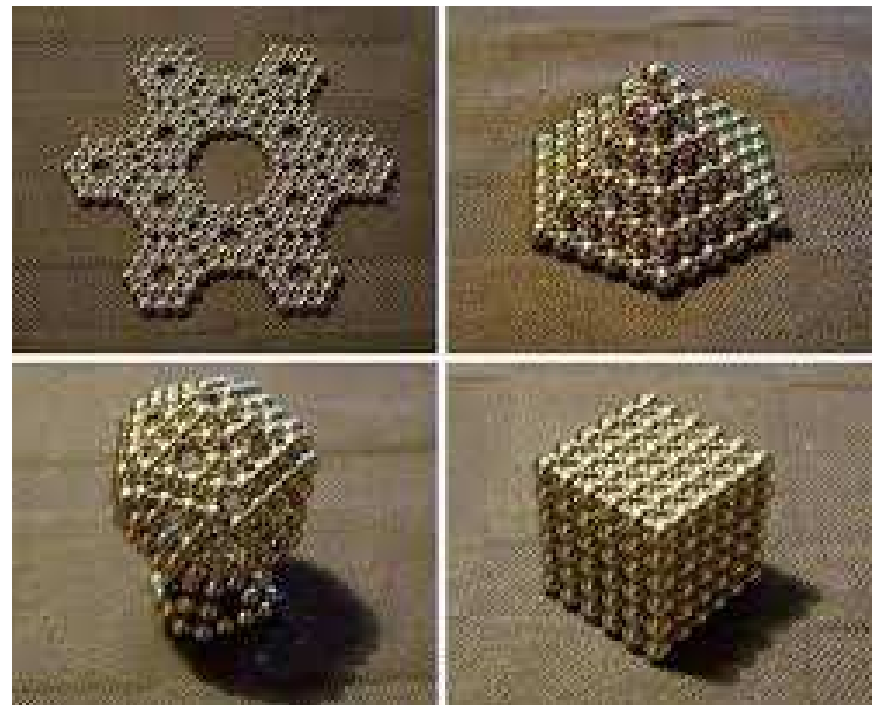


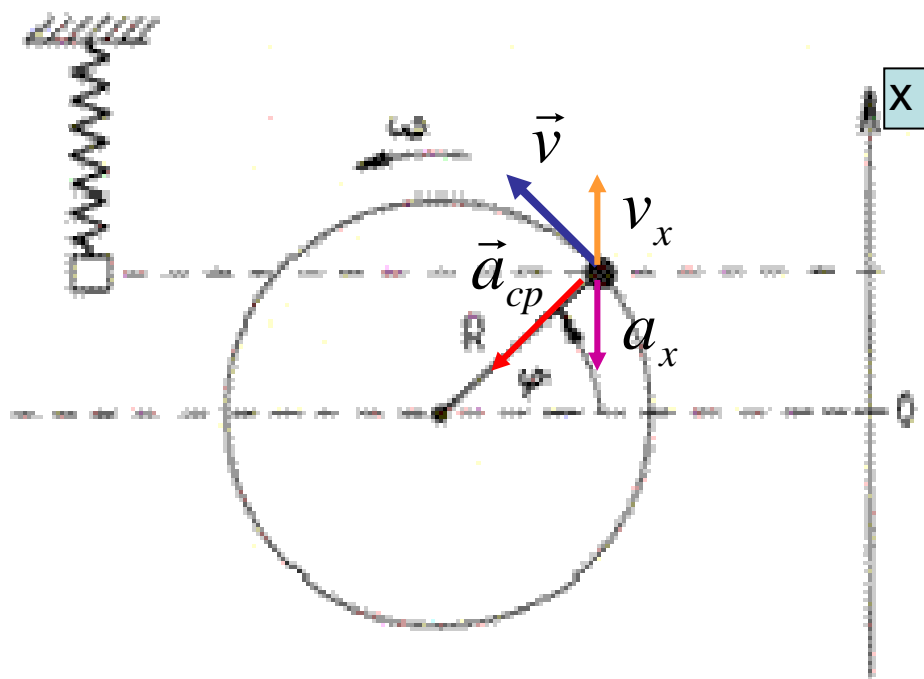
# Fizika 112

## 7. és 8. Előadás



# Még egy kis rezgés

## Körmozgás – rezgőmozgás analógia!



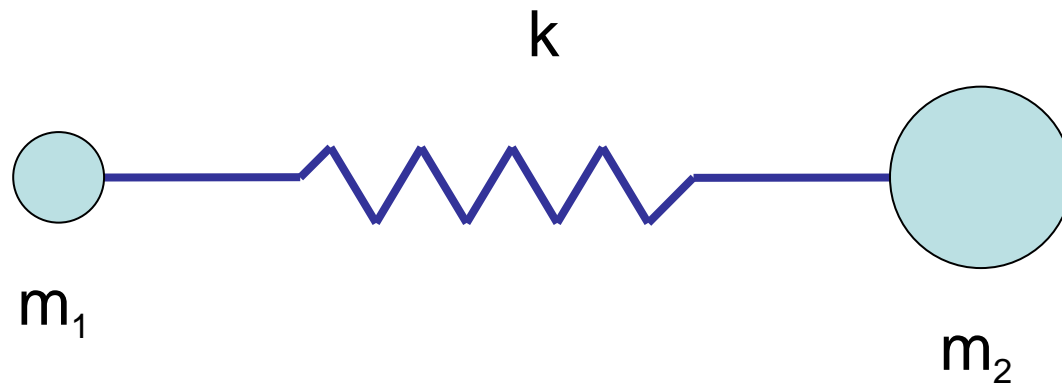
$$x(t) = R \sin \varphi = A \sin(\omega t)$$

$$v(t) = v \cos \varphi = R \omega \cos(\omega t) = A \omega \cos(\omega t)$$

+ kezdeti feltételek!!!

$$a_x(t) = -a_{cp} \sin \varphi = -R \omega^2 \sin(\omega t) = -A \omega^2 \sin(\omega t)$$

## *Molekula rezgés:*

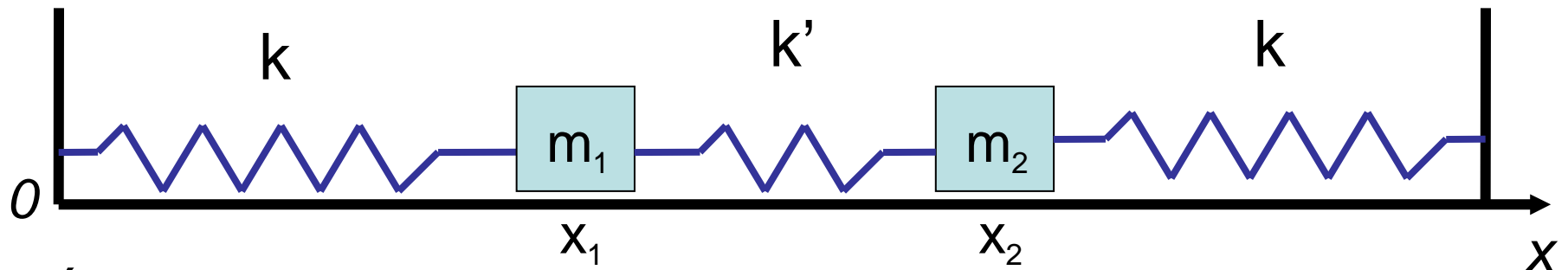


$$\omega = ?$$

$$k' = ?$$

$$m' = ?$$

## Csatolt rezgés:



Általában:  $k' \ll k$  (nullhosszúságú rugók)

$$I. \quad m_1 \ddot{x}_1 = -kx_1 + k'(x_2 - x_1)$$

$$II. \quad m_2 \ddot{x}_2 = k(\ell - x_2) - k'(x_2 - x_1)$$

$$m_2 = m_1 \quad \text{és} \quad \omega_o^2 = \frac{k}{m}$$

$$I. \quad \ddot{x}_1 = -\omega_o^2 x_1 + \frac{k'}{m}(x_2 - x_1)$$

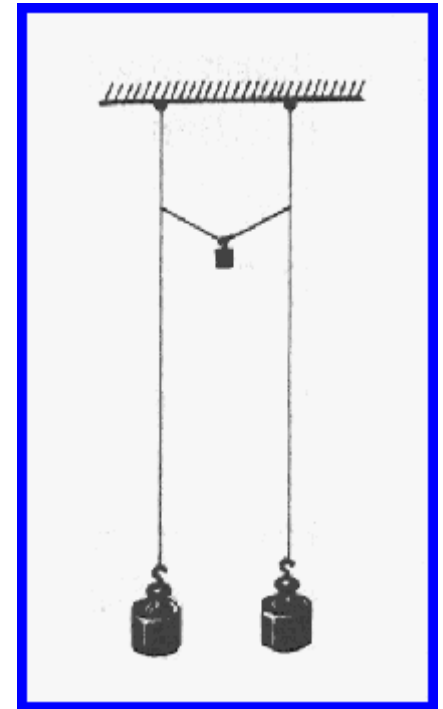
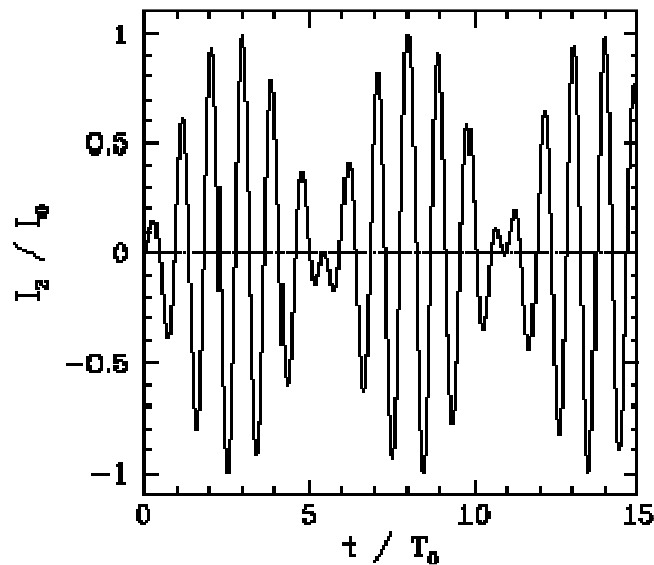
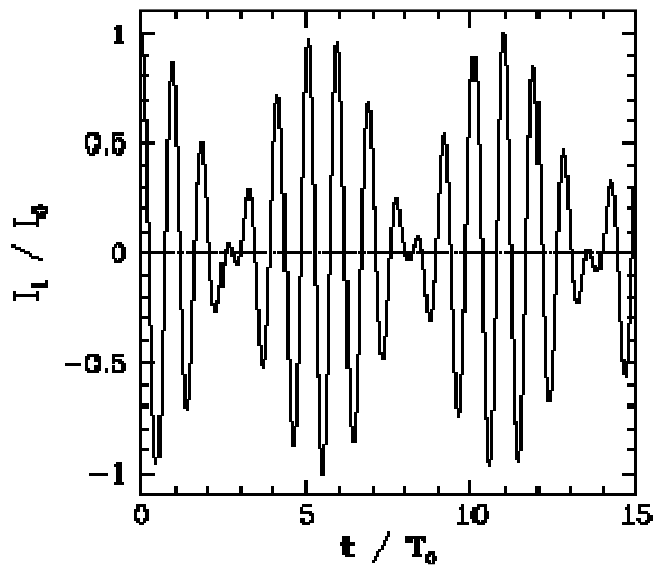
$$II. \quad \ddot{x}_2 = \omega_o^2(\ell - x_2) - \frac{k'}{m}(x_2 - x_1)$$

