```julia
#Problem 1

function GetLateralEOMCoefficients(Γ::Array{Float64},ap::AircraftParameters)
    #For roll rate p
    Cp0 = Γ[3]*ap.Cl0 + Γ[4]*ap.Cn0
    Cpβ = Γ[3]*ap.Clbeta + Γ[4]*ap.Cnbeta
    Cpp = Γ[3]*ap.Clp + Γ[4]*ap.Cnp
    Cpr = Γ[3]*ap.Clr + Γ[4]*ap.Cnr
    Cpδa = Γ[3]*ap.Clda + Γ[4]*ap.Cnda
    Cpδr = Γ[3]*ap.Cldr + Γ[4]*ap.Cndr

    #For yaw rate r
    Cr0 = Γ[4]*ap.Cl0 + Γ[8]*ap.Cn0
    Crβ = Γ[4]*ap.Clbeta + Γ[8]*ap.Cnbeta
    Crp = Γ[4]*ap.Clp + Γ[8]*ap.Cnp
    Crr = Γ[4]*ap.Clr + Γ[8]*ap.Cnr
    Crδa = Γ[4]*ap.Clda + Γ[8]*ap.Cnda
    Crδr = Γ[4]*ap.Cldr + Γ[8]*ap.Cndr

    CoefficientsDict = Dict(
                            "Cp0" => Cp0,
                            "Cpβ" => Cpβ,
                            "Cpp" => Cpp,
                            "Cpr" => Cpr,
                            "Cpδa" => Cpδa,
                            "Cpδr" => Cpδr,
                            "Cr0" => Cr0,
                            "Crβ" => Crβ,
                            "Crp" => Crp,
                            "Crr" => Crr,
                            "Crδa" => Crδa,
                            "Crδr" => Crδr
                        )

    return CoefficientsDict
end

function GetLongitudinalEOMCoefficients(tc::AircraftControl, α::Float64,ap::AircraftParameters)

    CLtrim = ap.CL0 + (ap.CLalpha*α) + (ap.CLde*tc.δe)
    CDtrim = ap.CDmin + (ap.K * (CLtrim - ap.CLmin)^2)
    CXtrim = ( CLtrim*sin(α) ) - ( CDtrim*cos(α) )
    CZtrim = ( -CLtrim*cos(α) ) - ( CDtrim*sin(α) )

    δCDδCL = 2*ap.K*(CLtrim-ap.CLmin)
    CDα = ap.CLalpha*δCDδCL
    CDq = ap.CLq*δCDδCL
    CDδe = ap.CLde*δCDδCL

    CXα = -CDα*cos(α) + CDtrim*sin(α) + ap.CLalpha*sin(α) + CLtrim*cos(α)
    CZα = -CDα*sin(α) - CDtrim*cos(α) - ap.CLalpha*cos(α) + CLtrim*sin(α)

    CXq = -CDq*cos(α) + ap.CLq*sin(α)
    CZq = -CDq*sin(α) - ap.CLq*cos(α)

    CXδe = -CDδe*cos(α) + ap.CLde*sin(α)
    CZδe = -CDδe*sin(α) - ap.CLde*cos(α)

    CoefficientsDict = Dict(
                            "CLtrim" => CLtrim,
                            "CDtrim" => CDtrim,
                            "CXtrim" => CXtrim,
                            "CZtrim" => CZtrim,
                            "CXα" => CXα,
                            "CZα" => CZα,
                            "CXq" => CXq,
                            "CZq" => CZq,
                            "CXδe" => CXδe,
                            "CZδe" => CZδe
                        )

    return CoefficientsDict
end

function GetLinearizedModel(::Type{LateralAircraftState},ts::AircraftState,tc::AircraftControl,ap::AircraftParameters)

    ρ = stdatmo(-ts.z)
    S = ap.S
    b = ap.b
    m = ap.m
    AirSpeedVector = [ts.u, ts.v, ts.w]  #because it has been given that wind speed is zero.
    wind_angles = AirRelativeVelocityVectorToWindAngles(AirSpeedVector)
    Va = wind_angles.Va
    β = wind_angles.β
    af_term = Va*cos(β)
    Q = 0.25*ρ*Va*S*b/m
    Γ = GetGammaValues(ap)
    lc = GetLateralEOMCoefficients(Γ,ap)

    A11 = 0.25*ρ*S*b*ts.v*( (ap.CYp*ts.p) + (ap.CYr*ts.r) )/(m*Va)
    A11 += ρ*S*ts.v*(ap.CY0 + ap.CYbeta*β + ap.CYda*tc.δa + ap.CYdr*tc.δr)/(m)
    A11 += 0.5*ρ*S*ap.CYbeta*sqrt(ts.u^2 + ts.w^2)/m
    A12 = ts.w + Q*ap.CYp
    A12 = A12/af_term
    A13 = -ts.u + Q*ap.CYr
    A13 = A13/af_term
    A14 = ap.g*cos(ts.θ)*cos(ts.ϕ)
```

```julia
    A14 = A14/af_term
    A15 = 0.0

    A21 = 0.25*ρ*S*b*b*ts.v*( (lc["Cpp"]*ts.p) + (lc["Cpr"]*ts.r) )/(Va)
    A21 += ρ*S*b*ts.v*(lc["Cp0"] + lc["Cpβ"]*β + lc["Cpδa"]*tc.δa + lc["Cpδr"]*tc.δr)
    A21 += 0.5*ρ*S*b*lc["Cpβ"]*sqrt(ts.u^2 + ts.w^2)
    A21 = A21*af_term
    A22 = (Γ[1]*ts.q) + (Q*b*m*lc["Cpp"])
    A23 = (-Γ[2]*ts.q) + (Q*b*m*lc["Cpr"])
    A24 = 0.0
    A25 = 0.0

    A31 = 0.25*ρ*S*b*b*ts.v*( (lc["Crp"]*ts.p) + (lc["Crr"]*ts.r) )/(Va)
    A31 += ρ*S*b*ts.v*(lc["Cr0"] + lc["Crβ"]*β + lc["Crδa"]*tc.δa + lc["Crδr"]*tc.δr)
    A31 += 0.5*ρ*S*b*lc["Crβ"]*sqrt(ts.u^2 + ts.w^2)
    A31 = A31*af_term
    A32 = (Γ[7]*ts.q) + (Q*b*m*lc["Crp"])
    A33 = (-Γ[1]*ts.q) + (Q*b*m*lc["Crr"])
    A34 = 0.0
    A35 = 0.0

    A41 = 0.0
    A42 = 1.0
    A43 = cos(ts.ϕ)*tan(ts.θ)
    A44 = (ts.q*cos(ts.ϕ)*tan(ts.θ)) - (ts.r*sin(ts.ϕ)*tan(ts.θ))
    A45 = 0.0

    A51 = 0.0
    A52 = 0.0
    A53 = cos(ts.ϕ)*sec(ts.θ)
    A54 = (ts.p*cos(ts.ϕ)*sec(ts.θ)) - (ts.r*sin(ts.ϕ)*sec(ts.θ))
    A55 = 0.0

    A = [A11 A12 A13 A14 A15
        A21 A22 A23 A24 A25
        A31 A32 A33 A34 A35
        A41 A42 A43 A44 A45
        A51 A52 A53 A54 A55
        ]

    B11 = (1/b)*2*Va*Q*ap.CYda
    B11 = B11/af_term
    B12 = (1/b)*2*Va*Q*ap.CYdr
    B12 = B12/af_term

    B21 = 2*Va*m*Q*lc["Cpδa"]
    B22 = 2*Va*m*Q*lc["Cpδr"]

    B31 = 2*Va*m*Q*lc["Crδa"]
    B32 = 2*Va*m*Q*lc["Crδr"]

    B41 = 0.0
    B42 = 0.0

    B51 = 0.0
    B52 = 0.0

    B = [B11 B12
        B21 B22
        B31 B32
        B41 B42
        B51 B52
        ]

    return A,B
end

function GetLinearizedModel(::Type{LongitudinalAircraftState},ts::AircraftState,tc::AircraftControl,ap::AircraftParameters)

    ρ = stdatmo(-ts.z)
    S = ap.S
    c = ap.c
    m = ap.m
    km = ap.kmotor
    AirSpeedVector = [ts.u, ts.v, ts.w]  #because it has been given that wind speed is zero.
    wind_angles = AirRelativeVelocityVectorToWindAngles(AirSpeedVector)
    Va = wind_angles.Va
    α = wind_angles.α
    af_term = Va*cos(α)
    lc = GetLongitudinalEOMCoefficients(tc,α,ap)

    A11 = ts.u*ρ*S*lc["CXtrim"]/m
    A11 -= 0.5*ρ*S*ts.w*lc["CXα"]/m
    A11 += 0.25*ρ*S*c*lc["CXq"]*ts.u*ts.q/(m*Va)
    A11 += ρ*ap.Sprop*ap.Cprop*tc.δt*( km*ts.u*(1-2*tc.δt)/Va + 2*ts.u*(tc.δt-1) )/m
    A12 = -ts.q + ts.w*ρ*S*lc["CXtrim"]/m
    A12 += 0.25*ρ*S*c*lc["CXq"]*ts.w*ts.q/(m*Va)
    A12 += 0.5*ρ*S*ts.u*lc["CXα"]/m
    A12 += ρ*ap.Sprop*ap.Cprop*tc.δt*( km*ts.w*(1-2*tc.δt)/Va + 2*ts.w*(tc.δt-1) )/m
    A12 = A12*af_term
    A13 = -ts.w + (0.25*ρ*Va*S*lc["CXq"]*c)/m
    A14 = -ap.g*cos(ts.θ)
    A15 = 0.0

    A21 = ts.q + ts.u*ρ*S*lc["CZtrim"]/m
    A21 -= 0.5*ρ*S*lc["CZα"]*ts.w/m
    A21 += 0.25*ts.u*ρ*S*lc["CZq"]*c*ts.q/(m*Va)
```

```
    A21 = A21/af_term
    A22 = ts.w*ρ*S*lc["CZtrim"]/m
    A22 += 0.5*ρ*S*lc["CZα"]*ts.u/m
    A22 += 0.25*ts.w*ρ*S*lc["CZq"]*c*ts.q/(m*Va)
    A23 = ts.u + (0.25*ρ*Va*S*lc["CZq"]*c)/m
    A23 = A23/af_term
    A24 = -ap.g*sin(ts.θ)
    A24 = A24/af_term
    A25 = 0.0

    A31 = ts.u*ρ*S*c*(ap.Cm0 + ap.Cmalpha*α + ap.Cmde*tc.δe)
    A31 -=  0.5*ρ*S*c*ap.Cmalpha*ts.w/ap.Iy
