NAME:____ **PART A**

MECH 372 Space Systems Design and Engineering II
Exam 3 - Winter 2017

Part A - Closed Book - 30 points

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

T [✓ F] a) The 4 broad classes of space missions we studied in this class – and which have dominated the space industry for decades – are communications, navigation, asteroid mining, and science missions.

[✓ T] F b) High gain antennae are often wonderful to have for communication payloads, but since such antennae typically lead to a narrower beamwidths, designers must ensure that the antenna pointing systems are good enough so that pointing losses don't exceed gain increases.

[✓ T] F c) While very high resolution (< 1 meter) visible light imaging is valuable, there are many applications where much lower resolution images (>1 km) are routinely used and which also provide great value. Weather system imaging is an example

T [✓ F] d) An observational satellite that detects the infrared emissions from forest fires uses a "active" observation strategy, rather than an "passive" observation strategy.

[✓ T] F e) To improve the resolution of an Earth imaging mission, the design team should reduce the wavelength sensed when performing observations.

[✓ T] F f) The quality of navigation solutions from systems using multi-angulation and/or multi-lateration is generally affected by the relative position of the user and the landmarks used for measurements.

T [✓ F] g) Highly accurate atomic clocks are used in most GPS receivers in order to synchronize timing signals from GPS satellites, thereby allowing the distance to each satellite to be computed.

T [✓ F] h) Science spacecraft that travel to other planets typically have similar power, thermal and attitude control components/subsystems/designs as low Earth orbiting spacecraft.

[✓ T] F i) It is easy for a complex scientific satellite (like the James Webb Space Telescope) to have several hundred mechanisms on board in order to support deployment, bus and payload functions.

T [✓ F] j) The three defining elements of a computer are a processor, communication busses, and input/output lines. It is a processor, memory, and i/o.

[✓ T] F k) The Fetch-Decode-Execute model of software execution consists of "fetching" the next instruction by retrieving it from memory, "decoding" the command to determine what function it is specifying to be accomplished, and then "executing" that instruction by performing the specified operation.

T [✓ F] l) NASA Science missions often employ highly sophisticated technology in order to perform impressive tasks and make extraordinary achievements. Accordingly, it is typical for them to use the newest and highest performing flight computers in order to provide the level of performance and automation demanded by their cutting-edge missions.

T [✓ F] m) The resources required to complete large scale software projects, such as personnel required and time for the development effort, are typically easy to predict with high accuracy. It is VERY hard

T [✓ F] n) The equation F=ma is an example of a kinematic relationship. It is a **dynamic** relationship

[✓ T] F o) A perfectly balanced inverted pendulum is in equilibrium but is unstable.

T [✓ F] p) The primary purpose of a transmission is to provide mechanical advantage. reorient force/torque line

T [✓ F] q) Stepper motors are simple actuators that typically spin when a constant voltage is placed across their two electrical inputs. Stepper motors lock up, standard dc motors spin

[✓ T] F r) Mechanical advantage is the multiplication of force from input to output that is achieved by virtue of the configuration of a passive mechanical device.

T [✓ F] s) The two primary justifications for requiring closed loop control are the need to be insensitive to disturbances and the need for control systems engineers to remain employed.

[✓ T] F t) The equation below is a time-invariant equation.

$$m*\frac{d^2}{dt}x(t)+b*\frac{d}{dt}x(t)+k*x(t)=f(t)$$

2. (3) For each of the following communication mission objectives, select the communication architecture that would be the most appropriate for a LEO communication satellite(s):

_____B	a) Realtime communication btw 2 points on Earth that are NOT in the field of view of a single communication satellite	A. Beaconing
_____C	b) Relay a message btw 2 points on the Earth that are NOT in the field of view of a single satellite such that there may be a delay in delivery of the message	B. Cross-Link
_____A	c) Send a short message to anyone in range as the satellite flies over different parts of the Earth	C. Store and Forward

3. (3) A central challenge for flight processing is the need to do multiple tasks concurrently. List three distinct ways to address this challenge, and describe each of these strategies with 1-2 sentences. Note that your three solutions should be very distinct from a strategic point of view – they should not be different variations of the same general strategy. Provide only three – no more.

