DIII-D ECH with linear Slab Profiles

Open Additional files:

Get dispersion routines by evaluating Disper.nb
Get plotting and printing routines by evaluating PlotPack.nb
Set Parameters by opening a Parameter Window

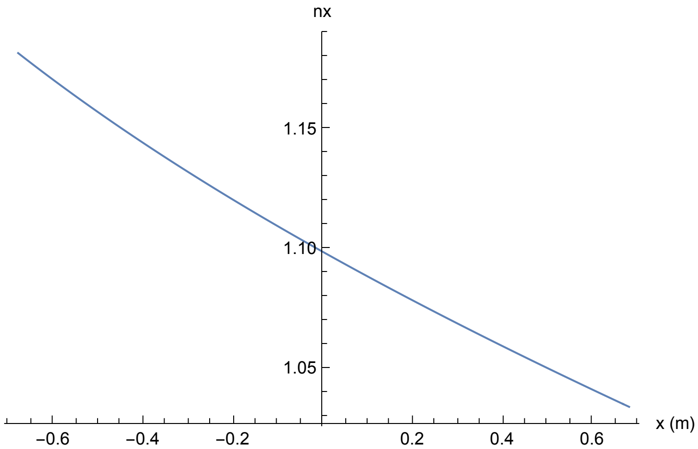
Note: Slab profile models defined in initialization cells at the bottom of this notebook.

First Do Cold Plasma

Plot Real and Imaginary parts of nx from 2nd order warm plasma dispersion relation (i.e. $E_{\|}\equiv 0$)

In[347]:=
```
nPerpCold[x_] := Module[{ne, b, x0}, x0 = x;
  ne = nprof[x0];
  b = bprof[x0];
  ColdDis0[freq, ne, b, nz, etaList]]
nt = Table[{x, nPerpCold[x]}, {x, xmin, xmax, (xmax - xmin)/(nPoints - 1)}];
ComplexListPlot[nt, "x (m)", "nx"]
paramPrint[{dataSet, xProfileMin, xProfileMax,
   nXmin, nXmax, BXmin, BXmax, freq, nz, etaList, xmin, xmax}];
```

Out[349]=

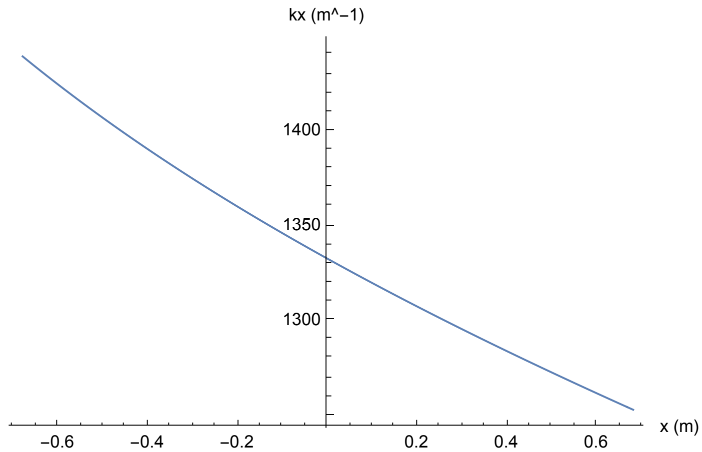



```
dataSet=DIII-D slab
xProfileMin=-0.68
xProfileMax=0.68
nXmin=2.5 × 10^19
nXmax=3.5 × 10^19
BXmin=1.9
BXmax=2.1
freq=55 990
nz=0.1
etaList={1., 0., 0., 0., 0.}
xmin=-0.68
xmax=0.68
```

Plot Real and Imaginary parts of kx from 2nd order cold plasma dispersion relation (i.e. $E_{\|}\equiv 0$)

In[287]:=
```
nPerpCold[x_] := Module[{ne, b, x0}, x0 = x;
  ne = nprof[x0];
  b = bprof[x0];
  ColdDis0[freq, ne, b, nz, etaList]]
nt = Table[{x, k0 nPerpCold[x]}, {x, xmin, xmax, (xmax - xmin)/(nPoints - 1)}];
ComplexListPlot[nt, "x  (m)", "kx  (m^-1)"]
paramPrint[{dataSet, xProfileMin, xProfileMax,
   nXmin, nXmax, BXmin, BXmax, freq, nz, etaList, xmin, xmax}];
```