    A31 += 0.25*ρ*S*c*c*ap.Cmq*ts.q*ts.u/(ap.Iy*Va)
    A32 = ts.w*ρ*S*c*(ap.Cm0 + ap.Cmalpha*α + ap.Cmde*tc.δe)
    A32 += 0.5*ρ*S*c*ap.Cmalpha*ts.u/ap.Iy
    A32 += 0.25*ρ*S*c*c*ap.Cmq*ts.q*ts.w/(ap.Iy*Va)
    A32 = A32*af_term
    A33 = (0.25*ρ*Va*S*c*c*ap.Cmq)/ap.Iy
    A34 = 0.0
    A35 = 0.0

    A41 = 0.0
    A42 = 0.0
    A43 = 1.0
    A44 = 0.0
    A45 = 0.0

    A51 = sin(ts.θ)
    A52 = -cos(ts.θ)
    A52 = A52*af_term
    A53 = 0.0
    A54 = (ts.u*cos(ts.θ)) + (ts.w*sin(ts.θ))
    A55 = 0.0

    A = [A11 A12 A13 A14 A15
        A21 A22 A23 A24 A25
        A31 A32 A33 A34 A35
        A41 A42 A43 A44 A45
        A51 A52 A53 A54 A55
        ]

    B11 = 0.5*ρ*Va*Va*S*lc["CXδe"]/m
    B12 = ρ*ap.Sprop*ap.Cprop*( Va*(km-Va) + 2*tc.δt*(km-Va)*(km-Va) )/m

    B21 = 0.5*ρ*Va*Va*S*lc["CZδe"]/m
    B21 = B21/af_term
    B22 = 0.0

    B31 = 0.5*ρ*Va*Va*S*c*ap.Cmde/ap.Iy
    B32 = 0.0

    B41 = 0.0
    B42 = 0.0

    B51 = 0.0
    B52 = 0.0

    B = [B11 B12
        B21 B22
        B31 B32
        B41 B42
        B51 B52
        ]

    return A,B
end


trim_definition = TrimDefinitionSL(18.0,0.0,1800.0)
state, control, results = GetTrimConditions(trim_definition, aircraft_parameters)
wind_inertial = [0.0,0.0,0.0]
Alat,Blat = GetLinearizedModel(LateralAircraftState,state,control,aircraft_parameters)
# Alat,Blat = @enter GetLinearizedModel(LateralAircraftState,state,control,aircraft_parameters)
Along,Blong = GetLinearizedModel(LongitudinalAircraftState,state,control,aircraft_parameters)
# Alat,Blat = @enter GetLinearizedModel(LateralAircraftState,state,control,aircraft_parameters)

println("A_lat")
display(Alat)
println("B_lat")
display(Blat)
println("A_long")
display(Along)
println("B_long")
display(Blong)


#=
Problem 1 - Part 2)
=#

reduced_Along = Along[1:4,1:4]
long_eigenvals, long_eigenvectors = eigen(reduced_Along)

reduced_Alat = Alat[1:4,1:4]
lat_eigenvals, lat_eigenvectors = eigen(reduced_Alat)

#Short Period Mode
```

```julia
short_natural_frequency = get_natural_frequency(long_eigenvals[1])
short_damping_ratio = get_damping_ratio(long_eigenvals[1])
#Phugoid Mode
phugoid_natural_frequency = get_natural_frequency(long_eigenvals[3])
phugoid_damping_ratio = get_damping_ratio(long_eigenvals[3])
#Roll Mode
roll_natural_frequency = get_natural_frequency(lat_eigenvals[1])
roll_damping_ratio = get_damping_ratio(lat_eigenvals[1])
#Dutch Roll Mode
dutch_roll_natural_frequency = get_natural_frequency(lat_eigenvals[2])
dutch_roll_damping_ratio = get_damping_ratio(lat_eigenvals[2])
#Spiral Mode
spiral_natural_frequency = get_natural_frequency(lat_eigenvals[4])
spiral_damping_ratio = get_damping_ratio(lat_eigenvals[4])


println("")
println("For Short Period Mode : ")
println("Damping Ratio : ", short_damping_ratio)
println("Natural Frequency : ", short_natural_frequency)
println("")
println("For Phugoid Mode : ")
println("Damping Ratio : ", phugoid_damping_ratio)
println("Natural Frequency : ", phugoid_natural_frequency)
println("")
println("For Dutch Roll Mode : ")
println("Damping Ratio : ", dutch_roll_damping_ratio)
println("Natural Frequency : ", dutch_roll_natural_frequency)


#=
Problem 1 - Part 2)
=#

println("")
println("For Roll Mode : ")
println("Damping Ratio : ", roll_damping_ratio)
println("Natural Frequency : ", roll_natural_frequency)
println("Time Constant : ", 1/roll_natural_frequency)
println("The roll mode is stable.")
println("")
println("For Spiral Mode : ")
println("Damping Ratio : ", spiral_damping_ratio)
println("Natural Frequency : ", spiral_natural_frequency)
println("Time Constant : ", 1/spiral_natural_frequency)
println("The spiral mode is unstable.")


#Problem 2

function PulseControl(t::Float64,true_control::Union{AircraftControl,Array{Float64,1}},pulse_control::Array{Float64,1},pulse_time::Array{Float64,1})

    if(t==0.0)
        return true_control
    end
    if( length(pulse_time) == 1 )
        if(t<=pulse_time[1])
            control = true_control + pulse_control
        else
            control = true_control
        end
    elseif( length(pulse_time) == 2)
        if(t<=pulse_time[1])
            control = true_control + pulse_control
        elseif(t>pulse_time[1] && t<=pulse_time[2])
            control = true_control - pulse_control
        else
            control = true_control
        end
    end

    return control
end

function AircraftEOMPulsed(t::Float64,aircraft_state::AircraftState,controls::AircraftControl,control_function::Function,
            pulse_control::Array{Float64,1},pulse_time::Array{Float64,1},wind_inertial::Array{Float64,1},aircraft_parameters::AircraftParameters)

    aircraft_surfaces = control_function(t,controls,pulse_control,pulse_time)
    return AircraftEOM(t,aircraft_state,aircraft_surfaces,wind_inertial,aircraft_parameters)
end

function aircraft_dynamics_pulsed!(du,u,p,t)
    aircraft_state = AircraftState(u...)
    control_function = p[1]
    control_inputs = AircraftControl(p[2]...)
    pulse_control = p[3]
    pulse_time = p[4]
    wind_inertial = p[5]
    aircraft_parameters = p[6]
    x_dot = AircraftEOMPulsed(t,aircraft_state,control_inputs,control_function,pulse_control,pulse_time,wind_inertial,aircraft_parameters)
    for i in 1:length(u)
        du[i] = x_dot[i]
    end
end

filename = "ttwistor.mat"
aircraft_parameters = AircraftParameters(filename)
```

```
location = "/HW5/plots"
save_plots = true
case_num = 3


trim_definition = TrimDefinitionSL(18.0,0.0,1800.0)
state, control, results = GetTrimConditions(trim_definition, aircraft_parameters)
initial_state = collect(values(state))
control_input = collect(values(control))
wind_inertial = [0.0,0.0,0.0]

if(case_num == 1)
    pulse_control = [pi/10,0.0,0.0,0.0]
    pulse_time = [1.0]
end

if(case_num == 2)
    pulse_control = [0.0,pi/10,0.0,0.0]
    pulse_time = [1.0,2.0]
end

if(case_num == 3)
    pulse_control = [0.0,0.0,pi/10,0.0]
    pulse_time = [1.0,2.0]
end


time_interval = [0.0,200.0]
extra_parameters = [PulseControl,control_input,pulse_control,pulse_time,wind_inertial,aircraft_parameters]
trajectory_states = simulate(aircraft_dynamics_pulsed!,initial_state,time_interval,extra_parameters,1.0)
time_values = [i for i in 0:length(trajectory_states)-1]
control_array = [AircraftControl(PulseControl(1.0*(i-1),control_input,pulse_control,pulse_time)...) for i in 1:length(trajectory_states)]
PlotSimulation(time_values, trajectory_states, control_array , location, save_plots)
```

