```
In[1]:= Off[General::"spell"]; Off[General::"spell1"];
```

■ The potential energy density from Bombaci01:

```
In[2]:= εA = 2/3 A/n0 ((1 + x0/2) n^2 - (1/2 + x0) (nn^2 + np^2)) /. n → nn + np
```

Out[2]= $$\frac{2A\left((nn+np)^2\left(1+\frac{x0}{2}\right)-(nn^2+np^2)\left(\frac{1}{2}+x0\right)\right)}{3\,n0}$$

```
In[3]:= Teq = ((1 + x3/2) n^2 - (1/2 + x3) (nn^2 + np^2)) n^(σ-1) /. n → nn + np
```

Out[3]= $$(nn+np)^{-1+\sigma}\left((nn+np)^2\left(1+\frac{x3}{2}\right)-(nn^2+np^2)\left(\frac{1}{2}+x3\right)\right)$$

```
In[4]:= εB = 4 B/3/n0^σ T/(1 + 4/3 Bp/n0^(σ-1) T/n/n) /. n → nn + np /. T → T[nn, np]
```

Out[4]= $$\frac{4\,B\,n0^{-\sigma}\,T[nn,np]}{3\left(1+\frac{4\,Bp\,n0^{1-\sigma}\,T[nn,np]}{3\,(nn+np)^2}\right)}$$

```
In[5]:= εC = 4 (Ci + 2 zi) n/5/n0 (2/(2 π)^3 4 π Integrate[k^2 fn[k] g[k], {k, 0, ∞}] +
          2/(2 π)^3 4 π Integrate[k^2 fp[k] g[k], {k, 0, ∞}]) +
        2 (Ci - 8 zi)/5/n0 (nn (2/(2 π)^3 4 π Integrate[k^2 fn[k] g[k], {k, 0, ∞}]) +
          np (2/(2 π)^3 4 π Integrate[k^2 fp[k] g[k], {k, 0, ∞}])) /. n → nn + np
```

Out[5]= $$\frac{4\,(nn+np)\,(Ci+2\,zi)\left(\frac{\int_0^\infty k^2\,fn[k]\,g[k]\,dk}{\pi^2}+\frac{\int_0^\infty k^2\,fp[k]\,g[k]\,dk}{\pi^2}\right)}{5\,n0}+\frac{2\,(Ci-8\,zi)\left(\frac{nn\int_0^\infty k^2\,fn[k]\,g[k]\,dk}{\pi^2}+\frac{np\int_0^\infty k^2\,fp[k]\,g[k]\,dk}{\pi^2}\right)}{5\,n0}$$

Compute the integrals for various forms of g[k]:

BGBD and BPAL:

```
In[6]:= Simplify[Integrate[2/(2 π)^3 4 π k^2 ((1 + k^2/Λ^2)^-1), {k, 0, kf}], {kf > 0, Λ > 0}]
```

Out[6]= $$\frac{\Lambda^2\left(kf-\Lambda\,\mathrm{ArcTan}\left[\frac{kf}{\Lambda}\right]\right)}{\pi^2}$$

Skyrme:

```
In[7]:= Integrate[2/(2 π)^3 4 π k^2 (k^2), {k, 0, kf}]
```

Out[7]= $$\frac{kf^5}{5\,\pi^2}$$

SL:

```
In[8]:= Expand[Simplify[Integrate[2/(2 π)^3 4 π k^2 (1 - k^2/Λ^2), {k, 0, kf}], {kf > 0, Λ > 0}]]
```

Out[8]= $$\frac{kf^3}{3\,\pi^2}-\frac{kf^5}{5\,\pi^2\,\Lambda^2}$$

■ The potential energy density from Das03:

I have rewritten ρ as n, ρn as nn, etc.

```
In[9]:=  ε2AB = Au nn np / n0 + Al / 2 / n0 (nn^2 + np^2) + B / (σ + 1) n^(σ+1) / n0^σ (1 - x δ^2) /.
            δ → 1 - 2 np / (nn + np) /. n → (nn + np)
```

Out[9]= $\frac{\text{Au nn np}}{\text{n0}} + \frac{\text{Al}(\text{nn}^2+\text{np}^2)}{2\,\text{n0}} + \frac{\text{B n0}^{-\sigma}(\text{nn}+\text{np})^{1+\sigma}\left(1-\left(1-\frac{2\,\text{np}}{\text{nn}+\text{np}}\right)^2 \text{x}\right)}{1+\sigma}$

```
In[10]:= intg = (2 / 8 / π^3)^2 4 / 3 π^2 Λ^2
            ((qf - Λ / 2 ArcTan[2 qf / Λ]) 4 (pft^3 + pftp^3) - (3 (pft^2 + pftp^2) + Λ^2 / 2) qf^2 +
              qf^4 + (3 Λ^2 / 4 (pft^2 + pftp^2) + Λ^4 / 8 - 3 / 8 (pft^2 - pftp^2)^2) Log[1 + 4 qf^2 / Λ^2])
```

Out[10]= $\frac{1}{12\pi^4}\left(\Lambda^2\left(\text{qf}^4-\text{qf}^2\left(3(\text{pft}^2+\text{pftp}^2)+\frac{\Lambda^2}{2}\right)+4(\text{pft}^3+\text{pftp}^3)\left(\text{qf}-\frac{1}{2}\Lambda\,\text{ArcTan}\left[\frac{2\,\text{qf}}{\Lambda}\right]\right)+\left(-\frac{3}{8}(\text{pft}^2-\text{pftp}^2)^2+\frac{3}{4}(\text{pft}^2+\text{pftp}^2)\Lambda^2+\frac{\Lambda^4}{8}\right)\text{Log}\left[1+\frac{4\,\text{qf}^2}{\Lambda^2}\right]\right)\right)$

```
In[11]:= ε2C = Simplify[Cl / n0 (intg /. pft → kfn /. pftp → kfn)] +
            Simplify[Cl / n0 (intg /. pft → kfp /. pftp → kfp)] +
            Simplify[Cu / n0 (intg /. pft → kfn /. pftp → kfp)] +
            Simplify[Cu / n0 (intg /. pft → kfp /. pftp → kfn)]
```