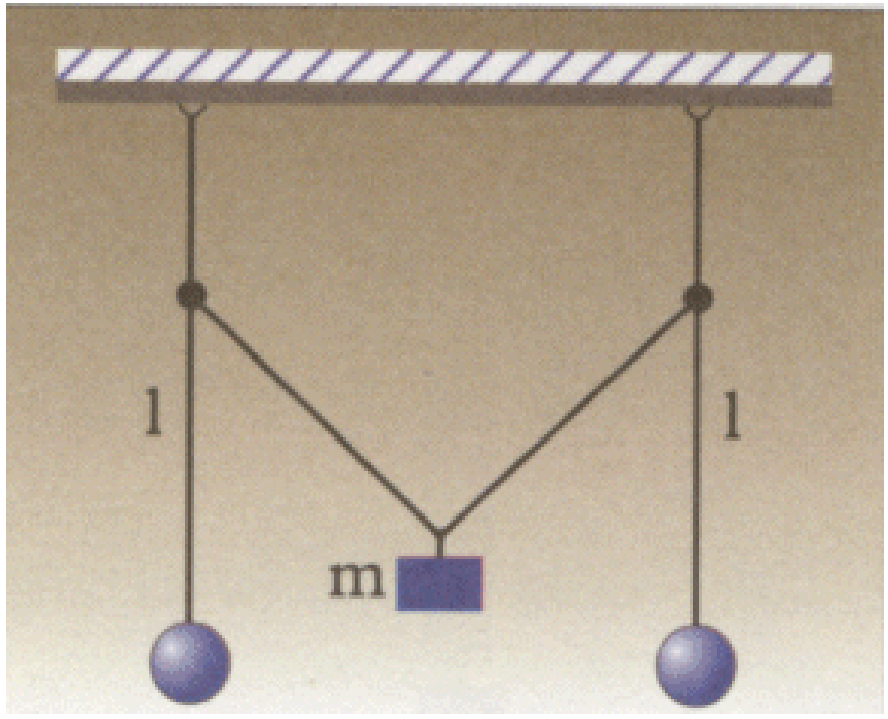
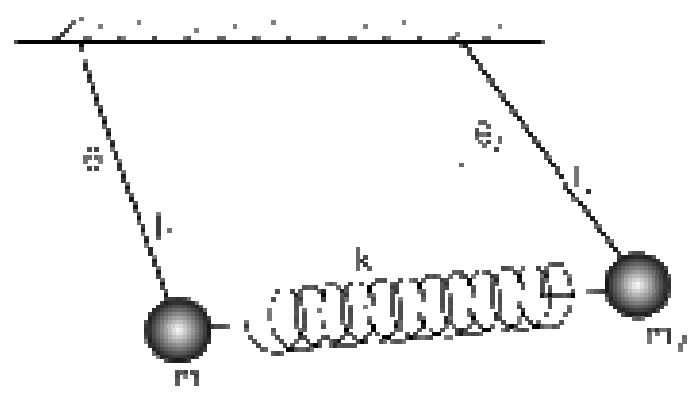
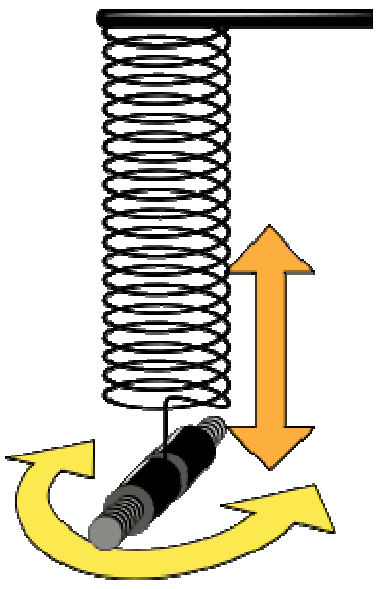
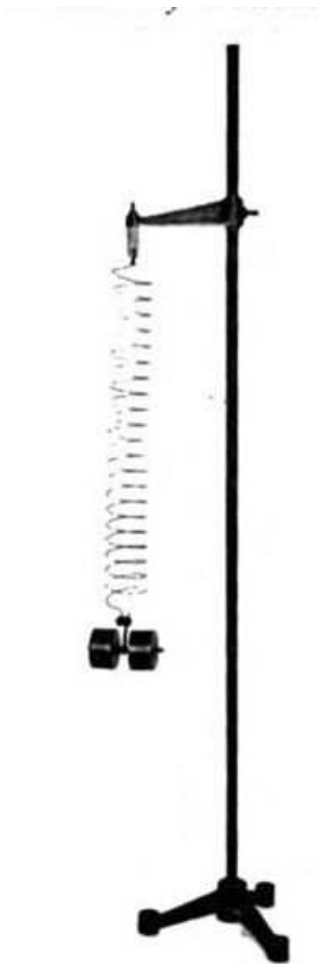
***megoldás:***

$$\omega = \sqrt{\omega_0^2 + 2\kappa} \quad \text{ahol} \quad \kappa = \frac{k'}{m}$$

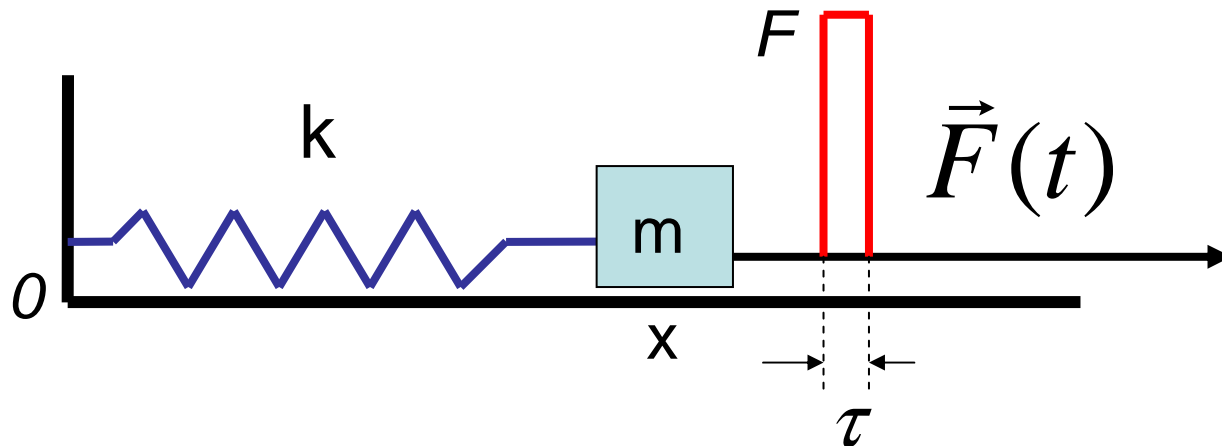
$$x_1 = C \cos\left(\frac{\omega - \omega_0}{2} t\right) \cos\left(\frac{\omega + \omega_0}{2} t\right)$$

$$x_2 = C \sin\left(\frac{\omega - \omega_0}{2} t\right) \sin\left(\frac{\omega + \omega_0}{2} t\right)$$





## A Dirac-delta:



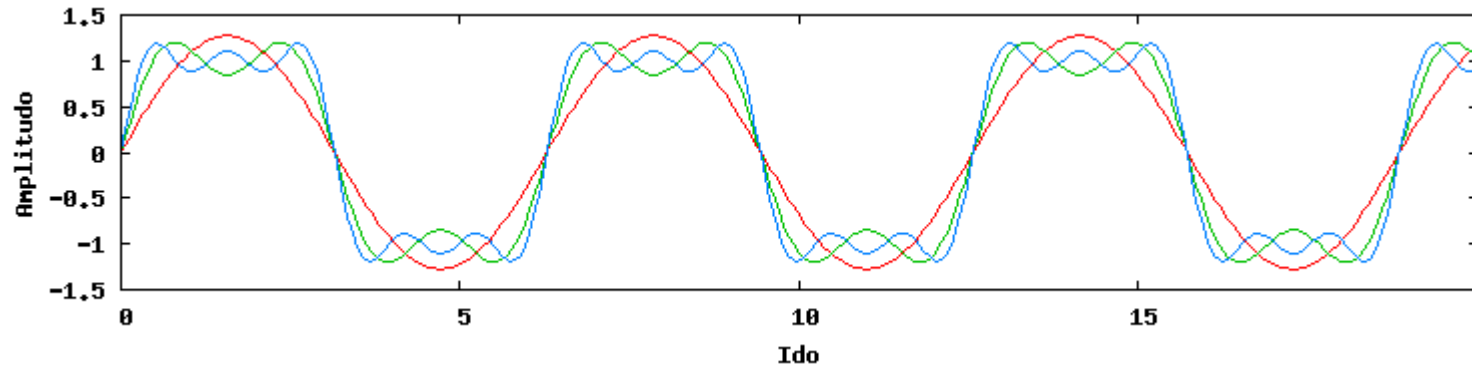
Erőlökés:  $\Delta p = I = F \tau = \text{áll.}$  de  $\tau \rightarrow 0$

$$x(t=0) = x_0 = 0 : \quad x(t) = \frac{F \tau}{m \omega_0} \sin(\omega_0 t)$$

$F(t)$  : gerjesztés

$$x(t) = \int_{-\infty}^t \frac{F(t-\tau)}{m \omega_0} \sin[\omega_0(t-\tau)] d\tau$$

## Rezgések Fourier-felbontása:



Tehát a Fourier transzformáció:

$$f(t) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} F(j\omega) e^{j\omega t} d\omega$$

$$F(j\omega) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(t) e^{-j\omega t} dt$$

$$a_n = \frac{2}{T} \int_0^T f(t) \cos\left(2\pi n \frac{t}{T}\right) dt \quad \longrightarrow \quad f(t) = c_0 + \sum_{n=1}^{\infty} \left[ a_n \cdot \cos\left(2\pi n \frac{t}{T}\right) + b_n \cdot \sin\left(2\pi n \frac{t}{T}\right) \right]$$



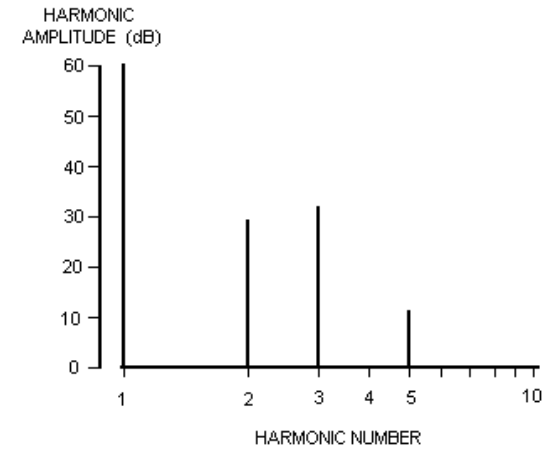
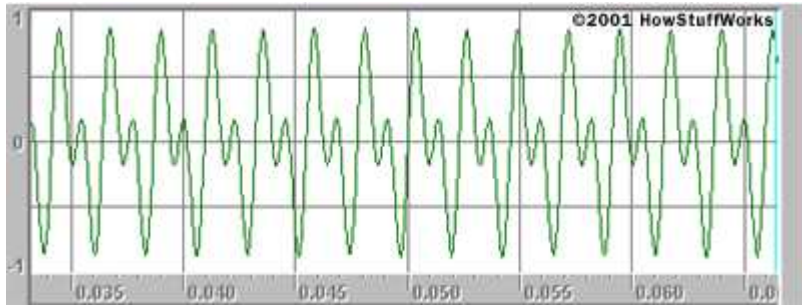
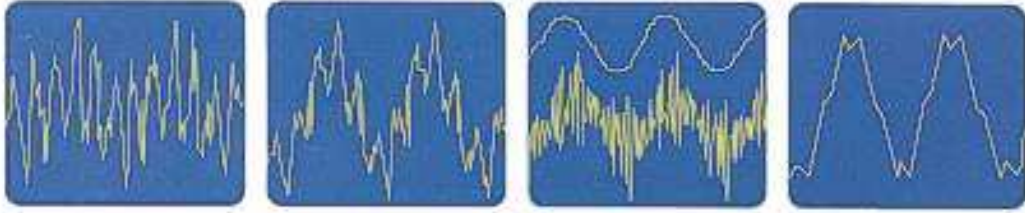
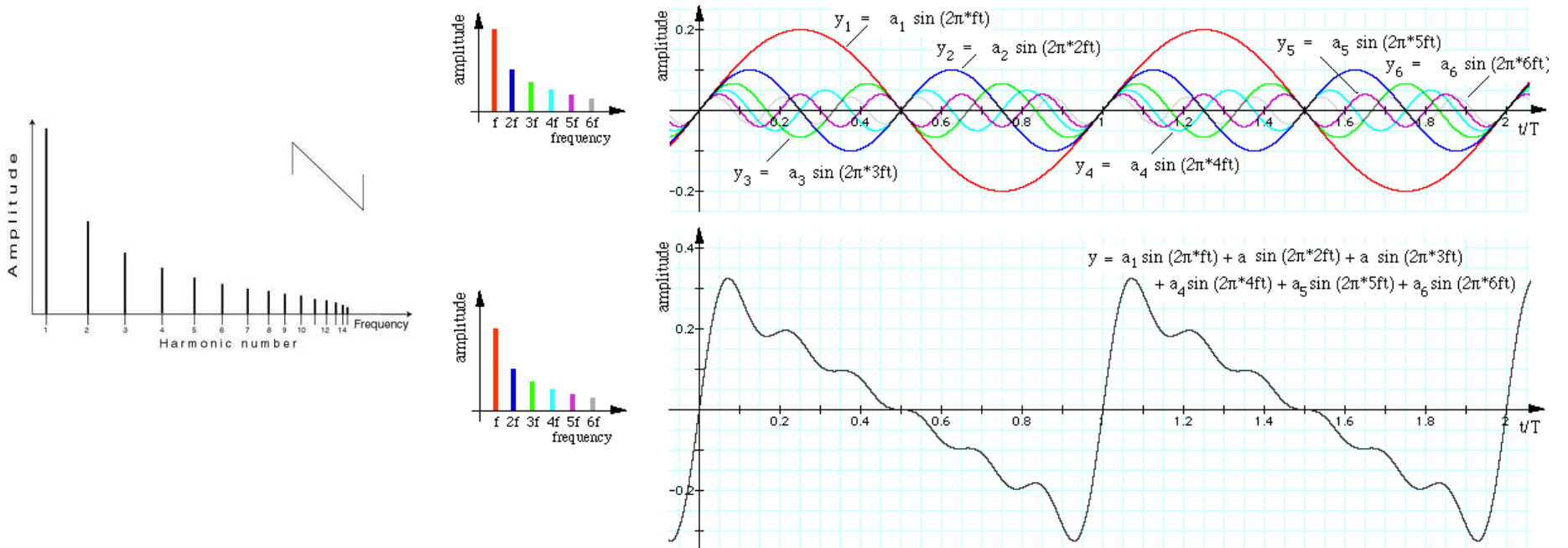


