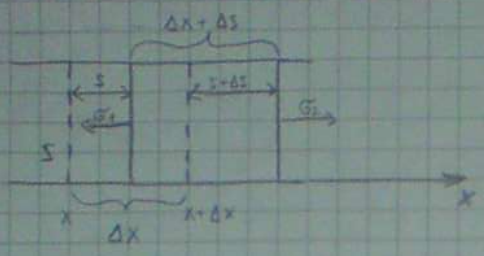
① LONGITUDINALNI VAL U ŠTAPU



- dijelić volumena ΔV debljine Δx

$$\sigma = E\,\varepsilon = E\,\frac{\partial s}{\partial x}$$

naprezanje — rel. deformacija

$$\Delta F = F_1 - F_2 = S(\sigma_1 - \sigma_2) = S\,\Delta\sigma$$

→ za male Δx i Δs $\quad \Delta\sigma = \frac{\partial \sigma}{\partial x}\Delta x$

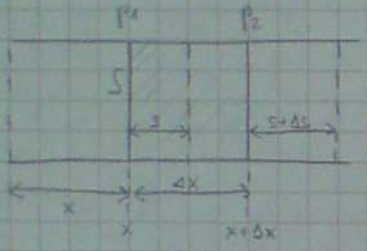
$$\Delta F = S E \frac{\partial^2 s}{\partial x^2}\Delta x \quad \cdot$$

$$\Delta F = \Delta m \cdot a \qquad \Delta m = \rho S \Delta x$$

$$S E \frac{\partial^2 s}{\partial x^2}\Delta x = \rho S \Delta x \frac{\partial^2 s}{\partial t^2} \Rightarrow \boxed{\frac{\partial^2 s}{\partial x^2} - \frac{\rho}{E}\frac{\partial^2 s}{\partial t^2} = 0} \qquad \boxed{v = \sqrt{\frac{E}{\rho}}}$$

② LONGITUDINALNI VAL U PLINU

- okomita cijev



- titranje — mijenjaju se p i ρ ($= \rho(H)$)

$x \quad p$
$x + \Delta x \quad p + \Delta p$ } ΔV se mijenja zbog sile

$$\Delta F = F_1 - F_2 = S p_1 - S p_2 = -S\,\Delta p$$

- promjena V, ρ, ali m ostaje ista

$$\Delta F = \Delta m\, a$$

$$-S\,\Delta p = \rho S \Delta x \frac{\partial^2 s}{\partial t^2} \qquad \boxed{\frac{\partial p}{\partial x} = -\rho \frac{\partial^2 s}{\partial t^2}}$$

$$\Delta p = -B\frac{\Delta V}{V} = -B\frac{S(s+\Delta s - s)}{S\Delta x} = -B\frac{\Delta s}{\Delta x} \qquad \boxed{\Delta p = -B\frac{\partial s}{\partial x}} \quad / \frac{\partial}{\partial x}$$

$$\frac{\partial p}{\partial x} = -B\frac{\partial^2 s}{\partial x^2}$$

$s(x,t) = A \sin(\omega t - kx)$

$d p = \omega^2 \rho A \sin(\omega t - kx)\, dx \quad / \int$

$$\boxed{\frac{\partial^2 s}{\partial x^2} - \frac{\rho}{B}\frac{\partial^2 s}{\partial t^2} = 0} \qquad \boxed{v = \sqrt{\frac{B}{\rho}}} \text{ — volumni modul elast.}$$

$p = p_0 + \rho v \omega A \cos(\omega t - kx)$

$\Delta p_{max} = \rho v \omega A \rightarrow \boxed{\Delta p = \Delta p_{max} \cos(\omega t - kx)}$ $\qquad \boxed{\frac{\partial^2 p}{\partial x^2} - \frac{\rho}{B}\frac{\partial^2 p}{\partial t^2} = 0}$