Out[289]=



dataSet=DIII-D slab

xProfileMin=-0.68

xProfileMax=0.68

nXmin=2.5×10^{19}

nXmax=3.5×10^{19}

BXmin=1.9

BXmax=2.1

freq=56 990

nz=0.1

etaList={1., 0., 0., 0., 0.}

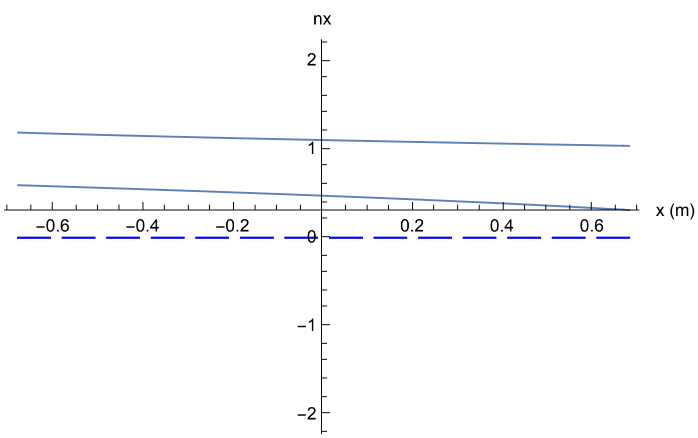
xmin=-0.68

xmax=0.68

Plot Real and Imaginary parts of nx from 4nd order cold plasma dispersion relation (i.e. fast and slow)

In[351]:=
```
nPerp2FS[x_] := Module[{ne, b, x0}, x0 = x;
   ne = nprof[x0];
   b = bprof[x0];
      ColdDis2FS[freq, ne, b, nz, etaList]]
nt2FS = Table[Flatten[{x, nPerp2FS[x]}], {x, xmin, xmax, (xmax - xmin)/(nPoints - 1)}];
nF = Transpose[{Transpose[nt2FS][[1]], Transpose[nt2FS][[2]]}];
nS = Transpose[{Transpose[nt2FS][[1]], Transpose[nt2FS][[3]]}];
g1 = ComplexListPlot[nF, "x (m)", "nx"];
g2 = ComplexListPlot[nS, "x (m)", "nx"];
Show[{g1, g2}, PlotRange → {-2., 2.}]
paramPrint[{dataSet, xProfileMin, xProfileMax,
   nXmin, nXmax, BXmin, BXmax, freq, nz, etaList, xmin, xmin}];
```

Out[357]=



dataSet=DIII-D slab

xProfileMin=-0.68

xProfileMax=0.68

nXmin=2.5×10^{19}

nXmax=3.5×10^{19}

BXmin=1.9

BXmax=2.1

freq=55 990

nz=0.1

etaList={1., 0., 0., 0., 0.}

xmin=-0.68

xmin=-0.68

Now Warm Plasma Stuff

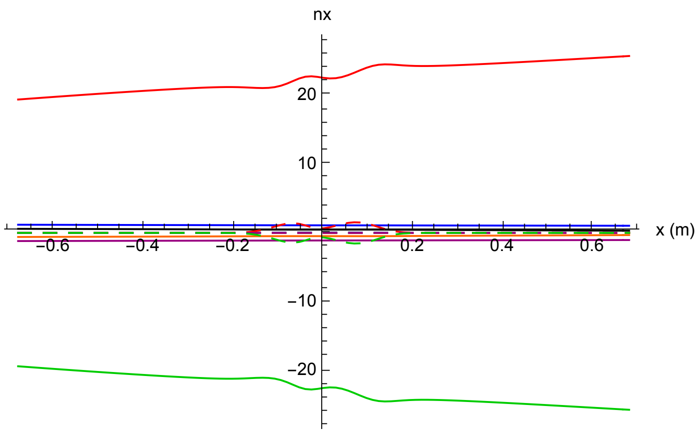
Plot Real and Imaginary parts of nx from 6th order warm plasma dispersion relation (expanded to 2nd order in $k_\perp \rho$)

In[359]:=
```
nPerpWarm6[x_] := Module[{ne, te, b, x0, TL},
        x0 = x;
   ne = nprof[x0];
   b = bprof[x0];
     TL = tprof[x0] * TList;
     WarmDis6[freq, ne, b, nz, etaList, TL]]

nxwarm = Table[Flatten[{x, nPerpWarm6[x]}], {x, xmin, xmax, (xmax - xmin)/(nPoints - 1)}];
roots = rootSort[nxwarm];
rootsRe = Table[Flatten[{roots[[i]][[1]],
     Table[Re[roots[[i]][[j]]], {j, 2, Length[roots[[i]]]}]}], {i, Length[roots]}];

rootsIm = Table[Flatten[{roots[[i]][[1]],
     Table[Im[roots[[i]][[j]]], {j, 2, Length[roots[[i]]]}]}], {i, Length[roots]}];

g6 = ComplexVectorListPlot[roots, "x (m)", "nx"];
paramPrint[{dataSet, xProfileMin, xProfileMax, nXmin, nXmax,
   BXmin, BXmax, freq, nz, etaList, TList, modelList, xmin, xmax}];
Show[g6, PlotRange → All]
Show[g6, PlotRange → {-1.5, 1.5}]
ComplexVectorListPlot[rootsRe, "x", "Re[kx]", PlotRange → {-2., 2.}]
ComplexVectorListPlot[rootsIm, "x", "Re[kx]"]
```

