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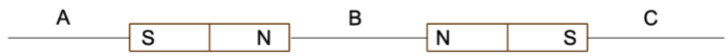
I. [60 pts] Multiple Choice: Mark your answer on BOTH the bubble sheet and this page.

1. [5 pts] Two identical bar magnets are arranged as shown at right. In which section of the horizontal axis connecting the magnets can the magnetic field be zero? The areas inside the magnets are excluded.



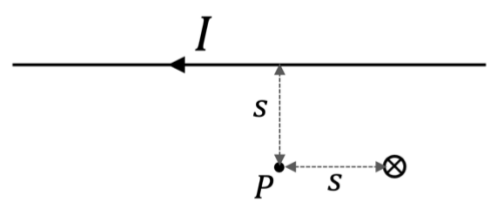
A. Section A

B. Section B

C. Section C

D. None of the above

2. [5 pts] Point P is equidistant from two current carrying wires as shown at right. One of the wires carries a current to the left parallel to the page and the other wire carries the same amount of current, I, perpendicularly into the page. What is the magnitude of the magnetic field at point P?



A. $B = \frac{\mu_o I}{\pi s}$

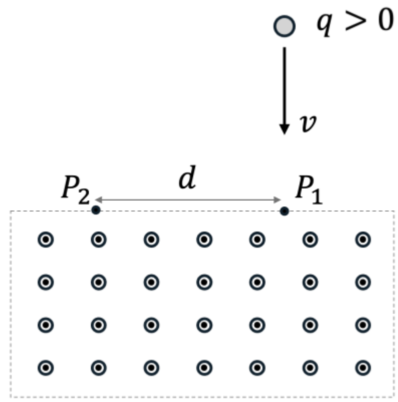
B. $B = \frac{\mu_o I}{2\pi s}$

C. $B = \frac{\mu_o I}{\sqrt{2}\pi s}$

D. $B = \frac{\sqrt{2}\mu_o I}{\pi s}$

E. $B = 0$

3. [5 pts] A particle of charge $q > 0$ and mass m moves downward at velocity v and enters a uniform magnetic field of strength B at point P_1 as shown at right. The magnetic field lines point out of the page. The charge exits the magnetic field at point P_2, which is on the same horizontal line with P_1. Determine the distance d between points P_2 and P_1.



A. $d = \frac{mv}{qB}$

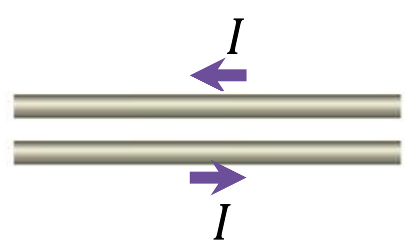
B. $d = \frac{mv}{2qB}$

C. $d = \frac{\sqrt{2}mv}{qB}$

D. $d = \frac{2mv}{qB}$

E. $d = \frac{mv}{\sqrt{2}qB}$

4. [5 pts] Two parallel wires carry current in opposite directions. Is there a force on the top wire due to the bottom wire, and if so in what direction is it?



A. There is no force.

B. There is a force out of the page.

C. There is a force into the page.

D. There is a force pointed downward.

E. There is a force up.

5. [5 pts] The label on a candy bar says 400 Calories. Assuming that the efficiency for energy use by the body is 25%, if a 60 kg person were to use the energy in this candy bar to climb stairs, how high could the person go? (Note: $g = 9.8\ \mathrm{m/s^2}$)

   A. 330 m

   B. 710 m

   C. 950 m

   D. 2900 m

   E. 11000 m

6. [5 pts] The all-time highest temperatures recorded in Finland, Ireland, and the United States are as follows (according to Wikipedia). Finland: 37.2 °C, Ireland: 91.9 °F, United States: 330 K. Rank these countries from warmest to coldest in terms of the temperature record?

   A. Finland > Ireland > United States

   B. United States > Ireland > Finland

   C. Ireland > United States > Finland

   D. United States > Finland > Ireland

   E. Ireland > Finland > United States

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7. [5 pts] 500 J of work are done on a system in a process that decreases the system's thermal energy by 200 J. How much energy is transferred to ($Q > 0$) or from ($Q < 0$) the system as heat?

