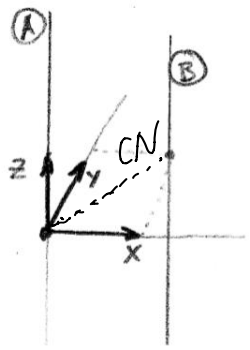
Problem Set 1

1.1 Common Normal

Draw or solve the common normals for each set of axes A,B below.

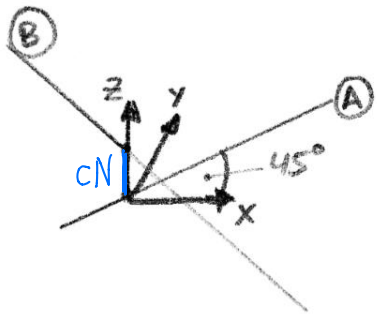
1.1.1



A is equal to Z axis.
$B = [2 \quad 2 \quad z]^T$
Unique? ___ Yes ___ No

No.

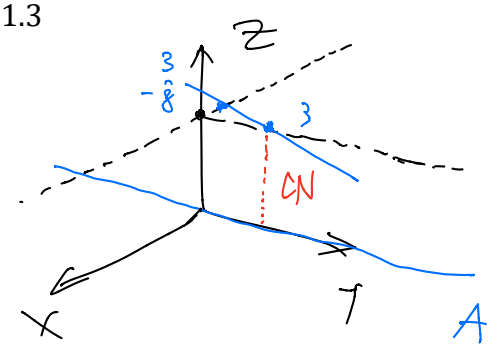
1.1.2



A is in the XY plane.
B is perpendicular to Z axis.
Unique? ___ Yes ___ No

Yes.

1.1.3



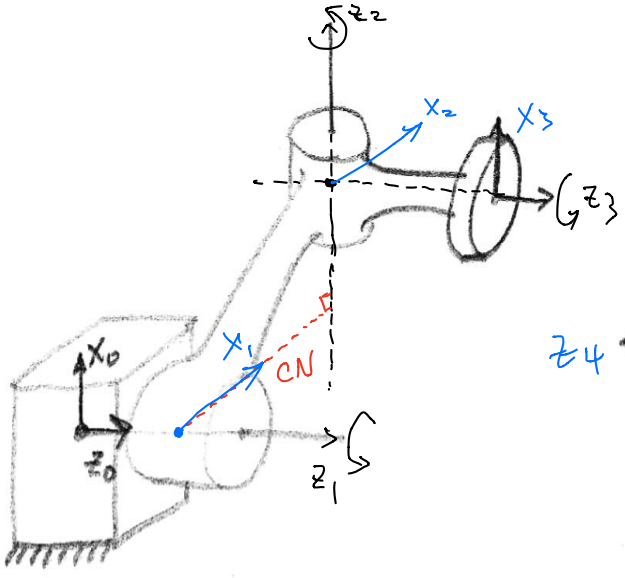
Make a drawing and find the Common Normal for:
A = Y axis.
B = $[x \quad 3.0 + 0.8x \quad 5]^T$.
Unique? ___ Yes ___ No

Yes

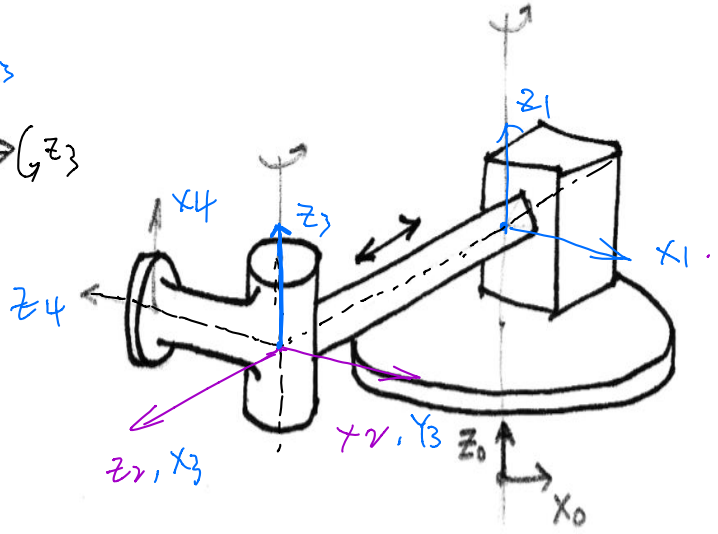
1.2 Link Frame Assignment

Draw Common Normals and assign link frames for the following manipulators. (**NOTE:** Please create clear graphics for your homework submission. For example, copy/paste the graphic from this assignment and use colored arrows for the link frames.)

