Physics 115 A
Spring 2025

115A - STEPHANIK

Midterm 1
April 29th, 2025

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

Printed Name	

first *last*

UW Net ID	

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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 not open the exam until told to do so.
When prompted, clearly print the information required at the top of each page of this exam booklet.
You can remove the equation sheet(s). Otherwise, keep the exam booklet intact.
You will have 60 minutes to complete the examination.

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I. [60 pts] Multiple Choice: Mark your answer on BOTH the bubble sheet and this page.

1. [5 pts] A positively charged rod (net charge +Q) attracts a neutral insulator without the rod and the insulator touching each other. Choose the correct explanation for this observation.

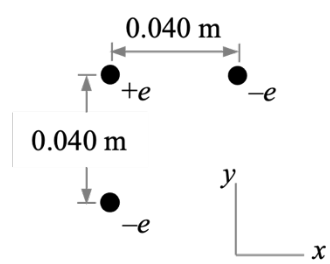
   A. A total charge of -Q is induced in the insulator, causing an attractive force.

   B. All the negative charge of the insulator is pulled to the edge of the insulator that is closest to the rod, causing an attractive force.

   C. Objects with excess charge always repels electrically neutral objects even if the charge in the insulator cannot move.

   D. The atoms of the insulator get polarized in such a way that slightly more negative than positive charge is closer to the rod, causing an attractive force.

2. [5 pts] A proton and two electrons are fixed in place as shown. What is the ***x*-component** of the electric force on the **top-right electron?** A coordinate system is defined in the diagram.



   A. 2.5×10^{-25} N

   B. -4.2×10^{-26} N

   C. -7.2×10^{-26} N

   D. -9.3×10^{-26} N

   E. None of these

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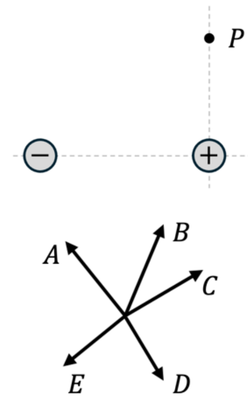
3. [5 pts] An electric dipole is illustrated at right. Which of the vectors $A - E$ in the diagram below best represents the direction of the electric field at point P?



   A. Vector A

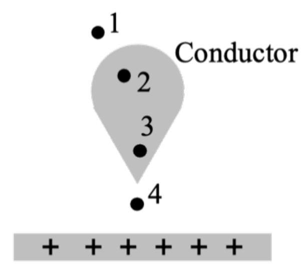
   B. Vector B

   C. Vector C

   D. Vector D

   E. Vector E

4. [5 pts] A neutral conductor is placed near a large positively charged plate. Rank, from greatest to least, the four points according to the magnitude of the electric field.



   A. 4 > 3 > 2 > 1

   B. 4 > 1 > 3 = 2

   C. 1 > 2 > 3 > 4

   D. 2 = 3 > 4 > 1

   E. 4 > 2 > 3 > 1

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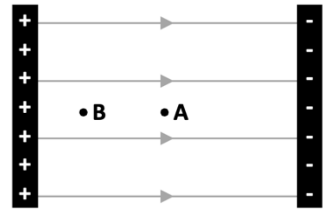
5. [5 pts] A positive charge is moved at constant speed from point A to point B in a uniform electric field as shown at right. Choose the correct statement for the work W done by the external force moving the charge and the change of the electric potential energy of the charge configuration, ΔU.



A. $W > 0,\ \Delta U < 0$

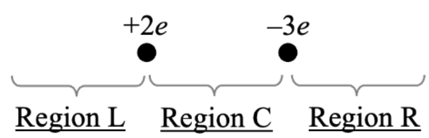
B. $W > 0,\ \Delta U > 0$

C. $W = 0,\ \Delta U = 0$

D. $W < 0,\ \Delta U < 0$

E. $W < 0,\ \Delta U > 0$

6. [5 pts] Two point charges are fixed in place, as shown. Three regions are defined; regions L and R are large but do not extend to infinity. In which regions could the electric potential be zero?



A. Only region L

B. Only region C

C. Only region R

D. Both regions L and R

E. Both regions L and C

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7. [5 pts] Along the x-axis, the electric potential depends on x, the distance from the origin, as $V(x) = Cx$, where C is a constant. What is the magnitude of the electric field on the x-axis?

