Physics 115 B
Autumn 2025

115B - AL-BINNI

Midterm 1
October 21st, 2025

Please use the boxes below to <u>clearly print</u> your name and UW NetID.
<u>Please write within the boxes</u>.

Printed Name	

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(part before @uw.edu)

I certify that the work I shall submit is my own creation, not copied from any source.

Signature ________________________________ **Seat Number** _________________

Clearly fill out this cover page and the top portion of the provided bubble sheet with the necessary information.

Do <u>not</u> open the exam until told to do so.
When prompted, clearly print the information required at the top of <u>each page</u> of this exam booklet.

You can remove the equation sheet(s). Otherwise, keep the exam booklet intact. You will have <u>60 minutes</u> to complete the examination.

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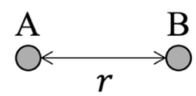
Multiple Choice [5 pts each] Bubble in the most correct answer on your bubble sheet and circle the correct answer here.

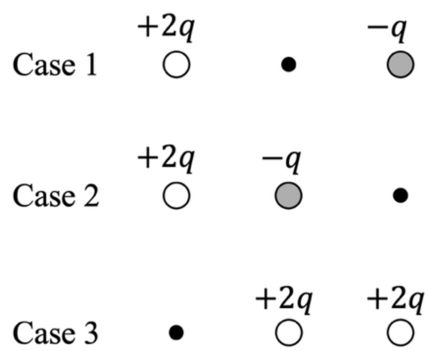
1. [5 pts] Find the net charge of a system consisting of 180 electrons and 235 protons.
   A. 3.76×10^{-17} C
   B. -2.88×10^{-17} C
   C. 6.13×10^{-18} C
   D. 8.80×10^{-18} C
   E. 4.27×10^{-18} C

2. [5 pts] When charge B is separated from charge A by a distance r, charge B experiences a force of magnitude F. If the separation between the charges is increased to $2r$, what force does charge B experience?



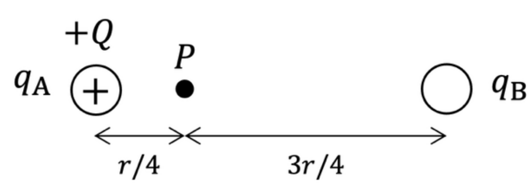
   A. $4F$
   B. $2F$
   C. F
   D. $F/2$
   E. $F/4$

3. [5 pts] Consider the three cases at right. The positive charges each have magnitude $2q$ and the negative charges each have magnitude q. Rank the magnitude of the electric field at the black dot in each case from largest to smallest. Treat each case separately (the charges in case 1 do not interact with the charges in case 2 and so on).



   A. 1 > 2 > 3
   B. 2 > 3 > 1
   C. 1 > 2 = 3
   D. 1 = 3 > 2
   E. 1 > 3 > 2

4. [5 pts] Point charges q_A and q_B are separated by a distance r as shown at right. It is known that the electric field is zero at point P. If $q_A = +Q$, what is the charge of q_B?



   A. $q_B = +3Q$
   B. $q_B = -3Q$
   C. $q_B = +6Q$
   D. $q_B = +9Q$
   E. $q_B = -9Q$

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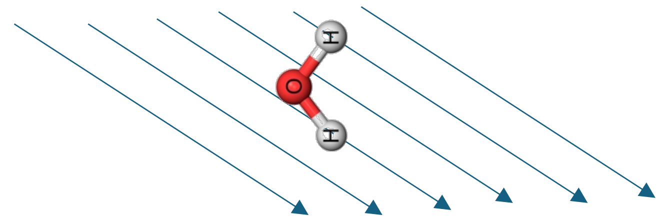
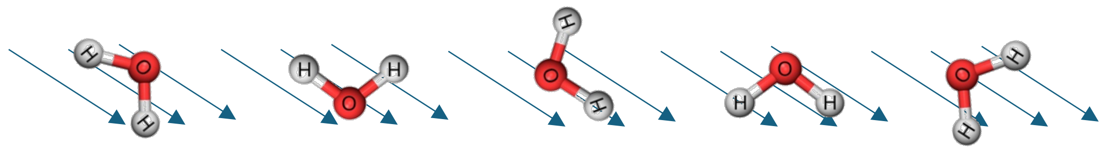
5. [5 pts] A water molecule is polar, since the oxygen side more negative than the hydrogen side. One water molecule is present in a region of a uniform electric field. Initially, the molecule has the orientation shown at right and is at rest. After equilibrium, which one of the following represents the correct orientation of the molecule?





