Physics 115 B
Autumn 2025

115B - AL-BINNI

Midterm 2
November 18th, 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 60 minutes to complete the examination.

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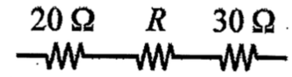
Multiple Choice [5 pts each] Bubble in the most correct answer on your bubble sheet and circle the correct answer here.



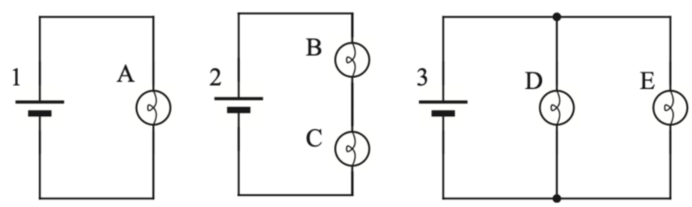
1. [5 pts] Consider the network of three resistors shown at right. If the equivalent resistance of the network of three resistors is 90 Ω, what is the unknown resistance R?
   A. 10 Ω

   B. 20 Ω

   C. 30 Ω

   D. 40 Ω

   E. 50 Ω



2. [5 pts] Consider the three circuits at right. All batteries are ideal and identical, and all bulbs are identical. Rank the current through the three batteries from largest to smallest.
   A. 1 > 2 = 3

   B. 1 = 2 = 3

   C. 3 > 1 > 2

   D. 2 = 3 > 1

   E. 2 > 1 > 3

3. [5 pts] In an experiment, a 12 V battery is connected in series with a $6.0 \times 10^3 \Omega$ resistor and a 4.0×10^{-5}F capacitor. The capacitor starts uncharged. What is charge on the positive plate of the capacitor after 1.0×10^{-2}s?
   A. 1.2×10^{-5} C

   B. 2.0×10^{-5} C

   C. 3.5×10^{-5} C

   D. 4.8×10^{-5} C

   E. 5.8×10^{-5} C

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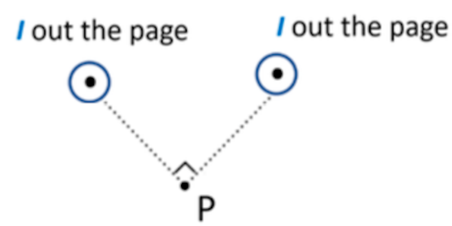
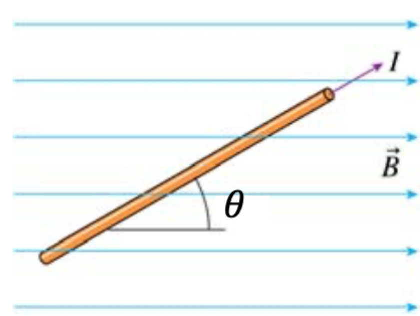
4. [5 pts] Now suppose you repeat the experiment in the previous question, but this time you double the resistance while keeping the battery voltage and capacitor unchanged. You again measure the capacitor's charge at 1.0×10^{-2}s after the circuit is connected (again starting with an uncharged capacitor). Is the charge on the positive plate now *greater than*, *less than* or *equal to* the charge on the positive plate in the experiment in the previous question?
   A. Greater than
   B. Less than
   C. Equal to
   D. Information provided is not enough to answer.

5. [5 pts] Point P is an equal distance from two current-carrying wires and forms the right angle indicated. In what direction is the magnetic field at point P?
   A. Into the page
   B. To the left side of the page
   C. To the right side of the page
   D. Toward the top of the page
   E. Toward the bottom of the page



6. [5 pts] A uniform 2.5 T magnetic field points to the right. A 3.0-m portion of a long wire, carrying current 15 A, is placed at an angle θ to the field, as shown. If the wire experiences a force of 56 N, what is the angle θ?
   A. 35°
   B. 30°
   C. 60°
   D. 25°
   E. 41°



