Diagnostic Ultrasound Imaging: Inside Out by T. L. Szabo
Prerequisites: Read Chapter 3
List of Problems

1. Calculate and plot TF and RF for oblique longitudinal waves in water at the boundary of each of the following media:

MEDIA	C (km/s)	Z (MegaRayls)
water	1.48	1.48
fat	1.45	1.33
muscle	1.63	1.74
Honey	2.03	2.89

Find critical angles for these combinations, if any.

2. Use ABCD matrices to find Z_{in1} for the following (assume $\omega = 2\pi f$):

(a) What value of L_2 will minimize the magnitude of the overall input impedance looking from the left ?

Assume that l is an inductance and C is a capacitance with impedances $i\omega L$ and $-i/(\omega C)$ in the attached figures for this problem.

(b) Find the overall input impedance looking from the left the overall input impedance looking from the left ?
for the second diagram where R is a resistor.

(c) Find the overall input impedance looking from the left for the third diagram.

Find the impedance of a quarter wave layer needed to match a piezoelectric transducer (Z_T =34.2 Mrayls and c_L =4.56 km/s) to tissue (Z_L =1.5 Mrayls). Hint: Assume the left side of the layer is loaded by Z_T and the impedance Z_{IN2} =Z_L. Plot RF at the tissue boundary vs f (0 to $2f_c$). Let the thickness of the layer be $\lambda_c = c_{ml} / 4 f_c$, c_{ml} =3 km/s and f_c = 5 MHz. The TL program is symmetric A=D and can be used either looking to the right zin1 or to the left zin2.

3. Find the stress T and strain S in abbreviated notation for waves in an isotropic medium with the following displacements and describe the wave type: (A and θ_0 are constants)

(a) $u = \hat{x}\sin(\omega t - kz)$

(b) $u = \hat{y}\cos(\omega t - kz - \theta_0)$

(c) $u = \hat{z}\sin\left[A(\omega t - kz)\right]$

4. For an oblique longitudinal water wave incident on the boundary of an isotropic transducer with the following characteristics, find TF and RF

for longitudinal and shear waves at the boundary as a function of incident angle 0:90 deg.: Z_L =34.2 MRayls and c_L =4.56 km/s, Z_{SV} = 22.5 MRayls and c_{SV} =3km/s.

Note: The turns ratios for the transformers are the following:

$$n_L = \left(k_{svz}^2 - k_{svx}^2\right)/k_{sv}^2 = \cos\left(2\theta_{sv}\right)$$

$n_{sv} = \left(2k_{svz}k_{svx}\right)/k_{sv}^2 = \sin\left(2\theta_{sv}\right)$ where k_{svz} is the component of k_{sv} along z , etc.

5. Find the RF's and TF's for problem 5 if a matching layer (Problem 3) for normally incident longitudinal waves is placed between the water and the transducer. The thickness of the matching layer is found at normal incidence and at the center frequency only. Then tl.m is used to find RF(f). Assume that Z_{ml} does not change with angle for calculating the load impedance ($Z_{in} = Z_{ml}^2 / Z_{Load}$ but account for refraction in the matching layer.