Out[11]= $\frac{1}{96\,\text{n0}\,\pi^4}\left(\text{Cl}\,\Lambda^2\left(4\,\text{qf}\,(16\,\text{kfn}^3-12\,\text{kfn}^2\,\text{qf}+2\,\text{qf}^3-\text{qf}\,\Lambda^2)-32\,\text{kfn}^3\,\Lambda\,\text{ArcTan}\left[\frac{2\,\text{qf}}{\Lambda}\right]+(12\,\text{kfn}^2\,\Lambda^2+\Lambda^4)\,\text{Log}\left[1+\frac{4\,\text{qf}^2}{\Lambda^2}\right]\right)\right)+\frac{1}{96\,\text{n0}\,\pi^4}\left(\text{Cl}\,\Lambda^2\left(4\,\text{qf}\,(16\,\text{kfp}^3-12\,\text{kfp}^2\,\text{qf}+2\,\text{qf}^3-\text{qf}\,\Lambda^2)-32\,\text{kfp}^3\,\Lambda\,\text{ArcTan}\left[\frac{2\,\text{qf}}{\Lambda}\right]+(12\,\text{kfp}^2\,\Lambda^2+\Lambda^4)\,\text{Log}\left[1+\frac{4\,\text{qf}^2}{\Lambda^2}\right]\right)\right)+\frac{1}{6\,\text{n0}\,\pi^4}\left(\text{Cu}\,\Lambda^2\left(\text{qf}^4-\frac{1}{2}\text{qf}^2\,(6\,\text{kfn}^2+6\,\text{kfp}^2+\Lambda^2)+2\,(\text{kfn}^3+\text{kfp}^3)\left(2\,\text{qf}-\Lambda\,\text{ArcTan}\left[\frac{2\,\text{qf}}{\Lambda}\right]\right)+\frac{1}{8}\left(-3\,(\text{kfn}^2-\text{kfp}^2)^2+6\,(\text{kfn}^2+\text{kfp}^2)\,\Lambda^2+\Lambda^4\right)\text{Log}\left[1+\frac{4\,\text{qf}^2}{\Lambda^2}\right]\right)\right)$

■ The single particle energy is defined (loosely) by d ε / d n_i. Do the neutron first:

```
In[12]:= en1 = Simplify[D[εA, nn]]
```

Out[12]= $\frac{2\,\text{A}\,(\text{nn}-\text{nn x0}+\text{np}\,(2+\text{x0}))}{3\,\text{n0}}$

```
In[13]:= en2 = Simplify[D[εB, nn]]
```

Out[13]= $\frac{4\,\text{B}\,(\text{nn}+\text{np})\,(8\,\text{Bp n0 T}[\text{nn},\text{np}]^2+3\,\text{n0}^\sigma\,(\text{nn}+\text{np})^3\,\text{T}^{(1,0)}[\text{nn},\text{np}])}{(3\,\text{n0}^\sigma\,(\text{nn}+\text{np})^2+4\,\text{Bp n0 T}[\text{nn},\text{np}])^2}$

```
In[14]:= dTdnn = Simplify[D[Teq, nn]]
```

Out[14]= $\frac{1}{2}(\text{nn}+\text{np})^{-2+\sigma}\left(-\text{nn}^2\,(-1+\text{x3})\,(1+\sigma)+\text{np}^2\,(3-\text{x3}\,(-3+\sigma)+\sigma)+2\,\text{nn np}\,(1+\text{x3}\,(-1+\sigma)+2\,\sigma)\right)$

In[15]:= **en3 = Simplify[D[εC, nn]]**

Out[15]= $$\frac{(6\,\text{Ci} - 8\,\text{zi})\int_0^\infty k^2\,\text{fn}[k]\,g[k]\,dk + 4\,(\text{Ci} + 2\,\text{zi})\int_0^\infty k^2\,\text{fp}[k]\,g[k]\,dk}{5\,\text{n0}\,\pi^2}$$

Now the distribution function part:

In[16]:= **en4 = 4 (Ci + 2 zi) n / 5 / n0 g[k] + 2 (Ci − 8 zi) / 5 / n0 nn g[k] /. n → nn + np**

Out[16]= $$\frac{2\,\text{nn}\,(\text{Ci} - 8\,\text{zi})\,g[k]}{5\,\text{n0}} + \frac{4\,(\text{nn} + \text{np})\,(\text{Ci} + 2\,\text{zi})\,g[k]}{5\,\text{n0}}$$

If C1 and C2 are both non−zero, then:

In[17]:= **en4both = (en4 /. Ci → C1 /. zi → z1) + (en4 /. Ci → C2 /. zi → z2 /. g[k] → g2[k])**

Out[17]= $$\frac{2\,\text{nn}\,(\text{C1} - 8\,\text{z1})\,g[k]}{5\,\text{n0}} + \frac{4\,(\text{nn} + \text{np})\,(\text{C1} + 2\,\text{z1})\,g[k]}{5\,\text{n0}} + \frac{2\,\text{nn}\,(\text{C2} - 8\,\text{z2})\,\text{g2}[k]}{5\,\text{n0}} + \frac{4\,(\text{nn} + \text{np})\,(\text{C2} + 2\,\text{z2})\,\text{g2}[k]}{5\,\text{n0}}$$

As a function of T and its derivatives

In[18]:= **entot = en1 + en2 + en3 + en4**

Out[18]= $$\frac{2\,A\,(\text{nn} - \text{nn}\,\text{x0} + \text{np}\,(2 + \text{x0}))}{3\,\text{n0}} + \frac{2\,\text{nn}\,(\text{Ci} - 8\,\text{zi})\,g[k]}{5\,\text{n0}} + \frac{4\,(\text{nn} + \text{np})\,(\text{Ci} + 2\,\text{zi})\,g[k]}{5\,\text{n0}} + \frac{(6\,\text{Ci} - 8\,\text{zi})\int_0^\infty k^2\,\text{fn}[k]\,g[k]\,dk + 4\,(\text{Ci} + 2\,\text{zi})\int_0^\infty k^2\,\text{fp}[k]\,g[k]\,dk}{5\,\text{n0}\,\pi^2} + \frac{4\,B\,(\text{nn} + \text{np})\,\left(8\,\text{Bp}\,\text{n0}\,T[\text{nn}, \text{np}]^2 + 3\,\text{n0}^\sigma\,(\text{nn} + \text{np})^3\,T^{(1,0)}[\text{nn}, \text{np}]\right)}{\left(3\,\text{n0}^\sigma\,(\text{nn} + \text{np})^2 + 4\,\text{Bp}\,\text{n0}\,T[\text{nn}, \text{np}]\right)^2}$$