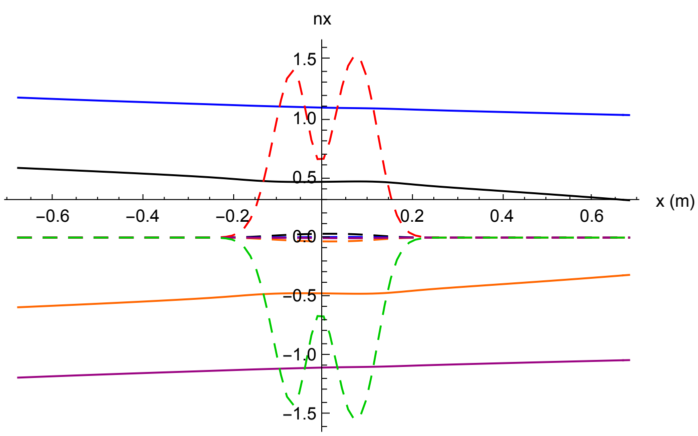
```
dataSet=DIII-D slab

xProfileMin=-0.68

xProfileMax=0.68

nXmin=2.5 × 10^19

nXmax=3.5 × 10^19

BXmin=1.9

BXmax=2.1

freq=55 990

nz=0.1

etaList={1., 0., 0., 0., 0.}
```

```
TList={1., 1., 0., 0., 0., 0.}
modelList={1, 1, 0, 0, 0, 0}
xmin=-0.68
xmax=0.68
```