   A. $E(x) = C$

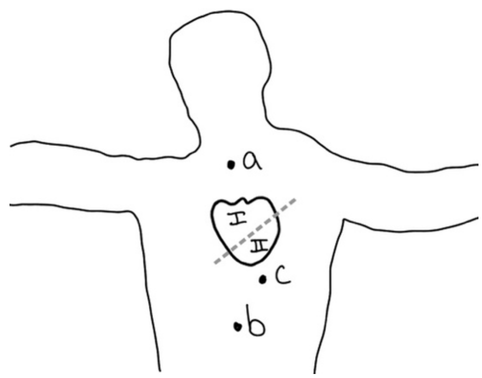
   B. $E(x) = Cx^2$

   C. $E(x) = C/x$

   D. $E(x) = Cx$

   E. $E(x) = 0$

8. [5 pts] At the instant shown in the diagram, the heart can be modeled as an electric dipole. The dashed line represents a small portion of a much larger equipotential line.

   Suppose that at the instant shown, electrodes placed at locations c and a are measured to have voltage $V_a - V_c > 0$.

   What can be said about the sign of the voltage $V_b - V_a$ between electrodes a and b?

   A. $V_b - V_a > 0$

   B. $V_b - V_a < 0$

   C. $V_b - V_a = 0$

   D. More information is needed.

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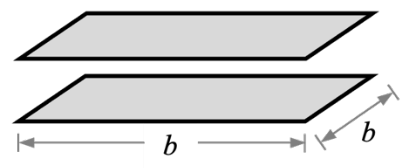
9. [5 pts] A vacuum parallel plate capacitor is composed of two identical square conductors (plates) that are separated by 0.01 m. When a 100-volt battery is attached to the plates, the charge stored on the positive plate is measured to be $4.0\ \mu\text{C} = 4.0 \times 10^{-6}$ C. What is the **area** of each plate?



A. 0.45 m^2

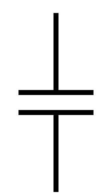
B. 6.7 m^2

C. 45 m^2

D. 67 m^2

E. None of these

10. [5 pts] A capacitor is initially connected to a battery to charge its plates. It is then disconnected from the battery, as shown.



Suppose a dielectric slab with dielectric constant 5 is inserted into the capacitor while it is disconnected from the battery. How does the energy stored in the capacitors change due to the dielectric?

A. Energy increases by a factor of 5

B. Energy decreases by a factor of 5

C. Energy increases by a factor of 25

D. Energy decreases by a factor of 25

E. Energy remains the same.

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11. [5 pts] An experiment is conducted on an unknown electrical device. The voltage between its two terminals is varied and the resulting current is measured. The data is shown at right.

I (amps)	$\lvert\Delta V\rvert$ (volts)
2	6
3	8
4	10
5	12

Based on this data, can the device be considered ohmic?

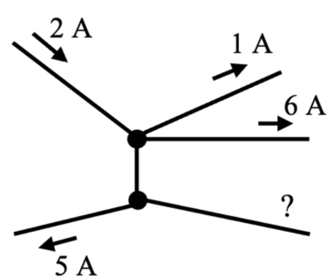
A. Yes, the device is ohmic because equal changes in voltage result in equal changes in current.

B. Yes, the devices is ohmic because only whole numbers are measured.

C. No, the device is not ohmic because only whole numbers are measured.

D. No, the device is not ohmic because the resistance is different for each data point.

12. [5 pts] A portion of a circuit is shown in the diagram. Determine the current in the unknown wire, including its direction.



A. 0 A (no current)

B. 1 A, rightward

C. 5 A, leftward

D. 10 A, leftward

E. 11 A, rightward

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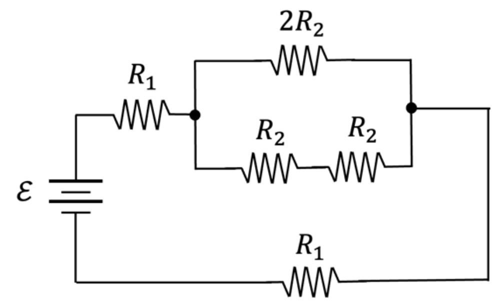
II. Lecture long-answer questions (20 points total)

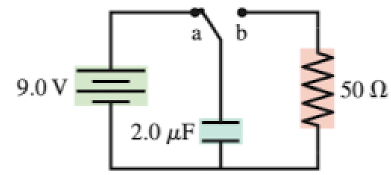
Consider the circuit shown at right for the next two questions.



13. [5 pts] Draw an equivalent circuit containing only one resistor and express the equivalent resistance with the quantities given in the original circuit. Explain how you determined the equivalent resistance.

14. [5 pts] Express Kirchhoff's loop law for the equivalent circuit and determine the current through the battery.

Consider the circuit shown at right for the next two questions.



