1. [10 pts] Consider the function given below (where \( s = i\omega \)):

\[
T(s) = \frac{s + 5}{10s^4 + 10s^3 + 20s^2 + s + 1}
\]

(1) The amplitude and phase angle (in rad) of \( T(i0.7) \) are

a) \( T = 0.726, \psi = 2.88 \)

b) \( T = 0.726, \psi = -0.264 \)

c) \( T = 1.38, \psi = 2.88 \)

d) \( T = 1.38, \psi = -0.264 \)

(2) The imaginary part of \( T(i0.7) = \text{Re} + i \text{Im} \) is

a) \(- i0.360 \)

b) \( i0.357 \)

c) \(-0.360 \)

d) 0.189

e) \(-0.189 \)
2. [25 pts] A centrifugal pump and its mounting foundation is modeled by a geometrical model shown to the right below. The mass of the rotating part of the pump is \( m \) with its center of gravity, \( e \), offset from the axis of rotation. This unbalance, \( me \), generates a rotating centrifugal force inducing a vertical vibration of the system.

The governing equation of the model is given by

\[
\begin{bmatrix}
    m_1 & 0 \\
    0 & m_2
\end{bmatrix}
\begin{bmatrix}
    \dot{x}_1 \\
    \dot{x}_2
\end{bmatrix}
+
\begin{bmatrix}
    0 & 0 \\
    0 & c_2
\end{bmatrix}
\begin{bmatrix}
    x_1 \\
    x_2
\end{bmatrix}
+
\begin{bmatrix}
    k_1 & -k_1 \\
    -k_1 & k_1 + k_2
\end{bmatrix}
\begin{bmatrix}
    x_1 \\
    x_2
\end{bmatrix}
=
\begin{bmatrix}
    me\omega^2 \cos(\omega t + \alpha) \\
    0
\end{bmatrix}
\]

Let \( m_1 = 350 \) kg, \( m_2 = 800 \) kg, \( me = 0.1 \) kg-m, \( k_1 = 300,000 \) N/m, \( k_2 = 0.5k_1 \), \( c_2 = 25,000 \) N-s/m, \( \omega = 1800 \) rpm and \( \alpha = \pi / 3 \).

(1) The functional expression for the follow-up response of \( x_i(t) \) is given by

a) \( x_i(t) = X_i \sin(\omega t + \psi_i) \)

b) \( x_i(t) = X_i \cos(\omega t + \psi_i) \)

c) \( x_i(t) = X_i e^{i(\omega t + \alpha + \psi_i)} \)

d) \( x_i(t) = X_i \cos(\omega t + \alpha + \psi_i) \)

e) \( x_i(t) = X_i e^{i(\omega t + \psi_i)} \)

(2) Write down the numerical values of the impedance matrix:
The amplitudes of vibrations in meters are

a) \( X_1 = 2.93 \times 10^{-4} \) and \( X_2 = 8.5 \times 10^{-6} \)

b) \( X_1 = 4.27 \times 10^{-4} \) and \( X_2 = 8.5 \times 10^{-6} \)

c) \( X_1 = 2.93 \times 10^{-4} \) and \( X_2 = 3.1 \times 10^{-6} \)

d) \( X_1 = 4.27 \times 10^{-4} \) and \( X_2 = 3.1 \times 10^{-6} \)

The phase shifts (in rad) of the responses from the excitation are

a) \( \psi_1 = 1.57 \) and \( \psi_2 = 1.21 \)

b) \( \psi_1 = -3.14 \) and \( \psi_2 = -1.21 \)

c) \( \psi_1 = 3.14 \) and \( \psi_2 = 0.167 \)

d) \( \psi_1 = -1.57 \) and \( \psi_2 = 2.97 \)

The magnitude of the force transmitted to the soil ground is

a) \( F_{\text{to}} = 14.6 \) N

b) \( F_{\text{to}} = 15.5 \) N

c) \( F_{\text{to}} = 18.7 \) N

d) \( F_{\text{to}} = 22.4 \) N