Check Root Finders nx(nz)

Open Additional files:

Get dispersion routines by evaluating Disper_no_package.nb
Get plotting and printing routines by evaluating PlotPack.nb

Data

```
dataSet = "GDC";
```

RF Parameters

```
freq = 7.5;
c = 3. × 10^8;
k0 = (2 N[π] freq 10^6)/c;
kz = 20;
nz = kz / k0;
```

Plasma Parameters

```
ne0 = 2.0 × 10^20;
B0 = 1.2;
etaList = Table[0., {i, 1, 5}];
etaList[[1]] = 0.; etaList[[2]] = 1.; etaList[[3]] = 0.0;
etaList[[4]] = 0.; etaList[[5]] = 0.;

TList = Table[0., {i, 1, 6}];
TList[[1]] = 0.006; TList[[2]] = .0;
TList[[3]] = 0.006 ; TList[[4]] = 0.;
TList[[5]] = 0.; TList[[6]] = 0.;

modelList = Table[0, {i, 1, 6}];
modelList[[1]] = 1; modelList[[2]] = 1;
modelList[[3]] = 1; modelList[[4]] = 0;
modelList[[5]] = 0; modelList[[6]] = 0;

nminList = Table[0., {i, 1, 6}];
nminList[[1]] = -1; nminList[[2]] = -2;
nminList[[3]] = -2; nminList[[4]] = -2;
nminList[[5]] = -2; nminList[[6]] = -2;

nmaxList = Table[0., {i, 1, 6}];
nmaxList[[1]] = 1; nmaxList[[2]] = 2;
nmaxList[[3]] = 2; nmaxList[[4]] = 2;
nmaxList[[5]] = 2;
nmaxList[[6]] = 2;
```

Find Roots

Cold Plasma

```
rootsCold = ColdDis2FS[freq, ne0, B0, nz, etaList]
paramPrint[{dataSet, ne0, B0, freq, nz, etaList}];
```

```
{155.418, 0. + 16 053.1 i}
```

```
dataSet=GDC
ne0=2. × 10^20
B0=1.2
freq=7.5
nz=127.324
etaList={0., 1., 0., 0., 0.}
```

Warm Plasma (6th order system solved with NSolve)

```
rootsWarm = WarmDis6[freq, ne0, B0, nz, etaList, TList]
paramPrint[{dataSet, ne0, B0, freq, nz, etaList, TList}];
```

```
{153.33 + 0.478592 i, 2235.95 + 13.7363 i, 3990.31 + 594.599 i,
 - 153.33 - 0.478592 i, - 2235.95 - 13.7363 i, - 3990.31 - 594.599 i}
```

```
dataSet=GDC
ne0=2. × 10^20
B0=1.2
freq=7.5
nz=127.324
etaList={0., 1., 0., 0., 0.}
TList={0.6, 0., 0.6, 0., 0., 0.}
```

Warm Plasma (6th order system solved with FindRoot i.e. all species modelList=1)

```
rootsWarm = WarmDis6[freq, ne0, B0, nz, etaList, TList]
model1 = Table[1, {i, 1, 6}];
FindRoot[DisFuncGeneral[freq, ne0, B0, nz, nx, etaList, TList,
  nminList, nmaxList, model1], {nx, rootsWarm[[1]]}, MaxIterations -> 30]
FindRoot[DisFuncGeneral[freq, ne0, B0, nz, nx, etaList, TList, nminList,
  nmaxList, model1], {nx, rootsWarm[[2]]}, MaxIterations -> 30]
FindRoot[DisFuncGeneral[freq, ne0, B0, nz, nx, etaList, TList, nminList,
  nmaxList, model1], {nx, rootsWarm[[3]]}, MaxIterations -> 30]
FindRoot[DisFuncGeneral[freq, ne0, B0, nz, nx, etaList, TList, nminList,
  nmaxList, model1], {nx, rootsWarm[[4]]}, MaxIterations -> 30]
FindRoot[DisFuncGeneral[freq, ne0, B0, nz, nx, etaList, TList, nminList,
  nmaxList, model1], {nx, rootsWarm[[5]]}, MaxIterations -> 30]
FindRoot[DisFuncGeneral[freq, ne0, B0, nz, nx, etaList, TList, nminList,
  nmaxList, model1], {nx, rootsWarm[[6]]}, MaxIterations -> 30]
paramPrint[{dataSet, ne0, B0, freq, nz, etaList, TList, modelList}];
```

```
{153.33 + 0.478592 i, 2235.95 + 13.7363 i, 3990.31 + 594.599 i,
 -153.33 - 0.478592 i, -2235.95 - 13.7363 i, -3990.31 - 594.599 i}
```

```
{nx → 153.33 + 0.478592 i}
```

```
{nx → 2235.95 + 13.7363 i}
```

```
{nx → 3990.31 + 594.599 i}
```

```
{nx → -153.33 - 0.478592 i}
```

```
{nx → -2235.95 - 13.7363 i}
```

```
{nx → -3990.31 - 594.599 i}
```

```
dataSet=GDC
```

```
ne0=2. × 10^20
```

```
B0=1.2
```

```
freq=7.5
```

```
nz=127.324
```