A B C D E

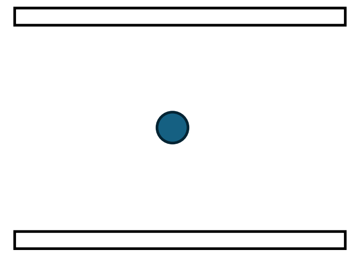
6. [5 pts] A plastic rod is charged uniformly with negative charge. The tip of the rod is brought close (without touching) to a neutral solid metallic sphere and held in place. Which one of the following is true? Assume that electrostatic equilibrium has been reached and that no charges jumped across between the two objects.

   A. The negative charges on the rod accumulate at the tip close to the sphere.
   B. The electric field inside the sphere has its maximum value close to the rod.
   C. A force of attraction forms between the rod and sphere.
   D. The sphere does not react to the presence of the rod, as it is neutral.
   E. Electrons in the sphere move as far away from the rod as they can and protons accumulate close to it.

7. [5 pts] A charge of -5.3×10^{-9} C is moved at constant speed by an external agent from a point where the electric potential is -6.0 V to a point where the potential is $+8.0$ V. How much work did the external agent do to move the charge?
   A. $+7.4 \times 10^{-8}$ J
   B. -7.4×10^{-8} J
   C. -1.1×10^{-8} J
   D. $+1.1 \times 10^{-8}$ J
   E. 0 J

Use the following scenario to answer the next two questions:

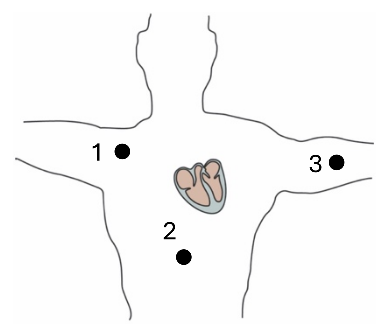
A small oil drop of mass 3.2×10^{-15}kg is suspended between two horizontal charged plates separated by a distance of 5.0×10^{-2} m, as shown at right. The uniform electric field between the plates is measured to be 1.2×10^{4} N/C and is pointing downward.



8. [5 pts] Calculate the approximate amount charge the oil drop has in terms of electrons. *Hint*: Do not neglect gravity, recall $g = 9.8\ \mathrm{m/s^2}$.
   A. About 2 electrons were added to the drop.
   B. About 2 electrons were removed from the drop.
   C. About 20 electrons were removed from the drop.
   D. About 20 electrons were added to the drop.
   E. The correct answer is not listed above.

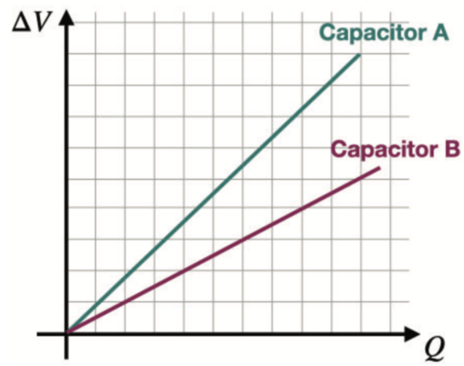
9. [5 pts] Calculate the electric potential difference ΔV between the negative plate and the midway point between the two plates, i.e. $\Delta V = V_{\text{midway}} - V_{\text{negative plate}}$.
   A. 600 V
   B. 300 V
   C. 240 V
   D. 150 V
   E. 0 V

10. [5 pts] An ECG machine has three electrodes connected to a patient's body at the points designated 1, 2 and 3 in the figure. At one instant, the readings of the electric potential at those electrodes shows that $V_1 > V_3 > V_2$. Choose the correct orientation of the heart's dipole moment vector at that instant.



   A. ↓
   B. ↗
   C. ↙
   D. ↖
   E. ↘

11. [5 pts] You are exploring the behavior of two different capacitors, Capacitor A and Capacitor B. You apply a varying amount of charge to each capacitor and measure the potential difference across them. Using your data, you develop two models shown in the graph. Which of the following would explain your data?



For the answer choices,

d_A represents the plate separation of capacitor A,
d_B represents the plate separation of capacitor B,
A_A represents the plate area of capacitor A, and
A_B represents the plate area of capacitor B.

A. $d_A > d_B$ and $A_A = A_B$
B. $d_A < d_B$ and $A_A = A_B$
C. $d_A = d_B$ and $A_A = A_B$
D. $d_A = d_B$ and $A_A > A_B$
E. None of these are possible.

