Quiz 3

Constants

permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{C^2/(N \times m^2)}$
mass of an electron	$m_e = 9.11 \times 10^{-31}$ kg
mass of a proton	$m_p = 1.67 \times 10^{-27}$ kg
nano, n	1×10^{-9}
micro, μ	1×10^{-6}
coulomb constant	$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ \mathrm{Nm^2/C^2}$
magnitude of the charge of an electron or proton	$e = 1.6 \times 10^{-19}$ C
electrostatic constant	$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ \mathrm{N \cdot m^2/C^2}$

Coulomb force

$$|\vec{F}_{coul}| = \frac{1}{4\pi\varepsilon_0}\frac{|q_1||q_2|}{r^2}$$

Electric field due to a charged particle

$$|\vec{E}| = \frac{1}{4\pi\varepsilon_0}\frac{|q|}{r^2}$$

Force by an electric field on a charged particle

$$\vec{F} = q\vec{E}$$

Potential Difference

Along a path in the x-direction between initial point i and final point f, if $\vec{E}$ is constant or if Δx is small, then

$$\Delta V = -E_x \Delta x$$

Often, it's useful to calculate the magnitude of the potential difference. For a 1-D constant electric field, the potential difference a distance d along a direction parallel to the field is:

$$|\Delta V| = Ed$$

Physics 1520, Fall 2012
Quiz 3, Form: A

Name: Key
Date:

Numeric answers must include units. Sketches must be labeled. All short-answer questions must include your reasoning, for full credit. A correct answer with no reasoning will only receive partial credit.

Section 1. Exercises

1. Four lightweight balls A, B, C, and D are suspended by threads. Ball A has been touched by a plastic rod that was rubbed with wool. When the balls are brought close together, without touching, the following observations are made:

   –Balls B, C, and D are attracted to ball A.
   –Balls B and D have no effect on each other. B and D are neutral
   –Ball B is attracted to Ball C. Ball C is charged ; C and A are charged.

   What is the charge state (positive, negative, neutral) of Ball A?

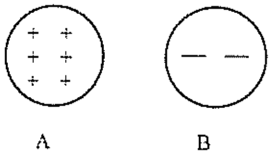
   Since C is attracted to A, then they are oppositely charged.

   (a) positive
   (b) negative
   (c) neutral
   [✓ (d)] It is definitely charged, but it could be positively charged or negatively charged.

2. What is the charge state of Ball B in the previous question?

   (a) positive
   (b) negative
   [✓ (c)] neutral
   (d) It is definitely charged, but it could be positively charged or negatively charged.

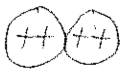
Questions 3–5: A metal sphere A has a charge of +6 μC and a metal sphere B has a charge of −2 μC.



Total charge is 4μC.

The two spheres hang by threads and are allowed to make contact with each other.

3. After they make contact, what is the charge of sphere B?

   charge spreads evenly.

   (a) zero; it will be neutral.
   (b) +4 μC
   (c) +3 μC
   (d) −2 μC
   [✓ (e)] +2 μC

4. How did sphere B gets its charge after making contact with sphere A?

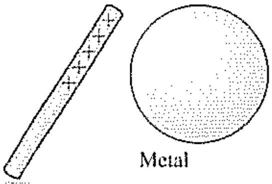
   Protons don't move.
   Sphere B lost negative charge.
   Sphere A gained negative charge.

   (a) Protons moved from sphere B to sphere A.
   (b) Protons moved from sphere A to sphere B.
   (c) Electrons moved from sphere A to sphere B.
   [✓ (d)] Electrons moved from sphere B to sphere A.
   (e) None of the above because no charge was transferred between the spheres.

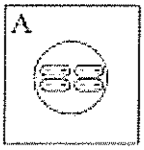
5. After the spheres make contact, they will

[✓ (a)] repel each other until reaching mechanical equilibrium.
(b) attract each other and remain in contact.
(c) be neutral and remain in contact, though they neither repel nor attract.

