Physics 1B: Electricity & Magnetism
Summer Session I, 2010

Quiz #1, 07/01/2010

1. A metallic object holds a total charge of -6.6×10^{-7} C. What total number of electrons does this amount of charge represent?

a. 1.1×10^{11}
b. 1.6×10^{13}
c. 4.1×10^{12}
d. 1.6×10^{12}
e. 9.0×10^{9}

The unit of elementary charge, e, is 1.6×10^{-19} C; each electron has a charge –e. The number of electrons is (total charge)/(–e) = $(-6.6 \times 10^{-7}$ C)/(1.6×10^{-19} C) = 4.1×10^{12}.

2. Two identical balls have the same amount of charge, but the charge on ball A is positive and the charge on ball B is negative. The balls are placed on a smooth, level, frictionless table whose top is an insulator. Which of the following is true?

a. Since the force on A is equal but opposite to the force on B, they will not move.
b. They will move together with constant acceleration.
c. Since the force on both balls is negative they will move in the negative direction.
d. Since the forces are opposite in direction, the balls will move away from each other.
e. None of the above is correct.

The two balls will start moving towards each other, but their acceleration will not be constant. The acceleration a of each ball is related to the magnitude of the instantaneous electrostatic force F_e via $F_e = ma$, but F_e at any given instant depends on the distance of separation r of the two balls, which is decreasing as the balls roll towards each other. So as r decreases, F_e increases, and the instantaneous acceleration will also be increasing (not constant). So the answer is "none of the above."

3. A ping-pong ball covered with a conducting graphite coating has a total mass of 4 grams and carries an excess charge of -0.2μC. What is the magnitude and direction of the electric field needed to exactly balance the weight of the ball? ($g = 9.8$ m s^{-2})

a. 2.0×10^{5} N/C, upward
b. 2.0×10^{5} N/C, downward
c. 20×10^{8} N/C, upward
d. 2.0×10^{-1} N/C, downward
e. 20×10^{8} N/C, downward

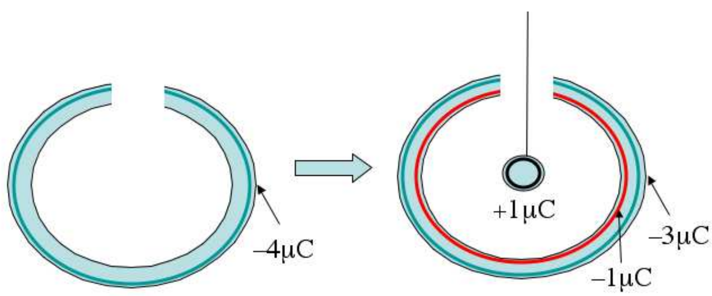
We need to counterbalance the gravitational force $\vec{F_g}$ pulling the ball downward with an electrostatic force $\vec{F_e}$ pulling the ball upward. Because the charge is negative, $\vec{F_e}$ and $\vec{E}$ will point in opposite directions, so we need an electric field whose field lines point **downward**.

We have $F_g = mg$ where g is the gravitational acceleration and $F_e = qE$, and the magnitudes of the two forces are equal.

$mg = qE$
$E = mg/q = (0.004\text{kg})(9.8 \text{ m s}^{-2})/(2 \times 10^{-7}\text{C}) = 2.0 \times 10^5 \text{ N/C}$

4. A hollow metallic conducting sphere with an initial charge X and with a radius of 4 cm has a small, cube-shaped object with a charge of $+1\mu$C carefully placed at the center of the sphere through a hole in the sphere's surface. With the charge in place, the charge now present on the outside surface of the sphere is measured to be -3μC. What was the initial charge X on the sphere?
a. $+2\mu$C
b. zero
c. -4μC
d. $+4\mu$C
e. -2μC

After the small cube with a charge of $+1\mu$C is placed into position, it will cause -1μC to accumulate on the inner surface of the conducting sphere. But the total charge in the conductor must be conserved (there was no contact between the cube and the conducting sphere): the initial charge X must be equal to the total of the charges on the inner and outer surfaces after the cube is in place. So X must be $(-1\mu\text{C}) + (-3\mu\text{C}) = -4\mu$C.



5. An object with total charge $+10\mu$C is placed at the origin, and a second object is placed on the negative x-axis at (x = –10 cm, y = 0). If the resulting force on the second object is 5.5 N in the positive x-direction, what is the value of its charge?
a. -61.0μC
b.$+6.1\mu$C
c. -0.61μC
d. $+0.61\mu$C
e. -6.1μC

The resulting force directs object 2 towards object 1: it's an attracting force, so the two objects must have charges which are opposite in sign, so the answer must be a negative value.

