Diplomvorprüfung zur Vorlesung Experimentalphysik II

Prof. Dr. M. Stutzmann, 09.09.2004

Time: 90 min
5 Tasks
Points in total: 52

Declaration:
Hereby I declare my agreement for publication of my results of this exam together with my student–ID (without name) on the E25 webpage to simplify the information procedure

Garching, September 9^{th} 2004 Name (block letters):

Student ID: Signature

Problem 1: Working cycle (16 Points)

In a thermodynamic cycle, $n = 10$ Mol of an ideal gas are subject to three process steps: In the first step $1 \rightarrow 2$ the working gas is being expanded adiabatically, while the following step $2 \rightarrow 3$ consists of an isobaric cooling.
Furthermore, the following relations hold:
$p_2 = 1$ bar, $p_1 = 2\, p_3$, $T_1 = 600$ K, and $V_1 = V_3$.
The molar heat capacity at constant volume of the gas is $c_{v,mol} = 2.5\, R$, where R denotes the universal gas constant.

a) Sketch the process in the p-V diagram.
b) What would be the correct denotation of the change of state in step $3 \rightarrow 1$?
c) Calculate the adiabatic coefficient κ of the gas.
d) Calculate the state variables V_1, V_2, T_2, and T_3.
e) Determine the amounts of heat and work introduced into the system, $Q_{1\rightarrow 2}$, $Q_{2\rightarrow 3}$, $Q_{3\rightarrow 1}$, and $W_{1\rightarrow 2}$, $W_{2\rightarrow 3}$, $W_{3\rightarrow 1}$, respectively.
f) Compute the area which is enveloped by the curve in the p-V-diagram by integration. Compare this with the results from e).
g) In which direction of rotation can this process be used as a heat engine, and what degree of efficiency would such a heat engine exhibit?

Problem 2 (7 Points)

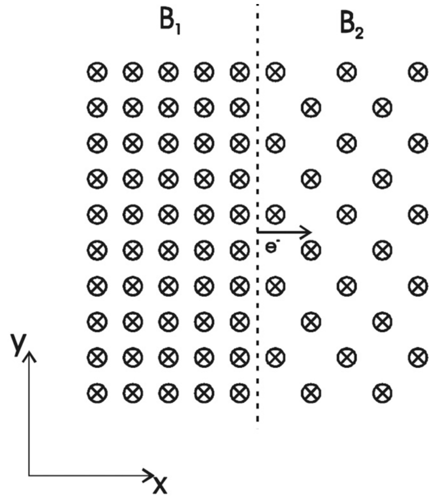
In the Bohr's classical model of an atom, electrons move on circular trajectories around positively charged nucleons. Consider a single electron orbiting a single proton. Additionally, the orbital momentum of the electron has to be an integer multiple n of $\hbar = h/2\pi$. Here, h is the Planck's constant.

a) Calculate the equilibrium radius as a function of n and give a numerical value for $n = 1$.
b) Calculate the magnetic moment caused by the motion of the electron as function of n.
c) The motion of the electron induces a magnetic field at the position of the proton. Give a numerical value for the magnetic field at the position of the proton for $n = 1$.

Problem 3 (15 Points)

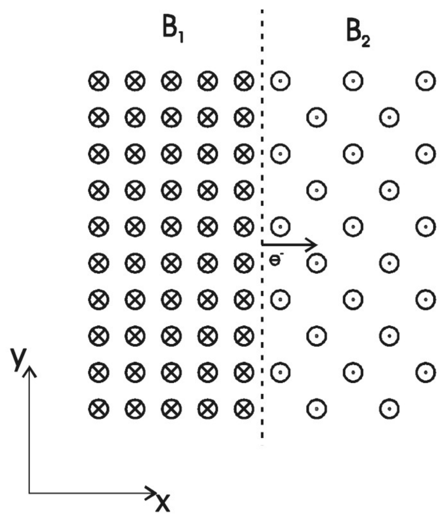
The space is divided into two regions with two different but parallel orientated magnetic fields.

The magnetic fields are directed into the paper plain as depicted in the picture on the right hand side ($B_1 > B_2$). Electrons with kinetic energy *E*, mass m_e, and charge *e* are emitted by an electron source at the boundary between the two fields in positive *x* direction.



(a) Calculate the velocity *v* of the electrons after the emission from the electron source.
(b) In which direction will the electrons be deflected (positive or negative *y* direction)?
(c) Calculate the radius of the electron trajectory for the two cases: (i) the electrons are in the right magnetic field region, $B = B_2$, and (ii) the electrons are in the left magnetic field region, $B = B_1$.
(d) Draft the trajectory of the electrons for the case that B_1 is twice B_2. Denote the two different radii. Are collisions of electrons possible? If yes, where?
(e) Calculate the average velocity of the electrons in *y* direction for given kinetic energy *E* and for arbitrary magnetic fields B_1 and B_2, respectively? Note: Calculate the time of flight in the two regions with the two different magnetic fields.

