Electrodynamic loudspeakers

Exercise session

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Acoustics and electroacoustics
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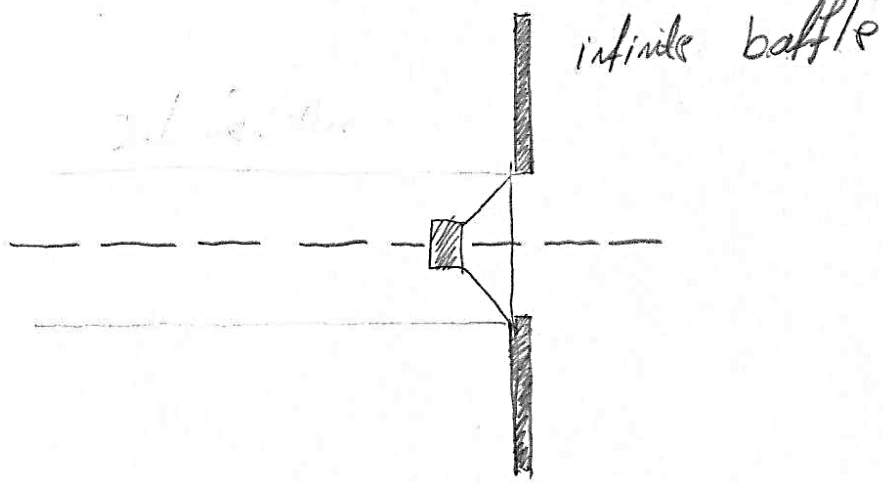
Question 1, « problème 3 » :



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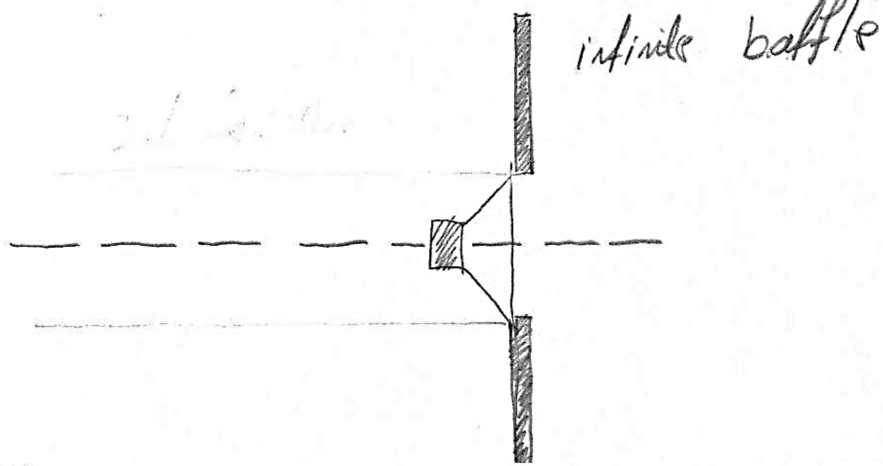

1.1)

$$f_0 = \frac{1}{2\pi \sqrt{\left(m_M + \frac{16}{3}\rho_0 a^3\right) C_M}}$$

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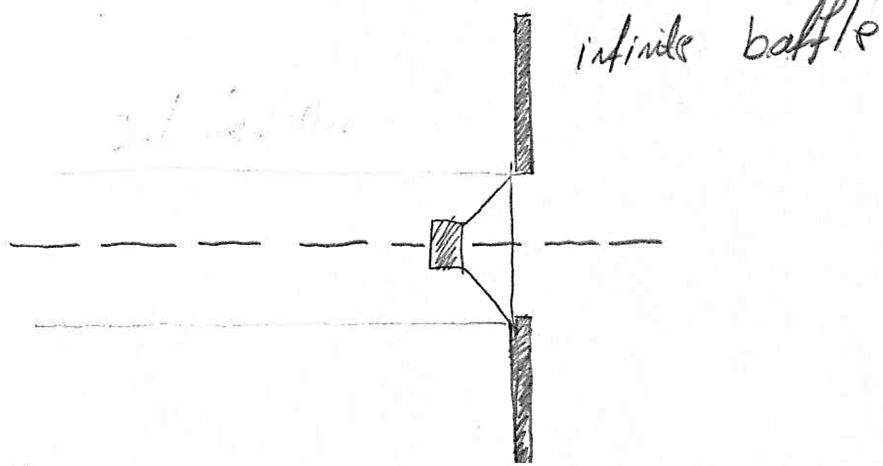