In[19]:= **entotboth = en1 + en2 + en3 + en4both**

Out[19]= $$\frac{2\,A\,(\text{nn} - \text{nn}\,\text{x0} + \text{np}\,(2 + \text{x0}))}{3\,\text{n0}} + \frac{2\,\text{nn}\,(\text{C1} - 8\,\text{z1})\,g[k]}{5\,\text{n0}} + \frac{4\,(\text{nn} + \text{np})\,(\text{C1} + 2\,\text{z1})\,g[k]}{5\,\text{n0}} + \frac{2\,\text{nn}\,(\text{C2} - 8\,\text{z2})\,\text{g2}[k]}{5\,\text{n0}} + \frac{4\,(\text{nn} + \text{np})\,(\text{C2} + 2\,\text{z2})\,\text{g2}[k]}{5\,\text{n0}} + \frac{(6\,\text{Ci} - 8\,\text{zi})\int_0^\infty k^2\,\text{fn}[k]\,g[k]\,dk + 4\,(\text{Ci} + 2\,\text{zi})\int_0^\infty k^2\,\text{fp}[k]\,g[k]\,dk}{5\,\text{n0}\,\pi^2} + \frac{4\,B\,(\text{nn} + \text{np})\,\left(8\,\text{Bp}\,\text{n0}\,T[\text{nn}, \text{np}]^2 + 3\,\text{n0}^\sigma\,(\text{nn} + \text{np})^3\,T^{(1,0)}[\text{nn}, \text{np}]\right)}{\left(3\,\text{n0}^\sigma\,(\text{nn} + \text{np})^2 + 4\,\text{Bp}\,\text{n0}\,T[\text{nn}, \text{np}]\right)^2}$$

In[20]:= **entot2 = entot /. T[nn, np] → Teq /. T^(1,0)[nn, np] → dTdnn**

$$\text{Out[20]}= \frac{2\,A\,(nn - nn\,x0 + np\,(2 + x0))}{3\,n0} + \Bigg(4\,B\,(nn + np)\Bigg(8\,Bp\,n0\,(nn + np)^{-2+2\sigma}\left((nn + np)^2\left(1 + \frac{x3}{2}\right) - (nn^2 + np^2)\left(\frac{1}{2} + x3\right)\right)^2 + \frac{3}{2}\,n0^{\sigma}\,(nn + np)^{1+\sigma}\left(-nn^2\,(-1 + x3)\,(1 + \sigma) + np^2\,(3 - x3\,(-3 + \sigma) + \sigma) + 2\,nn\,np\,(1 + x3\,(-1 + \sigma) + 2\,\sigma)\right)\Bigg)\Bigg) \Bigg/ \left(3\,n0^{\sigma}\,(nn + np)^2 + 4\,Bp\,n0\,(nn + np)^{-1+\sigma}\left((nn + np)^2\left(1 + \frac{x3}{2}\right) - (nn^2 + np^2)\left(\frac{1}{2} + x3\right)\right)\right)^2 + \frac{2\,nn\,(Ci - 8\,zi)\,g[k]}{5\,n0} + \frac{4\,(nn + np)\,(Ci + 2\,zi)\,g[k]}{5\,n0} + \frac{(6\,Ci - 8\,zi)\int_0^{\infty} k^2\,fn[k]\,g[k]\,dk + 4\,(Ci + 2\,zi)\int_0^{\infty} k^2\,fp[k]\,g[k]\,dk}{5\,n0\,\pi^2}$$

In[21]:= **entot2both = entotboth /. T[nn, np] → Teq /. T^(1,0)[nn, np] → dTdnn**

$$\text{Out[21]}= \frac{2\,A\,(nn - nn\,x0 + np\,(2 + x0))}{3\,n0} + \Bigg(4\,B\,(nn + np)\Bigg(8\,Bp\,n0\,(nn + np)^{-2+2\sigma}\left((nn + np)^2\left(1 + \frac{x3}{2}\right) - (nn^2 + np^2)\left(\frac{1}{2} + x3\right)\right)^2 + \frac{3}{2}\,n0^{\sigma}\,(nn + np)^{1+\sigma}\left(-nn^2\,(-1 + x3)\,(1 + \sigma) + np^2\,(3 - x3\,(-3 + \sigma) + \sigma) + 2\,nn\,np\,(1 + x3\,(-1 + \sigma) + 2\,\sigma)\right)\Bigg)\Bigg) \Bigg/ \left(3\,n0^{\sigma}\,(nn + np)^2 + 4\,Bp\,n0\,(nn + np)^{-1+\sigma}\left((nn + np)^2\left(1 + \frac{x3}{2}\right) - (nn^2 + np^2)\left(\frac{1}{2} + x3\right)\right)\right)^2 + \frac{2\,nn\,(C1 - 8\,z1)\,g[k]}{5\,n0} + \frac{4\,(nn + np)\,(C1 + 2\,z1)\,g[k]}{5\,n0} + \frac{2\,nn\,(C2 - 8\,z2)\,g2[k]}{5\,n0} + \frac{4\,(nn + np)\,(C2 + 2\,z2)\,g2[k]}{5\,n0} + \frac{(6\,Ci - 8\,zi)\int_0^{\infty} k^2\,fn[k]\,g[k]\,dk + 4\,(Ci + 2\,zi)\int_0^{\infty} k^2\,fp[k]\,g[k]\,dk}{5\,n0\,\pi^2}$$

