Problem 1: Part 1)

$\mathbf{A}_{lat}$

```
[  -0.371441    0.0458582  -0.980285   0.544278  0.0
 -20.6405    -15.7093      2.67741    0.0       0.0
  11.5196     -1.23555    -0.566909   0.0       0.0
   0.0         1.0         0.0515269  0.0       0.0
   0.0         0.0         1.00133    0.0       0.0
]
```

$\mathbf{B}_{lat}$

```
[ -0.000762643   0.00309103
 -5.35799       0.0315897
 -0.256564     -0.130882
  0.0           0.0
  0.0           0.0
]
```

$\mathbf{A}_{long}$

```
[ -0.0609492   11.4379   -0.910211  -9.797      0.0
 -0.0425166   -6.32127   0.940645  -0.0280821  0.0
  0.108966   -38.0151   -3.28532    0.0        0.0
  0.0         0.0        1.0        0.0        0.0
  0.0514586  -17.9523    0.0       18.0        0.0
]
```

$\mathbf{B}_{long}$

```
[  0.00185606  3.38461
 -0.00686655  0.0
 -1.3996      0.0
  0.0         0.0
  0.0         0.0
]
```

Problem 1: Part 2)

For Short Period Mode :
Damping Ratio: 0.6380975226632497
Natural Frequency: 7.54563457743263

For Phugoid Mode :
Damping Ratio: 0.030058661111159526
Natural Frequency: 0.6293676188992627

For Dutch Roll Mode :
Damping Ratio: 0.1510641420677276
Natural Frequency: 3.7508625777027906

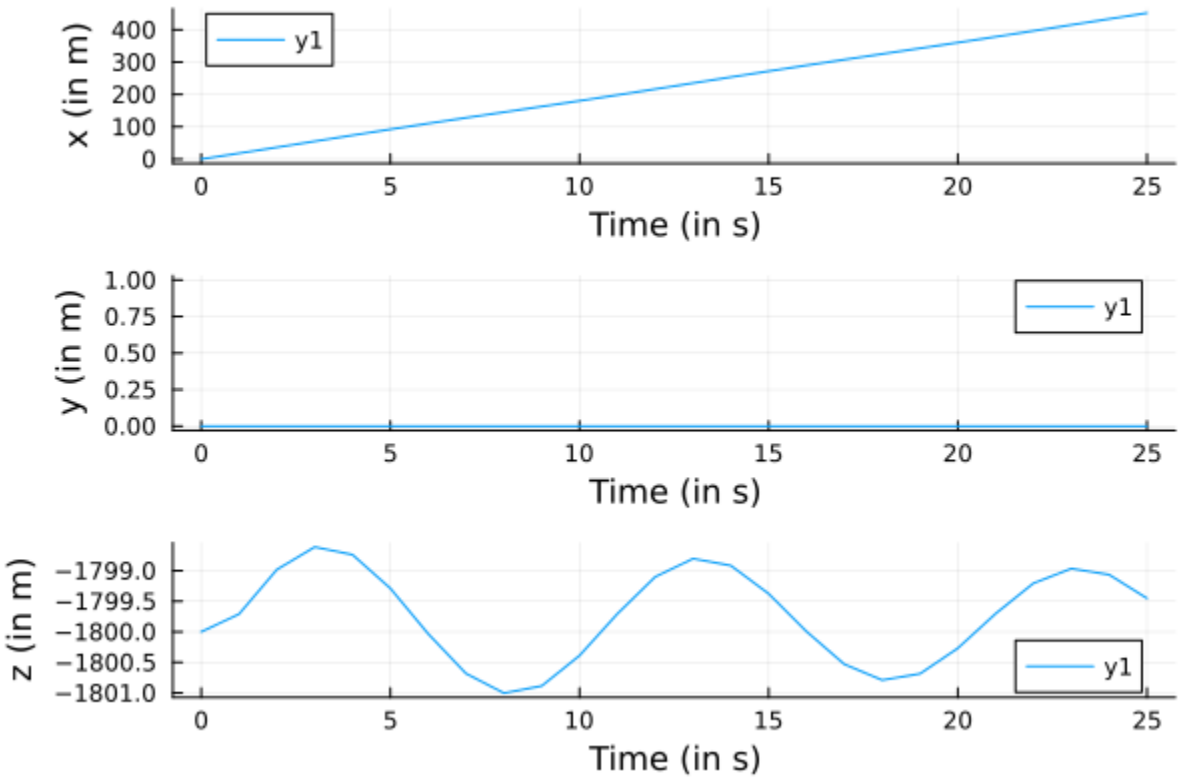
Problem 1: Part 3)

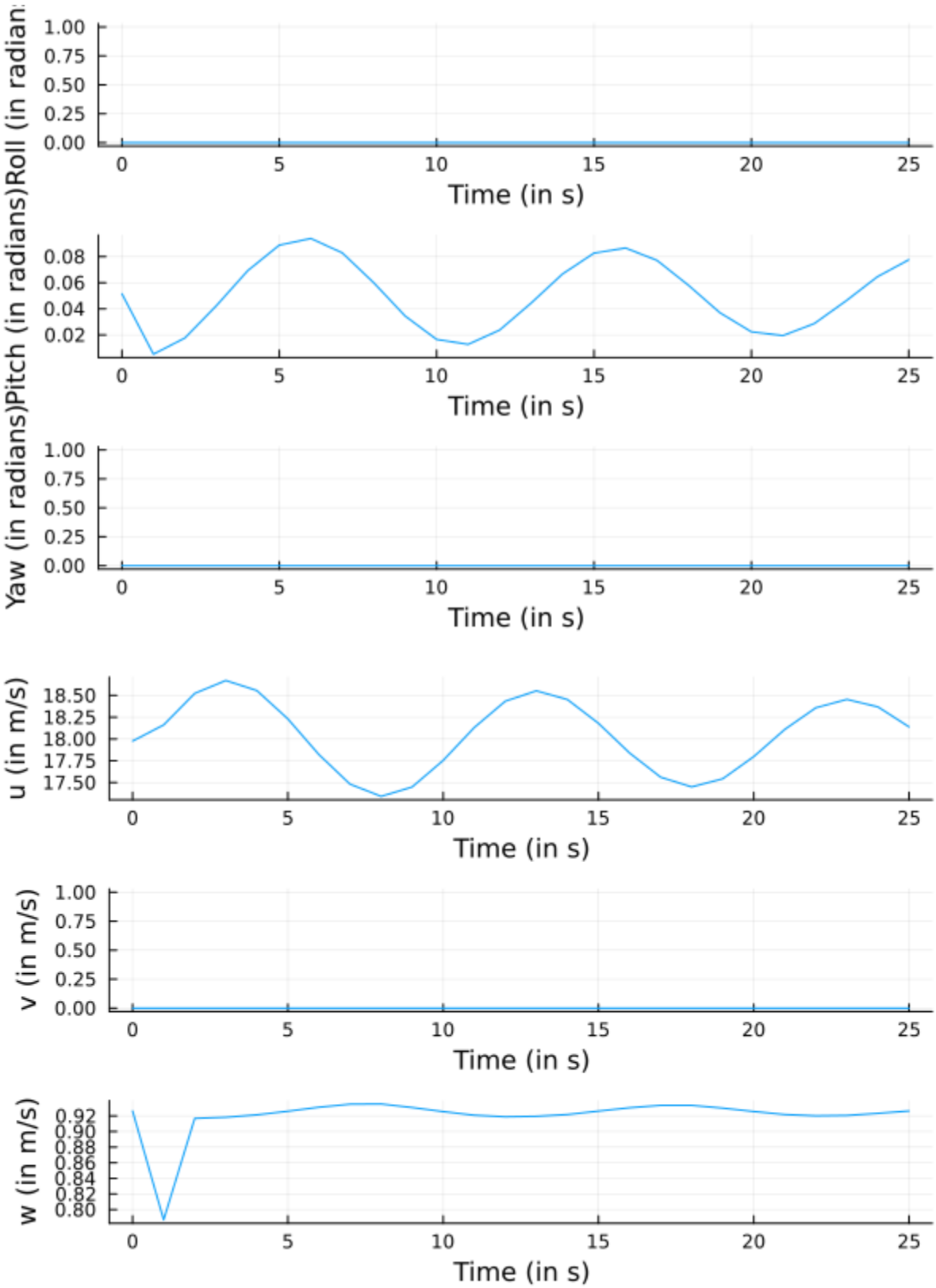
For Roll Mode :
Damping Ratio: 1.0
Natural Frequency: 15.5882856117332
Time Constant: 0.06415073632262079
The roll mode is stable.

