Name ________________________________ **Student ID** ____________________ **Score**__________

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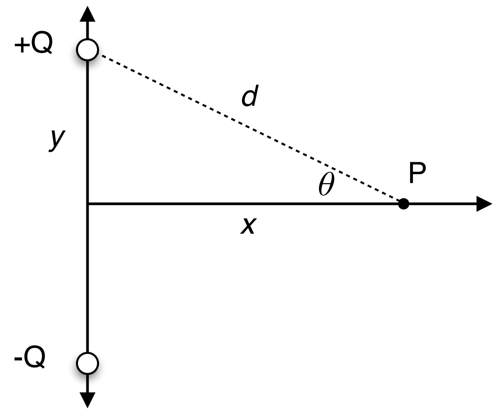
Part I [43 points]. Answer on your scantron sheet.

For the next **two questions**, consider the charge configuration shown to the right: Two equal and opposite charges are placed at equal distances ±*y* above the *x* axis.



1. [4 points] What is the **electric field** at point *P* on the *x* axis?

A. $E = 0$

B. $E = \dfrac{2kQ}{x^2}$, in +x direction

C. $E = \dfrac{2kQ}{d^2}$, in -y direction

D. $E = \dfrac{2kQ\cos\theta}{d^2}$, in +x direction

E. $E = \dfrac{2kQ\sin\theta}{d^2}$, in -y direction

2. [3 points] What is the **electric potential** at point P (relative to infinity)?

A. $V = 0$

B. $V = \frac{2kQ}{d}\cos\theta$

C. $V = \frac{2kQ}{d}\sin\theta$

D. $V = -\frac{2kQ}{d}$

E. $V = \frac{2kQ}{d}$

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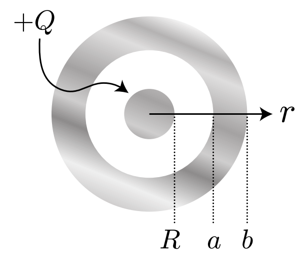
Consider the following charge configuration to answer the **next three questions**: A solid metal sphere of radius R has net charge $+Q$. It is surrounded by a thick concentric metal shell of inner radius a and outer radius b as shown. The shell has zero net charge. [Assume $V(\infty) = 0$.]



3.[4 points] Which choice best represents the electric potential on the outer surface of the shell $V(b)$?

A. $V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$ **B.** $V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{a}$ **C.** $V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{b}$ **D.** $V = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q}{R} - \frac{Q}{a} + \frac{Q}{b}\right)$ **E.** $V = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q}{R} + \frac{Q}{a} + \frac{Q}{b}\right)$

4. [3 points] What is the potential on the sphere $V(R)$?

A. $V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$ **B.** $V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{a}$ **C.** $V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{b}$ **D.** $V = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q}{R} - \frac{Q}{a} + \frac{Q}{b}\right)$ **E.** $V = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q}{R} + \frac{Q}{a} + \frac{Q}{b}\right)$

5. [2 points] What is the potential at the center of the spherical conductor $V(0)$?

A. $V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$ **B.** $V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{a}$ **C.** $V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{b}$ **D.** $V = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q}{R} - \frac{Q}{a} + \frac{Q}{b}\right)$ **E.** $V = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q}{R} + \frac{Q}{a} + \frac{Q}{b}\right)$

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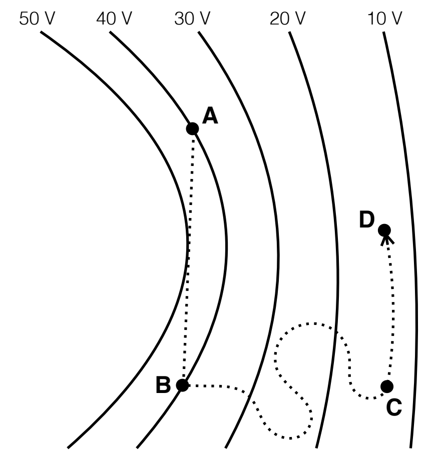
6. [3 points] A test charge is moved through a potential field, starting at point **A** and continuing to point **D** as shown at right. Which of the following statements are true about the potential difference between each segment of the move? [V_A is the potential at point **A**, and ΔV_{AB} is the potential from point **A** to point **B**.]



A. $\Delta V_{AB} > \Delta V_{CD}$; $V_A > V_D$

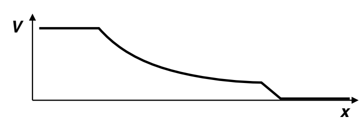
B. $\Delta V_{AB} = 0$; $V_B = V_D$

C. $\Delta V_{BC} = 0$; $V_A > V_C$

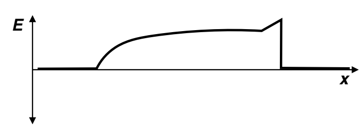
D. $V_A > V_B$; $V_C < V_D$

E. $\Delta V_{AD} = \Delta V_{BC}$; $V_A > V_D$

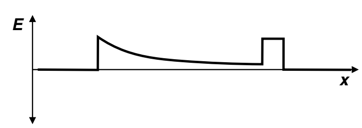
7. [3 points] A plot of the potential is shown in the first figure below. Choose which plot of the **Electric field** corresponds to this potential. (Hint: Where is the E field zero and where a maximum?)



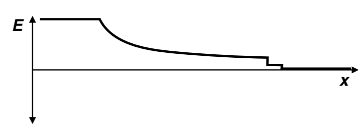
A.



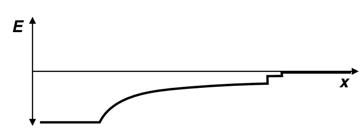
B.



