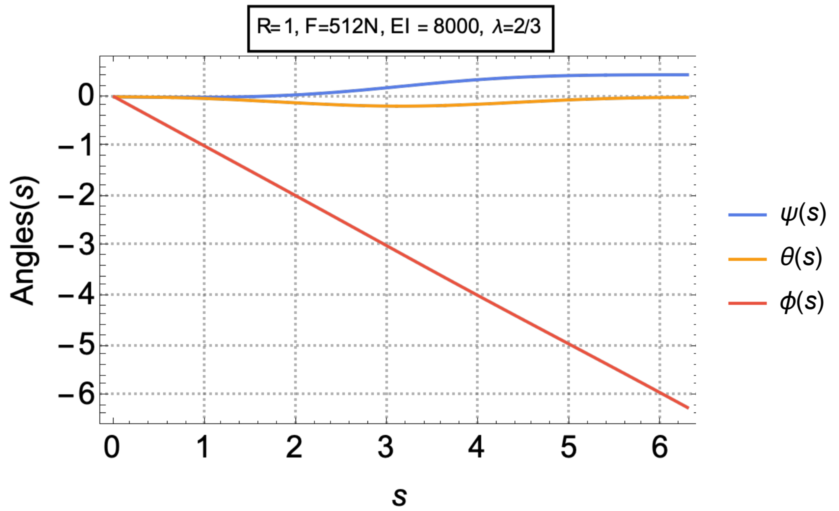
```
ClearAll["Global`*"];
(* Setting up the kirchoff rod problem *)
R1 = RotationMatrix[-ψ[s], {0, 0, 1}];
R2 = RotationMatrix[-θ[s], {0, 1, 0}];
R3 = RotationMatrix[-ϕ[s], {1, 0, 0}];
Fvec = R3.R2.R1.{F, 0, 0};
d1 = FullSimplify[Inverse[R3.R2.R1].{1, 0, 0}];
d2 = FullSimplify[Inverse[R3.R2.R1].{0, 1, 0}];
d3 = FullSimplify[Inverse[R3.R2.R1].{0, 0, 1}];
kn = {-1 / R, 0, 0};
k = {ϕ'[s] - Sin[θ[s]] * ψ'[s], θ'[s] * Cos[ϕ[s]] + Cos[θ[s]] * Sin[ϕ[s]] * ψ'[s],
   -Sin[ϕ[s]] * θ'[s] + Cos[θ[s]] * Cos[ϕ[s]] * ψ'[s]};
{M1, M2, T} = B * {{1, 0, 0}, {0, 1, 0}, {0, 0, RR}}.(k - kn);
Mvec = {M1, M2, T} ;
Expand[D[Mvec, s]] // MatrixForm;
crss = FullSimplify[{{k〚2〛 * Mvec〚3〛 - k〚3〛 * Mvec〚2〛},
    {k〚3〛 * Mvec〚1〛 - k〚1〛 * Mvec〚3〛}, {k〚1〛 * Mvec〚2〛 - k〚2〛 * Mvec〚1〛}}];
eqns = FullSimplify[Thread[D[Mvec, s] + crss == {{Fvec〚2〛}, {-Fvec〚1〛}, {0}}] /.
      R → 1 /. B → 8000. /. RR → 2 / 3];
H = FullSimplify[{{-Sin[θ[s]], 0, 1}, {Cos[θ[s]] * Sin[ϕ[s]], Cos[θ[s]], 0},
       {RR * Cos[θ[s]] * Cos[ϕ[s]], -RR * Sin[ϕ[s]], 0}} /.
      R → 1 /. B → 8000. /. RR → 2 / 3];

(* Setting up BVP *)
startpt = 0.01;
startval = 0.001;
endpt = 2 Pi;
IC1 = ψ[startpt] == startval;
IC2 = θ[startpt] == startval;
IC3 = ϕ[startpt] == startval;
IC5 = FullSimplify[Part[k, 1] - Part[kn, 1]] == startval /. s → endpt /. R → 1;
IC4 = FullSimplify[Part[k, 2] - Part[kn, 2]] == startval /. s → endpt /. R → 1;
IC6 = FullSimplify[Part[k, 3] - Part[kn, 3]] == startval /. s → endpt /. R → 1;
bcs = {IC1, IC2, IC3, IC4, IC5, IC6};
solution = Block[{F = 512},
   NDSolve[Join[eqns, bcs], {ψ[s], θ[s], ϕ[s]}, {s, startpt, endpt},
    Method → "BoundaryValues" → {"Shooting", "StartingInitialConditions" →
        {ψ'[startpt] == 1., θ'[startpt] == 1., ϕ'[startpt] == 1.}}]];
```

```
Plot[Evaluate[{ψ[s], θ[s], ϕ[s]} /. solution], {s, 0.01, 2 * Pi},
 PlotTheme → {"BoldColors", "Frame", "Grid"},
 FrameLabel → {s, Angles[s]},
 FrameStyle → Directive[16, Black], PlotLegends → {ψ[s], θ[s], ϕ[s]},
 PlotLabel → Style[Framed["R=1, F=512N, EI = 8000, λ=2/3"]]]
```

Out[188]=

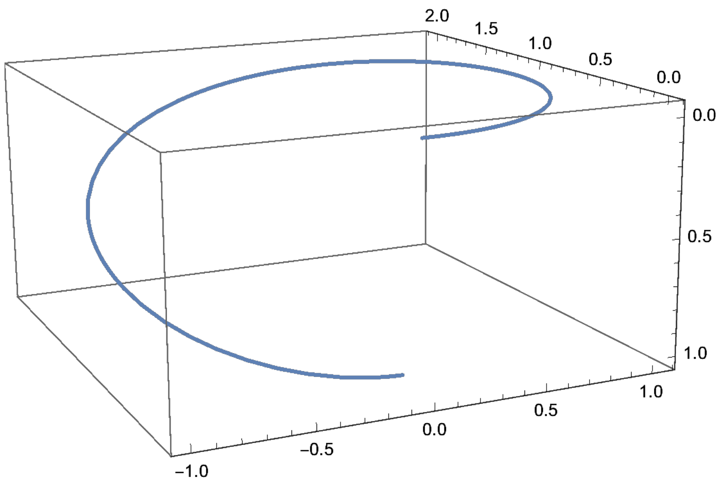



```
In[205]:= (* Integrating d3 over s to get deformed configuration *)
dyds = d3 /. solution;
fn[z_?NumericQ] := NIntegrate[dyds, {s, startpt, z}];
fn[2 Pi * R] /. R → 1
```

```
Out[207]= {{1.00122, 0.173959, 0.00416271}}
```

```
In[189]:= ParametricPlot3D[{fn[y][[1, 1]], fn[y][[1, 2]], fn[y][[1, 3]]}, {y, 0.01, 2 π * 1}]
```

Out[189]=



In[192]:=