Problem 1: Part 1)

A_{lat}

$$\begin{bmatrix} -0.371441 & 0.0458582 & -0.980285 & 0.544278 & 0.0 \\ -20.6405 & -15.7093 & 2.67741 & 0.0 & 0.0 \\ 11.5196 & -1.23555 & -0.566909 & 0.0 & 0.0 \\ 0.0 & 1.0 & 0.0515269 & 0.0 & 0.0 \\ 0.0 & 0.0 & 1.00133 & 0.0 & 0.0 \end{bmatrix}$$

B_{lat}

$$\begin{bmatrix} -0.000762643 & 0.00309103 \\ -5.35799 & 0.0315897 \\ -0.256564 & -0.130882 \\ 0.0 & 0.0 \\ 0.0 & 0.0 \end{bmatrix}$$

A_{long}

$$\begin{bmatrix} -0.0609492 & 11.4379 & -0.910211 & -9.797 & 0.0 \\ -0.0425166 & -6.32127 & 0.940645 & -0.0280821 & 0.0 \\ 0.108966 & -38.0151 & -3.28532 & 0.0 & 0.0 \\ 0.0 & 0.0 & 1.0 & 0.0 & 0.0 \\ 0.0514586 & -17.9523 & 0.0 & 18.0 & 0.0 \end{bmatrix}$$

B_{long}

$$\begin{bmatrix} 0.00185606 & 3.38461 \\ -0.00686655 & 0.0 \\ -1.3996 & 0.0 \\ 0.0 & 0.0 \\ 0.0 & 0.0 \end{bmatrix}$$

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

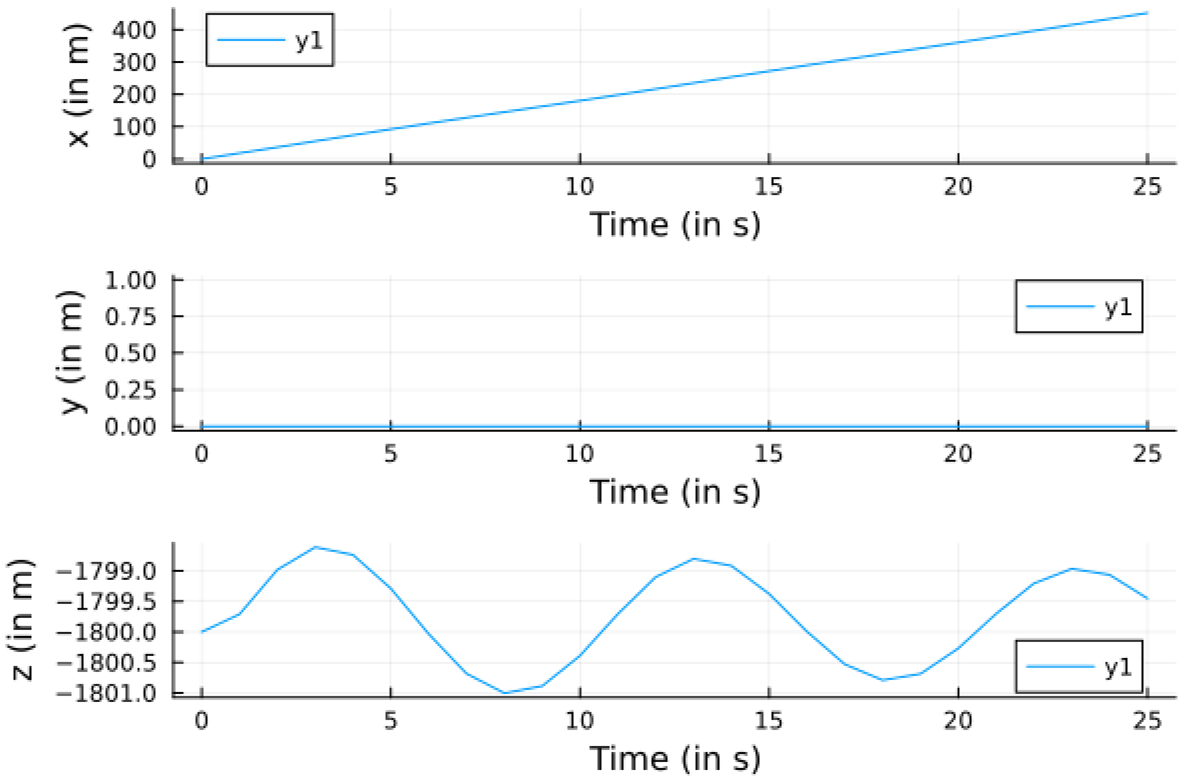
Problem 1: Part 3)

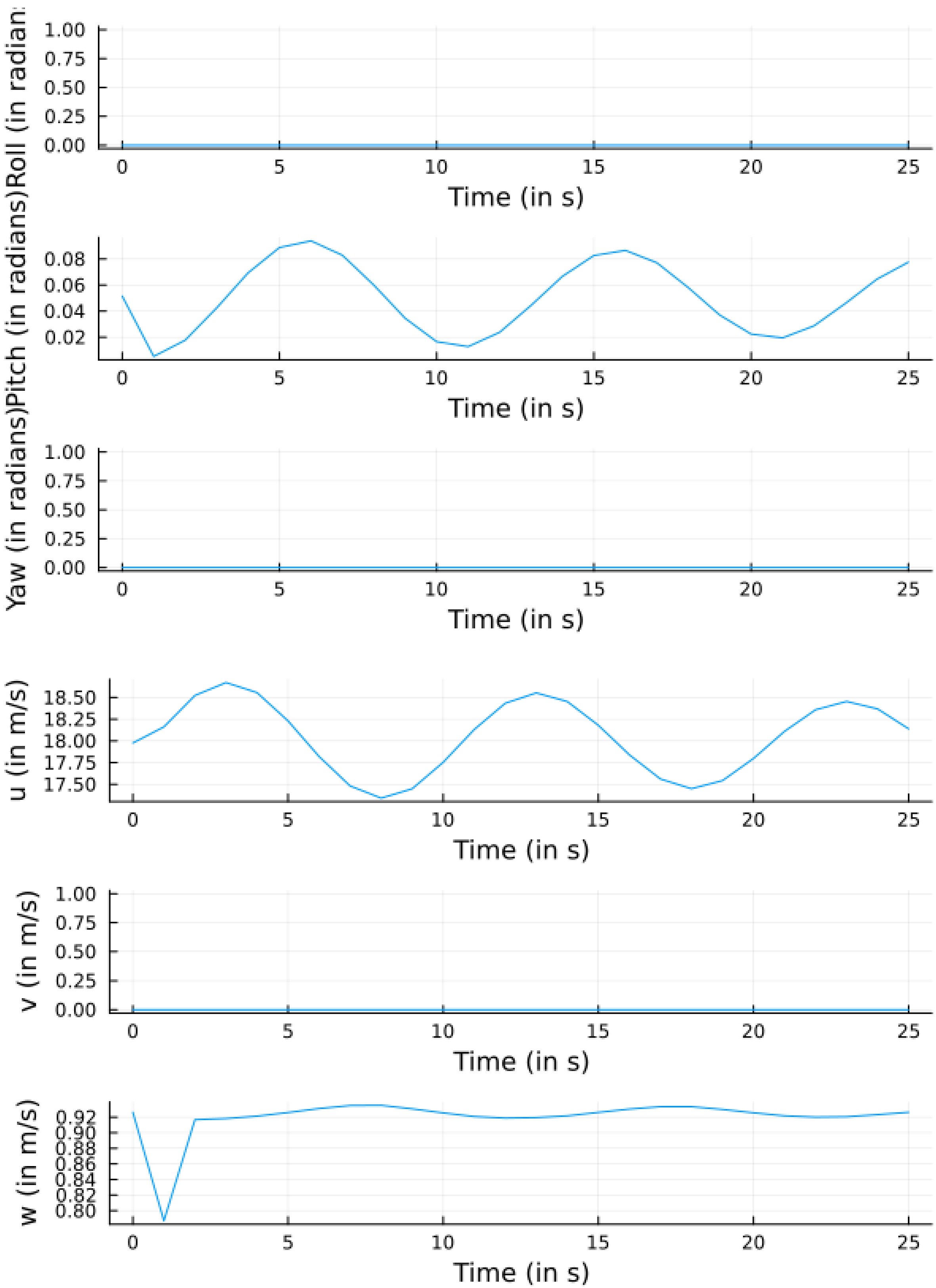
For Roll Mode :
Damping Ratio: 1.0
Natural Frequency: 15.5882856117332
Time Constant: 0.06415073632262079
The roll mode is stable.

