Physics 7B, Fall 2022

Final Exam - Prof. R. Birgeneau

Dec. 12, 2022 / 11:30am – 2:30pm

Name:

Instructions:

- Write your answer to each question in the designated box provided. Otherwise, you will not be given credits for your answer.
- You can use the back page of the paper for your solution but make sure that only your final answer to each question is within the box.
- Write legibly and only use variables given in the problem. The graders will be strict in distinguishing upper- and lower-case letters so make sure to use what is specified in the problem.
- If asked for a numerical answer, always round up your answer to 2 decimal places. If your answer is an integral value, no need to add two decimal places anymore.
- You can use any equations without the need to prove them unless stated explicitly in the problem.
- Write your SID # in all pages of the exam paper for us to easily find your paper if ever it gets detached from the rest of your paper.
- You may use constants in your answer such as k for $\frac{1}{4\pi\epsilon_0}$, μ_0, ϵ_0, e for the magnitude of the charge of electron/proton, R for gas constant, g, etc.
- If not stated, you can assume that the units of the given variables are in SI unit system.

Problem 1: [10 points]

Part 1:
Suppose n moles of an ideal gas of volume V_1 at T_1 are allowed to expand isothermally to V_2.

(a) [2 points] Determine the work done by the gas, W.

$W =$

(b) [1 point] What is the heat added to the gas, Q?

$Q =$

(c) [1 point] What is the change in internal energy of the gas, ΔU?

$\Delta U =$

Part 2:
In an engine, an almost ideal gas is compressed adiabatically to half its volume. In doing so, W work is done on the gas. The gas is not necessarily monoatomic. If initially, the gas has a temperature of T_1 and a volume V_1.

(a) [2 points] How much heat flows into or out of the gas?

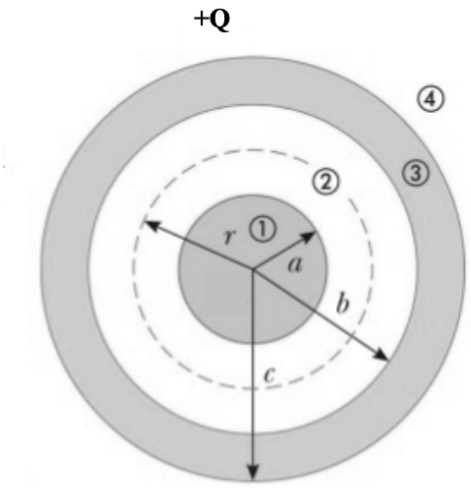
(b) [1 point] What is the change in internal energy of the gas?

$\Delta U =$ [ ]

(c) [3 points] What is the final temperature of the gas? Does it rise or fall?

$T_2 =$ [ ], Rise or Fall? [ ]

Problem 2: [15 points]



A nonconducting sphere of radius a is uniformly charged with volume charge density ρ_E. It is surrounded by a concentric metal (conducting) spherical shell of inner radius b and outer radius c, which carries a net charge of +Q. Using Gauss's Law, determine the resulting enclosed charge and electric field in four different regions:

(a) [4 points] $0 < r < a$

$Q_{encl} =$

$E(r) =$

(b) [4 points] $a < r < b$

$Q_{encl} =$

$E(r) =$

(c) [3 points] $b < r < c$

$Q_{encl} =$

$E(r) =$

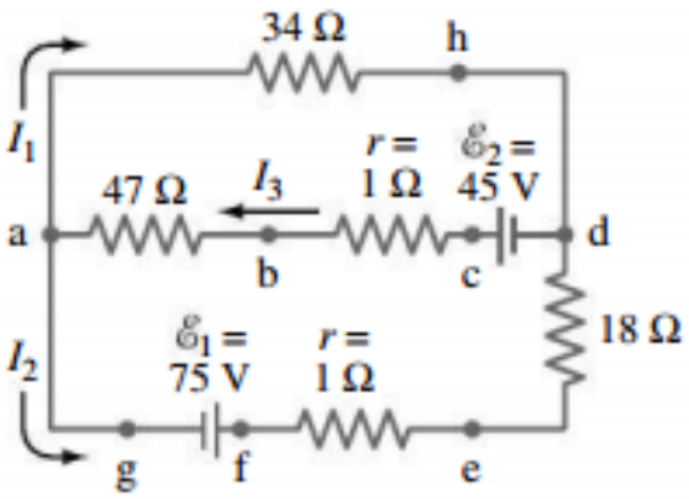
(d) [4 points] $r > c$

$Q_{encl} =$

$E(r) =$

Problem # 3: [10 points]

Using the figure below, find the following:



(a) [2 points] Using Kirchhoff's Loop Rule, derive an equation in terms of I_1, I_2 *and* I_3 from the upper loop. Combine similar terms in your equation.

