

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

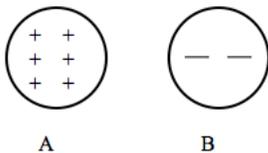
1. Four lightweight balls A, B, C, and D are suspended by threads. Ball A has been touched by a plastic rod that was rubbed with wool. When the balls are brought close together, without touching, the following observations are made:

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

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

- (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.

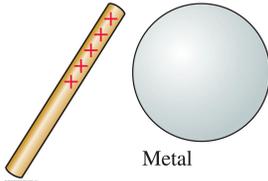
Questions 3–5: A metal sphere A has a charge of  $+6 \mu\text{C}$  and a metal sphere B has a charge of  $-2 \mu\text{C}$ .



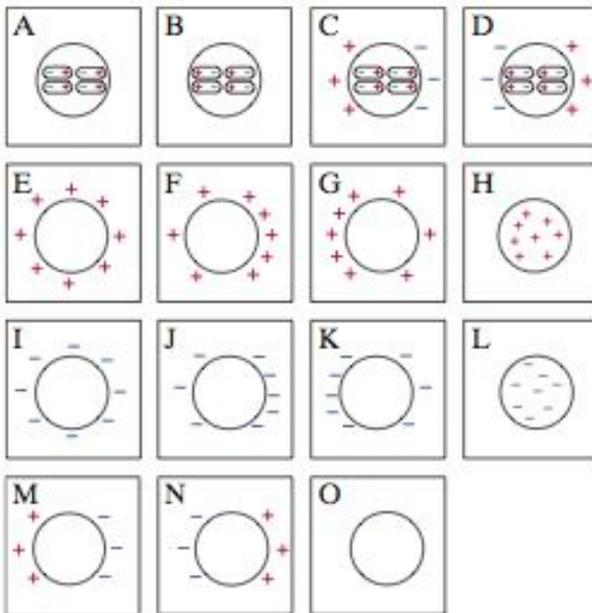
The two spheres hang by threads and are allowed to make contact with each other.

3. After they make contact, what is the charge of sphere B?
- (a) zero; it will be neutral.
  - (b)  $+4 \mu\text{C}$
  - (c)  $+3 \mu\text{C}$
  - (d)  $-2 \mu\text{C}$
  - (e)  $+2 \mu\text{C}$
4. How did sphere B get its charge after making contact with sphere A?
- (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
- repel each other until reaching mechanical equilibrium.
  - attract each other and remain in contact.
  - 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.

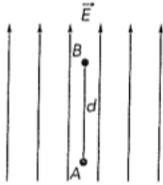


Which picture below most closely resembles the metal sphere?

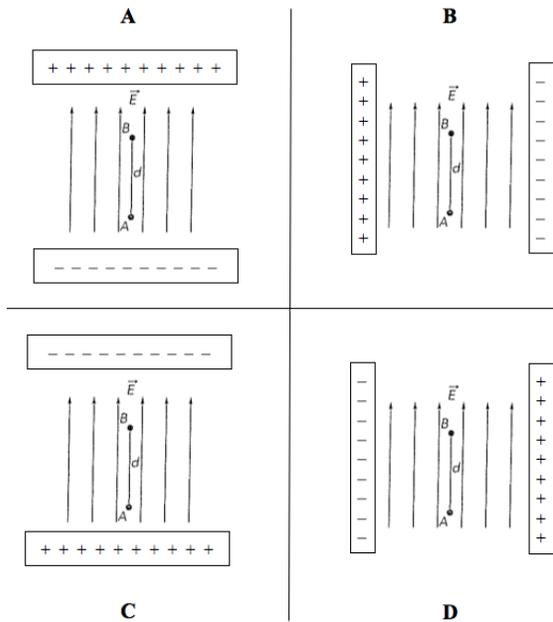


- A
  - F
  - I
  - K
  - N
7. A hydrogen nucleus, which has a charge  $+e$ , is situated to the left of a carbon nucleus, which has a charge  $+6e$ . On which nucleus is the electric force (by the other nucleus) the largest in magnitude?
- Hydrogen nucleus.
  - Carbon nucleus.
  - Neither; the force on each nucleus is the same.

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)  $1 \times 10^8$  electrons  
 (b)  $6 \times 10^{10}$  electrons  
 (c)  $1.6 \times 10^{11}$  electrons  
 (d)  $1.6 \times 10^{19}$  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?

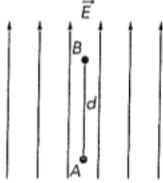


- (a) A  
 (b) B  
 (c) C  
 (d) D
10. An atom of helium and an atom of argon are singly ionized (one electron is removed from each atom). The argon atom has about 36 times more mass than the helium atom. The two ions are then accelerated from rest by an electric field between two plates with a potential 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.

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.

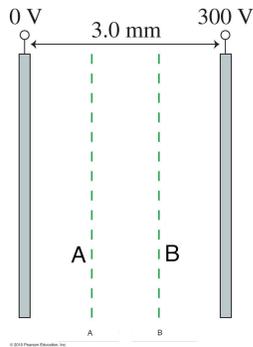
12. As an electron travels from point A to point B in the electric field shown below, the electron



- (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

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)  $1 \times 10^5$  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?



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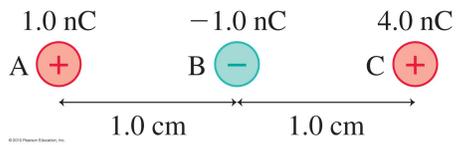
- (a) A
- (b) B
- (c) C
- (d) D

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?

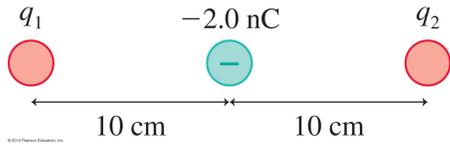
- (a)  $6.3 \times 10^{-15}$  N
- (b) 39,200 N
- (c)  $2.24 \times 10^{-16}$  N
- (d) 1,400 N
- (e)  $3.1 \times 10^{20}$  N

Section 2. Critical Thinking

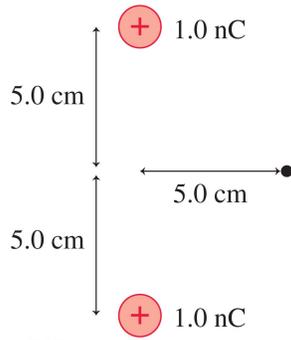
17. What are the magnitude and direction of the net electric force on charge A shown below?



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.



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



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?

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

# Answer Key for Exam A

## Section 1. Exercises

- |        |         |
|--------|---------|
| 1. (d) | 9. (c)  |
| 2. (c) | 10. (c) |
| 3. (e) | 11. (a) |
| 4. (d) | 12. (b) |
| 5. (a) | 13. (b) |
| 6. (e) | 14. (e) |
| 7. (c) | 15. (d) |
| 8. (b) | 16. (a) |

## Section 2. Critical Thinking

17.

18.

19.

20.