Exam in acoustics 2010-12-17, at 08.00-13.00

Maximum score is 60 p. For passing 30 p is needed.

Grades: grade 3: 30-39p, grade 4: 40-49p, grade 5: 50-60p.

Allowed aids are calculator and formulas.

The tasks are not sorted are difficulty.

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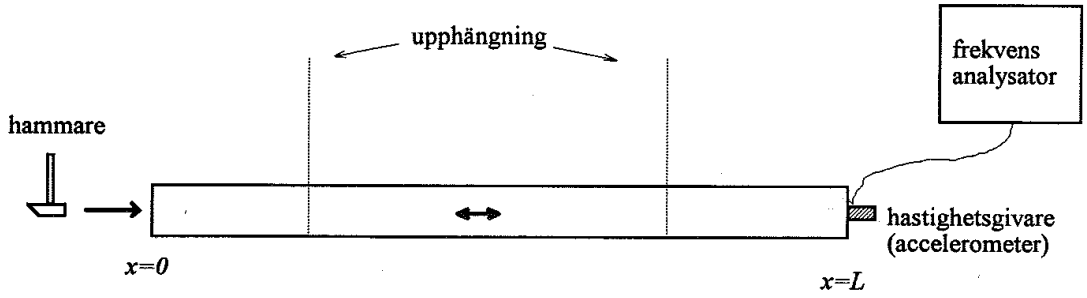
1. A circular steel rod with length L = 1.025 m, diameter d = 0.024 m, density ρ = 7800 kg/m^3 and Young's modulus E = 200 GPa, is hanging ("upphängning") from two strings according to the figure. A hammer ("hammare") is used to knock in one end of the rod and the acceleration is measured in the other end by means of an accelerometer. The signal is registered as a function of time $a(t)$, and there is also the possibility to perform a frequency analysis of the signal ("frekvens analysator") so that you get the frequency content of the acceleration. The rod is free-free, which means that both ends are free of stress and that a wave is reflected without greater loss.



a) Write the wave equation for the longitudinal wave propagation in the rod expressed with stress σ_x. (you do not need to demonstrate or derive, just write) (2 p)

b) Give a harmonic solution and show that it satisfies the wave equation. (2 p)

c) How long from the impact of the hammer at x = 0 does it take until the impact is registered with the accelerometer at $x = L$? (2 p)

d) A certain amount of time later another top in the $a(t)$-signal is shown and then yet another top. How come and what is the time interval between the tops? (2 p)

e) You can either knock at the end of the rod as described above, or on the middle. Which one of the two knocks are loudest for a bystanding person? Explain! (2 p)

2. This is a continuation of the previous task with the same rod, equipment and approach. First you knock at the end and then you register the signal starting a second after the impact and measuring for a few second on. When you analyse the frequency content in the signal you find a number of tops for different frequencies.

a) What do you call the frequencies that you observe here? (2 p)

b) Calculate the frequencies we can be expected to see (the three lowest). (2 p)

c) Calculate the wavelength for the respective frequency in b). (2 p)

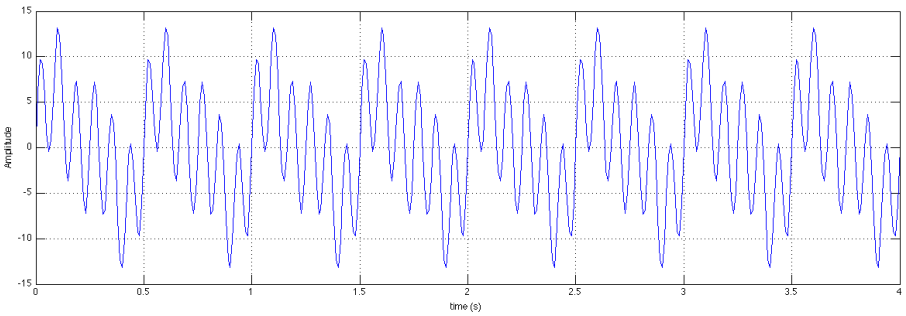
d) Sketch the mode forms to the corresponding frequency in b). (2 p)

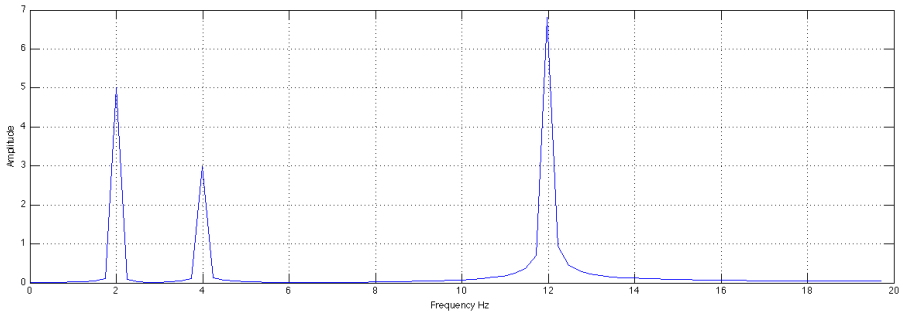
e) Suppose that we replace the hammer with a shaker that can drive the end $x = 0$ with the lowest frequency calculated in b). Is there any location on the rod that is still at all times? (2 p)

3. Take the highest calculated frequency of interest in previous task 2 b).

a) What sampling frequency must be used in order to fulfill the Nyquist criteria? (4 p)

b) In the plots below two curves are presented. What is the relation between them and what mathematical operation has been performed in order to attain the second plot from the first? (6 p)





4. When measuring sound isolation in a wall, pink noise is generated from an emitting room with sound level L_{p1} = 90 dB/octave. Using a sonometer, the sound level L_{p2} is measured in a reception room, where we also measure the reverberation time T_{60}. The measurement is performed in presence of a background noise given in the octave bands L_{p0}. The reception room has the volume V = 40 m^2 and the area of the wall is S = 10 m^2.

f (Hz)	125	250	500	1000	2000	4000
L_{p1} (dB)	90	90	90	90	90	90
L_{p2} (dB)	70	65	60	52	46	40
L_{p0} (dB)	65	60	50	47	40	32
T_{60} (s)	0.9	0.8	0.7	0.6	0.5	0.5

Determine the measured reduction index of the wall and plot in a diagram as a function of frequency. (10 p)

5. A guitar string is clamped in both ends. If you strike with some force on the string a tone with a certain frequency is heard. How is this frequency changed at a doubling of:

a) The string's length (m) (2 p)

b) The string's Youngs modulus (N/m^2) (2 p)

c) The string's length density (kg/m) (2 p)

d) The force of the stroke (N) (2 p)

e) The tensile force in the string (N) (2 p)

Motivate your answers!

6. A sound wave incidents from air to another medium *y* with much higher impedance than air, i.e. $Z_{air} << Z_y$. Calculate:

a) transmission factor *t*, (2 p)

b) transmission coefficient τ (2 p)

c) reflection factor *r* (2 p)

d) reflektion coefficient ρ (2 p)

Explain with words what the parameters above denote.

e) Comment on the result in a): if a sound wave incidents from air to e.g. a hard wall, should it then be any transmission at all? (2 p)

Merry X-mas!