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Multiple Choice [5 pts each] Bubble in the most correct answer on your bubble sheet and circle the correct answer here.

1. [5 pts] A system consists of 155 protons and 34 electrons. What is the net charge of the system in units of Coulombs?

88%

   A. +121 C
   B. +189 C
   C. $+1.9 \times 10^{-17}$ C
   D. -1.9×10^{-17} C
   E. $+3.1 \times 10^{-17}$ C

$Q_{tot} = +155e + (-34e) = 121e$
$= (121)(1.6\times10^{-19}C)$
$= 1.9\times10^{-17}C$

65%

2. [5 pts] A proton of mass m_p and an electron of mass m_e are placed a distance r apart and then released from rest. Which one of the following is true about this situation? Recall, $m_p > m_e$.

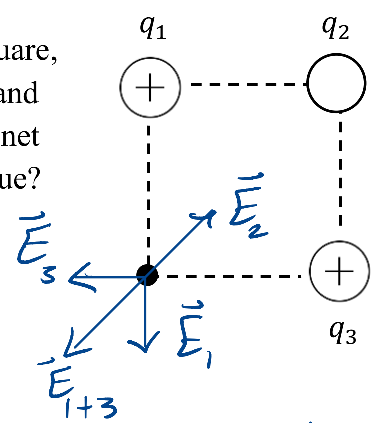
violates Coulomb and Newton 3rd

   × A. The electric force on the electron is greater than the electric force on the proton.
   B. The electric force on the electron is the same in magnitude as that on the proton.
   × C. When released, the electron's acceleration is smaller than that of the proton.
   × D. The electron and the proton both experience the same acceleration upon release.
   × E. More than one of the above is correct.

$F_{ep} = F_{pe} \Rightarrow a_e > a_p$

69%

3. [5 pts] Consider three charges placed at the corners of a square, $q_1 = q_3 = +q$ and another charge q_2 of an unknown sign and magnitude. At the fourth corner, there is no charge and the net electric field there is zero. Which one of the following is true?



   A. q_2 is negative and less in magnitude than q.
   B. q_2 is positive and less in magnitude than q.
   C. q_2 is negative and greater in magnitude than q.
   D. q_2 is positive and greater in magnitude than q.
   E. q_2 is negative and equal in magnitude to q.

$\vec{E}_2$ points towards $q_2 \Rightarrow q_2 < 0$; q_2 is farther than q_1 and q_3 and has to provide a larger field $\Rightarrow |q_2| > q$

4. [5 pts] The electric field at a given location is pointing in the $-y$ direction and has a magnitude of 50.0 N/C. What is the acceleration of particle of charge -1.30 C and mass 6.00 kg placed at that location? Assume the electric force is the only force acting.

86%

   A. 10.8 m/s^2 in the $+y$ direction.
   B. 12.3 m/s^2 in the $-y$ direction.
   C. 9.26 m/s^2 in the $+y$ direction.
   D. 17.2 m/s^2 in the $-y$ direction.
   E. 18.0 m/s^2 in the $+y$ direction.

$\vec{F} = m\vec{a} = q\vec{E}$
$\Rightarrow \vec{a} = \frac{q}{m}\vec{E}$
$\downarrow \vec{E} \quad \downarrow -y$
$a_y = \frac{(-1.30C)(-50.0N/C)}{6.00kg}$
$= +10.8 s^2$

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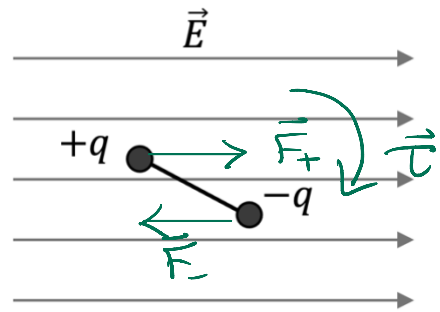
63%

5. [5 pts] An electric dipole is initially at rest in a region of uniform electric field in the orientation shown at right.



Immediately after the dipole is released, which of the following statements are **true**? Ignore gravity.

✓ I. The dipole will begin to rotate clockwise.
✓ II. The net force on the dipole is zero.
✗ III. The entire dipole will accelerate to the right.

A. I and II
B. I and III
C. II only.
D. III only.
E. I, II, and III.

Since $\vec{E}$ = const $\Rightarrow$ $\vec{F}_+ = -\vec{F}_-$
$\Rightarrow \vec{F}_{net} = 0 \Rightarrow$ (III) is wrong and (II) is correct

The direction of the forces will cause a clockwise rotation $\Rightarrow$ (I) is correct

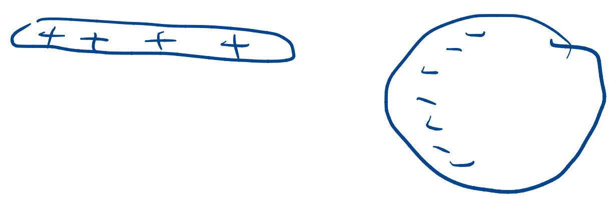
71%

6. [5 pts] A plastic rod is uniformly charged with positive charge. When the rod is brought close to a conducting sphere, there is an attractive force between the rod and the sphere. In this scenario, which of the following are **possible**?