Possible answers include:

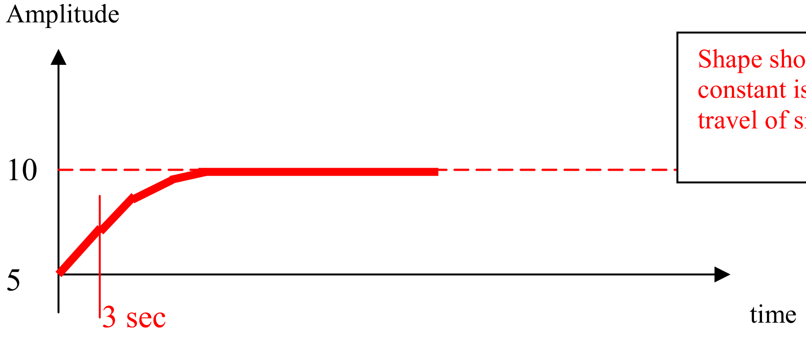
Interrupts – main program is "interrupted" by pre-arranged conditions such as timers or externally set pins; when they occur, the main program is paused and its state is saved, and then a pre-programmed interrupt response is executed.

Multi-threading – program distinct threads, and an OS kernel manages the switching among threads

Off-chip – enable some tasks in electronic support circuitry s.t. they aren't implemented via software. Examples might include chips/circuits for A/D and D/A conversion, filters, encoders/decoders, PWM generation, etc.

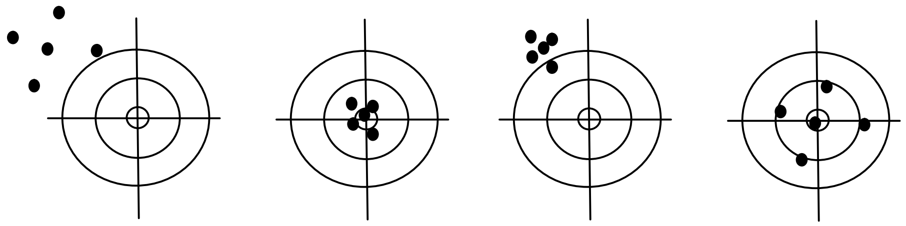
Multiple processors – use parallel or distributed processing architectures

4. (2) In several subsystem topics, we've studied the classical time response for a 1st order system. On the axes below, sketch the step response of such a system (note that the shape of the curve is critical); assume that the initial condition is an amplitude of 5 and that the final amplitude is 10. The system has a time constant of 3 seconds. Provide values on each axis as appropriate in order to establish the scale of the plot.



Shape should be an exponential, time constant is at the location of 63% of full travel of signal

5. (2) Given the diagrams below showing attempts to place a point at the center of the bullseye, classify the results in each of the diagrams as being either high/low average accuracy and also either high/low repeatability (compared to each other).



Ave. Accuracy:	High / [✓ Low]	[✓ High] / Low	High / [✓ Low]	[✓ High] / Low
Repeatability:	High / [✓ Low]	[✓ High] / Low	[✓ High] / Low	High / [✓ Low]

NAME:____ **PART B**

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Part B - Open Book – 25 points

BOX YOUR SOLUTIONS

6. (3) Consider the Link Equation and the effects of certain actions on a link's signal to noise ratio. For each action stated below, circle the approximate effect on the signal to noise ratio (compared to its original value):

a. Power is cut in half S/N double [✓ S/N is halved] S/N quadruples S/N is cut to ¼
b. Data rate is doubled S/N double [✓ S/N is halved] S/N quadruples S/N is cut to ¼
c. Distance is doubled S/N double S/N is halved S/N quadruples [✓ S/N is cut to ¼]

7. (2) Using slide 15 from the Payloads presentation, consider a satellite using Convolutionally Coded PSK (r=1/2, k=7) for its encoding and modulation specifications. The satellite's communication system performs with a BER (bit error rate) of 10^{-5}. The Link Equation shows the S/N ratio of the link to be 10 dB. For this configuration, what is the approximate Link Margin for the system?

~6dB. The required S/N for this configuration is about 4 dB.
So, having S/N of 10 dB provides 6 dB of margin

8. (7) An LEO satellite is observing rockets launched from the Earth. The rocket plumes have a rough average temperature of about 1,200°C, and the satellite is in a circular orbit with a constant altitude of 42,164 km. The satellite's observational payload has a focal length of 10m and an aperture of 1m.

a. What is the peak wavelength of emission given off by the rocket plumes? WL=2898/1473=1.96µm

b. Given the peak wavelength computed in part (a), what is the frequency band of that wavelength (use one of the following choices)?