   A. $Q = 300$ J

   B. $Q = 700$ J

   C. $Q = -700$ J

   D. $Q = 200$ J

   E. $Q = -500$ J

8. [5 pts] A hot reservoir at temperature 576 K transfers 1050 J of heat to a cold reservoir at temperature 305 K. Find the change in entropy of the universe.

   A. 3.21 J/K

   B. 98.1 J/K

   C. 0.72 J/K

   D. 1.77 J/K

   E. 1.62 J/K

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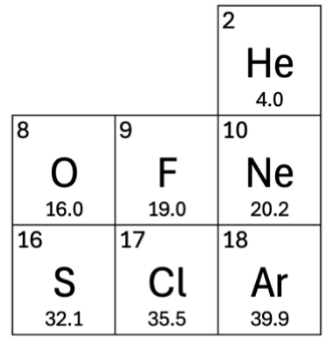
9. [5 pts] A container has 1.0 gram of pure gaseous diatomic oxygen (O_2). A relevant portion of the periodic table is given. How many molecules of O_2 are in the container? (As shown in the diagram at right, the molar mass of atomic oxygen is 16 g/mol.)



A. 1.9×10^{22}

B. 3.8×10^{22}

C. 7.5×10^{22}

D. 6.0×10^{23}

E. None of these are correct

10. [5 pts] Container A has 5 moles of helium gas (monatomic) and container B has 5 moles of neon gas (monatomic). Both gases are at $-4°\mathrm{C}$. How do the total kinetic energies of the two samples of gas compare, or is it not possible to compare?

A. Container A (helium) has more total kinetic energy.

B. Container B (neon) has more total kinetic energy.

C. Both containers have equal total kinetic energy.

D. Impossible to determine since the pressures and volumes are not given.

11. [5 pts] A sealed container of ideal gas undergoes an isothermal compression. Which of the following is true about the thermal energy of the gas and its and pressure?

    A. Thermal energy remains the same, pressure increases.

    B. Thermal energy remains the same, pressure decreases.

    C. Thermal energy increases, pressure increases.

    D. Thermal energy increases, pressure decreases.

    E. None of these are completely correct.

12. [5 pts] A medical experiment requires a tube of length 0.18 m to be heated from $20°\mathrm{C}$ to $60°\mathrm{C}$. For the experiment to function properly, the tube must not increase in length by more than 0.00010 m. What is the maximum possible coefficient of thermal expansion for the tube?

    A. $9.3 \times 10^{-6}\ \mathrm{K}^{-1}$

    B. $1.4 \times 10^{-5}\ \mathrm{K}^{-1}$

    C. $2.8 \times 10^{-5}\ \mathrm{K}^{-1}$

    D. $4.8 \times 10^{-5}\ \mathrm{K}^{-1}$

    E. None of these are correct

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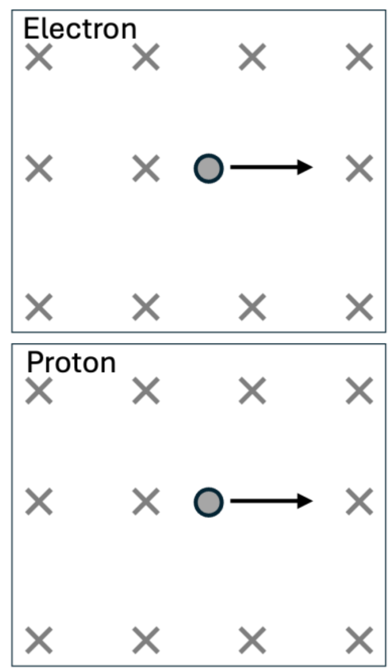
II. Lecture long-answer questions (20 points total)

13. [5 pts] A long wire that carries current into the page is placed to the right of a bar magnet, as shown.

Determine the direction of the magnetic field directly between the wire and bar magnet. Assume the two sources produce magnetic fields of equal magnitude at the point of interest. Show your work and/or explain.

14. [5 pts] An electron and a proton move perpendicularly to identical uniform magnetic fields in the indicated directions at equal speeds. The mass of the electron is less than that of the proton.

In the diagrams at right, **sketch** the resulting trajectories for both the electron and proton. Your sketch should be qualitatively correct. **Explain** your reasoning.