1.1)

$$f_0 = \frac{1}{2\pi\sqrt{(m_M + \frac{16}{3}\rho_0 a^3)\, C_M}}$$

⚠ a is radius ≡ half of the diameter (i.e. $a = 0.1$)

⚠ if $k \cdot$ radius < 0.3 at f_0

$$\Rightarrow \quad f_0 = \frac{1}{2\pi\sqrt{0.015 + 16/3\,(1.2)\,10^{-3}}} = 109\ Hz$$

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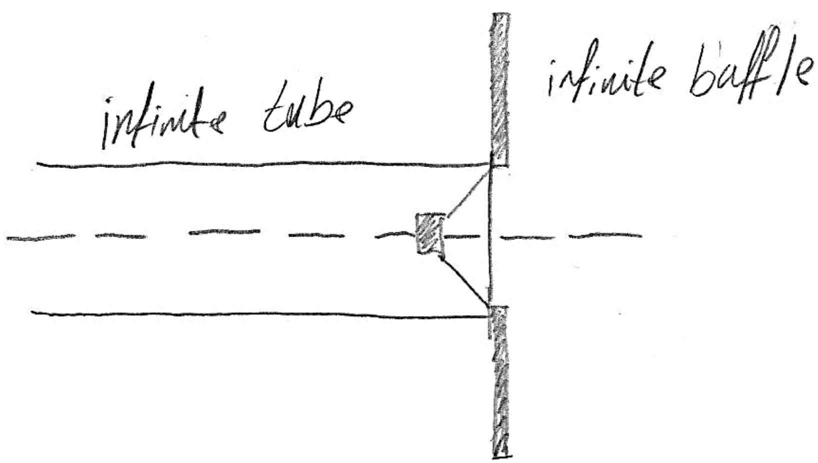

Electroacoustic model

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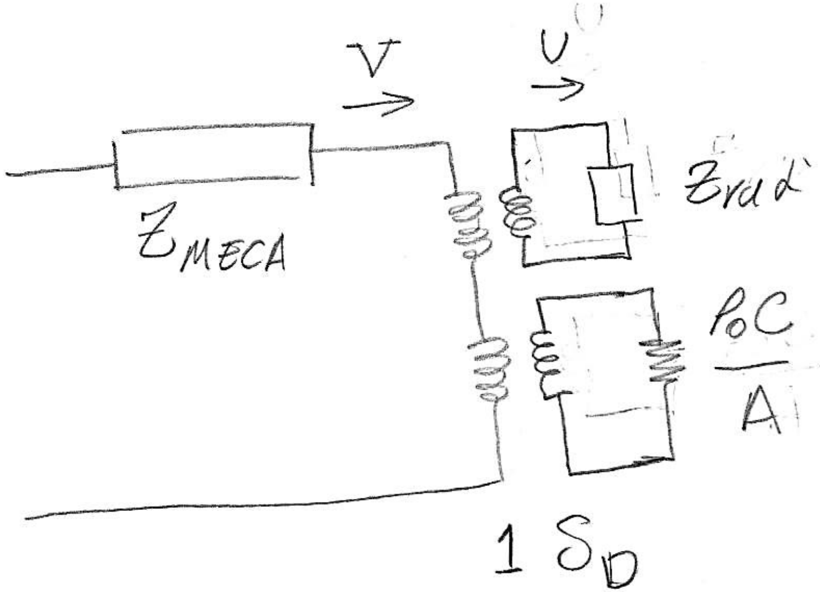
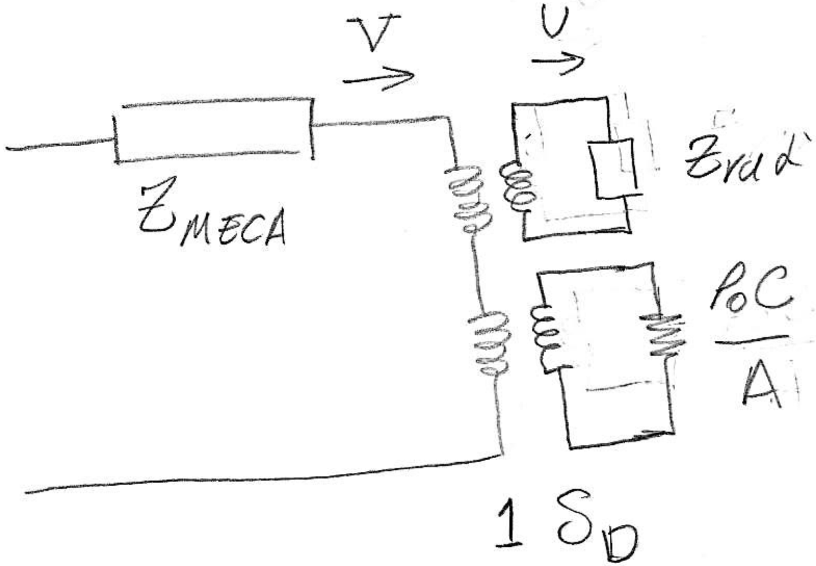


