3) The convexity of the 3 securities is given by the following formula:

$$C(0) = \frac{\sum_{i=1}^{n} c_i e^{-y_i T_i} (T_i)^2}{\text{Price}(0)}$$

A simple numerical application (Jupyter) yields:

Convexity_portfolio(0) $\simeq$ 18.29
Convexity_bond1(0) $\simeq$ 41.47
Convexity_bond2(0) $\simeq$ 17.06

b) Using the formula in the course, we need that:

$$\frac{d}{ds}\left(\Pi(s) + q_1 H_1(s) + q_2 H_2(s) \right)\Big|_{s=0} = 0$$

$$\frac{d^2}{ds^2}\left(\Pi(s) + q_1 H_1(s) + q_2 H_2(s) \right)\Big|_{s=0} = 0$$

This system has the following solution:

$$\begin{pmatrix} q_1 \\ q_2 \end{pmatrix} = \begin{pmatrix} -D_{H_1} H_1(0) & -D_{H_2} H_2(0) \\ C_{H_1} H_1(0) & C_{H_2} H_2(0) \end{pmatrix}^{-1} \begin{pmatrix} D_\Pi \Pi(0) \\ -C_\Pi \Pi(0) \end{pmatrix}$$

with Portfolio being Π, Bond 1 H_1 and Bond 2 H_2