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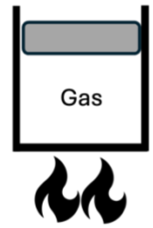
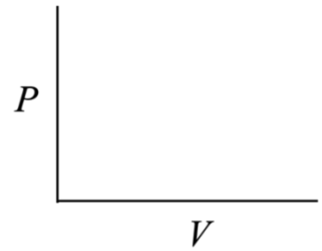
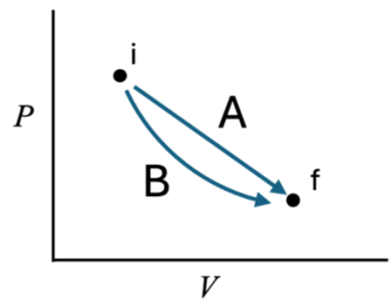
15. [5 pts] A flame is held underneath a sealed container of ideal gas. A piston that seals the top of the container is free to move up or down without friction. The temperature of the gas is observed to slowly increase.



Sketch this process on the PV diagram provided. Explain.



16. [5 pts] The PV-diagram shows two different processes, A and B, connecting two states of a sample of ideal gas. The initial and final temperatures of the states are the same (i.e., $T_\mathrm{i} = T_\mathrm{f}$).



Is the heat added to the gas during process A *greater than, less than,* or *equal to* the heat added during process B, or is there *not enough information* to answer? Explain.

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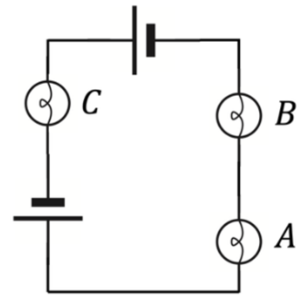
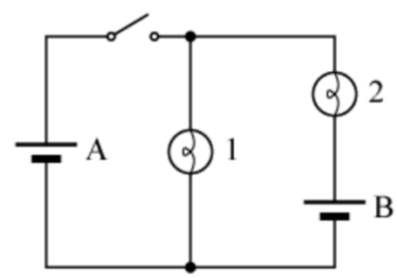
III. Tutorial long answer questions (20 points total)

In the circuits in $Q17$ and $Q18$, all bulbs are identical, and all batteries are ideal and identical.



17. [5 pts] Rank the bulbs A-C according to brightness, from brightest to dimmest. Explain your reasoning.

18. [5 pts] After the switch is closed in the circuit at right, does the brightness of bulb 1 *increase*, *decrease*, or *stay the same*? Explain your reasoning.



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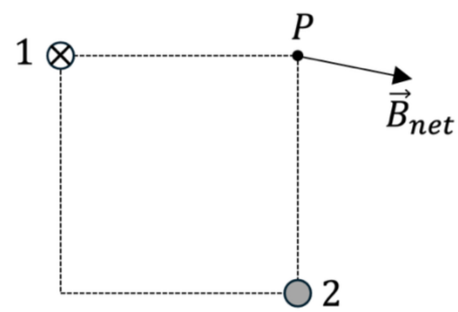
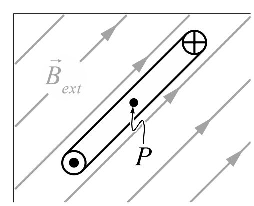
19. A long wire, wire 1, carries a current I_0 into the page. A second wire, wire 2, is located as shown. At point *P*, the net magnetic field points as shown (the wires are equidistant from point *P*).



   a) [3 pts] Does wire 2 carry a current into or out of the page? Explain.

   b) [3 pts] Is the current in wire 2 *greater than, less than* or *equal to* I_0? Explain.

20. [4 pts] A small loop of wire is placed in a region with a uniform magnetic field $\vec{B}_{ext}$ that does not change with time. The loop is attached to a battery (not shown) so that there is a current through it as shown in the cross-sectional diagram at right. The center of the loop is at point *P*.



   Note: The symbol ⊗ indicates current into the page and the symbol ⊙ indicates current out of the page.

   Is the magnitude of the net magnetic field at point *P* *greater than, less than,* or *equal to* the magnitude of $\vec{B}_{ext}$? Explain your reasoning.

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: $k_\mathrm{B} = 1.38 \times 10^{-23}\,\mathrm{J/K}$

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: $1\ \mathrm{eV} = 1.60 \times 10^{-19}$ 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: $T(^\circ C) = \frac{5}{9}[T(^\circ F) - 32^\circ]$

Kelvin conversion: $T(K) = T(^\circ C) + 273$

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