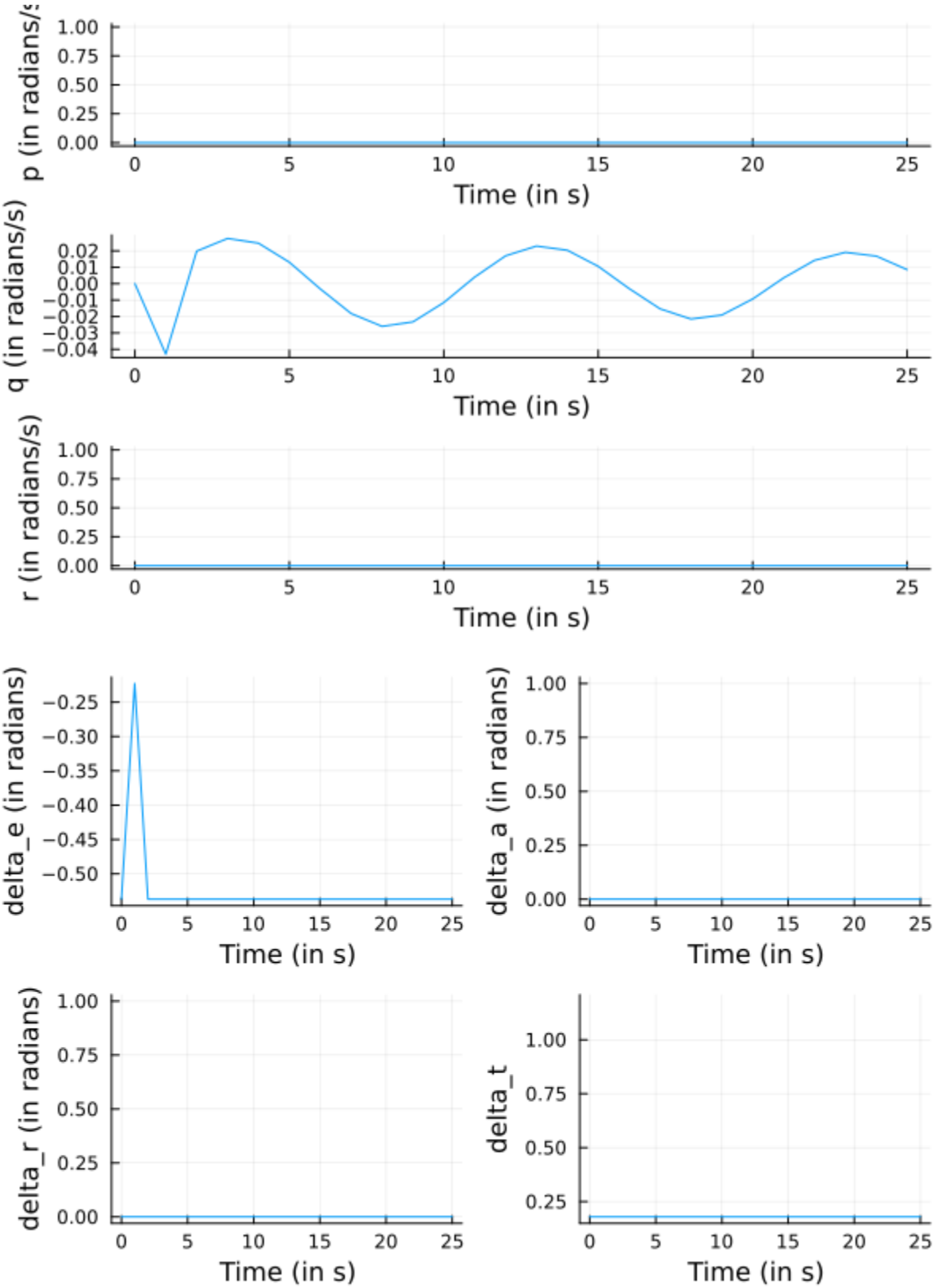
For Spiral Mode :
Damping Ratio: 1.0
Natural Frequency: 0.07390663902876486
Time Constant: 13.530584168640042
The spiral mode is unstable.

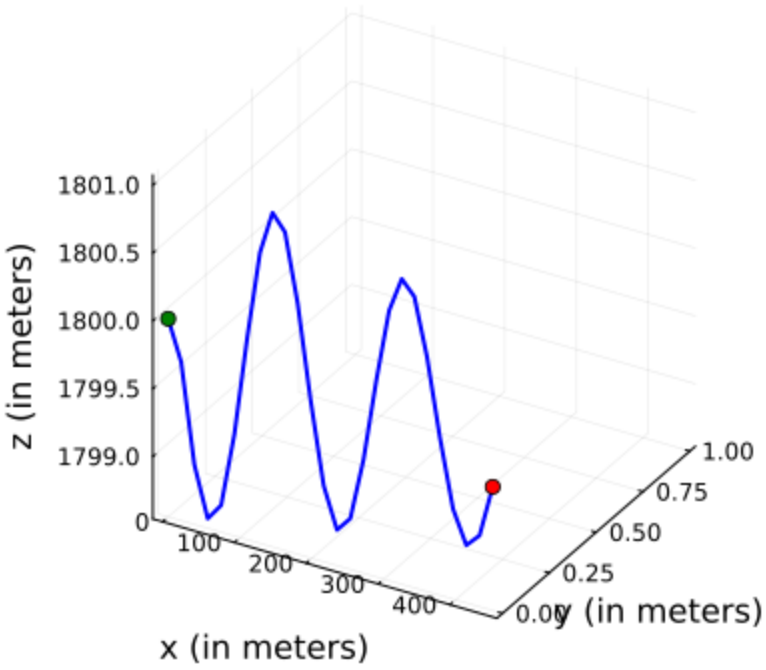
Problem 2: Part 1)

First, plots are generated for just 25 seconds to show the initial short-period behavior.




