SPM – Pre-Course Study Guide

Revision Date: 18-December-2017

This Pre-Course Study Guide is intended for review by those scheduled to attend the Calhoon MEBA Engineering School's 32-hour, one-week, **Shore Power Management (SPM)** course. This **Guide** is offered for the purpose of reducing the classroom time allocated to reviewing fundamental concepts. For those attending the course, questions related to any of these basic concepts will be addressed upon request or as needed.

The material presented below is a summary of the basic scientific concepts needed for the course. The material is presented in a bullet-point format and presumes most of the concepts and ideas were learned previously in high school and/or college. The material is presented from the perspectives of electric power and marine corrosion and is consistent with the way the course material is covered in class.

There is a self-evaluation exercise consisting of twenty (20) questions at the end of this Study-Guide with an Answer Key available at URL2. This document is available at URL1

OVERVIEW

The technical topics in the SPM course deal with electric power systems and the corrosion of metals. Both subjects have a foundation in the fundamental behaviors of the Universe. Specific concepts within the topics of: Force, Matter, Energy, Power, Electrical Conventions, Electrical Concepts, and Chemistry Basics are the focus of the review.

Force:

1. There are four (4) fundamental forces in the Universe: Strong force, Weak force, Gravitational force, and the Electromagnetic force.
2. The Strong force and Weak force are responsible for holding the nucleus together and for some aspects of radioactive decay. Due to the temperatures, energy levels, and the scale over which the interactions occur, these first two forces are of no consequence for this course (important though in the design of nuclear reactors).
3. Gravity is also of no consequence for this course due to several factors: its effects cannot be controlled (no anti-gravity machines), the force is only one of attraction, and the magnitude of this force is extremely weak. By the last statement it's meant that the attractive force of gravity developed between even two large bodies by human standards, such as two automobiles, is far too weak to be of any practical use. On a cosmic scale however, gravity rules the universe.
4. Electromagnetism (EM) is the fourth force and is the only fundamental force that is controllable in an environment in which humans and their machines can exist. The EM force is also many orders of magnitude greater than the gravitational force and easily generates forces having useful application at the scale of human endeavor. Finally, the EM force can be attractive and repulsive.
5. The EM force is usually divided into electric forces and the magnetic forces. Fundamentally both the electric field and the magnetic field have the same origins - the magnetic field being explained in terms of the electric field with relativistic effects considered. For this course, the electric force and the magnetic force are being treated as separate forces.
6. Force has units of newtons (N) in the metric system, and units of pounds (lbs) in the English system. One newton is a bit less than ¼ lb.
7. Force is a vector since it has both a magnitude and a direction.
8. Force is exerted on a mass due to a gravitational field. Force is exerted on an electric charge due to an electric field. Force is also exerted on an electric charge due to a magnetic field.

Matter:

1. For this course, it is sufficient to understand the Universe, as being composed of only matter and energy with the atom as the fundamental building block of all matter. The concepts of Dark Matter and Dark Energy and other models are of no value to the Classic model used here.
2. The Bohr model of the atom (solar system model) is sufficient for all aspects of the SPM course.
3. At the center of each atom is a nucleus. Surrounding this core nucleus are orbiting electrons that are arranged in various shells and bands.
4. The nucleus is composed of only protons and neutrons while only electrons orbit the nucleus of an atom. The number of neutrons is of no consequence in this course.
5. All matter is composed of either groups of identical atoms or atomic-level combinations of two or more atoms called molecules.
6. There are approximately 90 naturally occurring unique atoms (called elements) found in nature. The Periodic Table of the Elements displays these naturally occurring elements plus two-dozen-plus other unique atoms developed in laboratories.
7. Any particular element is distinguished from all other elements in all its characteristics by only the number of protons in its nucleus. This is its Atomic Number. Copper has an Atomic Number of 29 and Iron has an Atomic Number of 26. An atom normally has a number of electrons orbiting its nucleus equal to the number of protons in its nucleus.
8. At the temperatures and energy levels that have to exist for human-made machines to operate, it is only possible to add or remove one, two three or four electrons from the outermost shell of any atom or molecule. Adding or removing electrons closer to the nucleus requires higher levels of energy and high temperatures and is classified as being in the realm of Plasma Physics. Changing the number of protons in the nucleus requires extremely high temperatures and extremely high energy levels and such modifications to the nucleus of an atom lie in the realm of Nuclear Physics.
9. Any atom with a number of orbiting electrons differing from its Atomic Number is in an ionized state. An ionized atom or molecule only exists because of an excess or deficiency of electrons in the outermost band of electrons – called the valance band. Protons in the nucleus remain fixed.
10. An atom/molecule in an ionized state is called an ion. Ions are particles with a net electric charge.
11. Molecules are formed by the transfer or sharing of electrons between like or different atoms. Shared or transferred electrons are always from the outer-most valance band. Shifting electrons between atoms is called a chemical reaction. Chemistry is the study of the rules for the transfer of electrons between atoms to form different molecules. Corrosion is the study of chemical reactions involving the degradation of metals.
12. Of all the properties associated with electrons and protons, the only one of interest for this course is the force developed between these atomic particles. A force developed between protons and electrons results from a property associated with these particles called "the electric charge".
13. A convention evolved that identifies the type of charge carried by a proton with a (+) symbol. The charge carried by the electron is assigned the (-) symbol. There are no other types of charge.
14. The magnitude of the electric charge on the proton is exactly equal to the magnitude of the electric charge on the electron.
15. The rule that describes the direction of the force between the two charge types (+ and -) is "like charges repel and unlike charge attract".
16. The rule that describes the strength (magnitude) of the force between point charges is "force is proportional to the product of the two charges and inversely proportional to the square of the distance between them". Actual force vs. distance plot depends upon the arrangement of charges.
17. There is a tendency for atoms to want to maintain a balance between the number of + charges in the nucleus and the number of – charge carried by the orbiting electrons because of the attractive force of the two charge types.
18. This tendency for an internal charge balance is frequently overridden by the competing need to find a stable number of electrons in the valance band.