SD : is surface of the membrain

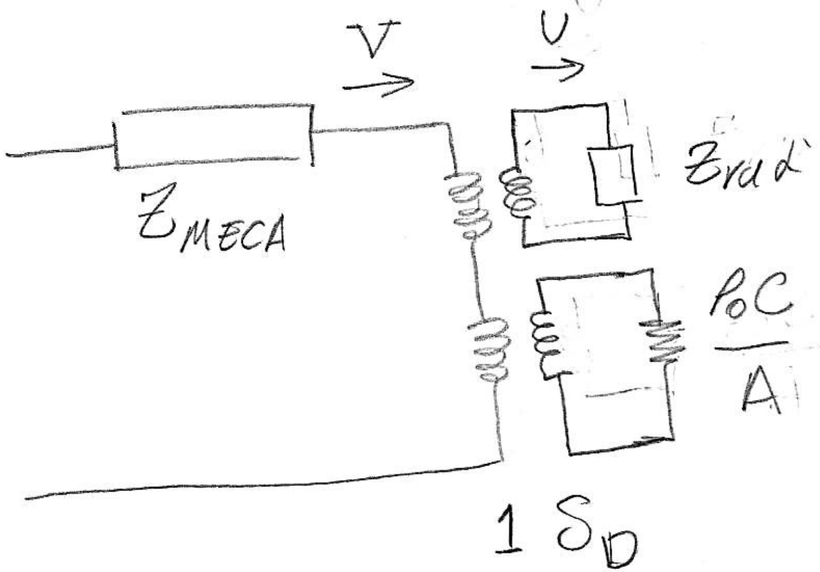
Electroacoustic model



(radiatio impedance in infinite baffle)

S_D : is surface of the membrain

Electroacoustic model



(radiatio impedance in infinite baffle)

A: is the Cross-section of the infinite tube

S_D : is surface of the membrain

With infinte tube, the resonance freq is:

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$$f_0' = \frac{1}{2\pi\sqrt{\left(m_M + \frac{8}{3}\rho_0 a^3\right) C_M}} = 118\ \text{Hz}$$

unchanged

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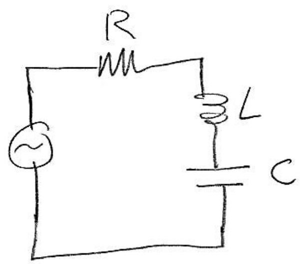
Explanation:

resonance frequency of RLC Circuit



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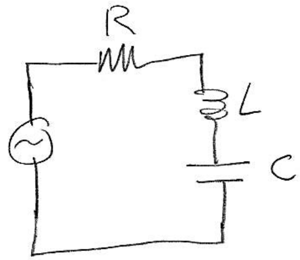

