Department of Electrical Engineering
Assignment
Date: 23/06/2020

Course Details

Course Title: Direct Energy Conversions **Module:** ______
Instructor: ______ **Total Marks:** 50

Student Details

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Note: Plagiarism of more than 20% will result in negative marking.
Similar answers of students will result in cancellation of the answer for all parties.

Q1.	(a)	Magneto hydrodynamics (MHD) is a direct energy conversion technique. What are the basic differences in working principle of this system as compared to conventional hydro power systems. How is the output power obtained from this system.	Marks 10
Q2.	(a)	Thermo-electric systems are emerging as a popular alternate to conventional thermal power systems. What are the main factors involved in the technology that determine the output power of thermos-electric generator. How can the maximum power be obtained from this system.	Marks 10
Q3.	(a)	The Thermionic generator has two main types (i) Vacuum Convertor and (ii) Cesium Gas Convertor. Explain in detail why which convertor is more efficient, has more life-time and is easier to construct/operate.	Marks 10
Q4	(a)	Thermo-electric and Thermionic are DEC techniques. What are the common principle in both systems. What are the main differences between both the systems. Explain in detail.	Marks 10
Q5	(a)	Thermo-Nuclear fusion has the potential to provide unlimited clean power. But the technology has not been mainstreamed due to technical difficulties. What are the main issues with the system. How can they be solved.	Marks 10

Question # 01: What are the main issues with Thermo-Nuclear Energy? How can they be solved?

The energy obtained after nuclear fusion or fission of atomic nuclei at very high temperature is termed as thermonuclear energy. Thermonuclear energy is a divisive issue that many people have mixed feelings about. It has many dangerous effects to the environment and the people living near a power plant. Many countries use this as an alternate source of electrical energy from fossil fuels. This energy has to be handled with extreme care or it could lead to disastrous damages. These problems included:

1. Radiations
2. Disposing of Nuclear wastes
3. High costs of building
4. Maintaining power plants.

Additional important issues related to thermonuclear energy are listed below with possible solutions.

Main issues of thermonuclear energy and Solutions:

1. While it is extremely dangerous to use thermonuclear energy, it does provide an alternate source of energy. According to the EPA, thermonuclear energy originates from the splitting of uranium atoms in a process called fission. Fission releases energy that can be used to make steam, which is used in a turbine to generate electricity. Thermonuclear energy is generally used in a combine mixture with Uranium and Plutonium. EPA further states, in the nuclear reactor, neutrons from uranium atoms collide with each other, releasing heat and neutrons in a chain reaction. This heat is used to generate steam, which powers a turbine to generate electricity. Unfortunately, thermonuclear energy also generates some nasty by-products like tritium, cesium, krypton, neptunium and iodine. This disadvantage can be reduced if the by-products are controlled and not exposed to the environment.

2. Thermonuclear energy is also bad for the environment and to people living near to the power plants. The problems with sharing this knowledge, is that countries will have access to the knowledge of how to make nuclear weapons, which could be bad for some nations. The International Energy Agency or IEA is responsible for energy in many countries, but some have criticizes them for not being able to keep the knowledge from hostile countries. To solve these problems, the plants need to be constructed away from the human populations and strict safety measures must be taken to solve these problems. Humans need to be protected with safety kits who are working near the plants.

3. There are also many environmental problems with using thermonuclear energy as well. The problem with mining uranium and the use of plutonium leads to contamination of the area around it. Humans become affected by this contamination as well as ecosystems. Some of these contaminations last for thousands of years, leaving toxic chemicals in our ecosystems for many years. This is only the beginning affects shown by thermonuclear energy, there could be many more we have not discovered yet. These wastes must be controlled to safe humans and ecosystems.

Question # 02: What is the common principle between Thermo-Electrical, Thermo-Ionic and Thermo-Hydro energy? Explain the main difference between them.

The main principle is to attain the thermal energy by using three different methods. The individual principle of three methods is given below.

1. **Thermo-ionic Energy:**

Thermal ionization, also known as surface ionization or contact ionization is a physical process whereby the atoms are desorbed from a hot surface, and in the process are ionized. Thermal ionization is used to make simple ion sources for mass spectrometry and for generating ion beams. Thermal ionization has seen extensive use in determining atomic weights, in addition to being used in many geological/nuclear applications. One application of thermal ionization is thermal ionization mass spectrometry (TIMS). In thermal ionization mass spectrometry, a chemically purified material is placed onto a filament which is then heated to high temperatures to cause some of the material to be ionized as it is thermally desorbed (boiled off) the hot filament. Filaments are generally flat pieces of metal around 1-2mm wide, 0.1mm thick, bent into an upside-down U shape and attached to two contacts that supply a current.

2. **Thermo-Electrical Energy:**

A temperature difference created by thermoelectric generators which is turned it into electrical energy. Heating one end of a thermoelectric material causes the electrons to move away from the hot end toward the cold end. When the electrons go from the hot side to the cold side this causes an electrical current, which the PowerPot harnesses to charge USB devices. The larger the temperature difference the more electrical current is produced and therefore more power generated. The tricky part about thermoelectric generators is that as you heat the hot side, the cold side of the generator heats up too. In order to generate power with the thermoelectric generator you need both a heat source and a way of dissipating heat in order to maintain a temperature difference across the thermoelectric materials. This is done with no moving parts by heating water in the PowerPot. Water holds several times more heat than aluminum per pound, so it makes a wonderful heatsink. Also, water never gets hotter than 212 F (100 C) at a boil, effectively limiting the maximum temperature of the “cold” side of the thermoelectric generator. This is why you always need to have something watery in the PowerPot or else it is possible to overheat the thermoelectric generator.

