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DANGER

Indian Institute of Technology, Delhi
Centre for Energy Studies

ESL 360: Direct Energy Conversion Methods

Minor-I Examinations
Duration: 60 minutes.

Marks: 20
15 Feb. 2015

1) Fill in the blanks: [2.5]
   a. The axial current is ideally zero in a ________ MHD generator.
   b. The magnetic Reynold's number is a measure of the extent to which ________ modifies or deflects the magnetic field and is defined as the ratio of ________ to ________.
   c. The Hall parameter is the product of the magnetic field and ________.

2) Given that the following ionizing reaction occurs in a monoatomic gas

$$B \Leftrightarrow B^{+} + e$$

Considering that the mixture of the monoatomic gas, ion and electrons can be assumed to be a mixture of three ideal gases

   a. Show that

$$\ln\left[\left(\frac{\varepsilon_e^2}{1-\varepsilon_e^2}\right)P\right] = -\frac{FE}{RT} + \frac{5}{2}\ln T + \ln D$$

   where, P is the pressure, T is the temperature of the gas, ε_e is the degree of ionization reaction, F is the Faraday's constant, E is the ionization potential of the atom in volts, R is the molar gas constant, ln D is proportional to the change in entropy of the system.

   b. Show the conductivity of an ionized gas is inversely proportional to the momentum transfer cross-section(Q). [5.5]

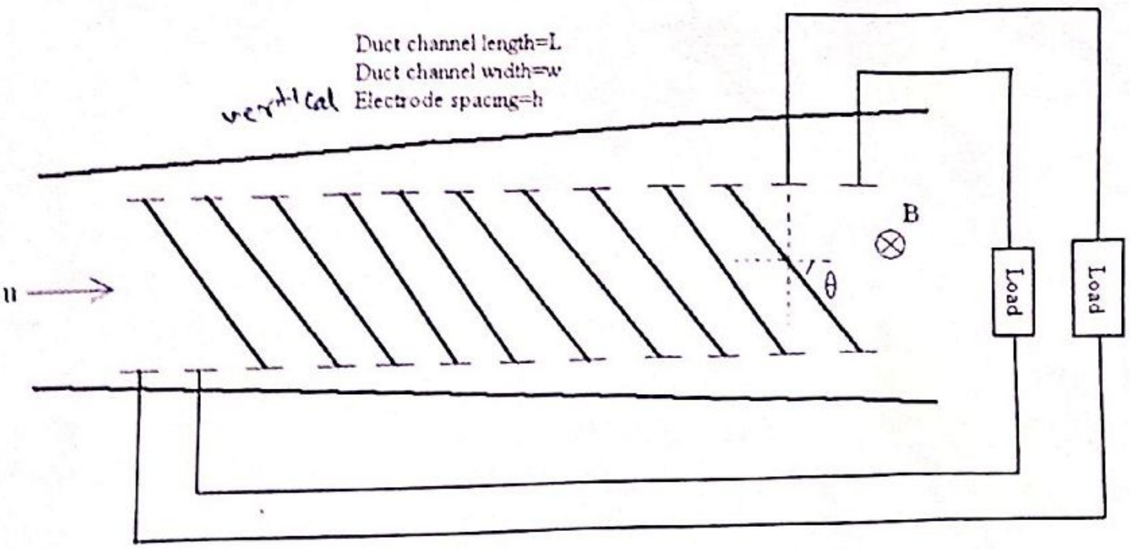
3)
   a. Through combustion of a fossil fuel at 3750R, an engine receives energy at a rate of 4000 Btu/s to heat steam to 1250R. There is no energy loss in the combustion process. The steam in turn produces 1000 Btu/s of work and rejects the remaining to the surroundings at 500R. Utilizing the work output through this process the plant is able to generate 0.5 MW$_e$h for distribution. What is the irreversibility of the plant?
   b. An electric commuter vehicle uses a 20-hp electric motor and is to have a photovoltaic array on the roof to charge the batteries both while moving and parked. The commute is one hour each way and the vehicle is parked for 7 hours. Thus for each hour of operation you estimate that the vehicle will be parked for 3.5 hours during daylight hours. The overall electromagnetic to electrical to mechanical energy conversion is 12.5% and the storage efficiencies of the batteries is 55%. Determine the area required to provide sufficient energy for the commute. Solar flux = 600 W/m² [6]

Which of the above two cases can be expressed as a direct energy conversion method. Why?

4) Given that the total current density (j) is

$$\vec{j} = \sigma\vec{\varepsilon} - \frac{\omega\tau}{B}\vec{j}\times\vec{B}$$

Where, ε is the sum of all electric fields and u × B terms. Determine the perpendicular ($j_\perp$) and parallel ($j_\parallel$) current densities, in terms of the total load voltage (V), Hall parameter, and the gas conductivity (σ), for the following electrode configuration of a diagonal MHD generator, as shown below. Parallel and perpendicular components here imply with respect to the source internal electric field (E) available to drive the external load. [6]



Additional inputs:

I. Chemical potential of j[th] ideal gas in a mixture of ideal gases can be written as:

$$\mu_j = RT[\phi_j + \ln(P) + \ln(x_j)]$$

With P being the pressure, T is the temperature, R is the molar gas constant, x_j being the mole fraction of the j[th] constituent of a mixture of ideal gases and ϕ_j is a function of temperature alone given as:

$$\phi_j = \frac{h_{0j}}{RT} - \frac{1}{R}\int \frac{\int C_{pj} dT}{T^2} dT - \frac{S_{0j}}{R}$$

with h_{0j} and S_{0j} being constant enthalpy and entropy terms, C_{pj} the heat capacity at constant pressure.

II. Rankine Temperature = (9/5) * Kelvin Temperature=Fahrenheit Temperature+459.67

III. Cp-Cv=R; and internal energy of a gas with f degrees of freedom and temperature T is equal to f{(1/2)kT}

IV. 1-hp=746 W; 3412 Btu=1 kW,h

V. Under steady state 1-d MHD flow and no heat conduction, it can be considered that

the continuity equation is given as:
$\rho u A$=constant

the momentum equation is given as:
$\rho u(du/dx) + \nabla p = \mathbf{j} \times \mathbf{B}$

the energy equation is given as:
$\rho u \, d[h+(u^2/2)] / dx = \mathbf{j}.\mathbf{E}$

where, h is the enthalpy per unit mass, A is the cross-section of the duct through which the gas is flowing with flow velocity **u** (u being its magnitude). **j** is the current density driven and **E** and **B** are the electric field and magnetic fields, p is the pressure and ρ is the mass density.