Name________________________________

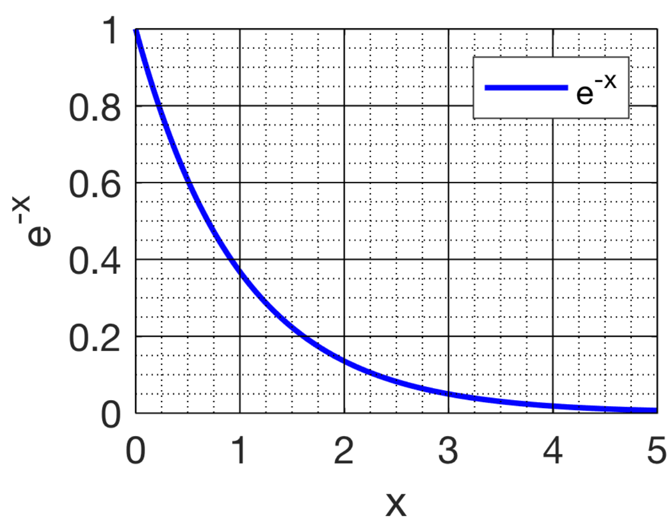
Homework 5 is the Midterm Exam from Fall 2018...

ECE 179d

Midterm Exam

- Extra pages are provided at back of exam. **Turn in all work!**
- Please write ONLY ON THE FRONT sides of exam pages.
- You are allowed one (1) single-sided sheet of notes.
- No calculators or other computing devices are allowed.

Good Luck!



P1 ______________

P2 ______________

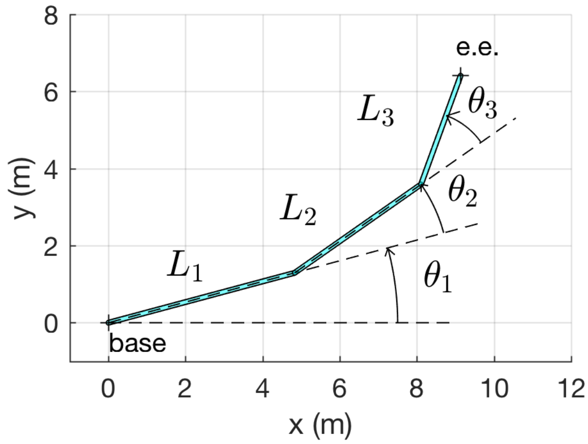
P3 ______________

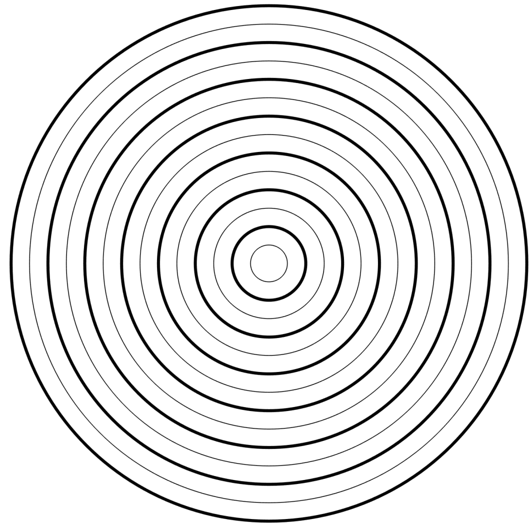
P4 ______________

______________ Total Score

Prob	(a)	(b)	(c)	(d)	Tot Pts
1	10	9	6		25
2	13	12			25
3	10	10	5		25
4	4	10	5	6	25

Problem 1 – Jacobians

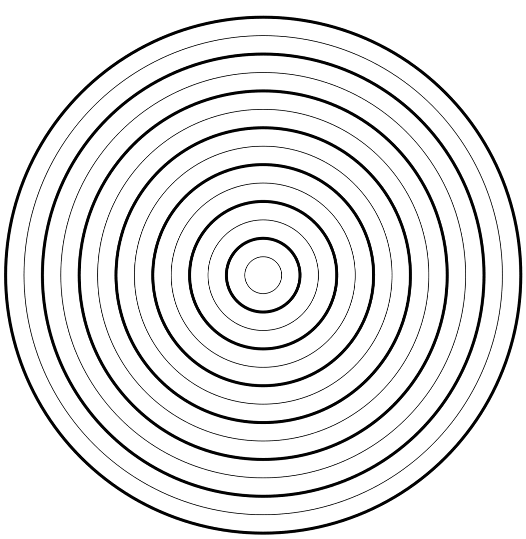




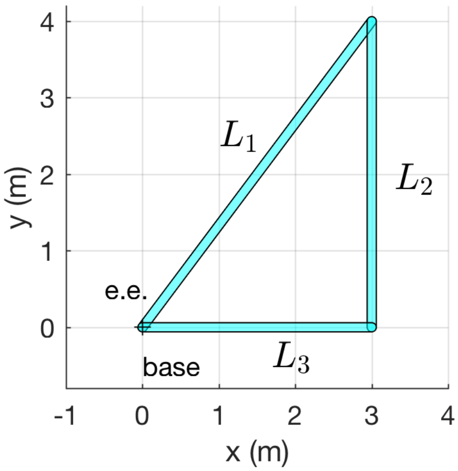
A planar, 3-link arm has lengths L_1=5, L_2=4, L_3=3 (all in meters), as shown above, at left.

(a) Determine and sketch both the reachable workspace (RWS) and the dexterous workspace (DWS) for the end effector. (Assume the links cannot "self-collide".) Label each clearly.

(The polar grid lines above at right can be used to make the "sketching" part easier. A second set is included below, just in case you "mess up" and want to start over…)



(b) For the configuration shown below (for the same 3-link arm), calculate the Jacobian (from actuator to end effector velocities).

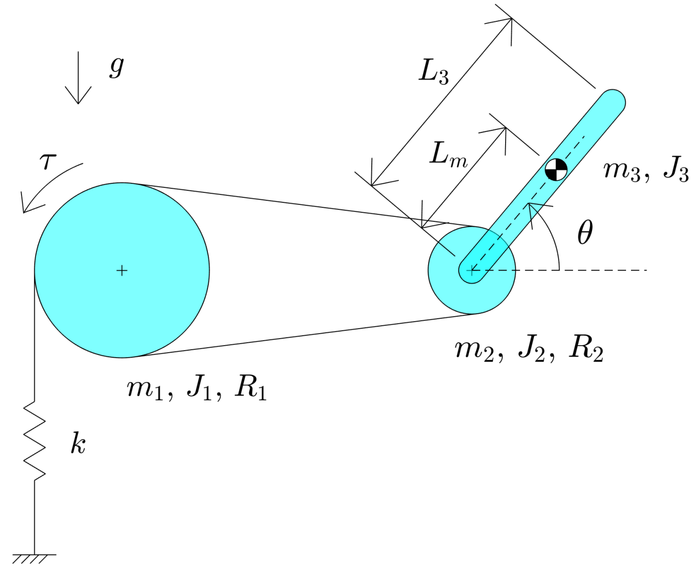


$$q_{act} = \begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \end{bmatrix}$$

$$\xi_{ee} = \begin{bmatrix} x_e \\ y_e \\ \theta_e \end{bmatrix}$$

(c) For the configuration shown above, solve for the required actuator velocities, $\dot{\theta}_1$, $\dot{\theta}_2$, and $\dot{\theta}_3$, to set the end effector velocities to $\dot{x}_e = 12$ (m/s), $\dot{y}_e = 6$ (m/s), $\dot{\theta}_e = 0$ (rad/s).

Problem 2 – Reflected Impedance and/or Lagrangian EOM; Control Law Partitioning



$R_1 = 2R_2$

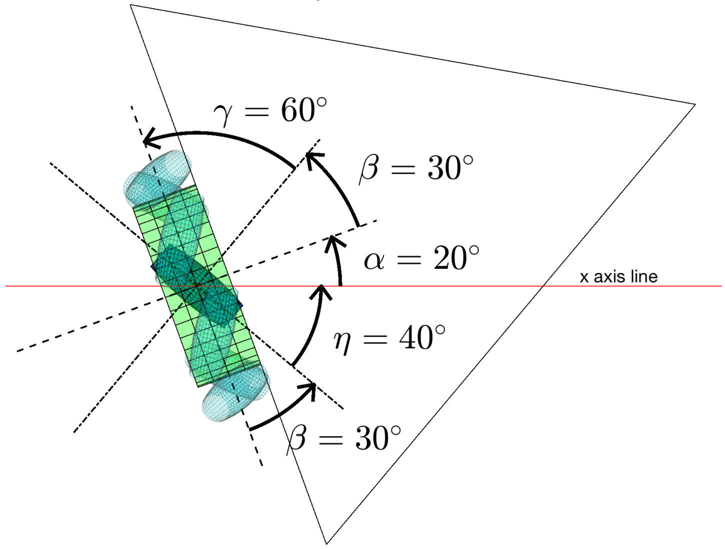
In the pulley system shown, the centers of J_1 and J_2 stay fixed, and the disks rotate with no slip. The pulley at J_2 is glued to a rod (of mass m_3, with moment of inertia about its center of mass J_3). There is also gravity, a spring, and an input torque, all as shown.

a) Derive an equation of motion (symbolically); use θ as the generalized coordinate.

b) Determine a control law (i.e., an equation) for τ so that this system behaves as a second-order linear system, with $\zeta = 0.7$ and $\omega_n = 5$ (rad/s), with theta oscillating about an equilibrium angle of pi/4 radians. [Hint: use "control law partitioning".]

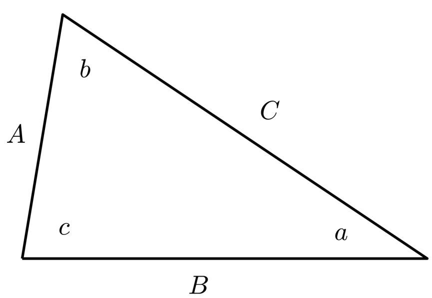
- Note: If you're unsure of part "a)", just make an approximate guess for the solution of "a)" to get a general form, and then proceed here...

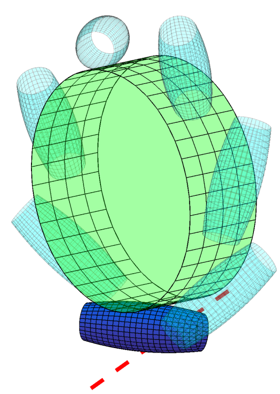
Problem 3 – Wheeled Systems: Omnibot.



- Above is an omnibot, with only one wheel shown (for clarity). If the powered wheel has positive angular velocity, its motion would be "up and to the left" here.
- Assume we wish to move the omnibot with no angular rotation of the chassis (body), and at velocity v_b (b:body), exactly in the +x direction (i.e., along the "x axis line").
- The wheel shown must achieve this through powered velocity, v_p (p:powered) and roller velocity, v_r (r:roller).

a) Show work and sort in order the magnitude of v_b, v_p, and v_r. For example, if v_p=v_r and both are less than v_b, then: v_r=v_p<v_b. (Please circle your answer.)



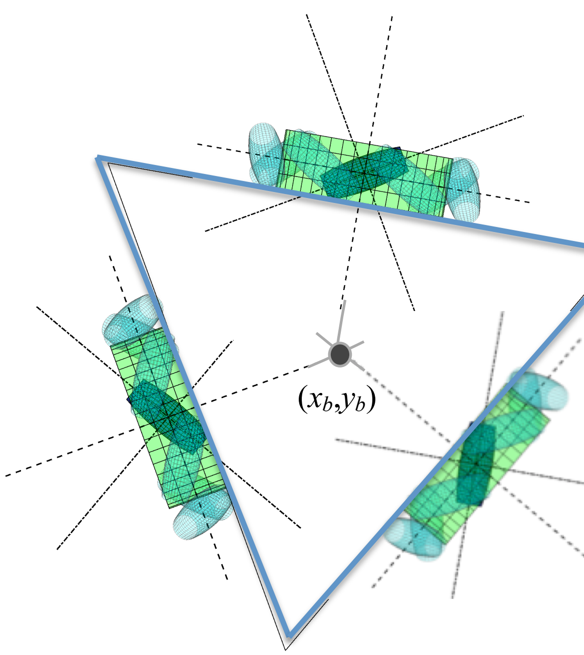


Notes:

- If angles of a triangle obey a<b<c, then opposing side lengths obey A<B<C.
- Above is a "perspective" view of the omniwheel. The dark roller touches the ground, and the dashed line shows the direction in which it can freely roll.

b) Assume the wheel radius is R_w=4.5 cm. (i.e., 0.045 meters). Estimate powered rotational wheel velocity, $\dot{\phi}_p$, for v_b=1 (m/s); both magnitude and sign are important.
- As in part a), assume motion of chassis is in +x direction, with no chassis rotation.
- Don't obsess over calculations. Use geometry and estimate. Two digits of precision is OK!

c) Assume the wheel on the last page is "wheel 1", and that we power this wheel with a POSITIVE powered angular velocity, $\dot{\phi}_p > 0$. Sketch the ICR. Show vectors for the powered, rolling, and net motion at wheel 1. Sketch the instantaneous velocity at (x_b,y_b) [at center of chassis].



Problem 4 – 2^{nd}-order system response.

It is December 11^{th} in the year 2022. You work at NASA as an engineer, and over the past 2 years, you've been designing active suspension control for spacecraft landing.

On this day, NASA is excitedly awaiting its first lunar landing in exactly 50 years.

After waking up from a bad dream (involving confusion over SI vs English units), your boss asks you to come to her office to go over some details of the planned landing…

Previously, you had calculated that (for t>0, after touchdown) height of the spacecraft, *x(t)*, matches that of a unit step response for this transfer function:

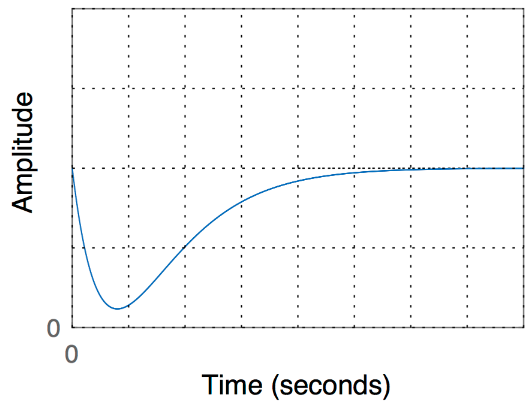
$$G(s) = \frac{20s^2 - 18s + 180}{10s^2 + 6s + 90}$$

a) Given the four candidate unit step responses (pulled from your recycling bin) on the next page, circle the one that matches G(s), to show to your anxious boss. (see part b.)
b) Determine and justify your choice for "a)", above, by calculating the following:
    i. Initial value of x, at t=0+.
    ii. Final value of x, at t goes to infinity.
    iii. Initial velocity of x, at t=0+.
    iv. Time between successive peaks (or half-peaks; label as appropriate).

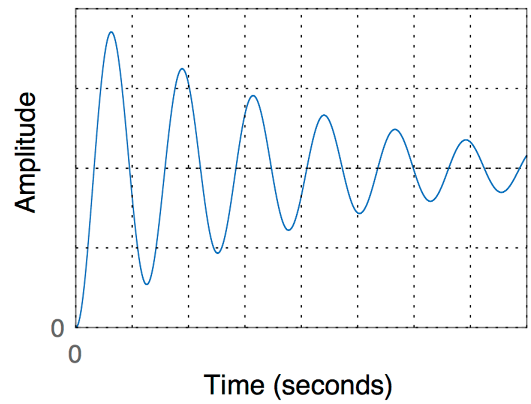
c) Label tick marks on x and y axes. (0,0) is labeled at "bottom left" of each plot.

d) Finally, label (or otherwise illustrate) a-i through a-iv on your chosen plot!!

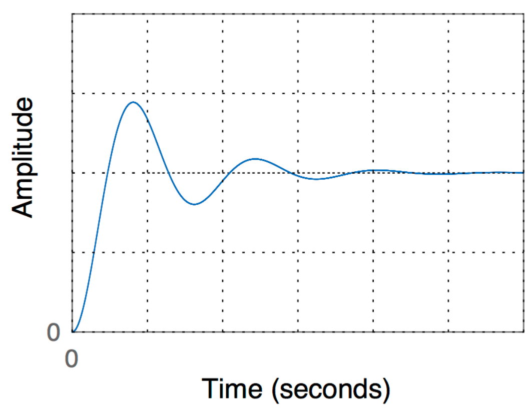
A


Amplitude
0
0
Time (seconds)

B


Amplitude
0
0
Time (seconds)

C


Amplitude
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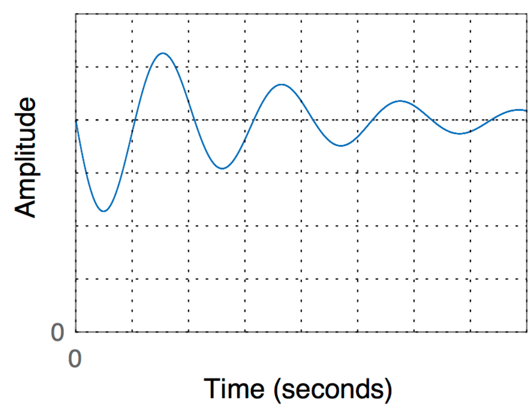
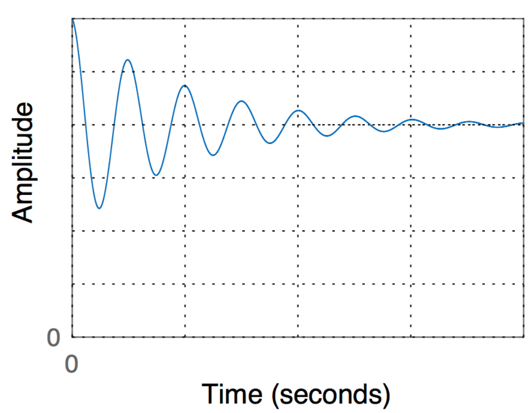
0
Time (seconds)

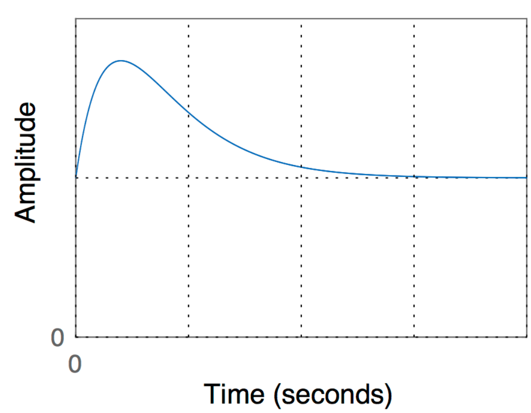
D


Amplitude
0
0
Time (seconds)

E

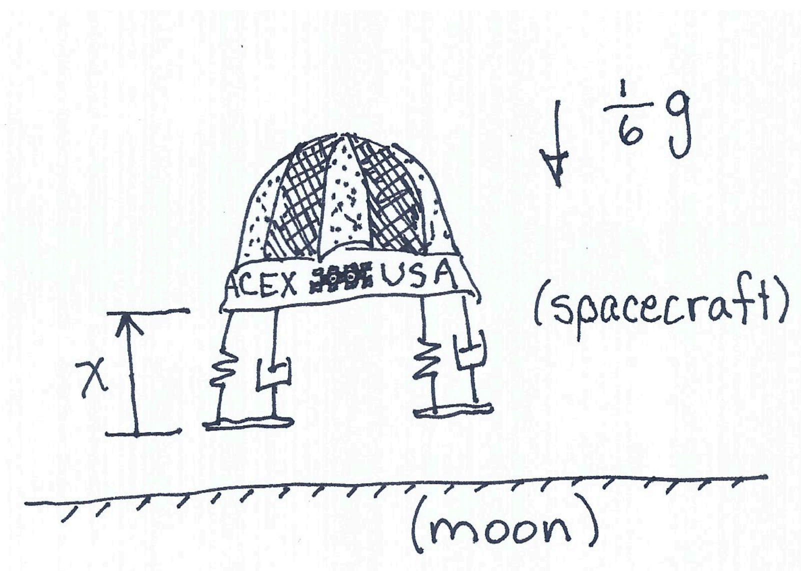

Amplitude
0
0
Time (seconds)

F


Amplitude
0
0
Time (seconds)

<u>Extra Credit</u>: (**Can be done at home tonight…** Exam will be posted on GauchoSpace.)

Estimate the peak "g-forces felt" by payload onboard the spacecraft during touchdown, based on your chosen plot and/or other calculations. (This includes the moon's gravity, which is around 1/6 of earth's, along with the acceleration, $\ddot{x}$, of the spacecraft itself. $g \approx 9.8$ (m/s^2) on earth.) You only need to be accurate to one significant digit. For example, 30g, or 300 (m/s^2) would be enough precision (although this answer happens to be incorrect).



END OF EXAM!
Additional Space for Calculations. LABEL PROBLEM(S) YOU ARE WORKING ON!

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