NAME:____ **PART A**

MECH 372 Space Systems Design and Engineering II
Exam 3 - Fall 2014

Part A - Closed Book - 32 points

1. (18) True or False (1 pt each):

T F a) The three defining components of a computer or microcontroller are the processor, the keyboard, and the monitor. **No – processor, i/o, and memory**

T F b) The Fetch-Execute model of software execution consists of "fetching" the next instruction from memory, and then "executing" that instruction by performing the specified operation. "Execution" is typically done by performing a computation or by moving data bits from one location to another. **Yes – as described in the slides and in lecture**

T F c) A central challenge for flight processing is the need to do multiple tasks concurrently. A common strategy of dealing with conflicting, "simultaneous" software tasks is to re-engineer one of these tasks so that it is implemented in hardware.

T F d) When expressed in standard binary notation, the number 114 may be written as 01110010.

T F e) Software engineering is very similar to mechanical engineering given that the disciplines are hundreds of years old, they both exploit basic laws of physics to inform their analytic techniques, etc.

T F f) The equation $x=r*\cos\theta$ is an example of a kinematic relationship. **Yes - it is a frame transform.**

T F g) Consider a vector written in Frame A. If I want to take the time derivative of this vector, I must do this with respect to Frame A. **No, no, no…. see the discussion on kinematics, the BKE, etc.**

T F h) One must be careful when applying Newton's Law to the analysis of mechanisms on spinning spacecraft because a device's acceleration expressed in spacecraft coordinates won't be proportional to the actual forces applied to the device.

T F i) If a body is in equilibrium, then it cannot be moving. **It can move – but it can't be accelerating**

T F j) A regular (not inverted) pendulum is considered to be positively stable.

T F k) One of the two primary justifications for using closed looped feedback control (vs. an open loop strategy) is to counteract the effect of external disturbances, which may be unpredictable.

T F l) The actuator of a spacecraft mechanism is commanded using a proportional control strategy and applies a torque of 10Nm when the error is 1° of angular position. If the error grows to 2°, then the actuator will provide a torque of 5Nm. **Twice the error -> twice the torque: 20 NM**

T F m) For brushed DC motors, output torque is proportional to the voltage applied to the motor. **NOTE – I gave credit for T on this problem. But to be precise, T is linear in V, not proportional. T is proportional to current.**

T F n) Triangulation is a navigation technique that uses three measured distances in order to determine location. **Not Distances…. That would be trilateration….. triangulation is ANGLES**

T F o) For a wireless communication link, cutting the transmission data rate in half will cut the quality of the link (signal to noise ratio) in half. **It will double it!**

T F p) For a wireless communication link, doubling the distance between transmitter and receiver will cut the quality of the link (signal to noise ratio) in half. **It will cut it down to 1/4**

T F q) For a wireless communication link, doubling the transmit power will double the quality of the link.

T F r) For an observing satellite, increasing the aperture size will decrease the field of view.

2. (2) Briefly state (no more than 2 sentences) a few of the primary differences between embedded computing compared to general computing one might do using a PC-based workstation.

Would expect things like constrained resources (memory, power, i/o, etc.), realtime reliability, and focus of purpose

3. (2) Briefly state (no more than 1 sentence) a few of the main tasks that a primary flight computer would typically perform. Note that I am NOT looking for special functions that a payload computer might do, but rather a few of the standard tasks that must be done on nearly every spacecraft.

Command processing (execution, error handling, time- or event-based execution), Telemetry processing (data acq, storage, calibration, summarization, etc.), or perhaps some higher level functions like planning, scheduling, fault diag

4. (1) Why might it be normal to expect that decade-old computing technology might be selected for flight on a specific spacecraft?

Heritage and low risk choices are greatly valued… plus, newer technologies typically have small feature sizes which are more susceptible to radiation

5. (3) A central challenge for flight processing is the need to do multiple tasks concurrently. Consider a situation in which one of the members of your design team, a flight processing engineer, says that they are trying to implement a specific function in software but that it must execute simultaneously with another function that is already implemented. They are trying to decide on whether to implement the new function through an interrupt process or by using a parallel processor. What do these two options mean, and what are the pros/cons of each?

