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 No (01):

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?

Answer No (01):

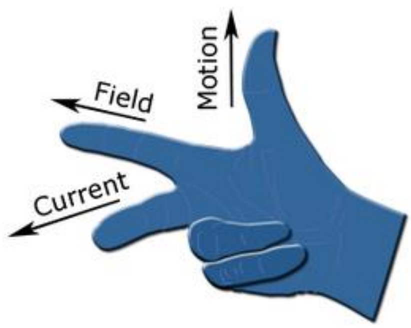
MAGNETO-HYDRO DYNAMIC GENERATOR

An MHD generator is a device for converting heat energy of a fuel directly into electrical energy without conventional electric generator.

MHD Working Principle:

Fuels like coal, oil, natural gas, and other fuels that are capable of producing high temperatures can be utilized in MHD generators. Besides this, MHD generators can use nuclear energy to generate electricity.

Fleming's right-hand rule (for generators) shows the direction of induced current when a conductor attached to a circuit moves in a magnetic field.



This effect is a result of FARADAYS 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

Eind = u x B

Where u = velocity of the conductor.

B = magnetic field intensity.

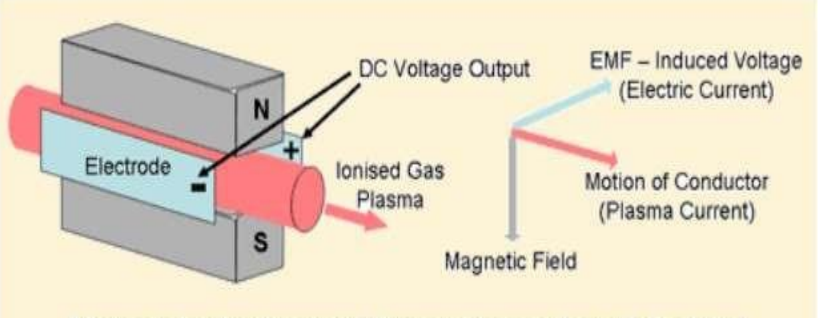
The induced current is given by,

Iind = C x Eind where C = electric conductivity

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

Find = Iind X B.

The conducting fluid flow is forced between the plates with a kinetic energy and pressure differential sufficient to overcome the magnetic induction force. An ionized gas is employed as the conducting fluid. Ionization is produced either by thermal means I.e. by an elevated temperature or by seeding with substance like cesium or potassium vapors which ionizes at relatively low temperatures. The atoms of seed element split off electrons. The presence of the negatively charged electrons makes the gas an electrical conductor.



Magnetohydrodynamic Power Generation (Principle)

Hydro-power-plant:

Hydropower plants capture the energy of falling water to generate electricity. A turbine converts the kinetic energy of falling water into mechanical energy. Then a generator converts the mechanical energy from the turbine into electrical energy.

Comparison MHD and hydropower system:

A Magneto Hydrodynamic Generator is a device which converts heat energy of a fuel directly into electrical energy without a conventional electric generator. This system eliminates all the intermediate linking conversion processes thereby improving the efficiency. It can be used with any high-temperature heat source like Nuclear,
Solar
Energy,
Chemical
etc.

Hydropower plants capture the energy of falling water to generate electricity. A turbine converts the kinetic energy of falling water into mechanical energy. Then a generator converts the mechanical energy from the turbine into electrical energy.

The power output of an MHD generator for each cubic metre of its channel volume is proportional to the product of the gas conductivity, the square of the gas velocity, and the square of the strength of the magnetic field through which the gas passes.

$$\rho = \sigma B2\ v2K\ (1 - K)\ W/m3$$

Where σ is the specific electrical conductivity of gas in siemen/ metre,

B is magnetic field strength in Tesla (Wb/m2),

v is the velocity of gas in m/s

K is the ratio of external load voltage to open-circuit voltage.

Question No (02):

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?

Answer No (02):

Thermoelectric power generator:

Thermoelectricity refers to a class of phenomena in which a temperature difference creates an electric potential or an electric potential creates a temperature difference.

