Physics 115 A
Summer 2025

115A - STEPHANIK

Midterm 2
August 6th, 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	

(part before @uw.edu)

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

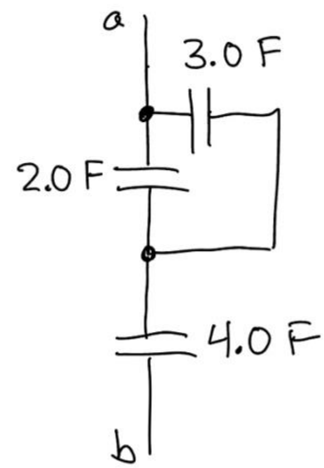
Signature ________________________________ **Seat Number** _________________

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

Do 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 90 minutes to complete the examination.

Q1–Q15: Lecture multiple choice — Fill in the correct answer on your bubble sheet.

1. [4 pts] The circuit diagram at right represents a small part of a much larger circuit. Suppose all three capacitors between points *a* and *b* were replaced with a single capacitor such that the rest of the circuit's behavior remained unchanged. What is the capacitance of that single capacitor?



   A. 0.92 F

   B. 1.6 F

   C. 2.2 F

   D. 5.2 F

   E. 9.0 F

2. [4 pts] An ideal 10-volt battery, an ohmic resistor, a switch, and a 0.10-farad capacitor that is initially uncharged are all arranged in a single-loop circuit. The switch is closed at $t = 0$. The current through the resistor at $t = 0$ is 0.50 amps.

   What is the current through the resistor at $t = 1.0$ s?

   A. 0.18 amps

   B. 0.30 amps

   C. 0.40 amps

   D. 0.48 amps

   E. 0.55 amps

3. [4 pts] Electrical signal transmission along nerve cell axons can be modeled, in part, as multiple RC circuits. The amount of time for a signal to propagate from one location to another is proportional to the time constant $\tau = RC$. Suppose that the distance between the 'parallel plates' of the capacitors in this model is **increased,** but any resistance remains unchanged. How would this change affect the **amount of time** it takes for an electrical signal to propagate across nerve cells?

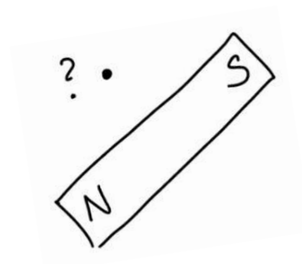
   A. The time would increase

   B. The time would decrease

   C. The time would remain the same

   D. None of these are correct.

4. [4 pts] Which option below best represents the direction of the magnetic field at the indicated point? Assume the magnetic field is due only to the shown bar magnet.



   A. ⊗ (into the page)

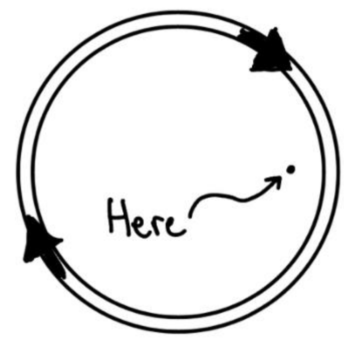
   B. ↙

   C. ↗

   D. ↑

   E. ←

5. [4 pts] A circular loop of wire carries current clockwise, as shown. What is the direction of the magnetic field at the indicated point? Assume that the point is located in the plane of the loop.



A. ⊗ (into the page)

B. ⊙ (out of the page)

C. →

D. ←

E. ↗

6. [4 pts] A single circular loop of current with **diameter** 10 cm = 0.10 m is oriented so that the magnetic field it produces at the center of the loop is oriented opposite the magnetic field produced by the Earth. If the Earth has magnetic field $50\ \mu\text{T} = 50 \times 10^{-6}$ T, what is the current in the loop if the **net** magnetic field at the center of the loop is zero?