Interrupt – added as a function to an existing processor, but using an interrupt routine rather than putting it into the main loop of code. Pro – one processor; Con – complexity of programming and not truly simultaneous

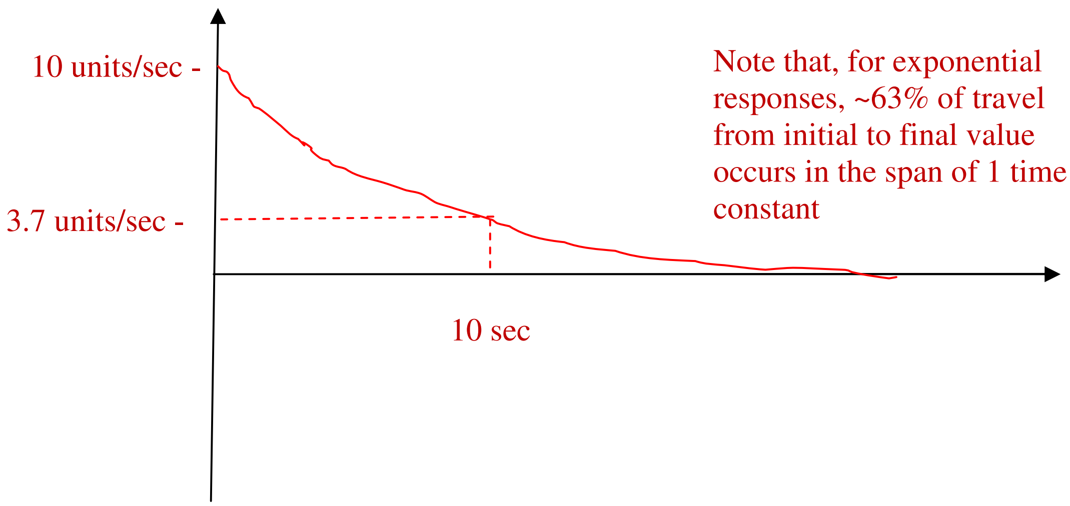
Parallel processor – implementing the task in software on a separate processor. Pro – truly simultaneous and easier to program; Con – need another processor

6. (2) Consider an observing mission in which the satellite is supposed to have very good resolution (a small number for resolution) and which is supposed to be "agile" (which means that the satellite can be very quickly turned from one object to another). The payload engineer has decided that he wants to quadruple the aperture of the payload (from 0.5 m diameter to 2 m diameter) in order to significantly improve resolution. What are the probable concerns expressed by:

a) The structural engineer: **that's a big increase in size…. Must mechanically attach it, deploy it after launch, support it, etc.**

b) The attitude control engineer: **It increases the inertia (making it more costly to change attitude), and it is probably flexible, which means you would get oscillations, etc. Also – bigger antenna means smaller beam, so more stringent pointing requirements**

7. (2) On the axis provided, draw the time response of a first order system with an initial condition of 10 units/sec and which decays to a final value of 0 units/sec with a time constant of 10 sec. Your sketch should be to scale, and both axes should indicate numeric values.

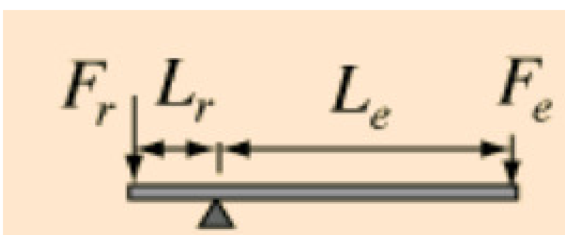


8. (2) To balance the lever (e.g., to place the lever into equilibrium with no angular velocity), determine the force F that should be applied to the system at the location provided. In addition, determine the Ideal Mechanical Advantage (IMA) of this simple machine.

Given: L_r = 2 meters
L_e = 5 meters
F_r = 10 N

F_e = ____________ 10 / (5/2) = 4 N

IMA = _________ 5/2 = 2.5



NAME:____ **PART B**

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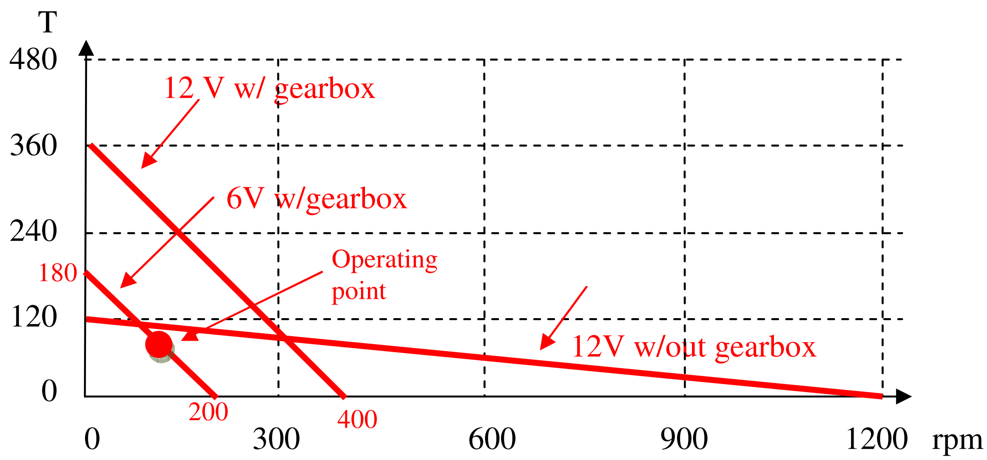
Part B - Open Book – 18 points

BOX YOUR SOLUTIONS

9. (6) A dc motor is rated at 12V with a stall torque of 120 oz-inches and a max speed of 1200 rpm. It is operated with a gearbox that has an 3:1 mechanical advantage. For a particular task, the motor voltage is dropped to 6V. Show the equivalent Torque-Speed curve for motor in this operating configuration. While in this configuration, if the motor is moving at a speed of 100 rpm, how much torque is it exerting? Plot this operating point.