In[22]:= **Simplify[entot2]**

$$\text{Out[22]}= \frac{2\,A\,(nn - nn\,x0 + np\,(2 + x0))}{3\,n0} + \Bigg(4\,B\,(nn + np)\Bigg(2\,Bp\,n0\,(nn + np)^{-2+2\sigma}\left(nn^2\,(-1 + x3) + np^2\,(-1 + x3) - 2\,nn\,np\,(2 + x3)\right)^2 + \frac{3}{2}\,n0^{\sigma}\,(nn + np)^{1+\sigma}\left(-nn^2\,(-1 + x3)\,(1 + \sigma) + np^2\,(3 - x3\,(-3 + \sigma) + \sigma) + 2\,nn\,np\,(1 + x3\,(-1 + \sigma) + 2\,\sigma)\right)\Bigg)\Bigg) \Bigg/ \left(3\,n0^{\sigma}\,(nn + np)^2 - 2\,Bp\,n0\,(nn + np)^{-1+\sigma}\left(nn^2\,(-1 + x3) + np^2\,(-1 + x3) - 2\,nn\,np\,(2 + x3)\right)\right)^2 + \frac{2\,nn\,(Ci - 8\,zi)\,g[k]}{5\,n0} + \frac{4\,(nn + np)\,(Ci + 2\,zi)\,g[k]}{5\,n0} + \frac{(6\,Ci - 8\,zi)\int_0^{\infty} k^2\,fn[k]\,g[k]\,dk + 4\,(Ci + 2\,zi)\int_0^{\infty} k^2\,fp[k]\,g[k]\,dk}{5\,n0\,\pi^2}$$

Now the proton part:

In[23]:= **ep1 = Simplify[D[εA, np]]**

$$\text{Out[23]}= \frac{2\,A\,(np - np\,x0 + nn\,(2 + x0))}{3\,n0}$$

In[24]:= `ep2 = Simplify[D[εB, np]]`

Out[24]=
$$\frac{4\,B\,(nn+np)\,\left(8\,Bp\,n0\,T[nn,np]^2+3\,n0^{\sigma}\,(nn+np)^3\,T^{(0,1)}[nn,np]\right)}{\left(3\,n0^{\sigma}\,(nn+np)^2+4\,Bp\,n0\,T[nn,np]\right)^2}$$

In[25]:= `dTdnp = Simplify[D[Teq, np]]`

Out[25]=
$$\frac{1}{2}\,(nn+np)^{-2+\sigma}\,\left(-np^2\,(-1+x3)\,(1+\sigma)+nn^2\,(3-x3\,(-3+\sigma)+\sigma)+2\,nn\,np\,(1+x3\,(-1+\sigma)+2\,\sigma)\right)$$

In[26]:= `ep3 = Simplify[D[εC, np]]`

Out[26]=
$$\frac{4\,(Ci+2\,zi)\int_0^{\infty}k^2\,fn[k]\,g[k]\,dk+2\,(3\,Ci-4\,zi)\int_0^{\infty}k^2\,fp[k]\,g[k]\,dk}{5\,n0\,\pi^2}$$

Now the distribution function part:

In[27]:= `ep4 = 4 (Ci + 2 zi) n / 5 / n0 g[k] + 2 (Ci - 8 zi) / 5 / n0 np g[k] /. n → nn + np`

Out[27]=
$$\frac{2\,np\,(Ci-8\,zi)\,g[k]}{5\,n0}+\frac{4\,(nn+np)\,(Ci+2\,zi)\,g[k]}{5\,n0}$$

In[28]:= `ep4both = (ep4 /. Ci → C1 /. zi → z1) + (ep4 /. Ci → C2 /. zi → z2 /. g[k] → g2[k])`

Out[28]=
$$\frac{2\,np\,(C1-8\,z1)\,g[k]}{5\,n0}+\frac{4\,(nn+np)\,(C1+2\,z1)\,g[k]}{5\,n0}+\frac{2\,np\,(C2-8\,z2)\,g2[k]}{5\,n0}+\frac{4\,(nn+np)\,(C2+2\,z2)\,g2[k]}{5\,n0}$$

As a function of T and its derivatives

In[29]:= `eptot = ep1 + ep2 + ep3 + ep4`

Out[29]=
$$\frac{2\,A\,(np-np\,x0+nn\,(2+x0))}{3\,n0}+\frac{2\,np\,(Ci-8\,zi)\,g[k]}{5\,n0}+\frac{4\,(nn+np)\,(Ci+2\,zi)\,g[k]}{5\,n0}+\frac{4\,(Ci+2\,zi)\int_0^{\infty}k^2\,fn[k]\,g[k]\,dk+2\,(3\,Ci-4\,zi)\int_0^{\infty}k^2\,fp[k]\,g[k]\,dk}{5\,n0\,\pi^2}+\frac{4\,B\,(nn+np)\,\left(8\,Bp\,n0\,T[nn,np]^2+3\,n0^{\sigma}\,(nn+np)^3\,T^{(0,1)}[nn,np]\right)}{\left(3\,n0^{\sigma}\,(nn+np)^2+4\,Bp\,n0\,T[nn,np]\right)^2}$$

In[30]:= `eptotboth = ep1 + ep2 + ep3 + ep4both`

Out[30]=
$$\frac{2\,A\,(np-np\,x0+nn\,(2+x0))}{3\,n0}+\frac{2\,np\,(C1-8\,z1)\,g[k]}{5\,n0}+\frac{4\,(nn+np)\,(C1+2\,z1)\,g[k]}{5\,n0}+\frac{2\,np\,(C2-8\,z2)\,g2[k]}{5\,n0}+\frac{4\,(nn+np)\,(C2+2\,z2)\,g2[k]}{5\,n0}+\frac{4\,(Ci+2\,zi)\int_0^{\infty}k^2\,fn[k]\,g[k]\,dk+2\,(3\,Ci-4\,zi)\int_0^{\infty}k^2\,fp[k]\,g[k]\,dk}{5\,n0\,\pi^2}+\frac{4\,B\,(nn+np)\,\left(8\,Bp\,n0\,T[nn,np]^2+3\,n0^{\sigma}\,(nn+np)^3\,T^{(0,1)}[nn,np]\right)}{\left(3\,n0^{\sigma}\,(nn+np)^2+4\,Bp\,n0\,T[nn,np]\right)^2}$$