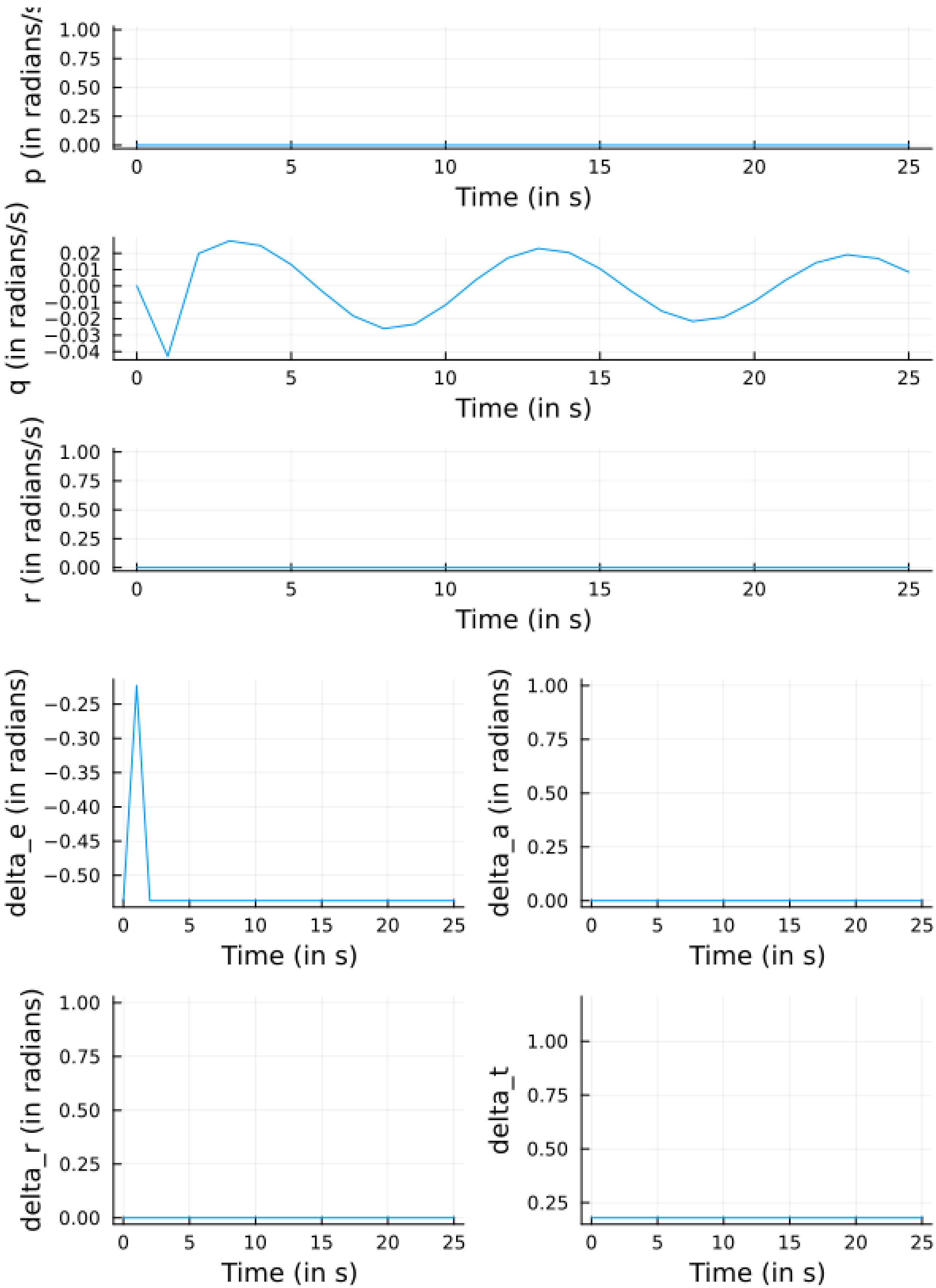
For Spiral Mode :
Damping Ratio: 1.0
Natural Frequency: 0.07390663902876486
Time Constant: 13.530584168640042
The spiral mode is unstable.

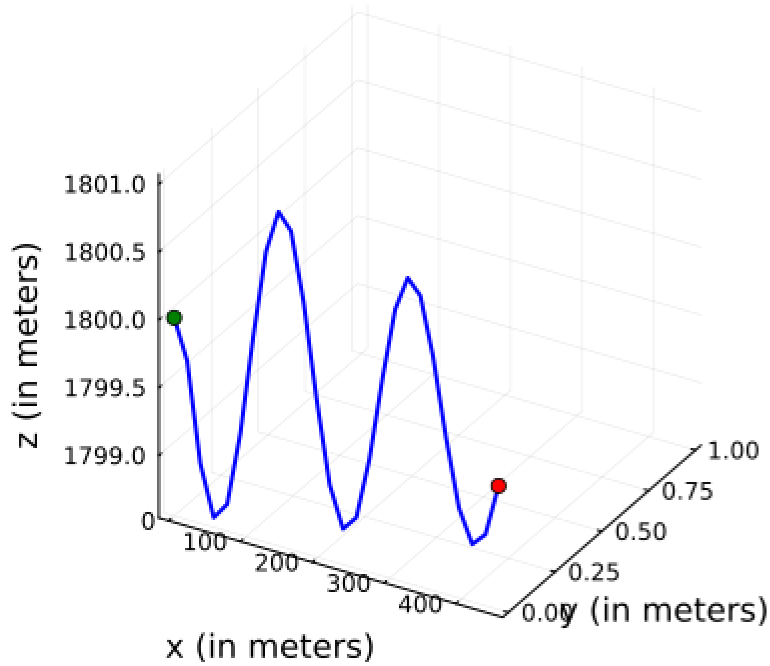
Problem 2: Part 1)

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




Roll (in radians)
1.00
0.75
0.50
0.25
0.00
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)
0
5
10
15
20
25

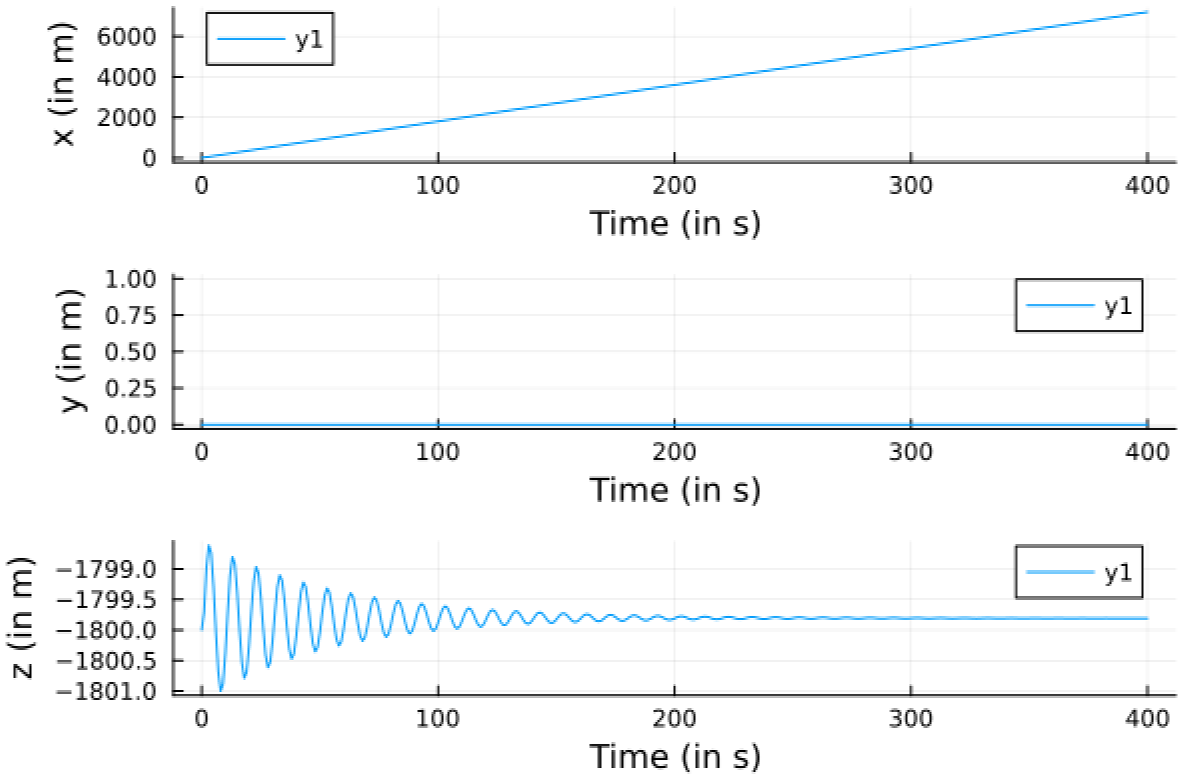

p (in radians/s
Time (in s)
q (in radians/s)
Time (in s)
r (in radians/s)
Time (in s)
delta_e (in radians)
Time (in s)
delta_a (in radians)
Time (in s)
delta_r (in radians)
Time (in s)
delta_t
Time (in s)