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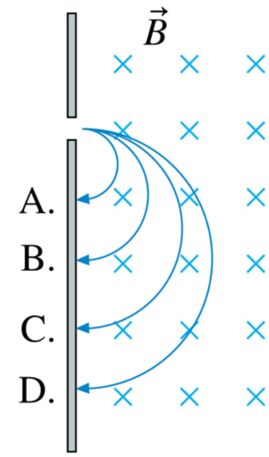
7. [5 pts] The figure at right shows four particles moving to the right as they enter a region of uniform magnetic field, directed into the paper as shown. All particles have the same speed and the same mass. Which particle has the largest magnitude of charge?



   A. A

   B. B

   C. C

   D. D

   E. They all have the same magnitude of charge.

8. [5 pts] Wind turbine A can generate electric power from wind at an efficiency of 35%, while wind turbine B's efficiency is 45%. On a certain day, turbine A was able to generate 4.3×10^6 W of electric power, how much electric power did turbine B generate if both turbines are at the same location?

   A. 3.3×10^6 W

   B. 4.3×10^6 W

   C. 8.0×10^6 W

   D. 6.8×10^6 W

   E. 5.5×10^6 W

9. [5 pts] You wish to run a distance of 6.0 km at 15 km/h. Assuming your metabolic power of running at 15 km/h is 1150 W, and if your energy comes from food, which of the following food choices is closest to the minimum amount of energy needed to make the trip?

   A. A slice of pizza supplying 1260 kJ of energy

   B. A frozen burrito supplying 1470 kJ of energy

   C. A slice of apple pie supplying 1680 kJ of energy

   D. A fast-food meal supplying 5660 kJ of energy

10. [5 pts] A certain amount of gas is inside a cylinder covered by a movable piston. The piston is pushed down slowly doing 450 J of work on the gas. The internal (thermal) energy of the gas is found to have decreased at the end of the process by 320 J. Which one of the following must be true?

    A. The gas has lost 770 J of heat to the environment.

    B. The gas has absorbed 770 J of heat from the environment.

    C. The gas has lost 130 J of heat to the environment.

    D. The gas has absorbed 130 J of heat from the environment.

    E. Not enough information

11. [5 pts] You toss five identical fair coins (the probability of getting heads equals that of getting tails). What is the ratio of the probability of getting 3 heads to the probability of 4 heads?

    A. 1/5

    B. 0.5

    C. 3/4

    D. 4/3

    E. 2

12. [5 pts] An insulated box is divided into two parts by a partition. On the left side, we place a gas at temperature T_L, and on the right side, another gas at temperature T_R, where $T_\mathrm{L} < T_\mathrm{R}$. We remove the partition and allow the gases to mix. After a long time, what happens to the entropy S of the combined system?

    A. It reaches a value S_avg representing the average of the initial entropies of the two separate gases.

    B. It increases and reaches a maximum value after a while.

    C. It keeps increasing with time (with no upper bound).

    D. It decreases below the entropy of either one of the initial entropies of the two separate gases.

    E. It stays the same as before the mixing, since the system is insulated.

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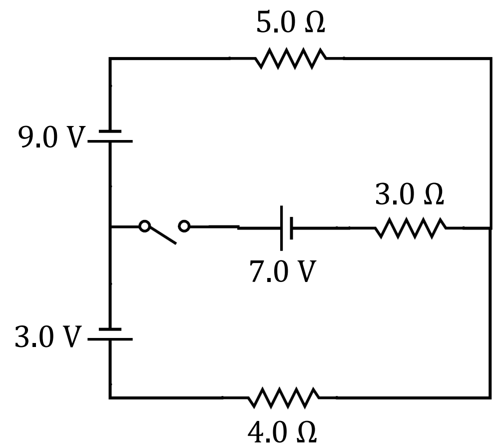
Lecture Free Response [20 pts total]: Show work and/or explain reasoning where indicated.

