B.DAY

ESL 360: DIRECT ENERGY CONVERSION METHODS
MAJOR TEST (5th May 2015)

MAX. MARKS: 50

Universal Gas Constant = 8.314 J/mol.K, Boltzmann's Constant = 1.38×10^{-23} J/K, Faraday Constant=96500 C/mol, Fundamental charge = 1.6×10^{-19} C, Stefan-Boltzman constant =5.67×10^{-8} W/m^{2}K^4

Section A

[1]. Write down solar cell individual energy conversion process like absorption, thermodynamical and practical efficiencies.

[2]. Explain with schematic under dark and illumination conditions, the Schottky barrier formation for charge carriers between n-type semiconductor and metal junction; consider that semiconductor has smaller workfunction than metal workfunction. [3]

[3]. Write transport equations for electrons and holes in a semiconductor, and explain briefly about the current density term. [3]

[4]. The Sun (radius = 6,95,990 km) can be modeled as an ideal black-body at 5800 K. The mean Sun-Earth distance is 1.5×10^{11} m. The absorptance on earth surface is 70% only, which is averaged over the incident Sun's energy spectrum, the re-emission from the Earth surface after absorption is 60%. Calculate the Earth surface temperature after finding the solar constant? [5]

[5]. If V_{oc} of a Silicon solar cell is 0.8 V and J_{sc} = 25 mA/cm^2 under STP conditions. What is the reverse saturation current for a 10 cm diameter solar cell? [2]

[6]. A solar cell has a short circuit current density of 40 mA/cm^2 and open circuit voltage of 0.70 V under one-sun illumination at room temperature. By using ideal diode equation calculate the open circuit voltage under the illumination of 140 suns, with the assumption of short circuit increases linearly but the reverse saturation current and fill factor do not change with concentrated light. The measured open circuit voltage is 0.76 V with the concentrated light, compare this with calculated value and write the reasons for the discrepancy. [5]

[7]. The minority carrier conc^n in an n-type material is about 10^3 cm^{-3}. Due to illumination the minority carrier concentration changed to ~10^{16} cm^{-3}. If the excess minority carriers travel a distance of 2 μm in 2 μsec before recombining. Calculate the recombination rate of the minority carriers. [2]

[8]. Write mathematical statements of the first and second laws of thermodynamics for a fuel cell? [2]

[9]. At STP, the highest voltage attainable from H_2-O_2 fuel cell is 1.229 V for the available Gibbs free-energy change of -237 KJ/mol in the chemical reaction. If we operate the fuel cell at room temperature on 4 atm pure H_2 and 7 atm air pressure, what will be the fuel cell voltage? What is the difference in cell voltage, when we operate the cell at 1 atm H_2 and 1 atm air pressure? [3]

[10]. For the following chemical reaction in H_2-O_2 fuel cell

$2H_2 + O_2 \rightarrow 2H_2O$

(where H_2 and O_2 are gasses at 25 ^{0}C and 1 atm. pressure)

The change in heat content of the reaction is -136.5 Kcal/mole, and change in Gibb's free

energy is -113.4 Kcal/mole, the actual fuel flow rate is 4.09×10^{-4} mole/min but the independent measurements reveal that 1.56×10^{-5} mole/min of fuel is escaping through the electrolyte unreacted, the cell delivers 1.35 amps current and the actual cell voltage is 0.85 V.

Calculate the ideal electromotive force generated in fuel cell, and also calculate current, power, and practical efficiencies of a fuel cell. [6]

[11]. **The following statements are True or False, justify with the comments, Marks will be given only with justification** [6]

a. Fuel cell is limited by the Carnot efficiency.
b. If we consider solar cell is a heat engine, the conversion efficiency will be >98%.
c. In a p-type semiconductor with $N_A = 1 \times 10^{18}$ cm^{-3}, if we increase the doping of acceptors 10 times further the net recombination rate is also going to increase 10 times at equilibrium condition.
d. The current density-voltage curve of solar cell will deviate from its original shape due to the radiative and non-radiative recombination processes.

Section B

Note: NEGATIVE MARKING IS THERE. For each incorrect answer, 25% additional marks will be deducted.

Any variables used to answer questions have to be also defined to get the marks for your answer.

[5]

1. Fill in the blanks:
   a) The ratio of the ion slip velocity to the gas flow velocity is related to the charged particle masses as _____.
   b) The absence of a closed-circuit path for the Hall current is in the _____ MHD generator.
   c) Ion slip in a MHD generator occurs when ion _____ velocity with respect to _____ becomes significant.
   d) The fundamental difference between ion slip and Hall effect is that the former increases _____ whereas the latter does not.
   e) The maximum relative efficiency of a thermoelectric generator as a function of the figure of merit of the elements _____ with increasing ratios of hot junction temperatures (T_H) to cold junction temperatures (T_C).

2. Certain elements A and B have the following properties in the temperature range: mean Seebeck coefficient, S_m=7 mV/°K; thermal conductance of each element = 100 mW/°K; resistance of each element=15 mΩ. The elements operate between junction temperature of 1050 K and 600 K. Determine the maximum output and efficiency at maximum output. [2]

3. State True or False. *If False, state the correct answer or else marks will not be given*: [3]
   a) The polytropic efficiency is proportional to the electrical efficiency in a MHD generator.
   b) The interaction length at constant pressure is inversely proportional the gas flow velocity in a MHD generator.
   c) The Seebeck coefficient is inversely proportional to the Peltier coefficient in a thermoelectric generator.