3. **Thermo-hydel Energy**

Hydropower or water power is power derived from the energy of falling or fast-running water, which may be harnessed for useful purposes. Since ancient times, hydropower from many kinds of watermills has been used as a renewable energy source for irrigation and the operation of various mechanical devices, such as gristmills, sawmills textile mills, trip hammers, dock cranes, domestic lifts and ore mills. A trompe, which produces compressed air from falling water, is sometimes used to power other machinery at a distance.

Question # 03: Explain in detail why cesium gas confinement is more efficient and has more life than vacuum containment in Thermo-ionic generators.

A thermionic generator consists of a hot electrode which thermionically emits electrons over a potential energy barrier to a cooler electrode, producing a useful electric power output. Cesium vapor is used to optimize the electrode work functions and provide an ion supply, by surface ionization or electron impact ionization in plasma, to neutralize the electron space charge.

The scientific aspects of thermionic energy conversion primarily concern the fields of surface physics and plasma physics. The electrode surface properties determine the magnitude of electron emission current and electric potential at the electrode surfaces and the plasma properties determine the transport of electron current from the emitter to the collector. All practical thermionic converters to date employ cesium vapor between the electrodes, which determines both the surface and plasma properties. Cesium is employed because it is the most easily ionized of all stable elements. A thermionic generator is like a cyclic heat engine and its maximum efficiency is limited by Carnot's law. It is a low-Voltage high current device where current densities of 25-50 (A/squarecm) have been achieved at voltage from 1-2V. The energy of high temperature gases can be partly converted into electricity if the riser tubes of the boiler are provided cathode and anode of a thermionic generator with the interspace filled with ionized Cesium vapor.

The surface property of primary interest is the work function, which is the barrier that limits electron emission current from the surface and essentially is the heat of vaporization of electrons from the surface. The work function is determined primarily by a layer of cesium atoms adsorbed on the electrode surfaces. The properties of the interelectrode plasma are determined by the mode of operation of the thermionic converter. In the ignited (or "arc") mode the plasma is maintained via ionization internally by hot plasma electrons (~ 3300 K); in the unignited mode the plasma is maintained via injection of externally produced positive ions into a cold plasma; in the hybrid mode the plasma is maintained by ions from a hot-plasma interelectrode region transferred into a cold-plasma interelectrode region. Substantial improvements in generator performance can be obtained now at lower operating temperatures by addition of oxygen to the cesium vapor by suppression of electron reflection at the electrode surfaces and by hybrid mode operation. Similarly, improvements via use of oxygen-containing electrodes have been demonstrated along with design studies of systems employing the advanced thermionic generator performance. Recent studies have shown that excited Cesium-atoms in thermionic generator form clusters of Cs-Rydberg matter which yield a decrease of collector emitting work function from 1.5 eV to 1.0 – 0.7 eV. Due to long-lived nature of Rydberg matter this low work function remains low for a long time which essentially increases the low-temperature converter's efficiency.

Question # 04: What are the main factors that determine the output power of thermoelectric generator? How can we attain maximum power?

The factors that determine the output power of a thermoelectric generator are given below:

1. The seedback Effect
2. Temperature Difference
3. Electric Conductivity
4. Material Resistance
5. Load Resistance

Mathematically, these factors are defined as with association to output power:

[redacted]

To attain maximum power P_{max}, the material resistance must be equal to load resistance i.e., $R=R_{L.}$

Question # 05: Explain the working principle of magnetohydrodynamic generator. How is the output power obtained?

A magnetohydrodynamic generator (MHD generator) is a magnetohydrodynamic converter that utilizes a Brayton cycle to transform thermal energy and kinetic energy directly into electricity. MHD generators are different from traditional electric generators in that they operate without moving parts (e.g. no turbine) to limit the upper temperature. They therefore have the highest known theoretical thermodynamic efficiency of any electrical generation method. MHD has been extensively developed as a topping cycle to increase the efficiency of electric generation, especially when burning coal or natural gas. The hot exhaust gas from an MHD generator can heat the boilers of a steam power plant, increasing overall efficiency. An MHD generator, like a conventional generator, relies on moving a conductor through a magnetic field to generate electric current. The MHD generator uses hot conductive ionized gas (a plasma) as the moving conductor. The mechanical dynamo, in contrast, uses the motion of mechanical devices to accomplish this. Practical MHD generators have been

developed for fossil fuels, but these were overtaken by less expensive combined cycles in which the exhaust of a gas turbine or molten carbonate fuel cell heats steam to power a steam turbine. MHD dynamos are the complement of MHD accelerators, which have been applied to pump liquid metals, seawater and plasmas.
Right-hand rule is used as a principle to measure quantities. This effect is a result of Faraday's Laws of Electro-magnetic induction i.e. when the conductor moves through a magnetic field; it generates an electric field perpendicular to the magnetic field & direction of conductor. The induced EMF is given by

$$E_{ind} = u \times B \quad (1)$$

Where
u = velocity of the conductor.
B = magnetic field intensity.

The induced current is given by,

$$I_{ind} = C \times E_{ind} \quad (2)$$

Where
C = electric conductivity

The retarding force on the conductor is the Lorentz force given by

$$F_{ind} = I_{ind} \times B \quad (3)$$

The output power can be calculated as:

$$\rho = \sigma B^2 v^2 K (1 - K) \ W/m^3 \quad (4)$$

Where
σ is the specific electrical conductivity of gas in siemen/ metre,
B is magnetic field strength in Tesla (Wb/m^2),
v is the velocity of gas in m/s
K is the ratio of external load voltage to open-circuit voltage.