Thermoelectric power generator is a device that converts the heat energy into electrical energy based on the principles of Seebeck effect.

Later, In 1834, French scientist Peltier and in 1851 Thomson (later Lord Kelvin) described the thermal effects on conductors.

Seebeck effect

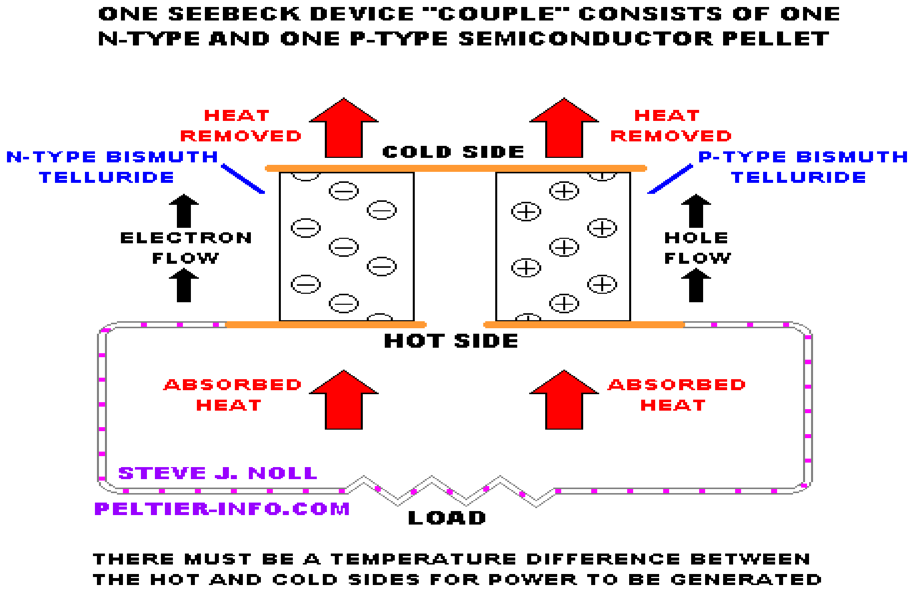
When the junctions of two different metals are maintained at different temperature, the emf is produced in the circuit. This is known as Seebeck effect.

The conductor 1 is maintained at $T+\Delta T$ temperature

The conductor 2 is maintained at

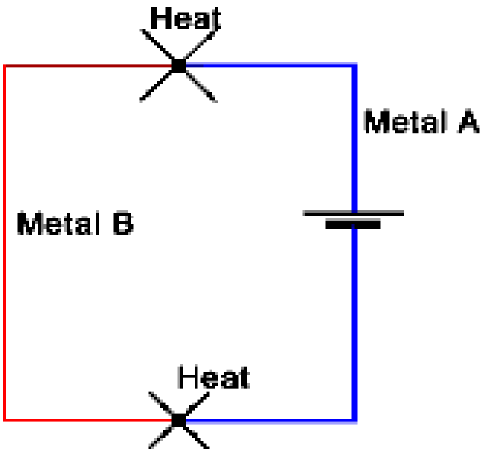
temperature ‘T’.

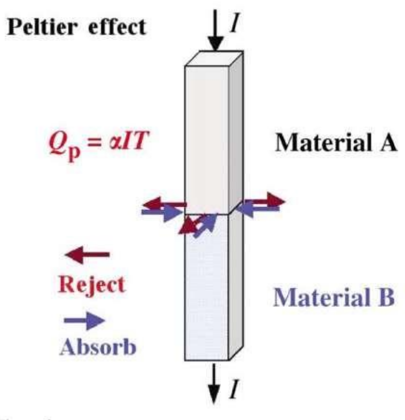
Since the junctions are maintained at different temperature, the emf ‘U’ flows across the circuit.

