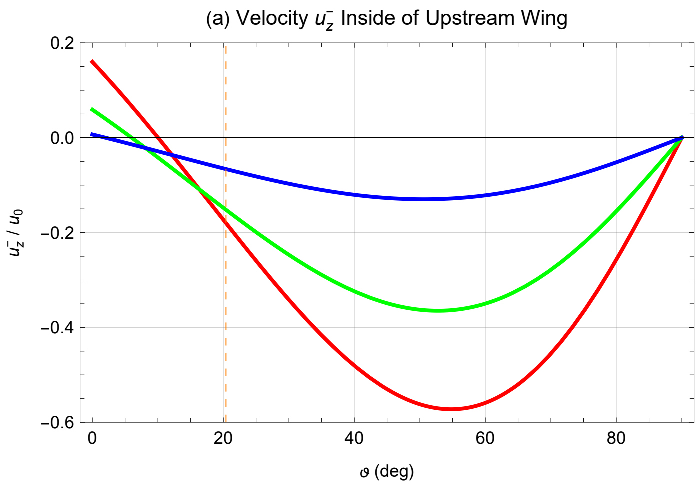
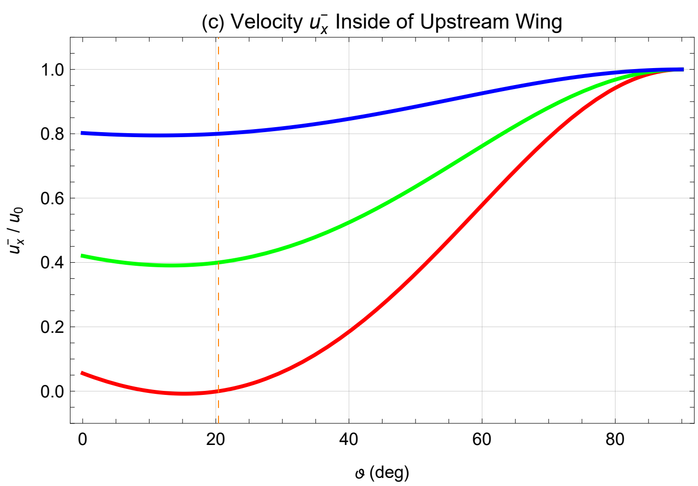
```
In[*]:= (*05/16/21*)
(*velocity u_z (constant) inside the norhern Alfven wing generated by a box-
 like ionospheric obstacle*)
B0 = 5.1369 * 10^-9;(*upstream magnetic field in Tesla*)
n0 = 0.11 * 10^6;(*upstream number density in 1/m^3*)
mp = 1.6726231 * 10^-27; (*proton mass*)
m = 7.5 * mp; (*upstream ion mass*)
mu0 = 4 * 3.14159265359 * 10^-7; (*magnetic permeability of vacuum*)
vA = B0 / Sqrt[mu0 * n0 * m]; (*Alfven velocity*)
u0 = 43 * 10^3; (*magnitude of upstream flow velocity in m/s*)
MA = u0 / vA(*Alfvenic Mach number, Europa*)


uz[theta_, a_] = B0 * Cos[theta] / (Sqrt[mu0 * n0 * m] (1 + MA^2 - 2 MA Sin[theta])) *
   (-Sqrt[(1 + MA^2 - 2 MA Sin[theta] - MA^2 a^2 (1 - Sin[theta] * Sin[theta]))] +
     MA * (a - 2) * Sin[theta] + MA^2 (1 - a) + 1);
ux[theta_, a_] = u0 + B0 / (Sqrt[mu0 * n0 * m] (1 + MA^2 - 2 MA Sin[theta])) * ((Sin[theta] - MA) *
      Sqrt[(1 + MA^2 - 2 MA Sin[theta] - MA^2 a^2 (1 - Sin[theta] * Sin[theta]))] +
     MA * a * Cos[theta] * Cos[theta] - Sin[theta] * (1 + MA^2 - 2 MA Sin[theta]));

Out[*]= 0.348577
```

```
In[ ]:= Plot1 = Plot[
  {uz[theta * 2π/360, 0.0] / (u0), uz[theta * 2π/360, 0.4] / (u0), uz[theta * 2π/360, 0.8] / (u0)},
  {theta, 0, 90}, FrameLabel → {"θ (deg)", "u_z^- / u_0"}, GridLines → Automatic,
  Frame → True, PlotLabel → "(a) Velocity u_z^- Inside of Upstream Wing",
  PlotStyle → {{Red, Thick}, {Green, Thick}, {Blue, Thick}},
  (*PlotLegends →{"λ⁻ = 1.0","λ⁻ = 0.6","λ⁻ = 0.2"},*)
  PlotRange → {-0.6, 0.2}, Epilog → {Directive[Dashed, Orange],
    InfiniteLine[{{ArcSin[MA] * 360/(2π), -0.6}, {ArcSin[MA] * 360/(2π), 0.2}}]}]
Plot2 = Plot[{ux[theta * 2π/360, 0.0] / (u0), ux[theta * 2π/360, 0.4] / (u0),
   ux[theta * 2π/360, 0.8] / (u0)}, {theta, 0, 90},
  FrameLabel → {"θ (deg)", "u_x^- / u_0"}, GridLines → Automatic, Frame → True,
  PlotLabel → "(c) Velocity u_x^- Inside of Upstream Wing",
  PlotStyle → {{Red, Thick}, {Green, Thick}, {Blue, Thick}},
  (*PlotLegends →{"λ⁻ = 1.0","λ⁻ = 0.6","λ⁻ = 0.2"}, *)
  PlotRange → {-0.1, 1.1}, Epilog → {Directive[Dashed, Orange],
    InfiniteLine[{{ArcSin[MA] * 360/(2π), -0.1}, {ArcSin[MA] * 360/(2π), 1.1}}]}]
Plot3 = Plot[{Abs[uz[theta * 2π/360, 0.0] / ux[theta * 2π/360, 0.0]],
   Abs[uz[theta * 2π/360, 0.4] / ux[theta * 2π/360, 0.4]],
   Abs[uz[theta * 2π/360, 0.8] / ux[theta * 2π/360, 0.8]]}, {theta, ArcSin[MA] * 360/(2π), 90},
  FrameLabel → {"θ (deg)", "|u_z^- / u_x^-|"}, GridLines → Automatic, Frame → True,
  PlotLabel → "(e) Ratio |u_z^- / u_x^-| Inside of Upstream Wing",
  PlotStyle → {{Red, Thick}, {Green, Thick}, {Blue, Thick}}, (*,
  PlotLegends →{"λ⁺ = 1.0","λ⁺ = 0.6","λ⁺ = 0.2"},*)PlotRange → {0, 2}]
```