1.2.1



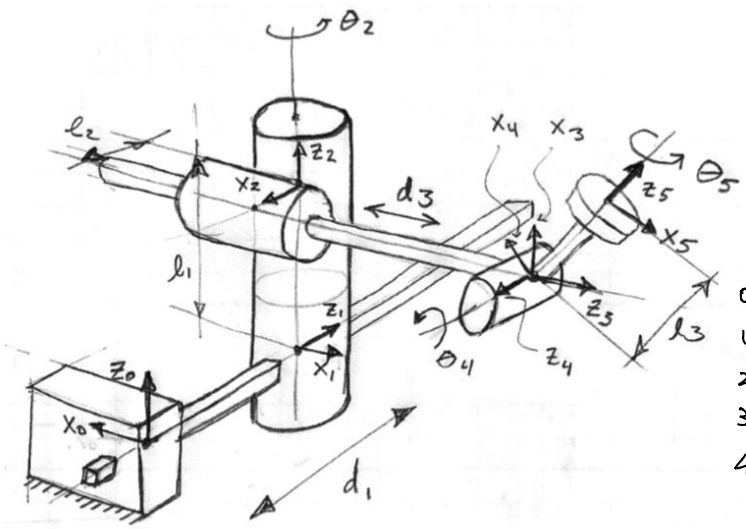
1.1.2 (z, a, d, theta).



1.3 DH Table

Make a table of DH parameters for each of the robot manipulators.

1.3.1



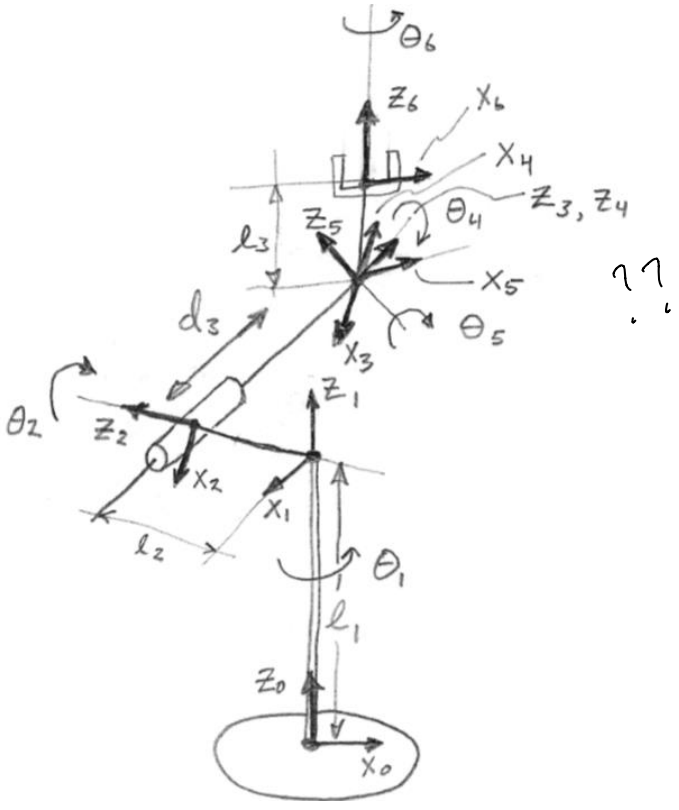
English :)

l means fixed length.

d means variable.

	i	α_{i-1}	a_{i-1}	d_i	θ_i
0 →	1	$\pi/2$	0	d_1	π
1 →	2	$\pi/2$	0	l_1	$\theta_2 - \pi/2$
2 →	3	$-\pi/2$	l_2	d_3	$\pi/2$
3 →	4	$-\pi/2$	0	0	θ_4
4 →	5	$-\pi/2$	0	l_3	$\theta_5 - \pi$

1.3.2



bite bait 餐饵.

It's hard to tell the relationship between 3, 4, 5

??.

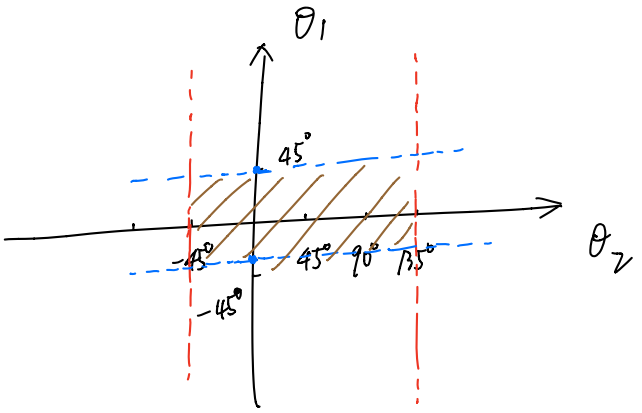
	i	α_{i-1}	a_{i-1}	d_i	θ_i
0→	1	0	0	l_1	$\theta_1 - \pi/2$
1→	2	$\pi/2$	0	l_2	$\theta_2 - \phi_2$
2→	3	$\pi/2$	0	d_3	0
3→	4	0	0	0	θ_4
4→	5	$\pi/2$	0		
5→	6				

