

RBE 521: Legged Robotics

Final Exam

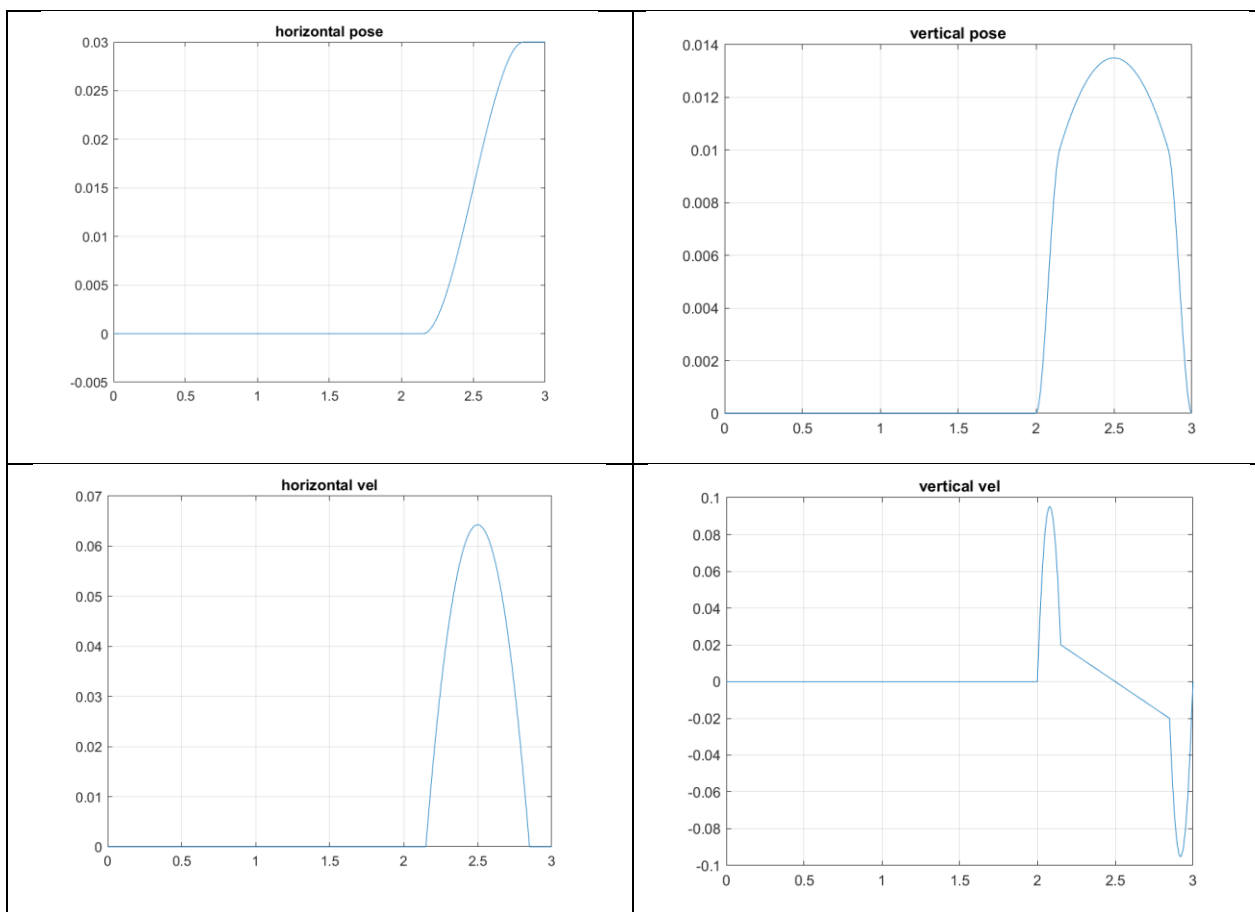