Figure 7 Harmonic Flute spectrum



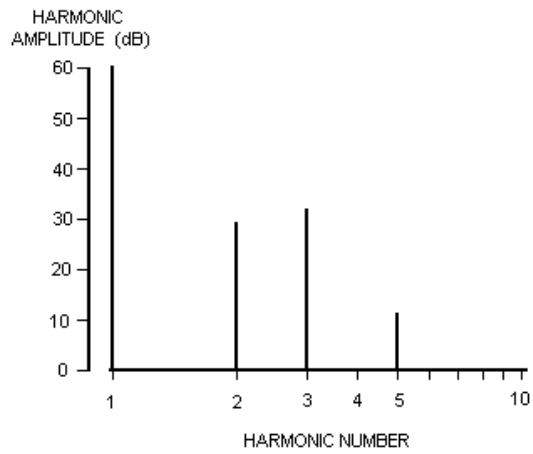
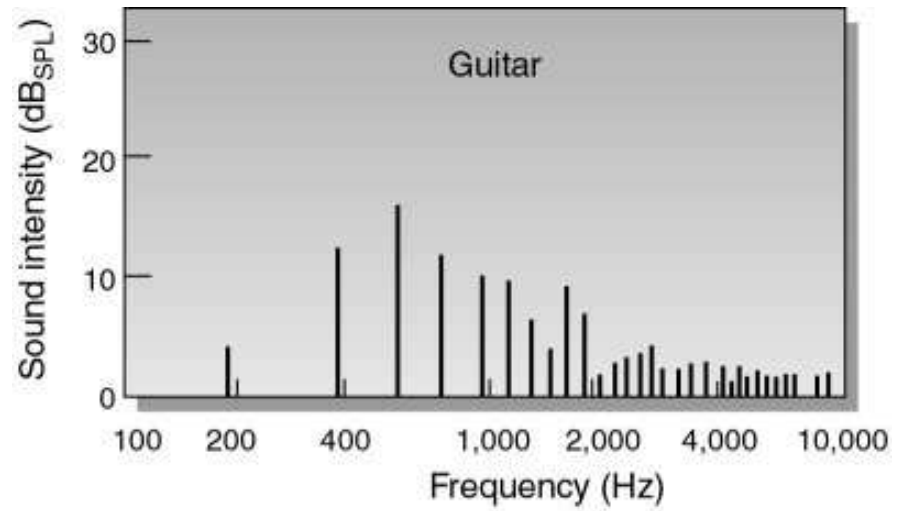
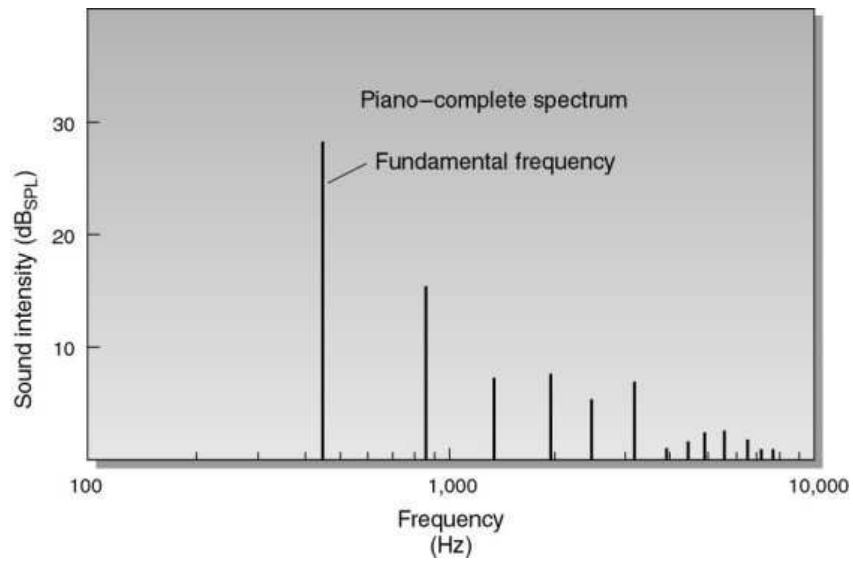
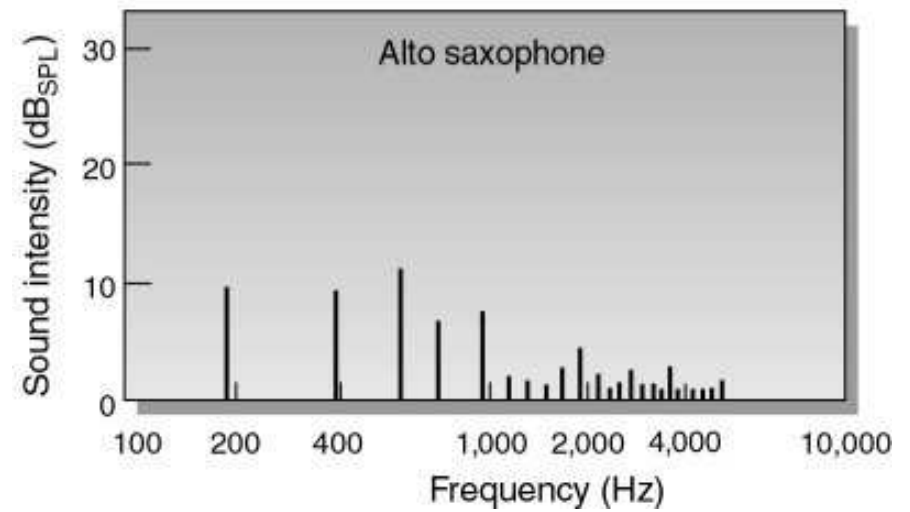


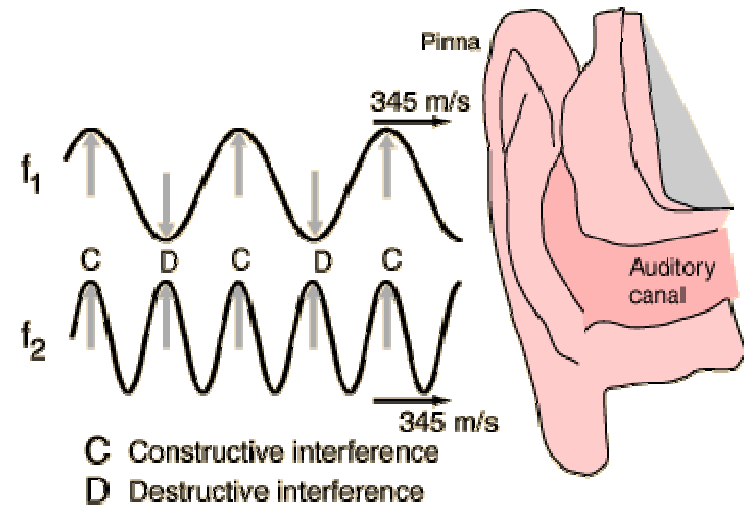
Figure 7 Harmonic Flute spectrum



## A lebegés jelensége:

$$y_1(t) = A \cos(\omega_1 t)$$

$$y_2(t) = A \cos(\omega_2 t)$$



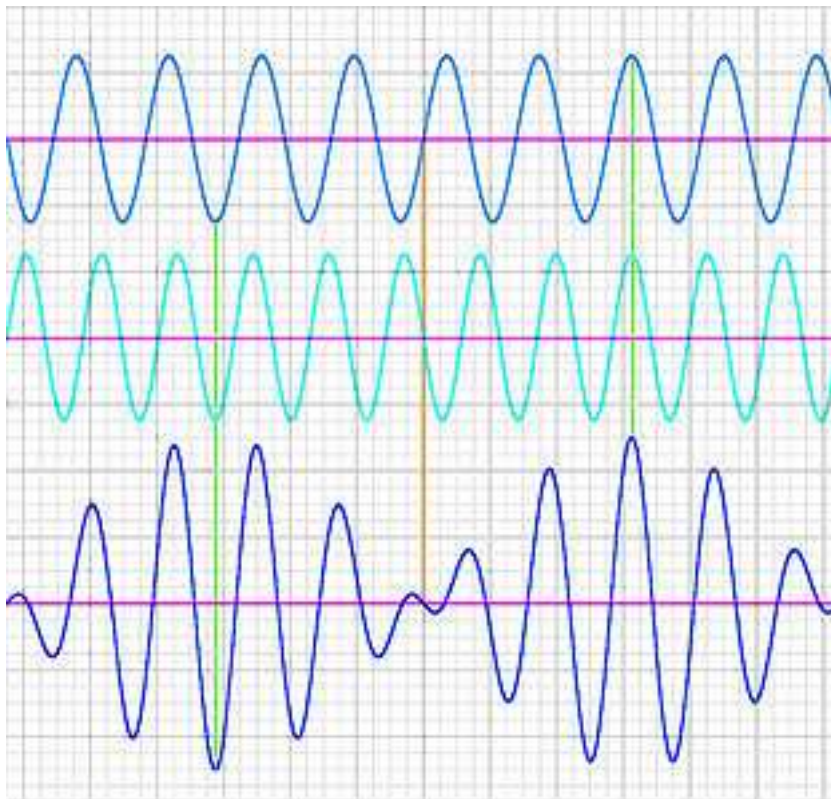
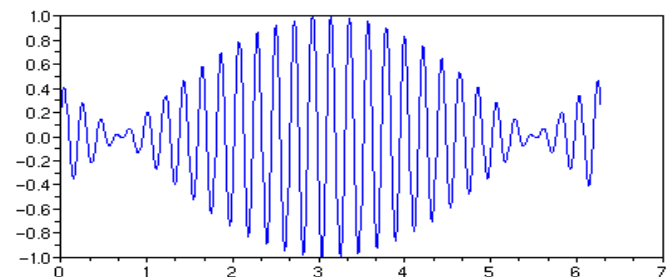
$$y(t) = y_1(t) + y_2(t)$$

$$y(t) = A \cos(\omega_1 t) + A \cos(\omega_2 t)$$

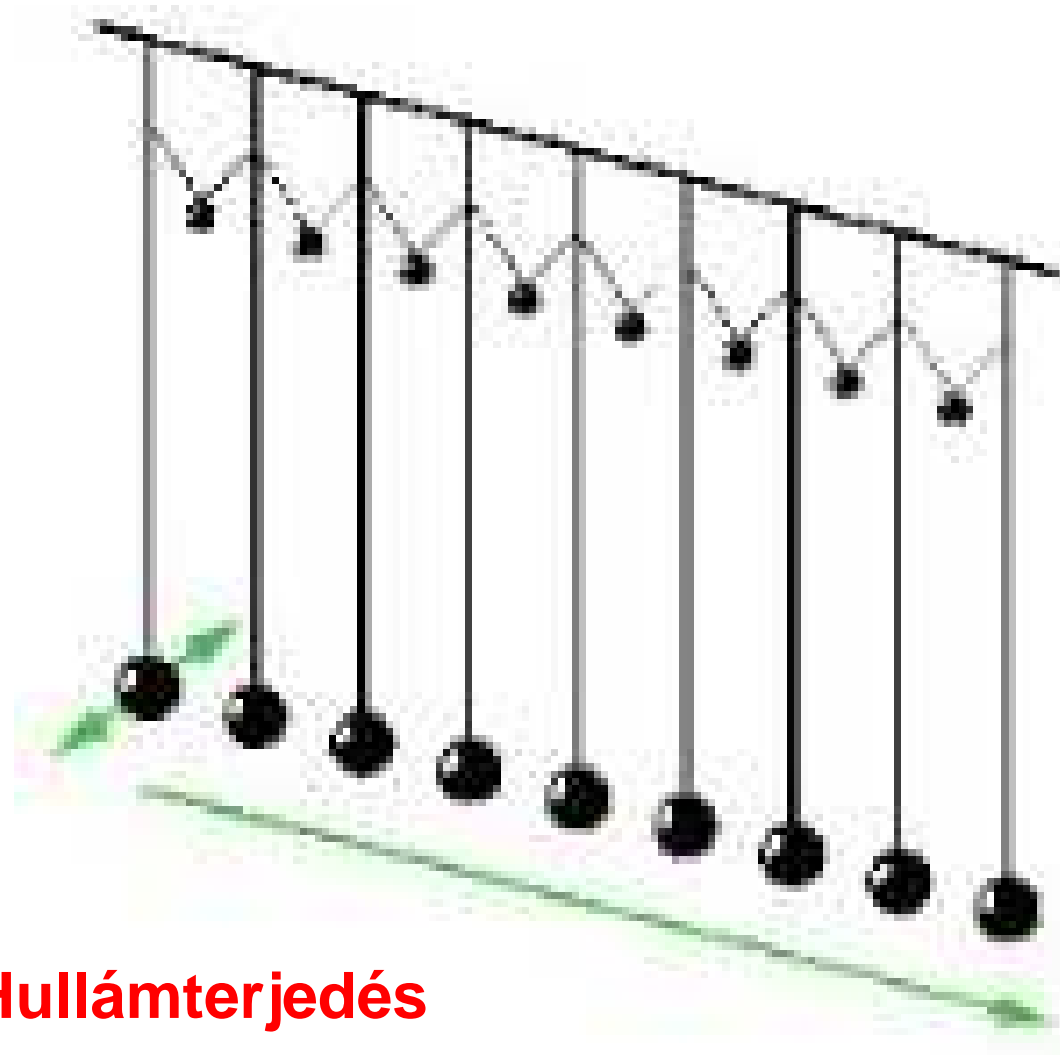
$$y(t) = 2A \cos\left(\frac{\omega_1 + \omega_2}{2} t\right) \cos\left(\frac{\omega_2 - \omega_1}{2} t\right)$$

$$y(t) = 2A \cos\left(2\pi \frac{f_1 + f_2}{2} t\right) \cos\left(2\pi \frac{f_2 - f_1}{2} t\right)$$

