NAME:____ **PART A**

MECH 372 Space Systems Design and Engineering II
Quiz 1

Part A - Closed Book (45 points)

1. (7) Match each of the missions listed with the single most compelling justification for using a spacecraft in order to achieve the stated mission. Each justification may be used once, more than once, or not at all; but for any one mission, you may only list one justification (or it will be marked wrong).

_____	Mars Exploration Rovers	A. Global view of Earth
_____	SpaceShip 2 (buy a ticket for sub-orbital human space flight)	B. Above Earth's atmosphere
_____	GOES weather satellite	C. Space environmental characteristics
_____	A protein growth experiment requiring microgravity	D. In situ characterization and exploration
_____	Hubble space telescope	E. Exploitation of resources
_____	Sputnik	F. Space Tourism
_____	Direct broadcast radio satellite	G. Pride and distinction

2. (2) What would the payload be on a typical photoreconnaissance satellite? List at least 2 different, specific components that would be plausible payload components for such a system.

3. (1) State Kirchhoff's Current Law (this should be a written statement that states the general law – not a specific example with a diagram and/or an equation):

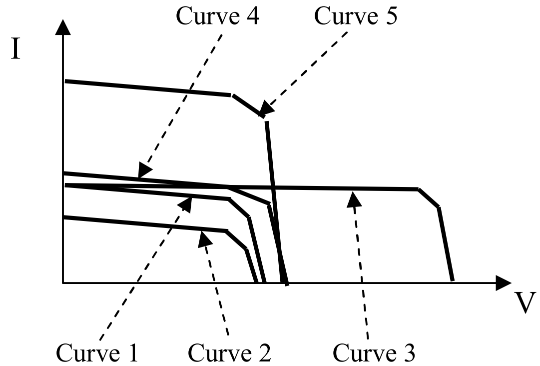
4. (2) Radiation damage to a circuit has been known to cause short circuits. What is a short circuit (be precise) and why is a short circuit a potentially dangerous condition for a satellite?

5. (1) A power subsystem supplies 500W of power at 28V. How much current is available?

6. (2) Why is it beneficial to operate a solar array at the "knee" of its V-I curve? Will the array naturally operate at this point?

7. (2) Give an example of a condition that would cause a "load shed" to occur. In addition, state what happens during a "load shed" process.

8. (4) In the set of solar cell IV curves given below, Curve 1 is the IV curve for a standard solar cell operating in standard conditions (one solar illumination, room temperature, etc.). For each of the other curves, select the description that best depicts what that curve would represent; each curve represents a different case listed in A-D (all answers from A-D are used once and only once).



_____ Curve 2 A. 2 standard cells in parallel

_____ Curve 3 B. 2 standard cells in series

_____ Curve 4 C. 1 standard cell at -100°C

_____ Curve 5 D. 1 standard cell at ~ 2/3 illumination

9. (2) In the lecture and the homework assignments, we typically considered four primary sources of thermal energy in order to perform thermal balance computations (these did not include particle heating). List these four ***sources***.

10. (2) What is the "beta" angle for a spacecraft's orbit (be explicit about how this angle is defined)? Explain why it is important for a thermal analysis by identifying the two primary thermal inputs (two of the four from question 10) that are significantly affected by this angle.

11. (20) True or False: Circle the appropriate solution for each individual question.

T F a. Having a global or wide field of view is the primary competitive motivation for the vast majority of communications, navigation and Earth observing spacecraft.

T F b. A capacitor stores energy in an electric field, and it has a I-V relationship that is a function of time.

T F c. The decimal number 42 is represented in binary by the following 8 bits: 00101010 (the most significant bit is on the left):

T F d. In low Earth orbit, a single eclipse may last for up to approximately 90 minutes.

T F e. Solar cell efficiency does not depend on the materials used to make the cells; rather, it is primarily a function of the cell's level of illumination and its temperature.

T F f. The term "multi-junction cells" is used to describe separate cells wired in a parallel configuration on a solar panel.

T F g. RTGs (radioisotope thermoelectric generators) use nuclear fission to produce electrical power.

T F h. RTG power output is usually actively controlled to provide the specific level of power required by the satellite's loads.

T F i. A battery typically operates based on a "redox" process. Oxidation is part of such a process. Oxydation is a process by which a molecule, atom or ion looses electrons.

T F j. In the lecture and slides, the term "secondary battery" was used to refer to a back-up battery that is used for redundancy when a "primary battery" fails.

T F k. A NiCad battery typically has a very predictable discharge profile in which voltage drops linearly over time, assuming a standard discharge rate and temperature appropriate for the battery.