Submitted by: Prasham Patel

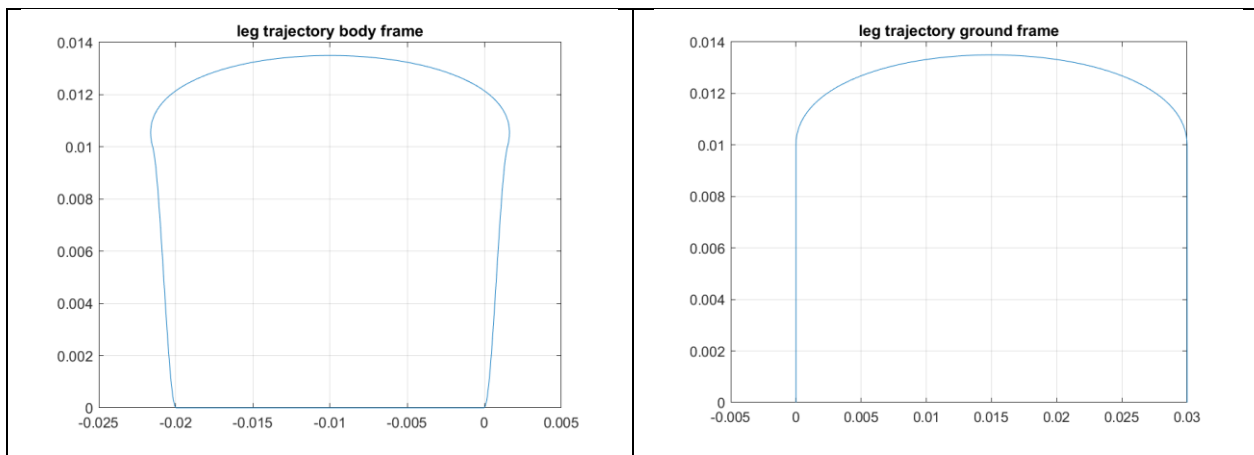
Problem 1:

Part 1 to 5 in assignment 5

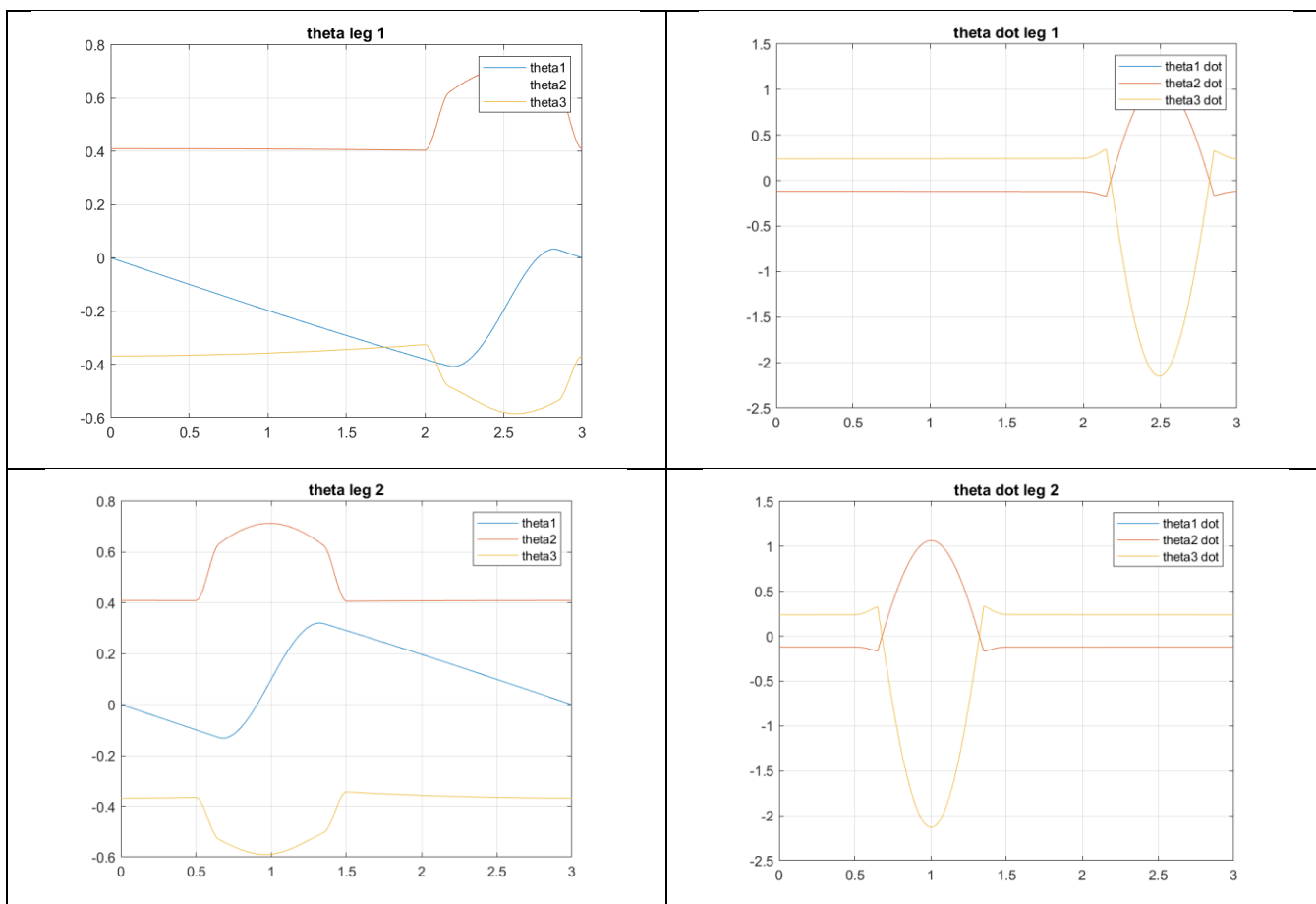
Part 6:

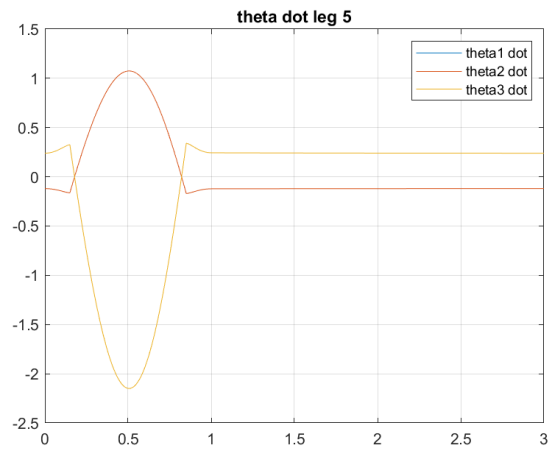
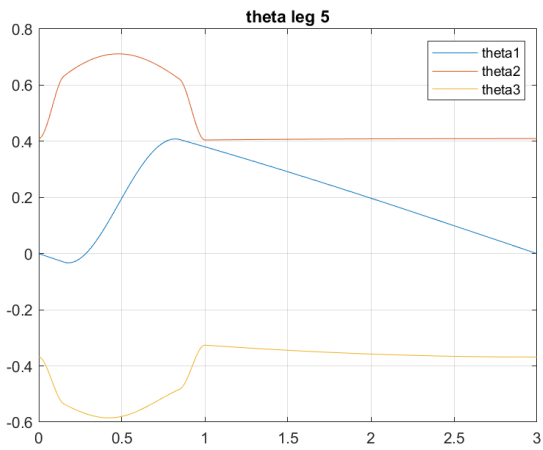
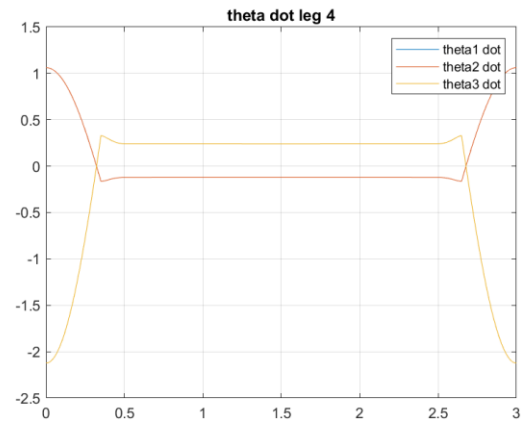
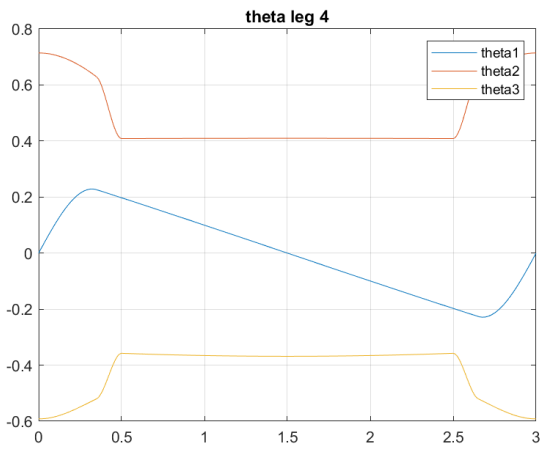
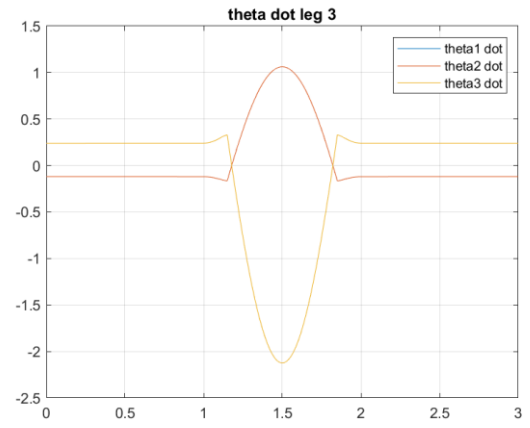
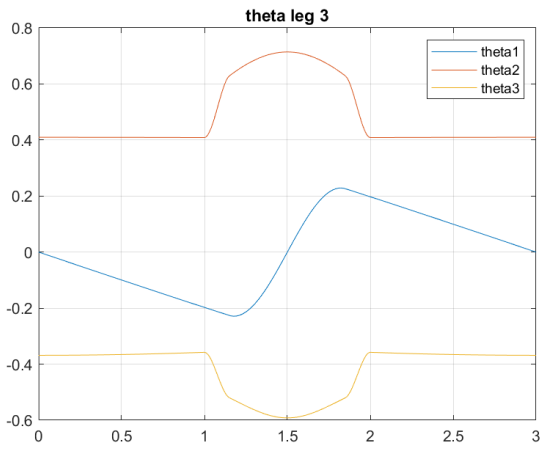
A minimum acceleration trajectory (**cubic trajectory**) was generated for this part instead of constant acceleration. The Graphs shown below are for foot tip of leg number 1. Please run problem_1.m file.