19. Quantum Mechanics is the study of the rules that govern the behavior of electrons in the valance band. If it were not for these rules about electron populations in the valance bands, the Universe would consist of only the basic elements shown in the Periodic Table of the Elements.
20. The quantity of charge carried by an electron or proton is too small to be of practical use for industrial processes. A quantity of charge call a coulomb (coul) is equal to 6.24E18 electric charges (either the charge on a single electron or on a single proton). The electric charge carried by atoms or molecules is not always equal to the number of atoms or molecules due to possibility of multiple levels of ionization.

Energy

1. Energy is the second of the two divisions describing the composition of the entire Universe.
2. The classic high school definition of energy is given as: "energy is the ability to do work".
3. "Work" in the mechanical or physics sense is force (F) times distance (d). The units of F*d are the same for mechanical work or mechanical energy. The unit-of-measure for Work and Energy are interchangeable. The unit-of-measure (UOM) for mechanical work and energy in the Imperial (English) system is foot-pounds (ft-lbs) and in the metric (SI) system it is newton-meters (N-m).
4. Recall that torque and work are totally different physical measurements even though they have the same UOM. The unit ft-lbs is ambiguous as it can mean either work or torque – similar to the way the term 30-deg is ambiguous since it can mean 30 degrees of angle or 30 degrees of temperature.
5. In addition to mechanical energy, there is also thermal energy, chemical potential energy, nuclear energy, rotational kinetic energy, gravitational potential energy, etc. Different fields of study have evolved different names and units for energy. Although different in name, they are all convertible.
6. Any UOM for any type of energy can be converted to any other unit of measure for energy with examples being ft-lbs to BTU's; N-m to calories; kWhr to watt-seconds, Btu's to calories, etc.
7. Newton-meter is the fundamental unit of energy in the metric system and for all practical study in dealing with electric power systems. A force of one newton (about ¼ lb) trough a distance of 1 meter (about 3 feet) is a newton-meter of work or energy (a rather small amount of energy). The newton-meter is such a common and often-used concept and measure that the measurement has been given a special name – the joule (J). One (1) joule equals one newton-meter.
8. An engineering calorie is the thermal energy needed to increase the temperature of one gram of pure water by one degree C (or K). A food calorie is based on the same increase of temperature of one degree C (or K) but has a unit-of-mass equal to 1000 grams or 1 kg.