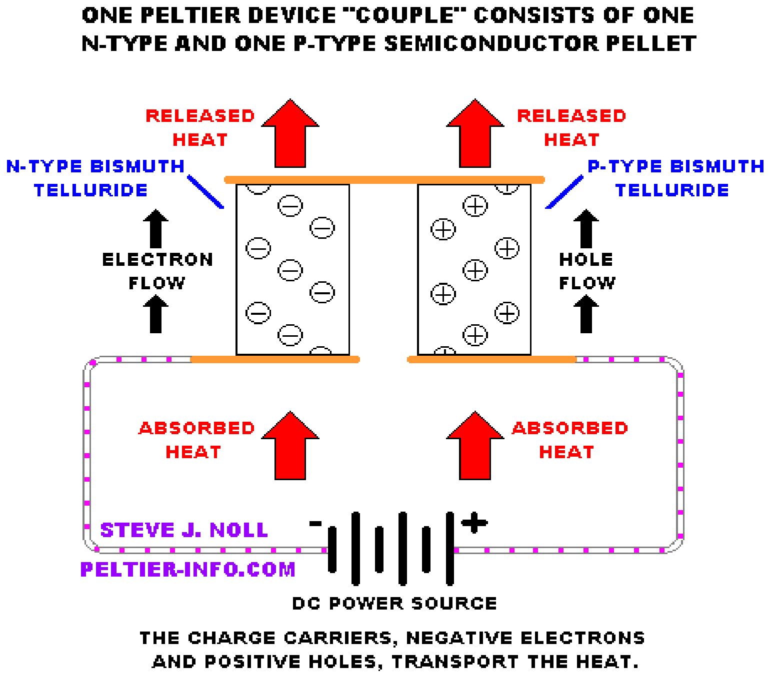


Peltier effect:

Whenever current passes through the circuit of two dissimilar conductors, depending on the current direction, either heat is absorbed or released at the junction of the two conductors. This is known as Peltier effect.







Thomson effect:

Heat is absorbed or produced when current flows in material with a certain temperature gradient. The heat is proportional to both the electric current and the temperature gradient. This is known as Thomson effect.

Thermoelectric effect:

The thermoelectric effect, is the direct conversion of heat differentials to electric voltage and vice versa.

The good thermoelectric materials should possess

1. Large Seebeck coefficients
2. High electrical conductivity
3. Low thermal conductivity

Question No (03):

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.

Answer: (03)

Introduction:

Thermionic Power Convertor is a static device that converts heat into electricity by boiling electrons from a hot emitter surface (approx. 1800 K) across a small inter electrode gap (< 0.5 mm) to a cooler collector surface (approx. 1000 K)

- A **Thermionic Generator** consists of one or more of these convertors coupled to give desired power output
- Thermionic generators can be operated from any primary heat source.
- For low power level (3 kW or less) solar energy can be used
- For high power level (50 kW or more) nuclear heat source can be used.

The two main types are as follows:

1) Vacuum Convertor.
2) Cesium Gas Convertor.

1) Vacuum Convertor.

The available power and the efficiency of a thermionic converter can be severely limited by buildup of space charge between the electrodes. The vacuum type of thermionic converter uses a very small gap between its emitter and collector electrodes—typically 0.025 to 0.038 mm (0.001 to 0.0015 inch)—in order to minimize the effects of this electronic space charge. At a temperature of 1,100 K (about 800 °C, or 1,500 °F) the electric power converted is 0.1 to 1 watt per square centimeter of emitter surface. Converters with such small spacing are difficult to manufacture, though. As a result, the vacuum converter has had only limited practical application.

Has been under extensive research since 1957
Physical spacing of .0005 inch or less is maintained between anode and cathode
Will have engineering difficulty
Lifetime is 40 hours.

2) Cesium Gas Convertor. These devices are designed so that positively charged ions are continuously generated and mixed with negatively charged electrons in the space between the emitter and the collector to provide a plasma with a relatively neutral space charge. Because of this, a liberated electron encounters little electrostatic resistance force in passing from the emitter to the collector. Alkali metals are used to produce a readily ionizable vapor. Cesium is used in the most efficient converters because of its low ionization potential (3.89 electron volts). Potassium, rubidium, and various other elements may also be used. The vapor pressure is normally on the order of 100 pascals. Contact ionization occurs when the ionization potential is less than the work function of the emitter material. Tungsten is a suitable emitter material because of its ability to operate at relatively high temperatures.