The direction of the magnetic field in the right hand region is now inverted (compare picture on the right hand side).



(f) Draft the trajectory of the electrons for the case $|B_1| = 2 \times |B_2|$. Denote the two different radii. Are collisions of the electrons possible and if yes, where?
(g) Calculate the average velocity of the electrons in *y* direction (depending from *E*, B_1, B_2).
(h) The area of B_2 is now limited in *x* direction by a wall in a distance of 10 cm from the boundary. How large must B_2 be chosen at least that electrons with a kinetic energy of 100 eV will not crash into?

Problem 4: Magneto-Hydrodynamic-Generator (5 Points)

The following idealised conditions are considered for a MHD-Generator (Magneto-Hydrodynamic Generator):

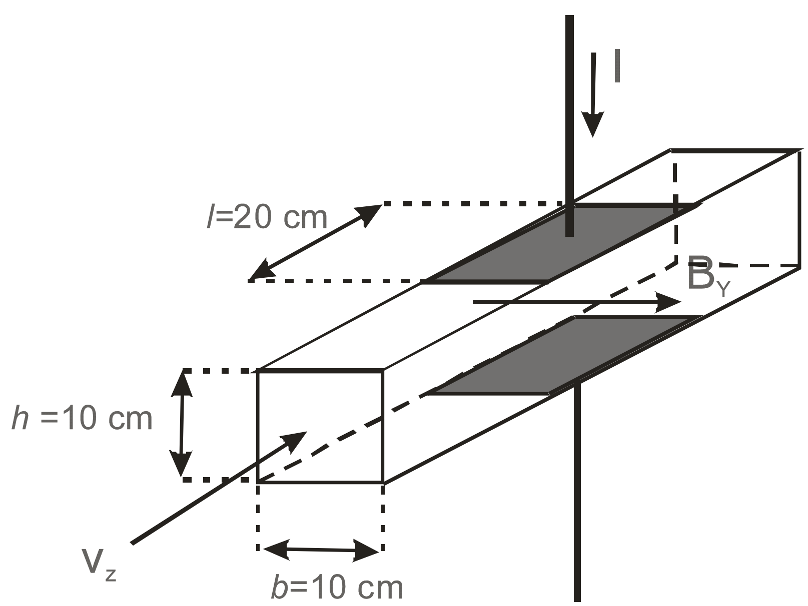
A liquid with a specific electrical conductivity σ = 1 S/cm streams with a constant velocity v_z = 1 km/s through a channel with a square cross section (width b = 10 cm, height b = 10 cm). Perpendicular to the streaming direction a homogenous magnetic field B_y = 1 T is applied over the length l = 20 cm. The current I can be drained from square sized electrodes (10 cm x 20 cm) mounted on both sides. The additional magnetic field induced by the current I should be neglected.

a) Calculate the electric field strength E_{ind} between the electrodes?

b) Calculate the open circuit voltage V_{OC} of the generator?

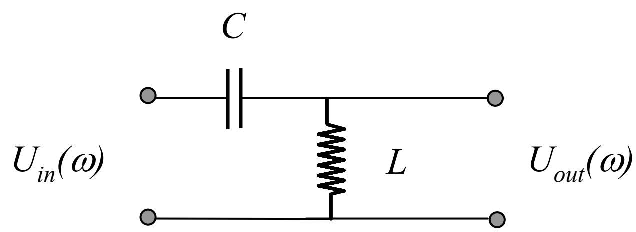
c) Which is the value of the generator's internal resistance assuming that the drained current I is distributed homogeneously over the square sized contact area (10 cm x 20 cm)?

d) Calculate the maximum drainable current (short circuit current) I_{SC}?



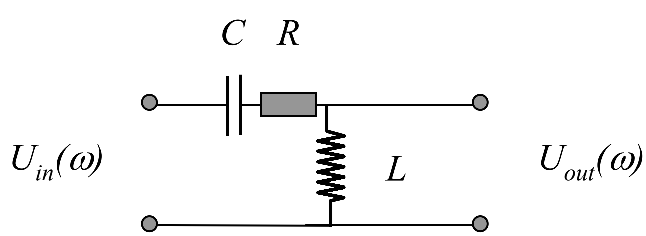
Problem 5 (5 Points)

Consider the following circuit:



a) Calculate the complex input impedance $Z_{in}(\omega)$ and the frequency-dependent transfer function $S(\omega) = \left| \frac{U_{out}(\omega)}{U_{in}(\omega)} \right|$.

b) Now, consider the changed circuit as depicted below.



Calculate the transfer function $S(\omega)$ for this changed circuit

c) Sketch the frequency dependent transfer function calculated in a) and b). For what kind of application this circuit is normally used?