Now we calculate the magnitude of the charge:

$F_e = \frac{k_e q_1 q_2}{r^2}$
Here are given r,F_e and q_1, and we need to solve for q_2:
And we know that q_2 must be negative, since q_1 is positive:

$q_2 = -\frac{r^2 F_e}{k_e q_1} = -\frac{(0.1m)^2 5.5N}{9\times10^9 Nm^2C^{-2} 1.0\times10^{-5}C}$

$q_2 = -6.1 \times 10^{-7}C= -0.61\mu$C

6. An object with a charge 40μC is located at the origin. A second object with a charge 20μC is located at (x = +1 cm, y = 0). A third object with a charge 10μC is located at (x = 0, y = –1 cm). Which of the following best represents the magnitude of the electric field at a point far away along the +y-axis, at (x = 0, y = +0.5m)?

a. 1.8×10^8 N/C
b. 5.4×10^6 N/C
c. 1.8×10^6 N/C
d. 2.5×10^6 N/C
e. 1.3×10^6 N/C

The key here is the phrase "best represents" – we can do some simplifications here. Note that we're trying to measure the electric field at a distance r which is much, much greater than the separations of the three charges. So the total electric field from all three charges will be very similar to the electric field from a single charge that is located very close to the origin and whose charge is equal to the sum of the three charges above, 40μC + 20μC + 10μC = 70μC.

The electric field will be equal to $\frac{k_e Q}{r^2} = \frac{9\times10^9 Nm^2C^{-2} 70\times10^{-6}C}{(0.5m)^2} = 2.5 \times 10^6$ N/C

7. Object A is illustrated with 10 electric field lines coming out from it, Object B has 20 lines coming out, Object C has 30 lines coming out, and Object D also has 30 lines coming out. Which pair of these charges will have the largest electrostatic force between them if placed one cm apart?

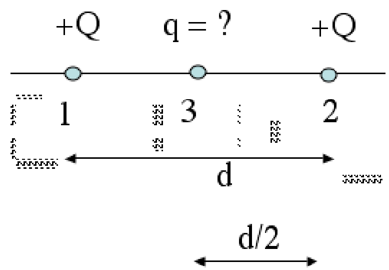
a. A and B
b. B and C
c. A and D
d. C and D
e. More information is needed.

The magnitude of the electrostatic force is $F_e = \frac{k_e q_1 q_2}{r^2}$, i.e., it's proportional to the magnitudes of each charge. Recall that the number of field lines terminating or beginning on any object is directly proportional to the amount of charge on that object. So objects C and D each have the most amount of charge, and these two will yield the strongest electrostatic force.

8. Two equal charges, each Q, are separated by some distance. What third charge would need to be placed halfway between the two charges so that the net force on each charge

would be zero?

a. –2Q
b. –Q
c. –Q/2
d. –Q/4
e. –Q/8



Label the charges as shown: objects 1 and 2 each have charge +Q and are separated by a distance d. Let's say the third object has some unknown charge q.

The force on object 2 due to the electric field associated with object 1 is $\vec{F_{12}}$. The force on object 2 due to the electric field associated with object 3 is $\vec{F_{32}}$. These two vectors must sum up to be zero.

$\vec{F_{12}} + \vec{F_{32}} = 0.$

$\frac{k_e QQ}{d^2} + \frac{k_e Qq}{(d/2)^2} = 0$

Cancel out the k_e and one Q from each side:

$\frac{Q}{d^2} + \frac{q}{(d/2)^2} = 0$

$\frac{Q}{d^2} + \frac{4q}{d^2} = 0$

Q + 4q = 0

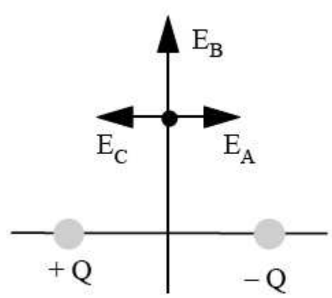
q = –Q/4

9. Two charges, +Q and –Q, are located two meters apart and there is a point equidistant

from the two charges as indicated. Which vector best represents the direction of the electric field at that point?

a. Vector E_A
b. Vector E_B
c. Vector E_C
d. The electric field at that point is zero.
e. None of the above

The electric field lines originate on the positive cahrge and terminate on the negative charge. Everywhere along the line which is equidistant from both charges, the field lines will be pointing exactly to the right. The answer is Vector E_A.



E_B
E_C
E_A
+ Q
− Q