Roll (in radian
1.00
0.75
0.50
0.25
0.00
0
5
10
15
20
25
Time (in s)
Pitch (in radians)
0.08
0.06
0.04
0.02
Time (in s)
Yaw (in radians)
1.00
0.75
0.50
0.25
0.00
Time (in s)
u (in m/s)
18.50
18.25
18.00
17.75
17.50
Time (in s)
v (in m/s)
1.00
0.75
0.50
0.25
0.00
Time (in s)
w (in m/s)
0.92
0.90
0.88
0.86
0.84
0.82
0.80
Time (in s)

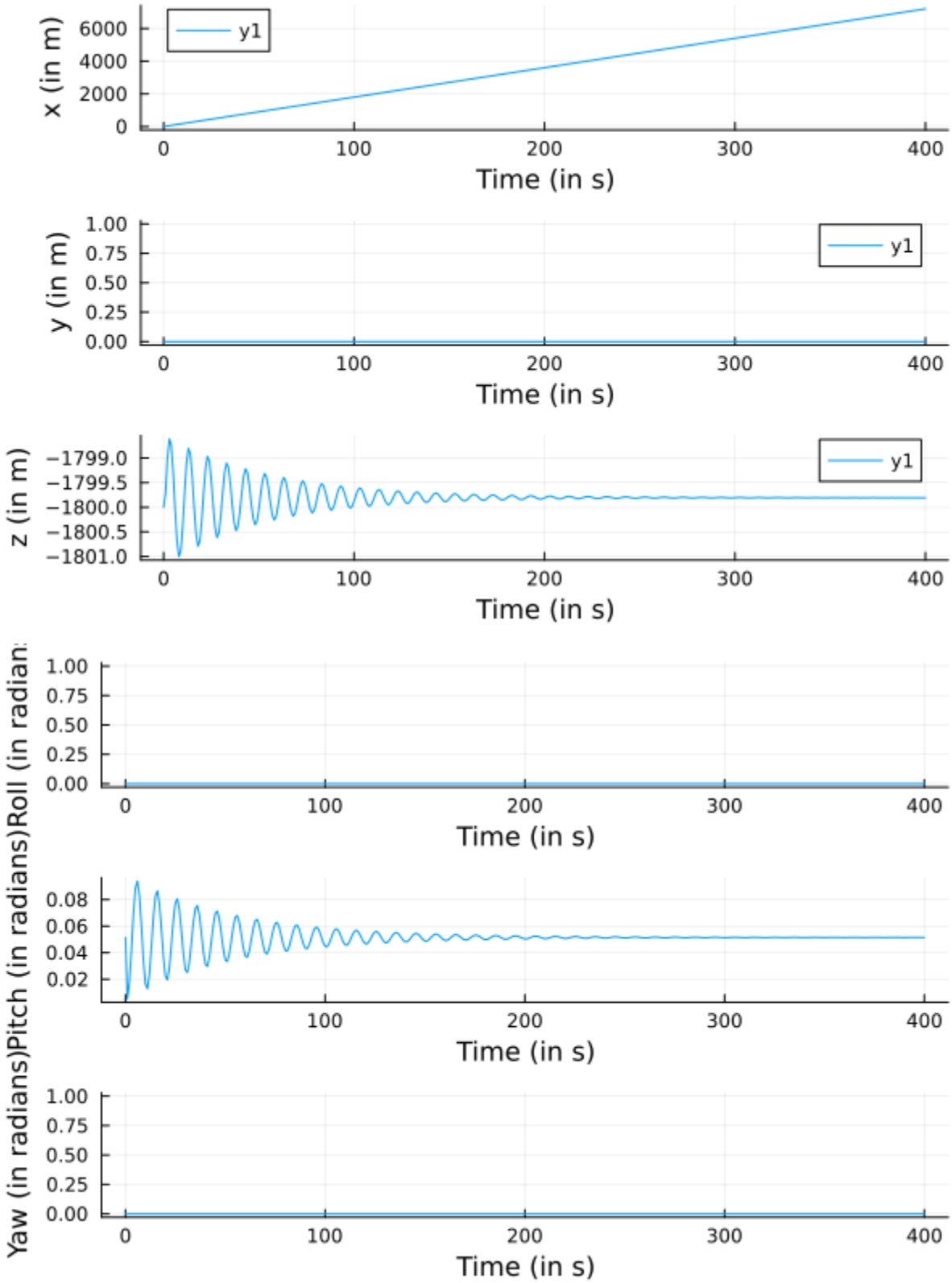

p (in radians/s
1.00
0.75
0.50
0.25
0.00
0
5
10
15
20
25
Time (in s)
q (in radians/s)
0.02
0.01
0.00
−0.01
−0.02
−0.03
−0.04
Time (in s)
r (in radians/s)
Time (in s)
delta_e (in radians)
−0.25
−0.30
−0.35
−0.40
−0.45
−0.50
Time (in s)
delta_a (in radians)
Time (in s)
delta_r (in radians)
Time (in s)
delta_t
Time (in s)