In[31]:= **eptot2 = eptot /. T[nn, np] → Teq /. T^(0,1)[nn, np] → dTdnp**

Out[31]=
$$\frac{2\,A\,(np - np\,x0 + nn\,(2 + x0))}{3\,n0} + \Bigg(4\,B\,(nn + np)\Bigg(8\,Bp\,n0\,(nn + np)^{-2+2\sigma}\left((nn + np)^2\left(1 + \frac{x3}{2}\right) - (nn^2 + np^2)\left(\frac{1}{2} + x3\right)\right)^2 + \frac{3}{2}\,n0^\sigma\,(nn + np)^{1+\sigma}\,(-np^2\,(-1 + x3)\,(1 + \sigma) + nn^2\,(3 - x3\,(-3 + \sigma) + \sigma) + 2\,nn\,np\,(1 + x3\,(-1 + \sigma) + 2\,\sigma))\Bigg)\Bigg) \Big/ \left(3\,n0^\sigma\,(nn + np)^2 + 4\,Bp\,n0\,(nn + np)^{-1+\sigma}\left((nn + np)^2\left(1 + \frac{x3}{2}\right) - (nn^2 + np^2)\left(\frac{1}{2} + x3\right)\right)\right)^2 + \frac{2\,np\,(Ci - 8\,zi)\,g[k]}{5\,n0} + \frac{4\,(nn + np)\,(Ci + 2\,zi)\,g[k]}{5\,n0} + \frac{4\,(Ci + 2\,zi)\int_0^\infty k^2\,fn[k]\,g[k]\,dk + 2\,(3\,Ci - 4\,zi)\int_0^\infty k^2\,fp[k]\,g[k]\,dk}{5\,n0\,\pi^2}$$

In[32]:= **eptot2both = eptotboth /. T[nn, np] → Teq /. T^(0,1)[nn, np] → dTdnp**

Out[32]=
$$\frac{2\,A\,(np - np\,x0 + nn\,(2 + x0))}{3\,n0} + \Bigg(4\,B\,(nn + np)\Bigg(8\,Bp\,n0\,(nn + np)^{-2+2\sigma}\left((nn + np)^2\left(1 + \frac{x3}{2}\right) - (nn^2 + np^2)\left(\frac{1}{2} + x3\right)\right)^2 + \frac{3}{2}\,n0^\sigma\,(nn + np)^{1+\sigma}\,(-np^2\,(-1 + x3)\,(1 + \sigma) + nn^2\,(3 - x3\,(-3 + \sigma) + \sigma) + 2\,nn\,np\,(1 + x3\,(-1 + \sigma) + 2\,\sigma))\Bigg)\Bigg) \Big/ \left(3\,n0^\sigma\,(nn + np)^2 + 4\,Bp\,n0\,(nn + np)^{-1+\sigma}\left((nn + np)^2\left(1 + \frac{x3}{2}\right) - (nn^2 + np^2)\left(\frac{1}{2} + x3\right)\right)\right)^2 + \frac{2\,np\,(C1 - 8\,z1)\,g[k]}{5\,n0} + \frac{4\,(nn + np)\,(C1 + 2\,z1)\,g[k]}{5\,n0} + \frac{2\,np\,(C2 - 8\,z2)\,g2[k]}{5\,n0} + \frac{4\,(nn + np)\,(C2 + 2\,z2)\,g2[k]}{5\,n0} + \frac{4\,(Ci + 2\,zi)\int_0^\infty k^2\,fn[k]\,g[k]\,dk + 2\,(3\,Ci - 4\,zi)\int_0^\infty k^2\,fp[k]\,g[k]\,dk}{5\,n0\,\pi^2}$$

- **Now express in terms of β to compare with Eq. 71 of Bombaci01 (in the case of BGBD and Bp == 0):**

In[33]:= **npsols = Solve[{(nn - np) / n == β, n == nn + np}, {nn, np}][[1]]**

Out[33]= $\left\{nn \to -\frac{1}{2}\,(-n - n\,\beta),\ np \to -\frac{1}{2}\,n\,(-1 + \beta)\right\}$

In[34]:= **entotβ = Simplify[entot2 /. npsols[[1]] /. npsols[[2]] /. n → u n0 /. B → Bpp / (1 + σ)]**

Out[34]=
$$-\frac{1}{3}\,A\,u\,(-3 + \beta + 2\,x0\,\beta) + \Big(Bpp\,u\,(n0\,u)^\sigma\,\big(2\,Bp\,(n0\,u)^\sigma\,(-3 + (1 + 2\,x3)\,\beta^2)^2 - 3\,n0^\sigma\,u\,((2 + 4\,x3)\,\beta + (1 + 2\,x3)\,\beta^2\,(-1 + \sigma) - 3\,(1 + \sigma))\big)\Big) \Big/ \left((-3\,n0^\sigma\,u + Bp\,(n0\,u)^\sigma\,(-3 + (1 + 2\,x3)\,\beta^2))^2\,(1 + \sigma)\right) + \frac{4}{5}\,u\,(Ci + 2\,zi)\,g[k] + \frac{1}{5}\,u\,(Ci - 8\,zi)\,(1 + \beta)\,g[k] + \frac{(6\,Ci - 8\,zi)\int_0^\infty k^2\,fn[k]\,g[k]\,dk + 4\,(Ci + 2\,zi)\int_0^\infty k^2\,fp[k]\,g[k]\,dk}{5\,n0\,\pi^2}$$

The term involving A:

```
In[35]:= Expand[entotβ /. B → 0 /. Bpp → 0 /. Ci → 0 /. zi → 0]
```

Out[35]= $A\,u - \frac{A\,u\,\beta}{3} - \frac{2}{3} A\,u\,x0\,\beta$

The term involving Bpp:

```
In[36]:= tmp = Simplify[entotβ /. A → 0 /. Ci → 0 /. zi → 0 /. Bp → 0, n0 > 0]
```

Out[36]= $-\frac{Bpp\,u^{\sigma}\,((2+4\,x3)\,\beta + (1+2\,x3)\,\beta^2\,(-1+\sigma) - 3\,(1+\sigma))}{3\,(1+\sigma)}$

```
In[37]:= Simplify[SeriesCoefficient[Series[tmp, {β, 0, 3}], 0]]
```

Out[37]= $Bpp\,u^{\sigma}$

```
In[38]:= Simplify[SeriesCoefficient[Series[tmp, {β, 0, 3}], 1]] β
```

Out[38]= $-\frac{2\,Bpp\,u^{\sigma}\,(1+2\,x3)\,\beta}{3\,(1+\sigma)}$

```
In[39]:= Simplify[SeriesCoefficient[Series[tmp, {β, 0, 3}], 2]] β^2
```

Out[39]= $-\frac{Bpp\,u^{\sigma}\,(1+2\,x3)\,\beta^2\,(-1+\sigma)}{3\,(1+\sigma)}$