$$f_{\text{lebegés}} = \Delta f$$



## *Csatolt rezgés még egyszer*



**Hullámterjedés**



## *Hullámterjedés (Hullámmozgás)*



## Óriás-hullámok (*Freak wave*)

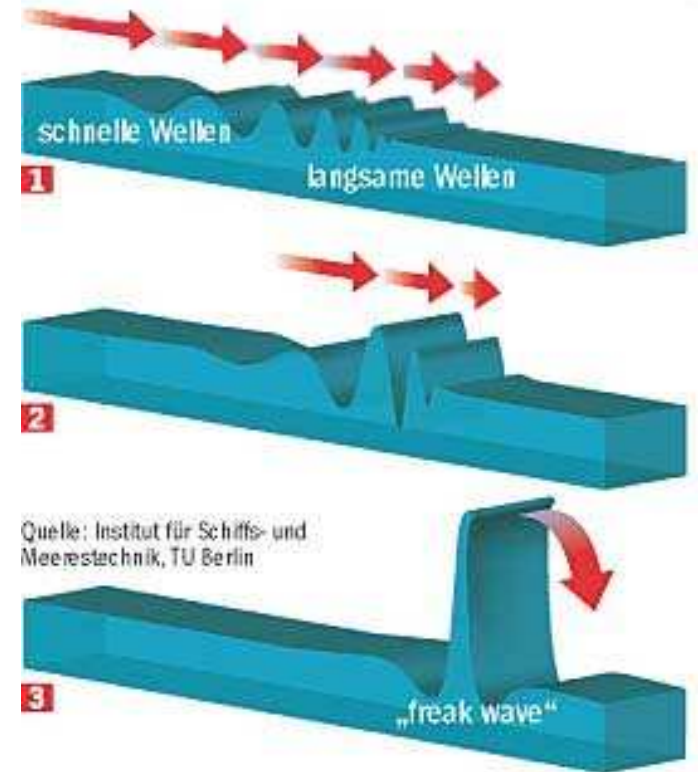
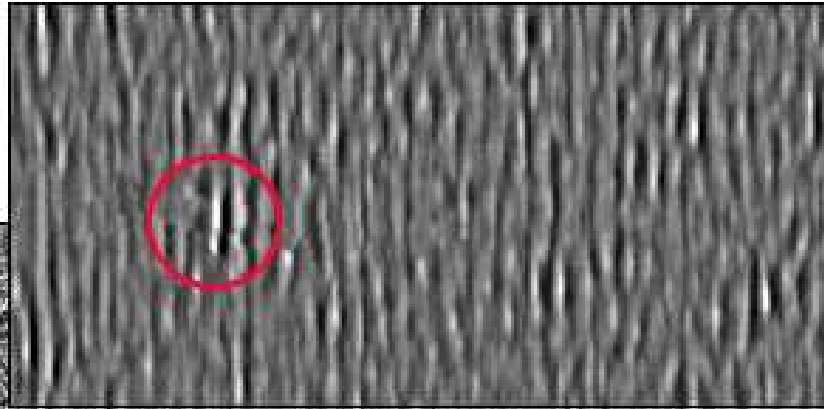
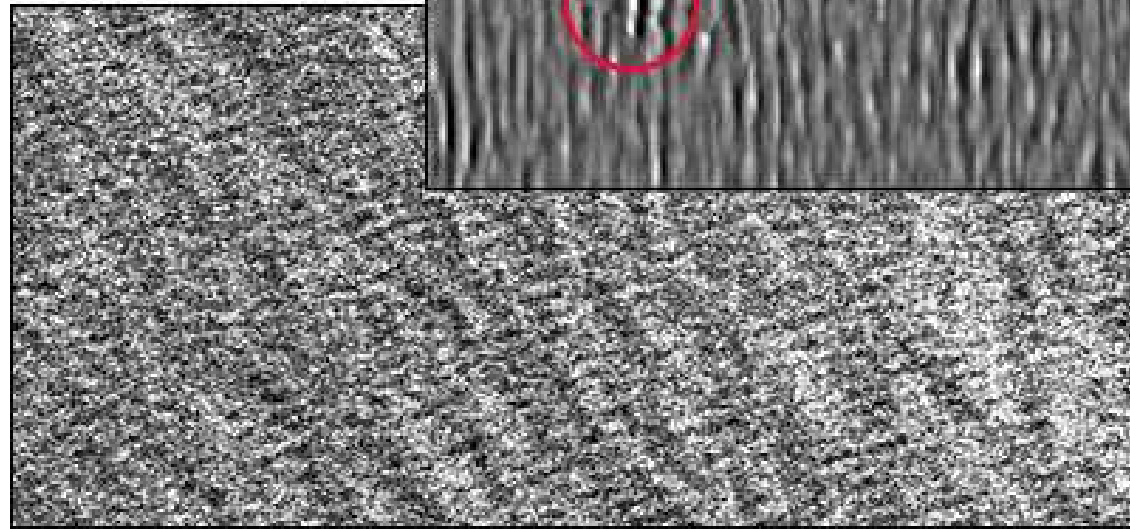
### ”Árulkodó nyers adatok

Az ESA ERS-1 és ERS-2 műholdjai 1991. illetve 1995. óta keringenek a Föld körül. A fedélzetükön elhelyezett SAR-radar az óceánok felett a hullámok alakulását vizsgálja. A 200 kilométeres közönként készített 10 x 5 kilométeres területet lefedő radarfelvételek matematikai elemzésével megállapítható a hullámok iránya és átlagos energiája.

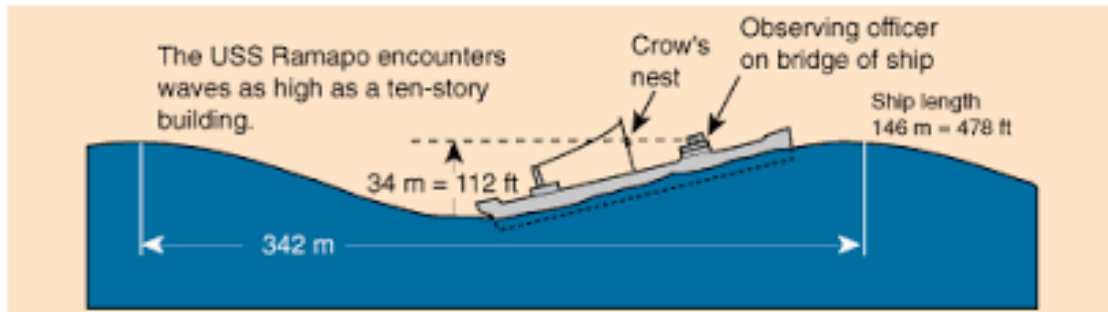
Ez az óceán-hullámspektrum nyilvánosan hozzáférhető, a meteorológusok például a tengeri időjárás pontosabb előrejelzésére használják az adatbázist. A nyers képi adatok ugyanakkor rendszerint nem sokra jók, Rosenthal és munkatársai viszont meg tudják belőlük állapítani az egyes hullámok, köztük a fenyegető óriások magasságát.”

A szakértő szerint valószínűleg ugyanez a jelenség tehető felelőssé sok hajó elsüllyedéséért. **Szerte a világban hetente átlagosan két nagy hajó süllyed el.** (Index, 2015. Febr. 27.)





Quelle: Institut für Schiffs- und Meerestechnik, TU Berlin

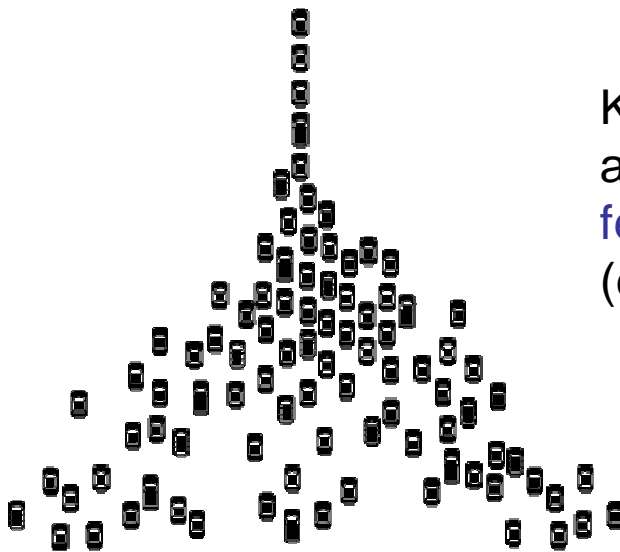


# Hullámzás a stadionban



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id 35059855  
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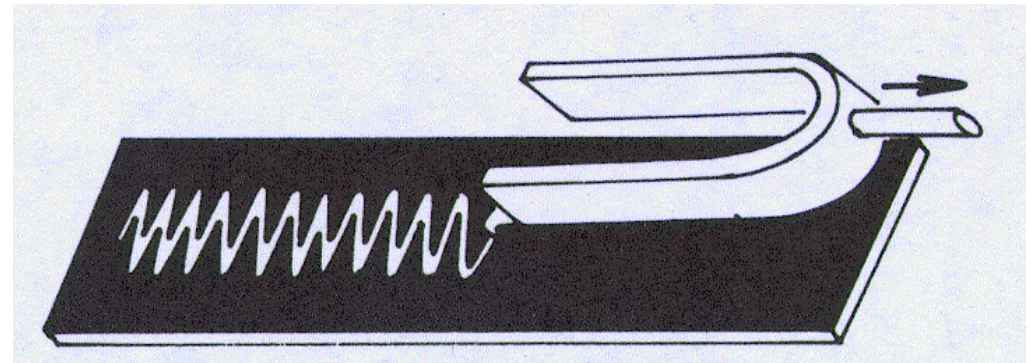
Közlekedési dugó  
a sztrádán:  
fékezési hullám  
(ennél bonyolultabb)



Photo: MTreiber



## Hullámok:



A vibrating tuning fork will force air within a pipe to begin vibrating back and forth in a direction parallel to the energy transport; sound is a longitudinal wave.



When a slinky is stretched, the individual coil assume an equilibrium or rest position.



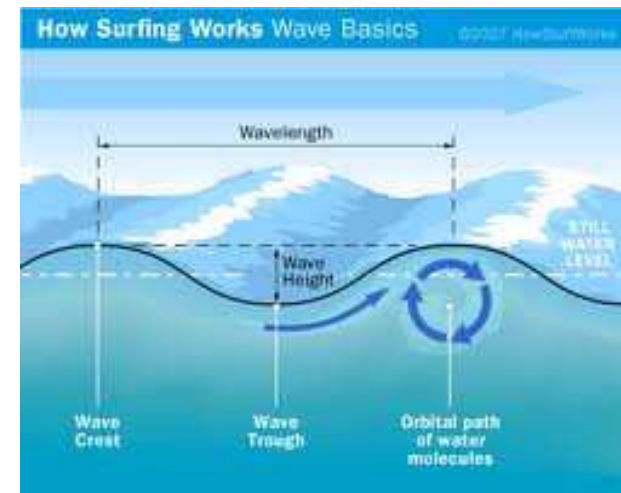
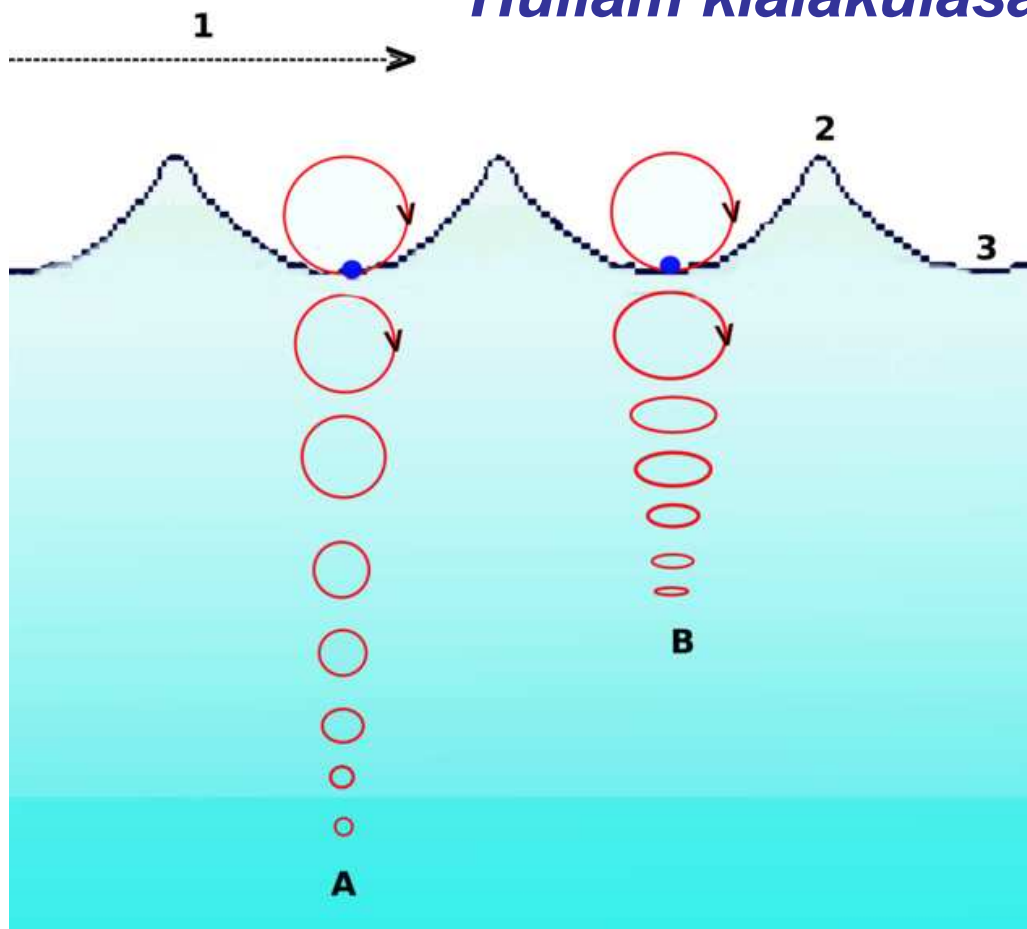
When the first coil of the slinky is repeatedly vibrated back and forth, a disturbance is created which travels through the slinky from one end to the other.

