[Instructions: Solve the question below. Show all the steps to your solution; you do not have to derive any equations included on the Formula Sheet. Number of points awarded for each question is included in the brackets. Partial marks will be awarded.

You are allowed: a non-communicating calculator, a one-page formula sheet (can be annotated)].

A wave of amplitude A_i is coming from glycerol ($v_{glycerol} = 1900\,\frac{\mathrm{m}}{\mathrm{s}}, \rho_{glycerol} = 1260\,\frac{\mathrm{kg}}{\mathrm{m}^3}$) is incident on a boundary with another, unknown liquid.

a. What is the bulk modulus of the glycerol? [2 points]

$$v = \sqrt{\frac{B}{\rho}} \rightarrow B = v^2\rho = (1900)^2 * (1260) = 4.55\ \mathrm{GPa}$$

1 point for referring to the equation on the sheet; 1 for calculation

b. What is the impedance of the glycerol? [2 points]

$$Z = \sqrt{B\rho} = \rho v$$

$$Z = 2.39 \times 10^6\,\frac{\mathrm{kg}}{\mathrm{m}^2 s}$$

Either equation is ok as both appear on the formula sheet (ρv is hidden in the power formula)

c. After the reflection from the boundary the reflected wave carries 5.6% of the energy of the original and the reflected and incident waves are in phase with each other. Assuming there are no losses, determine the values of the transmission of reflection coefficients for the **energy** of the wave. [2 points]

$$R_e = \frac{P_r}{P_i} = 0.056$$

$$R_e + T_e = 1 \rightarrow T_e = 1 - R_e = 0.944$$

Any solution is ok, somehow energy/power coefficients and energy/power conservation need to be included.

d. What are the transmission and reflection coefficients for the amplitude of the wave? [2 points]

$R^2 = R_e \rightarrow R = \pm\sqrt{R_e} = \pm(0.236)$, choose positive as waves are in phase

$$T = 1 + R = 1.236$$

One point each; two signs need to be considered for R (as it could be positive or negative)

e. Determine the impedance of the unknown liquid [2 points]

Easiest:

$$T_e = \frac{Z_2}{Z_1}T^2 \rightarrow Z_2 = \frac{T_e Z_1}{T^2} = \left(\frac{0.944}{1.236^2}\right) 2.39 \times 10^6 = 1.48 \times 10^6\,\frac{\mathrm{kg}}{\mathrm{m}^2\mathrm{s}}$$

Also possible: $R = \frac{Z_1 - Z_2}{Z_1 + Z_2}; T = (\frac{2Z_1}{Z_1 + Z_2})$