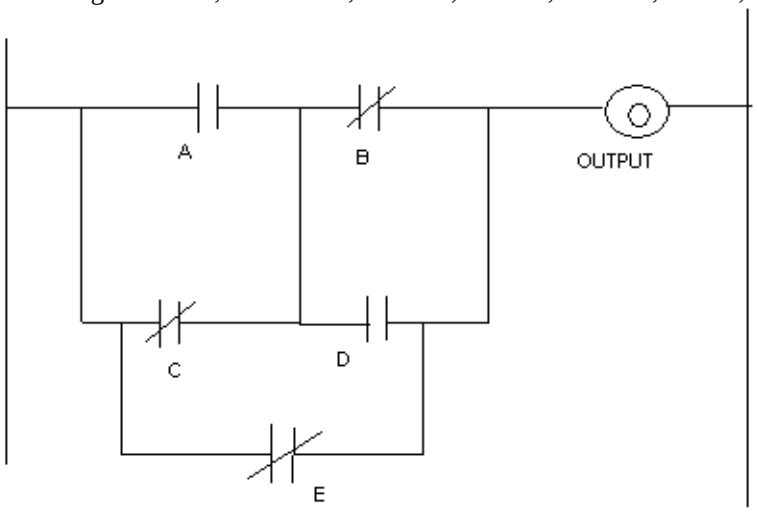
MAE 464-564
October 17, 2007
Mid term
Total Time: 75 min.
Your question paper has 6 pages. Total Points for MAE 464: 55 MAE 564: 75

1. Answer the following short questions (2 Points each):

A. For the figure shown, if A = false, B= false, C=false, D= false, E=true, then Output would be ?



a. True (Solution)
b. False
c. Either True or False
d. Cannot be determined from given information

B. Assume a fixed coordinate system X,Y,Z and a moving coordinate system U,V,W. A point moves a distance of *a* units in the OV direction followed by a rotation of α degrees along OX axis followed by *b* units along OU axis. Write down the order of multiplication of the matrices to obtain the transformation matrix T. (do not expand the matrices)

Solution: Three transformation matices, T(a)R(α)T(b) , if any other order is given points have not been awarded as matrix multiplication is not commutative.

C. 'State space' search technique is used for:

a. Collision detection
b. Task planning (Solution)
c. Path planning
d. Trajectory planning

D. Given a mobile robot with 5 joints, how many trajectory segments have to be evaluated for a 5-5-5- trajectory?

15x5 trajectory segments.

E. Describe briefly the concept of 'Configuration Space' technique for path planning?

Solution: For a robotic system with 'k' d.o.f the state or configuration of the robot can be completely described by k values. For a certain path with multiple obstacles, certain configuration set will satisfy collision free motion along the path. The configuration space of a robot is generally defined in terms of suitable joint angles.

F. Why are traditional Robots usually not used in metal cutting applications?

Solution: Lack of rigidity to withstand machining forces. Compliance.

G. We know the following transformation matrices (points 3):

$$T\,1 = {}^{\text{Camera}}T_{\text{Base}}$$

$$T\,2 = {}^{\text{Base}}T_{\text{Table}}$$

$$T\,3 = {}^{\text{Table}}T_{\text{Fixture}}$$

Find the transformation matrix from Camera to Fixture

Solution: $T_1 * T_2 * T_3$

H. Transformation matrix between the base of a robot and its end effector is give by the equation:

$^{0}A_{6}$ =

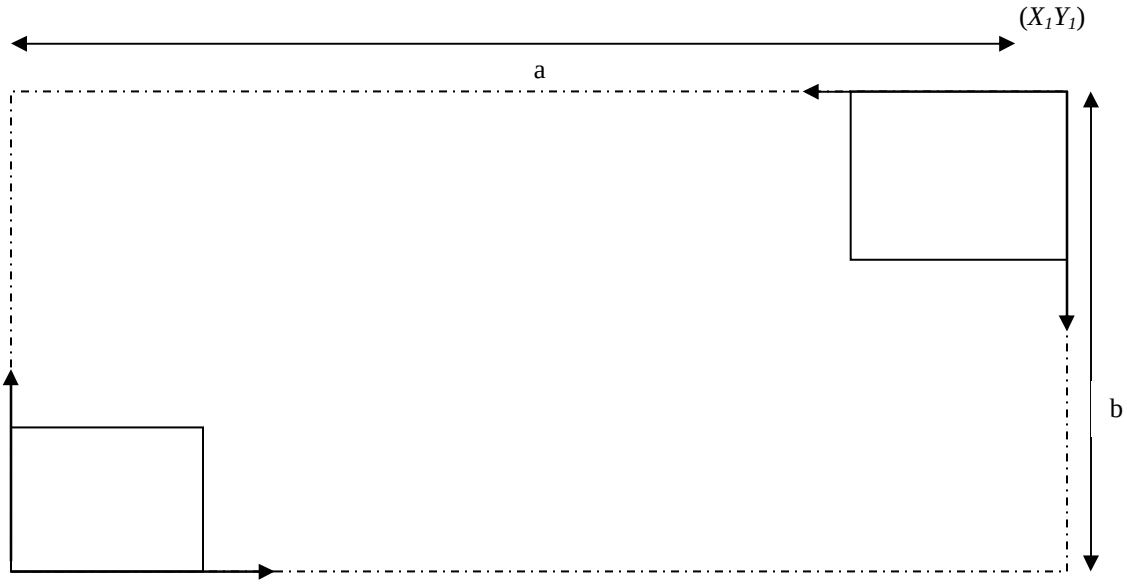
1	0	0	11
0	1	0	5
0	0	1	4
0	0	0	1

How far is the end effector from the base? (points 3) Draw the two frames of references (base and end effector) with exact orientation of the (X0,Y0,Z0) and (X6, Y6 and Z6) (points 3)