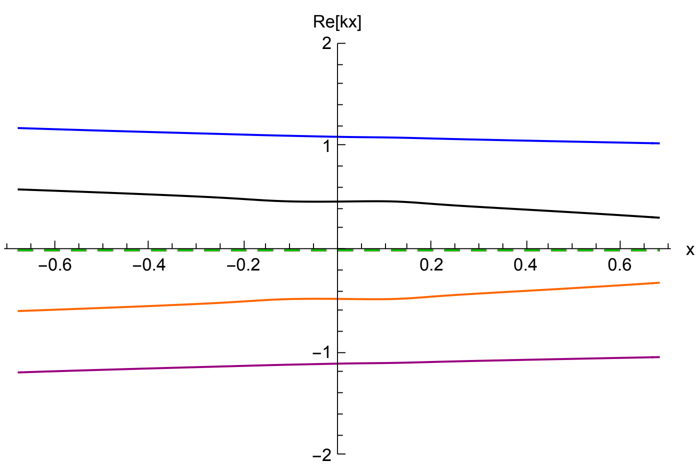
Out[366]=



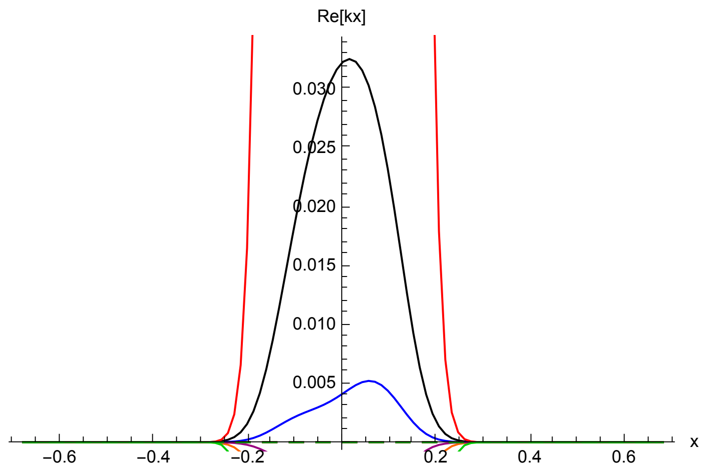
Out[367]=



Out[368]=



Out[369]=



Now Try with Hot Plasma Dispersion using root finder

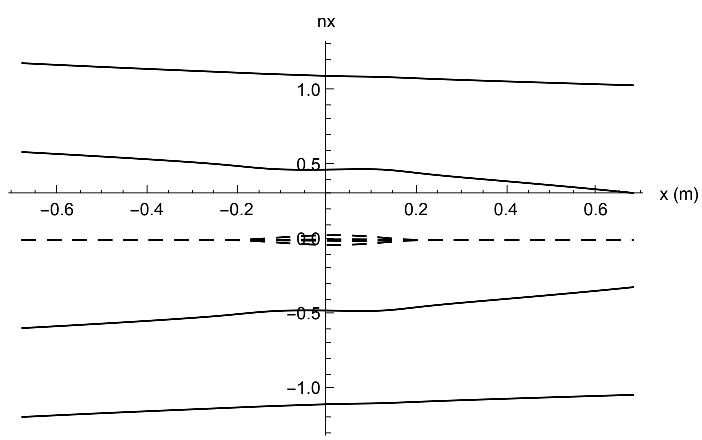
In[370]:=
```
nPerpHot[x_, nxGuess_] := Module[{ne, b, x0, TL, nx0},
        x0 = x;
  nx0 = nxGuess;
  ne = nprof[x0];
  b = bprof[x0];
  TL = tprof[x0] * TList;
rootRule = FindRoot[DisFuncGeneral[freq, ne, b, nz, nx, etaList, TL,
     nminList, nmaxList, modelList], {nx, nx0}, MaxIterations -> 30];
  nx /. rootRule]
```

First try root finding on warm plasma dispersion rel (model = 1)

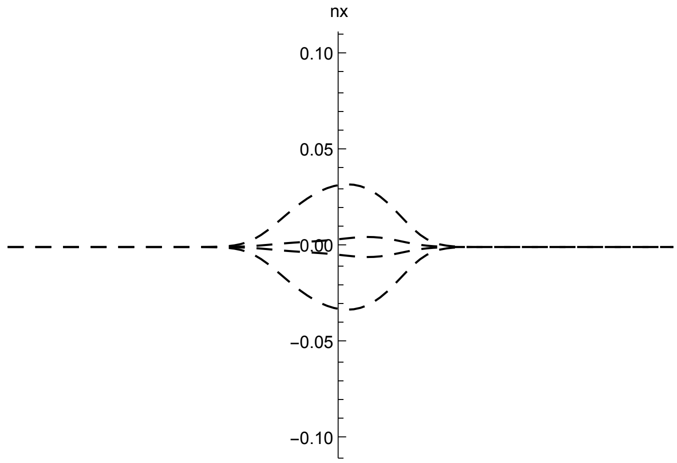
In[420]:=
```
modelList = Table[1, {i, 1, 6}];
```

In[421]:=
```
nxhot[iRoot_] := Module[{iRoot0, nxWarm, rootsWarm, nxH, x0, ne, b, t, TL},
    nxWarm = Table[Flatten[{x, nPerpWarm6[x]}], {x, xmin, xmax, (xmax - xmin)/(nPoints - 1)}];
    iRoot0 = iRoot;
    rootsWarm = rootSort[nxWarm];
    nxH = Table[0., {i, 1, nPoints}];
    Do[
     (x0 = xmin + (i - 1) (xmax - xmin)/(nPoints - 1);
      nxGuess = rootsWarm[[i]][[iRoot0 + 1]];
      (*Print["x0 = ", x0,"  nxGuess= ",nxGuess];*)
      nxH[[i]] = {x0, nPerpHot[x0, nxGuess]};), {i, 1, nPoints}];
    nxH];
g7 = ComplexVectorListPlot[nxhot[1], "x (m)", "nx"];
g8 = ComplexVectorListPlot[nxhot[2], "x (m)", "nx"];
g9 = ComplexVectorListPlot[nxhot[3], "x (m)", "nx"];
g10 = ComplexVectorListPlot[nxhot[4], "x (m)", "nx"];
g11 = ComplexVectorListPlot[nxhot[5], "x (m)", "nx"];
g12 = ComplexVectorListPlot[nxhot[6], "x (m)", "nx"];
Show[{g7, g8, g10, g11}, PlotRange → All]
Show[{g7, g8, g10, g11}, PlotRange → {-.1, .1}]
paramPrint[{dataSet, ne0, nsep, B, freq, nz, etaList,
   TList, modelList, rmaj, rmin, rsep, sol, alphan, alphaT}];
```

Out[425]=



Out[426]=




```
dataSet=DIII-D slab
ne0=ne0
nsep=nsep
B=B
freq=55 990
nz=0.1
etaList={1., 0., 0., 0., 0.}
TList={1., 1., 0., 0., 0., 0.}
modelList={1, 1, 1, 1, 1, 1}
rmaj=rmaj
rmin=rmin
rsep=rsep
sol=sol
alphan=alphan
alphaT=alphaT
```

Now try with hot plasma (model = 2) for all species. Can I find the warm plasma roots with the full dispersion relation?