Use the circuit at right to answer the following questions:

13. [4 pts] When the switch is open, how does the current through the 4.0 Ω resistor compare to the current through the 5.0 Ω resistor?



14. [6 pts] With the switch still open, write down a loop equation for the outer loop and use it to find the current flowing through the 4.0 Ω resistor.

15. [6 pts] When the switch is closed, a current of 0.89 A flows right to left through the 3.0 Ω resistor. Write down a loop equation for the upper loop.

16. [4 pts] Find the value of the current in the 5.0 Ω resistor after the switch has been closed. *Hint*: you can use your answer to the previous question.

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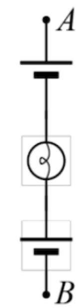
Tutorial Free Response [20 pts total]: Problems 17-20. Show work and/or explain reasoning where indicated.

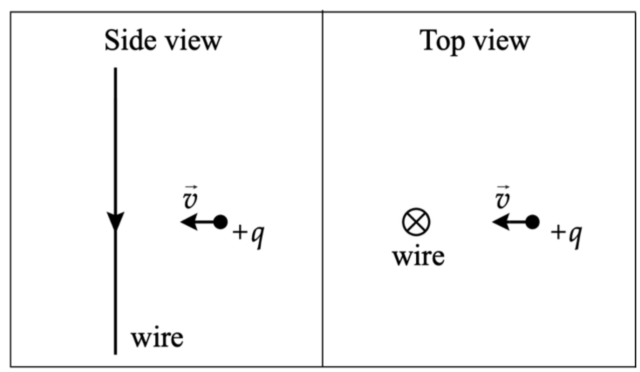
17. Two identical batteries, each with voltage ΔV_{bat}, are connected to a bulb as shown. **No other circuit elements or wires are connected**.

    [6 pts] What is the absolute value of the potential difference between points A and B? Explain your reasoning.



18. A very long wire has current directed through it as shown in the top and side view diagrams at right. A point charge $+q$ is moving directly toward the wire with speed v.

    [6 pts] In **both the top and side view diagrams**, sketch the direction of the magnetic force on the charged particle. Explain your reasoning.



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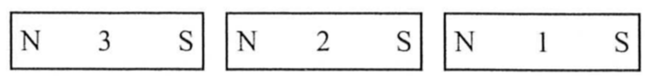
The following two questions are related.

In experiment X, two magnets labeled 1 and 2 are placed next to each other. Magnet 2 is fixed in place.

Experiment X

19. [4 pts] On the diagram at right, indicate the direction of the net force on magnet 1 from magnet 2. If the magnetic force is zero, state so explicitly. Explain your reasoning.

In experiment Y, a third magnet is added to the left of magnet 2 as shown at right. Magnets 2 & 3 are fixed in place.



Experiment Y

20. [4 pts] Is the magnitude of the net force on magnet 1 *greater than*, *less than*, or *the same as* what it was in experiment X above? Explain your reasoning.

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Phys 115, Equation Sheet, Midterm 2

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	$\epsilon_0 = 1/4\pi K = 8.85 \times 10^{-12}\mathrm{C^2/N \cdot m^2}$
Atmospheric pressure	$1\ \mathrm{atm} = 1.01 \times 10^{5}\mathrm{Pa} = 760\ \mathrm{mm\ Hg}$
Atomic mass unit	$1\ \mathrm{u} = 1.66 \times 10^{-27}\ \mathrm{kg}$
Avogadro's number	$N_\mathrm{A} = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
Boltzmann's constant	$k_\mathrm{B} = 1.38 \times 10^{-23}\ \mathrm{J/K}$
Gas constant	$R = N_\mathrm{A} k_\mathrm{B} = 8.31\ \mathrm{J/mol \cdot K}$
Boltzmann-Stefan constant	$\sigma = 5.67 \times 10^{-8}\mathrm{W/(m^2 \cdot K^4)}$
Permeability of free-space	$\mu_0 = 1.26 \times 10^{-6}\ \mathrm{T \cdot m/A}$

