Two Thick Lenses in Air

Two thick lenses in air are combined into a single imaging system. Both lenses are 25 mm thick and both lenses have a focal length of 100 mm, however the index of the first lens is 1.6 and the index of the second lens is 1.5. The vertex-to-vertex spacing of the lenses is 50 mm. The principal plane locations for the two individual lenses with respect to surface vertices are shown in the figure. All units are in mm.

\[
\begin{align*}
\text{f}_1 &= 100 \\
\text{t}_1 &= 25 \\
n_1 &= 1.6 \\
\text{Z}_1^P &= 9.38 \\
\text{Z}_1^R' &= -6.90 \\
\text{R}_1 &= \text{R}'_1 \\
\text{f}_2 &= 100 \\
\text{t}_2 &= 25 \\
n_2 &= 1.5 \\
\text{Z}_2^P &= 9.84 \\
\text{Z}_2^R' &= -7.58 \\
\end{align*}
\]

50

**NOTE:** Only Gaussian methods may be used for this problem.

a) Determine the Radii of Curvature of both surfaces of the first lens \((n_1 = 1.6)\).

b) For the system comprised of the two thick lenses, determine:
   - System Focal Length
   - Location of the Rear Principal Plane of the system relative to the rear vertex of the second lens
   - Back Focal Distance
   - Location of the Front Principal Plane of the system relative to the front vertex of the first lens
   - Front Focal Distance
Solution:

(a) Radii of Curvature of the First Lens:

\[
f_1 = 100\, \text{mm} \quad \phi_1 = 0.01\, /\, \text{mm}
\]

\[
t_1 = 25\, \text{mm} \quad n_1 = 1.6 \quad \tau_1 = 15.625\, \text{mm}
\]

\[
\delta_1 = d_1 = \frac{\phi_2}{\phi_1} \tau_1 = 9.38\, \text{mm}
\]

\[
\delta_2 = d_2 = -\frac{\phi_1}{\phi_1} \tau_1 = -6.9\, \text{mm}
\]

\[
\phi_2 = 0.00600\, /\, \text{mm} \quad \phi_{\tau_1} = 0.00442\, /\, \text{mm}
\]

\[
\phi_{z_2} = (1 - n_1) / R'_1 \quad \phi_{z_1} = (n_1 - 1) / R_1.
\]

\[
R'_1 = -100\, \text{mm} \quad R_1 = 135.8\, \text{mm}
\]

(b) System Analysis:

\[
\phi_1 = \phi_2 = 0.01\, /\, \text{mm}
\]

\[
t = P'_1 \rightarrow P_2 = 50 - d_1 + d_2 = 50 + 6.9 + 9.54 = 66.74\, \text{mm}
\]

\[
\phi = \phi_1 + \phi_2 - \phi_1 \phi_2 t = 0.0133\, /\, \text{mm}
\]

\[
f = 1 / \phi = 75.0\, \text{mm} \quad n' = 1
\]
\[ \delta' = d' = -\frac{\phi}{\phi} t = -50.1 \text{mm; (from } P_2') \]

\[ d'_2 = -7.58 \text{mm} \]

\[ V_2'P' = d' + d'_2 = -57.7 \text{mm} \]

\[ BFD = f + d' + d'_2 = 17.3 \text{mm} \]

\[ \delta = d = \frac{\phi}{\phi} t = 50.1 \text{mm} \text{ (from } P_1) \]

\[ d_1 = 9.38 \text{mm} \]

\[ V_1P = d_1 + d = 59.5 \text{mm} \]

\[ FFD = -f + d_1 + d = -15.5 \text{mm} \]