EXAMPLE 3.3

$ORIGIN := 1$

$T := 298 \qquad P := 11.53 \qquad R := 8.314 \cdot 10^{-2}$

$T_c := 365.2 \qquad P_c := 46.0 \qquad \omega := 0.144$

$T_r := \frac{T}{T_c} \qquad P_r := \frac{P}{P_c}$

$$\alpha := \left[1 + \left(0.37464 + 1.54226 \cdot \omega - 0.26992 \cdot \omega^2\right) \cdot \left(1 - \sqrt{T_r}\right)\right]^2$$

$$A := 0.45724 \cdot \left(\frac{P_r}{T_r^{\,2}}\right) \cdot \alpha \qquad B := 0.0778 \cdot \frac{P_r}{T_r}$$

$p := -1 + B \qquad q := A - 3 \cdot B^2 - 2 \cdot B \qquad r := -A \cdot B + B^2 + B^3$

$$M := Z^3 + p \cdot Z^2 + q \cdot Z + r = 0 \quad \left| \begin{array}{l} \text{solve} \\ \text{assume , } Z = \text{real} \end{array} \right. \rightarrow \begin{pmatrix} 0.13413805670776659273 \\ 0.037166908383178117177 \\ 0.8047968136659855498 \end{pmatrix}$$

$ZL := \min(M) = 0.037 \qquad ZV := \max(M) = 0.805$

$VL := \frac{ZL \cdot R \cdot T}{P} = 0.08 \qquad VV := \frac{ZV \cdot R \cdot T}{P} = 1.729$

Alternative Approach

$$root(p, q, r) := \left| \begin{array}{l} v \leftarrow \begin{pmatrix} r \\ q \\ p \\ 1 \end{pmatrix} \\ x \leftarrow \text{polyroots}(v) \\ \text{for } i \in 1 .. 3 \\ \quad x_i \leftarrow 0 \text{ if } \text{Im}(x_i) \neq 0 \\ x1 \leftarrow \max(x) \\ y \leftarrow \min(x) \\ x2 \leftarrow \left| \begin{array}{l} \max(x) \text{ if } y = 0 \\ y \text{ otherwise} \end{array} \right. \\ \begin{pmatrix} x1 \\ x2 \end{pmatrix} \end{array} \right.$$

$$V(T, P) := \begin{bmatrix} T_r \leftarrow \frac{T}{T_c} \\ P_r \leftarrow \frac{P}{P_c} \\ \alpha \leftarrow \left[1 + \left(0.37464 + 1.54226 \cdot \omega - 0.26992 \cdot \omega^2\right) \cdot \left(1 - \sqrt{T_r}\right)\right]^2 \\ A \leftarrow 0.45724 \cdot \left(\frac{P_r}{T_r^{\,2}}\right) \cdot \alpha \\ B \leftarrow 0.0778 \cdot \frac{P_r}{T_r} \\ p \leftarrow -1 + B \\ q \leftarrow A - 2 \cdot B - 3 \cdot B^2 \\ r \leftarrow -A \cdot B + B^2 + B^3 \\ Z_V \leftarrow \text{root}(p, q, r)_1 \\ Z_L \leftarrow \text{root}(p, q, r)_2 \\ V_V \leftarrow \frac{Z_V \cdot R \cdot T}{P} \\ V_L \leftarrow \frac{Z_L \cdot R \cdot T}{P} \\ \begin{pmatrix} V_L \\ V_V \end{pmatrix} \end{bmatrix}$$

$$\begin{pmatrix} V_L \\ V_V \end{pmatrix} := V(298, 11.53) = \begin{pmatrix} 0.08 \\ 1.729 \end{pmatrix}$$