_____ I_1 + _____ I_2 + _____ I_3 = _____

(b) [2 points] Repeat part (a) but this time using the lower loop.

_____ I_1 + _____ I_2 + _____ I_3 = _____

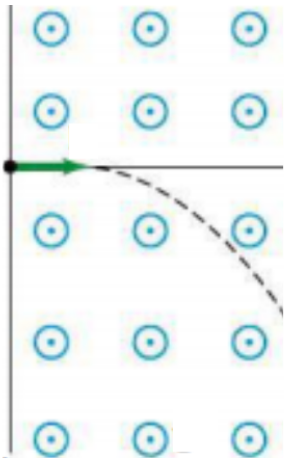
(c) [2 points] Using Kirchhoff's Junction Rule, derive an equation for node *a*.

_____ I_1 + _____ I_2 + _____ I_3 = _____

(d) [2 points] What is the terminal voltage of the 45V battery?

(e) [2 points] What is the potential difference between points *a* and *d*?

Problem # 4: [10 points]



A doubly charged helium atom whose mass is M is initially at rest. It is accelerated by a voltage of X *volts* which causes it to move. Upon reaching its maximum speed, it enters a region of uniform magnetic field of magnitude B which is perpendicular to the direction of the Helium atom motion.

(a) [4 points] What is the speed, v, of the helium atom as it enters the region of the magnetic field?

$v =$

(b) [3 points] What is the radius of curvature, R, of the motion of the helium atom? You may leave your answer in terms of the speed v (solved in part a).

$R =$

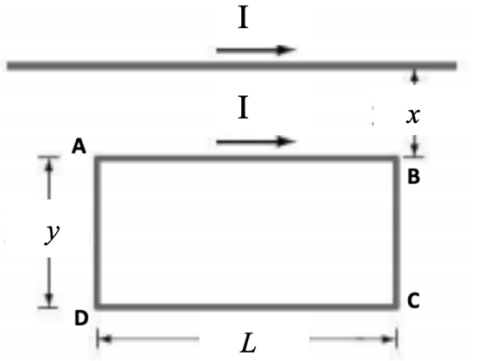
(c) [3 points] What is the period of revolution, *T*, of the Helium atom? You may leave your answer in terms of R (solved in part b).

$T =$

<u>Problem # 5:</u> [20 points]

Part 1:

A rectangular loop of wire is placed next to a straight wire as shown in the figure below. There is a current of *I Amperes* in both wires, as shown in the figure.



(a) [2 points] Determine the magnetic field (in Tesla) at the location of segment AB, both magnitude and direction.

$B_{AB} =$, direction =

(b) [2 points] Determine the magnetic field at the location of segment CD, both magnitude and direction.

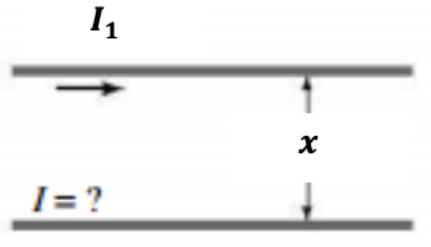
$B_{CD} =$, direction =

(c) [4 points] What is the net force (magnitude and direction) acting on the loop?

$F =$, direction =

Part 2:

A long horizontal wire carries a current of I_1 Amperes. A second wire, made of *d* diameter copper wire and parallel to the first, is kept in suspension magnetically a distance of *x* below. Consider the effect of gravity in this problem and assume that the density of copper wire is ρ_c.



(a) [2 point] What must be the direction of force on the lower wire due to I_1 for it to be kept in suspension?

