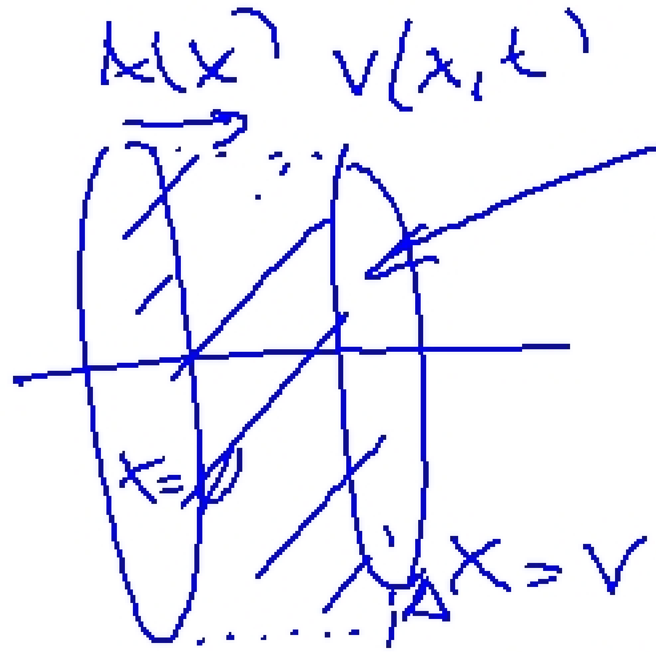
Protok označavamo sa $u(x,t)$

$u(x,t) =$

$v(x,t) \cdot A(x$



$$\Delta V = A(x) \cdot \Delta X = A(x) \cdot v(x,t) \cdot \Delta T$$

$$\Delta X = v(x,t) \cdot \Delta T$$

m^3

$t=0$ $\quad$ $t = 0 + \Delta T$

$$\Delta X = v(x,t) \cdot \Delta T \qquad V = \frac{s}{t} \qquad s = v \cdot t$$

protok $\dfrac{\Delta V}{\Delta T} = A(x) \cdot v(x,t)$

s

$$\frac{\Delta X}{\Delta T} = v(x,t)$$

$$u(x,t) = A(x) \cdot v(x,t)$$

$[m^3/s]$

$x(t) = \sin(\omega t)$ ← kretanje klipa po sinusnom zakonu

$\Delta x \simeq \frac{dx}{dt} \cdot \Delta T$

$\Delta x \simeq \cos(\omega t) \cdot \omega \cdot \Delta T$

brzina protoka volumena zraka po kosinus. zakonu.

$v(x,t) = \frac{\Delta x}{\Delta T} \simeq \cos(\omega t) \cdot \omega$

$u(x,t) \simeq A(x) \cdot \cos(\omega t) \cdot \omega$

const = A

$u(x,t) \doteq A \cos(\omega t) \cdot \omega$

$$A(x,t) = \text{const} \neq f(x)$$
$$\neq f(t)$$

$$L = \frac{\rho}{A} \quad C = \frac{A}{\rho c^2}$$

$$-\frac{\partial p}{\partial x} = \rho \frac{\partial (u/A)}{\partial t} = \ldots = \rho/A \frac{\partial u}{\partial t}$$

$$-\frac{\partial u}{\partial x} = \frac{1}{\rho c^2} \cdot \frac{\partial (pA)}{\partial t} + \frac{\partial A}{\partial t} = \ldots = \frac{A}{\rho c^2} \cdot \frac{\partial p}{\partial t}$$

Linija bez gubitaka L, C ind. i kap. po jed. dui.

$v(x,t)$..napon, $i(x,t)$...struja u

p

$$-\frac{\partial v}{\partial x} = L \frac{\partial i}{\partial t}, \quad -\frac{\partial i}{\partial x} = C \frac{\partial v}{\partial t}$$

$$t - \frac{x}{c} = z(x,t) \quad \ldots \quad \frac{\partial z(x,t)}{\partial t} = 1, \quad \frac{\partial z(x,t)}{\partial x} = -\frac{1}{c}$$

$$t + \frac{x}{c} = w(x,t) \qquad \frac{\partial w(x,t)}{\partial t} = 1 \qquad \frac{\partial w(x,t)}{\partial x} = \frac{1}{c}$$

$$\frac{\partial u^+(z(x,t))}{\partial t} = \frac{\partial u^+}{\partial z} \cdot \frac{\partial z}{\partial t}$$

$$\frac{\partial u^+(z(x,t))}{\partial x} = \frac{\partial u^+}{\partial z} \cdot \frac{\partial z}{\partial x}$$

$$-\frac{\varrho \cancel{c}}{A}\left(\frac{\partial u^+(z)}{\partial z} \cdot \left(-\frac{1}{\cancel{c}}\right) + \frac{\partial u^-(w)}{\partial w} \cdot \left(\frac{1}{\cancel{c}}\right)\right) =$$

$$\frac{\varrho}{A}\left(\frac{\partial u^+(z)}{\partial z}(1) - \frac{\partial u^-(w)}{\partial w}(1)\right)$$

$\cancel{c}$ prct. r.
zad. 1.
par. dif. jed.