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

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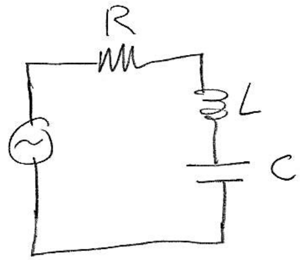

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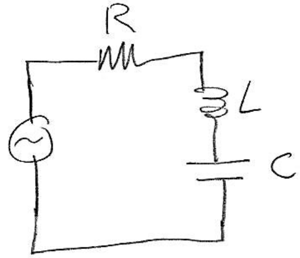

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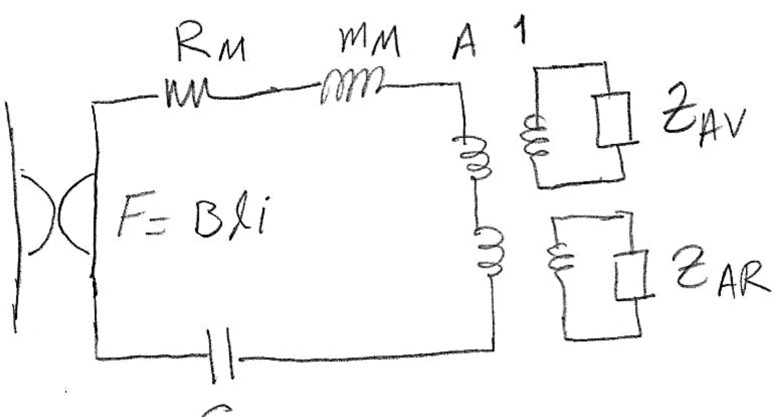
infinite baffle without tube:



$$A^2 Z_{AV} = A^2 Z_{AR}$$

$$= \bigcirc + j\omega \frac{8\rho_0 a^3}{3}$$

$$f_0 = \frac{1}{2\pi\sqrt{ C_M}} \Rightarrow$$

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(Avant)

$$f_0 = \frac{1}{2\pi\sqrt{\left(m_M + \frac{8\rho_0 a^3}{3} + \frac{8\rho_0 a^3}{3}\right) C_M}} \Rightarrow$$

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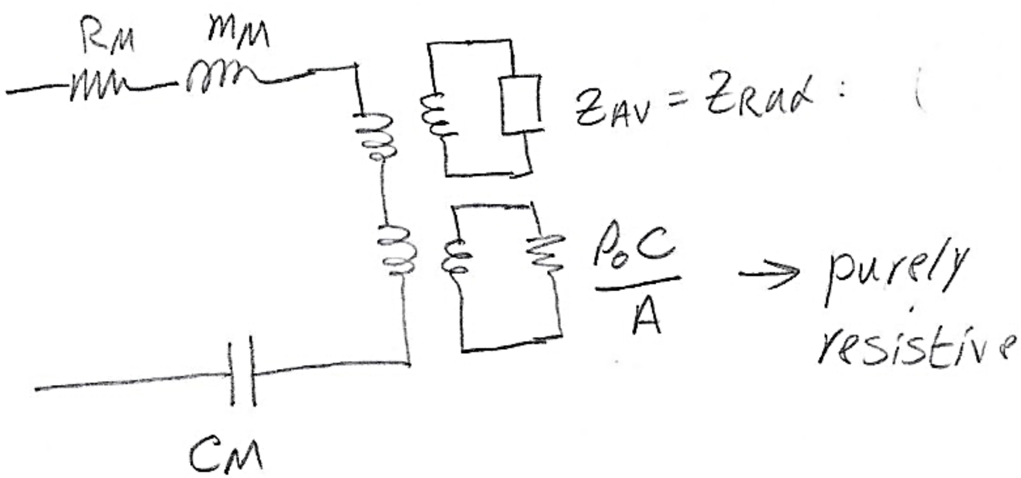
infinite tube and infinite baffle:



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Electroacoustic model at 1 kHz

