ISP220, fall 2021: In-Class Project #7; 15 pts, Plus 10 points bonus!

Quarks, Spacetime, and the Big Bang

Tuesday, September 28, 2021

Name: KEY Student # __________

1 Electrostatic Forces, 7 points

Figure 1 shows two electric charges, Q_A and Q_B.

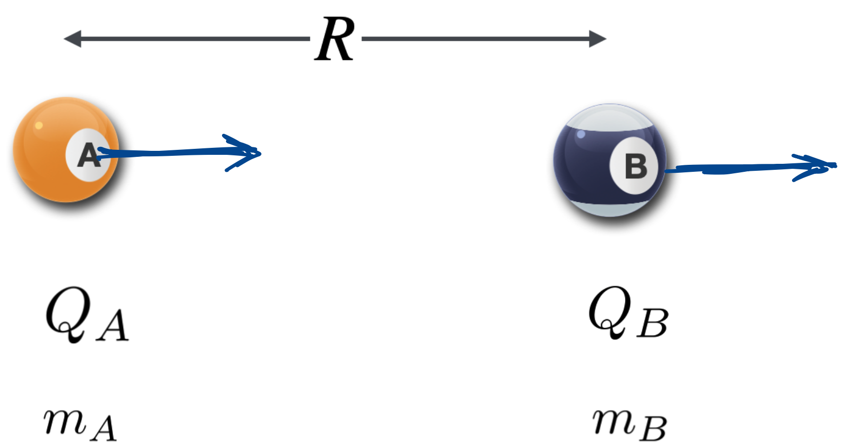


Figure 1: Two charges which will be a part of this first set of questions.

Answer (1 point): **If Q_A is positive and Q_B is negative, draw an arrow at Q_A to represent the force that Q_A experiences due to B.**

Answer (1 point): **If Q_A is positive and Q_B is positive, draw an arrow at Q_B to represent the force that Q_B experiences due to B.**

(Taken together, these two uses of one image will be incompatible situations, just preserving space!)

In each of the following, relate F_{AB}(after) (the force on A due to B in an original charge configuration) and F_{BA}(before one of the parameters has changed):

$$F_{AB}(\text{after}) = X F_{AB}(\text{before})$$

We'll be looking for X:

Answer (1 point): If $|Q_A| = |Q_B|$, $X =$ 1

("| |" means the magnitude of a quantity, without a sign)

Answer (1 point): If $|Q_A| = 2 \times |Q_B|$, $X =$ 2

Answer (1 point): If $|Q_A| = 0.5 \times |Q_B|$, $X =$ 0.5

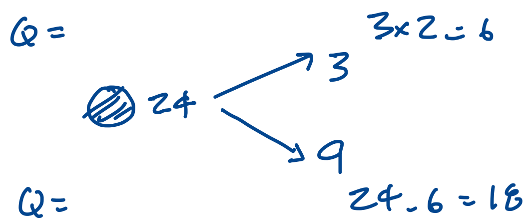
Answer (1 point): If $|Q_A| = |Q_B|$ and $m_A = m_B$, $X =$ 1

Answer (1 point): If $|Q_A| = |Q_B|$ and $m_A = 2 \times m_B$, $X =$ 1

2 Charge Conservation, 3 points

Imagine the decay of a very unusual particle that has a charge of $Q = +24e$.

Answer (3 points): If it decays into 12 particles, 3 of which have electrical charges of $2e$ each, what is the collective charge of the other 9 particles?



Q_{total} 18 e

3 Explicit Coulomb's Law, 3 points

This is a about accurate. Suppose you walk across the carpet in December. Your socks will pick up negative charges which will be distributed over your body. Let's say that total charge is

$$Q_T = 160 \text{ micro-Coulombs}$$

Answer (1 point): In scientific notation ($A \times 10^B$), what is that charge in "just" Coulombs?