12. [5 pts] Two resistors of the same length L are made from wire of resistivity ρ. Resistor 1 has twice the cross-sectional area of resistor 2. What is the relationship between the resistances R_1 and R_2?

A. $R_1 = R_2$
B. $R_1 = 2R_2$
C. $R_1 = \frac{1}{2}R_2$
D. $R_1 = 4R_2$
E. $R_1 = \frac{1}{4}R_2$

Lecture free response (20 points total)

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

The electric field inside a vacuum-filled parallel-plate capacitor is measured to be $400\ \text{N/C}$. Each plate has an area of $1.6 \times 10^{-3}\text{m}^2$.

13. [5 pts] What is the absolute value of charge on either plate of the capacitor?

14. [5 pts] The capacitor is connected to a 1.5 V battery. How far part are the plates?

15. [5 pts] A charged point particle is released midway between the plates. The particle accelerates towards the lower plate, in the direction of higher potential. What is the sign of the particle's charge and what are the signs of the charge on capacitor's plates? Explain your reasoning briefly.

    Sign of particle's charge:

    Sign of charge on upper plate:

    Sign of charge on lower plate:

16. [5 pts] We now disconnect the battery from the charged capacitor (ensuring the plates are kept insulated), **<u>then</u>** insert a piece of plastic of dielectric constant $\kappa = 2$ between the plates. Calculate the new value of the potential difference ΔV_C and the new value of charge.

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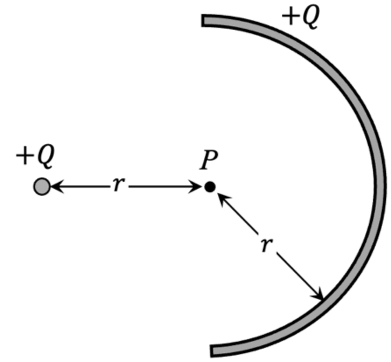
Tutorial Free Response [20 pts total]: Problems 17-20. Show work and/or explain reasoning where indicated.

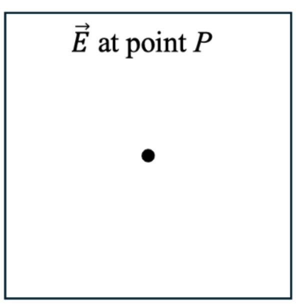
The next two questions are related to the following scenario.

A thin semicircular rod has total charge $+Q$ uniformly distributed along it, and a point charge $+Q$ is placed as shown.



17. [5 pts] Suppose a negative test charge, $-q_{test}$, is placed at point P. In the space provided below, sketch a vector to represent the net electric force on $-q_{test}$. **Explain your reasoning**.

18. [5 pts] In the space provided below, sketch a vector to represent the net electric field at point P. **Explain your reasoning**.



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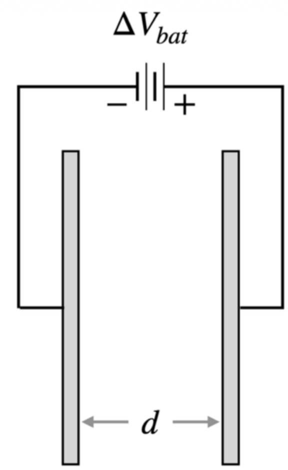

A capacitor with adjustable plates is connected to a battery. In its initial configuration, the plates are a distance d apart and the battery has a potential difference of ΔV_{bat} as shown. As a result, the charge on one plate is $+Q_o$, the charge on the other plate is $-Q_o$, and the electric field between the plates is E_o.

The circuit is then adjusted. In its final configuration, the plates are a distance $2d$ apart and the potential difference of the battery is increased to $6\Delta V_{bat}$.

19. [5 pts] After the circuit is adjusted, what is the charge on the positive plate? Express your answer in terms of Q_o. **Explain your reasoning**.

20. [5 pts] After the circuit is adjusted, what is the electric field strength between the plates? Express your answer in terms of E_o. **Explain your reasoning**.