Zamislimo da je cijev. pob. sa kompl. exp.

$$u(0,t) = U_G(t) = \underbrace{U_G}_{\text{komp. amp.}} \cdot \underbrace{e^{j\Omega t}}_{\text{komp. exp}}$$

sadrži inf. o amp. i poč. fazi

$$= \underset{\text{modul}}{r} \cdot \underbrace{e^{j\vartheta} \cdot e^{j\Omega t}}_{e^{j(\Omega t + \vartheta)}}$$

$$\cos(\Omega t + \vartheta) + j\sin(\Omega t + \vartheta)$$

fr. (at Ω), poč. faza (at ϑ)

$$u^+\left(t-\frac{x}{c}\right) = K^+ e^{j\Omega\left(t-\frac{x}{c}\right)}$$

ucrtahuc komp. ampl.
ovisuc o x

$$u^-\left(t+\frac{x}{c}\right) = K^- e^{j\Omega\left(t+\frac{x}{c}\right)}$$

$K^+ \ldots K^-$?

Rubu. uvj. $u(0,t) = U_G(t) = U_G \cdot e^{j\Omega t}$

na počijetu

$p(l,t) = \emptyset$ ... idealni kratki spoj.

na kraju

$$u(x,t) = u^{+}\left(t-\frac{x}{c}\right) - u^{-}\left(t+\frac{x}{c}\right)$$

$$= k^{+} e^{j\Omega\left(t-\frac{x}{c}\right)} - k^{-} e^{j\Omega\left(t+\frac{x}{c}\right)}$$

$x=0$

$$u(0,t) = \left(k^{+} - k^{-}\right)\cdot \cancel{e^{j\Omega t}} = U_G \cdot \cancel{e^{j\Omega t}}$$

$$\rightarrow \quad k^{+} - k^{-} = U_G$$

rów. w. na pocz.

$$p(x,t) = \frac{\rho c}{A}\left(u^{+}\left(t-\frac{x}{c}\right) + u^{-}\left(t+\frac{x}{c}\right)\right)$$

$$p(l,t) = \frac{\rho c}{A}\left(k^{+} e^{j\Omega\left(t-\frac{l}{c}\right)} + k^{-} e^{j\Omega\left(t+\frac{l}{c}\right)}\right) = 0$$

$$\left(k^+ \cdot e^{-j\Omega\frac{l}{c}} + k^- e^{+j\Omega\frac{l}{c}}\right) \cdot e^{j\Omega t} = 0$$

$$k^+ e^{-j\Omega\frac{l}{c}} = -k^- e^{+j\Omega\frac{l}{c}}$$

$$\left.\begin{aligned} k^+ &= -k^- \cdot e^{2j\Omega\frac{l}{c}} \\ k^+ - k^- &= U_G \end{aligned}\right\} \quad \begin{aligned} k^- &= -\frac{U_G(\Omega)}{1+e^{j\Omega\frac{2l}{c}}} \\ k^+ &= \frac{U_G(\Omega)\cdot e^{j\Omega\frac{2l}{c}}}{1+e^{j\Omega\frac{2l}{c}}} \end{aligned}$$

$$u(x,t) = u^+\left(t - \frac{x}{c}\right) - u^-\left(t + \frac{x}{c}\right)$$

$$u^+(t) = K^+ \cdot e^{j\Omega t}$$

$$u^+\left(t - \frac{x}{c}\right) = K^+ \cdot e^{j\Omega\left(t - \frac{x}{c}\right)}$$

$$u(x,t) = \frac{U_G e^{j\Omega \frac{2l}{c}} \cdot e^{j\Omega\left(t - \frac{x}{c}\right)} + U_G \cdot e^{j\Omega\left(t + \frac{x}{c}\right)}}{1 + e^{j\Omega \frac{2l}{c}}}$$

$$= U_G e^{j\Omega t} \frac{e^{j\Omega \frac{2l - x}{c}} + e^{j\Omega \frac{x}{c}}}{1 + e^{j\Omega \frac{2l}{c}}} \cdot \frac{e^{-j\Omega \frac{l}{c}}}{e^{-j\Omega \frac{l}{c}}}$$

$$\varphi \qquad \varphi$$

$$= U_G e^{j\Omega t} \frac{e^{j\Omega\left(l - \frac{x}{c}\right)} + e^{-j\Omega\left(l - \frac{x}{c}\right)}}{e^{-j\Omega \frac{l}{c}} + e^{j\Omega \frac{l}{c}}}$$

$$e^{j\varphi} + e^{-j\varphi}$$

$$\varphi_2 \qquad \varphi_2$$

$$u(x,t) = U_G \cdot e^{j\Omega t} \cdot \frac{\cancel{2}\cos\left(\frac{\Omega}{c}(l-x)\right)}{\cancel{2}\cos\left(\frac{\Omega}{c}l\right)}$$

$$= U_G \cdot e^{j\Omega t} \cdot \left(\frac{\cos\left(\frac{\Omega}{c}(l-x)\right)}{\cos\left(\frac{\Omega}{c}l\right)} \right)$$

Što je na kraju cijevi sa $u(x,t)$

$x = l \ldots \; u(l,t) = U_G \cdot e^{j\Omega t} \cdot \frac{1}{\cos\left(\frac{\Omega}{c}l\right)}$

kompl. amp. $\Rightarrow$

ctp. na izlazu.