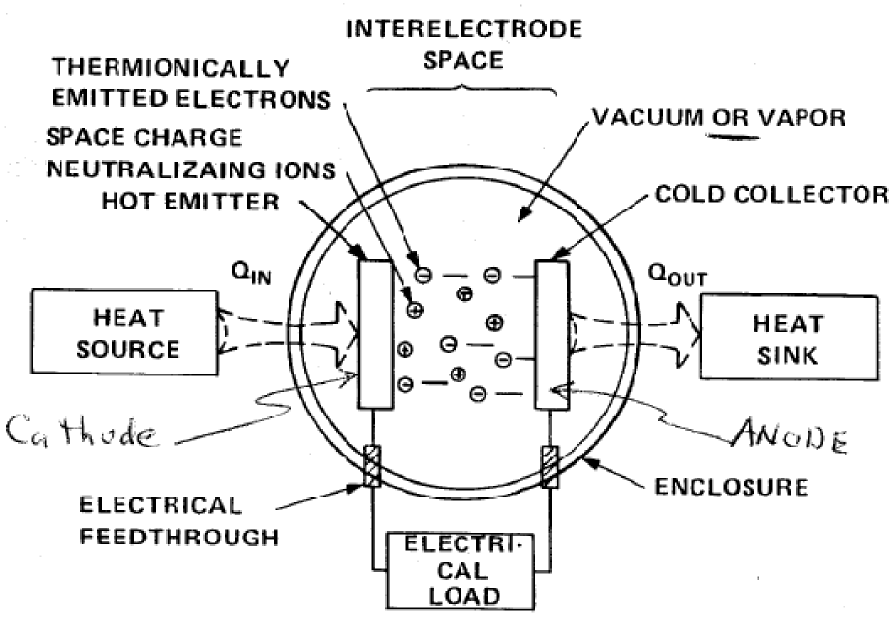
Cesium gas is filled between anode and cathode.
Working efficiency is higher than former one.
Lifetime is nearly 600 hours.
Main problem is efficient sealing and corrosive nature of cesium.

Conclusion:

Hence it is concluded that the life time and working efficiency of cesium gas convertor is more efficient that the vacuum convertor so the cesium gas convertor is best choice.

Common Points:

THERMIONIC CONVERTERS



TYPICAL OPERATING REGIME

EMITTER TEMPERATURE:	1600–2000 K (2420–3140°F)
COLLECTOR TEMPERATURE:	800–1100 K (980–1520°F)
ELECTRODE EFFICIENCY:	UP TO 20%
POWER DENSITY:	1–10 W/cm^2

MATERIALS

EMITTER MATERIALS:	W, Re, Mo
COLLECTOR MATERIALS:	Nb, Mo
INSULATOR MATERIALS:	Al_2O_3, Al_2O_3/Nb CERMET
ELECTRODE ATMOSPHERE:	Cs AT 1 Torr

Question No (04):

Thermo-electric and thermionic are DEC techniques. What are the common principle in both system. what are the main difference between both the system, explain in detail.

ANSWER 04:

Thermo-electric generator:

Thermo-electric generators is a device that converts heat energy into electrical energy based on principle of see beck effect.

Thermionic Power generator:

Thermionic Power Convertor is a static device that converts heat into electricity by boiling electrons from a hot emitter surface (approx. 1800 K) across a small inter electrode gap (<0.5 mm) to a cooler collector surface (approx. 1000 K).

COMMON PRINCIPLE:

Both Thermo-electric generators and Thermionic Power generator employ electron gas as working fluid.