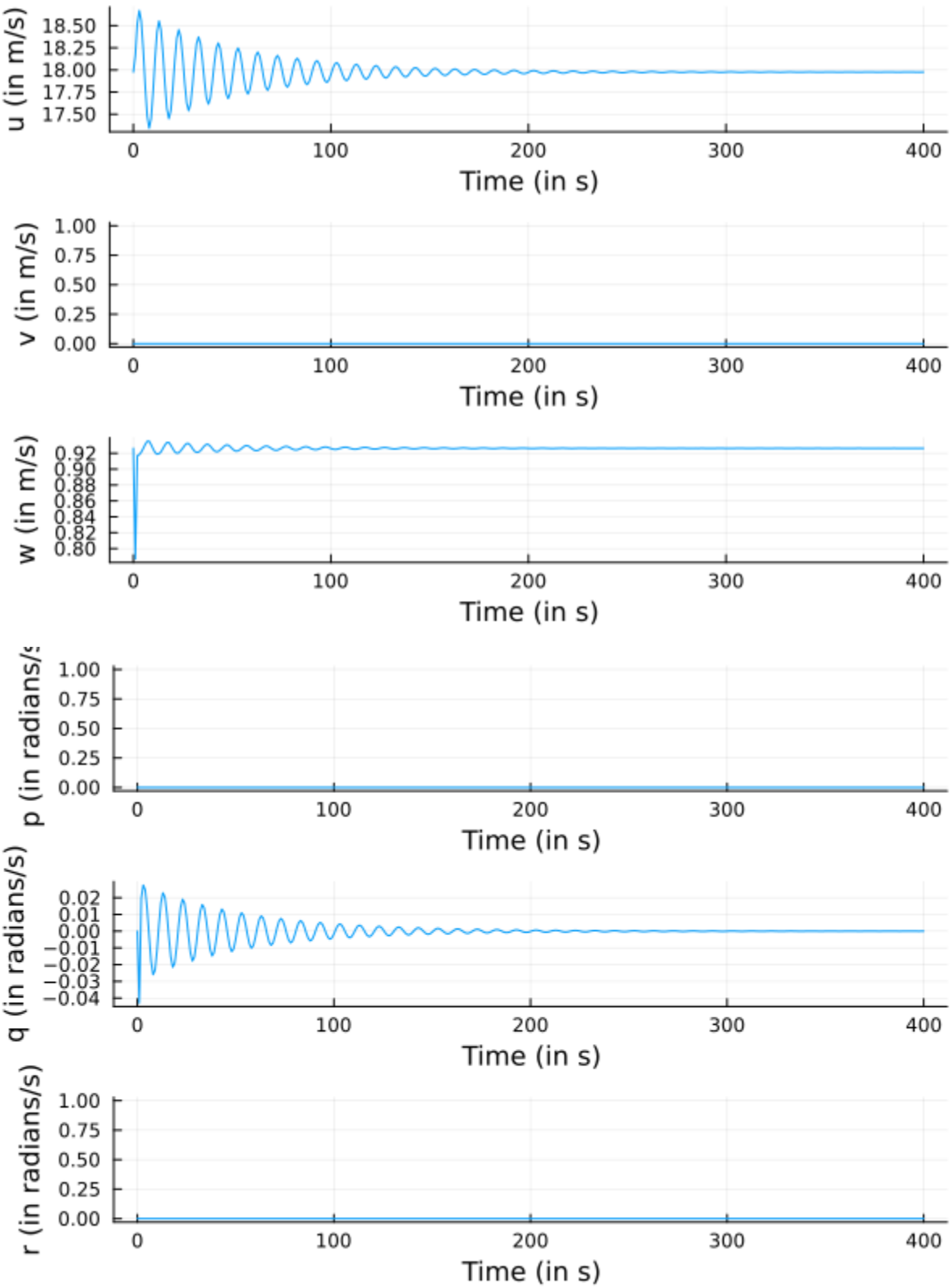


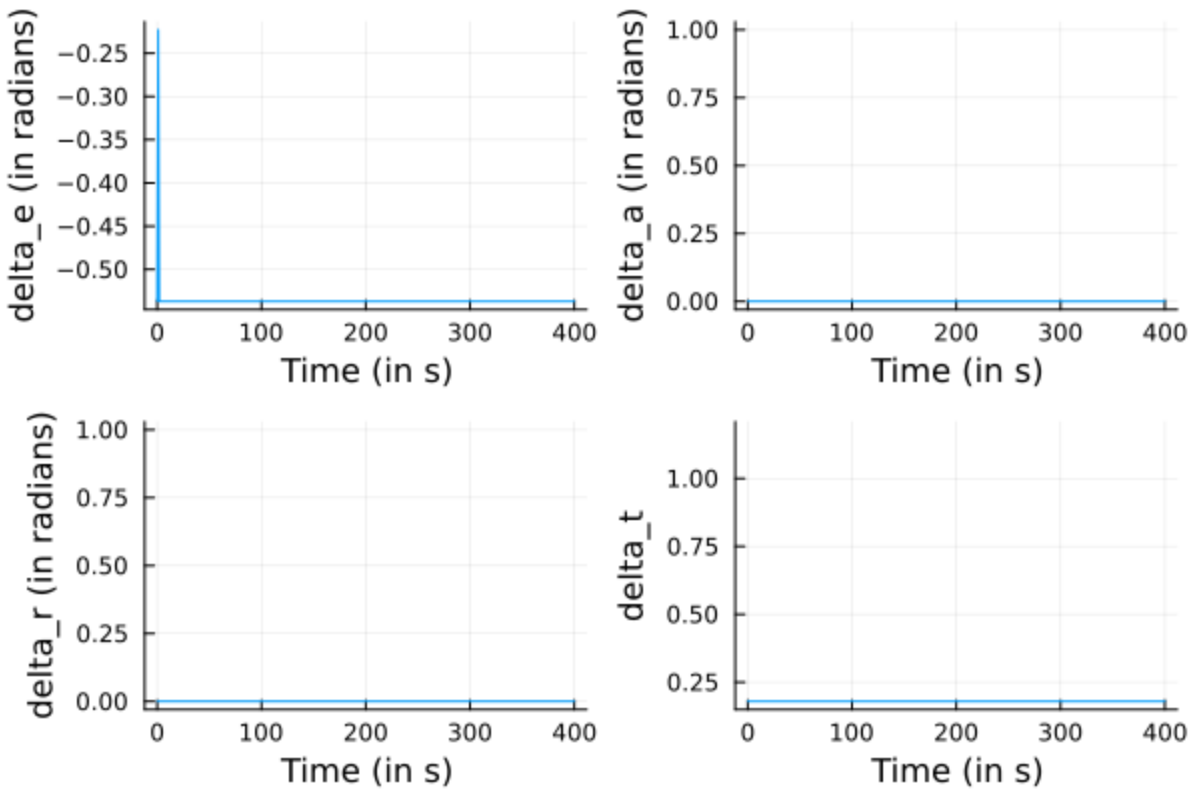
Applying an impulse to the elevator when in trim excites the short-period mode and phugoid mode, which can be seen from the aircraft's trajectory, and the plot of pitch angle with respect to time.

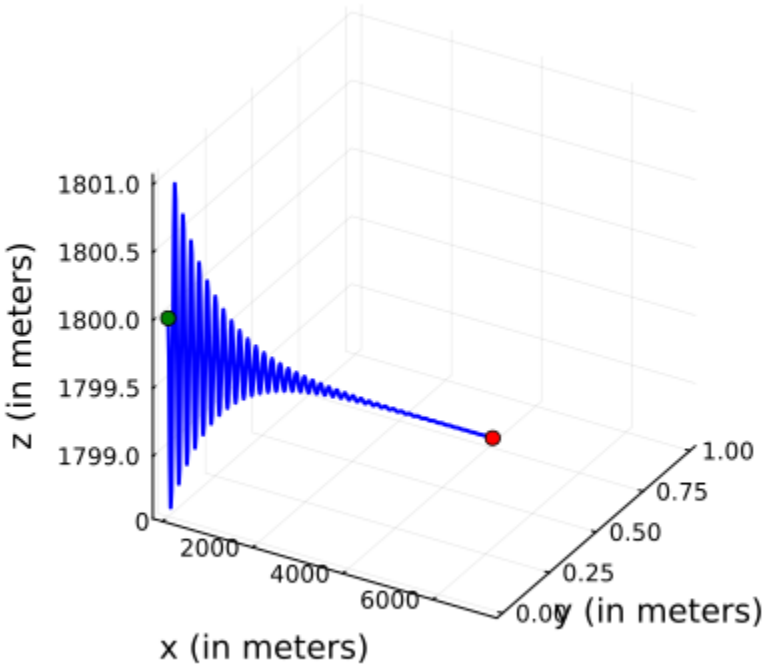
Since both the modes are stable modes, the disturbances soon go to zero after a sufficient amount of time, as can be seen from the plots below.

Now, plots are generated for 400 seconds to show the long-period behavior.