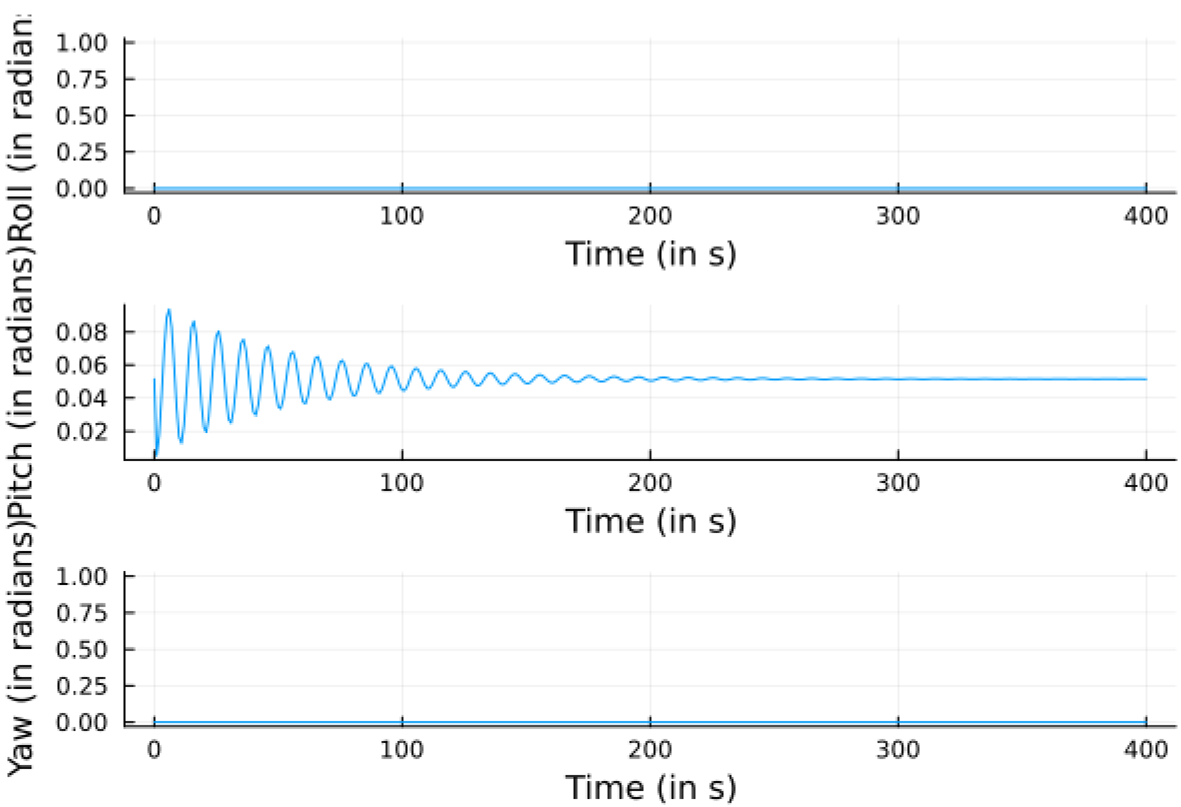


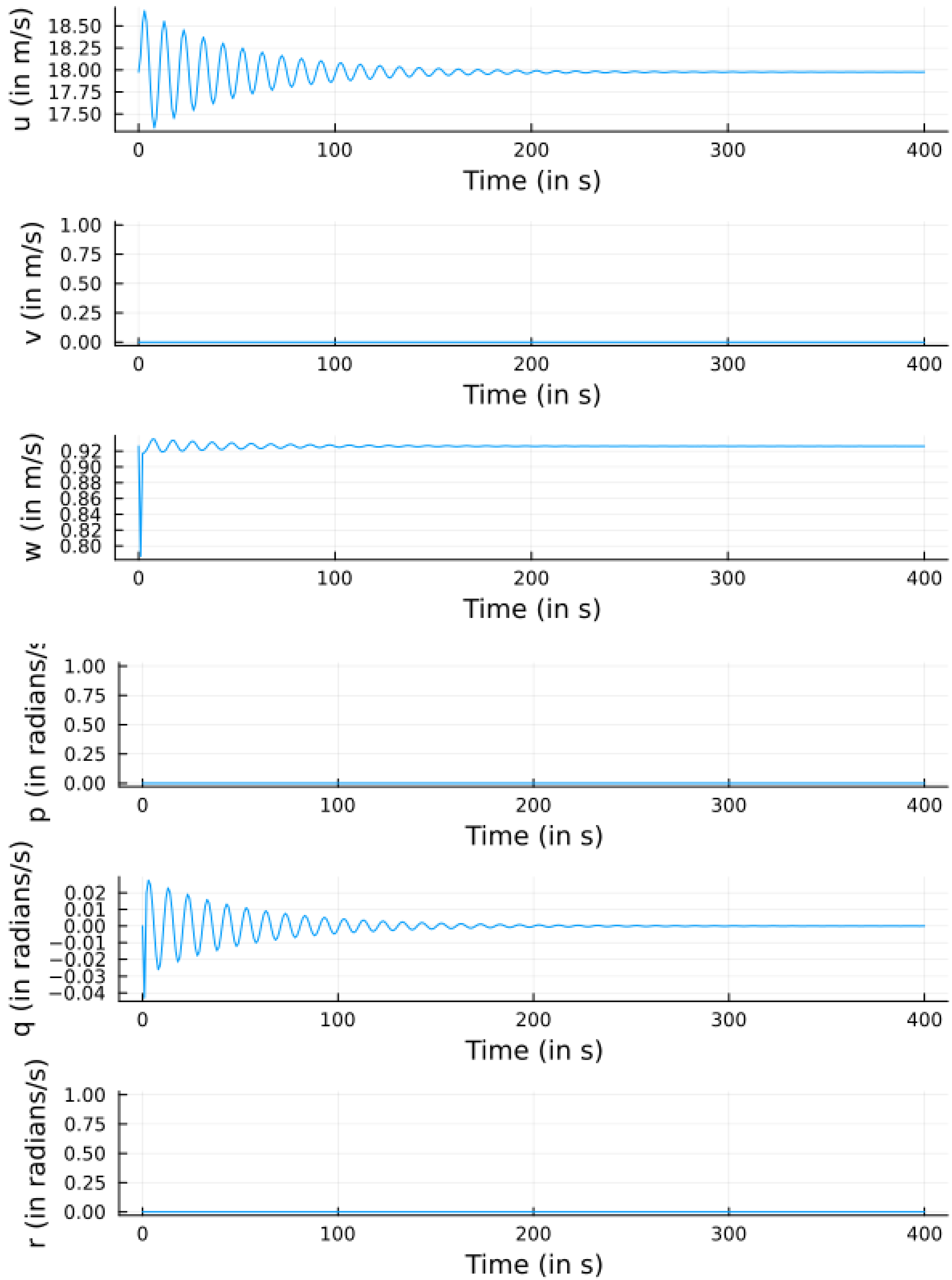
Applying an impulse to the elevator when in trim excites the short-period mode and phugoid mode, which can be seen from the aircraft's trajectory, and the plot of pitch angle with respect to time.

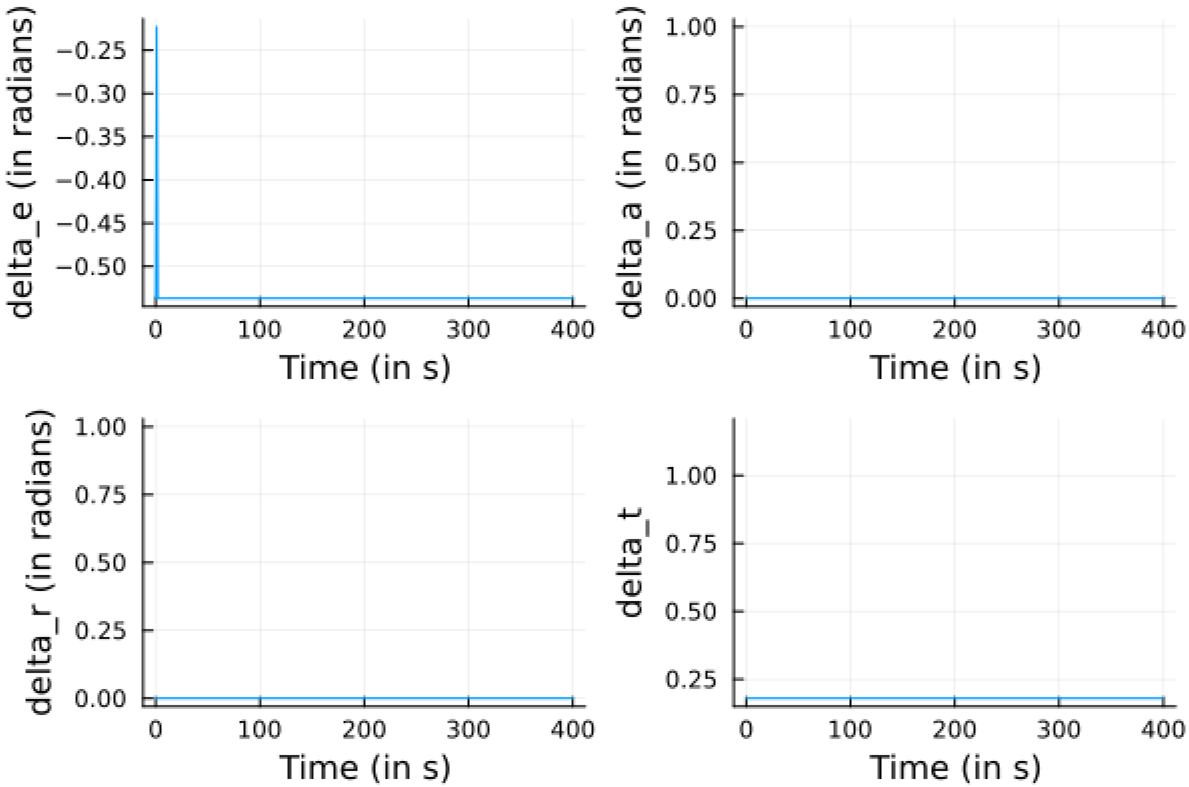
Since both the modes are stable modes, the disturbances soon go to zero after a sufficient amount of time, as can be seen from the plots below.

