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

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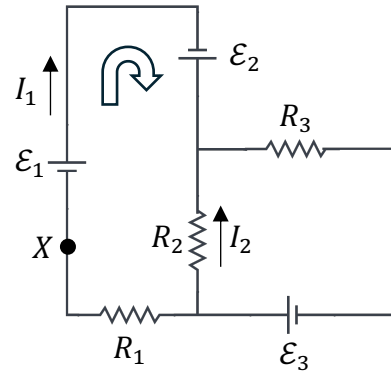
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**Multiple Choice** [5 pts each] Bubble in the most correct answer on your bubble sheet and circle the correct answer here.

Use the circuit at right to answer the next two questions.

1. [5 pts] In the circuit shown, if  $I_1 = 3.2$  A and  $I_2 = 1.7$  A, what is the current flowing through the resistor  $R_3$  and in what direction?



- A. 3.2 A to the left.
- B. 4.9 A to the right.
- C. 1.5 A to the right.
- D. 1.7 A to the left.
- E. 2.5 A to the right.

2. [5 pts] Consider the left loop designated by the thick arrow. Which one of the following represents correct application of Kirchhoff's loop equation to that loop starting and ending at point X?

- A.  $-\mathcal{E}_1 - \mathcal{E}_2 + I_2 R_2 + I_1 R_1 = 0$
- B.  $+\mathcal{E}_1 + \mathcal{E}_2 - I_1 R_2 - I_1 R_1 = 0$
- C.  $+\mathcal{E}_1 + \mathcal{E}_2 + I_2 R_2 - I_1 R_1 = 0$
- D.  $+\mathcal{E}_1 - \mathcal{E}_2 + I_2 R_2 - I_1 R_1 = 0$
- E.  $+\mathcal{E}_1 + \mathcal{E}_2 - I_2 R_2 - I_1 R_1 = 0$

Use the circuit at right to answer the next two questions

The circuit at right has a charged capacitor of capacitance  $C$  connected to a resistor of resistance  $R$ .

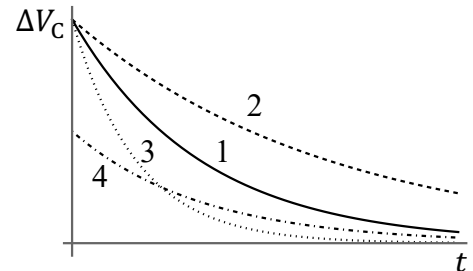
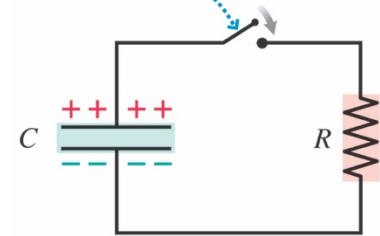
3. [5 pts] When the switch is closed, we measure the potential difference across the capacitor  $\Delta V_C$  as a function of time.

The solid curve in the graphic at right to the bottom is obtained, labeled "1". If we now repeat this experiment by recharging the capacitor to the same initial potential difference but use a smaller resistance than  $R$ , which curve would we get for the new  $\Delta V_C$ ?

Hint:  $\tau = RC$

- A. Curve 1 (solid), no change.
- B. Curve 2 (dashed)
- C. Curve 3 (dotted)
- D. Curve 4 (dot-dashed)

The switch will close at  $t = 0$ .







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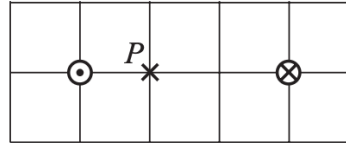
12. [5 pts] Consider a system whose entropy is decreasing during a certain time interval. According to the second law of thermodynamics:
- A. this process is impossible, as the second law prohibits entropy from decreasing.
  - B. the entropy change of the surroundings must be at least as large and opposite in sign, so that the total entropy change of the system plus surroundings is positive.
  - C. the entropy of a system fluctuates all the time, so that it would increase back again.
  - D. this could happen only if the system is isolated in order not to affect the increase of entropy of the entire universe.
  - E. this could not happen, because no system can be isolated from the rest of the universe.



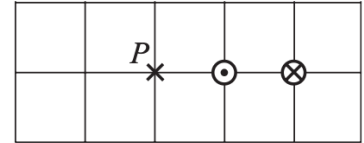
**Tutorial Free Response** [20 pts total]: Problems 17-20. Show work and/or explain reasoning where indicated.

*The next two questions are related to the following scenario.*

In each case at right, two infinite parallel wires carry equal, constant currents  $I$ . ( $\otimes$  and  $\odot$  indicates current into and out of the page, respectively.)