## *Hullámterjedés feltétele: rugalmas közeg*

- Megfeszített húr, rugó
- Vízfelszín, folyadék
- Szilárd test
- Gáz
- Stb.



# Hullám kialakulása víz (folyadék) felszínén

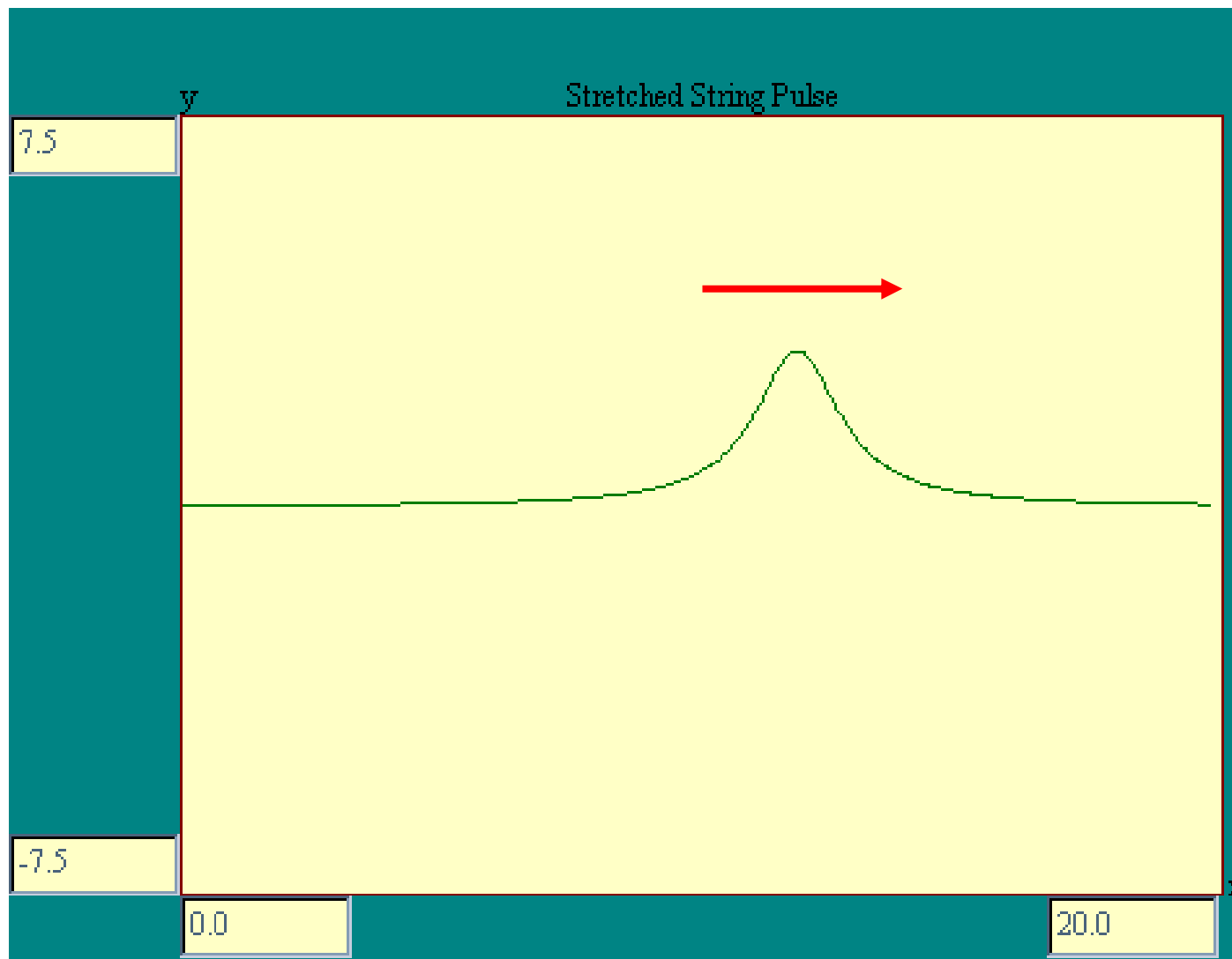


## Surface Wave

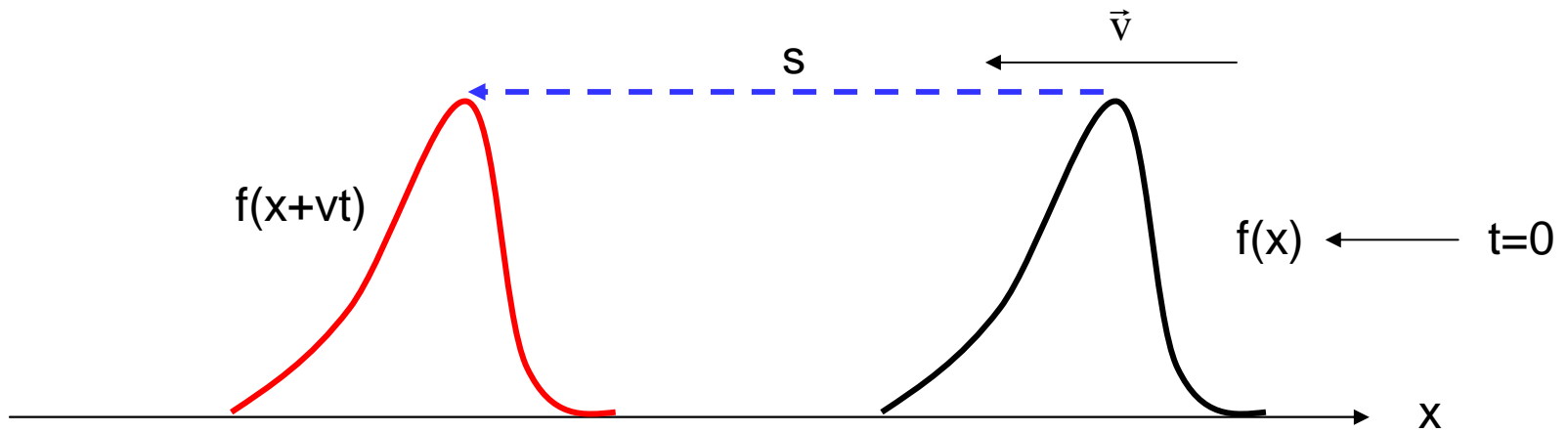
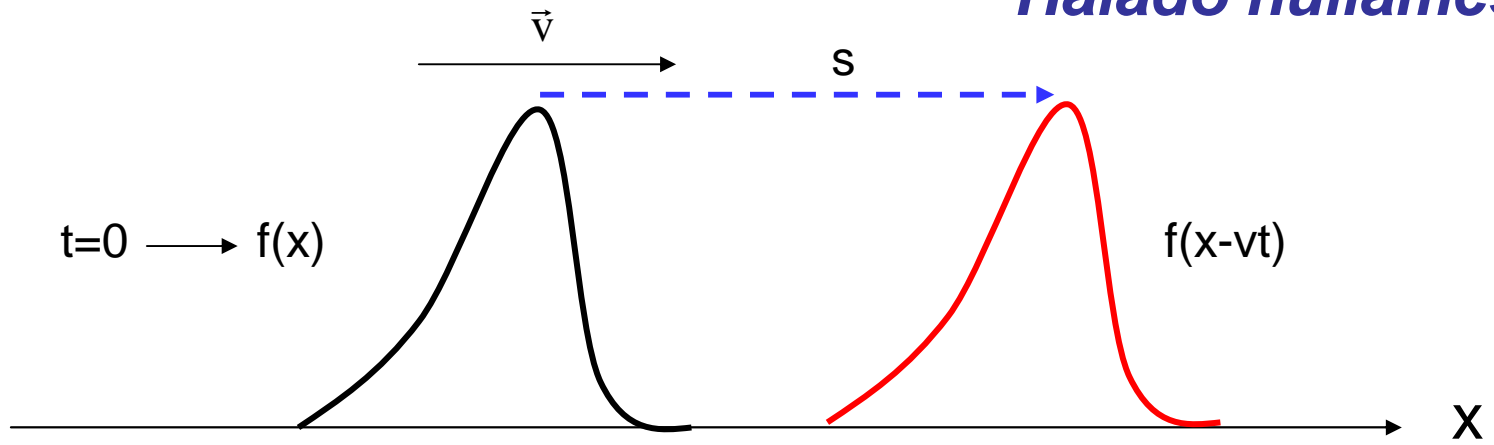


A surface wave is sometimes referred to as a circular wave since particles of the medium undergo a motion in a complete circle.

# Hullámimpulzus - hullámcsomag



# Haladó hullámcsomag



## Longitudinal wave

Source moves  
left and right

Coils move  
left and right



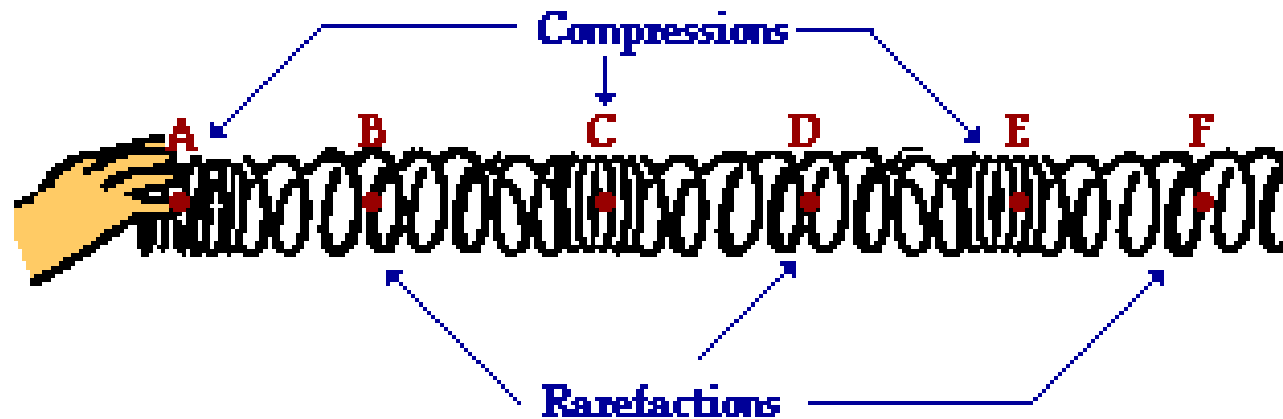
## Transverse Wave

Source moves  
up and down

Coils move  
up and down

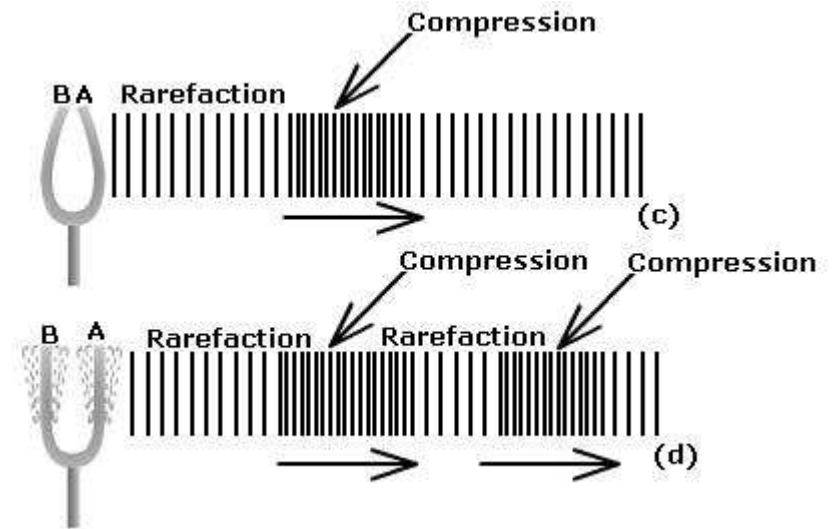
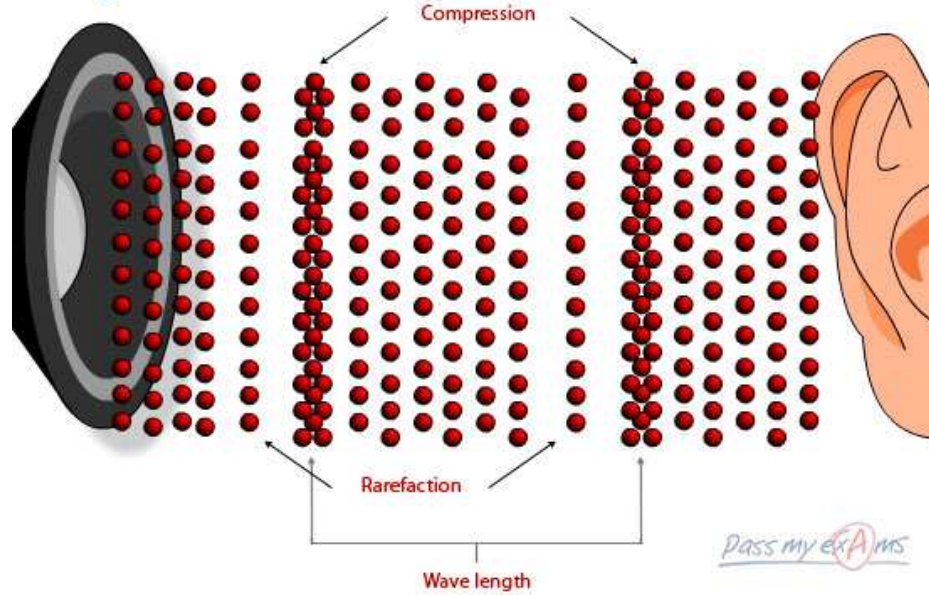


The subsequent direction of motion of individual particles of a medium is the same as the direction of vibration of the source of the disturbance.