15. [4 pts] What are the charge Q on the capacitor and the current I through the resistor when the switch has been in position a for a long time? Show your work.

16. The switch is changed to position b at $t = 0$ s.

    i. [3 pts] What is the current I through the resistor immediately after the switch is changed? Show your work.

    ii. [3 pts] What is the current I through the resistor at $t = 50\ \mu s$? Show your work.

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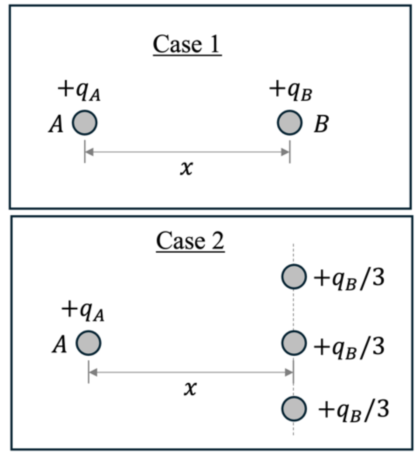
III. Tutorial and lab long answer questions (20 points total)

Use this context for questions 17 and 18.

Two experiments involve charged particles: In case 1, two positively charged particles, A and B are held a distance x apart as shown. The magnitude of the charge on particle A is *greater than* the magnitude of the charge on particle B ($|q_A| > |q_B|$).

In case 2, particle B is replaced by three identical particles of charge $q_B/3$ that lie along a line as shown.



17. [5 pts] In case 1, is the magnitude of the electric force on particle A *greater than*, *less than*, or *equal to* the magnitude of the electric force on particle B? Explain.

18. [5 pts] Is the magnitude of the net electric force on particle A in case 2 *greater than*, *less than*, or *equal to* the magnitude of the electric force on particle A in case 1? Explain.

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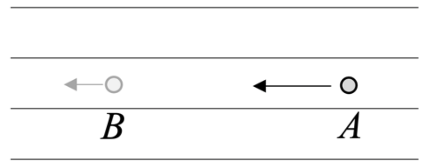
19. [5 pts] An electron is present in a uniform horizontal electric field (the direction of the field is not shown). At point *A*, the electron has a speed v and is moving to the left. At point *B*, the electron has a speed $v/2$.



Does the electric field point to the right or the left? Explain.

20. [5 pts] A capacitor is connected to an ideal battery of voltage V_0. The distance between the two plates is then increased, while the capacitor remains connected to the battery. Will the magnitude of the charge on the plates *increase, decrease* or *remain the same* as a result of increasing the distance between the plates? Explain.

115 Equation Sheet: Final

Physical Constants

Elementary charge: $e = 1.60 \times 10^{-19}$ C

Electron mass: $m_e = 9.11 \times 10^{-31}$ kg

Couloumb's constant:

$$K = \frac{1}{4\pi\epsilon_0} = 9.0 \times 10^9 \, \mathrm{N \cdot m^2/C^2}$$

Permittivity of free-space:

$$\epsilon_0 = 8.85 \times 10^{-12} \, \mathrm{C^2/N \cdot m^2}$$

Permeability constant:

$$\mu_0 = 1.26 \times 10^{-6} \, \mathrm{T \cdot m/A}$$

Boltzmann's constant: $k_\mathrm{B} = 1.38 \times 10^{-23}$ J/K

Avogadro's number: $N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$

Gas constant: $R = 8.31\,\mathrm{J/mol \cdot K}$

Boltzmann-Stefan constant:

$$\sigma = 5.67 \times 10^{-8}\,\mathrm{W/(m^2 \cdot K^4}$$

Unit Conversions

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

Calorie: $1\,\mathrm{Cal} = 4186\,\mathrm{J}$

Helpful Equations from 114

Kinematics (constant acceleration):

$$x_f = x_i + (v_x)_i \Delta t + \tfrac{1}{2} a_x (\Delta t)^2$$

$$(v_x)_f = (v_x)_i + a_x \Delta t$$

$$(v_x)_f^2 = (v_x)_i^2 + 2a_x \Delta x$$

Newton's 2nd Law: $\vec{a} = \dfrac{\vec{F}_\mathrm{net}}{m}$

Weight (Gravitational Force): $F_g = mg$

Work: $W = F_\parallel d = Fd\cos\theta$

Work-Energy Theorem: $\Delta E_{mech} = W$

Kinetic Energy: $K = \frac{1}{2}mv^2$

Gravitational Potential Energy: $U_g = mgy$

Power: $P = \dfrac{\Delta E}{\Delta t}$

Momentum: $p = mv$

Chapter 20:

Coulomb's Law: $F_{1 \text{ on } 2} = F_{2 \text{ on } 1} = \dfrac{K|q_1||q_2|}{r^2}$

Electric field: $\vec{E} = \dfrac{\vec{F}_\mathrm{on\,q}}{q}$

Electric field for a point charge: $E = \dfrac{K|q|}{r^2}$

Electric field in a parallel-plate capacitor:

$$E = \frac{Q}{\epsilon_0 A}$$

Chapter 21:

Electric Potential Energy: $U_{elec} = qV$

Electric Energy Conservation:

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

Electric Potential of a Point Charge: $V = \dfrac{Kq}{r}$

Capacitance: $C = \dfrac{\epsilon_0 A}{d} = \dfrac{Q}{\Delta V_C}$

Energy stored in a capacitor: $U_C = \frac{1}{2}C(\Delta V_C)^2$

Electric Field inside a parallel-plate capacitor:

$$E = \frac{\Delta V_C}{d}$$

Chapter 22:

Current: $I = \dfrac{\Delta q}{\Delta t}$

Resistance: $R = \dfrac{\rho L}{A}$

Ohm's Law: $I = \dfrac{\Delta V}{R}$

Power dissipated across a resistor:
$$P_R = I\Delta V_R = I^2 R = \frac{(\Delta V_R)^2}{R}$$

Batteries in series: $\Delta V_{\text{total}} = \mathcal{E}_1 + \mathcal{E}_2 + \mathcal{E}_3 + ...$

Chapter 23:

Kirchoff's Loop rule: $\sum \Delta V = 0$

Kirchoff's Junction rule: $\sum I_{in} = \sum I_{out}$

Equivalent resistance:

Series: $R_{eq} = R_1 + R_2 + R_3 ...$

Parallel: $R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...\right)^{-1}$

Equivalent capacitance:

Series: $C_{eq} = \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ...\right)^{-1}$

Parallel: $C_{eq} = C_1 + C_2 + C_3 + ...$

RC Time Constant: $\tau = RC$

Current in an RC Circuit:
$$I = I_0 e^{-t/\tau}$$

Potential in an RC Circuit:

Charging: $V_C = (V_C)_0(1 - e^{-t/\tau})$

Discharging: $V_C = (V_C)_0 e^{-t/\tau}$

Chapter 24:

Magnetic field due to:

Long straight wire: $B = \frac{\mu_0 I}{2\pi r}$

Current loop: $B = \frac{\mu_0 I}{2R}$

Solenoid: $B = \frac{\mu_0 N I}{L}$

Force on moving charge: $F = |q|\, vB\sin\alpha$

Force on current-carrying wire: $F = ILB\sin\alpha$

Circular motion radius for charge in magnetic field: $r = \frac{mv}{|q|\, B}$

Chapter 11:

Efficiency: $e = \frac{\text{what you get}}{\text{what you had to pay}} = \frac{W_{\text{out}}}{Q_{\text{H}}}$

Maximum efficiency: $e_{\max} = 1 - \frac{T_{\text{C}}}{T_{\text{H}}}$

Fahrenheit conversion: $T(°C) = \frac{5}{9}[T(°F) - 32°]$

Kelvin conversion: $T(K) = T(°C) + 273$

First law of thermodynamics: $\Delta E_{\text{th}} = W + Q$

Entropy change at constant temp.: $\Delta S = \frac{Q}{T}$

Entropy change of universe: $\Delta S_{\text{univ}} > 0$

Chapter 12:

Number of moles: $n = \frac{M\,(\text{in grams})}{M_{\text{mol}}}$

Thermal energy: $E_{\text{th}} = \frac{3}{2}k_B N T$

rms speed: $v_{\text{rms}} = \sqrt{\frac{3k_{\text{B}}T}{m}}$

Pressure: $p = \frac{F}{A}$

Ideal gas law: $pV = Nk_{\text{B}}T = nRT$

Volume thermal expansion: $\Delta V = \beta V_{\text{i}}\Delta T$

Linear thermal expansion: $\Delta L = \alpha L_{\text{i}}\Delta T$

Specific heat: $Q = Mc\Delta T$

Heat of transformation: $Q = \pm ML$

Molar specific heat:

at constant volume: $Q = nC_{\text{V}}\Delta T$

at constant pressure: $Q = nC_{\text{P}}\Delta T$

Conduction: $\frac{Q}{\Delta t} = \left(\frac{kA}{L}\right)\Delta T$

Radiation: $\frac{Q}{\Delta t} = e\sigma A T^4$