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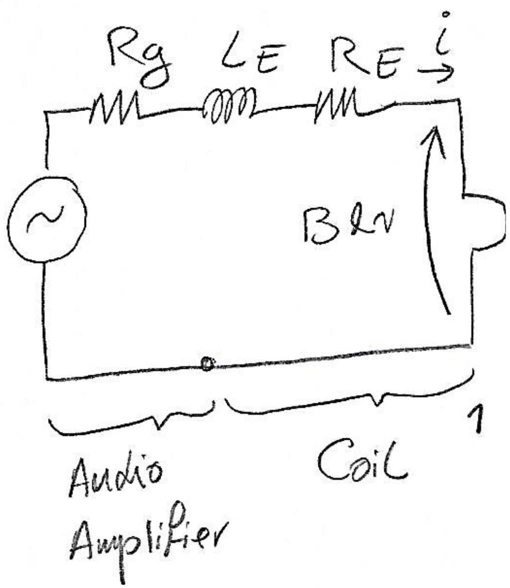

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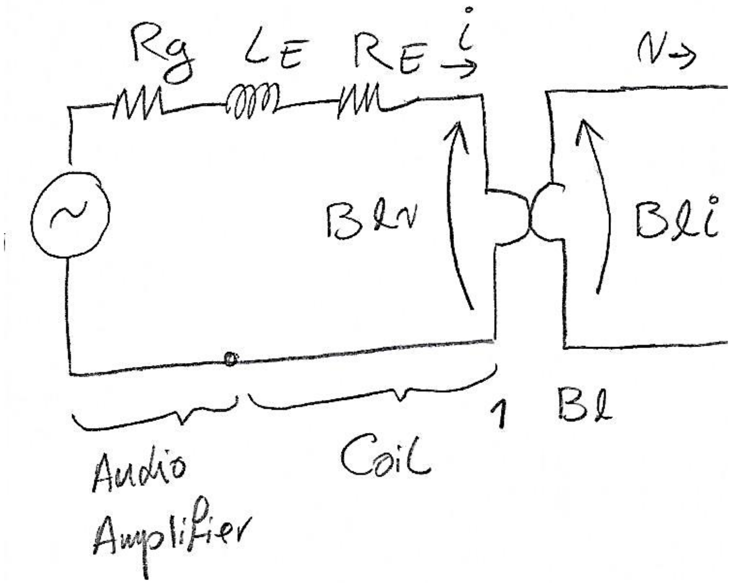

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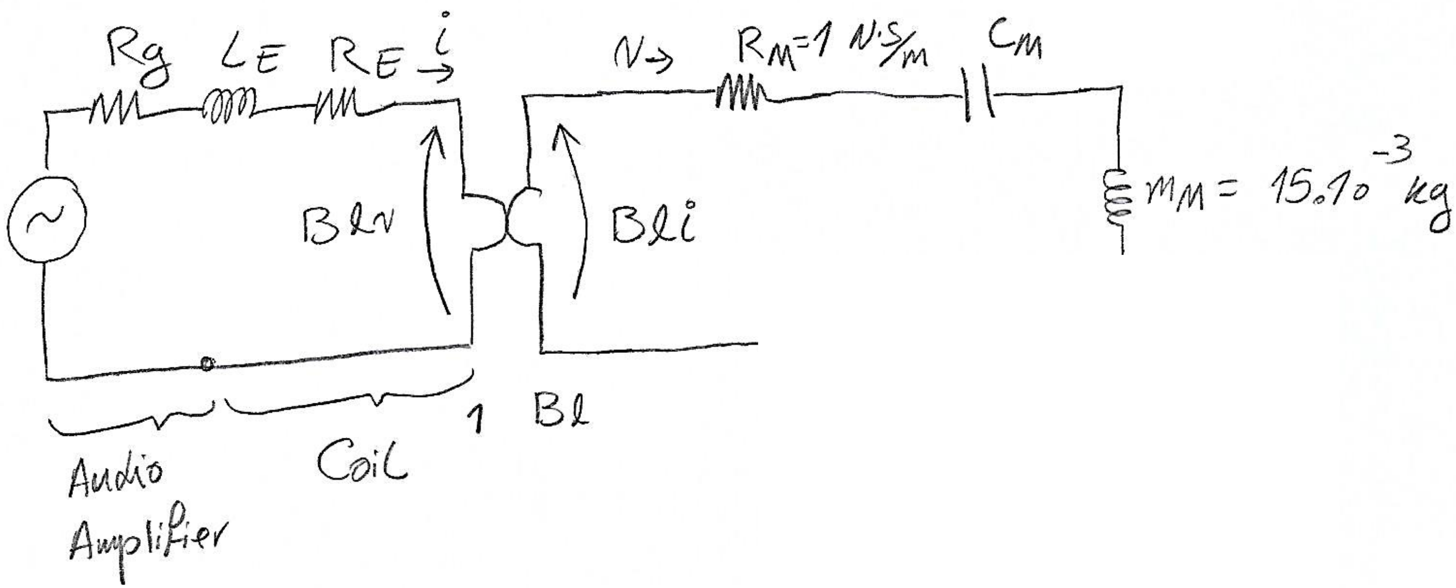