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

```
TList={0.6, 0., 0.6, 0., 0., 0.}
```

```
modelList={1, 1, 1, 0, 0, 0}
```

Hot Plasma (Full Maxwellian system solved with FindRoot i.e. all species modelList=2)

```
rootsWarm = WarmDis6[freq, ne0, B0, nz, etaList, TList]
model2 = Table[2, {i, 1, 6}];
FindRoot[DisFuncGeneral[freq, ne0, B0, nz, nx, etaList, TList,
  nminList, nmaxList, model2], {nx, rootsWarm[[1]]}, MaxIterations -> 30]
FindRoot[DisFuncGeneral[freq, ne0, B0, nz, nx, etaList, TList, nminList,
  nmaxList, model2], {nx, rootsWarm[[2]]}, MaxIterations -> 30]
FindRoot[DisFuncGeneral[freq, ne0, B0, nz, nx, etaList, TList, nminList,
  nmaxList, model2], {nx, rootsWarm[[3]]}, MaxIterations -> 30]
FindRoot[DisFuncGeneral[freq, ne0, B0, nz, nx, etaList, TList, nminList,
  nmaxList, model2], {nx, rootsWarm[[4]]}, MaxIterations -> 30]
FindRoot[DisFuncGeneral[freq, ne0, B0, nz, nx, etaList, TList, nminList,
  nmaxList, model2], {nx, rootsWarm[[5]]}, MaxIterations -> 30]
FindRoot[DisFuncGeneral[freq, ne0, B0, nz, nx, etaList, TList, nminList,
  nmaxList, model2], {nx, rootsWarm[[6]]}, MaxIterations -> 30]
paramPrint[{dataSet, ne0, B0, freq, nz, etaList, TList, modelList}];
```

$$\{7202.97 + 21\,065.7\,i,\ 155.317 + 0.00388435\,i,\ 22\,157.7 + 201.984\,i,$$
$$-7202.97 - 21\,065.7\,i,\ -155.317 - 0.00388435\,i,\ -22\,157.7 - 201.984\,i\}$$

$$\{nx \to 7435.6 + 21\,220.7\,i\}$$

$$\{nx \to 155.317 + 0.00388436\,i\}$$

$$\{nx \to 155.317 + 0.00388436\,i\}$$

$$\{nx \to -7435.6 - 21\,220.7\,i\}$$

$$\{nx \to -155.317 - 0.00388436\,i\}$$

$$\{nx \to -155.317 - 0.00388436\,i\}$$

dataSet=GDC

ne0=$2. \times 10^{20}$

B0=1.2

freq=7.5

nz=127.324

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

TList={0.006, 0., 0.006, 0., 0., 0.}

modelList={1, 1, 1, 0, 0, 0}

Look at $k_\perp \rho$. In this case $\Gamma = 1/2 (k_\perp \rho)^2$

```
Do[
 If[TList[[iSpec]] > 0.,
  Print["  species = ", iSpec, "  root = ", iRoot, "  nx = ", rootsWarm[[iRoot]],
   "  Γ= ", Chop[Warmgamma[freq, B, rootsWarm[[iRoot]], TList]][[iSpec]]]],
 {iSpec, 1, 6}, {iRoot, 1, 6}]
```

```
  species = 1  root = 1  nx = 7202.97 + 21065.7 i  Γ= -0.0000912712 + 0.0000706801 i
  species = 1  root = 2  nx = 155.317 + 0.00388435 i  Γ= 5.61848 × 10^-9
  species = 1  root = 3  nx = 22157.7 + 201.984 i  Γ= 0.000114339 + 2.08474 × 10^-6 i
  species = 1  root = 4  nx = -7202.97 - 21065.7 i  Γ= -0.0000912712 + 0.0000706801 i
  species = 1  root = 5  nx = -155.317 - 0.00388435 i  Γ= 5.61848 × 10^-9
  species = 1  root = 6  nx = -22157.7 - 201.984 i  Γ= 0.000114339 + 2.08474 × 10^-6 i
  species = 3  root = 1  nx = 7202.97 + 21065.7 i  Γ= -0.334965 + 0.259396 i
  species = 3  root = 2  nx = 155.317 + 0.00388435 i  Γ= 0.0000206198 + 1.03137 × 10^-9 i
  species = 3  root = 3  nx = 22157.7 + 201.984 i  Γ= 0.419625 + 0.00765101 i
  species = 3  root = 4  nx = -7202.97 - 21065.7 i  Γ= -0.334965 + 0.259396 i
  species = 3  root = 5  nx = -155.317 - 0.00388435 i  Γ= 0.0000206198 + 1.03137 × 10^-9 i
  species = 3  root = 6  nx = -22157.7 - 201.984 i  Γ= 0.419625 + 0.00765101 i
```