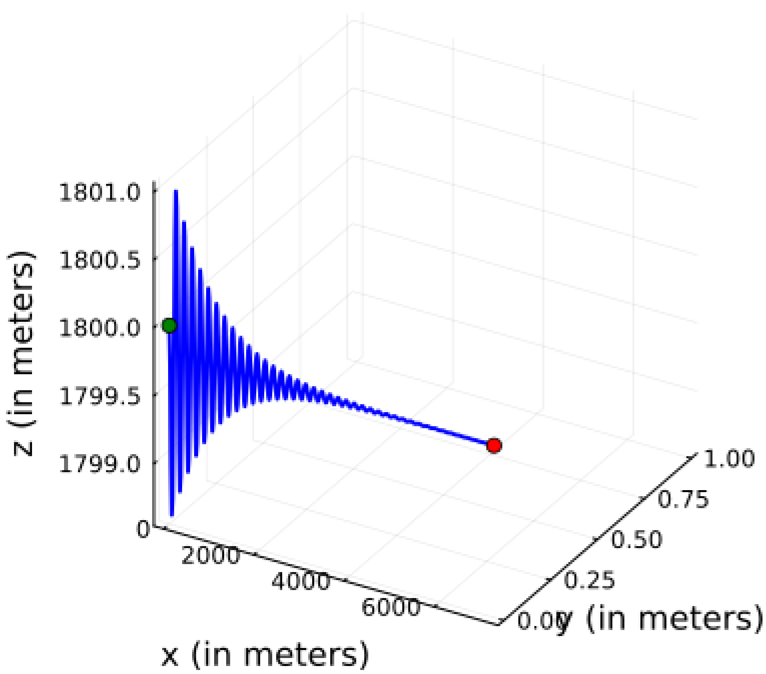
Now, plots are generated for 400 seconds to show the long-period behavior.





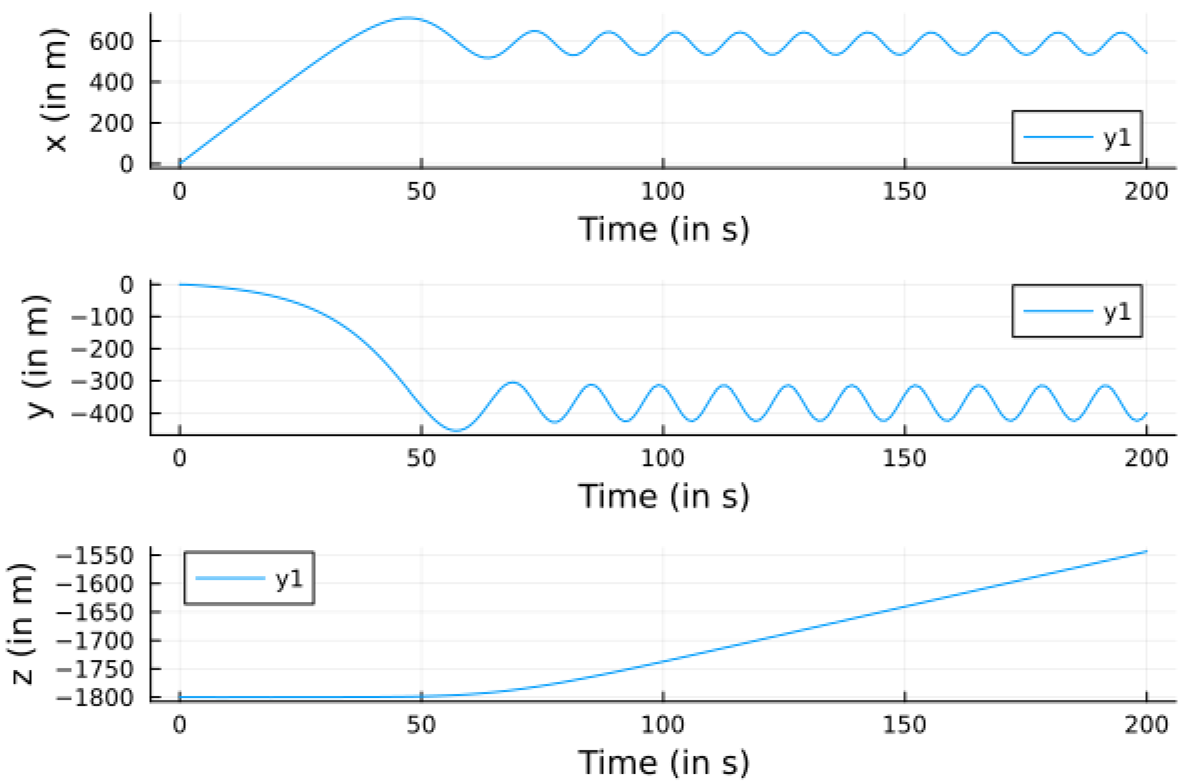

u (in m/s)
18.50
18.25
18.00
17.75
17.50
0
100
200
300
400
Time (in s)
v (in m/s)
1.00
0.75
0.50
0.25
0.00
0
100
200
300
400
Time (in s)
w (in m/s)
0.92
0.90
0.88
0.86
0.84
0.82
0.80
0
100
200
300
400
Time (in s)
1.00
0.75
0.50
0.25
0.00
0
100
200
300
400
Time (in s)
q (in radians/s)
0.02
0.01
0.00
−0.01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

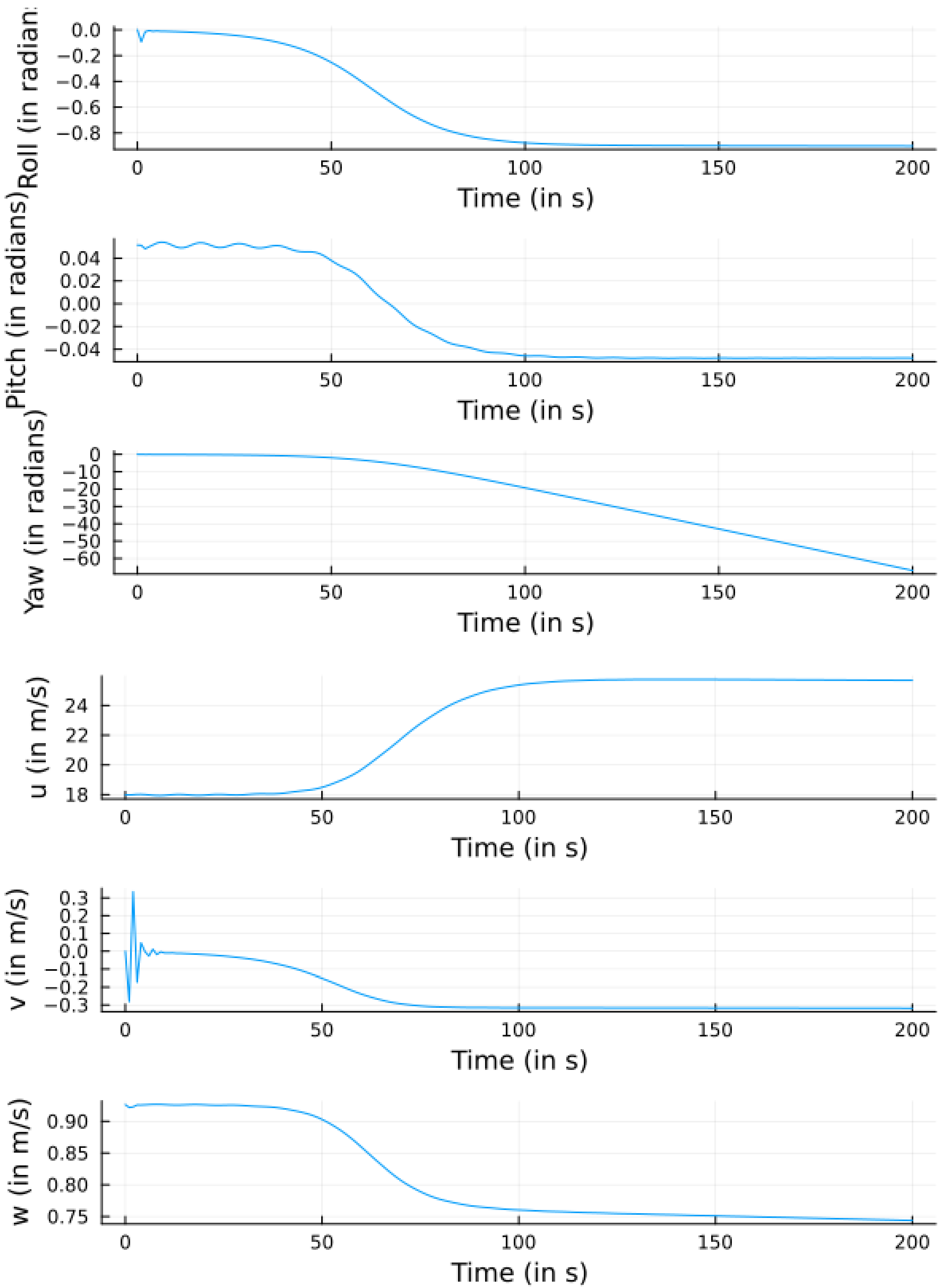

delta_e (in radians)
−0.25
−0.30
−0.35
−0.40
−0.45
−0.50
Time (in s)
0
100
200
300
400
delta_a (in radians)
1.00
0.75
0.50
0.25
0.00
Time (in s)
delta_r (in radians)
1.00
0.75
0.50
0.25
0.00
Time (in s)
delta_t
1.00
0.75
0.50
0.25
Time (in s)