The terms involving Ci and zi:

```
In[40]:= entotβ /. A → 0 /. Bpp → 0 /. B → 0
```

Out[40]= $\frac{4}{5} u\,(Ci + 2\,zi)\,g[k] + \frac{1}{5} u\,(Ci - 8\,zi)\,(1+\beta)\,g[k] + \frac{(6\,Ci - 8\,zi)\int_0^{\infty} k^2\,fn[k]\,g[k]\,dk + 4\,(Ci + 2\,zi)\int_0^{\infty} k^2\,fp[k]\,g[k]\,dk}{5\,n0\,\pi^2}$

■ Now for the Das03 potential energy density:

```
In[41]:= end1 = D[ε2AB, nn]
```

Out[41]= $\frac{Al\,nn}{n0} + \frac{Au\,np}{n0} + B\,n0^{-\sigma}\,(nn+np)^{\sigma}\left(1 - \left(1 - \frac{2\,np}{nn+np}\right)^2 x\right) - \frac{4\,B\,n0^{-\sigma}\,np\,(nn+np)^{-1+\sigma}\left(1 - \frac{2\,np}{nn+np}\right) x}{1+\sigma}$

Compare with Eq. 3.3:

```
In[42]:= Simplify[
          end1 - (Au np / n0 + Al nn / n0 + B (n / n0)^σ (1 - x δ^2) - x B / (σ + 1) n^(σ+1) / n0^σ (4 δ np / n^2) /.
              δ → 1 - 2 np / (nn + np)) /. n → nn + np, {σ > 0, n0 > 0}]
```

Out[42]= 0

For the terms involving integrals, we just copy the result:

In[43]:= `mintg = 2 / (2 π)^3 π Λ^3 ((pft^2 + Λ^2 - p^2) / 2 / p / Λ Log[((p + pft)^2 + Λ^2) / ((p - pft)^2 + Λ^2)] + 2 pft / Λ - 2 (ArcTan[(p + pft) / Λ] - ArcTan[(p - pft) / Λ]))`

Out[43]=
$$\frac{\Lambda^3 \left(\frac{2\,\text{pft}}{\Lambda} - 2\left(-\text{ArcTan}\left[\frac{p-\text{pft}}{\Lambda}\right] + \text{ArcTan}\left[\frac{p+\text{pft}}{\Lambda}\right]\right) + \frac{(-p^2+\text{pft}^2+\Lambda^2)\,\text{Log}\left[\frac{(p+\text{pft})^2+\Lambda^2}{(p-\text{pft})^2+\Lambda^2}\right]}{2\,p\,\Lambda}\right)}{4\,\pi^2}$$

In[44]:= `end2 = Simplify[2 Cl / n0 mintg /. pft → kfn /. pftp → kfn] + Simplify[2 Cu / n0 mintg /. pft → kfn /. pftp → kfp]`

Out[44]=
$$\frac{1}{2\,\text{n0}\,\pi^2}\left(\text{Cl}\,\Lambda^3\left(\frac{2\,\text{kfn}}{\Lambda} - 2\left(\text{ArcTan}\left[\frac{\text{kfn}-p}{\Lambda}\right] + \text{ArcTan}\left[\frac{\text{kfn}+p}{\Lambda}\right]\right) + \frac{(\text{kfn}^2 - p^2 + \Lambda^2)\,\text{Log}\left[\frac{(\text{kfn}+p)^2+\Lambda^2}{(\text{kfn}-p)^2+\Lambda^2}\right]}{2\,p\,\Lambda}\right)\right) + \frac{1}{2\,\text{n0}\,\pi^2}\left(\text{Cu}\,\Lambda^3\left(\frac{2\,\text{kfn}}{\Lambda} - 2\left(\text{ArcTan}\left[\frac{\text{kfn}-p}{\Lambda}\right] + \text{ArcTan}\left[\frac{\text{kfn}+p}{\Lambda}\right]\right) + \frac{(\text{kfn}^2 - p^2 + \Lambda^2)\,\text{Log}\left[\frac{(\text{kfn}+p)^2+\Lambda^2}{(\text{kfn}-p)^2+\Lambda^2}\right]}{2\,p\,\Lambda}\right)\right)$$

In[45]:= `epd1 = D[ε2AB, np]`

Out[45]=
$$\frac{\text{Au nn}}{\text{n0}} + \frac{\text{Al np}}{\text{n0}} + \text{B}\,\text{n0}^{-\sigma}\,(\text{nn}+\text{np})^{\sigma}\left(1 - \left(1 - \frac{2\,\text{np}}{\text{nn}+\text{np}}\right)^2 x\right) - \frac{2\,\text{B}\,\text{n0}^{-\sigma}\,(\text{nn}+\text{np})^{1+\sigma}\left(\frac{2\,\text{np}}{(\text{nn}+\text{np})^2} - \frac{2}{\text{nn}+\text{np}}\right)\left(1 - \frac{2\,\text{np}}{\text{nn}+\text{np}}\right)x}{1+\sigma}$$

In[46]:= `epd2 = Simplify[2 Cl / n0 mintg /. pft → kfp /. pftp → kfp] + Simplify[2 Cu / n0 mintg /. pft → kfp /. pftp → kfn]`

Out[46]=
$$\frac{1}{2\,\text{n0}\,\pi^2}\left(\text{Cl}\,\Lambda^3\left(\frac{2\,\text{kfp}}{\Lambda} - 2\left(\text{ArcTan}\left[\frac{\text{kfp}-p}{\Lambda}\right] + \text{ArcTan}\left[\frac{\text{kfp}+p}{\Lambda}\right]\right) + \frac{(\text{kfp}^2 - p^2 + \Lambda^2)\,\text{Log}\left[\frac{(\text{kfp}+p)^2+\Lambda^2}{(\text{kfp}-p)^2+\Lambda^2}\right]}{2\,p\,\Lambda}\right)\right) + \frac{1}{2\,\text{n0}\,\pi^2}\left(\text{Cu}\,\Lambda^3\left(\frac{2\,\text{kfp}}{\Lambda} - 2\left(\text{ArcTan}\left[\frac{\text{kfp}-p}{\Lambda}\right] + \text{ArcTan}\left[\frac{\text{kfp}+p}{\Lambda}\right]\right) + \frac{(\text{kfp}^2 - p^2 + \Lambda^2)\,\text{Log}\left[\frac{(\text{kfp}+p)^2+\Lambda^2}{(\text{kfp}-p)^2+\Lambda^2}\right]}{2\,p\,\Lambda}\right)\right)$$