Using the 6V w/gearbox curve, Ts=180 (120*3/2) and Wmax=200 rpm (1200/3/2).
100 rpm is half speed.
Since the curve is linear, the torque is half of Ts = 90 oz-inches.

10. (2) Perform a simple 2-D planar trilateration analysis by considering two signal sources that each broadcast a signal that moves at 1 unit per second. Source A is at a location of (10,0) in the XY plane, and Source B is at the location (0,15) in the XY plane. Your receiver states that you are approximately 14.14 sec away from Source A and approximately 5 sec away from Source B. Provide at least 1 of your possible locations in the Cartesian plane?

(0, 10) by geometric construction. The simplest way to do this is to simply sketch the circles and it will be obvious that you have a solution near (0,10). This is easily confirmed if you recall your 45° angle trig (which you should!). there's a 2^{nd} solution which is a pain to compute, but you can do it w/some trig. It is somewhere around (4.7, 13.2) plus or minus

11. (3) Imagine having an observing payload optimized for viewing objects that are 100° C. The payload is on a satellite orbiting at an altitude of 1,000 km, and it has an aperture of 2 meters.

a. What is the peak wavelength of emission given off by the objects of interest? WL=2898/373=7.77 µm

b. What is the instrument's resolution at this wavelength for objects directly below the satellite? (2.44*WL*1000000)/2 = 9.48m

c. If the payload is commanded to look at object's on Earth that are not directly below, with the effective resolution increase or decrease, and why? Distance increases, so resolution increases

12. (3) This problem is unlike the problems you've been given on the homework. It is an attempt to make you apply your understanding of a specific topic rather than simply reproduce problems that you have seen before. Do not panic. Think it through, and you'll be fine. With this problem, I am interested in assessing your understanding of the geometric issues relating to trilateration, specifically, the issue that some choices of landmarks are better than others. Here is your scenario. You are somewhere in the XY plane. You have 4 landmarks to choose from in order to perform your trilateration analysis. As I hope you recall, you can use two landmarks in order to find 2 specific candidates for your location. The use of a third landmark will typically narrow those 2 down to a single possibility. However, poor geometrical arrangement of the landmarks and your location may prevent this from happening. For this problem, consider the 4 landmarks you are given. I want you to select 3 of these that allow you to determine a single location for your position. As you do this, you most likely will run into options where 3 specific landmarks won't work. Again – provide a list of the 3 landmarks you would choose to use in order to determine your position in the XY plane without any ambiguity.

The table shows the location of each landmark as well as the distance that you are from each.

Landmark	Location	Distance .
A	(1,5)	5*sqrt(2) units
B	(1,0)	5 units
C	(1,-5)	5*sqrt(2) units
D	(8.5,0)	2.5 units

The 3 landmarks you choose are _____ , _____ , and _____ .

A, B, and C are collinear and symmetric wrt your location. This means that these 3 won't work together. If you try it, you will see that using 2 of them gives you two specific points but then adding the third results in a circle that still goes through both of those points. You need to use D. So, the correct answer is D and any 2 of the others.

13. (4) Solar array drives rotate external solar array panels with respect to the main body of a satellite. These devices tend to be open loop mechanisms that spin at a constant rate (for GEO satellites) with the objective of rotating approximately 360 degrees per orbit. Because they are run open loop on a daily basis, they may not perform perfectly, and it is typical to go through a realignment procedure periodically in order to correct any built up error. For these reasons, designers and operators are often interested in knowing the accuracy and repeatability of these space mechanisms.

Drive	**Trial 1**	**Trial 2**	**Trail 3**	**Trail 4**	**Trail 5**	**Average**
Drive A	360.32°	360.51°	360.48°	360.39°	360.54°	**360.45°**
Drive B	360.12°	359.98°	359.96°	360.02°	360.03°	**360.02°**
Drive C	360.11°	359.89°	359.82°	360.24°	359.88°	**359.99°**
Drive D	359.89°	359.82°	359.90°	359.86°	359.80°	**359.85°**

Consider the 4 designs listed in the table. For each design, 5 experimental trials were run during which the angular rotation was measured over a 24 hour period. Given this data:

Which two have the best accuracy? _____ and _____ B and C

Which two have the best repeatability? _____ and _____ B and D

Best averages are the best accuracy, so that's B and C
Smallest spreads (std dev could be used perhaps) are the best repeatability. A spreads over 0.22°. B over 0.14°. C over 0.42°. D over 0.10° So B and D seem like great answers.