Phys 115, Equation Sheet, Midterm 1

Constants

Free-fall acceleration	$g = 9.80\ \mathrm{m/s^2}$
Elementary charge	$e = 1.60 \times 10^{-19}\mathrm{C}$
Coulomb's constant	$K = 8.99 \times 10^9\ \mathrm{N \cdot m^2/C^2}$
Permittivity of free-space	$\epsilon_0 = 1/4\pi K = 8.85 \times 10^{-12}\mathrm{C^2/N \cdot m^2}$
Atomic mass unit	$1\ \mathrm{u} = 1.66 \times 10^{-27}\ \mathrm{kg}$
Avogadro's number	$N_\mathrm{A} = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$

Mathematics

Components of a 2D vector $\vec{A}$	$A_x = A\cos\theta,\ \ A_y = A\sin\theta$
Magnitude and direction of $\vec{A}$ relative to x-axis	$A = \sqrt{A_x^2 + A_y^2},\quad \theta = \tan^{-1}(A_y/A_x)$
Volume & surface area of a sphere	$V = \frac{4}{3}\pi r^3,\quad A = 4\pi r^2$

Mechanics Background

Kinematics (const. accel. a)	$v = v_0 + at,\quad x = x_0 + v_0 t + \frac{1}{2}at^2$ $v^2 = v_0^2 + 2a\Delta x$
Newton's Laws	$\sum\vec{F} = m\vec{a},\quad \vec{F}_{12} = -\vec{F}_{21}$
Weight	$w = mg$
Work due to a constant force	$W = Fd\cos\theta$
Conservation of energy	$\Delta E = W$
Power	$P = W/t = Fv$
Kinetic energy	$K = \frac{1}{2}mv^2$
Momentum	$p = mv$
Torque	$\tau = rF\sin\phi$

Conversions

Electron volt	$1\ \text{electron volt} = 1\ \mathrm{eV} = 1.60 \times 10^{-19}\mathrm{J}$

Electrostatic force and Fields

Coulomb's law	$F_{1\text{ on }2} = F_{2\text{ on }1} = \dfrac{K\lvert q_1\rvert\lvert q_2\rvert}{r^2}$
Electric field	$\vec{E} = \dfrac{\vec{F}_{\text{on }q}}{q},\quad \vec{E}_{\text{tot}} = \vec{E}_1 + \vec{E}_2 + \cdots$
Electric field due to point charge	$\vec{E} = \left(\dfrac{K\lvert q\rvert}{r^2}, \begin{bmatrix}\text{away from } q \text{ if } q > 0 \\ \text{toward } q \text{ if } q < 0\end{bmatrix}\right)$
Electric field inside capacitor	$E = \dfrac{\sigma}{\epsilon_0} = \dfrac{Q}{\epsilon_0 A}$
Electric field of charged sheet	$E = \dfrac{\sigma}{2\epsilon_0} = \dfrac{Q}{2\epsilon_0 A}$
Area charge density	$\sigma = \dfrac{Q}{A}$

Electric Potential and Energy

Potential and potential energy	$U = qV$
Work and potential energy difference	$\Delta U_{\text{elec}} = -W_{\text{elec}}$
Work and potential energy difference ($\Delta K = 0$)	$\Delta U_{\text{elec}} = W_{\text{ext}}$
Uniform electric field	$E = -\Delta V/\Delta x$
Potential inside capacitor	$\Delta V_\mathrm{C} = V_+ - V_- = Ed,\quad V = (x/d)\Delta V_\mathrm{C}$
Potential energy between point charges	$U_{\text{elec}} = \dfrac{Kqq'}{r} = \dfrac{1}{4\pi\epsilon_0}\dfrac{qq'}{r}$
Potential due to point charge	$V = K\dfrac{q}{r} = \dfrac{1}{4\pi\epsilon_0}\dfrac{q}{r}$
Potential due to multiple point charges	$V = \sum_i K\dfrac{q_i}{r_i} = \sum_i \dfrac{1}{4\pi\epsilon_0}\dfrac{q_i}{r_i}$
Potential outside uniform spherical charge distribution	$V = K\dfrac{Q}{r} = \dfrac{1}{4\pi\epsilon_0}\dfrac{Q}{r},\quad V = \dfrac{R}{r}V_0$

Phys 115, Equation Sheet, Midterm 1

Capacitance

Capacitance	$C = \frac{Q}{\Delta V_C}$
Parallel-plate capacitance	$C = \frac{\epsilon_0 A}{d}$
Dielectrics	$C \rightarrow \kappa C_0$
Energy in capacitors	$U_C = \frac{1}{2} Q \Delta V_C = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\, C(\Delta V_C)^2$

Circuits/General

Current	$I = \frac{\Delta q}{\Delta t}$
Resistance & resistivity	$R = \frac{\rho L}{A}$
Ohm's law	$I = \frac{\Delta V}{R}$