③ BRZINA ZVUKA

$$B = -V\frac{\Delta p}{\Delta V} = \rho\frac{\Delta p}{\Delta \rho}$$

adijabatski procesi $\quad \boxed{p V^\kappa = \text{const}}$, $\boxed{p = \text{const}\,\rho^\kappa}$ $\quad \kappa$ — adijabatski koef. $\left(\frac{c_p}{c_v}\right)$

$$\boxed{B = -V\frac{dp}{dV} = \rho\frac{dp}{d\rho} = \rho(\text{const}\cdot\kappa\,\rho^{\kappa-1}) = \kappa p}$$

vol. modul el.

$$v = \sqrt{\frac{B}{\rho}} \qquad \boxed{v = \sqrt{\kappa\frac{p}{\rho}}} \text{ — brzina zvuka u plinu}$$

$$pV = \frac{m}{\mu}RT \qquad p = \frac{\rho}{\mu}RT \rightarrow \boxed{v = \sqrt{\kappa\frac{RT}{M}}}$$

kompresivnost $\quad K = -\frac{1}{V}\frac{dV}{dp}$ — kompresibilnost $\qquad \boxed{v = \sqrt{\frac{1}{\rho K}}}$

4) STOJNI LONGITUDINALNI VALOVI

- štap – držimo na sredini – ČVOR
  – slobodni krajevi – TRBUSI

$s_1 = A\sin(\omega t - kx)$ ⊕ $s_2 = A\sin(\omega t + kx)$ ⇒ $s = 2A \cos kx \sin \omega t$

⇒ trbusi na oba kraja, sredina – čvor

$\cos kl = \pm 1$

$\cos k\frac{l}{2} = 0$ → $\lambda_1 = 2l$ (duljina štapa)

* Kundtova cijev (prašina ... razmak č = λ/2)

$f_i = \frac{v_i}{\lambda_i} = \frac{1}{2l}\sqrt{\frac{E}{\rho}}$ $v_p = f\lambda_p = \sqrt{\kappa \frac{p}{\rho}}$ (f) – ostaje ista

SVIRALA – oštrica – trbuh   a) otvorena – trbuh na kraju $\frac{\lambda}{2} = L$

b) zatvorena – čvor na kraju $\frac{\lambda}{4} = L$

5) ENERGIJA MEH. VALOVA

čestica $E = E_k + E_p = \frac{1}{2}kA^2 = \frac{1}{2}m\omega^2 A^2$ gustoća E $w = \frac{\Delta E}{\Delta V}$

6) DOPPLEROV EFEKT

a) IZVOR miruje, DETEKTOR se giba brzinom (v_d)

izvor → $f = \frac{v}{\lambda}$

detektor → f'

približavanje $v' = v + v_d$

udaljavanje $v' = v - v_d$

$\Rightarrow f' = \frac{v'}{\lambda} = \frac{v \pm v_d}{\lambda} = \frac{v \pm v_d}{v} f = f\left(1 \pm \frac{v_d}{v}\right)$

b) IZVOR SE GIBA

$\lambda' = \lambda - v_i T = \frac{v}{f} - \frac{v_i}{f} = \frac{v - v_i}{f}$ $\lambda' = \frac{v}{f'}$ ← detektor $f' = \frac{v}{v \mp v_i} f$

$f' = f\frac{v + v_d}{v - v_i}$ $v_d > 0$, $v_i > 0$ } približavanje

• EM valovi $f' = f\sqrt{\frac{1+\beta}{1-\beta}}$ $\beta > 0$ približavanje, $\beta = \frac{v}{c}$

• PROMJENA f PRI REFLEKSIJI VALA NA PREDMETU KOJI SE GIBA

val frekvencije (f) upada okomito na površinu – giba se (v_p)

a) izvor miruje, detektor se giba $f' = f\frac{v + v_d}{v} = f\left(1 + \frac{v_d}{v}\right)$ → to sada postaje emitirani val

b) detektor miruje, izvor se giba $f'' = f'\frac{v}{v - v_p} = f\frac{v + v_p}{v - v_p}$ (*) $v_p > 0$ približavanje

$\Delta f = f'' - f = \frac{2 f v_p}{c - v_p}$ $v \ll c$ → $v_p = \frac{c\Delta f}{2f}$ brzina automobila

(UDARI)