6. A positively charged rod is brought near (but does not touch) a neutral metal sphere as shown below.



Which picture below most closely resembles the metal sphere?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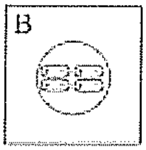
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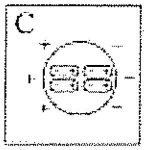
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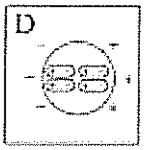
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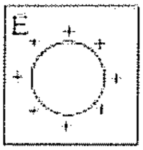
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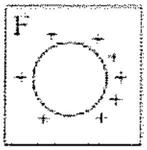
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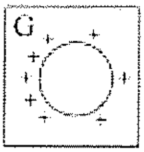
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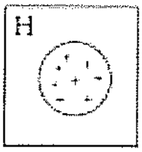
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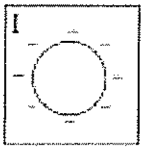
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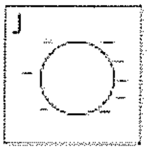
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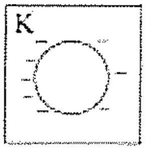
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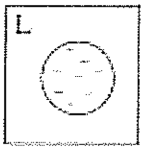
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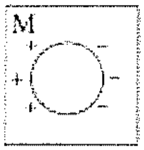
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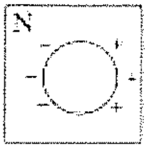
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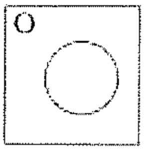

O

(a) A
(b) F
(c) I
(d) K
[✓ (e)] N

Electrons are attracted toward the rod, leaving positive charge behind.

7. A hydrogen nucleus, which has a charge $+e$, is situated to the left of a carbon nucleus, which has a charge $+6e$. On which nucleus is the electric force (by the other nucleus) the largest in magnitude?

(a) Hydrogen nucleus.
(b) Carbon nucleus.
[✓ (c)] Neither; the force on each nucleus is the same.

Newton's third law.

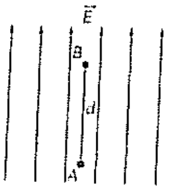
Also, $F_{coul} = \frac{(9\times10^9)|q_1||q_2|}{r^2}$ is same for both.

8. You have two neutral pieces of Scotch tape stuck together. You rip them apart. Using a charged ball on a pendulum, you figure out that a piece of tape has a charge of approximately $+1 \times 10^{-8}$ C. How many electrons did this piece of tape lose when the two pieces of tape were pulled apart?

   (a) 1×10^{8} electrons
   [✓ (b)] 6×10^{10} electrons
   (c) 1.6×10^{11} electrons
   (d) 1.6×10^{19} electrons

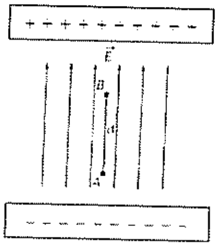
$$(1 \times 10^{-8} C)\left(\frac{1 \text{ electron}}{1.6 \times 10^{-19} C}\right) = 6.25 \times 10^{10} \text{ electrons}$$

9. A uniform electric field is shown below.



The electric field is produced by plates of charge $+Q$ and $-Q$. Which of the pictures below shows the orientation of the plates?

A



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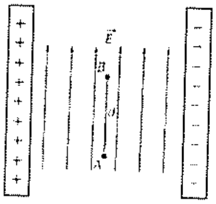

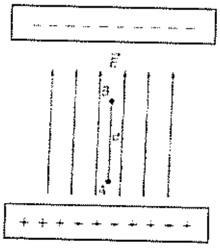

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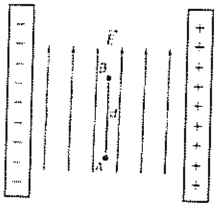


D

$\vec{E}$ points toward − and away from +.

   (a) A
   (b) B
   [✓ (c)] C
   (d) D

10. An atom of helium and an atom of argon are singly ionized (one electron is removed from each atom). The argon atom has about 36 times more mass than the helium atom. The two ions are then accelerated from rest by an electric field between two plates with a potential difference of 150 V. After accelerating from one plate to the other,

   (a) The helium ion has more kinetic energy.
   (b) The argon ion has more kinetic energy.
   [✓ (c)] Both ions have the same kinetic energy.
   (d) There is not enough information to say which ion has more kinetic energy.

$$\Delta K + \Delta U = 0$$
$$\Delta K = -\Delta U = -(-e\Delta V)$$
$$= e\Delta V$$
$$= 150 \text{ eV}$$

same ΔK!

11. For the atoms in the previous question, which one will have a greater speed after reaching the other plate?

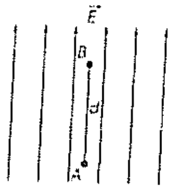
[✓ (a)] The helium atom

(b) The argon atom

(c) Neither; because they will have the same speed.