A. 0 amps

B. 1.4 amps

C. 2.7 amps

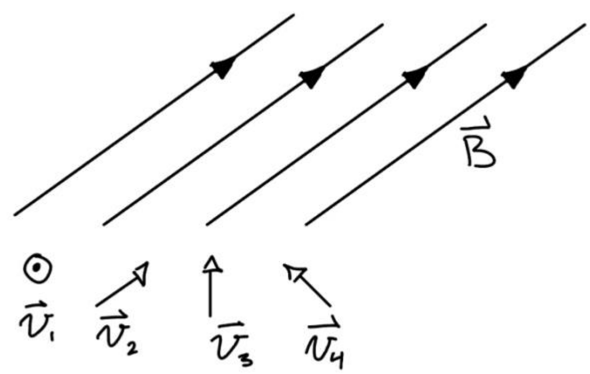
D. 4.0 amps

E. 7.9 amps

7. [4 pts] Suppose you want a large 3-dimensional region of space to contain a **uniform** magnetic field. Which of the following regions and current configurations would best accomplish this?

   A. Directly between two magnets with their north poles (or south poles) facing each other
   B. Outside of an infinitely long wire that carries **constant** current
   C. Outside of an infinitely long wire that carries an **exponentially decreasing** current
   D. The region immediately around a compass.
   E. Inside of a solenoid

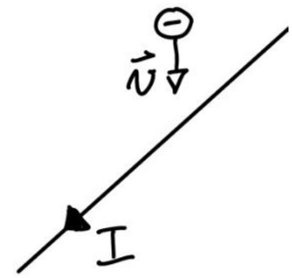
8. [4 pts] Consider the region of uniform magnetic field shown at right. The four vectors labeled $\vec{v}_1$ through $\vec{v}_4$ represent possible velocities of a charged particle. The speeds corresponding to each velocity are identical. Note that $\vec{v}_4$ is perpendicular to the B-field.



   Rank the magnitude of the resulting magnetic force vector for each of the four possible velocity vectors.

   A. $F_4 = F_3 > F_2 > F_1$
   B. $F_2 > F_3 > F_1 > F_4$
   C. $F_2 > F_3 > F_4 > F_1$
   D. $F_4 > F_3 > F_2 > F_1$
   E. $F_1 = F_4 > F_3 > F_2$

9. [4 pts] A long wire carries current in the direction shown (diagonally down-and-left). What is the direction of the magnetic force on the **negatively charged** particle moving in the indicated direction? Assume both the wire and the velocity vector are in the plane of the paper.

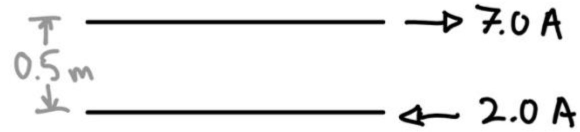


   A. ⊗ (into the page)
   B. ⊙ (out of the page)
   C. ↗
   D. ←
   E. None of these are correct

10. [4 pts] The wire shown carries current 4.0 A to the right. A uniform magnetic field of magnitude 2.0 T is indicated. What is the magnitude of the magnetic force exerted on a 1.0-cm region of the wire?

   A. 0 N
   B. 0.080 N
   C. 0.80 N
   D. 8.0 N
   E. None of these are correct

11. [4 pts] Two very long, parallel wires are situated 0.50 m apart from each other. The top wire carries 7.0 A of current rightward and the bottom carries 2.0 A of current leftward.



Is the magnetic force between the two wires attractive or repulsive, and what is the magnitude of the force exerted on a 3.0-meter length of the bottom wire?

A. Attractive, 1.7×10^{-5} N

B. Attractive, 4.7×10^{-7} N

C. Repulsive, 3.2×10^{-6} N

D. Repulsive, 1.3×10^{-6} N

E. None of these are completely correct

12. [4 pts] The metabolic power of a 68-kg person who is swimming quickly is 800 W. How much **mechanical work** in Calories (kcal) does such a person do **on the water** during a 1-minute swim? Use the conversion 1 Calorie = 4,186 J. Recall that the efficiency of the human body for physical activity is 25%.

A. 0.19 Cal

B. 0.76 Cal

C. 1.5 Cal

D. 2.9 Cal

E. 11 Cal

13. [4 pts] You have a container of 0 °C liquid water in which you place an ice cube that is also at 0 °C. Which of the following best describes the heat flow between the two substances if they are put into contact?