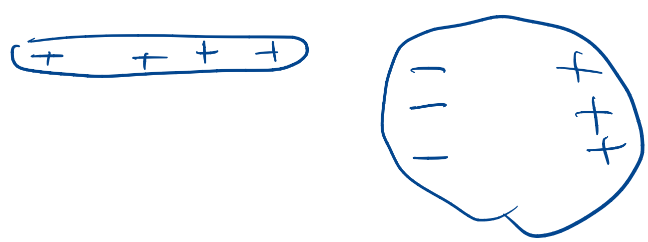
I. The conducting sphere has excess negative charge.
II. The conducting sphere has zero excess charge.
✗ III. While the rod is nearby, all the charges in the sphere are uniformly distributed throughout the sphere.

A. I. only.
B. II. only.
C. I. and II.
D. I. and III.
I., II. and III.

I.



II.



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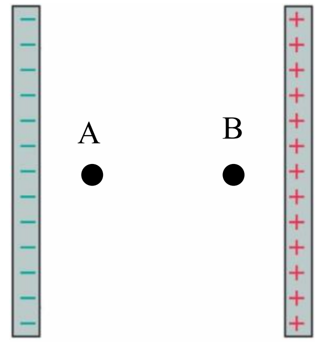
Use the following scenario to answer the next three questions:

The uniform electric field between the plates of a charged, vacuum-filled parallel-plate capacitor has a magnitude of 300 N/C. Each plate has an area of $0.270\ \mathrm{m}^2$ and the plates are separated by a distance of ~~5.00×10^{-3} m.~~ d



7. [5 pts] What is the magnitude of the charge on either one of the two plates?
   - A. 4.31×10^{-10} C
   - B. 2.62×10^{-10} C
   - C. 1.12×10^{-10} C
   - D. 7.17×10^{-10} C
   - E. 9.65×10^{-10} C

82%

$E_{cap} = \frac{\sigma}{\epsilon_0} = \frac{Q}{\epsilon_0 A} \Rightarrow Q = \epsilon_0 E A$

$\Rightarrow Q = (8.85 \times 10^{-12} \frac{F}{m})(300 \frac{N}{C})(0.27 m^2)$

8. [5 pts] A particle of charge $Q = -6.40 \times 10^{-6}$C (not depicted) is moved a distance of 1.00×10^{-2}m by a hand from position A to position B at constant speed. What is the work done by the hand?
   - A. -2.34×10^{-5} J
   - B. $+4.18 \times 10^{-5}$ J
   - C. -5.66×10^{-5} J
   - D. $+8.60 \times 10^{-5}$ J
   - E. -1.92×10^{-5} J

61%

$W_{ext} = \Delta E = \Delta U_{elec} + \Delta K$

$= \Delta U_{elec} + 0 = Q \Delta V$

$= Q E d$

$= (-6.40 \times 10^{-6} C)(300 \frac{N}{C})(1.00 \times 10^{-2} m)$

$= -1.92 \times 10^{-5}$ J

9. [5 pts] Is the potential difference $\Delta V = V_B - V_A$ experienced by that charged particle as it moved from position A to position B *positive*, *negative* or *zero*?
   - A. Positive
   - B. Negative
   - C. Zero
   - D. Information provided is not enough to answer.

60%

When a negative charge is moved closer to the positive plate, the potential energy decreases $\Rightarrow \Delta U < 0$

$\Rightarrow \Delta V = \frac{\Delta U}{Q} = \frac{neg}{neg} = pos$

$c = \frac{Q}{\Delta V}$

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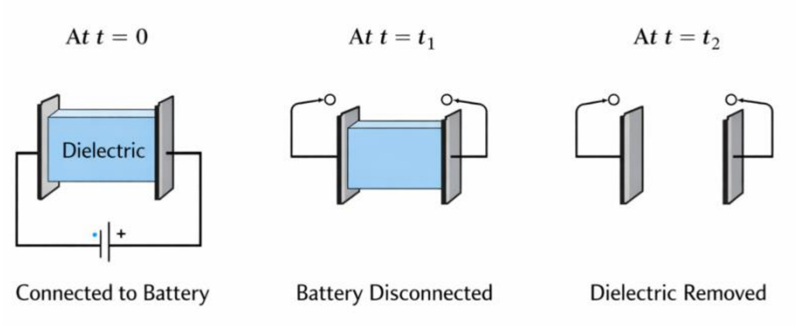
10. [5 pts] At time $t = 0$, a parallel-plate capacitor has a piece of plastic of dielectric constant $\kappa > 1$ between its plates. The capacitor is connected to a battery of emf $\mathcal{E}$. At time $t = t_1$ the battery is disconnected. Then at time $t = t_2 > t_1$, the piece of plastic is removed. Is the potential difference between the plates of the capacitor at time $t = t_2$ *greater than*, *less than* or *equal to* the potential difference between the plates at $t = 0$?