Mathematics

Components of a 2D vector $\vec{A}$	$A_x = A\cos\theta,\quad A_y = A\sin\theta$
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	$1\ \text{electron volt} = 1\ \mathrm{eV} = 1.60 \times 10^{-19}\mathrm{J}$
Calorie	$1\ \mathrm{cal} = 4.186\ \mathrm{J},\quad 1\ \mathrm{Cal} = 1\ \mathrm{kcal}$
Liter	$1\ \mathrm{L} = 10^{-3}\mathrm{m^3}$

Electric Potential and Energy

Potential and potential energy	$U = qV$
Potential inside capacitor	$\Delta V_\mathrm{C} = V_+ - V_- = Ed,\quad V = (x/d)\Delta V_\mathrm{C}$

Capacitance

Capacitance	$C = \frac{Q}{\Delta V_\mathrm{C}}$
Parallel-plate capacitance	$C = \frac{\epsilon_0 A}{d}$
Dielectrics	$C \to \kappa C_0$

Circuits/General

Current	$I = \frac{\Delta q}{\Delta t}$
Ohm's law	$I = \frac{\Delta V}{R}$
Junction law	$\sum I_\mathrm{in} = \sum I_\mathrm{out}$
Loop law	$\Delta V_\mathrm{loop} = \sum_i \Delta V_i = 0$

Circuits/RC

RC discharging	$I = I_0 e^{-t/\tau},\quad \Delta V_\mathrm{C} = (\Delta V_\mathrm{C})_0 e^{-t/\tau}$
RC charging	$I = I_0 e^{-t/\tau},\quad \Delta V_\mathrm{C} = \mathcal{E}(1 - e^{-t/\tau})$
RC time constant.	$\tau = RC$

Phys 115, Equation Sheet, Midterm 2

Magnetism

Magnetic field due to straight wire	$B_{\text{wire}} = \frac{\mu_0 I}{2\pi r}$
Magnetic field at center of one loop or coil	$B_{\text{coil/loop}} = \frac{\mu_0 N I}{2R}$
Magnetic field inside solenoid	$B_{\text{solenoid}} = \frac{\mu_0 N I}{L}$
Magnetic force on a point charge	$F_{\text{charge}} = \lvert q\rvert vB \sin\alpha$
Magnetic force on a current-carrying wire	$F_{\text{wire}} = ILB \sin\alpha$
Charged particle moving perpendicular to magnetic field	$F = \frac{mv^2}{r} = \lvert q\rvert vB, \quad r = \frac{mv}{\lvert q\rvert B}$

Thermal Physics

Efficiency	$e = \text{what you get/what you pay}$
Celsius to Fahrenheit	$T_{\text{F}} = \frac{9}{5}T_{\text{C}} + 32$
Celsius to Kelvin	$T = T_{\text{C}} + 273.15^\circ\text{C}$
First law of thermodynamics	$\Delta E_{\text{th}} = W_{\text{on system}} + Q$
Number of moles	$n = N/N_{\text{A}}, \quad n = M\ (\text{in grams})/M_{\text{mol}}$
Temperature & average. kinetic energy	$T = \frac{2}{3}K_{\text{avg}}/k_{\text{B}}$
Thermal energy	$E_{\text{th}} = NK_{\text{avg}} = \frac{3}{2}Nk_{\text{B}}T = \frac{3}{2}nRT$
Average kinetic energy	$K_{\text{avg}} = \frac{1}{2}m(v^2)_{\text{avg}}$
Root-mean-square velocity	$v_{\text{rms}} = \sqrt{(v^2)_{\text{avg}}} = \sqrt{\frac{3k_{\text{B}}T}{m}} = \sqrt{\frac{3RT}{M}}$
# of micro states with n tosses to end up with m heads	$\frac{n!}{m!\,(n-m)!}$
Entropy	$S = k_{\text{B}} \ln\Omega$
Entropy change at T due to heat exchange	$\Delta S = Q/T$