Case X

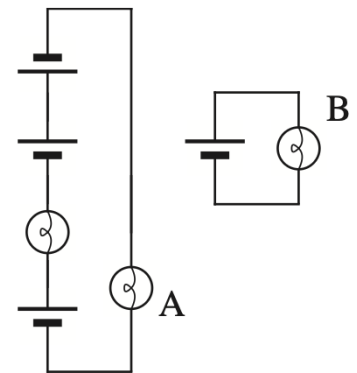


Case Y

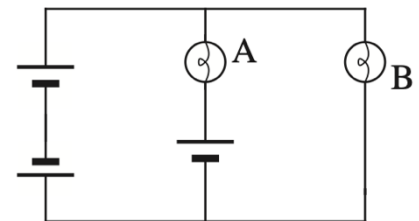
17. [5 pts] In each case, a compass is placed at point  $P$ . On each diagram, indicate the direction in which the north pole of the compass needle will point. No explanation needed.
18. [5 pts] Is the magnitude of the magnetic field at point  $P$  in case X *greater than, less than, or equal to* that in case Y? **Explain.**

In the next two questions, assume all bulbs are identical and all batteries are identical and ideal.

19. [5 pts] Two circuits are shown at right. Is bulb A *brighter than, dimmer than, or as bright as* bulb B? **Explain your reasoning.**



20. [5 pts] The circuit elements are rearranged to form the circuit at right. In this new circuit, does bulb B light up? **Explain your answer using the loop rule.**



## Phys 115, Equation Sheet, Midterm 2

### Constants

Free-fall acceleration	$g = 9.80 \text{ m/s}^2$
Elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
Coulomb's constant	$K = 8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2$
Permittivity of free-space	$\epsilon_0 = 1/4\pi K = 8.85 \times 10^{-12} \text{ C}^2/\text{N} \cdot \text{m}^2$
Atmospheric pressure	$1 \text{ atm} = 1.01 \times 10^5 \text{ Pa} = 760 \text{ mm Hg}$
Atomic mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
Avogadro's number	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
Boltzmann's constant	$k_B = 1.38 \times 10^{-23} \text{ J/K}$
Gas constant	$R = N_A k_B = 8.31 \text{ J/mol} \cdot \text{K}$
Boltzmann-Stefan constant	$\sigma = 5.67 \times 10^{-8} \text{ W}/(\text{m}^2 \cdot \text{K}^4)$
Permeability of free-space	$\mu_0 = 1.26 \times 10^{-6} \text{ T} \cdot \text{m/A}$

### 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	$\Sigma \vec{F} = m\vec{a}, \quad \vec{F}_{12} = -\vec{F}_{21}$ $w = mg$
Weight	$W = Fd \cos \theta$
Work due to a constant force	$\Delta E = W$
Conservation of energy	$P = W/t = Fv$
Power	$K = \frac{1}{2}mv^2$
Kinetic energy	$p = mv$
Momentum	$\tau = rF \sin \phi$
Torque	

### Conversions

Electron volt	$1 \text{ electron volt} = 1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$
Calorie	$1 \text{ cal} = 4.186 \text{ J}, \quad 1 \text{ Cal} = 1 \text{ kcal}$
Liter	$1 \text{ L} = 10^{-3} \text{ m}^3$

### Electric Potential and Energy

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

### Capacitance

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

### Circuits/General

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

### Circuits/RC

RC discharging	$I = I_0 e^{-t/\tau}, \quad \Delta V_C = (\Delta V_C)_0 e^{-t/\tau}$
RC charging	$I = I_0 e^{-t/\tau}, \quad \Delta V_C = \mathcal{E}(1 - e^{-t/\tau})$
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

$$B_{\text{coil/loop}} = \frac{\mu_0 NI}{2R}$$

Magnetic field inside solenoid

$$B_{\text{solenoid}} = \frac{\mu_0 NI}{L}$$

Magnetic force on a point charge

$$F_{\text{charge}} = |q|vB \sin \alpha$$

Magnetic force on a current-carrying wire

$$F_{\text{wire}} = ILB \sin \alpha$$

Charged particle moving perpendicular to magnetic field

$$F = \frac{mv^2}{r} = |q|vB, \quad r = \frac{mv}{|q|B}$$

### Thermal Physics

Efficiency

$e = \text{what you get/what you pay}$

Celsius to Fahrenheit

$$T_F = \frac{9}{5}T_C + 32$$

Celsius to Kelvin

$$T = T_C + 273.15^\circ\text{C}$$

First law of thermodynamics

$$\Delta E_{\text{th}} = W_{\text{on system}} + Q$$

Number of moles

$$n = N/N_A, \quad n = M (\text{in grams})/M_{\text{mol}}$$

Temperature & average. kinetic energy

$$T = \frac{2}{3}K_{\text{avg}}/k_B$$

Thermal energy

$$E_{\text{th}} = NK_{\text{avg}} = \frac{3}{2}Nk_B T = \frac{3}{2}nRT$$

Average kinetic energy

$$K_{\text{avg}} = \frac{1}{2}m(v^2)_{\text{avg}}$$

Root-mean-square velocity

$$v_{\text{rms}} = \sqrt{(v^2)_{\text{avg}}} = \sqrt{\frac{3k_B T}{m}} = \sqrt{\frac{3RT}{M}}$$

# of micro states with  $n$  tosses to end up with  $m$  heads

$$\frac{n!}{m!(n-m)!}$$

Entropy

$$S = k_B \ln \Omega$$

Entropy change at  $T$  due to heat exchange

$$\Delta S = Q/T$$