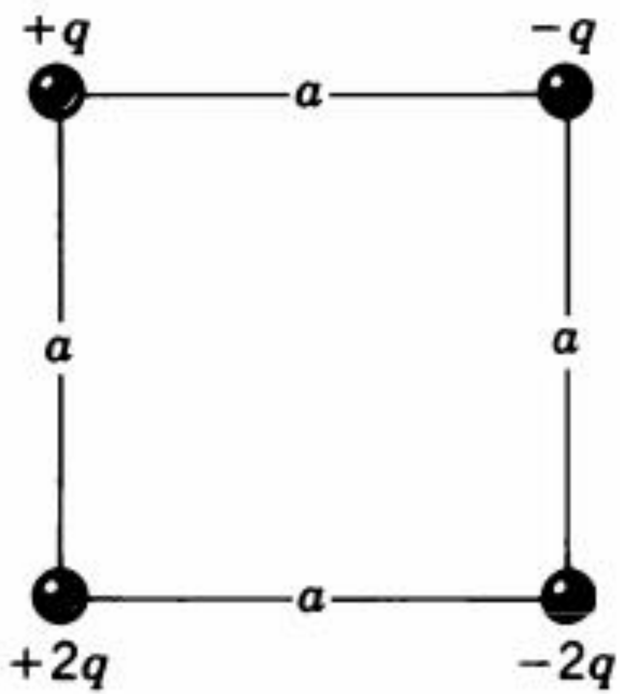
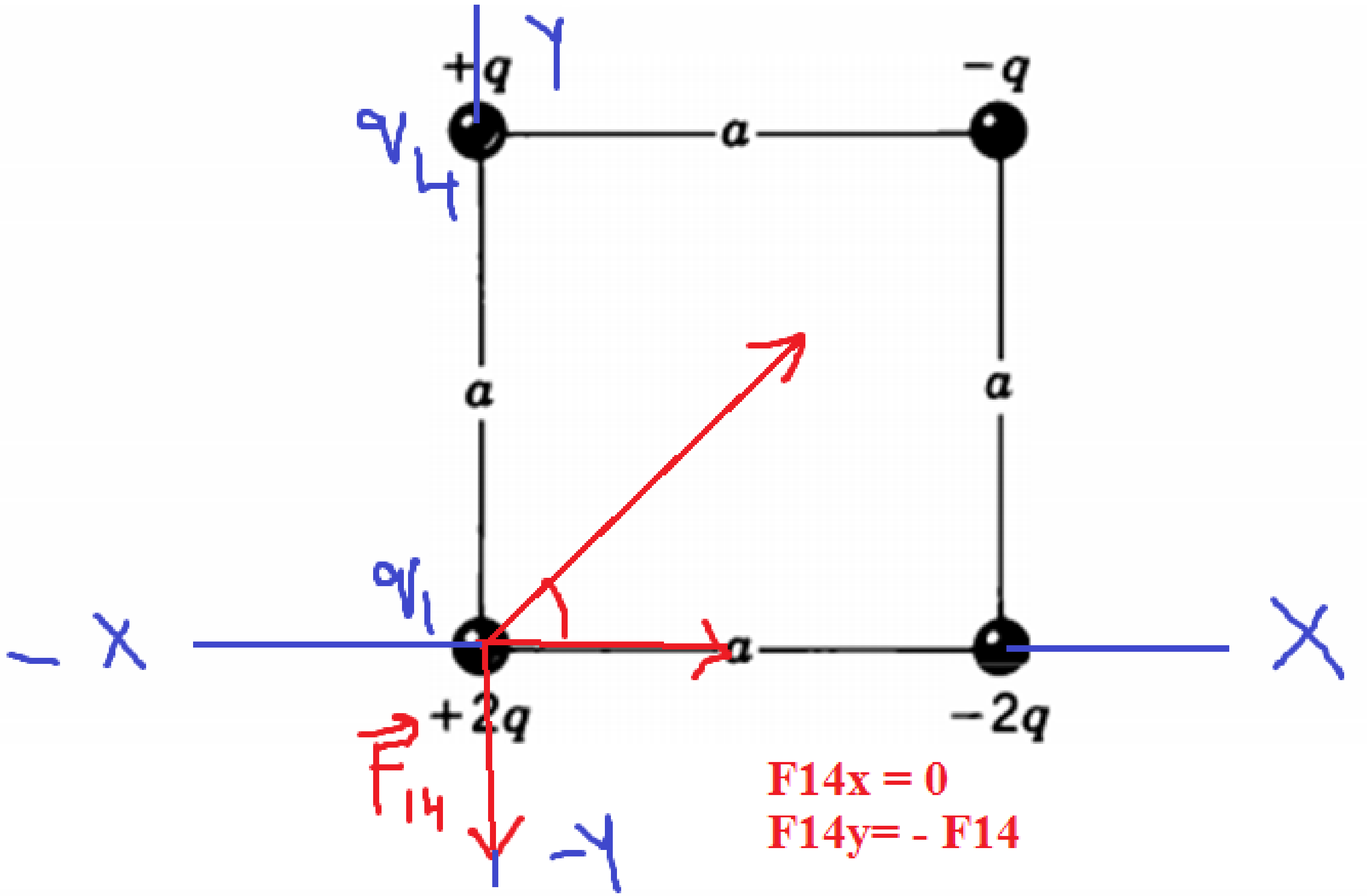