Print ε for different models

```
rootsWarm = WarmDis6[freq, ne0, B0, nz, etaList, TList]
nx0 = rootsWarm[[2]];
model = Table[0, {i, 1, 6}];
e0 = EpsGeneral[freq, ne0, B0, nz, nx0,
   etaList, TList, nminList, nmaxList, model, True];
model = Table[1, {i, 1, 6}];
e1 =
   EpsGeneral[freq, ne0, B0, nz, nx0, etaList, TList, nminList, nmaxList, model, True];
model = Table[2, {i, 1, 6}];
e2 =
   EpsGeneral[freq, ne0, B0, nz, nx0, etaList, TList, nminList, nmaxList, model, True];
paramPrint[{dataSet, ne0, B0, freq, nz, nx0, etaList,
    TList, nminList, nmaxList, modelList}];
```

```
{7202.97 + 21065.7 i, 155.317 + 0.00388435 i, 22157.7 + 201.984 i,
 -7202.97 - 21065.7 i, -155.317 - 0.00388435 i, -22157.7 - 201.984 i}
```

```
EpsGeneral    species=1    model for this species =0
```

Eps[i]={14.2858, 14.2858, -2.86721×10^8, -64000.3, 0, 0}

EpsGeneral species=3 model for this species =0

Eps[i]={159398., 159398., -78125.7, 194579., 0, 0}

EpsGeneral species=1 model for this species =1

Eps[i]={14.2858, 3.96741+1.67037 i, -4.18784×10^8+3.12213×10^8 i,
 -6.76343×10^-8-64000.3 i, -3.29909×10^-7, 16149.9+21663.6 i}

EpsGeneral species=3 model for this species =1

Eps[i]={159579.-0.000371902 i, 159555.-0.00160118 i, -78125.6+0.000615636 i,
 0.000907758+194750. i, -41.2051-0.00103051 i, -0.000949915+37.9826 i}

EpsGeneral species=1 model for this species =2

Eps[i]={14.2858, 3.96741+1.67037 i, -4.18784×10^8+3.12213×10^8 i,
 -9.0179×10^-8-64000.3 i, -3.29906×10^-7, 16149.9+21663.6 i}

EpsGeneral species=3 model for this species =2

Eps[i]={159579.-0.00037188 i, 159555.-0.00160093 i, -78125.6+0.000615579 i,
 0.000907675+194750. i, -41.203-0.00103035 i, -0.000949612+37.9786 i}

dataSet=GDC

ne0=2.×10^20

B0=1.2

freq=7.5

nz=127.324

nx0=155.317+0.00388435 i

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

TList={0.006, 0., 0.006, 0., 0., 0.}

nminList={-1, -2, -2, -2, -2, -2}

nmaxList={1, 2, 2, 2, 2, 2}

modelList={1, 1, 1, 0, 0, 0}

```
WarmEpsMaxwell[freq, ne0, B, nz,
 39.47282432290283, etaList, TList, nminList, nmaxList, True]
```

```
Eps full Bessel function, summed over harmonic    species=0
Eps[i]={0.854773, 0.334122, -673584., 0. - 757.899 i, -3.35294×10^-8, 0. + 11.7165 i}
```

```
Eps full Bessel function, summed over harmonic    species=1
Eps[i]={-480.88, -480.72, -366.095, 0. - 233.94 i, -0.0114197, 0. + 0.007001 i}
{-479.025 + 0. i, -479.385 + 2.62666×10^-277 i, -673949. + 4.34288×10^-268 i,
 0. - 991.839 i, -0.0114198 + 0. i, 7.55224×10^-273 + 11.7235 i}
```

```
DisFuncGeneral[freq, ne0, B, nz, 39.47282432290283,
 etaList, TList, nminList, nmaxList, modelList]
-0.00233704 + 1.51472×10^-276 i
```

```
FullDisFunc[freq, ne0, B, nz, 39.47282432290283, etaList, TList, nminList, nmaxList]
-0.00233704 + 1.51472×10^-276 i
```

```
FullDisFunc[freq, ne0, B, nz, 50., etaList, TList, nminList, nmaxList]
```

```
Eps full Bessel function, summed over harmonic    species=0
Eps[i]={0.854773, 0.0193803, -673584., 0. - 757.899 i, -4.24698×10^-8, 0. + 14.8434 i}
```

```
Eps full Bessel function, summed over harmonic    species=1
Eps[i]={-483.015, -482.755, -366.144, 0. - 236. i, -0.0152021, 0. + 0.00772075 i}
-0.463725 + 2.97745×10^-274 i
```

```
FindRoot[DisFuncGeneral[freq, ne0, B, nz, nx, etaList, TList,
  nminList, nmaxList, modelList], {nx, nx0, nx1}, MaxIterations -> 30]
{nx → 39.412}
```

```
FindRoot[DisFuncGeneral[freq, ne0, B, nz, nx, etaList, TList,
  nminList, nmaxList, modelList], {nx, nx0, 1.1 * nx0}, MaxIterations -> 30]
{nx → 39.412}
```