In[397]:=
```
xPoint = 0.;
guesses = nPerpWarm6[xPoint] (* Warm plasma roots at x=0 *)
```

Out[398]=
```
{0.472427 + 0.0323801 i, 1.10079 + 0.00415331 i, 22.5351 + 0.667857 i,
 -0.472427 - 0.0323801 i, -1.10079 - 0.00415331 i, -22.5351 - 0.667857 i}
```

- Change model to 2

In[428]:=
```
modelList = Table[2, {i, 1, 6}];
```

In[429]:=
```
{nPerpHot[xPoint, guesses[[1]]],
 nPerpHot[xPoint, guesses[[2]]],
 nPerpHot[xPoint, guesses[[3]]],
 nPerpHot[xPoint, guesses[[4]]],
 nPerpHot[xPoint, guesses[[5]]],
 nPerpHot[xPoint, guesses[[6]]]}
paramPrint[{dataSet, ne0, nsep, B, freq, nz,
   etaList, TList, modelList, rmaj, rmin, rsep, sol, alphan, alphaT}];
```

Out[429]= $\{0.590246 + 1.7869 \times 10^{-27}\, i,\ 1.18681 + 3.41307 \times 10^{-28}\, i,\ 1.18681 + 7.67968 \times 10^{-26}\, i,\ -0.590246 - 1.7869 \times 10^{-27}\, i,\ -1.18681 - 3.41307 \times 10^{-28}\, i,\ -1.18681 - 7.67968 \times 10^{-26}\, i\}$

```
dataSet=DIII-D slab
ne0=ne0
nsep=nsep
B=B
freq=55 990
nz=0.1
etaList={1., 0., 0., 0., 0.}
TList={1., 1., 0., 0., 0., 0.}
modelList={2, 2, 2, 2, 2, 2}
rmaj=rmaj
rmin=rmin
rsep=rsep
sol=sol
alphan=alphan
alphaT=alphaT
```

- Hot plasma root finder gets all roots. What about at xmin?

In[403]:=
```
xPoint = xmin;
guesses = nPerpWarm6[xPoint] (* Warm plasma roots at x=0  *)
```

Out[404]= {0.590188, 1.18597, 19.3865, -0.590188, -1.18597, -19.3865}

In[405]:=
```
{nPerpHot[xPoint, guesses[[1]]],
 nPerpHot[xPoint, guesses[[2]]],
 nPerpHot[xPoint, guesses[[3]]],
 nPerpHot[xPoint, guesses[[4]]],
 nPerpHot[xPoint, guesses[[5]]],
 nPerpHot[xPoint, guesses[[6]]]}
paramPrint[{dataSet, ne0, nsep, B, freq, nz,
   etaList, TList, modelList, rmaj, rmin, rsep, sol, alphan, alphaT}];
```

Out[405]= $\{0.590246 + 1.7869 \times 10^{-27}\, i,\ 1.18681 + 3.41307 \times 10^{-28}\, i,\ 1.18681 + 7.67968 \times 10^{-26}\, i,\ -0.590246 - 1.7869 \times 10^{-27}\, i,\ -1.18681 - 3.41307 \times 10^{-28}\, i,\ -1.18681 - 7.67968 \times 10^{-26}\, i\}$

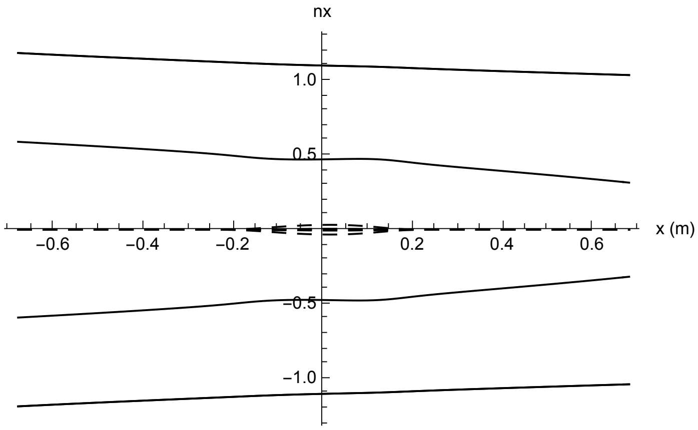
```
dataSet=DIII-D slab
ne0=ne0
nsep=nsep
B=B
freq=55 990
nz=0.1
etaList={1., 0., 0., 0., 0.}
TList={1., 1., 0., 0., 0., 0.}
modelList={2, 2, 0, 0, 0, 0}
rmaj=rmaj
rmin=rmin
rsep=rsep
sol=sol
alphan=alphan
alphaT=alphaT
```