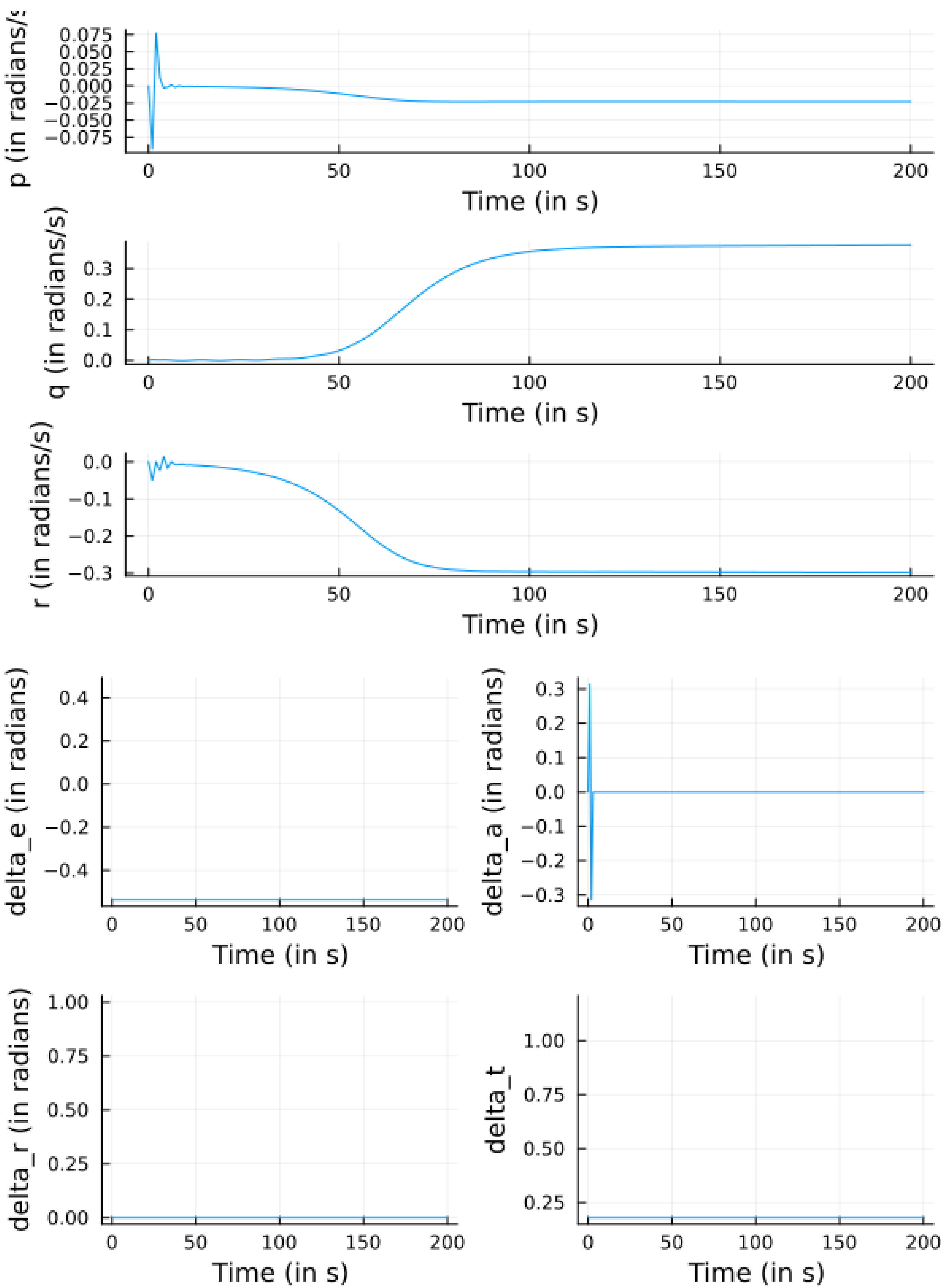

z (in meters)
1801.0
1800.5
1800.0
1799.5
1799.0
0
2000
4000
6000
x (in meters)
1.00
0.75
0.50
0.25
0.00
y (in meters)

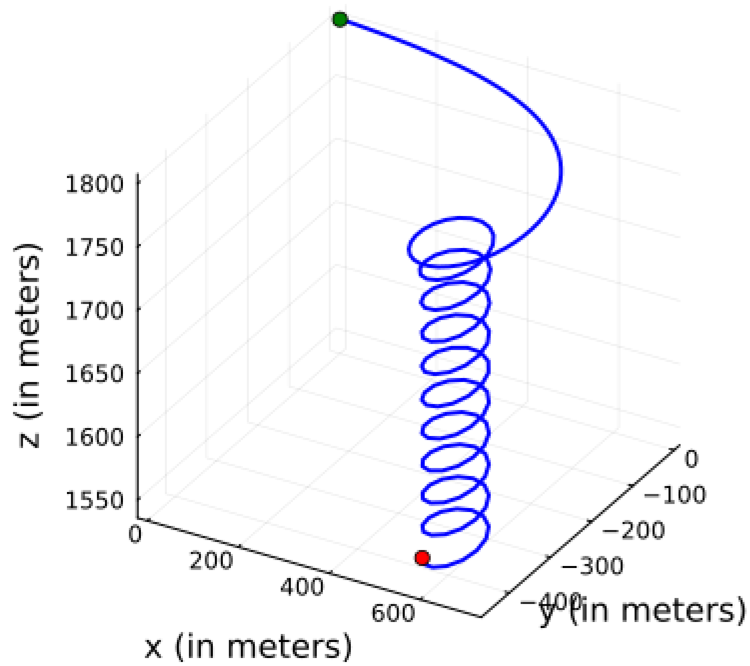
Problem 2: Part 2)

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
Time (in s)
Yaw (in radians)
0
−10
−20
−30
−40
−50
−60
Time (in s)
u (in m/s)
24
22
20
18
Time (in s)
v (in m/s)
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
Time (in s)
w (in m/s)
0.90
0.85
0.80
0.75
Time (in s)

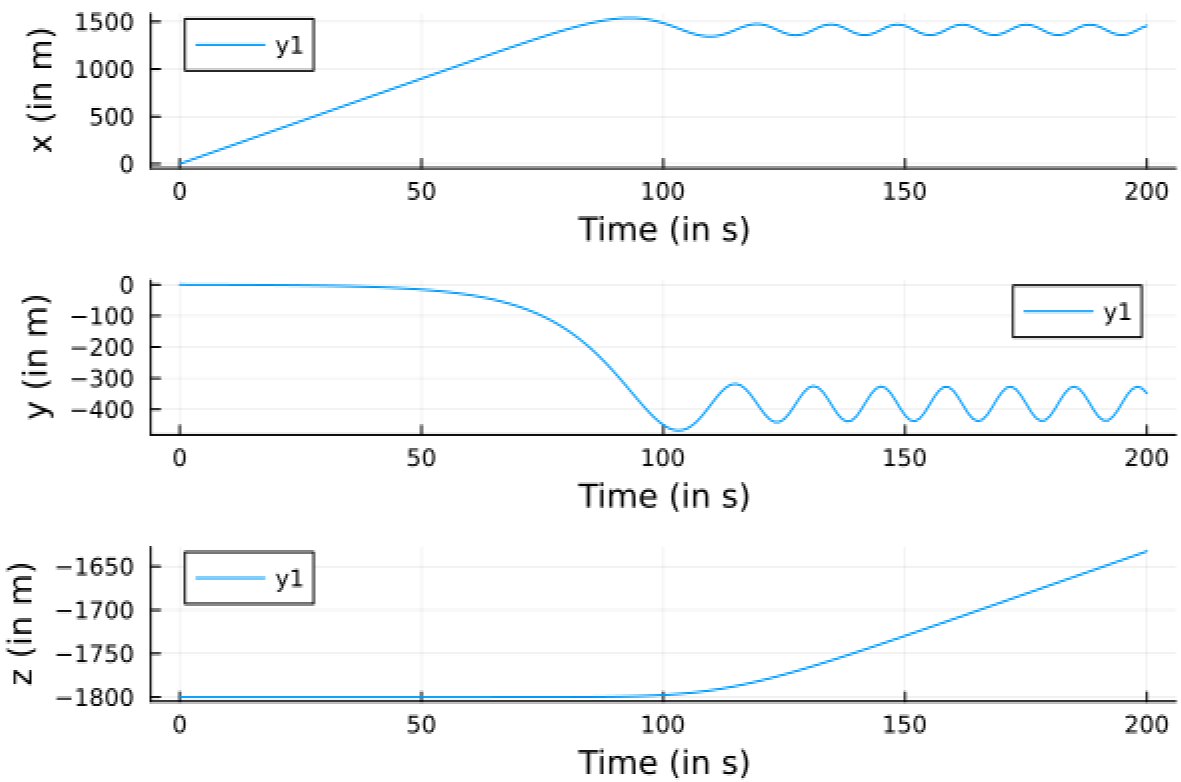

p (in radians/s
0.075
0.050
0.025
0.000
−0.025
−0.050
−0.075
0
50
100
150
200
Time (in s)
q (in radians/s)
0.3
0.2
0.1
0.0
Time (in s)
r (in radians/s)
0.0
−0.1
−0.2
−0.3
Time (in s)
delta_e (in radians)
0.4
0.2
0.0
−0.2
−0.4
Time (in s)
delta_a (in radians)
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
Time (in s)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

