Answer on Question 59024, Physics, Electric Circuits

Question:

A tiny ball of mass 0.60 g is suspended from a rigid support with a piece of thread in a horizontal electric field of intensity 700 N/C. The ball is in equilibrium when the thread is inclined at an angle of 20° to the vertical. What are the magnitude and sign of the charge on the ball? Take $g = 9.8\, ms^{-2}$.

a) $-3.1 \cdot 10^{-6}\ C$

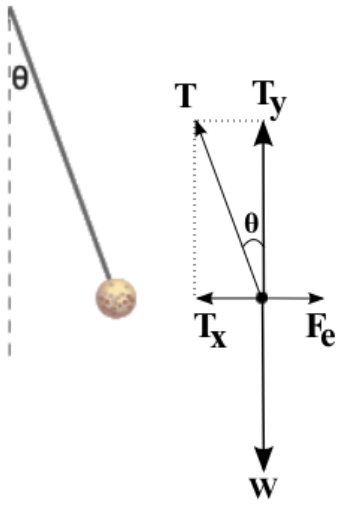
b) $3.2 \cdot 10^{-6}\ C$

c) $4.2 \cdot 10^{-6}\ C$

d) $-4.1 \cdot 10^{-3}\ C$

Solution:

Let's draw a free-body diagram:



Here, $W = mg$ is the force of gravity (or weight of the tiny ball), $F_e = qE$ is the electric force that acts on the tiny ball, T is the force of tension in the thread, T_x, T_y is the projections of the force of tension on axis x and y, respectively, θ is the angle of inclination of the thread to the vertical, q is the charge of the tiny ball and E is the intensity of the electric field.

Let's write the conditions of the equilibrium for the tiny ball:

$$\sum F_x = 0, \quad \sum F_y = 0.$$

Let's consider the forces that act on the tiny ball in the horizontal x- and vertical y-direction:

$$\sum F_x = -Tsin\theta + F_e = -Tsin\theta + qE = 0, \quad (1)$$

$$\sum F_y = Tcos\theta - mg = 0. \ (2)$$

We can express the force T from the second equation:

$$T = \frac{mg}{cos\theta}.$$

Then we can substitute it into the first equation and get:

$$-\frac{mg}{cos\theta}sin\theta + qE = 0,$$

$$-mgtan\theta + qE = 0.$$

From the last equation we can find the magnitude of the charge on the ball:

$$qE = mgtan\theta,$$

$$q = \frac{mgtan\theta}{E} = \frac{0.6 \cdot 10^{-3}\ kg \cdot 9.8\ \frac{m}{s^2} \cdot tan20^{\circ}}{700\ \frac{N}{C}} = 3.06 \cdot 10^{-6}\ C \sim 3.1 \cdot 10^{-6}\ C.$$

Let's discuss about the charge of the ball. Let's suppose that the electric field directed in the positive x-direction. Then, if we charged the ball with positive charge, the ball inclined at an angle 20° to the vertical to the right. Now, if we charged the ball with negative charge, the ball inclined at an angle 20° to the vertical in the opposite direction to the left. Now, let us imagine that we change the direction of the electric field. In this case, everything will be contrary. The positively charged ball will incline to the left while negatively charged ball will incline in opposite direction to the right. Therefore, both answers about the charge of the ball – either positive or negative are correct.

Answer: a) $-3.1 \cdot 10^{-6}\ C$