   A. Heat flows from the water to the ice.

   B. Heat flows from the ice to the water.

   C. Heat does not flow between the two.

14. [4 pts] Sample A contains an unknown amount of helium gas, which is the lightest monatomic gas. Sample B contains an unknown amount of xenon gas, which is also monatomic. The pressures, volumes, and amount of gas particles are unknown, but it is known that the root-mean-square speeds of the two samples of gas are the same. How do the temperatures of the samples compare?

   A. Sample A (helium) has greater temperature.

   B. Sample B (xenon) has greater temperature

   C. Both samples have identical temperatures

   D. Impossible to determine

15. [4 pts] In Experiment A, an isobaric process is performed on a sample of gas in which the temperature of the gas goes from 300 K to 400 K. In Experiment B, an isochoric process is performed on an identical sample of gas in which the temperature goes from 300 K to 400 K. How does the work done **by the gas** on the environment compare in the two experiments? Negative work should be considered as being *less* than zero or positive work.

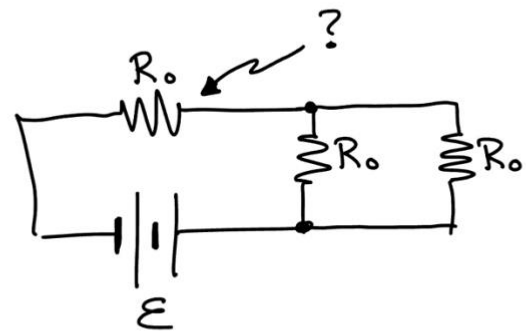
A. Greater work is done by the gas in Experiment A

B. Greater work is done by the gas in Experiment B

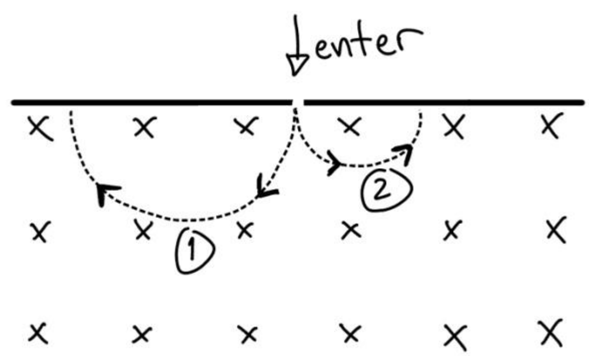
C. Equal works done in both experiments

Q16–Q20: Lecture free-response — Unless otherwise noted, explain your reasoning or show your work.

16. [4 pts] An ideal battery (emf $\mathcal{E}$) and three identical resistors (resistance R_0) are arranged as shown. Determine the absolute values of the current through and voltage across the top resistor (i.e., the one indicated by a '?') in terms of the given variables. Show your work.



17. [4 pts] Particles 1 and 2 have identical masses ($m_1 = m_2$) and identical absolute values of charge ($|q_1| = |q_2|$). The two particles enter a region of uniform magnetic field and undergo the trajectories shown.



Is the **amount of time** it takes particle 1 to complete its half-circular trajectory greater than, less than, or equal to the amount of time it takes particle 2 to complete its half-circular trajectory? Show your work. Ignore gravity.

18. [4 pts] During some process, a system does 400 J of work on the environment, and the thermal energy of the system increases by 300 J.

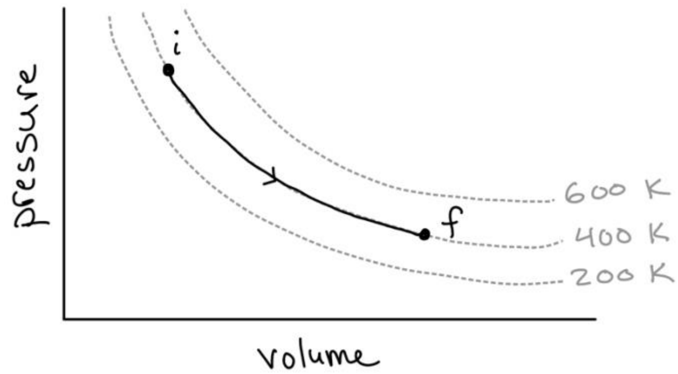
(i) [2 pts] Determine a numerical value in joules for the **amount of heat** that flows into the system (*positive* for flow *into* the system, as usual). Show your work.

