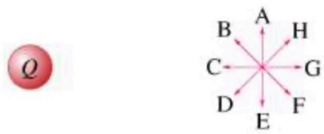
Imagine an isolated positive point charge with a charge Q (many times larger than the charge on a single electron).

If the total positive charge is $Q = 1.62 \times 10^{-6}$ C, what is the magnitude of the electric field caused by this charge at point P, a distance d = 1.53 m from the charge?

What is the direction of the electric field at point P?



Now find the magnitude of the force on an electron placed at point P. Recall that the charge on an electron has magnitude e = 1.60×10^{-19} C.

This charge Q is a source of an electric field. We want to calculate the magnitude and direction of the electric field produced by this charge. We are going to find the electric field at a specific distance from the source charge ($d = 1.53$ m). Think of this like placing an electric field detector at a spot 1.53 m away from Q. What will be the reading on the detector?

We can use $E = k\frac{Q}{r^2}$ to calculate the magnitude of the electric field.

$$E = \frac{(9 \times 10^{9}\ \mathrm{N \cdot m^2/C^2})(1.62 \times 10^{-6}\ \mathrm{C})}{(1.53\ \mathrm{m})^2} = 6230\ \mathrm{N/C}$$

what do these units tell us?

At this location from the source charge Q, the electric field can exert 6230 N of force on 1C of charge, if that 1C was placed in that location.

To determine the direction of the electric field at point P, we can use the "positive test charge" method. Pretend to place a small, positive charge at point P – how would that charge react to being near the source charge Q? The test charge would be repelled by Q, meaning the test charge would feel a force to the right.

This tells us that the electric field produced by Q at point P must also be to the right since it's this electric field that exerts the repelling force on the test charge in the first place.

We are asked to find the force on an electron if we placed it at point P. Fortunately we already know the magnitude and direction of the E-field at point P. Recall how we first defined electric field: $E = \frac{F}{q}$. Rearrange this to solve for force: $F = qE$

electric field produced by Q at point P

charge experiencing the force
this is the electron charge in this example

$$F = (-1.6 \times 10^{-19}\,C)(6230\,N/C) = -9.97 \times 10^{-16}\,N$$

The magnitude of this force on the electron is 9.97×10^{-16} N. But what does that minus sign tell us? It tells us about the direction of the force on the electron. We already determined the E-field direction to be to the right, which we can say is the $+x$ direction. Since the force we calculated was negative, the force on the electron is in the $-x$ direction. So the electron feels an attractive force toward Q which makes sense because unlike charges attract.

A Proton between Oppositely Charged Plates

A uniform electric field exists in the region between two oppositely charged parallel plates 1.51 cm apart. A proton is released from rest at the surface of the positively charged plate and strikes the surface of the negative plate in a time interval 1.58×10^{-6} s.

Find the magnitude of the electric field. (Use 1.60×10^{-19} C for the magnitude of the charge on an electron and 1.67×10^{-27} kg for the mass of a proton.)

Find the speed of the proton at the moment it strikes the negatively charged plate.

To find the electric field, we can use the definition : $E = \frac{F}{q}$ where F is the force exerted on the proton by the electric field and q is the proton's charge. We know the proton's charge is the elementary charge : $q = e = 1.6 \times 10^{-19}$ C. However, we don't know the force on the proton, but we can calculate it from the given data and Newton's 2nd Law. The net force on the proton is $F_{net} = ma$, where m is the proton's mass and a is its acceleration. Since the force is constant (we know this because the force comes from a uniform - or constant - electric field) the acceleration is also constant, so we can use kinematic equations (from physics 1) to solve for acceleration.

We know the proton starts from rest so the initial velocity is zero : $v_0 = 0$

We know the proton moves 1.51 cm from one plate to the other : $\Delta x = 1.51$ cm

It takes 1.58×10^{-6} s ($1.58\ \mu s$) to travel this distance : $\Delta t = 1.58 \times 10^{-6}$ s

Let's pull it all together with $\Delta x = v_0 t + \frac{1}{2} a t^2$

Rearrange to solve for acceleration : $a = \frac{2(\Delta x - v_0 t)}{t^2}$, then simplify with $v_0 = 0$

$$a = \frac{2(\Delta x)}{t^2} = \frac{2(0.0151\ m)}{(1.58 \times 10^{-6}\ s)^2} = 1.21 \times 10^{10}\ m/s^2$$

Then we can use this acceleration and the proton's mass to find the force :

$$F = ma = (1.67 \times 10^{-27}\ kg)(1.21 \times 10^{10}\ m/s^2) = 2.02 \times 10^{-17}\ N$$

Now we have what we need to solve for the electric field in the space between the charged plates:

$$E = \frac{F}{q} = \frac{2.02 \times 10^{-17}\,N}{1.6 \times 10^{-19}\,C} = 126\ N/C$$

To find the proton's speed when it hits the negative plate, we can use another kinematic equation: $v_f = v_0 + at = 0 + (1.21 \times 10^{10}\ m/s^2)(1.58 \times 10^{-6}\ s) = 19120\ m/s$