$K_f = \frac{1}{2} m v_f^2$ less m, greater v_f

12. As an electron travels from point A to point B in the electric field shown below, the electron



$\vec{v}$ ↑ e^- ↓ $\vec{F}$

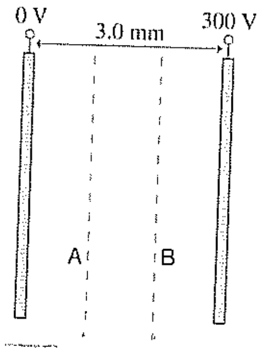
$\vec{F}$ is opposite $\vec{v}$, so the electron slows down.

(a) gains kinetic energy.

[✓ (b)] loses kinetic energy

(c) has no change in kinetic energy.

Questions 13–14:
Two plates of charge $+Q$ and $-Q$ are shown below.



13. What is the electric potential at a point along line A, in between the charged plates?

(a) 50 V

[✓ (b)] 100 V

(c) 150 V

(d) 200 V

(e) 250 V

V changes linearly. Since A is $\frac{1}{3}$ of the distance from 0 to 300 V, then it is $\frac{1}{3}$ the voltage (i.e. potential).

14. What is the electric field at any point between the plates?

(a) zero

(b) 100 V/m

(c) 300 V/m

(d) 0.9 V/m

[✓ (e)] 1×10^5 V/m

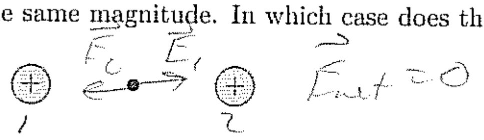
$|\Delta V| = Ed$

$$E = \frac{300V}{3\times10^{-3}m} = 1\times10^5 \frac{V}{m}$$

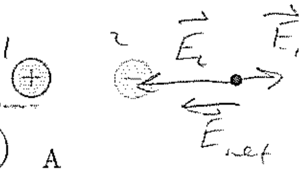
15. All of the charges shown below have the same magnitude. In which case does the electric field at the dot have the largest magnitude?

A.

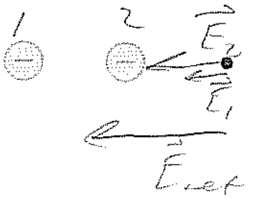
B.



C.



D.



[✓ (a)] A
(b) B
(c) C
(d) D

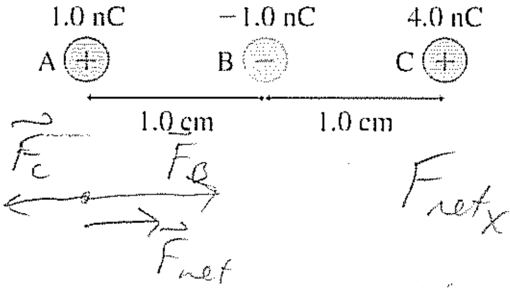
16. A protein molecule in an electrophoresis gel has a negative charge. The exact charge depends on the pH of the solution, but 30 excess electrons is typical. What is the magnitude of the electric force on a protein with the 28 excess electrons in a 1400 N/C electric field?

[✓ (a)] 6.3×10^{-15} N
(b) 39,200 N
(c) 2.24×10^{-16} N
(d) 1,400 N
(e) 3.1×10^{20} N

$F = qE$
$= 28(1.6\times10^{-19}C)(1400\frac{N}{C})$
$= 6.27\times10^{-15} N$

Section 2. Critical Thinking

17. What are the magnitude and direction of the net electric force on charge A shown below?



$$F_{net_x} = F_B - F_C$$

$$F_B = \left(9\times10^{9}\ \frac{Nm^2}{C^2}\right)\left(\frac{(1\times10^{-9}C)(1\times10^{-9}C)}{(1\times10^{-2}m)^2}\right) = 9\times10^{-5}\ N$$

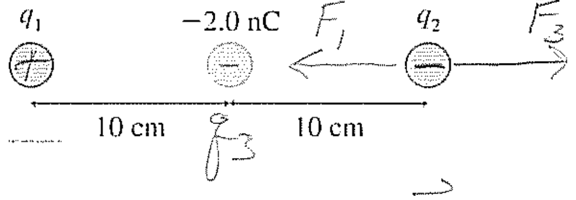
$$F_C = \left(9\times10^{9}\ \frac{Nm^2}{C^2}\right)\left(\frac{(1\times10^{-9}C)(4\times10^{-9}C)}{(2\times10^{-2}m)^2}\right)$$

$$= 9\times10^{-5}\ N$$

Thus $F_{net_x} = F_B - F_C = \boxed{0}$

charge A is in equilibrium

18. In the figure below, charge q_2 experiences no electric force. (i.e. It is in equilibrium.) What must be the force by charge q_1 on q_2? Give both the magnitude and direction.