(ii) [2 pts] During the process, was the system hotter or the environment hotter? Explain.

19. [4 pts] A hot object (Object A) exchanges 7 J of heat with cool object (Object B). Assume the objects are large enough that any change in temperature is negligible.

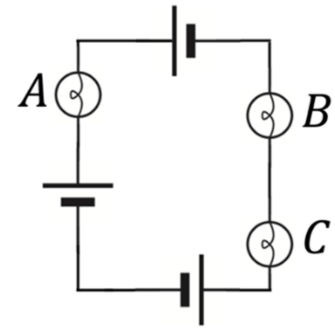
Is the change in entropy of the two-object system positive, negative, or zero? Assume no other heat exchanges occur. Explain or show your work.

20. [4 pts] A sample of gas undergoes the process shown at right. Is the heat flow into the gas during this process positive, negative, or zero? Explain or show your work.



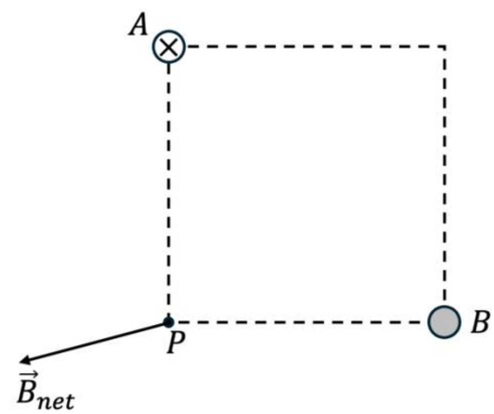
Q21–Q25: Tutorial questions.

In the circuit at right, all bulbs are identical, and all batteries are ideal and identical.



21. [4 pts] Rank the bulbs A-C according to brightness, from brightest to dimmest. If any bulbs do not light, state so explicitly. Explain your reasoning.

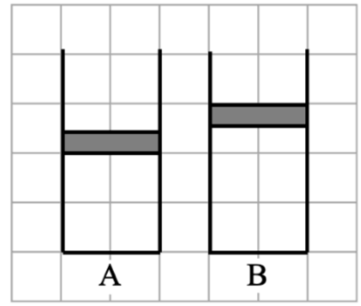
A long wire, wire A, carries a current I_0 into the page. A second wire, wire B, is located as shown. At point *P*, the net magnetic field points as shown (the wires are equidistant from point *P*). The net magnetic field is in the plane of the page.



22. [4 pts] Does wire B carry a current into or out of the page? Explain.

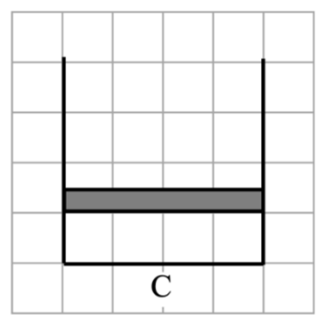
23. [4 pts] Is the current in wire B *greater than, less than* or *equal to* I_0? Explain.

The figure at right shows two identical cylinders, A and B that are fitted with identical pistons. Each piston is free to move without friction. Both cylinders have been in the same room for a long time. Cylinder A contains an ideal gas with a larger molecular mass than the ideal gas in cylinder B.



24. [4 pts] Is the pressure of the gas in cylinder A *greater than, less than,* or *equal to* the pressure of the gas in cylinder B? Explain. If not enough information is given, state so explicitly.

Cylinder C has a diameter that is twice as large as that of cylinder A and the mass of piston in cylinder C is four times larger than that of cylinder A. The cylinders have been in the same room for a long time, and the height of piston A is twice as high as that in cylinder C.



25. [4 pts] Is the number of particles in container C *greater than*, *less than*, or *equal to* the number of particles in container A? Explain.

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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):

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

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

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

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

Weight (Gravitational Force): $F_g = mg$

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

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

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

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