- Hot plasma root finder gets 2 of the roots

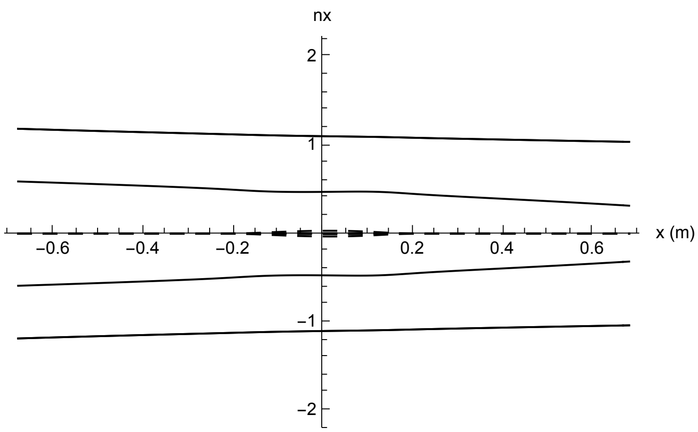
Plot hot plasma vs x

In[407]:=
```
g7 = ComplexVectorListPlot[nxhot[1], "x (m)", "nx"];
g8 = ComplexVectorListPlot[nxhot[2], "x (m)", "nx"];
g9 = ComplexVectorListPlot[nxhot[3], "x (m)", "nx"];
g10 = ComplexVectorListPlot[nxhot[4], "x (m)", "nx"];
g11 = ComplexVectorListPlot[nxhot[5], "x (m)", "nx"];
g12 = ComplexVectorListPlot[nxhot[6], "x (m)", "nx"];
Show[{g7, g8, g9, g10, g11, g12}, PlotRange → All, AxesOrigin → {0., 0.}]
Show[{g7, g8, g9, g10, g11, g12}, PlotRange → {-2., 2.}, AxesOrigin → {0., 0.}]
paramPrint[{dataSet, ne0, nsep, B, freq, nz, etaList,
   TList, modelList, rmaj, rmin, rsep, sol, alphan, alphaT}];
```

Out[410]=



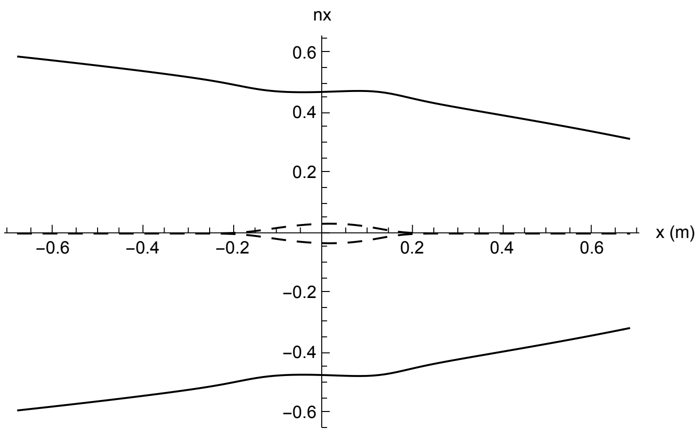
Out[411]=



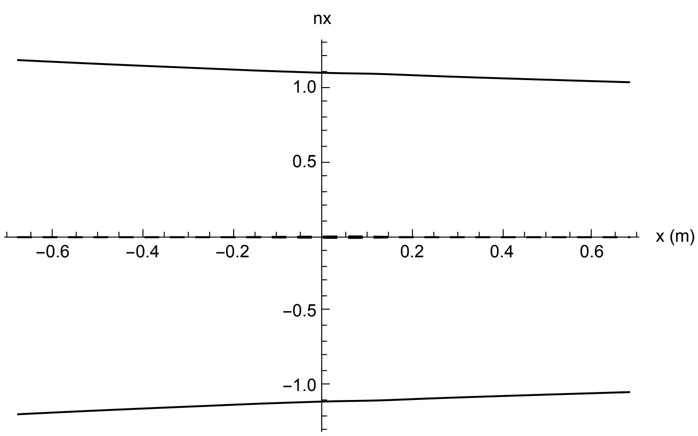

```
dataSet=DIII-D slab
ne0=ne0
nsep=nsep
B=B
freq=55 990
nz=0.1
etaList={1., 0., 0., 0., 0.}
TList={1., 1., 0., 0., 0., 0.}
modelList={2, 2, 0, 0, 0, 0}
rmaj=rmaj
rmin=rmin
rsep=rsep
sol=sol
alphan=alphan
alphaT=alphaT
```