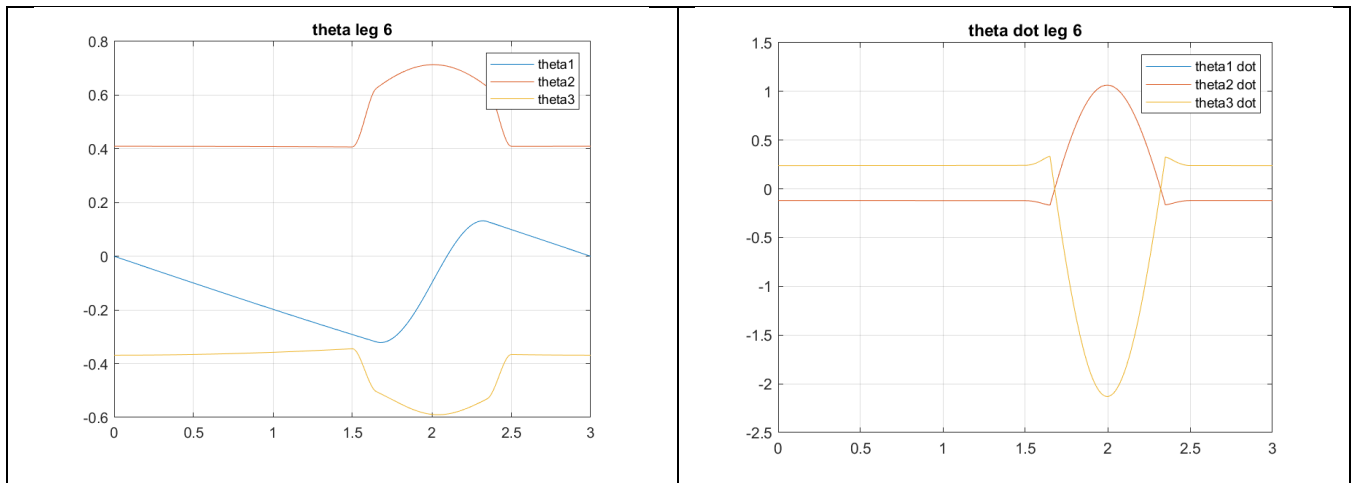




Part 7 and Part 8:







Joint Position

Body width is not considered, thus, x-co-ordinate is same for all joints. The Y co-ordinate for leg 1 and 2 will be offset by 0.3 m and for leg 3 and 4 it will be 0.15. The Body length is considered as 0.3 m.

It follows the pattern: [x1, y1, z1, x2, y2, z2, x3, y3, z3]

T 1=

0	0	0	0.0459	-0.0000	0.0199	0.0500	0.0000	-0.0800
0	0	0	0.0459	-0.0000	0.0199	0.0500	0.0000	-0.0800
0	0	0	0.0459	-0.0000	0.0199	0.0500	0.0000	-0.0800
0	0	0	0.0378	0.0000	0.0328	0.0500	0.0000	-0.0665
0	0	0	0.0459	-0.0000	0.0199	0.0500	0.0000	-0.0800
0	0	0	0.0459	-0.0000	0.0199	0.0500	0.0000	-0.0800

T2 =

0	0.0059	0	0.0456	0.0005	0.0199	0.0500	0.0000	-0.0800
0	0.0059	0	0.0426	0.0009	0.0258	0.0500	0.0000	-0.0740
0	0.0059	0	0.0456	0.0005	0.0199	0.0500	0.0000	-0.0800
0	0.0059	0	0.0451	0.0141	0.0199	0.0500	0.0150	-0.0800
0	0.0059	0	0.0366	0.0167	0.0323	0.0500	0.0207	-0.0667
0	0.0059	0	0.0456	0.0005	0.0199	0.0500	0.0000	-0.0800

T3 =

0	0.0119	0	0.0446	0.0013	0.0198	0.0500	0.0000	-0.0800
0	0.0119	0	0.0373	0.0224	0.0316	0.0500	0.0260	-0.0675
0	0.0119	0	0.0389	0.0029	0.0301	0.0500	0.0003	-0.0692
0	0.0119	0	0.0458	0.0147	0.0199	0.0500	0.0150	-0.0800
0	0.0119	0	0.0432	0.0275	0.0197	0.0500	0.0300	-0.0800
0	0.0119	0	0.0446	0.0013	0.0198	0.0500	0.0000	-0.0800

T4 =

0	0.0179	0	0.0432	0.0024	0.0197	0.0500	0.0000	-0.0800
0	0.0179	0	0.0446	0.0287	0.0198	0.0500	0.0300	-0.0800
0	0.0179	0	0.0387	0.0268	0.0304	0.0500	0.0294	-0.0689
0	0.0179	0	0.0458	0.0152	0.0199	0.0500	0.0150	-0.0800
0	0.0179	0	0.0446	0.0287	0.0198	0.0500	0.0300	-0.0800
0	0.0179	0	0.0373	0.0069	0.0314	0.0500	0.0031	-0.0678