Solution:

(a) Distance from base :- Translation = $[\ 11\ 5\ 4\ ]^{T}$, distance is given by RMS(Translation) ~ 12 units.
(b) There is a rotation of 'zero' degrees along Z axis.
(c) The coordinate frames have to be drawn based on the translation values

Show the homogenous transformation 0 A 1 for the two coordinates show here: (4)



Solution :- T(a,x) T(b,y)* R(Z,pi)*

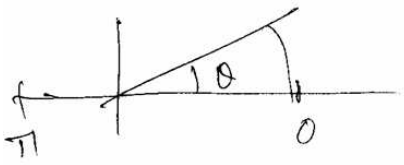
Solution for Question J: Anything relevant that explains the usage of force/pressure/tactile/position sensor.

2. A single link robot of the length 1 unit with a rotary joint is programmed to draw a semicircle in 5 seconds. Find the coefficients of a cubic polynomial, which accomplishes this motion and brings the manipulator to rest at the goal. Find position and velocity at time steps 0, 5, and 10 seconds. (20 points)

A cubic equation of motion is given by

$$\theta = a_0 + a_1 t + a_2 t^2 + a_3 t^3$$

The given conditions are



$\theta'(0) = 0$ $\quad \theta'(5) = 0$

$\theta(5) = \pi$ $\quad \theta(0) = 0$

The velocity of the object is given by

$$\theta' = a_1 + 2a_2 t + 3a_3 t^2$$

The acceleration is given by

$$\theta'' = 2a_2 + 6a_3 t$$

Using the initial / boundary conditions and solving for the co-efficients.

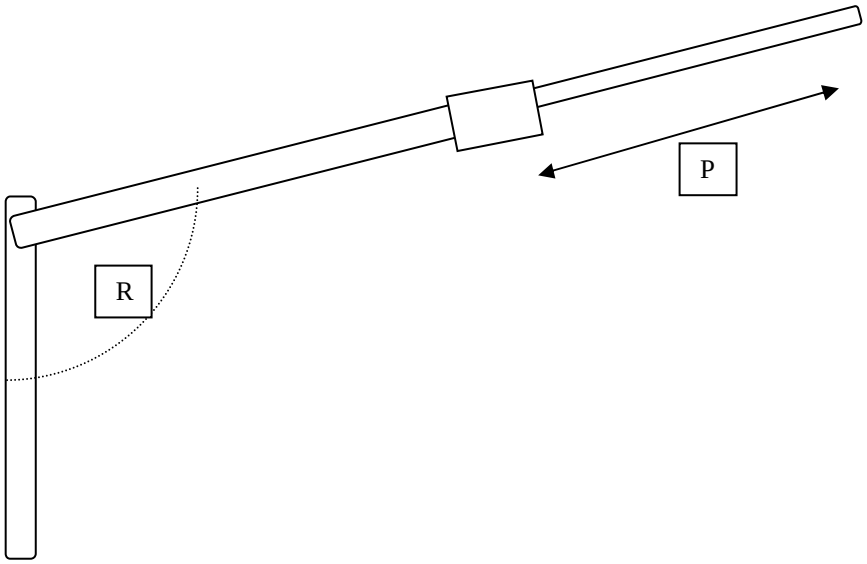
$a_0 = 0$ $\quad a_2 = 0.3768$

$a_1 = 0$ $\quad a_3 = -0.0502$

	θ	θ'	θ''
0	0	0	0.74
3	2.0358	0.9054	-0.7524
5	π	0	-0.74
	0	0	43.2
	116.4	51.84	-8.64
	180	0	-43.2

3. Fill in the D-H Parameters of the above two link robot? (10)

Axis	θ	d	a	α
1	variable	0	0	0
2	0	variable	0	90

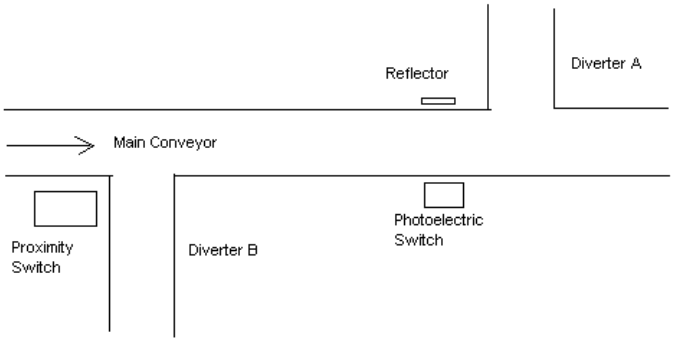


Three axis are to be fixed

1. At the revolute joint with Z axis facing away from the paper
2. At the beginning of the prismatic joint with Z facing along the link
3. At the end effector with Z facing along the link

MAE 564 Students only

4. The XYZ Company is in the toy business. It produces two types of toy cars, wooden cars and metal cars. A conveyor belt carries the product through the production floor (see figure). Wooden cars are sensed by a photoelectric switch and metal cars are sensed by a proximity switch. Cars are pushed to diverters by means of solenoids. The conveyor belt is activated by push button. However, in case of emergency, the whole system is shut down by means of an emergency push button. Assume that wooden cars are diverted to diverter A by means of solenoid 1 and that metal cars are diverted to diverter B by means of solenoid 2. Draw a ladder diagram for the control of this system (20 Points).



Question has been graded out of 10 points for all UG students. The final scores of all UG students will then be rounded off to the maximum points (55 points).