In[431]:=
```
Show[{g7, g10}, PlotRange → All, AxesOrigin → {0., 0.}]
Show[{g8, g11}, PlotRange → All, AxesOrigin → {0., 0.}]
Show[{g9, g12}, PlotRange → All, AxesOrigin → {0., 0.}]
```

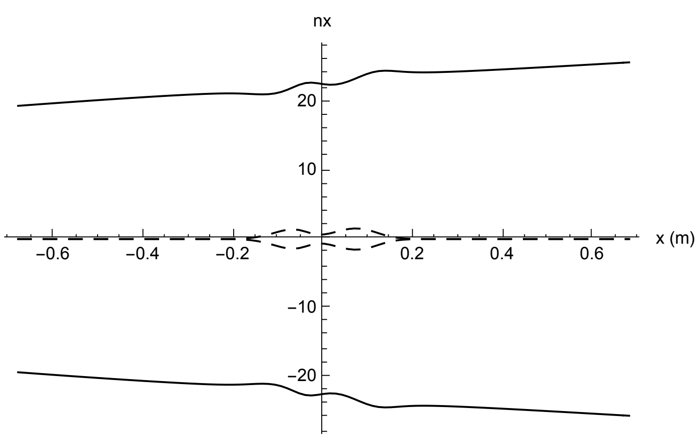
Out[431]=



Out[432]=



Out[433]=



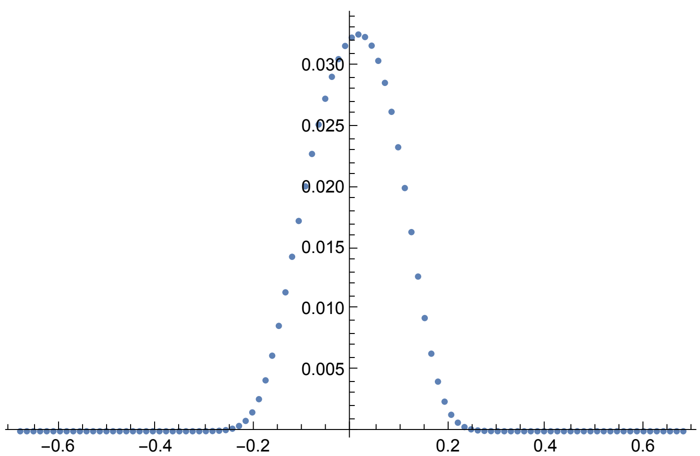
Focus on the damping

In[434]:=
```
nxhotIm[iRoot_] := Module[{iRoot0, nxWarm, rootsWarm, nxH, x0, ne, b, t, TL},
  nxWarm = Table[Flatten[{x, nPerpWarm6[x]}], {x, xmin, xmax, (xmax - xmin)/(nPoints - 1)}];
  iRoot0 = iRoot;
  rootsWarm = rootSort[nxWarm];
  nxH = Table[0., {i, 1, nPoints}];
  Do[
   (x0 = xmin + (i - 1) (xmax - xmin)/(nPoints - 1);
    nxGuess = rootsWarm[[i]][[iRoot0 + 1]];
    (*Print["x0 = ", x0," nxGuess= ",nxGuess];*)
    nxH[[i]] = {x0, Im[nPerpHot[x0, nxGuess]]};), {i, 1, nPoints}];
  nxH];
```