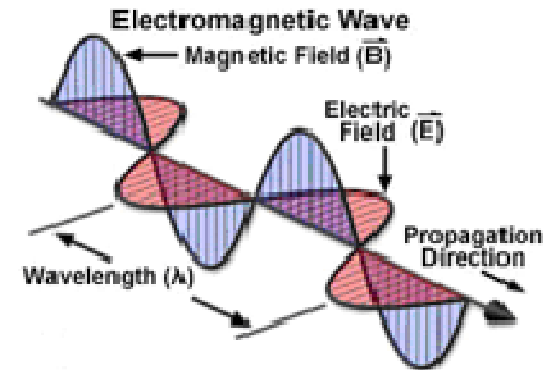
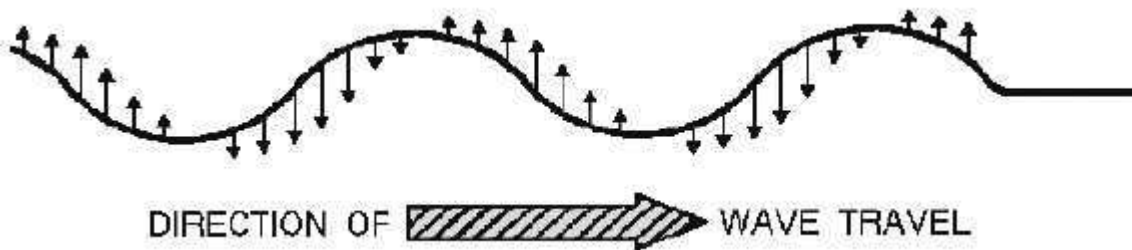


# Longitudinal Waves

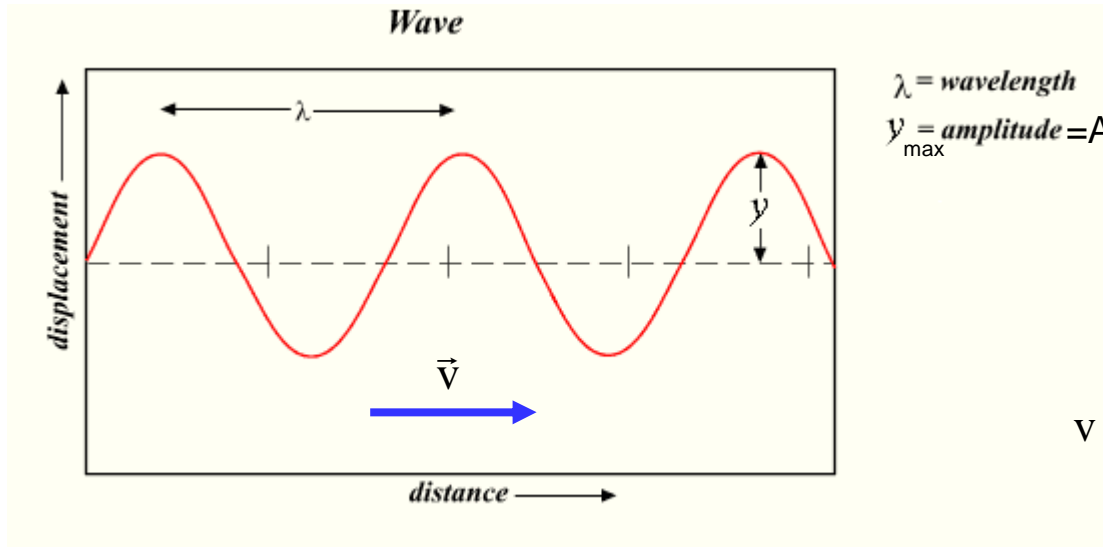
# Longitudinális hullám



# Transzverzális hullám



# Színusz(os) hullám



Hullámszám:  $k = \frac{2\pi}{\lambda}$

$v = \frac{\lambda}{T}$  és  $T = \frac{1}{f} \rightarrow f \cdot \lambda = v$

$v = \frac{\omega}{k}$

$$y(x, t = 0) = A \sin\left(\frac{2\pi}{\lambda} x\right)$$

$$y(x, t) = A \sin\left(\frac{2\pi}{\lambda} (x - vt)\right)$$

$$\frac{2\pi}{\lambda} vt = \frac{2\pi}{\lambda/v} t = \frac{2\pi}{T} t = \omega t$$

$$y(x, t) = A \sin(kx - \omega t + \varphi)$$

Hullám terjedési iránya!

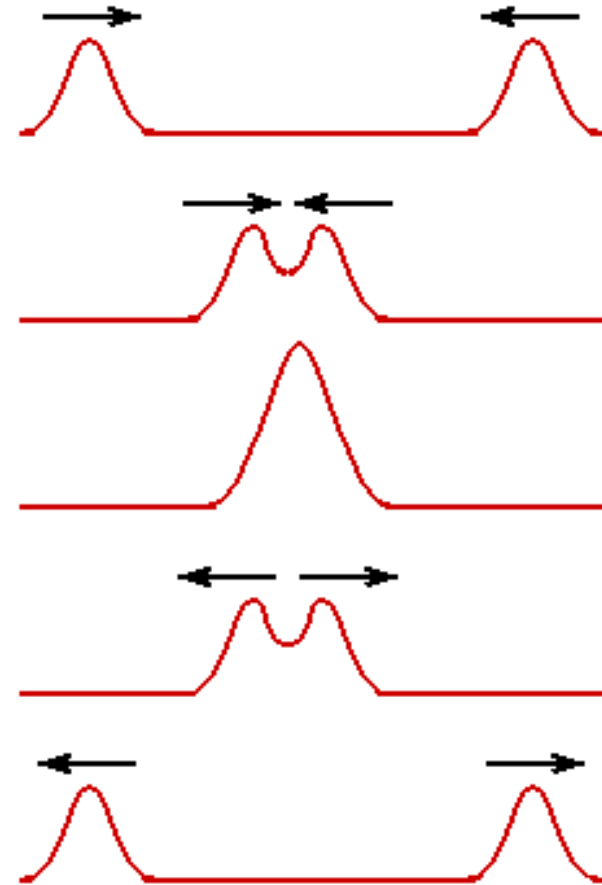
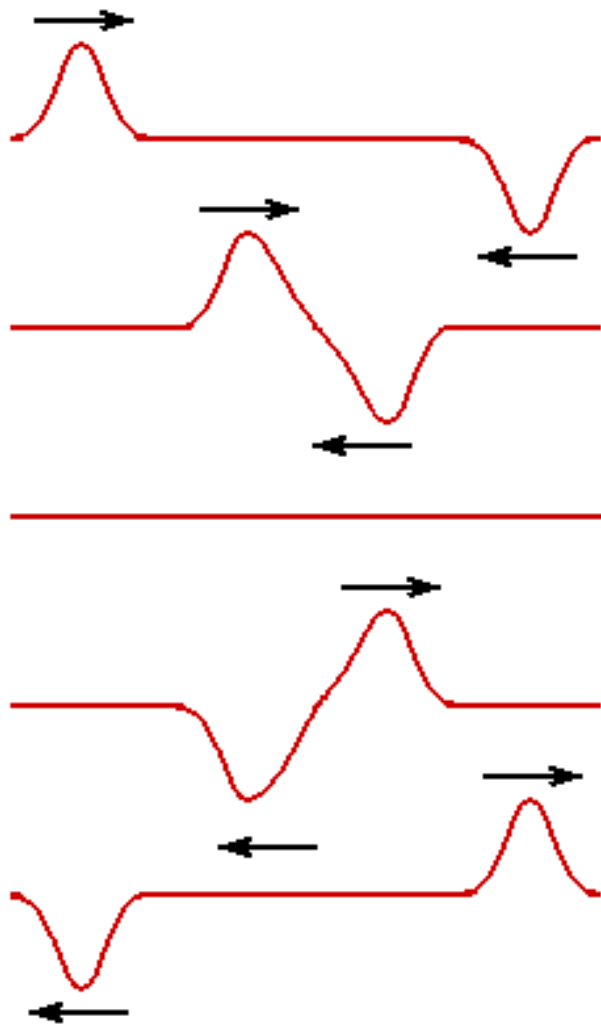
Hullámegyenlet:

$$\frac{\partial^2 y(x, t)}{\partial x^2} = \frac{1}{v^2} \frac{\partial^2 y(x, t)}{\partial t^2}$$

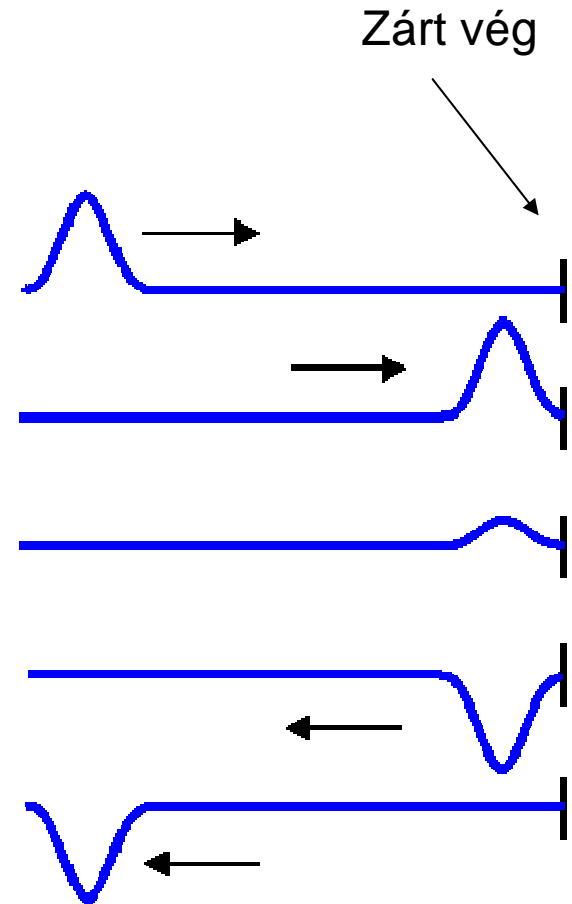
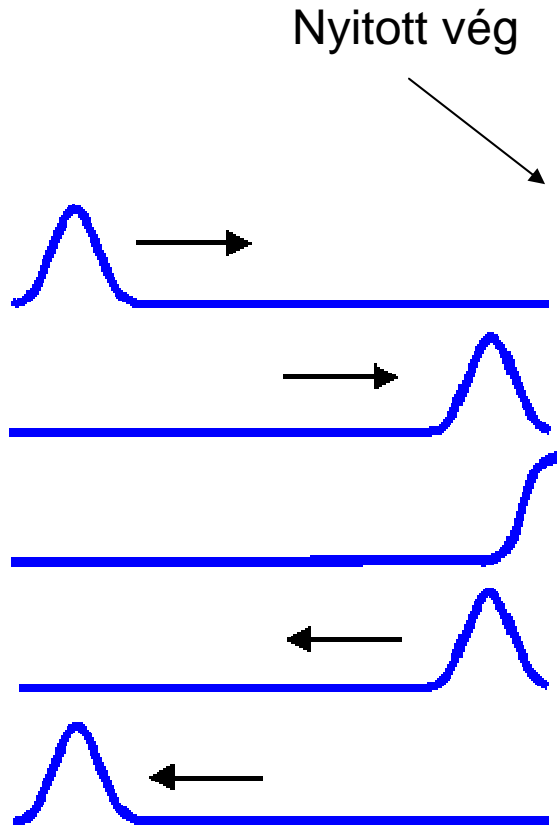


# Szuperpozíció

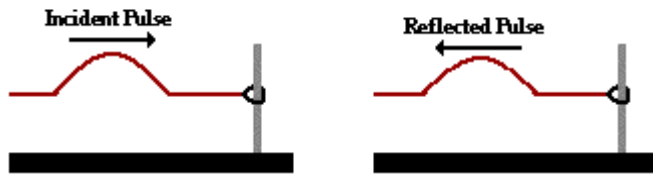
Linearitás!!!