Figure 13 Problem 8.

Hint



F14x = 0
F14y= - F14

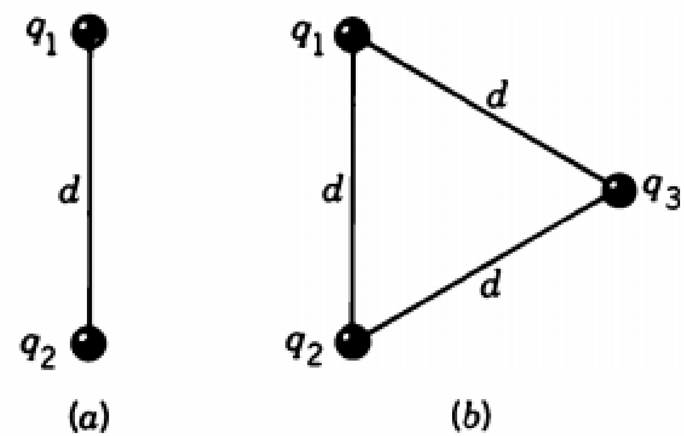
Assignment # 1

PROBLEMS

Section 27-4 Coulomb's Law

1. A point charge of $+3.12 \times 10^{-6}$ C is 12.3 cm distant from a second point charge of -1.48×10^{-6} C. Calculate the magnitude of the force on each charge.
2. What must be the distance between point charge $q_1 = 26.3\ \mu C$ and point charge $q_2 = -47.1\ \mu C$ in order that the attractive electrical force between them has a magnitude of 5.66 N?
3. In the return stroke of a typical lightning bolt (see Fig. 9), a current of 2.5×10^4 A flows for 20 μs. How much charge is transferred in this event?
4. Two equally charged particles, held 3.20 mm apart, are released from rest. The initial acceleration of the first particle is observed to be 7.22 m/s^2 and that of the second to be 9.16 m/s^2. The mass of the first particle is 6.31×10^{-7} kg. Find (*a*) the mass of the second particle and (*b*) the magnitude of the common charge.

5. Figure 10*a* shows two charges, q_1 and q_2, held a fixed distance d apart. (*a*) Find the strength of the electric force that acts on q_1. Assume that $q_1 = q_2 = 21.3\ \mu C$ and $d = 1.52$ m. (*b*) A third charge $q_3 = 21.3\ \mu C$ is brought in and placed as shown in Fig. 10*b*. Find the strength of the electric force on q_1 now.



Problem 5.