The Lagrangian $L(w,\epsilon,\xi,b,\eta,\lambda,\mu,\alpha,\beta,\gamma)$ with $\lambda,\alpha\in\mathbb{R}^p_+$, $\mu,\beta\in\mathbb{R}^q_+$, and $\gamma\in\mathbb{R}_+$ is given by

$$
\begin{aligned}
L(w,\epsilon,\xi,b,\eta,\lambda,\mu,\alpha,\beta,\gamma) &= \frac{1}{2}w^\top w - K_m\eta + K_s\begin{pmatrix}\epsilon^\top & \xi^\top\end{pmatrix}\mathbf{1}_{p+q}\\
&\quad + \begin{pmatrix}w^\top & \begin{pmatrix}\epsilon^\top & \xi^\top\end{pmatrix} & b & \eta\end{pmatrix} C^\top\begin{pmatrix}\lambda\\ \mu\\ \alpha\\ \beta\\ \gamma\end{pmatrix}.
\end{aligned}
$$

Since

$$
\begin{aligned}
\begin{pmatrix}w^\top & \begin{pmatrix}\epsilon^\top & \xi^\top\end{pmatrix} & b & \eta\end{pmatrix} C^\top\begin{pmatrix}\lambda\\ \mu\\ \alpha\\ \beta\\ \gamma\end{pmatrix} &= w^\top X\begin{pmatrix}\lambda\\ \mu\end{pmatrix} - \epsilon^\top(\lambda+\alpha) - \xi^\top(\mu+\beta) + b(\mathbf{1}_p^\top\lambda - \mathbf{1}_q^\top\mu)\\
&\quad + \eta(\mathbf{1}_p^\top\lambda + \mathbf{1}_q^\top\mu) - \gamma\eta,
\end{aligned}
$$

the Lagrangian can be written as

$$
\begin{aligned}
L(w,\epsilon,\xi,b,\eta,\lambda,\mu,\alpha,\beta,\gamma) &= \frac{1}{2}w^\top w - K_m\eta + K_s(\epsilon^\top\mathbf{1}_p + \xi^\top\mathbf{1}_q) + w^\top X\begin{pmatrix}\lambda\\ \mu\end{pmatrix} - \epsilon^\top(\lambda+\alpha)\\
&\quad - \xi^\top(\mu+\beta) + b(\mathbf{1}_p^\top\lambda - \mathbf{1}_q^\top\mu) + \eta(\mathbf{1}_p^\top\lambda + \mathbf{1}_q^\top\mu) - \gamma\eta\\
&= \frac{1}{2}w^\top w + w^\top X\begin{pmatrix}\lambda\\ \mu\end{pmatrix} + (\mathbf{1}_p^\top\lambda + \mathbf{1}_q^\top\mu - K_m - \gamma)\eta\\
&\quad + \epsilon^\top(K_s\mathbf{1}_p - (\lambda+\alpha)) + \xi^\top(K_s\mathbf{1}_q - (\mu+\beta)) + b(\mathbf{1}_p^\top\lambda - \mathbf{1}_q^\top\mu).
\end{aligned}
$$

To find the dual function $G(\lambda,\mu,\alpha,\beta,\gamma)$ we minimize $L(w,\epsilon,\xi,b,\eta,\lambda,\mu,\alpha,\beta,\gamma)$ with respect to w,ϵ,ξ,b, and η. Since the Lagrangian is convex and $(w,\epsilon,\xi,b,\eta)\in\mathbb{R}^n\times\mathbb{R}^p\times\mathbb{R}^q\times\mathbb{R}\times\mathbb{R}$, a convex open set, by Theorem 40.13, the Lagrangian has a minimum in (w,ϵ,ξ,b,η) iff $\nabla L_{w,\epsilon,\xi,b,\eta}=0$, so we compute its gradient with respect to w,ϵ,ξ,b,η, and we get

$$
\nabla L_{w,\epsilon,\xi,b,\eta} = \begin{pmatrix} X\begin{pmatrix}\lambda\\ \mu\end{pmatrix} + w\\ K_s\mathbf{1}_p - (\lambda+\alpha)\\ K_s\mathbf{1}_q - (\mu+\beta)\\ \mathbf{1}_p^\top\lambda - \mathbf{1}_q^\top\mu\\ \mathbf{1}_p^\top\lambda + \mathbf{1}_q^\top\mu - K_m - \gamma\end{pmatrix}.
$$

By setting $\nabla L_{w,\epsilon,\xi,b,\eta}=0$ we get the equations

$$
w = -X\begin{pmatrix}\lambda\\ \mu\end{pmatrix} \tag{$*_w$}
$$