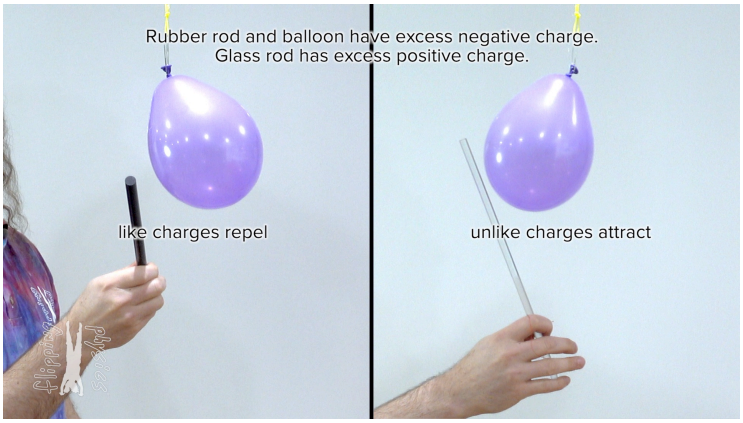
Flipping Physics Lecture Notes:

Electric Charge
https://www.flippingphysics.com/charge.html

The Law of Charges:

- Like charges repel &
- Unlike charges attract



When we rub fur against a rubber rod and then a rubber balloon, electrons transfer from the fur to the rubber objects leaving the rubber objects with a net negative charge and the fur with a net positive charge. When we rub silk against a glass rod, electrons transfer from the glass rod to the silk leaving the glass rod with a net positive charge and the silk with a net negative charge.

Electrons and Protons are very, very tiny particles with charge magnitude equal to e:

- e = 1.60 x 10-19 coulombs, C
- e = elementary charge
- e = smallest charge measured on an *isolated* particle.
- Coulombs, C = SI unit for charge
- Charge on electron = -e & Charge on proton = +e
- $m_{electron} = 9.11\times10^{-31} kg$ & $m_{proton} = 1.67\times10^{-27} kg$
- A proton is much more massive than an electron. $\frac{m_{proton}}{m_{electron}} = \frac{1.67\times10^{-27} kg}{9.11\times10^{-31} kg} \approx 1830$
- electron = elementary particle
- proton is not an elementary particle because it is composed of quarks.

Quarks are elementary particles which make up protons and neutrons:

- $q_{up quark} = +\frac{2}{3}e$ & $q_{down quark} = -\frac{1}{3}e$
- $q_{proton} = 2q_{up\ quark} + 1q_{down\ quark} = 2\left(+\frac{2}{3}e\right) + \left(-\frac{1}{3}e\right) = +\frac{4}{3}e - \frac{1}{3}e = +e$
- $q_{neutron} = 1q_{up\ quark} + 2q_{down\ quark} = \left(+\frac{2}{3}e\right) + 2\left(-\frac{1}{3}e\right) = +\frac{2}{3}e - \frac{2}{3}e = 0$

When you take a rubber balloon and rub it against fur, three things are possible.

1) The balloon will stay in your hair.
    a. Rub rubber balloon against hair and electrons transfer from hair to balloon.
    b. Balloon now has a net negative charge and hair now has a net positive charge.
    c. Law of Charges: unlike charges attract.
    d. Electric force pulls hair and balloon together.
2) Pull the balloon away from your hair and some of your hairs will stick out.
    a. Rub rubber balloon against hair and electrons transfer from hair to balloon.
    b. Hair now has a net positive charge.
    c. Law of Charges: like charges repel.
    d. • Electric force pushes hair apart.

3) The balloon will stick to a wall.
    a. This is polarization which we will learn about in a future lesson.
        i. https://www.flippingphysics.com/polarization.html

The elementary charge is very small: $e = 1.60 \times 10^{-19} C = 0.00000000000000000160 C$

Example: How many excess protons does it take to get a charge of 1 coulomb on an object?
For this we need a new equation: $q = ne$

- q = net charge on an object
- n = excess number of charge carriers
- e = elementary charge

$$q = ne \Rightarrow n = \frac{q}{e} = \frac{1C}{1.60 \times 10^{-19} \frac{C}{proton}} = 6.25 \times 10^{18} \, protons$$

$q = 6.25 \, quintillion \, protons = 6.25 \, million \, million \, million \, protons = 6{,}250{,}000{,}000{,}000{,}000 \, protons$

Example: Can an object have a net negative charge of 2.00 times 10 to the negative 19 coulombs?

$$q = ne \Rightarrow n = \frac{q}{e} = \frac{-2.00 \times 10^{-19} C}{-1.60 \times 10^{-19} \frac{C}{electron}} = 1.25 \, electrons$$

However, you cannot have a quarter of an electron because charge is *quantized*.

- Charge comes in discrete quantities in multiples of the elementary charge.
- Charge is caused by having more or fewer charged particles (protons or electrons).
- The charge on an object, q, must be an integer multiple of the elementary charge, e.
- In $q = ne$, n, the number of charge carriers, has to be an integer.
- Because you cannot cut protons and electrons into pieces.

So the answer is … No, you cannot have a net charge of $-2.00 \times 10^{-19} C$ on an object.