$Q_T =$ 160×10^{-6} C $= 1.6 \times 10^{-4}$ C

A single electron has a charge of

$$Q(e) = 1.6 \times 10^{-19} \text{ C}$$

Answer (2 points): Roughly how many electrons have you accumulated during your stroll?

$$\frac{1.6 \times 10^{-4}}{1.6 \times 10^{-19}} = 10^{15}$$

$N =$ 10^{15}

4 Compasses around a wire, 2 points

We'll use this image in Figure 2 a lot for currents and other directional quantities going into and out of a piece of paper or the screen. The image of literal arrows:

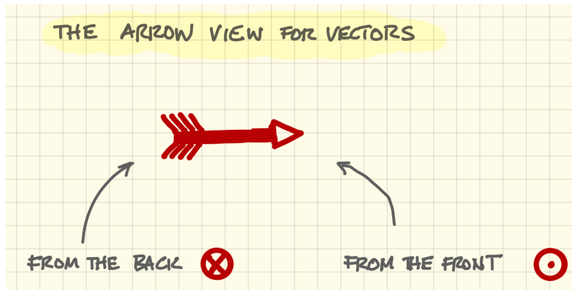


Figure 2: Vectors going into the screen or paper will be drawn as their back-end feathers. Arrows coming out of a screen or paper will be drawn as the point of the arrow.

Keeping the Oersted experiment in mind, look at Figure 3:

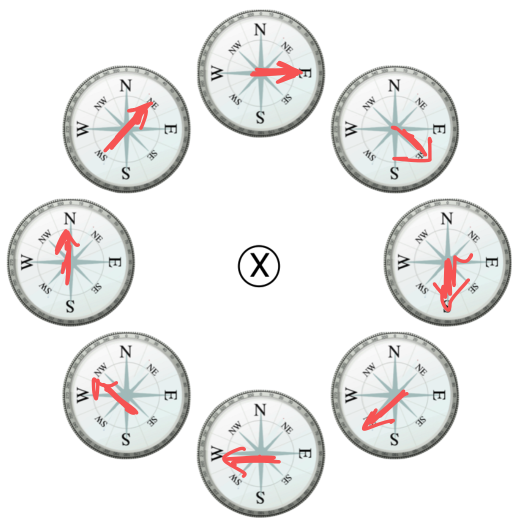


Figure 3: Vectors going into the screen or paper will be drawn as their back-end feathers. Arrows coming out of a screen or paper will be drawn as the point of the arrow.

Answer (2 points): **Draw in on Figure 3 what the compass needles would show if that current is as shown in the figure. Make the arrow the "North" direction.**

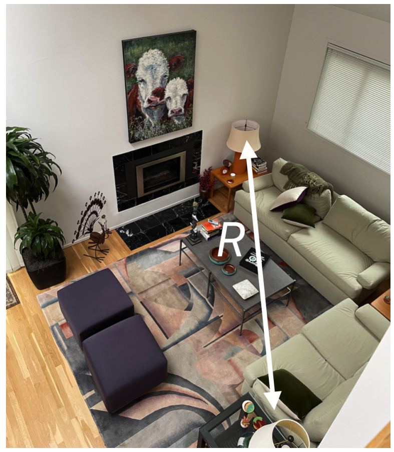


Figure 4: Home.

5 Charges in a current, 10 extra points

Figure 4 is a picture of part of our living room from a balcony above. The two lamps are separated by a distance

$$R = 3 \text{ m}$$

In each lamp (T, top and B, bottom) one Ampere of current flows.

Answer (2 point): From the definition of an Amp, how many Coulombs of charge per second flows through each lamp?

$Q =$ 1 C/s

Answer (3 point): From the definition of a Coulomb, how many electrons per second is that?

$$1\,\text{C}\left(\frac{1\,\text{electron}}{1.6\times10^{-19}\,\text{C}}\right) = 3.8\times10^{18}\ \text{electrons}$$

N(electrons) = 3.8×10^{18}

Answer (3 point): From Coulomb's law, $F = k\frac{Q_T Q_B}{R^2}$ how much force in N is that between those charges during a second? Use the approximation that $k = 9 \times 10^9$ Nm^2/C^2.

$$F = k \frac{Q_T Q_B}{R^2} = 9 \times 10^9 \frac{(1)(1)}{9} = 10^9 \text{ N}$$

$F =$ 10^9 N

Answer (2 points): Ask Mr Google how many tons this force is.

$F =$ ~100,000 tons