Power

1. Power is the rate of movement, generation, or consumption of energy. As with any rate, units are a quantity-per-unit-time (gallons per minute; litres per hour; cubic feet per minute). In the metric system, the basic unit of time is universally the second (sec). Power then has units of joules/sec (J/sec) in the metric system. All modern electrical measurements are based on metric SI units. The concept of power is such a valuable concept and is so frequently used as to have a special unit of measure assigned. A joule/sec is a watt (W) and the watt is the basic measurement unit of power. Power is the movement of energy, or the conversion of energy from one form to another.
2. Recall that energy cannot be created or destroyed but only converted from one form to another. In item 1, above, the terms generation and consumption are both terms that really denote conversion of energy from one form to another.
3. Power by its very definition implies a conversion or a movement of energy so the term "power flow" is technically redundant. However, the phrase is so commonly used that correcting the usage is not worth one's effort or time.
4. A ton of refrigeration is a measurement of power. Melting a ton (short ton = 2000#) of frozen water (ice) at 32 deg F to liquid water at 32 deg F over a 24-hour period is the definition of a ton of refrigeration. The modern measurement unit that describes of a ton of refrigeration is 12,000 BTU/hour. Recall that a BTU is the energy needed to change one pound of water by one degree Fahrenheit.

5. The definition of horsepower (hp) was derived from an estimation of the sustained rate a horse could lift water from a mineshaft. The conditions were: 150 lbs; through a distance of 220 feet; over a period of one minute. This value equates to the common variants of one (1) horsepower equaling either 33,000 ft-lbs/min or 550 ft-lbs/sec.
6. By definition, one electrical horsepower is defined as 746 watts even though the "true conversion" is a small bit different.

Electrical Conventions

1. The graphical depiction of the force field resulting from a distribution of charges is done with the convention that a small positive (+) test charge is placed in the electric field. The direction of the arrow is the direction the test charge would move and the length of the arrow is made proportional to the force on the test charge. The electric force acts in line with the electric field.
2. An electric field exists whenever there is an imbalance of charge from one place to another. It takes energy to create an imbalance of charge due to the attractive and repulsive electric forces.
3. In an electric field, if an atom or molecule has no net electric charge, there is no net force on the atom or molecule and there is no movement of that particle. However, the electrons are still attracted to the positive charges and protons in the nucleus are still attracted to negative charges.
4. The magnetic field also acts on charged particles but its forces only exist when the charge is moving. Most electrical energy in the world is generated using this property of nature.
5. Broadly speaking, electric circuits are designed to either move and process information; or move and control energy. While the underlying physics is the same for both, the perspective for studying the two is somewhat different. For this course, the power system perspective is taken.

Electrical Concepts

1. An electric current exists whenever there is a movement or shift of electric charge. In the environment in which human exist, the forms of electric charge are limited to electrons, positive ions, and negative ions. Remember that ions are the result of an atom or molecule gaining or losing one or more electrons from the valance band.
2. The unit of electric charge is the coulomb (coul) and movement of charge implies a quantity of electric charge passing a demarcation point over a certain period of time.
3. The UOM of coul/sec describes the movement of electric charge. The term coul/sec is given the more common name of ampere (A). For example, a movement of 20 coulombs of charge past a point in a circuit in 10 seconds represents an average electric current of 2 amps.
4. Electric charge can be made to flow in metals, certain liquids, and in some high temperature gases and vapors called plasmas.
5. In a metal, the movement of charge is only the result of electrons moving in the metal.
6. In water-based liquids with mobile ions (carbonate, sodium, calcium, sulfate, phosphate, chlorine), current is the result of the movement of both positive (+) and negative (-) ions. A liquid with mobile ions is called an electrolyte. There are no free electrons in an electrolyte.
7. In a high temperature gas or vapor such as: gas discharge lighting, a welding arc, a lightning bolt, an arcing short circuit, the movement of free electrons, positive ions, and negative ions all contribute to the total effective current.
8. A coulomb of positive charge, moving from position A to position B has the same net end effect on charge distribution as does a coulomb of negative charge moving from position B to position A. This relationship is the reason for two (2) current flow models being in common use. The two current flow models are electron-flow and conventional-current-flow.
9. An electric current exists whenever there is a movement or shift of electric charge. This is true for electrons in a copper bus bar; positive and negative ions in sample of boiler water; or all three charge-carrying particles in a welding arc.
10. The act of taking electrons from one area and depositing them in another area requires energy. Energy is needed to pull the electrons away from the positively charged nuclei and to force them to

an area where there is already an excess of electrons. Every coulomb of charge shifted requires a certain amount of energy (joules) to accomplish the transfer.