■ Now the effective masses are given by:

In[47]:= `mistar / m == (m / k den / dk)^-1`

Out[47]=
$$\frac{\text{mistar}}{m} == \frac{\text{dk}\,k}{\text{den}\,m}$$

In[48]:= `msom1 = Simplify[m D[entot2, k] / k /. npsols[[1]] /. npsols[[2]]]`

Out[48]=
$$\frac{m\,n\,(-8\,\text{zi}\,\beta + \text{Ci}\,(5+\beta))\,g'[k]}{5\,k\,\text{n0}}$$

Compare with Eq. 80 for the neutron effective mass in the case of the BGBD eos:

```
In[49]:= msom1 /. g′[k] → D[(1 + k^2 / Λ1^2)^-1, k] /. k → kfn /. npsols[[1]] /. npsols[[2]] /. n → u n0
```

Out[49]= $$-\frac{2\,m\,u\,(-8\,zi\,\beta + Ci\,(5+\beta))}{5\left(1+\frac{kfn^2}{\Lambda1^2}\right)^2 \Lambda1^2}$$

Use eq. 9 from Bombaci01:

```
In[50]:= Simplify[kfn^2 /. kfn → (3 π^2 / 2 (1 + β) n)^(1/3) /. n → u n0 /. n0 → 2 kf0^3 / 3 / π^2, {β > 1}]
```

Out[50]= $$(kf0^3\,u\,(1+\beta))^{2/3}$$

Examine the effective masses in general for all forms for g[k].
These are $(m^*/m)^{-1} - 1$:

BGBD:

```
In[51]:= {Simplify[m D[entot2, k] / k /. g[k] → (1 + k^2 / Λ^2)^-1 /. g′[k] → D[(1 + k^2 / Λ^2)^-1, k]] /.
    k → kfn, Simplify[
     m D[eptot2, k] / k /. g[k] → (1 + k^2 / Λ^2)^-1 /. g′[k] → D[(1 + k^2 / Λ^2)^-1, k]] /. k → kfp}
```

Out[51]= $$\left\{-\frac{4\,m\,(3\,Ci\,nn + 2\,Ci\,np - 4\,nn\,zi + 4\,np\,zi)\,\Lambda^2}{5\,n0\,(kfn^2+\Lambda^2)^2},\ -\frac{4\,m\,(2\,Ci\,nn + 3\,Ci\,np + 4\,nn\,zi - 4\,np\,zi)\,\Lambda^2}{5\,n0\,(kfp^2+\Lambda^2)^2}\right\}$$

Skyrme:

```
In[52]:= {Simplify[m D[entot2, k] / k /. g[k] → k^2 /. g′[k] → 2 k],
   Simplify[m D[eptot2, k] / k /. g[k] → k^2 /. g′[k] → 2 k]}
```

Out[52]= $$\left\{\frac{4\,m\,(3\,Ci\,nn + 2\,Ci\,np - 4\,nn\,zi + 4\,np\,zi)}{5\,n0},\ \frac{4\,m\,(2\,Ci\,nn + 3\,Ci\,np + 4\,nn\,zi - 4\,np\,zi)}{5\,n0}\right\}$$

BPAL:

```
In[53]:= {Simplify[m D[entot2both, k] / k /. g[k] → (1 + k^2 / Λ1^2)^-1 /. g′[k] → D[(1 + k^2 / Λ1^2)^-1, k] /.
      g2[k] → (1 + k^2 / Λ2^2)^-1 /. g2′[k] → D[(1 + k^2 / Λ2^2)^-1, k]] /. k → kfn,
   Simplify[m D[eptot2both, k] / k /. g[k] → (1 + k^2 / Λ1^2)^-1 /. g′[k] → D[(1 + k^2 / Λ1^2)^-1, k] /.
      g2[k] → (1 + k^2 / Λ2^2)^-1 /. g2′[k] → D[(1 + k^2 / Λ2^2)^-1, k]] /. k → kfp}
```

Out[53]= $$\left\{\frac{1}{5\,n0}\left(4\,m\left(-\frac{nn\,(C1-8\,z1)\,\Lambda1^2}{(kfn^2+\Lambda1^2)^2} - \frac{2\,(nn+np)\,(C1+2\,z1)\,\Lambda1^2}{(kfn^2+\Lambda1^2)^2} - \frac{nn\,(C2-8\,z2)\,\Lambda2^2}{(kfn^2+\Lambda2^2)^2} - \frac{2\,(nn+np)\,(C2+2\,z2)\,\Lambda2^2}{(kfn^2+\Lambda2^2)^2}\right)\right),\right.$$
$$\left.\frac{1}{5\,n0}\left(4\,m\left(-\frac{np\,(C1-8\,z1)\,\Lambda1^2}{(kfp^2+\Lambda1^2)^2} - \frac{2\,(nn+np)\,(C1+2\,z1)\,\Lambda1^2}{(kfp^2+\Lambda1^2)^2} - \frac{np\,(C2-8\,z2)\,\Lambda2^2}{(kfp^2+\Lambda2^2)^2} - \frac{2\,(nn+np)\,(C2+2\,z2)\,\Lambda2^2}{(kfp^2+\Lambda2^2)^2}\right)\right)\right\}$$

SL:

```
In[54]:= slmt = {m D[entot2both, k] / k /. g[k] → (1 - k^2 / Λ1^2) /. g′[k] → D[(1 - k^2 / Λ1^2), k] /.
         g2[k] → (1 + k^2 / Λ2^2)^-1 /. g2′[k] → D[(1 + k^2 / Λ2^2)^-1, k] /. k → kfn,
       m D[eptot2both, k] / k /. g[k] → (1 - k^2 / Λ1^2) /. g′[k] → D[(1 - k^2 / Λ1^2), k] /.
         g2[k] → (1 + k^2 / Λ2^2)^-1 /. g2′[k] → D[(1 + k^2 / Λ2^2)^-1, k] /. k → kfp}
```