T5 =

0	0.0239	0	0.0365	0.0124	0.0322	0.0500	0.0082	-0.0668
0	0.0239	0	0.0455	0.0295	0.0199	0.0500	0.0300	-0.0800
0	0.0239	0	0.0455	0.0295	0.0199	0.0500	0.0300	-0.0800
0	0.0239	0	0.0452	0.0159	0.0199	0.0500	0.0150	-0.0800
0	0.0239	0	0.0455	0.0295	0.0199	0.0500	0.0300	-0.0800
0	0.0239	0	0.0415	0.0290	0.0274	0.0500	0.0300	-0.0722

T6 =

0	0.0299	0	0.0458	0.0300	0.0200	0.0500	0.0300	-0.0799
0	0.0299	0	0.0459	0.0300	0.0199	0.0500	0.0300	-0.0800
0	0.0299	0	0.0459	0.0300	0.0199	0.0500	0.0300	-0.0800

0	0.0299	0	0.0378	0.0295	0.0327	0.0500	0.0294	-0.0665
0	0.0299	0	0.0459	0.0300	0.0199	0.0500	0.0300	-0.0800
0	0.0299	0	0.0459	0.0300	0.0199	0.0500	0.0300	-0.0800

Part 9:

Animation video is attached in the zip file

Part 10:

No, we cannot comment on stability with just the knowledge that leg 1, 2 and 5 are on ground. As we do not have any knowledge of the actual size or shape of the support polygon.

Problem 2:

Part 1:

	1/10	2/10	3/10	4/10	5/10	6/10	7/10	8/10	9/10	10/10
Leg 1										
Leg 2										

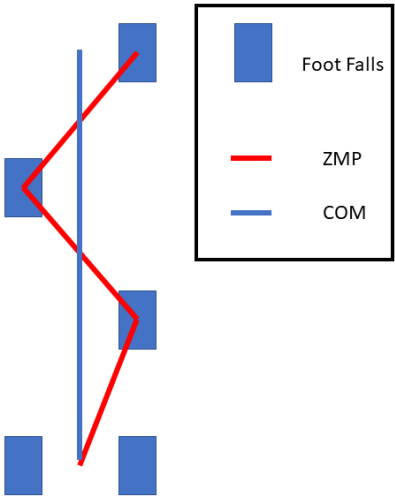
Human Walking Gait

Part 2:

Beta = 0.6

On an average 1.2 legs are in contact with ground. 20% of the cycle 2 legs are in contact and rest 80% of the cycle at least 1 leg is in contact.

Part 3:



Part 4:

	1/10	2/10	3/10	4/10	5/10	6/10	7/10	8/10	9/10	10/10
Leg 1										
Leg 2										

Human Running Gait

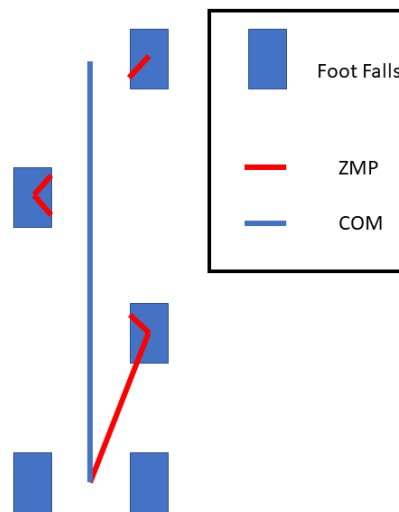
Part 5:

Beta = 0.4

On an average 0.8 legs are in contact with ground. 20% of the cycle no legs are in contact and rest 80% of the cycle at least 1 leg is in contact.