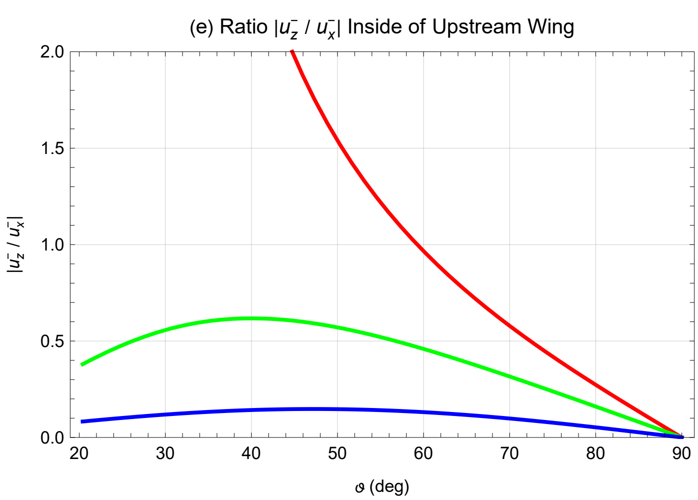
Out[ ]=


(a) Velocity $u_z^-$ Inside of Upstream Wing
$u_z^- / u_0$
$\vartheta$ (deg)
0.2
0.0
−0.2
−0.4
−0.6
0
20
40
60
80

Out[ ]=


(c) Velocity $u_x^-$ Inside of Upstream Wing
$u_x^- / u_0$
$\vartheta$ (deg)
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80

Out[ ]=


(e) Ratio $|u_z^- / u_x^-|$ Inside of Upstream Wing
$|u_z^- / u_x^-|$
$\vartheta$ (deg)
2.0
1.5
1.0
0.5
0.0
20
30
40
50
60
70
80
90

In[•]:=
```
Export["figure3a_new.pdf", Plot1]
Export["figure3c_new.pdf", Plot2]
Export["figure3e_new.pdf", Plot3]
```

Out[•]= figure3a_new.pdf

Out[•]= figure3c_new.pdf

Out[•]= figure3e_new.pdf

In[•]:=
```
uxroots[theta_] = u0 + B0 / (Sqrt[mu0 * n0 * m] (1 + MA^2 - 2 MA Sin[theta])) * ((Sin[theta] - MA) *
    √ (1 + MA^2 - 2 MA Sin[theta] - MA^2 a^2 (1 - Sin[theta] * Sin[theta])) +
   MA * a * Cos[theta] * Cos[theta] - Sin[theta] * ((1 + MA^2 - 2 MA Sin[theta])));
```

In[•]:= a = 0.1

Out[•]= 0.1

In[•]:=
```
Solve[uxroots[theta] == 0, theta]
Solve[uz[theta, 0.1] == 0, theta]
```

Solve: Inverse functions are being used by Solve, so some solutions may not be found; use Reduce for complete solution information.

Out[•]= {{theta → 0.270824 - 0.317337 i}, {theta → 0.270824 + 0.317337 i}, {theta → 2.87077 - 0.317337 i}, {theta → 2.87077 + 0.317337 i}}

Solve: Inverse functions are being used by Solve, so some solutions may not be found; use Reduce for complete solution information.

Out[•]= {{theta → -1.5708}, {theta → 0.15751}, {theta → 1.5708}}