48%



A. Greater than
B. Less than
C. Equal to
D. Information provided is not enough to answer.

At $t=0$ $\Delta V_c = \mathcal{E}$, when battery is removed at $t=t_1$ charge is same $\Rightarrow \Delta V_c = \mathcal{E}$ when dielectric is removed at $t=t_2$ capacitance decreases $\Rightarrow$ charge same $\Rightarrow \Delta V_c$ increases

11. [5 pts] A cylindrical wire has a resistance R, length L, cross-sectional area A and is made of a material of resistivity ρ. We wish to manufacture another wire with resistance $2R$ from a material of resistivity 3ρ. If we want both wires to have the same length, what should the cross-sectional area of the new wire be?

70%

A. $6A$
B. $A/6$
C. A
D. $2A/3$
E. $3A/2$

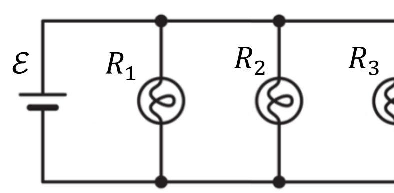
$R_1 = R = \frac{\rho L}{A}$

$R_2 = 2R = \frac{(3\rho)L}{A_2}$

divide: $\frac{R_1}{R_2} = \frac{R}{2R} = \frac{\rho L}{A} \frac{A_2}{(3\rho)L}$

$= \frac{1}{2} = \frac{A_2}{3A} \Rightarrow A_2 = \frac{3A}{2}$

12. [5 pts] In the circuit shown at right, there are three light bulbs connected in parallel with a battery of emf $\mathcal{E}$. The bulbs are not identical. They have resistances $R_1 = R$, $R_2 = 2R$ and $R_3 = 3R$. Choose the correct ranking of the currents and potential differences across the three bulbs.



70%

A. $\Delta V_1 = \Delta V_2 = \Delta V_3$ and $I_1 = I_2 = I_3$
B. $\Delta V_1 > \Delta V_2 > \Delta V_3$ and $I_1 > I_2 > I_3$
C. $\Delta V_1 = \Delta V_2 = \Delta V_3$ and $I_1 < I_2 < I_3$
D. $\Delta V_1 = \Delta V_2 = \Delta V_3$ and $I_1 > I_2 > I_3$
E. $\Delta V_1 < \Delta V_2 < \Delta V_3$ and $I_1 > I_2 > I_3$

Bulbs are in parallel $\Rightarrow \Delta V_1 = \Delta V_2 = \Delta V_3$
using Ohm's law:
$I = \frac{\Delta V}{R} \Rightarrow I_1 > I_2 > I_3$

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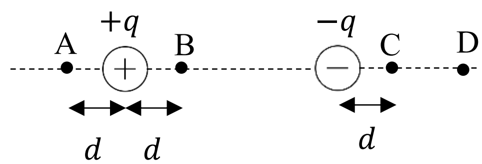
Lecture Free Response [20 pts total]: Show work and/or explain reasoning where indicated.

Two point charges $+q$ and $-q$ are fixed in space as shown at right. Locations A, B and C lie on a straight line along with the charges and are separated from the closer charge by a distance d.



13. [5 pts] Write down the correct ranking of the ***magnitudes*** of the net electric field E due to the two charges at locations A, B and C. (i.e., rank E_A, E_B and E_C). No calculation or explanation needed. $E_B > E_A = E_C$

58%

Location A is at distance d from $+q$ and a distance $d + x_{BC}$ from $-q$ and location C is also a distance d from $-q$ and $d + x_{BC}$ from $+q$, therefore the magnitudes of the field at these two locations are the same. Location B, on the other hand, is also a distance d from $+q$ but $x_{BC} - d$ from $-q$, so that $-q$ is closer and creates a field in the same direction as $+q$, hence it's larger than $E_A = E_C$.