X - mode

In[435]:=
```
ListPlot[nxhotIm[1], PlotRange → All]
```

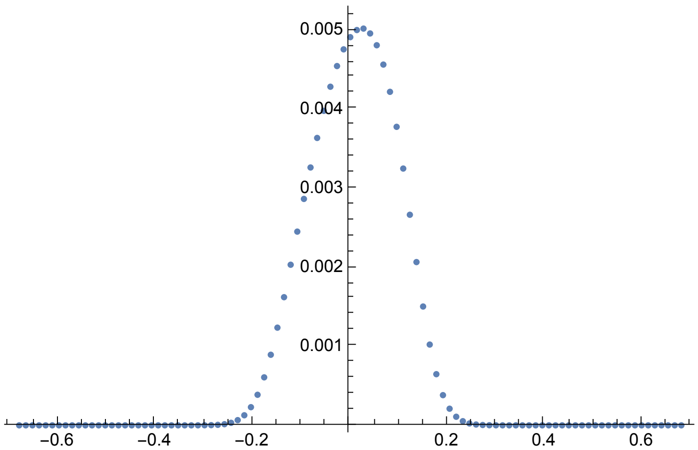
Out[435]=



O - mode

In[436]:= `ListPlot[nxhotIm[2], PlotRange → All]`

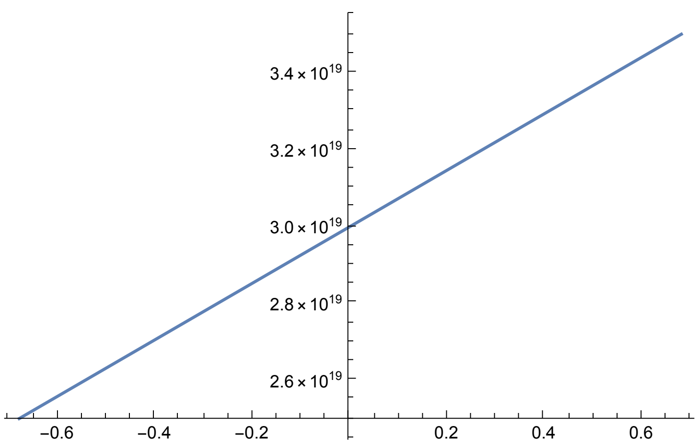
Out[436]=



Plot Profiles

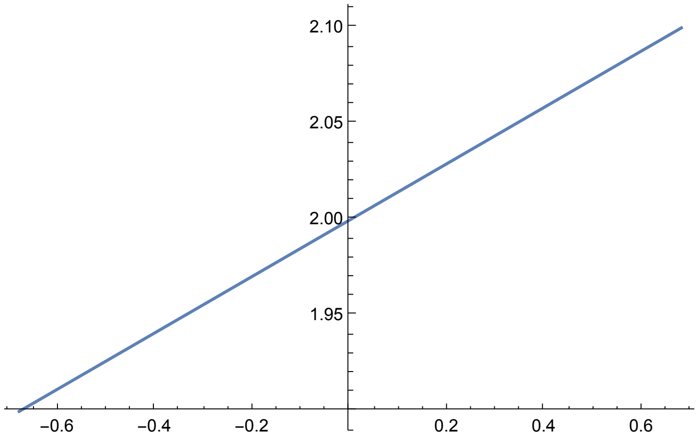
In[340]:= `Plot[nprof[x], {x, xmin, xmax}]`

Out[340]=



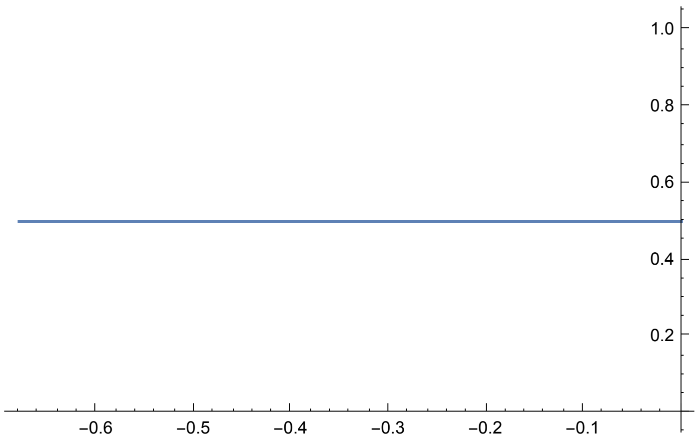
In[341]:=
```
Plot[bprof[x], {x, xmin, xmax}]
```

Out[341]=



In[187]:=
```
Plot[tprof[x], {x, xmin, xmax}]
```

Out[187]=



Initialization

Magnetic field,Density and Temperature Profiles

In[188]:=
```
bprof[x_] := If[Abs[(BXmax - BXmin) / BXmax] > 10^-6,
   BXmin + (x - xProfileMin) / (xProfileMax - xProfileMin) (BXmax - BXmin), BXmin];
```

In[189]:=
```
nprof[x_] := If[Abs[(nXmax - nXmin) / nXmax] > 10^-6,
   nXmin + (x - xProfileMin) / (xProfileMax - xProfileMin) (nXmax - nXmin), nXmin];
```

In[190]:=
```
tprof[x_] := If[Abs[(TXmax - TXmin) / TXmax] > 10^-6,
   TXmin + (x - xProfileMin) / (xProfileMax - xProfileMin) (TXmax - TXmin), TXmin];
```