Problem Set 2

2.1 Workspace

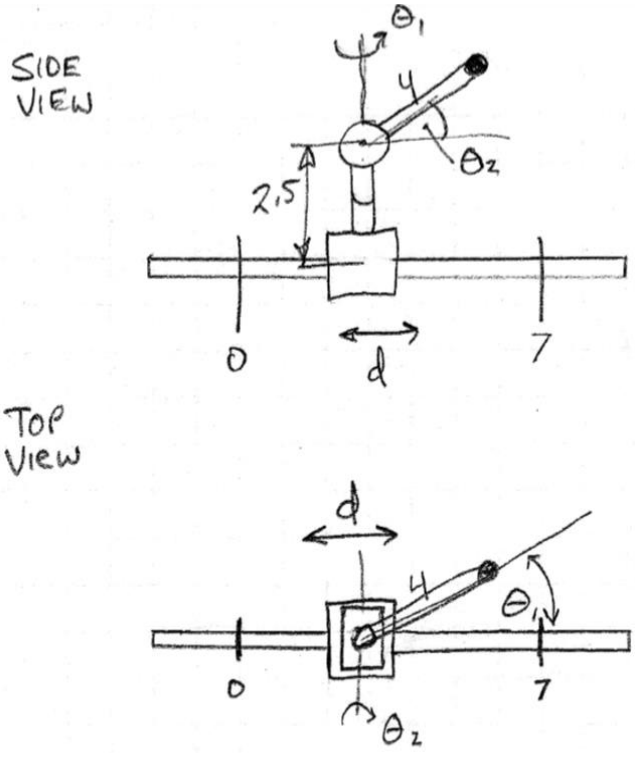
2.1.1 A 2-link planar manipulator has l1 = 2, l2 = 4. Draw the workspace using a compass and ruler (neatness counts!).

$$-30^\circ < \theta_1 < 45^\circ$$
$$-45^\circ < \theta_2 < 135^\circ$$



2.1.2 Sketch the 3D workspace (at least side view and top view) of the following manipulator for

$$0 < d < 7 \qquad 0^\circ < \theta_1 < 90^\circ \qquad -30^\circ < \theta_2 < 30^\circ$$



2.2 Inverse Kinematics: Algebraic Method

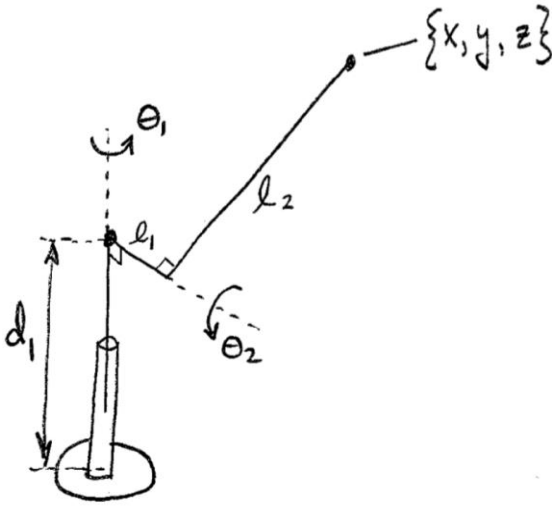
Find the solution by the algebraic method. How many solutions are there? Are there any joint angle values which cause a problem for the solution (also known as a singularity)? If so, what can you solve in that singular case?

$$\begin{bmatrix} r_{11} & r_{12} & r_{13} & 0 \\ r_{21} & r_{22} & r_{23} & 0 \\ r_{31} & r_{32} & r_{33} & Z \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} c_4c_5c_6 - s_4s_6 & -c_4c_5s_6 - s_4c_6 & c_4s_5 & 0 \\ s_4c_5c_6 - c_4s_6 & -s_4c_5s_6 + c_4c_6 & s_4s_5 & 0 \\ s_5s_6 & s_5c_6 & c_5 & d_3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Find $\theta_4, \theta_5, \theta_6, d_3$.

2.3 Inverse Kinematics: Geometric Method

How many solutions are there in order for the robot end effector to reach the point {x,y,z} and how do you find them?



Problem Set 3

3.1 Environment Setup

3.1.1 ROS Installation

- If you already have an Ubuntu 16.04 machine. Go ahead and install ROS following the steps here.
- If you don't already have one, follow the page here for instructions on installing a virtual machine and an image with Ubuntu 16.04 and ROS pre-installed.