T F l. Shunt regulators prevent too much power from going to satellite loads by shorting portions of the solar array to divert current flow.

T F m. Survival temperature requirements are typically more restrictive (have a small range) than the range defined by operating temperature requirements.

T F n. From a thermal design perspective, radiation is a process by which heat is transferred via electromagnetic waves.

T F o. The symbols α and ε are defined as being the absorptivity and the emissivity of a material's surface, respectively. However, in practice, spacecraft thermal engineers often use α to represent both absorptivity and emissivity for visible wavelength ranges, while ε is used to represent both absorptivity and emissivity for infrared wavelength ranges.

T F p. From the point of view of thermal analysis, a satellite in a "noon-midnight" orbit has a Beta angle of 0°.

T F q. Black paints/coatings will generally have a higher absorptivity to emissivity ration than white paints/coatings.

T F r. Experimental data shows that, in most cases, increasing the pressure on a joint between to materials will generally improve conduction between the materials.

T F s. Heat pipes use pumps and fans to move liquid and gases between different ends of the pipe in order to transfer heat from one end to the other.

T F t. When performing thermal environmental tests, "Acceptance" testing is typically more demanding than "Qualification" testing in terms of the temperature ranges used.

NAME:____ PART B

Part B - Open Book (35 points)

12. (5) A component that dissipates 100W is attached to a 0.16 m^2 radiator that sees only deep space and which has an emissivity of 0.9. The area of the attachment between the two components is 0.01 m^2. The component is insulated on all sides other than the thermal coupling to the radiator such that all dissipated power flows to the radiator. Assume that the system is in steady state and that the component must be kept below 70°C. It is your job to determine the minimum joint conductance required in order to ensure this.

Minimum Joint Conductance: __________

13. (5) Consider a battery pack consisting of 4 parallel strings of cells, with each string consisting of 15 cells in series. NiCad cells with a voltage of 1.2V and a capacity of 0.5 Amp-hrs are being used. What is the overall voltage of the battery pack? What is the Amp-hr rating of the overall battery pack? Assuming a Depth of Discharge policy of 50%, how long could this pack supply a constant current of 4 amps?

Pack Voltage: __________

Pack Amp-hr Rating: __________

How much time: __________

The following case is used for questions 14 and 15. Consider a spinning, cylindrical satellite that has a 1.5 meter diameter and a height of 2 meters. The satellite is in a circular, sun-synchronous, 1000 km altitude orbit that has β=90°. One of the circular ends of the satellite holds the Earth-referenced payload components and therefore always faces the Earth; the other circular end of the satellite always points away from the Earth.

14. (12) Solar Array Sizing. The satellite loads require a constant 600 W, and the power distribution/regulation's efficiency is 75% (regardless of charge/discharge mode). The body mounted solar array has cells mounted around the entire curved surface of the cylindrical structure. The array uses cells that are 28% efficient and which are mounted with a fill factor of 0.9. We will assume no losses due to temperature deviation or shadowing. The satellite has a mission life of 5 years, and the cells have a degradation factor of 3%/yr. We will assume that the solar illumination 1358 W/m^2.

a) How much power must the solar array generate during illumination? __________

b) What power density (W/m^2) is provided by the individual cells when they are fully illuminated (at beginning of life)? __________

c) For the moment, assume that the cells are placed on a planar solar array. Given the cell power density from part (b) as well as the packing factor and all degradations, what would the array's area need to be in order to meet the solar array power requirement from part (a) at the end of its 5 year life? Assume that the array is perfectly facing the sun for this question. __________

d) Now take into account the fact that this solar array is body mounted on the satellite's cylindrical surface. What total array surface area is required for the cylindrical installation? __________

e) Is the satellite large enough to hold the required array? __________

15. (13) Single Node Thermal Analysis. Assume for now that the sides of the satellite are coated with white paint (α=0.15, ε=0.95) (ignore the fact that solar cells and other components are installed on the exterior of the satellite). The satellite is internally dissipating 500W. Assume that the Earth's radius is 6,378 km and that albedo may be ignored for this initial analysis.

a) How many Watts are absorbed by the satellite due to direct solar heating? __________

b) How many Watts are absorbed by the satellite due to Earth IR heating? (Hint: remember to consider the input to all sides of the spacecraft) __________

c) What is the temperature of the satellite? __________

d) Now, let's assume that you are going to choose a different value for α and ε such that the satellite's average temperature is 10°C. If you select a value of ε=0.4, what value of α should you select in order to achieve this temperature? __________