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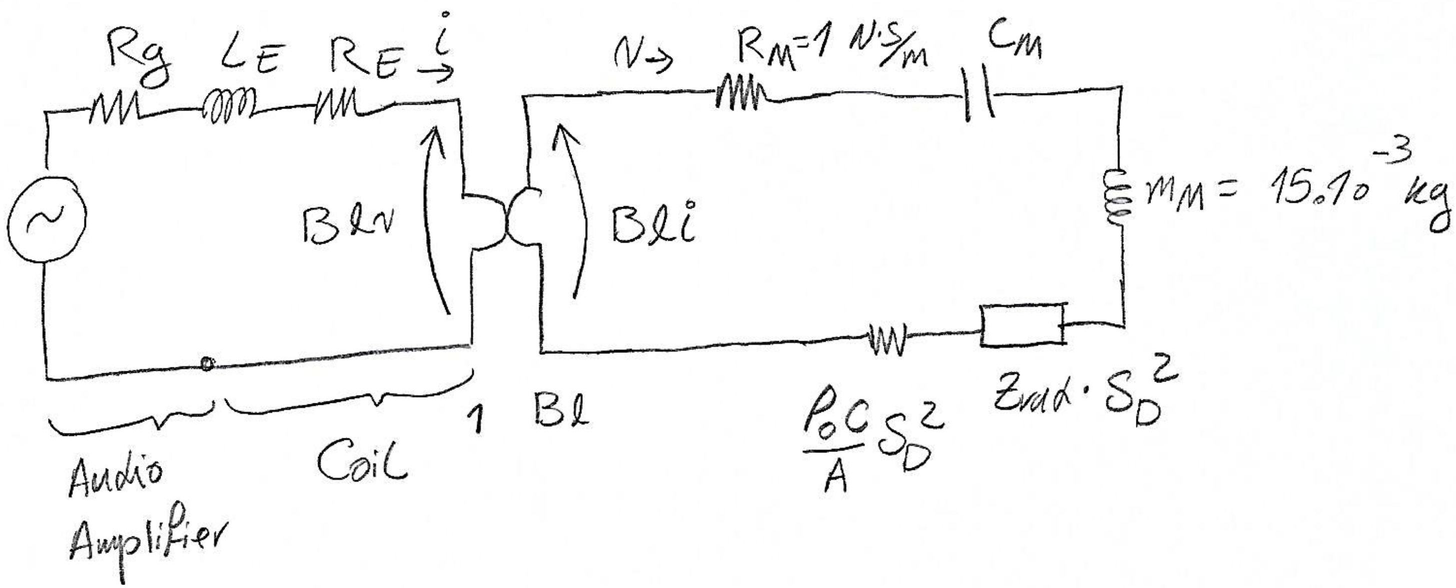

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→ with $R_{MR} = \mathrm{real}\{Z_{rad} S_D^2\}$ if efficency for the radiation by the front side of the membrain only.

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$$\Rightarrow R_{MR} = real\left\{\frac{\rho_0 c}{\pi a^2} \cdot (\pi a^2)^2 (1 + j\,0.6)\right\} = 12.8\ N.s/m$$

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→ with $Z_{MT} = R_M + j\omega m_M + \frac{1}{j\omega C_M} + S_D^2\left(\frac{\rho_0 c}{A} + Z_{Rad}\right)$

↳ total mechanic impedance, including acoustic one

$$\Rightarrow Z_{MT} = 1 + j94.25 + 0 + \rho_0 c(\pi a^2)(1 + 1 + j0.6)$$

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approxi.

