Answers and solution to the exam

1. a) Insert in wave equation and use $\omega = k/c$ to show that equation is satisfied.
b) p-t-plot of a cosine curve with amplitude 0.1 Pa and period T = 1 ms. The sound pressure as a function of time measured by a microphone placed in $x = 0$.
c) p-x-plot of a cosine curve with amplitude 0.1 Pa and period $\lambda = c/f = c\cdot T = 0.34$ m. The sound pressure as a function of location, that could be captured by a snapshot.
d) $p_{eff} = 0.1/\sqrt{2} = 0.0707$ Pa
e) $L_p = 20 \log(p_{eff}/p_{ref}) = 71$ dB

2. a) $\tau = I_t / I_i = 4Z_{air}Z_{water} / (Z_{air}+Z_{water})^2 = 1\cdot10^{-3} = 0.1\ \% \rightarrow 10 \log \tau = -30$ dB
b) $\tau = I_t / I_i = 4Z_{water}Z_{air} / (Z_{water} +Z_{air})^2 = 1\cdot10^{-3} = 0.1\ \% \rightarrow 10 \log \tau = -30$ dB
c) The signal is amplified by means of the relationships between area of eardrum and oval window, and the leverage in the bones in the middle ear.

3. This can be verified by inserting $p_r = 0 \Rightarrow F = 1 \Rightarrow \alpha$ should be 0!

With a 4 in the equation it can be simplified to:
$\alpha = 4F/(1+F)^2 = [\ 2(p_i\text{-}p_r)/(p_i+p_r)\ ] / [\ (2p_i)^2/(p_i+p_r)^2\ ] = 1 - p_r^2/ p_i^2$

and by assuming an incoming and reflected wave: $\alpha = I_a/I_i = 1 - I_r/I_i = 1 - p_r^2/ p_i^2$
i.e, they give the same result.

4. The speed of the travelling wave increases with frequency since it is a bending wave, so the higher frequencies will reach you first, and then the lower. The sound of impact will then be a sound with first a high and then a sinking frequency. If the sound would be travelling in air (longitudinal wave), it would have sounded "Tock" because all frequencies would have reached you at the same time, since c = 340 m/s for all frequencies.

5. $A_1 = 0.16\ V/T_{60} = 4.27\ \text{m}^2\text{S}$

$R - L_s = - L_{m1} + 10\log(S/A_1) = -36+10\log(4\cdot2.5/4.27) = -32.3$ dB (constant)

$10 \log(S/A_2) = R - L_s + L_{m2} = -32.3 + 30 = -2.3$ dB

$A_2 = S\cdot10^{0.23} = 17\ \text{m}^2\text{S} \Rightarrow$ an increase with 12.7 m^{2}S $\Rightarrow$ Absorbents needed $=A_2/\alpha = 18\ \text{m}^2$

6. f = 340 Hz $\Rightarrow \lambda$ = 1 m. Room length is even number of λ in both directions. Pressure maximum (where you here it the most) at $n\cdot\lambda/2$ from the wall = 0, 0.5, 1, 1.5 and 2 m from the wall.
Maximum sound reduction is where the particle velocity is maximal: at $\lambda/4 + n\cdot\lambda/2$ from the wall = 0.25, 0.75, 1.25 and 1.75 m from the wall.