Out[54]=
$$\left\{\frac{1}{\text{kfn}}\left(m\left(-\frac{4\,\text{kfn}\,\text{nn}\,(\text{C1}-8\,\text{z1})}{5\,\text{n0}\,\Lambda 1^2}-\frac{8\,\text{kfn}\,(\text{nn}+\text{np})\,(\text{C1}+2\,\text{z1})}{5\,\text{n0}\,\Lambda 1^2}-\frac{4\,\text{kfn}\,\text{nn}\,(\text{C2}-8\,\text{z2})}{5\,\text{n0}\left(1+\frac{\text{kfn}^2}{\Lambda 2^2}\right)^2\Lambda 2^2}-\frac{8\,\text{kfn}\,(\text{nn}+\text{np})\,(\text{C2}+2\,\text{z2})}{5\,\text{n0}\left(1+\frac{\text{kfn}^2}{\Lambda 2^2}\right)^2\Lambda 2^2}\right)\right),\right.$$
$$\left.\frac{1}{\text{kfp}}\left(m\left(-\frac{4\,\text{kfp}\,\text{np}\,(\text{C1}-8\,\text{z1})}{5\,\text{n0}\,\Lambda 1^2}-\frac{8\,\text{kfp}\,(\text{nn}+\text{np})\,(\text{C1}+2\,\text{z1})}{5\,\text{n0}\,\Lambda 1^2}-\frac{4\,\text{kfp}\,\text{np}\,(\text{C2}-8\,\text{z2})}{5\,\text{n0}\left(1+\frac{\text{kfp}^2}{\Lambda 2^2}\right)^2\Lambda 2^2}-\frac{8\,\text{kfp}\,(\text{nn}+\text{np})\,(\text{C2}+2\,\text{z2})}{5\,\text{n0}\left(1+\frac{\text{kfp}^2}{\Lambda 2^2}\right)^2\Lambda 2^2}\right)\right)\right\}$$

■ The effective masses for the Das03 potential:

Only the momentum−dependent part of the interaction contributes.
Again, we calculate $(m^* / m)^{-1} - 1$.

```
In[55]:= Simplify[m D[(end2 /. p → k), k] / k /. k → kfn]
```

Out[55]=
$$-\frac{(\text{Cl}+\text{Cu})\,m\,\Lambda^2\left(-4\,\text{kfn}^2+(2\,\text{kfn}^2+\Lambda^2)\,\text{Log}\left[1+\frac{4\,\text{kfn}^2}{\Lambda^2}\right]\right)}{4\,\text{kfn}^3\,\text{n0}\,\pi^2}$$

```
In[56]:= Simplify[m D[(epd2 /. p → k), k] / k /. k → kfp]
```

Out[56]=
$$-\frac{(\text{Cl}+\text{Cu})\,m\,\Lambda^2\left(-4\,\text{kfp}^2+(2\,\text{kfp}^2+\Lambda^2)\,\text{Log}\left[1+\frac{4\,\text{kfp}^2}{\Lambda^2}\right]\right)}{4\,\text{kfp}^3\,\text{n0}\,\pi^2}$$

■ The effective mass for the form "gbd_form":

```
In[57]:= gin = Λ^2 / π^2 (kfn - Λ ArcTan[kfn / Λ])
```

Out[57]=
$$\frac{\Lambda^2\left(\text{kfn}-\Lambda\,\text{ArcTan}\left[\frac{\text{kfn}}{\Lambda}\right]\right)}{\pi^2}$$

```
In[58]:= gip = Λ^2 / π^2 (kfp - Λ ArcTan[kfp / Λ])
```

Out[58]=
$$\frac{\Lambda^2\left(\text{kfp}-\Lambda\,\text{ArcTan}\left[\frac{\text{kfp}}{\Lambda}\right]\right)}{\pi^2}$$

```
In[59]:= in = Simplify[2 / (2 π)^3 4 π Integrate[k^2 (1 + k^2 / Λ^2)^-1, {k, 0, kf}], {kf > 0, Λ > 0}]
```

Out[59]=
$$\frac{\Lambda^2\left(\text{kf}-\Lambda\,\text{ArcTan}\left[\frac{\text{kf}}{\Lambda}\right]\right)}{\pi^2}$$

```
In[60]:= εx = Cl (nn gn + np gp) / rho0 + Cu (nn gp + np gn) / rho0
```

Out[60]=
$$\frac{\text{Cu}\,(\text{gp}\,\text{nn}+\text{gn}\,\text{np})}{\text{rho0}}+\frac{\text{Cl}\,(\text{gn}\,\text{nn}+\text{gp}\,\text{np})}{\text{rho0}}$$

A hack to calculate the single particle potential

In[61]:= **gbdpotn = D[εx, nn] + (εx /. gp → 0 /. gn → (1 + k^2 / Λ^2)^-1)**

Out[61]= $\frac{\text{Cl gn}}{\text{rho0}}+\frac{\text{Cu gp}}{\text{rho0}}+\frac{\text{Cl nn}}{\text{rho0}\left(1+\frac{k^2}{\Lambda^2}\right)}+\frac{\text{Cu np}}{\text{rho0}\left(1+\frac{k^2}{\Lambda^2}\right)}$

In[62]:= **gbdpotp = D[εx, np] + (εx /. gn → 0 /. gp → (1 + k^2 / Λ^2)^-1)**

Out[62]= $\frac{\text{Cu gn}}{\text{rho0}}+\frac{\text{Cl gp}}{\text{rho0}}+\frac{\text{Cu nn}}{\text{rho0}\left(1+\frac{k^2}{\Lambda^2}\right)}+\frac{\text{Cl np}}{\text{rho0}\left(1+\frac{k^2}{\Lambda^2}\right)}$

$(m^* / m)^{-1} - 1.$

In[63]:= **Simplify[m D[gbdpotn, k] / k /. k → kfn]**

Out[63]= $-\frac{2\,\text{m}\,(\text{Cl nn}+\text{Cu np})\,\Lambda^2}{\text{rho0}\,(\text{kfn}^2+\Lambda^2)^2}$

In[64]:= **Simplify[m D[gbdpotp, k] / k /. k → kfp]**

Out[64]= $-\frac{2\,\text{m}\,(\text{Cu nn}+\text{Cl np})\,\Lambda^2}{\text{rho0}\,(\text{kfp}^2+\Lambda^2)^2}$