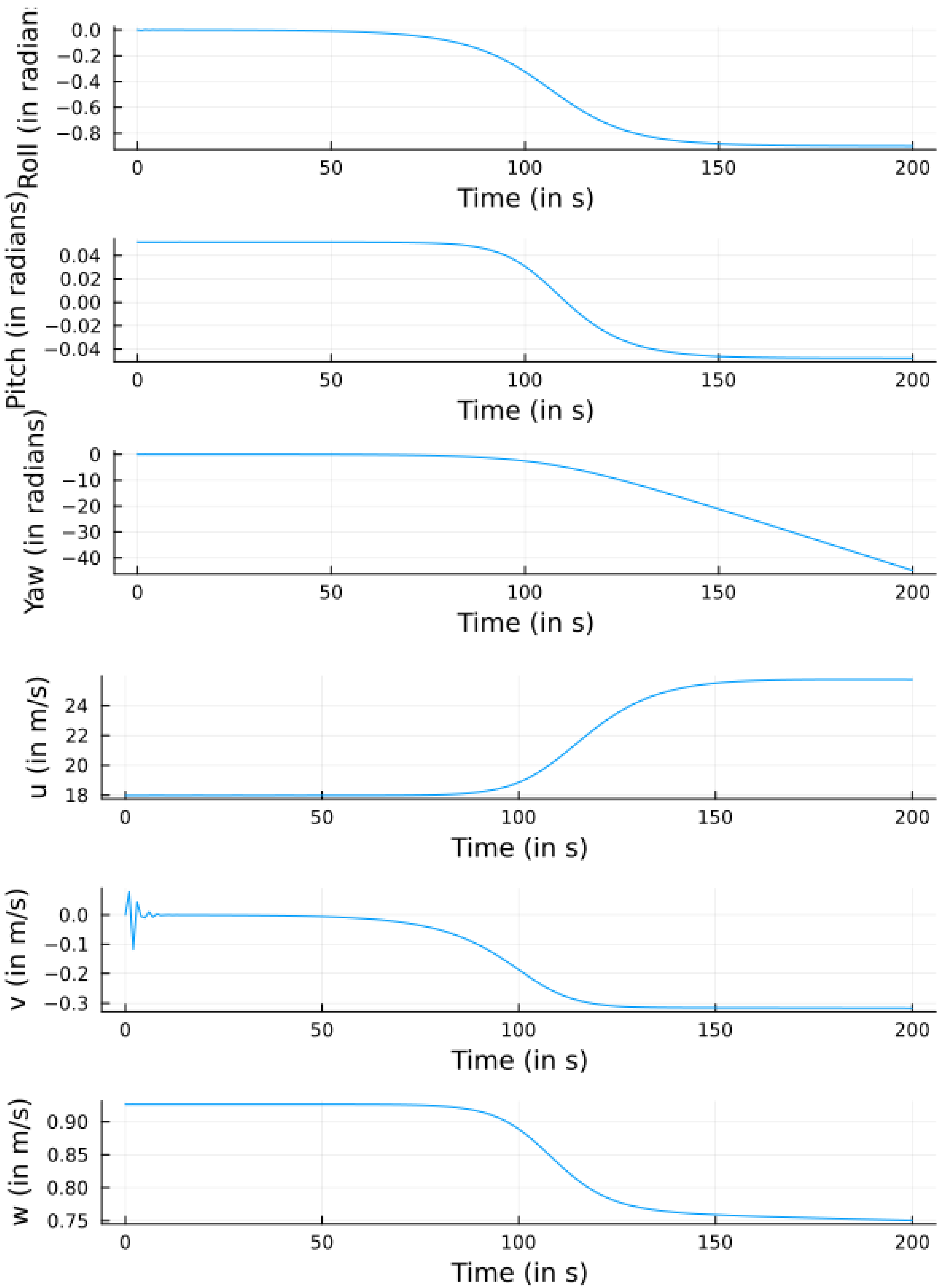


Applying a doublet to the rudder excited the lateral modes, dutch roll mode, and spiral mode. This is in accordance with the behavior observed in Problem 1. The eigenvalue corresponding to the spiral mode has a positive real part, so the system becomes unstable. The eigenvalues corresponding to the dutch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

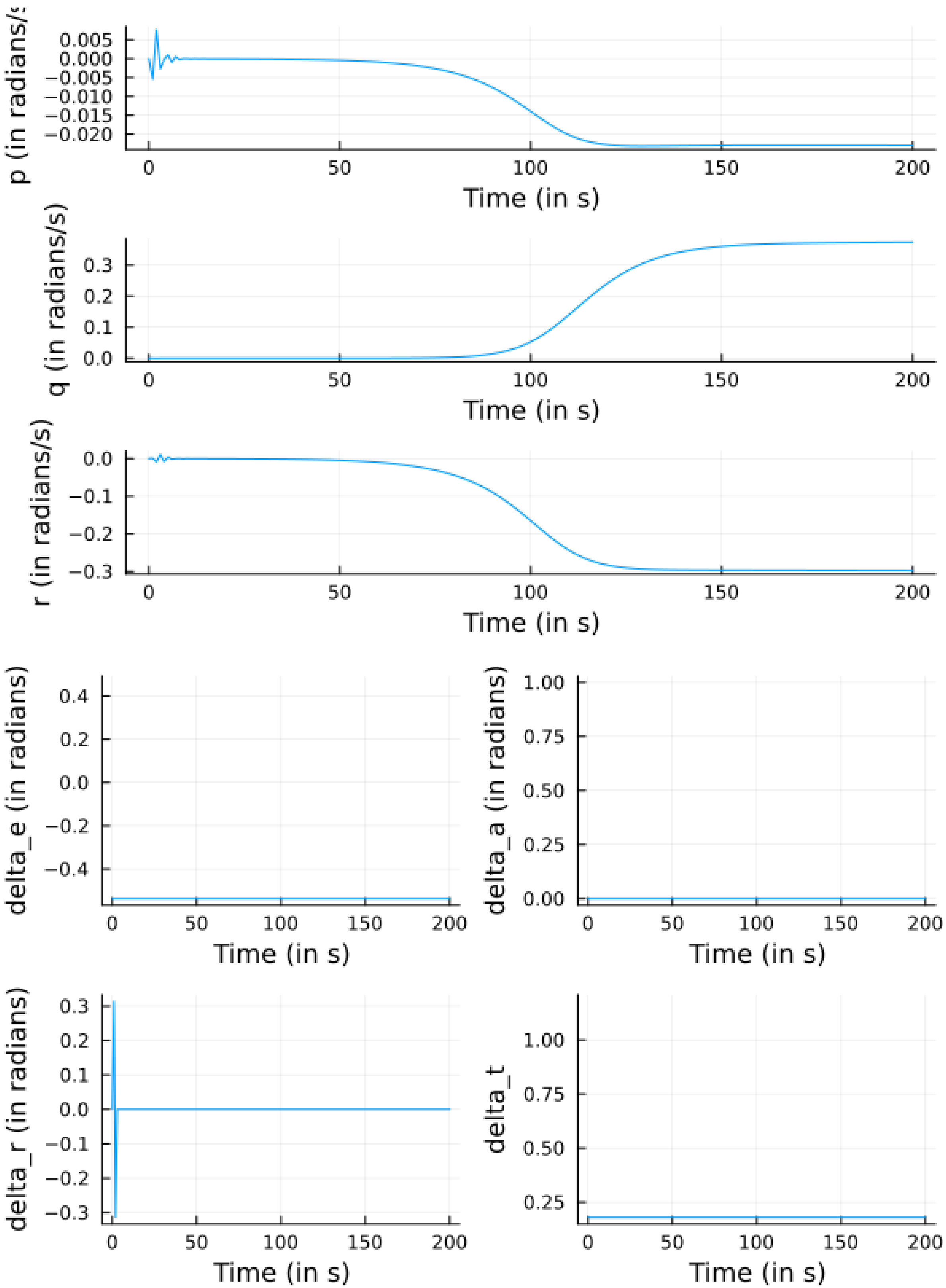
Problem 2: Part 3)

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

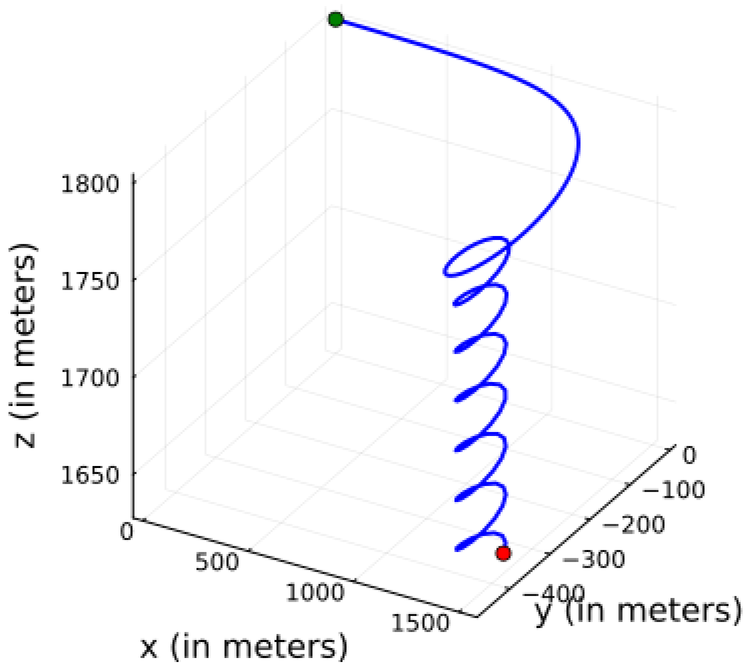




Roll (in radians)
0.0
−0.2
−0.4
−0.6
−0.8
0
50
100
150
200
Time (in s)
Pitch (in radians)
0.04
0.02
0.00
−0.02
−0.04
Time (in s)
Yaw (in radians)
0
−10
−20
−30
−40
Time (in s)
u (in m/s)
24
22
20
18
Time (in s)
v (in m/s)
0.0
−0.1
−0.2
−0.3
Time (in s)
w (in m/s)
0.90
0.85
0.80
0.75
Time (in s)



p (in radians/s
Time (in s)
q (in radians/s)
Time (in s)
r (in radians/s)
Time (in s)
delta_e (in radians)
Time (in s)
delta_a (in radians)
Time (in s)
delta_r (in radians)
Time (in s)
delta_t
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.