Assume q_2 is negatively charged.
Then q_1 is positively charged.

$$F_1 = F_3 \quad \text{So} \quad \vec{F}_{net} = 0$$

$$F_3 = \left(9\times10^{9}\,\frac{N\cdot m^2}{C^2}\right)\left(\frac{(2\times10^{-9}C)\,q_2}{(0.1m)^2}\right)$$

$$F_1 = \left(9\times10^{9}\,\frac{N\cdot m^2}{C^2}\right)\left(\frac{q_1 q_2}{(0.2m)^2}\right)$$

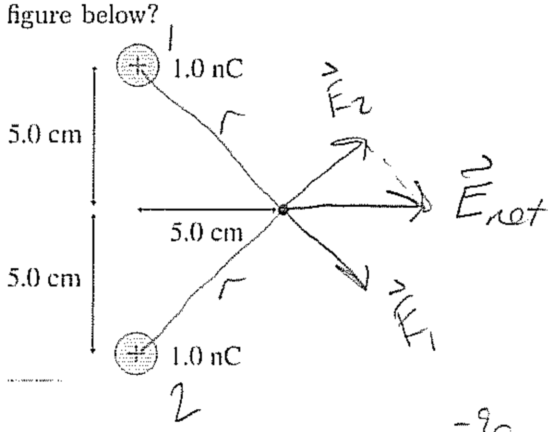
$$F_1 = F_3$$

$$\cancel{\left(9\times10^{9}\,\frac{N\cdot m^2}{C^2}\right)}\frac{(2\times10^{-9}C)\,\cancel{q_2}}{(0.1m)^2} = \cancel{\left(9\times10^{9}\,\frac{N\cdot m^2}{C^2}\right)}\frac{q_1\cancel{q_2}}{(0.2m)^2}$$

$$q_1 = (2\times10^{-9}C)\frac{(0.2m)^2}{(0.1m)^2} = 8\times10^{-9}C$$

$$\boxed{F_1 = \left(9\times10^{9}\,\frac{N\cdot m^2}{C^2}\right)\frac{(8\times10^{-9}C)\,q_2}{(0.2m)^2}}$$

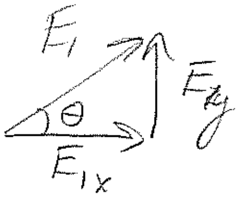
19. What are the strength and direction of the electric field at the position indicated by the dot in the figure below?



$$r = \sqrt{5cm^2 + 5cm^2}$$
$$= 7.07 \text{ cm}$$
$$= 0.0707 \text{ m}$$

$$E_1 = \left(9\times10^9 \frac{Nm^2}{C^2}\right)\left(\frac{1\times10^{-9}C}{(0.0707m)^2}\right) = 1800 \frac{N}{C}$$

$$E_2 = 1800 \frac{N}{C}$$



$$E_{net\,x} = E_{1x} + E_{2x}$$
$$= 1273 \frac{N}{C} + 1273 \frac{N}{C}$$
$$= \boxed{2550 \frac{N}{C}}$$

$$E_{1x} = E_1 \cos(45°) = 1800 \frac{N}{C} \cos(45°)$$
$$= 1273 \frac{N}{C}$$

20. A proton is accelerated from rest by a potential difference of magnitude 1000 V.

(a) What is the change in kinetic energy of the ion in units of eV? What is this in J?

$$\Delta K + \Delta U = 0$$

$$\Delta K = -\Delta U$$

$$= -(q\,\Delta V)$$

$$= -(1.6\times10^{-19}\,C)(-1000\,V)$$

$$= \boxed{1.6\times10^{-16}\,J}$$

$$\Delta K = -(e)(-1000\,V)$$

$$= \boxed{1000\,eV}$$

(b) What is the final speed of the ion after being accelerated through a potential difference of 1000 V?

$$K_f - \cancelto{0}{K_i} = 1.6\times10^{-19}\,J$$

$$K_f = \frac{1}{2} m v_f^2$$

$$v_f = \sqrt{\frac{2K_f}{m}} = \sqrt{\frac{2(1.6\times10^{-16}\,J)}{1.67\times10^{-27}\,kg}}$$

$$\boxed{v_f = 4.38\times10^{5}\,\frac{m}{s}}$$