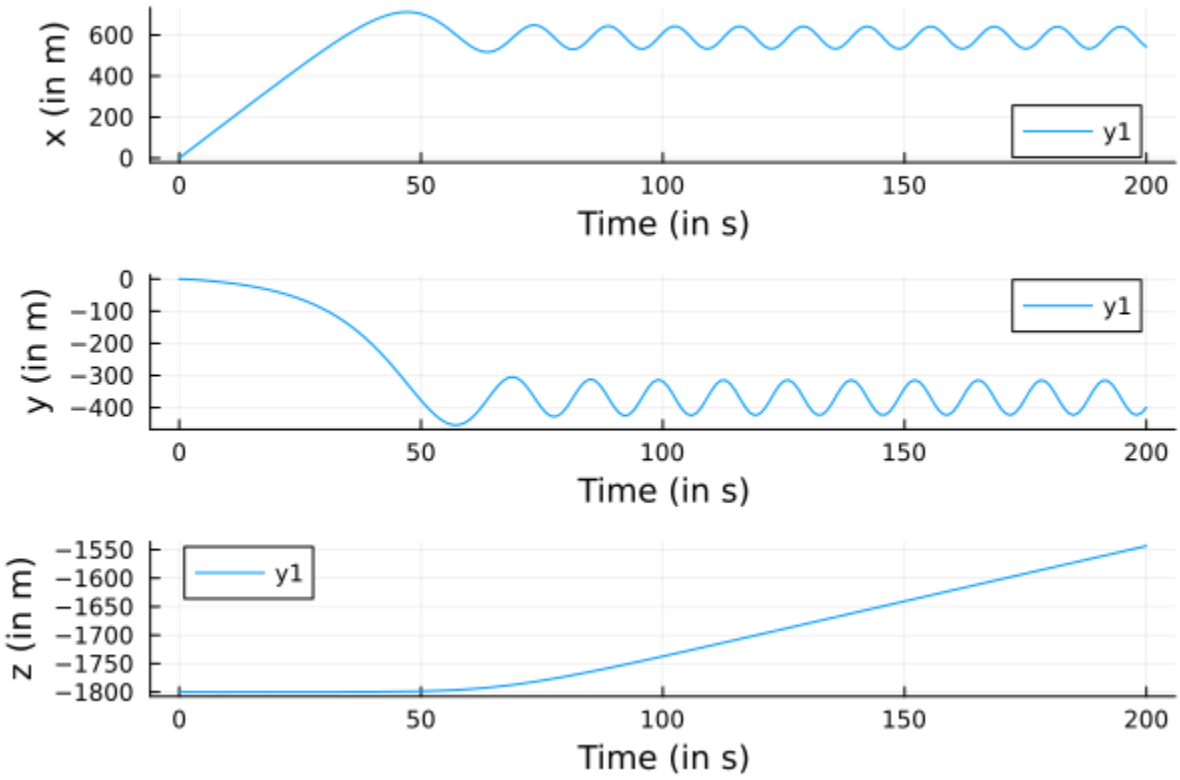

u (in m/s)
18.50
18.25
18.00
17.75
17.50
0
100
200
300
400
Time (in s)
v (in m/s)
1.00
0.75
0.50
0.25
0.00
0
100
200
300
400
Time (in s)
w (in m/s)
0.92
0.90
0.88
0.86
0.84
0.82
0.80
0
100
200
300
400
Time (in s)
p (in radians/s
1.00
0.75
0.50
0.25
0.00
0
100
200
300
400
Time (in s)
q (in radians/s)
0.02
0.01
0.00
−0.01
−0.02
−0.03
−0.04
0
100
200
300
400
Time (in s)
r (in radians/s)
1.00
0.75
0.50
0.25
0.00
0
100
200
300
400
Time (in s)

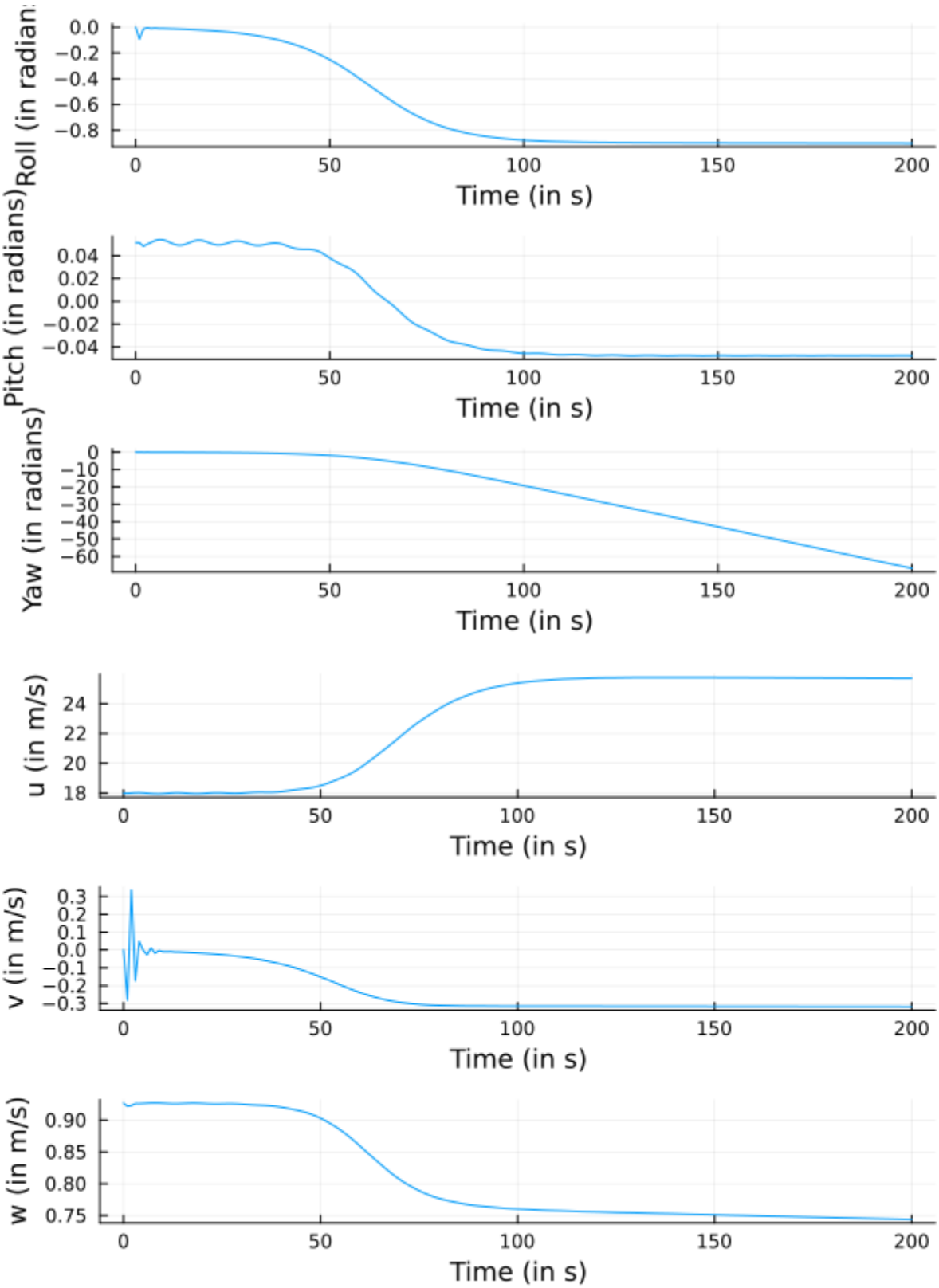

delta_e (in radians)
−0.25
−0.30
−0.35
−0.40
−0.45
−0.50
0
100
200
300
400
Time (in s)
delta_a (in radians)
1.00
0.75
0.50
0.25
0.00
Time (in s)
delta_r (in radians)
Time (in s)
delta_t
Time (in s)