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0 → approxi.
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most of the time $\eta < 10\%$

1.5)

$$\left| \frac{p_{rms} @ 1m}{e_{g,rms}} \right| = \frac{\rho_0 \omega}{2\pi} S_D \frac{(Bl)/R_E}{\left| \frac{(Bl)^2}{R_E} + Z_{MT} \right|}$$

if $R_g \simeq 0 \ \Omega$

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$$\simeq 0.35\ Pa/V$$

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if $e_{g,rms} = 1\text{V} \Rightarrow P_{rms}\ @\ 1m = 0.35\ \text{Pa}$

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if $e_{g,rms} = 1V \Rightarrow P_{rms} @ 1m = 0.35$ Pa

$$\Rightarrow P_{rms} @ 4m = \frac{0.35}{4} \ (\sim 73\ dB)$$

↙ ~ spherical wave

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(x = displacement)

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$$= 15\ \mu m \ (\text{rms})$$

Question 2 (Exercise 2):

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Missing Elements:

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$m_M \rightarrow 0.09$ $\quad$ $\frac{16}{3}\rho_0 a^3 \rightarrow 0.0216$

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$$\Rightarrow \boxed{C_M = (7772)^{-1}\ m/N}$$

$$Q_{MS} = 9.8 = \frac{1}{R_{MT}}\sqrt{\frac{m_M + \frac{16}{3}\rho_0 a^3}{C_M}} \Rightarrow$$

$$R_{MT} = R_M + 2\left(\frac{\rho_0 \pi}{2c} a^4 \omega^2\right) \Rightarrow \boxed{R_M \simeq 2.6 \ \frac{N.s}{m}}$$

Other parameters of Electroacustic model are known.

2.2)

$$P_{rms}\Big|_{@1m} = \frac{\rho_0 \omega a^2}{2} \frac{(Bl)\overbrace{(e_{g,rms})}^{=1V}}{R_E\left[\frac{(Bl)^2}{R_E} + Z_{MT}\right]}$$

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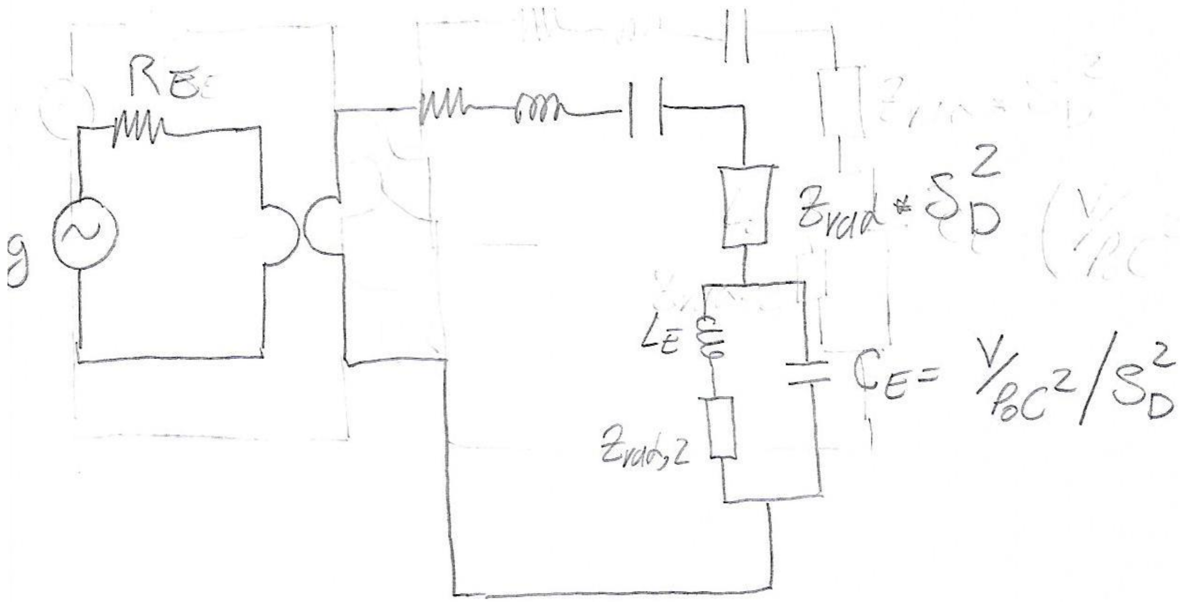
$$= 0.139 \quad (\text{or } 76.9 \ dB)$$