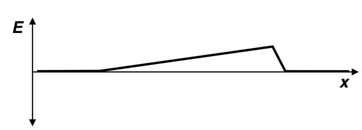
C.



D.



E.



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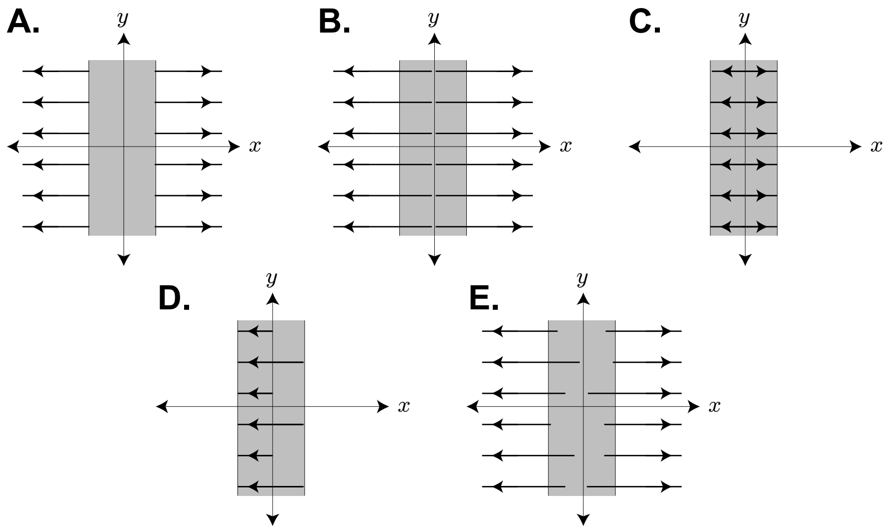
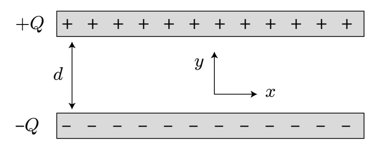
8. [4 points] Consider a large **insulating slab of uniform volume-charge density** ρ > 0, centered on the axis, with infinite extent in the y and z directions and finite width *L* in the *x* direction. Which **electric field line sketch** best approximates the field lines generated by the charge distribution?

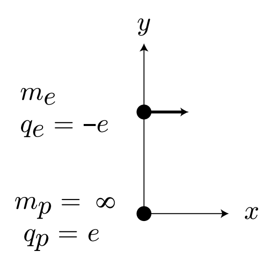


9. [3 points] What is the **force** on the bottom plate of a large parallel-plate capacitor with capacitance C, area A, plate spacing d and charge Q? (Hint: Does the E field generated by the bottom plate generate a net force on itself?)



A. $F = \frac{Q^2}{A\epsilon_0}$, **B.** $F = \frac{Q^2}{2Cd}$, **C.** $F = \frac{Q}{A\epsilon_0}$, **D.** $F = \frac{AQ}{d}$, **E.** $F = \frac{Q^2}{Cd}$,

10. [3 points] At $t = 0$ s, an electron at $\vec{r} = 10^{-10}\,\hat{y}$ m, has initial velocity $\vec{v} = 3\times10^6\,\hat{x}$ m/s. A proton sits at the origin. What is the magnitude of the **velocity** of the electron in the long time limit. (Hint: (i) Conservation of energy. (ii) Ignore the motion of the proton due to its large mass compared with the mass of the electron m_e. (iii) Formula sheet.)



A. $v = 3\times10^6$ m/s,
B. $v = 2\times10^6$ m/s,
C. $v = 6\times10^6$ m/s,
D. $v = 0$,
E. No well-defined limit since the electron is bound.

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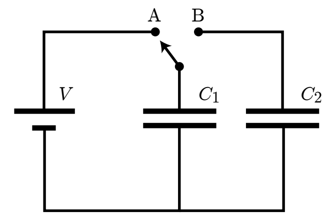
last *first*

For the next **three questions**, consider the following experiment: All capacitors start uncharged. Capacitor 1 with capacitance C_1 is charged to V using a battery. Once capacitor 1 is charged, it is disconnected from the battery and then used to charge capacitor 2 with capacitance C_2. (I.e. the switch is connected first to terminal A and then to terminal B.)



11. [2 points] When the switch is initially in the A position, what is the charge on capacitor 1?

A. $Q_1 = C_1V$, **B.** $Q_1 = C_2V$, **C.** $Q_1 = 0$, **D.** $Q_1 = (C_1 + C_2)V$, **E.** $Q_1 = \frac{C_1C_2}{C_1+C_2}V$,

12. [2 points] When the switch is in the B position, what is the total charge on both capacitors Q?

A. $Q = C_1V$, **B.** $Q = C_2V$, **C.** $Q = 0$, **D.** $Q = (C_1 + C_2)V$, **E.** $Q = \frac{C_1C_2}{C_1+C_2}V$,

13. [3 points] When the switch is in the B position, which of the following is true?

A. $Q_1 = Q_2$ **B.** $V_1 = V_2$, **C.** $Q_1 = 0$, **D.** $Q_1 = (C_1 + C_2)V$, **E.** $Q_1 = \frac{C_1C_2}{C_1+C_2}V$,

14. [4 points] What is the **final charge** on capacitor 1?

A. $Q_1 = \frac{(C_2)^2}{C_1+C_2}V$, **B.** $Q_1 = \frac{C_1+C_2}{C_1C_2}V$, **C.** $Q_1 = \frac{(C_1)^2}{C_1+C_2}V$, **D.** $Q_1 = 0$, **E.** $Q_1 = \frac{C_1C_2}{C_1+C_2}V$,