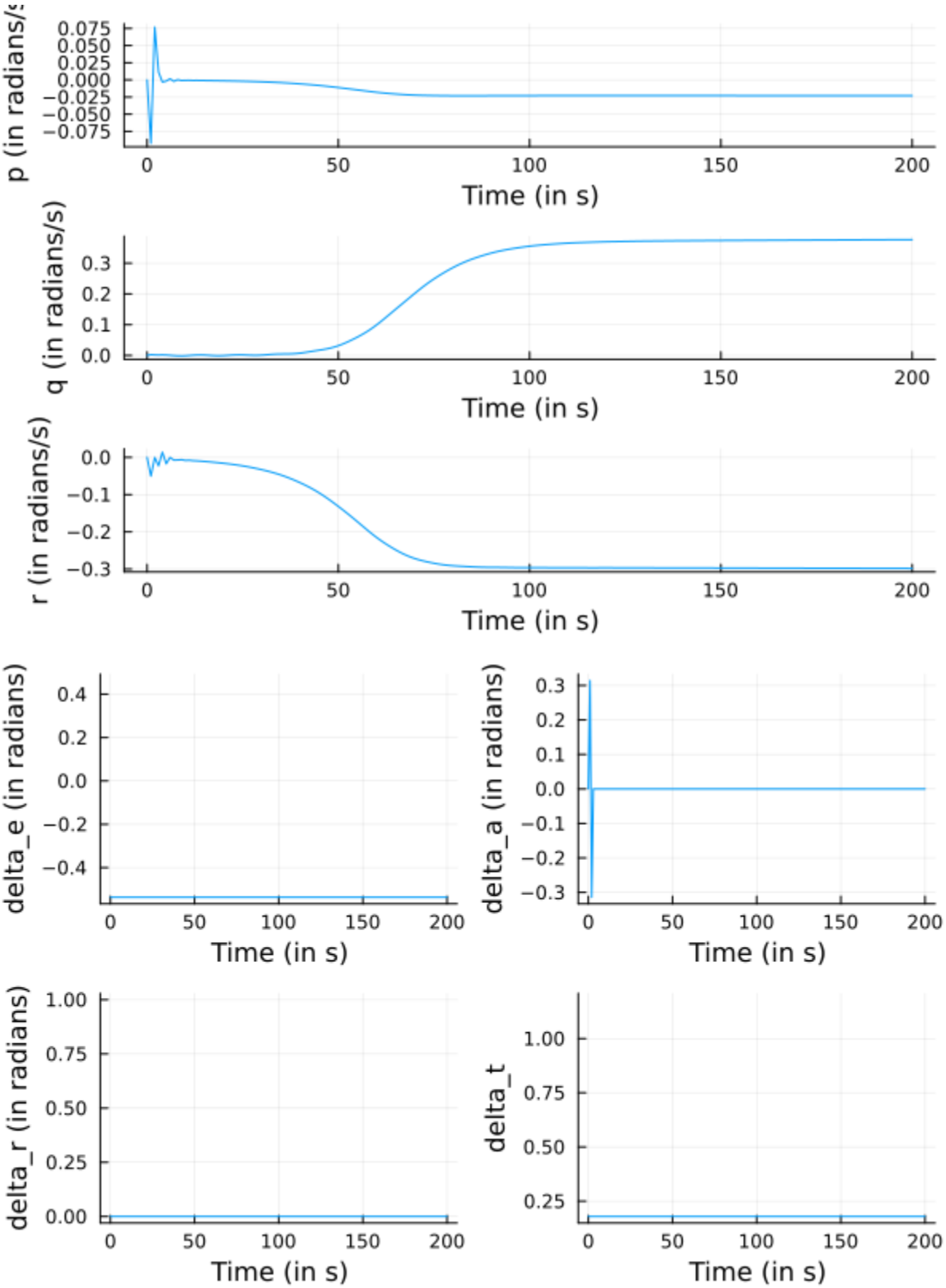

z (in meters)
1801.0
1800.5
1800.0
1799.5
1799.0
0
2000
4000
6000
x (in meters)
1.00
0.75
0.50
0.25
0.00
y (in meters)

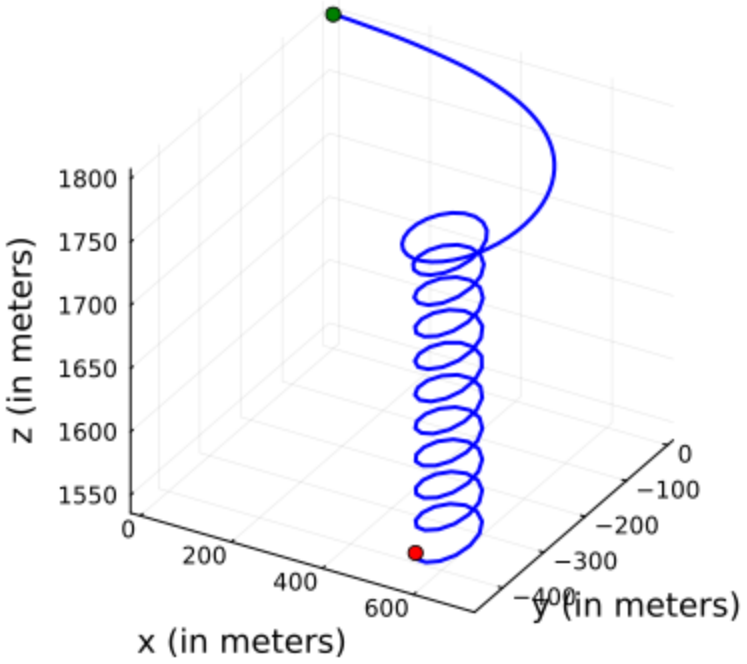
Problem 2: Part 2)

Plots are generated for 400 seconds to show the long-period behavior.




Roll (in radian
0.0
−0.2
−0.4
−0.6
−0.8
0
50
100
150
200
Time (in s)
Pitch (in radians)
0.04
0.02
0.00
−0.02
−0.04
0
50
100
150
200
Time (in s)
Yaw (in radians)
0
−10
−20
−30
−40
−50
−60
0
50
100
150
200
Time (in s)
u (in m/s)
24
22
20
18
0
50
100
150
200
Time (in s)
v (in m/s)
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
0
50
100
150
200
Time (in s)
w (in m/s)
0.90
0.85
0.80
0.75
0
50
100
150
200
Time (in s)