[2 pts] for realizing E_B is the biggest

[2 pts] for $E_A = E_C$

[1 pt] $E_B > E_A = E_C$

14. [5 pts] When an electron (not depicted) is released at location C from rest, by the time it reaches location D it is moving with a kinetic energy K_D. Calculate the change in the potential energy $\Delta U_{elec} = U_D - U_C$ in terms of K_D. $\Delta U_{elec} = -K_D$

46%

$$W_{ext} = \Delta E = \Delta U_{elec} + \Delta K$$

There is no external force doing work, so that $W_{ext} = \Delta E = 0$. Therefore:

$$0 = \Delta U_{elec} + \Delta K \Rightarrow \Delta U_{elec} = -\Delta K = -(K_D - K_C)$$

But $K_C = 0$, so that:

$$\Delta U_{elec} = -K_D$$

[5 pts] Correct answer $\Delta U_{elec} = -K_D$

[3 pts] Correct answer but missing the sign

15. [5 pts] Calculate the change in the electric potential $\Delta V = V_D - V_C$ in terms of K_D and the fundamental charge e and indicate whether it is *positive*, *negative* or *zero*. No need to use the charges $+q$ and $-q$. $\Delta V = K_D/e > 0$

32%

From the previous question:

$$\Delta U_{elec} = -K_D$$

But $\Delta U_{elec} = q\Delta V$ and for an electron $q = -e$, therefore:

$$\Delta V = -\frac{K_D}{-e} = \frac{K_D}{e}$$

[3 pts] Correct answer $\Delta V = K_D/e$

[2 pts] Recognizing answer is positive

16. [5 pts] Suppose we repeat the experiment described in Q14 using a particle that has the same charge as the electron, $-e$, but has a larger mass. Is the change in electric potential energy for this particle ΔU_{elec} as it travels from C to D *greater than, less than or equal to* that of the electron? Explain briefly. *Equal to.*

43%

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Realizing that the change in potential energy does not depend on mass, and that since the charge is the same and potential difference is the same, the potential energy difference must be the same.

[2.5 pts] Answering equal to.

[2.5 pts] Giving a correct full explanation.

[1 pt] Partial explanation

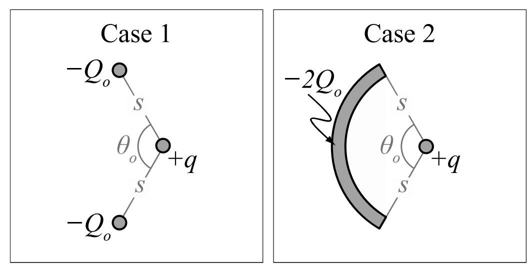
Tutorial Free Response [20 pts total]: Problems 17-20. Show work and/or explain reasoning where indicated.

The next two questions are related to the following scenario.

Consider the two cases described below.

Case 1: Two point charges $-Q_o$ are each located a distance s away from the point charge $+q$ and are an angle θ_o apart as measured from the location of $+q$. θ_o is greater than 0° and less than 180°.

Case 2: A circular arc of charge is centered on the location of $+q$. The ends of the arc make an angle θ_o. The arc has radius s and a total charge $-2Q_o$.



17. [5 pts] On the diagram above, sketch the **direction** of the net electric force in both Case 1 and in Case 2. **Explain your reasoning**.

69% [1.5 pts] Correct answer for Case 1 (to the left)

[1.5 pts] Correct answer for Case 2 (to the left)

[2 pts] Brief explanation involving symmetry / component cancellation

18. [5 pts] Is magnitude of the net electric force on $+q$ in case 1 *greater than, less than,* or *equal to* that in case 2? **Explain your reasoning**.

[3 pts] Correct answer (*Less than*, so $F_{net1} < F_{net2}$)

34% [1 pt] Treats Case 2 as many small point charges adding to $-2Q_o$

[1 pt] Explanation involves less vertical force components cancelling in Case 2 than in Case 1

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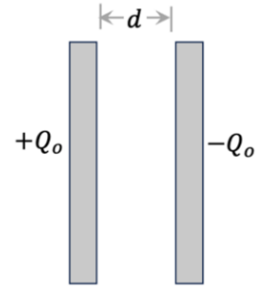
The next two questions are related to the following scenario.



Initially, a parallel-plate capacitor has plates of area A that are separated by a distance d as shown. The charge on one plate is $+Q_o$ and the charge on the other plate is $-Q_o$.

Two changes are now made: the distance between the plates is decreased to $d/3$ and the charge on the plates is tripled (*i.e.*, the plates have charge $+3Q_o$ and $-3Q_o$).

19. [5 pts] As a result of these changes, has the potential difference between the plates *increased*, *decreased*, or *remained the same*? Explain your reasoning.

[2 pts] Correct answer (*remains the same*)

82%

[2 pt] State either of the following two equations: $\Delta V_c = Ed$ or $\Delta V_c = Q/C$

[1 pt] Discuss how the relevant quantities changed (E tripled and d decreased by 1/3, or Q tripled and C tripled)

20. [5 pts] As a result of these changes, has the capacitance *increased*, *decreased*, or *remained the same*? Explain your reasoning.

83%

[3 pts] Correct answer (increased)

[2 pts] Brief explanation involving the equation $C = \epsilon_o A/d$ or the equation $C = Q/\Delta V$