11. The only charge carriers in metals are electrons. In metals, current is solely due to the movement of electrons. Even though electrons are the charge carriers in most circuits, it is the convention at the engineering level to assume positive charges are flowing in a direction opposite to the direction of that taken by the electrons. Even though this view is physically incorrect, for several reasons it is very much a practical necessity to accept this convention. An explanation will be given in class.
12. A centrifugal water pump does not create water and likewise, no source of electric potential (a voltage) creates electric charge. All voltage sources use some other form of energy to cause a separation of electric charge. Electrons are pushed to the negative (-) terminal and pulled away from the positive (+) terminal. In a circuit with metallic conductors a voltage source is an electron pump. There are also ion pumps
13. Work is needed to separate charge. Electrons have to be pulled away from nuclei that are positive and those same electrons have to be pushed to areas where there is an excess of negative charge.
14. The work done (joules) per coulomb of electric charge is described mathematically as joules/coul. Electric potential (U) measured in volts (V) has the fundamental units of joules/coul.
15. Voltage is the measure of the energy gained or lost when moving a coulomb of charge from one point in a circuit to another. In dealing with power systems, voltage (V) defines the energy gained or lost per coulomb of electric charge when that charge is moved from one point to another.
16. Most students studying electricity for the first time are introduced to the water analogy in dealing with electric circuits. The analogy likens voltage, and current to water pressure, and water flow respectively. This is not a good analogy to use for dealing with power circuits.
17. Once again, the voltage difference between two points in a power circuit defines the amount of energy either gained or lost for each coulomb of electric charge moved between those two points. The unit-of-measure for electric potential (U) is volts (V) and it has basic units of joules/coul.
18. If an analogy is needed for electric circuits then voltage in an electric circuit is exactly equivalent to height in a gravitational field. Height is the measure of joules/pound (Potential Energy = mgh) and voltage is a measure of joules/coul.
19. Measurements of height require a measurement point and a reference point. Voltage requires a similar measurement point (red lead) and a reference point (black lead). The expression V_{AB} means the voltage at point A with respect to point B. The notation implies that the red lead of the DMM is on point A and the black lead is on point B.
20. Electric power is P=V*I. This is consistent with joules/coul * coul/sec = joules/sec (watts).

Chemistry Basics

1. Corrosion is defined as the degradation of metals. Most corrosion results from chemical reactions
2. All chemical reactions involve the transfer of electrons from one atom or molecule to another.
3. Metals form a type of bond between like or different metal atoms called metallic bonding or covalent bonding. In metallic bonding, electrons in the outermost shell are shared with those of adjacent atoms. These shared electrons form a “cloud of electrons” where no valance electron is tightly held by any particular atom. These cloud electrons can be easily shifted throughout the entire bulk of the material. The force capable of moving electrons in a metal is the EM force.
4. In order for corrosion to occur (other than forms of mechanical corrosion such as erosion or cavitation), four elements must exist: anode, cathode, electron path, and ion path (electrolyte).
5. Once an electron is removed from a metal atom, the atom becomes an ion and is “no longer welcome” as part of the metal. For this separation to occur, the electron has to be consumed in one chemical reaction and the metal ion has to consumed in a separate chemical reaction.
6. An anode in electricity has the connotation of positive (+). In the corrosion field, anode is the location of oxidation reactions. Oxidation is the process of an atom/molecule loosing an electron.
7. Cathode in electricity has the connotation of negative (-). In the corrosion field, cathode is the location of reduction reactions. Reduction is the process of an atom/molecule gaining an electron.

Evaluation Exercise:

1. The only fundamental force controllable at room temperature is the _____________force
2. The unit of force in the SI (metric) system is the ___________________
3. What is the conversion between lbf and newtons (N) __________________
4. Is force is a scalar or a vector quantity? __________________________
5. An iron (Fe) ion cannot have what number of orbiting electrons? ________________
6. Two positive charges are going to experience a forced between them of ________________
7. How many protons are required to have a coulomb of charge _________________
8. One coulomb of Fe+++ ions consists of _______________________particles
9. How much energy is required to raise a 4 kg weight to a height of 4 metres ____________joules
10. What is the conversion between joules and engineering calories _____________________
11. What is the conversion between joules and BTU's __________________________
12. How many joules are in a kilowatt-hour ______________________________
13. What is the average power in problem 9 if the process takes 10 seconds ________________watts
14. A fully loaded 15 hp motor with a 90% efficiency consumes _______________watts
15. The two perspectives of current in a copper wire are electron flow and ___________________
16. The fundamental SI units for volts (V) are ______________________
17. The fundamental SI units for electric power are ____________________
18. Four requirements for corrosion to occur are: _________, __________, __________, __________
19. What chemical process occurs at the cathode ______________________________
20. What chemical process occurs at the anode _______________________________