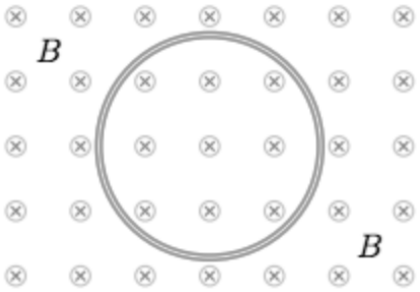
(b) [2 point] What should be the direction of the current in the lower wire to create such a force due to the upper wire?

(c) [4 points] Calculate the magnitude of the force per unit length to keep the lower wire suspended as stated in the problem.

$\frac{F}{L} =$

(d) [4 points] Calculate the magnitude of current in the lower wire.

Problem # 6: [20 points]



Part 1:

The area of an elastic circular loop decreases at a constant rate of $\frac{dA}{dt} = P$. The loop is in a uniform magnetic field, *B,* that is perpendicular to the plane of the loop. At t = 0, the loop has an area of A_0.

(a) [3 points] Determine the induced emf at $t = 0$.

$\mathcal{E}(0) =$

(b) [2 points] Determine the induced emf at $t = T$.

$\mathcal{E}(T) =$

Suppose the radius of the elastic loop increases at a constant rate $\frac{dr}{dt} = S$ instead.

(c) [3 points] Determine the induced emf at $t = 0$.

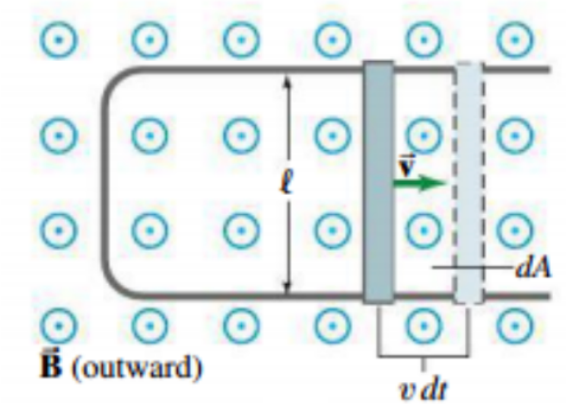
$\mathcal{E}(0) =$

(d) [4 points] Determine the induced emf at $t = T$.

$\mathcal{E}(T) =$

Part 2:

The rod moves to the right with a speed of v and has a resistance r. The rail separation is ℓ. The magnetic field is B, and the resistance of the U – shaped conductor is R at a given instant.



(a) [3 points] Calculate the induced emf.

$|\mathcal{E}| =$

(b) [2 points] Calculate the current in the U-shaped conductor.

$I =$

(c) [3 points] What is the required external force to keep the rod's velocity constant at that instant?

$F_{ext} =$

Problem # 7: [15 points]

Part 1:

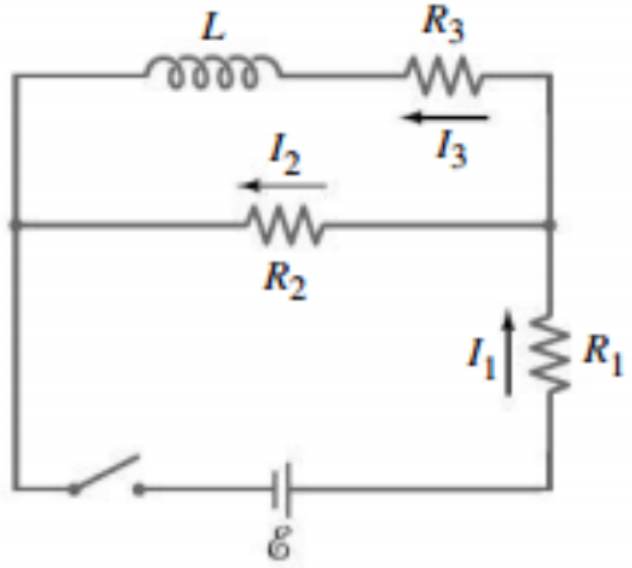
An air-filled cylindrical inductor has N_1 turns, and it is d_1 in diameter and l_1 long.

(a) [2 points] What is its inductance?

(b) [2 points] How many turns would you need to generate the inductance if the core were filled with iron of magnetic permeability μ?

Part 2:

Given the circuit diagram below. Solve for I_3 in all the following cases.



(a) [2 points] The moment the switch is closed:

(b) [5 points] The switch has been closed for a very long time:

(c) [2 points] Just after the switched is open:

(d) [2 points] The switched is open for a very long time: