Name________________________________

Tear off and save the ID number below, to look up your grade later…

ECE 179d

“Midterm” Quiz

- Extra pages are provided at back of exam, if needed. **Turn in all work!**
- You are allowed one (1) single-sided sheet of notes.
- No calculators or other computing devices are allowed.

Good Luck!

Problem 1 – In this problem, you will look at PD control of a plant, $P(s) = \frac{A}{s^2 + bs + c}$.

P(s) is a second-order system, with $\omega_n = 20$ (rad/sec), and $\zeta = 0.2$. Below is a UNIT STEP RESPONSE for P(s) and for 3 other systems.

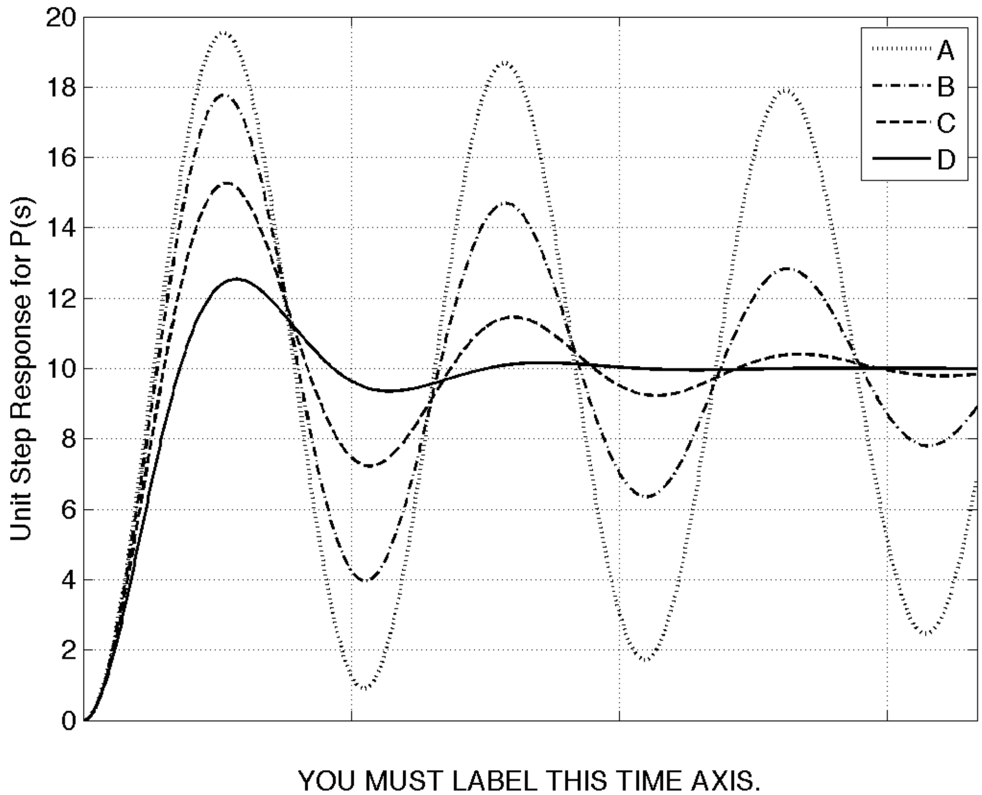

Figure 1. Step responses for P(s) and for 3 other systems.

(a) Which response (A, B, C, or D) corresponds to P(s), and (briefly) why? (Show work and/or explain reasoning in ALL problems on the exam.)

(b) Label the time axis in Figure 1.

(c) Given Figure 1 and the known values $\omega_n = 20$ (rad/sec) and $\zeta = 0.2$, solve for variables A, b, and c in $P(s) = \dfrac{A}{s^2 + bs + c}$.

A = ___________ ; b = ___________ ; c = ____________

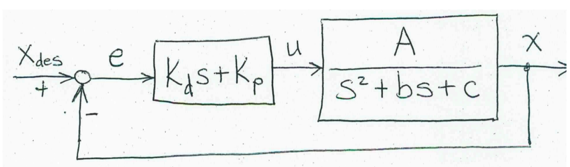

Figure 2. d) PD lefthand version.

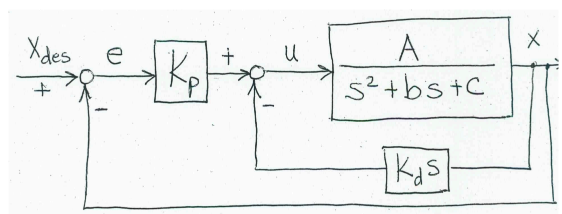

Figure 3. e) PD righthand version

(d) What is the closed loop transfer function (symbolically, without plugging in numbers for variables) for the PD controller shown above at left, in Figure 2?

(e) What is the closed loop transfer function (symbolically, without plugging in numbers for variables) for the PD controller shown above at right, in Figure 3?

(f) Use your earlier solutions for A, b, and c, along with Kp=1.9 and Kd=0.01, to solve for the FINAL VALUE OF A UNIT STEP RESPONSE for the closed-loop transfer function $X(s)/X_{des}(s)$ corresponding to the LEFTHAND system in Figure 2.

(g) Use your earlier solutions for A, b, and c, along with Kp=1.9 and Kd=0.01, to solve for the INITIAL SLOPE OF A UNIT STEP RESPONSE for the closed-loop transfer function $X(s)/X_{des}(s)$ corresponding to the LEFTHAND system in Figure 2.

Problem 2 – 3-link arm, in 3D space. Figures 4 and 5 show the same 3-link arm, with two different angles for q1, but with IDENTICAL angles q2 and q3.
NOTE: <u>q1 is a rotation about the (vertical) y axis!</u>
q2 and q3 are rotations about the axis pointing out of the page (toward you).

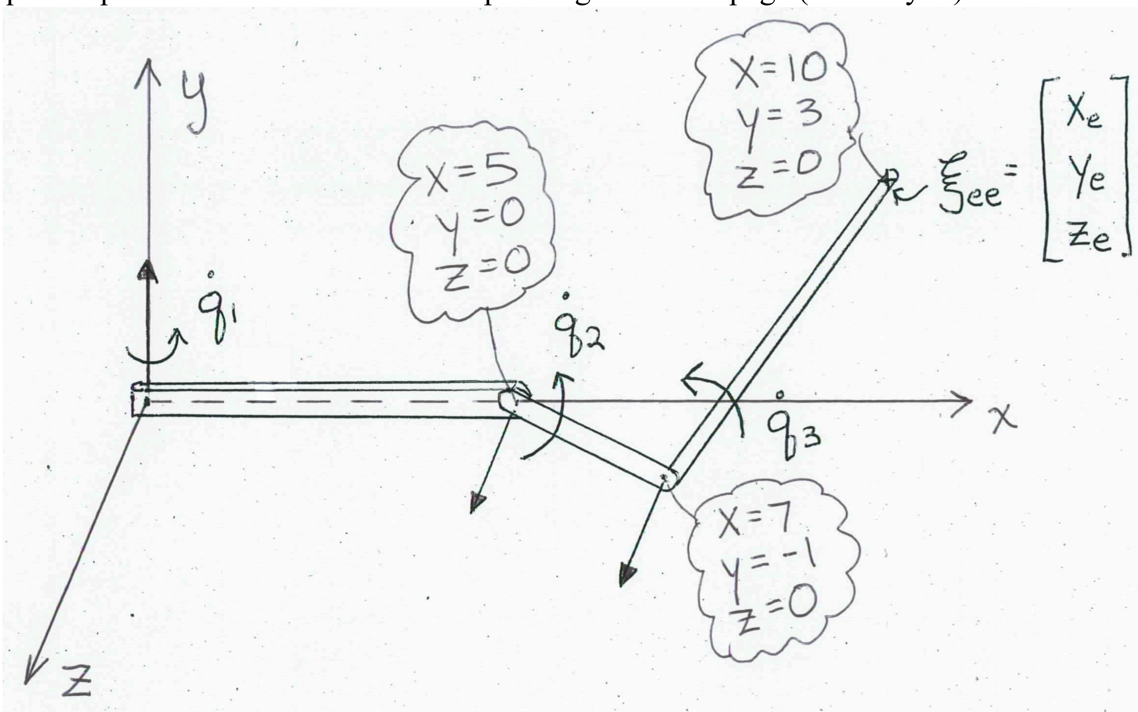

Figure 4. All points of the arm line in the x-y plane. Rotation of q1 is about y axis, while both q2 and q3 are about the z axis in this configuration

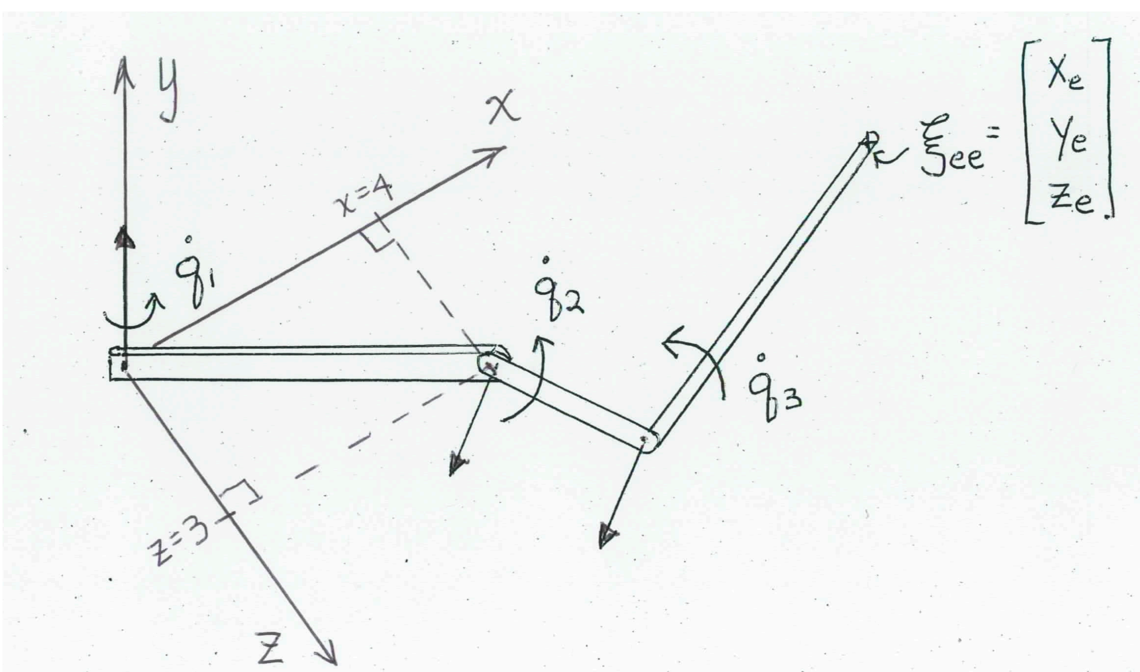

Figure 5. Same arm. q2 and q3 are IDENTICAL to their values in Figure 4. Only q1 has changed. Note the 3-4-5 triangle relationship of the new (x,z) location of the q2 joint.

For both parts (a) and (b) below, we care only about the POSITION (not orientation) of the end effector here, so we define $\xi_e = \begin{bmatrix} x_e \\ y_e \\ z_e \end{bmatrix}$ and $q = \begin{bmatrix} q_1 \\ q_2 \\ q_3 \end{bmatrix}$. As usual, $\dot{\xi} = J\dot{q}$.

Note: <u>There is no angle "phi" within vector "xi"!!</u> Only x, y, and z positions!!

(a) Solve for J, given the arm configuration shown in Figure 4.

(b) Now, solve for J, given the arm configuration shown in Figure 5.

Problem 3 – Omnibot.

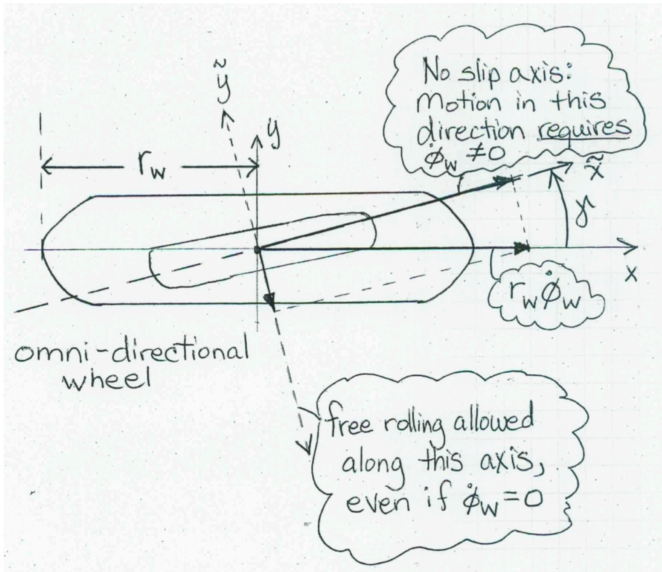

Figure 6. Omni-direction wheel.

(a) For a single omni-directional wheel, shown in Figure 6, assume motion is constrained such that the instantaneous velocity is exactly aligned with the x axis. The roller is aligned along the $\tilde{x}$ axis, which is at angle gamma (γ) to the x axis. (In Lab 3, gamma was equal to zero, but here it is not.) The wheel turns at speed $\dot{\phi}_w$ and has radius r_w. Motion along x axis direction is at velocity $\dot{x} = r_w \dot{\phi}_w$.
What is the velocity in the $\tilde{x}$ axis direction?

(b) Now, assume the robot constraints require instantaneous velocity is purely in the $\tilde{x}$ axis direction. To move at a velocity of 1 meter/sec in the $\tilde{x}$ axis direction, what is the required wheel velocity, $\dot{\phi}_w$?

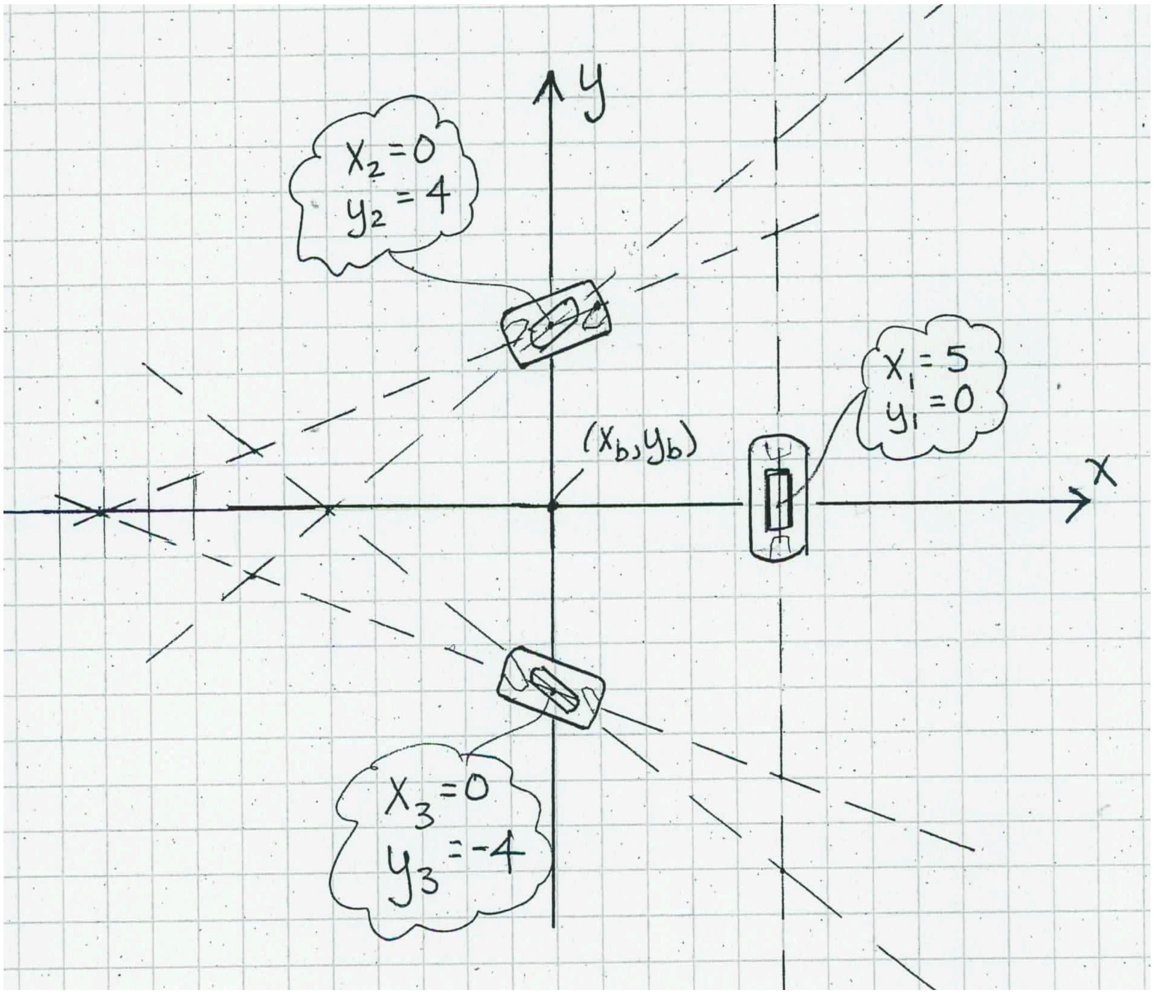

Figure 7. Gamma=0 for wheel 1, but not for wheels 2 and 3 here! Locations of wheels are with respect to the center of body, (xb,yb).

(c) Assume the 3 wheels in Figure 7 are all mounted on the same rigid robot chassis (body). LABEL (using "1", "2", and "3") the instantaneous center of rotation when only wheel 1 is powered, when only wheel 2 is powered, and when only wheel 3 is powered, respectively. (Construction lines are intentionally somewhat ambiguous! Think carefully.)

(d) When $\dot{\phi}_2 = \dot{\phi}_3 = 0$, and when $\dot{\phi}_1 = 1$, what are $\dot{x}_b$, $\dot{y}_b$, and $\dot{\phi}_b$? ($\dot{\phi}_b$ is positive in the counter-clockwise direction. The location of the center of body is as shown in Fig. 7.)

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

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