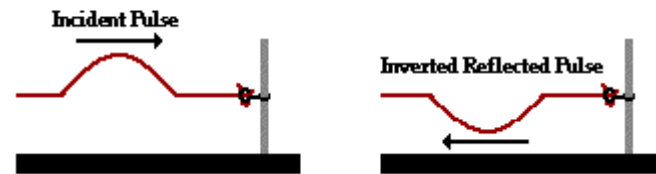
# Hullámok visszaverődése, reflexiója:



Free End Reflection



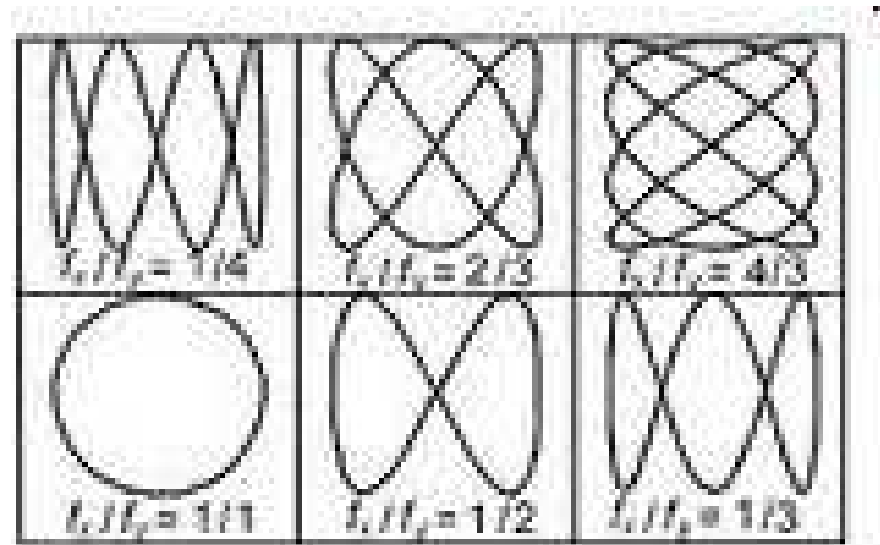
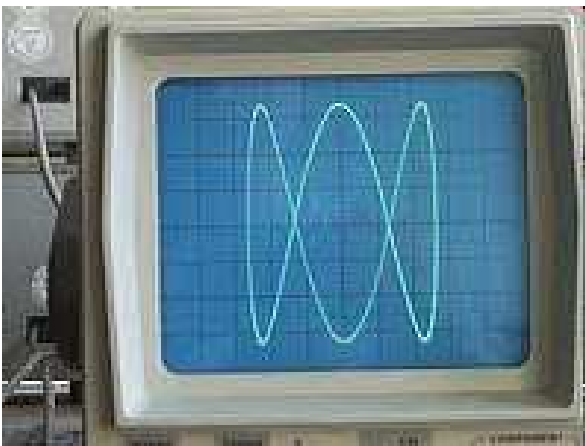
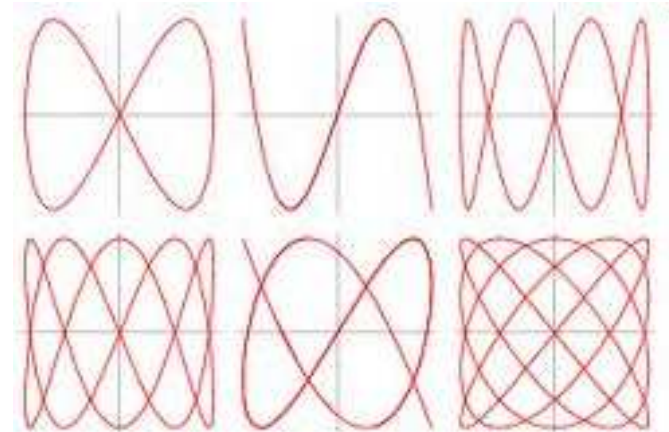
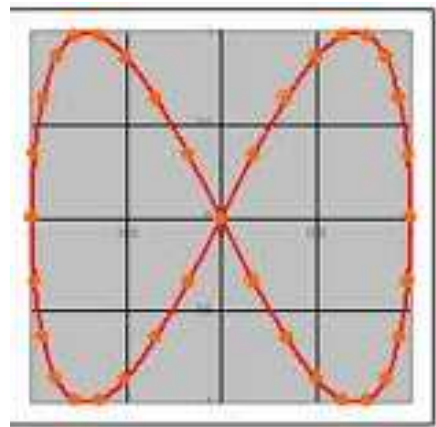
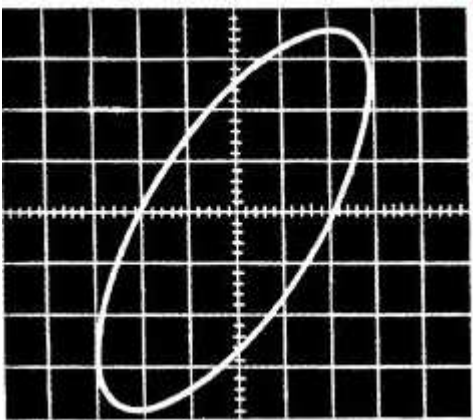
Fixed End Reflection




# Egymásra merőleges rezgések összetétele – Lissajou görbék

$$x(t) = A \sin(\omega t)$$

$$y(t) = A \sin(\omega t + \varphi)$$



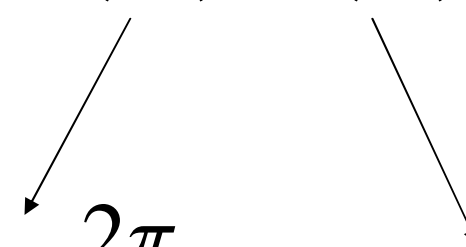
## Állóhullám



$y_1(x, t) = A \cos(kx - \omega t)$        $y_2(x, t) = A \cos(kx + \omega t)$

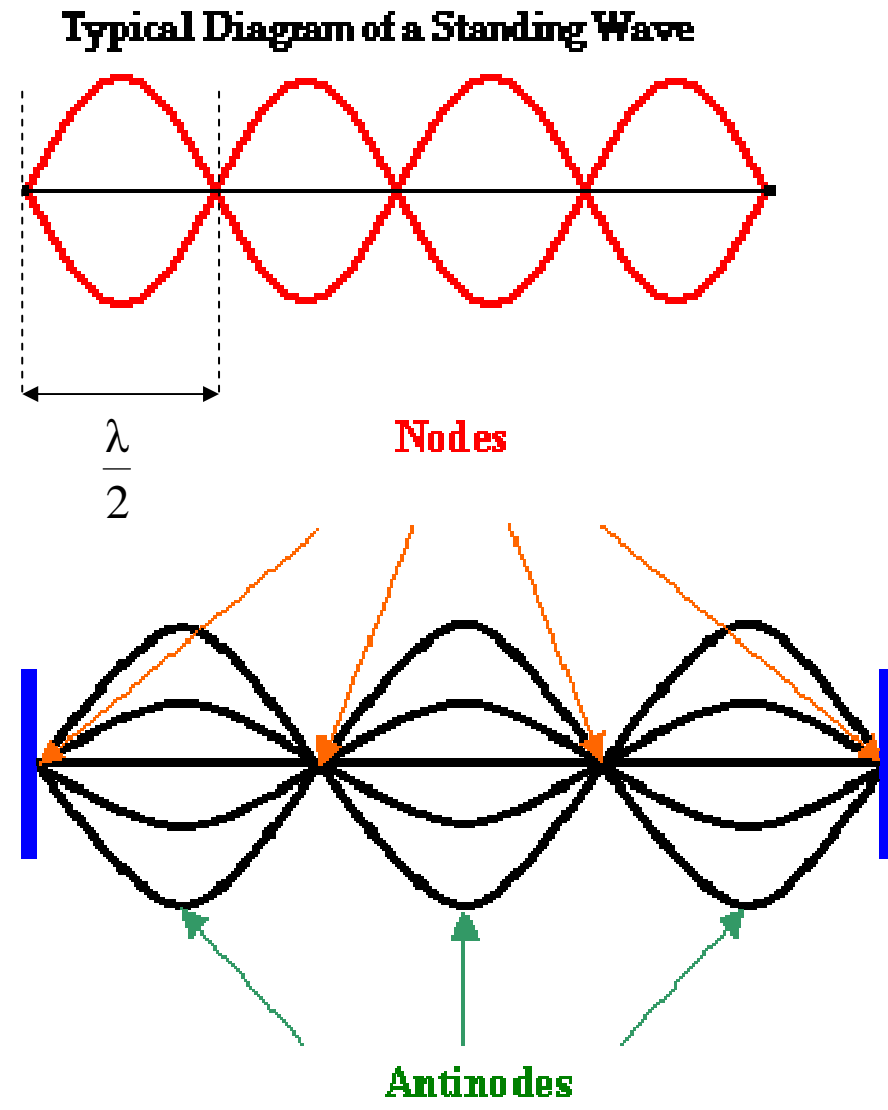
$$y = y_1 + y_2$$

$$y(x, t) = 2A \cos(\omega t) \cos(kx)$$

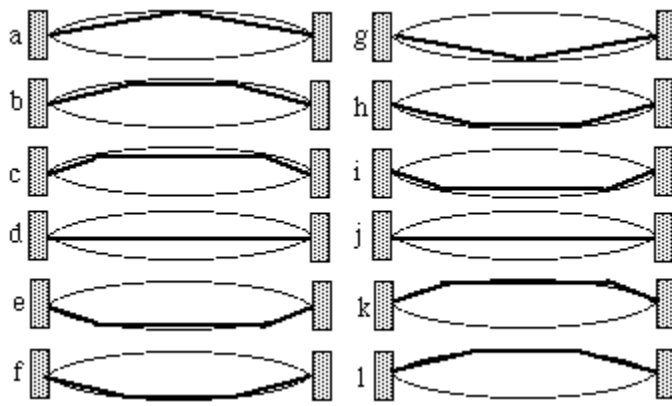

$$\omega = \frac{2\pi}{T}$$

$$k = \frac{2\pi}{\lambda}$$

# Állóhullám:



## Alap és felharmónikusok (mindkét vég zárt)



fixed

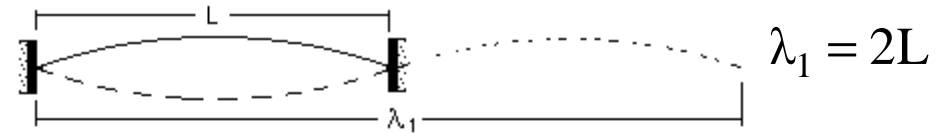
$$f = \frac{v}{\lambda}$$

$$f_1 = \frac{v}{\lambda_1} = \frac{v}{2L}$$

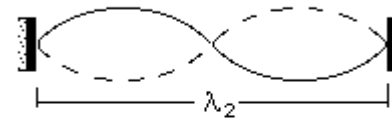
$$f_2 = \frac{v}{\lambda_2} = 2 \cdot \frac{v}{2L} = 2 \cdot f_1$$

$$f_3 = \frac{v}{\lambda_3} = 3 \cdot \frac{v}{2L} = 3 \cdot f_1$$

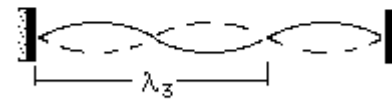
- 
- 
- 



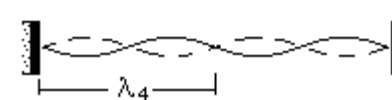
$$\lambda_1 = 2L$$



$$2 \cdot \frac{\lambda_2}{2} = L \rightarrow \lambda_2 = L$$



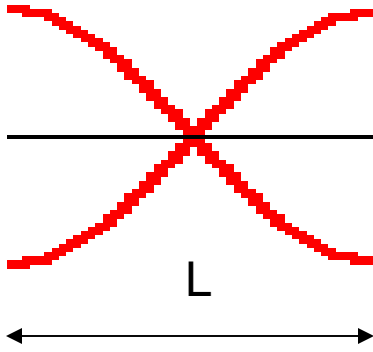
$$3 \cdot \frac{\lambda_3}{2} = L \rightarrow \lambda_3 = 2 \cdot \frac{L}{3}$$



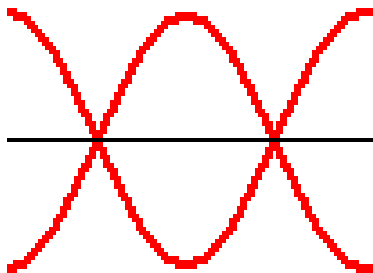
$$4 \cdot \frac{\lambda_4}{2} = L \rightarrow \lambda_4 = 2 \cdot \frac{L}{4}$$

$$f_n = n \cdot f_1$$

## *Mindkét vég nyitott*

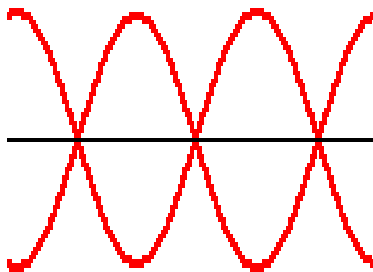


$$\lambda_1 = 2L \longrightarrow f_1 = \frac{v}{\lambda_1} = \frac{v}{2L}$$



$$\lambda_2 = \frac{2L}{2}$$

$$f_2 = \frac{v}{\lambda_2} = 2 \cdot \frac{v}{2L} = 2 \cdot f_1$$

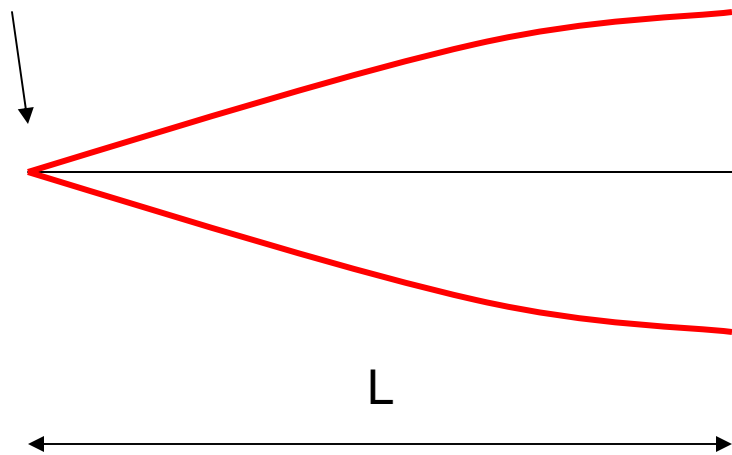


$$\lambda_3 = \frac{2L}{3}$$

$$f_3 = \frac{v}{\lambda_3} = 3 \cdot \frac{v}{2L} = 3 \cdot f_1$$

$$f_n = n \cdot f_1$$

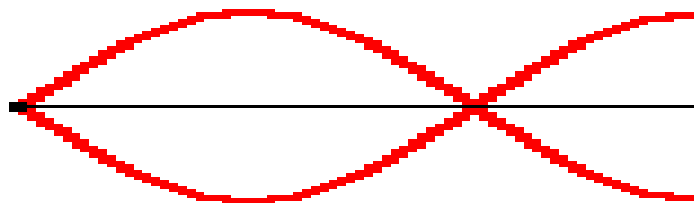
Zárt vég



Nyílt vég

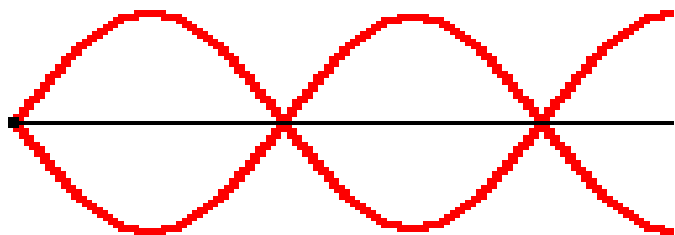
**Egyik vég nyitott**

$$\frac{\lambda_1}{4} = L \rightarrow \lambda_1 = 4L \longrightarrow f_1 = \frac{v}{\lambda_1} = \frac{v}{4L}$$