2.3)



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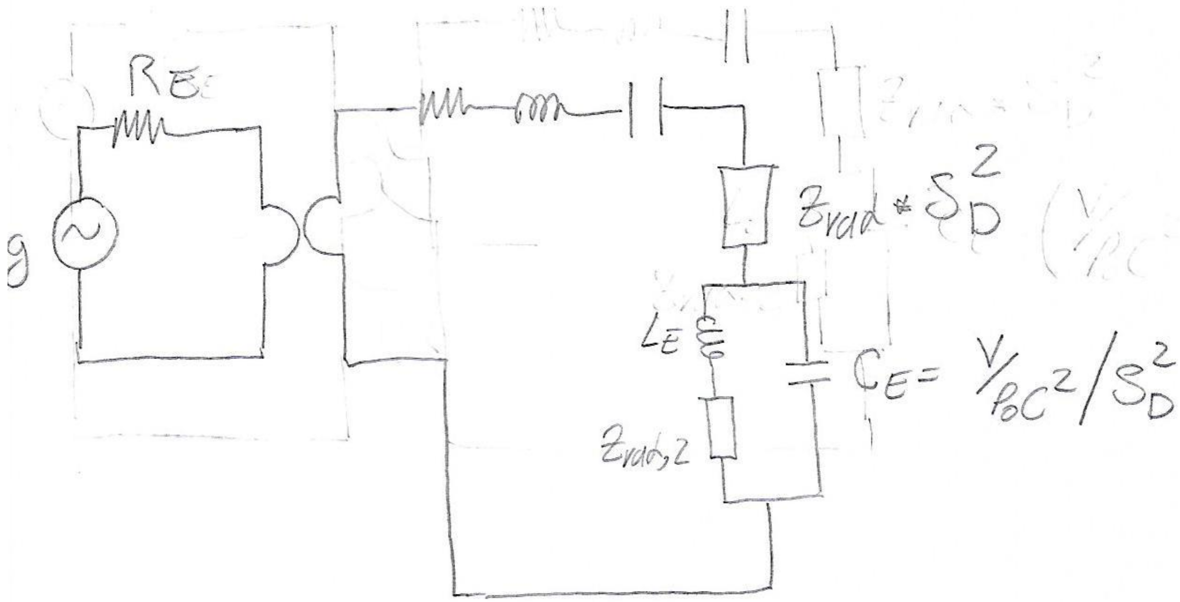

V = volum of the box

$L_E = \left(\frac{\rho_0 l_E}{S_E}\right) S_D^2$ acoustic impedance of the tunnel (vent)

Length : l_E

Cross-Section : S_E

$Z_{rad,2}$: radiation impedance of the vent
(multiplied by S_D^2 in the mechanical part)

↳ imaginary part = $\omega \left(\frac{8}{3} \frac{\rho_0}{\pi^2} \right) \frac{1}{a_E} * S_D^2$

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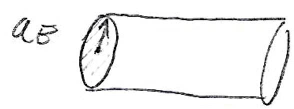

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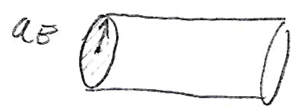

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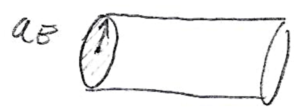

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Several Selection:

eg. if $a_E = 5$ cm

$\Rightarrow S_E = \pi \cdot 25\ cm^2$

$= 0.785\ 10^{-2}\ m^2$

$\Rightarrow l_E = 15$ cm