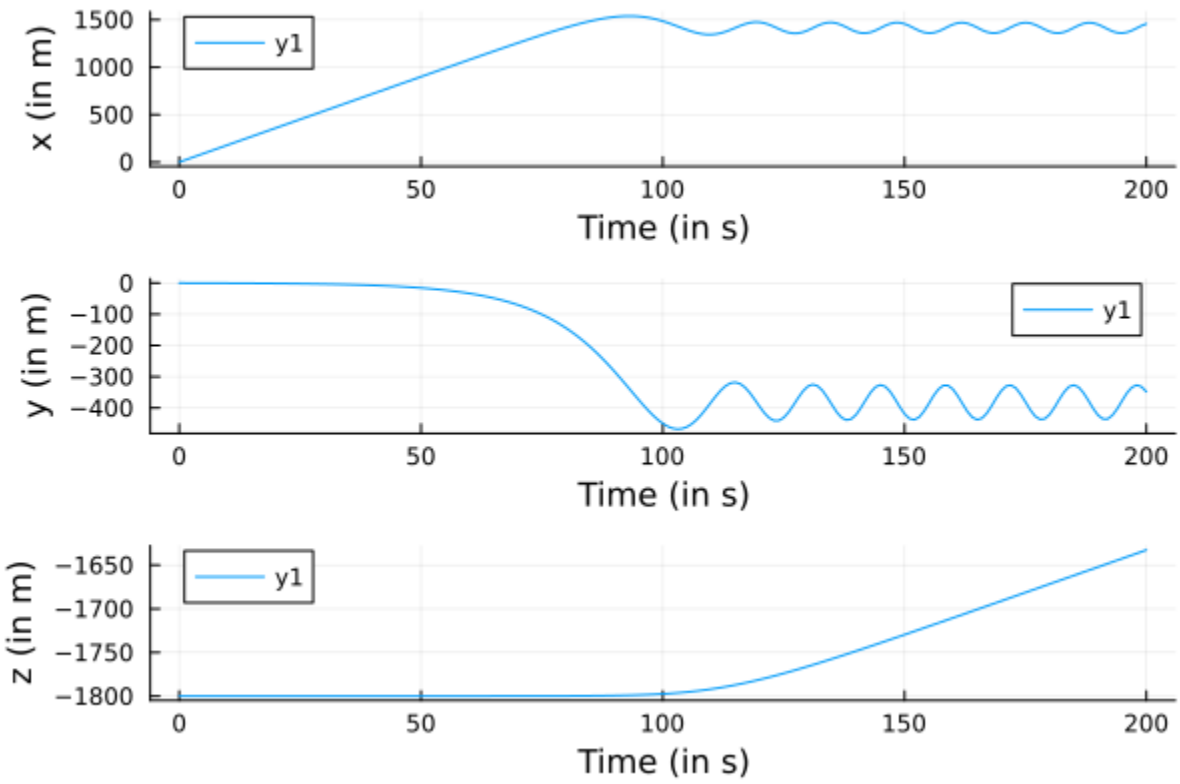

p (in radians/s
0.075
0.050
0.025
0.000
−0.025
−0.050
−0.075
0
50
100
150
200
Time (in s)
q (in radians/s)
0.3
0.2
0.1
0.0
0
50
100
150
200
Time (in s)
r (in radians/s)
0.0
−0.1
−0.2
−0.3
0
50
100
150
200
Time (in s)
delta_e (in radians)
0.4
0.2
0.0
−0.2
−0.4
0
50
100
150
200
Time (in s)
delta_a (in radians)
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
0
50
100
150
200
Time (in s)
delta_r (in radians)
1.00
0.75
0.50
0.25
0.00
0
50
100
150
200
Time (in s)
delta_t
1.00
0.75
0.50
0.25
0
50
100
150
200
Time (in s)

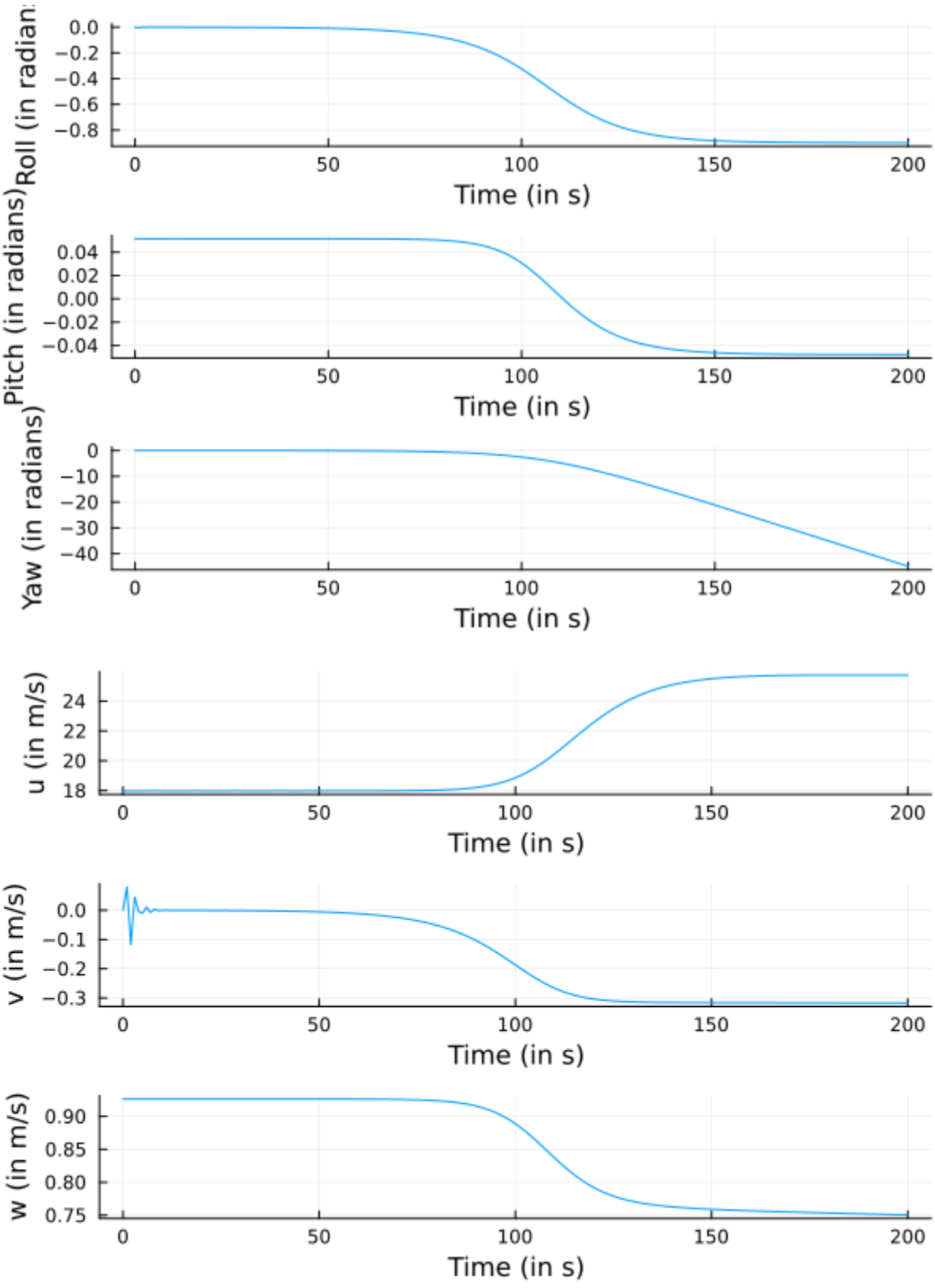


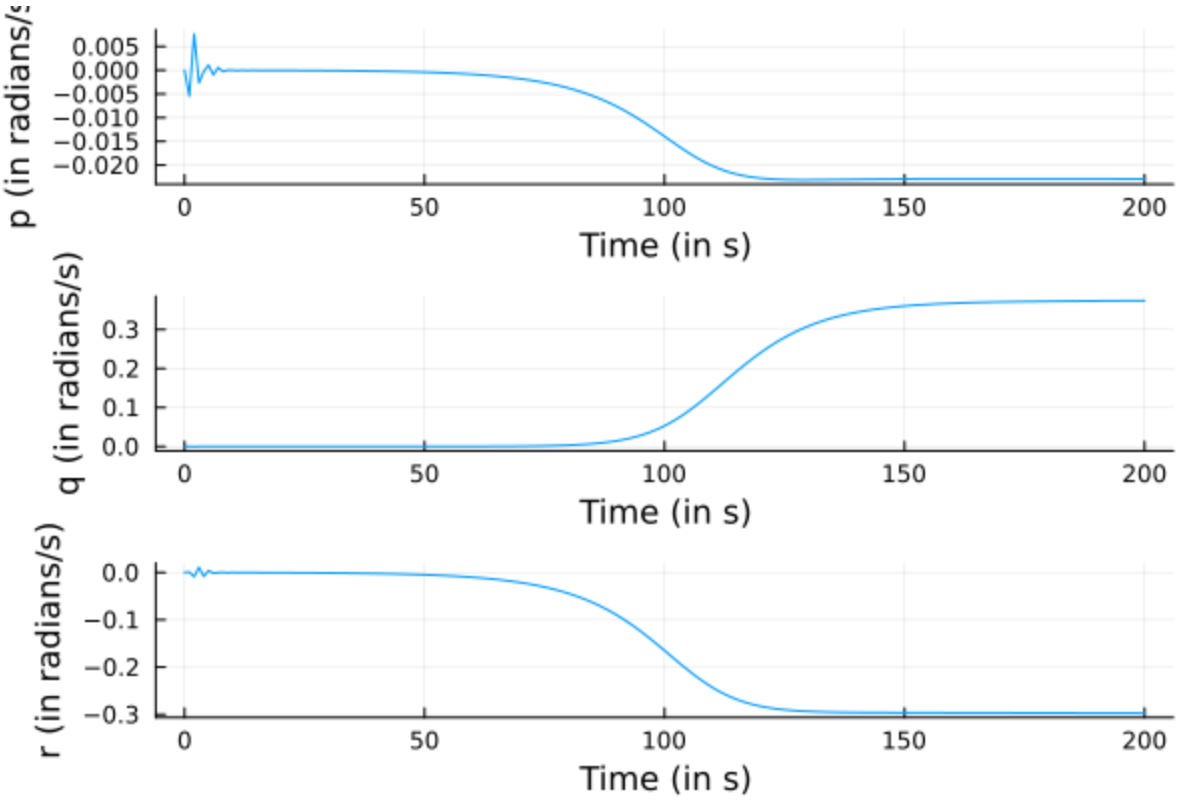
Applying a doublet to the rudder excited the lateral modes, dutch roll mode, and spiral mode. This is in accordance with the behavior observed in Problem 1. The eigenvalue corresponding to the spiral mode has a positive real part, so the system becomes unstable. The eigenvalues corresponding to the dutch roll have damping oscillations, and so the oscillations die out after some time.