In solid-state physics, the **free electron model** is a simple model for the behavior of charge carriers in a metallic solid. It was developed in 1927, principally by Arnold Sommerfeld, who combined the classical Drude model with quantum mechanical Fermi–Dirac statistics and hence it is also known as the **Drude–Sommerfeld model**.

DIFFERNCES:

A thermionic generator based on the ballistic current flow which is highly efficient, and its theoretical efficiency is close to the Carnot efficiency.

A thermoelectric generator, however, has poor efficiency due to the diffusive current flow.

A thermionic generator usually requires a high temperature heat source (e.g., 1500 K) to generate a practically useful current.

A thermoelectric generator, however can produce electrical power from low quality heat energy sources.

Thermionic generators can be operated from any primary heat source.

- For low power level(3 kW or less) solar energy can be used
- For high power level (50 kW or more) nuclear heat source can be used

Thermoelectric power generation (TEG) devices typically use special semiconductor materials, which are optimized for the Seebeck effect.

The simplest thermoelectric power generator consists of a thermocouple, comprising a p-type and n-type material connected electrically in series and thermally in parallel.

An electrical current is produced, proportional to the temperature gradient between the hot and cold junctions.

A thermionic energy converter (or) thermionic power generator is a device consisting of two electrodes placed near one another in a vacuum.

One electrode is normally called the cathode, or emitter, and the other is called the anode, or plate.

Ordinarily, electrons in the cathode are prevented from escaping from the surface by a potential-energy barrier.

When an electron starts to move away from the surface, it induces a corresponding positive charge in the material, which tends to pull it back into the surface.

To escape, the electron must somehow acquire enough energy to overcome this energy barrier.

At ordinary temperatures, almost none of theelectron can acquire enough energy to escape.

Thermoelectric power generation have present and future efficiency 3% and 13 respectively. While thermionic energy converter have present and future efficiency 15% and 40% respectively.

Question No (05):

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**?**

Answer No (05):

Nuclear fusion has the potential to offer almost unlimited clean energy, but harnessing it is extremely difficult. Plasma reaching temperatures of 150 million degrees Celsius needs to be produced by fusing two lighter atomic nuclei to form a heavier nucleus—the same process that powers the Sun.

The key problem in achieving thermonuclear fusion is how to confine the hot plasma. Due to the high temperature, the plasma cannot be in direct contact with any solid material, so it has to be located in a vacuum. Also, high temperatures imply high pressures. The plasma tends to expand immediately and some force is necessary to act against it. This force can take one of three forms: gravitation in stars, magnetic forces in magnetic confinement fusion reactors, or inertial as the fusion reaction may occur before the plasma starts to expand, so the plasma's inertia is keeping the material together.

Scientists at the Princeton Plasma Physics Laboratory have now found a way to help solve this problem, by eliminating a common instability seen in plasma—known as edge localized modes, or ELMs.

In a study published in Nature Physics, the team looked at ways to control the ELM bursts by disturbing the plasma with magnetic ripples. This reduces the pressure and helps prevent ELMs from happening. To do this they had to find the exact level of magnetic distortion—too little and you get ELMs, too much you end up with other instabilities that potentially cause even more damage.

Jong-Kyu Park and colleagues predicted a set of distortions that could control ELMs without any additional instabilities. They then tested these distortions at the Korean Superconducting Tokamak Advanced Research (KSTAR)—a ring-shaped magnetic fusion confinement device. Their experiments worked.

"We show for the first time the full 3D field operating window in a tokamak to suppress ELMs without stirring up core instabilities or excessively degrading confinement," Park said. "For a long time we thought it would be too computationally difficult to identify all beneficial symmetry-breaking fields, but our work now demonstrates a simple procedure to identify the set of all such configurations."

This breakthrough means scientists will be able to better predict the distortions for a far larger tokamak—the ITER, the world's largest fusion experiment that will take place inside the most complex machine ever built. Being able to control the plasma inside the ITER

Tokamak will be essential if fusion energy is to be produced from it. At the moment, scientists believe the ITER Tokamak will start producing plasma in December 2025.