Visible wavelengths [✓ Infrared Wavelengths] Radio Wavelengths

IR is ~ 700 nm to 1 mm

c. The mission of the satellite is to continuously view the entire Earth (e.g., the Earth should fill the field of view of the satellite for nominal pointing). Given this, what should the detector radius of the observational payload be?

Earth radius ~6371 km
Angular resolution = $\tan^{-1}(6371/(42164+6371))$ = 7.48 deg
FOV = 2*(angular resolution) = 14.9 deg
FOV = 2 $\tan^{-1}(r/10)$ = 14.9 deg
r=1.31m or by simple ratio: R/(alt+R) = r/f

d. If observations are conducted at the peak wavelength from part (a), what payload aperture size is required for a 25 m instrument resolution? Use the relationship RES = [2.44*λ*h]/D, where the variables are defined on Slide 23 of the Payloads slide package.

RES = 2.44*WL*h/D = 25m=2.44*0.00000196*42,164,000/D, so, D = 8m

9. (4) Perform a simple 2-D planar trilateration analysis by considering two signal sources that each broadcast a signal that moves at 2 units per second. Source A is at the origin of the XY plane, (0, 0), and Source B is at the location (30, 10). Your receiver states that you are approximately 14.14 sec away from Source A and approximately 7.07 sec away from Source B. Provide the coordinates of your possible locations in the Cartesian plane?

(20,20) and about (28, -4)

The (20,20) solution should be very close… the other could be +/- 1 or so

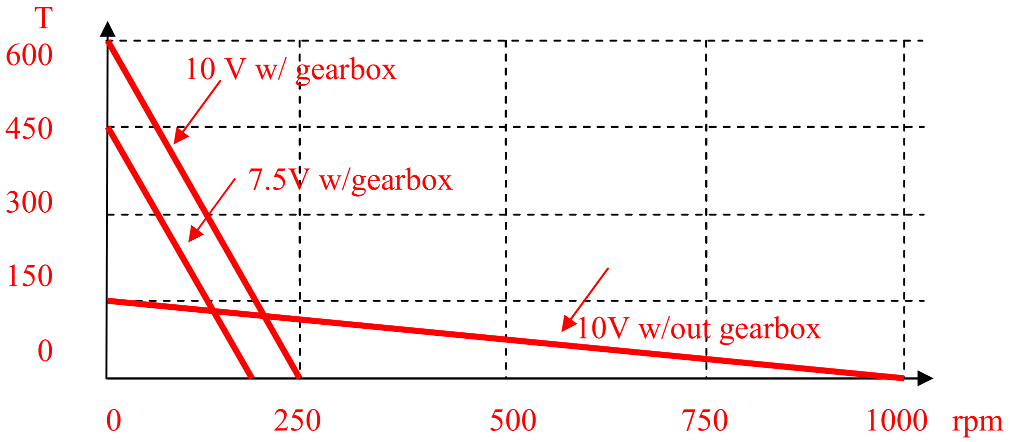
I was able to generate the solution by construction as well as by using the analytic solution provided

10. (2) A lever is used to establish mechanical advantage in order for a control force to be used to move a load. If the load is 10 cm away from the lever and a mechanical advantage of 5 is desired, how far away from the lever should the input force be applied? If an input force of 3 N is applied in this configuration, what force is applied to the load?

Input force distance / load distance = IMA, so, Control force distance = 50 cm

Load force / input force = IMA, so, Load force = 15 N

11. (7) A dc motor is rated at 10V with a stall torque of 150 oz-inches and a max speed of 1000 rpm. Show the Torque-Speed curve for this motor. Now, the motor is operated with a gearbox that has a 4:1 mechanical advantage; show the equivalent Torque-Speed curve for the output shaft of the gearbox. For a particular task, the motor voltage is dropped to 7.5V. Show the equivalent Torque-Speed curve for output shaft of the gearbox in this operating configuration. While in this configuration, if the output shaft of the gearbox is exerting a torque of 225 oz-in, how fast is it moving?



Using the 7.5V w/gearbox curve, Ts=450 and Wmax=.75*250=187.5 rpm.
A load of 225 is half the stall torque.
Since the curve is linear, the speed is half of Wmax = 93.75 rpm.