Problem 2: Part 3)

Plots are generated for 400 seconds to show the long-period behavior.

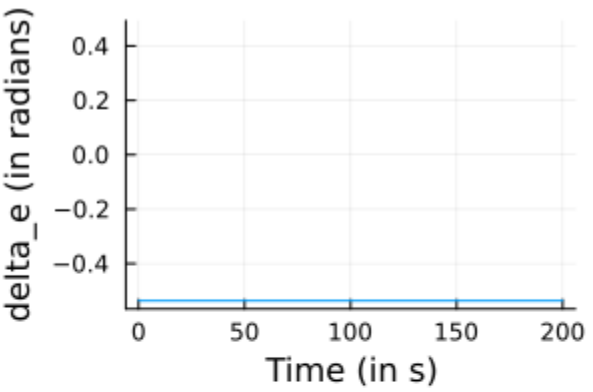


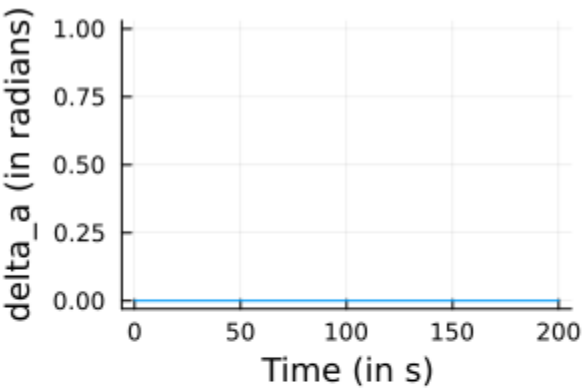

Roll (in radian
0.0
−0.2
−0.4
−0.6
−0.8
0
50
100
150
200
Time (in s)
Pitch (in radians)
0.04
0.02
0.00
−0.02
−0.04
0
50
100
150
200
Time (in s)
Yaw (in radians)
0
−10
−20
−30
−40
0
50
100
150
200
Time (in s)
u (in m/s)
24
22
20
18
0
50
100
150
200
Time (in s)
v (in m/s)
0.0
−0.1
−0.2
−0.3
0
50
100
150
200
Time (in s)
w (in m/s)
0.90
0.85
0.80
0.75
0
50
100
150
200
Time (in s)

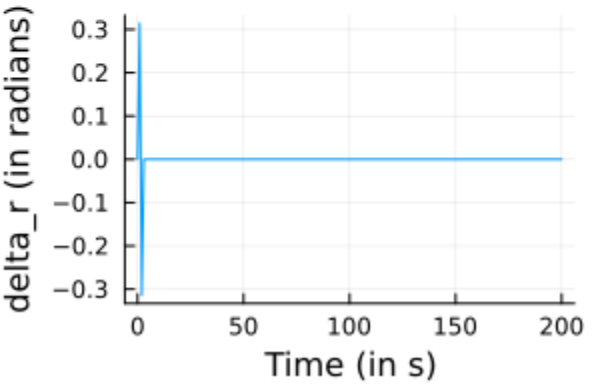

p (in radians/s
0.005
0.000
−0.005
−0.010
−0.015
−0.020
0
50
100
150
200
Time (in s)

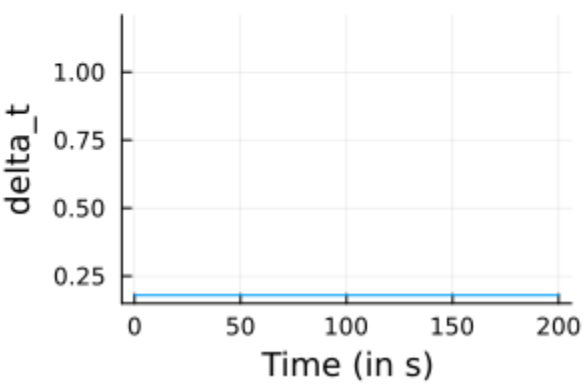
q (in radians/s)
0.3
0.2
0.1
0.0
0
50
100
150
200
Time (in s)

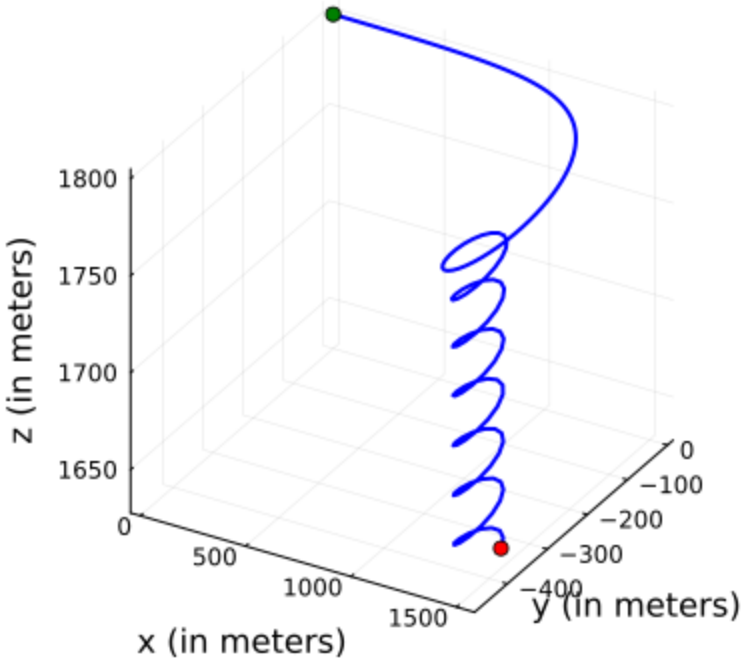
r (in radians/s)
0.0
−0.1
−0.2
−0.3
0
50
100
150
200
Time (in s)


delta_e (in radians)
0.4
0.2
0.0
−0.2
−0.4
0
50
100
150
200
Time (in s)


delta_a (in radians)
1.00
0.75
0.50
0.25
0.00
0
50
100
150
200
Time (in s)


delta_r (in radians)
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
0
50
100
150
200
Time (in s)


delta_t
1.00
0.75
0.50
0.25
0
50
100
150
200
Time (in s)



Applying a doublet to the rudder excited the lateral modes, dutch roll mode, and spiral mode. This is in accordance with the behavior observed in Problem 1. The eigenvalue corresponding to the spiral mode has a positive real part, so the system becomes unstable. The eigenvalues corresponding to the dutch roll have damping oscillations, and so the oscillations die out after some time.