REN NO:______________________ NAME:_______________________

DEPARTMENT OF ENERGY SCIENCE AND ENGINEERING

IIT BOMBAY

PHD ADMISSIONS

WRITTEN TEST

DATE: TIME: 1 HOUR

MAXIMUM MARKS: 35

PART A

1. Draw the energy band diagram of a p-n junction solar cell. [2M]
2. Emissivity of a perfect blackbody is zero: True or False [2M]
3. In a transformer, the coefficient of mutual induction between the primary and secondary coil is 0.2 H. When a current changes by 20 amperes/second, the emf induced in the secondary is [2M]
4. A parallel plate capacitor has a capacitance of 55 μF with air as dielectric and 110 μF with oil as a dielectric. The dielectric constant of the oil is ________ [2M]
5. If you and your friend randomly answered a multiple choice question that had 4 choices, what is the probability that you were correct and your friend was incorrect? [2M]
6. The inner and outer surface temperatures of a glass window 5 mm thick are 15^oC and 5°C, respectively. What is the heat loss per unit area through the window? The thermal conductivity of glass is 1.4 W/mK. [3M]
7. How high can a human throw a ball (in meters) if he/she can throw it with an initial velocity 90 mph (miles per hour)? [2M]
8. In order to design a horizontal piping system to supply water to a small plant, the pumping requirements are to be estimated by carrying out tests with air on a 1:8 scale model. The diameter of the pipe in the model at the supply point is 3cm and the velocity there is 150m/s. What would be the velocity in the plant at the supply point.

   Data given: $\mu_a = 1.8 \times 10^{-5} \frac{kg}{ms}$, $\rho_{air} = 1.2 \frac{kg}{m^3}$, $\mu_{water} = 1cP$, $\rho_{water} = 1000 \frac{kg}{m^3}$, [3M]
9. Find the Eigen values of the matrix: [2M]

   $$\begin{bmatrix} 2 & 7 \\ -1 & -6 \end{bmatrix}$$
10. Evaluate $$\underset{x\to 0}{Limit} \frac{x - \sin x}{x^2 \tan x}$$ [2M]
11. Evaluate the integral $$\int_0^{2\pi} \int_0^{\pi} \sin(x+y)\,dxdy$$ [3M]

PART B

READ THE ATTACHED ARTICLE AND ANSWER THE FOLLOWING QUESTIONS

[2 Marks Each]

1. Utilization of the sun's energy for human needs in the long term involves

   a. Capture of energy from the sun
   b. Conversion of the captured energy to only electrical energy
   c. Conversion of the captured energy to any form of useful energy
   d. Utilization the converted energy immediately
   e. Utilizing it immediately and storing the excess energy

2. The annual averaged efficiency for solar water splitting by PV-driven electrolysis would be about ____%

3. What are the conditions at which the power conversion efficiency of present commercial single-junction (single photo system) silicon solar cell modules is typically 18%.

4. Write down the two half cell reactions in an electrolyzer for water.

5. If the hydrogen half cell reaction potential is at -4.2eV, The value of the oxygen reaction is ___________

Excerpt from "**"Comparing Photosynthetic and Photovoltaic Efficiencies and Recognizing the Potential for Improvement",** Robert E.Blankenship et al, Science 332(2011)pp 805-809.

Efficiency is a concept that is deceptively simple yet can be elusive for comparisons between such different systems as living organisms and photovoltaic cells. The solar conversion efficiency of a PV device can be directly measured with high accuracy and is usually quoted by researchers and manufacturers in terms of power: electrical power out (W/cm^2) divided by incident solar irradiance (W/cm^2) measured over the entire solar spectrum. This instantaneous metric, measured at peak solar intensity, does not include energy storage and transmission. In contrast, natural photosynthesis stores energy in the chemical bonds of its molecular products and uses much of this energy to sustain and replicate the organism, typically over a defined growing season. A more direct comparison of PV and photo-synthetic solar energy conversion efficiencies would consider a process in which PV also stores energy in chemical bonds. Application of PV-derived energy to electrolysis of water is a good choice for this purpose: Existing commercial electrolyzers afford accurate efficiency benchmarks, and the free energy needed in order to split H_2O into H_2 and O_2 ($\Delta G°$=1.23eV) is essentially equal to the free energy change associated with photosynthesis [$\Delta G°$ = 1.24 eV for $CO_2 + H_2O$ to $(CH_2O) + O_2$, where (CH_2O) is shorthand for carbohydrate]. The power conversion efficiency of present commercial single-junction (single photo system) silicon solar cell modules is typically 18 %. This value pertains to peak solar intensity (1 kW/m^2), with an AM1.5 spectral distribution or solar zenith angle of 48.2° (sunlight passing through 1.5 atmospheres). The efficiency of a PV module changes during the day and through- out the year because of the changing solar zenith angle, and the PV efficiency averaged over a 1-year cycle is about 95% of the maximum AM1.5 value. Modern commercial electrolyzers have efficiencies as high as 80% [based on heat of combustion of H_2 to H_2O in liquid form at atmospheric pressure and 25°C, standard temperature and pressure (STP) conditions]. This assumes that there is no mismatch between the photo voltage generated by the PV array and the voltage required for electrolysis. Present Si PV modules arranged in electrical series would suffer mismatch losses as high as 20 to 30%, bringing the overall H_2O splitting efficiency down to ~10 to 11%. This constitutes the first benchmark to compare with the efficiency of photosynthetic fuel production. As discussed below, ongoing research is providing opportunities to construct PV devices with considerably higher efficiencies. Several different measures of efficiency have been used in describing natural photo-synthesis. The quantum efficiency is the percentage of absorbed photons that give rise to stable photoproducts. Photosynthetic organisms typically can operate at nearly 100% quantum efficiency under optimum conditions. For comparison with PV electrolysis over an annual cycle, the energy efficiency of photo-synthesis is a more useful parameter and is defined as the energy content (heat of combustion of glucose to $CO_2$and liquid H_2O at STP) of the biomass that can be harvested annually divided by the annual solar irradiance over the same area. Using this definition, solar energy conversion efficiencies for crop plants in both temperate and tropical zones typically do not exceed 1%, a value that falls far below the benchmark for PV-driven electrolysis. Higher 3% annual yields are reported for microalgae grown in bioreactors.

.-- End .--

ROUGH WORK