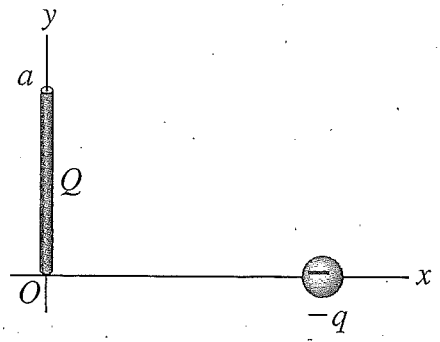
21.22. Two positive point charges q are placed on the y-axis at $y = a$ and $y = -a$. A negative point charge $-Q$ is located at some point on the $+x$-axis. (a) In a free-body diagram, show the forces that act on the charge $-Q$. (b) Find the x- and y-components of the net force that the two positive charges exert on $-Q$. (Your answer should involve only k, q, Q, a and the coordinate x of the third charge.) (c) What is the net force on the charge $-Q$ when it is at the origin $(x = 0)$? (d) Graph the x-component of the net force on the charge $-Q$ as a function of x for values of x between $-4a$ and $+4a$.

21.90. Positive charge Q is distributed uniformly along the positive y-axis between $y = 0$ and $y = a$. A negative point charge $-q$ lies on the positive x-axis, a distance x from the origin (Fig. 21.48). (a) Calculate the x- and y-components of the electric field produced by the charge distribution Q at points on the positive x-axis. (b) Calculate the x- and y-components of the force that the charge distribution Q exerts on q. (c) Show that if $x \gg a$, $F_x \cong -Qq/4\pi\epsilon_0 x^2$ and $F_y \cong +Qqa/8\pi\epsilon_0 x^3$. Explain why this result is obtained.

Figure **21.48** Problem 21.90.



21.104. A thin disk with a circular hole at its center, called an *annulus,* has inner radius R_1 and outer radius R_2 (Fig. 21.51). The disk has a uniform positive surface charge density σ on its surface. (a) Determine the total electric charge on the annulus. (b) The annulus lies in the yz-plane, with its center at the origin. For an arbitrary point on the x-axis (the axis of the annulus), find the magnitude and direction of the electric field $\vec{E}$. Consider points both above and below the annulus in Fig. 21.51. (c) Show that at points on the x-axis that are sufficiently close to the origin, the magnitude of the electric field is approximately proportional to the distance between the center of the annulus and the point. How close is "sufficiently close"? (d) A point particle with mass m and negative charge $-q$ is free to move along the x-axis (but cannot move off the axis). The particle is originally placed at rest at $x = 0.01R_1$ and released. Find the frequency of oscillation of the particle. (*Hint:* Review Section 13.2. The annulus is held stationary.)

Figure **21.51** Problem 21.104.