Part 6:

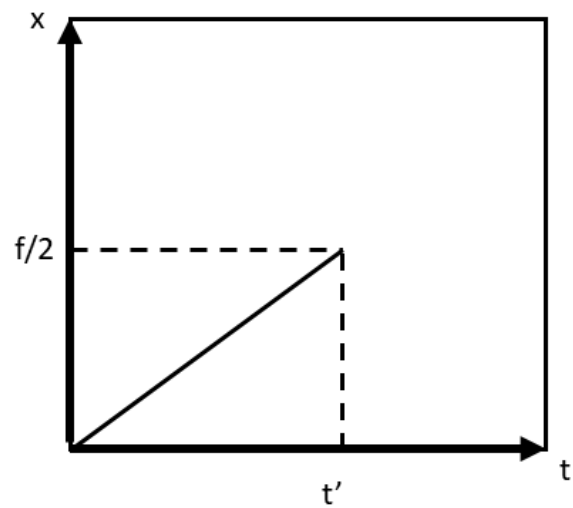
The ZMP does not exist when no foot is in contact. Thus, unlike ZMP for walking, ZMP for running is discontinues.

**Problem 3:**

The graphs show change in x-co-ordinate of ZMP. The initial position of ZMP is taken as zero for all three, left foot, right foot, and body. Robot body is considered as rigid mass and joints are considered to hold position during fall. A time t' is considered after which the robot starts to topple about the right edge of the right foot of the robot. Robot continues to topple about the edge until it falls.

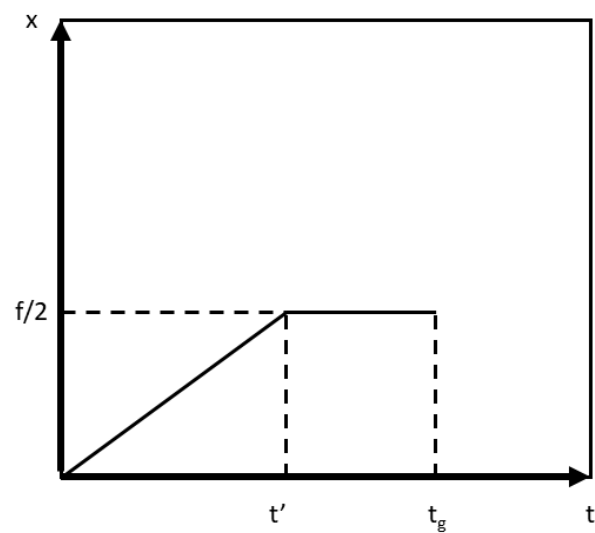
For Left Leg:

Left leg loses contact with ground when robot starts to topple, thus ZMP does not exist for left leg after time t' .



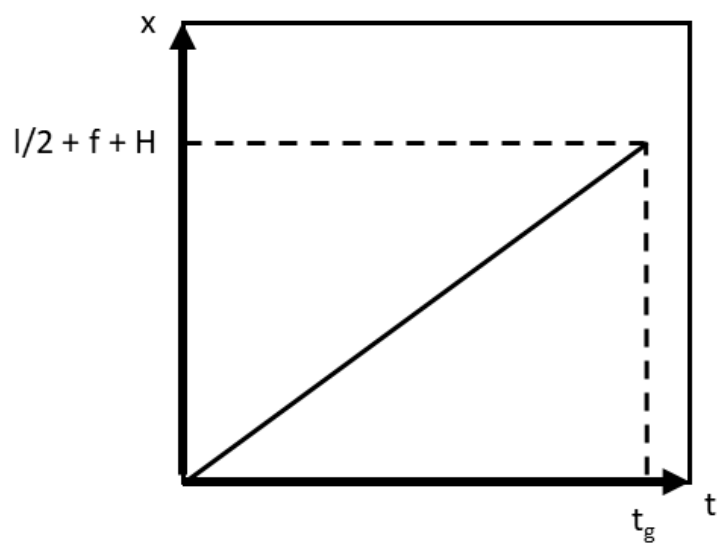
Change in x-co-ordinate of ZMP for Left foot

For Right Leg:



Change in x-co-ordinate of ZMP for Right foot

For Robot Body:



Change in x-co-ordinate of ZMP for body