3.1.2 Building a catkin workspace

- Follow the steps here to build a catkin workspace.
- Note: choose "kinetic" ROS distribution.

3.2 Hands-On Exercise: Publisher/Subscriber Node

In this assignment you are tasked with writing a **node that subscribes to a topic and publishes into another one**. Your code will subscribe to a topic called *'two_ints'*, on which a custom message containing two integers can be broadcast. Make sure to familiarize yourself with the message format of this topic (have a look at the TwoInts.msg in the msg directory). Those two integers are to be added and the result published to topic 'sum' as an Int16.

3.2.1 Download the code skeleton:

Extract the project1.zip file (link) and put the entire project1 folder under "*~/catkin_ws/src/".*

3.2.2 Write the code:

Fill in the TODO sections in the file "*~/catkin_ws/src/project1/src/solution.py*". Here is a useful tutorial that might be helpful.

3.2.3 Compile the code:

$ chmod +x ~/catkin_ws/src/project1/src/solution.py

$ cd ~/catkin_ws

$ catkin_make

$ source devel/setup.bash

3.2.4 Testing:

You will need to run 3 terminal commands:

1. Execute the ROS node that creates 2 topics. One that subscribes to /two_ints and the other that publishes into /sum.

   $ roslaunch project1 execute.launch

2. Subscribe to the topic /sum.

   $ rostopic echo /sum

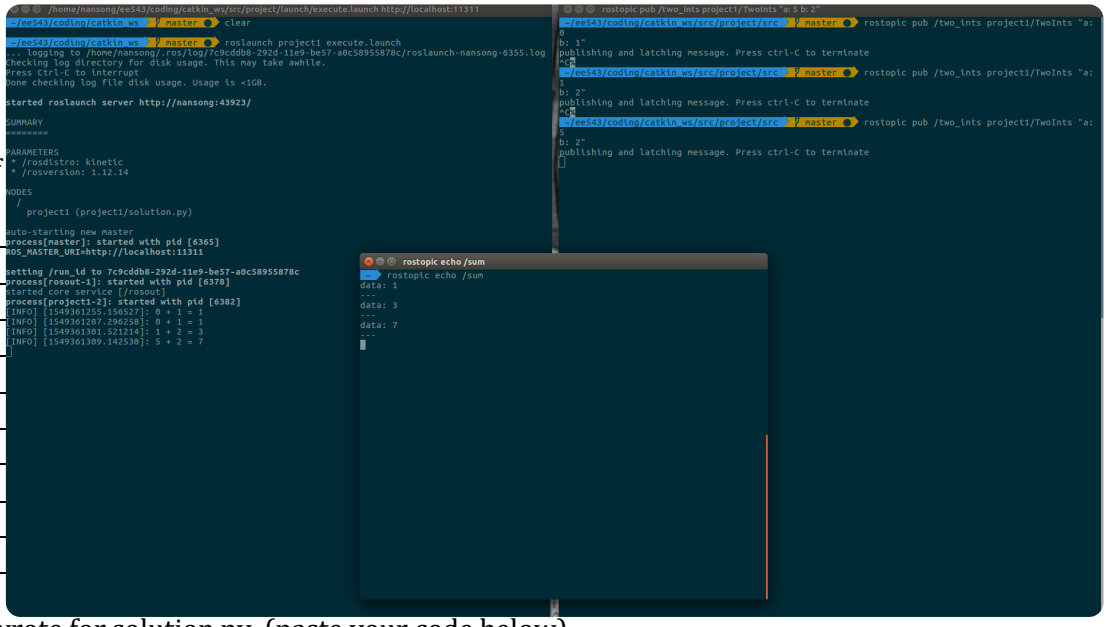
3. Publish into the topic /two_ints.

   $ rostopic pub /two_ints project1/TwoInts "{a: 1, b: 2}"

What to submit:

1. A screen shot of of your choice.

Test1 a= b=	Terminal 1 Terminal 2 Terminal 3
Test2 a= b=	Terminal 1 Terminal 2 Terminal 3
Test3 a= b=	Terminal 1 Terminal 2 Terminal 3



2. The script you wrote for solution.py. (paste your code below)

My code:

```python
#!/usr/bin/env python
import rospy

from std_msgs.msg import Int16
from project1.msg import TwoInts

def callback(data):
        msg = Int16(0)
        msg = data.a + data.b
        rospy.loginfo(str(data.a) + " + " + str(data.b) + " = " + str(msg))
        pub.publish(msg)

def talker_listener():

        rospy.init_node('solution')
        global pub
        pub = rospy.Publisher('sum', Int16, queue_size=1)
        sub = rospy.Subscriber("two_ints", TwoInts, callback)
        rospy.spin()


if __name__ == '__main__':
        try:
                talker_listener()
        except rospy.ROSInterruptException:
                raise e
```