$$3 \cdot \frac{\lambda_2}{4} = L \rightarrow \lambda_2 = \frac{4L}{3}$$

$$f_2 = \frac{v}{\lambda_2} = 3 \cdot \frac{v}{4L}$$



$$5 \cdot \frac{\lambda_3}{4} = L \rightarrow \lambda_3 = \frac{4L}{5}$$

$$f_3 = \frac{v}{\lambda_3} = 5 \cdot \frac{v}{4L}$$

○  
○  
○

$$f_n = (2n-1) \cdot f_1$$



## Hullám intenzitása

$$\text{Hangerősség: } \beta = (10\text{dB}) \lg \frac{I}{I_0}$$

$$\text{intenzitás} = \frac{\text{teljesítmény}}{\text{felület}}$$

194 Elméleti határ, hanghullám esetén, 1 atmoszféra környezeti nyomásnál

180 A [Krakatau](#) vulkán robbanása 100 mérföldről (160 km) a levegőben

168 géppuska lövése 1 méterről

150 repülőgép sugárhajtóműve 30 méterről

140 pisztolylövés 1 méterről; 120 fájdalomküszöb; vonatkürt 10 méterről

110 gyorsító motorkerékpár 5 méterről; láncfűrész 1 méterről

100 légalapács 2 méterről; diszkó belül

90 üzemi zaj, kamion 1 méterről

80 porszívó 1 méterről, zaj forgalmas utca járdáján

70 erős forgalom 5 méterről

60 iroda vagy vendéglő belül

50 csendes vendéglő belül

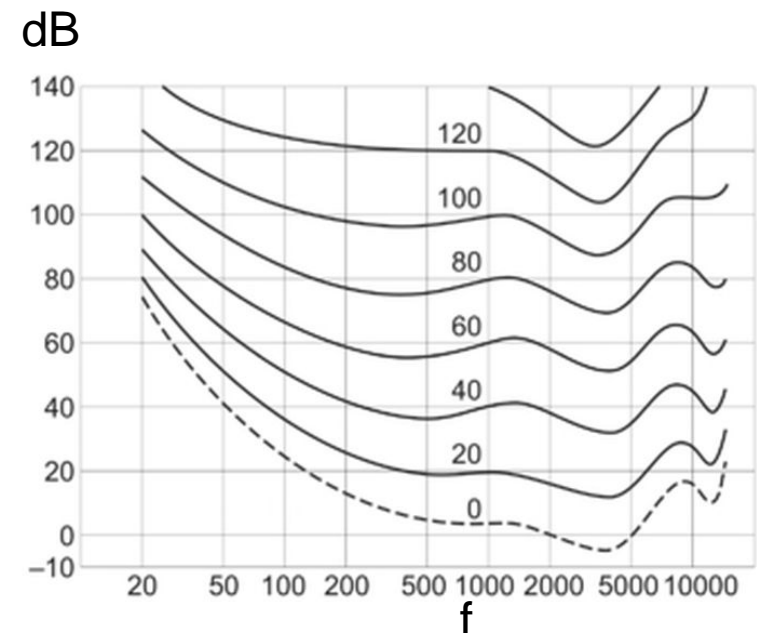
40 lakóterület éjjel

30 színházi csend

10 emberi lélegzet 3 méterről

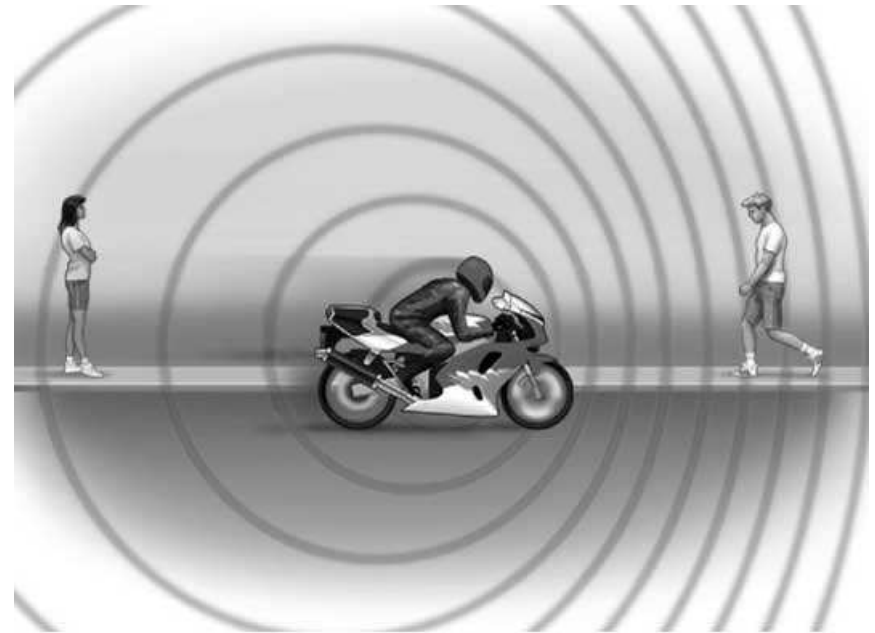
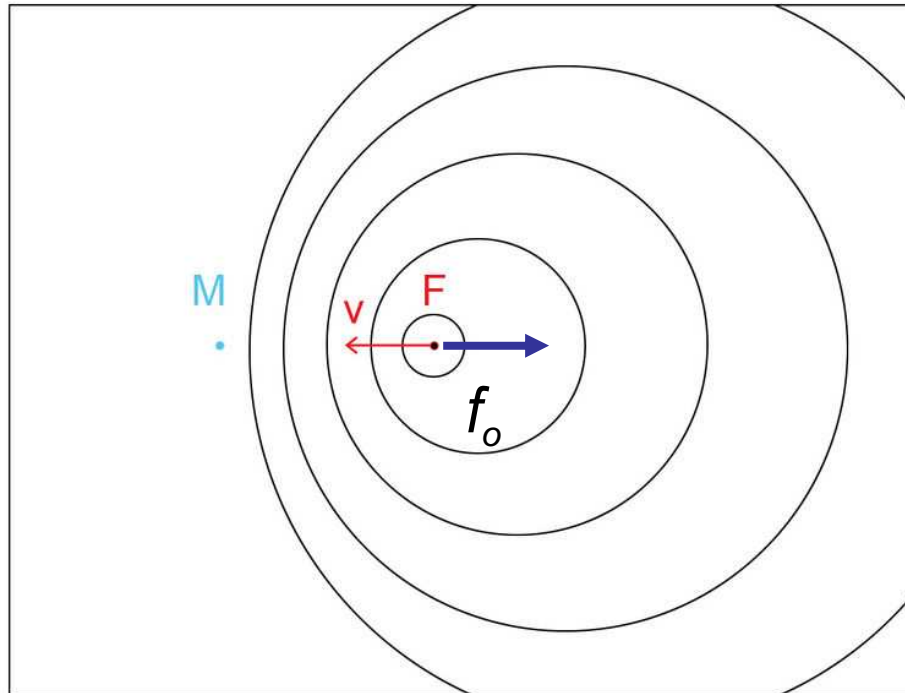
0 emberi [hallásküszöb](#) (egészséges fül esetén);

egy szúnyog repülésének hangja 3 méterről



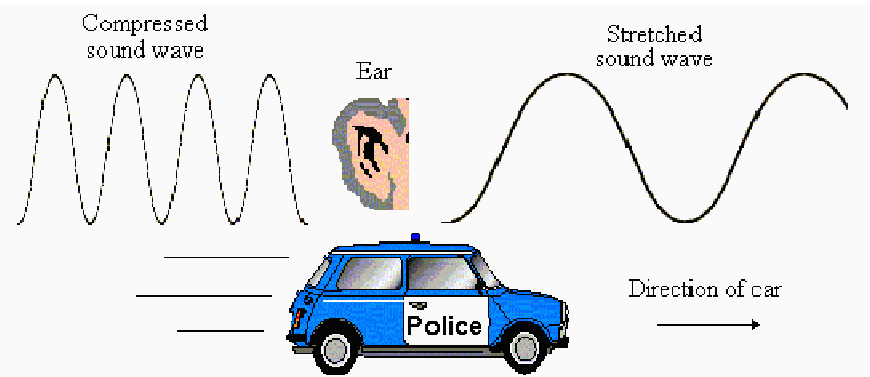
# Doppler effektus 1.

Forrás mozog, a megfigyelő áll

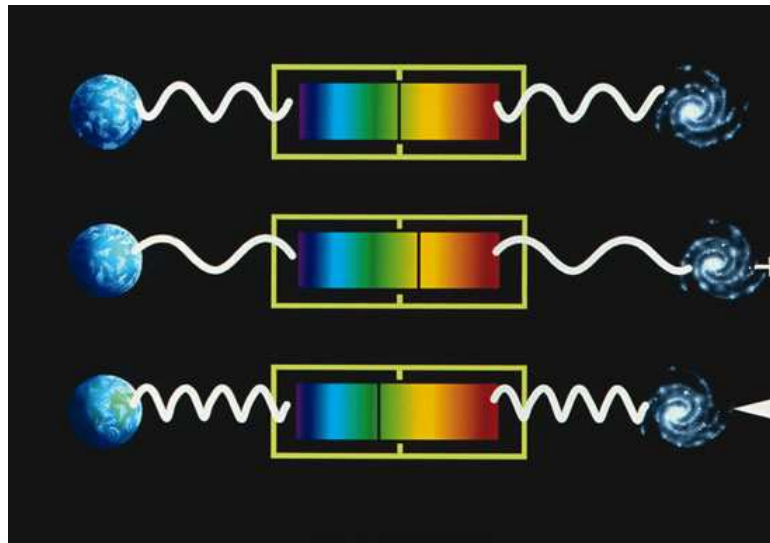
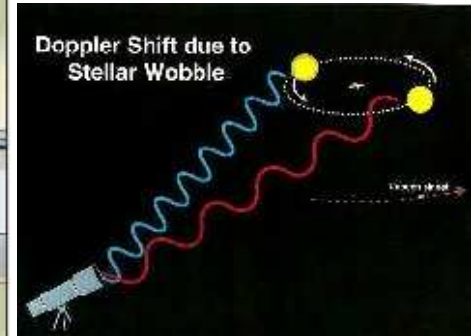
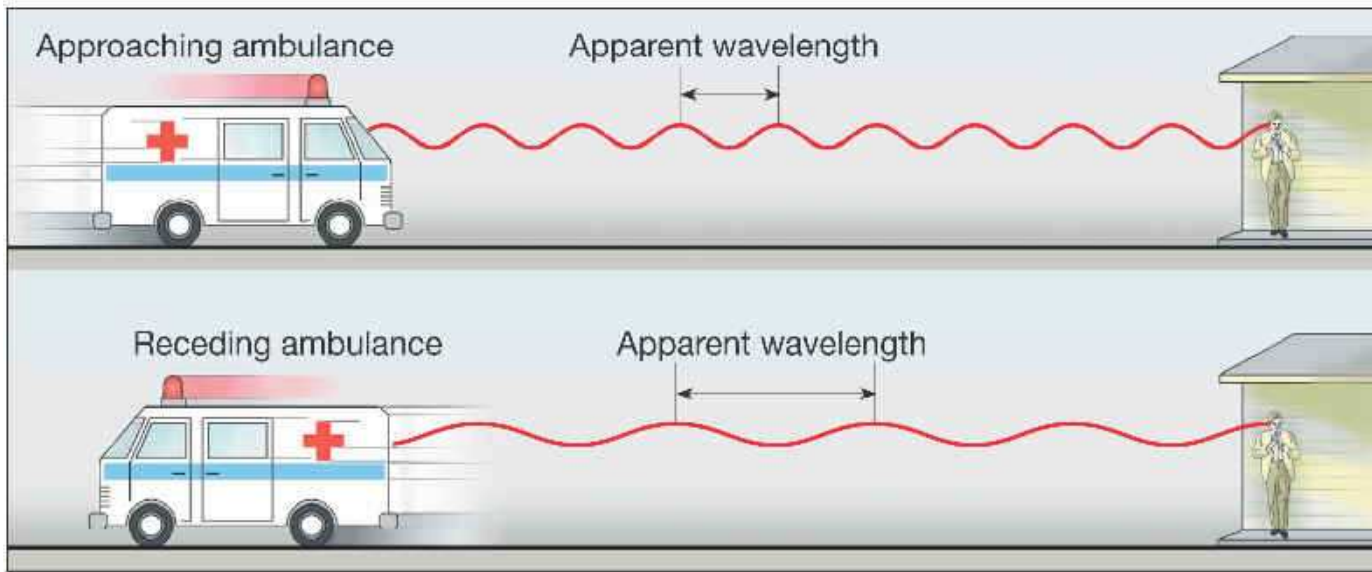


Precision Graphics

$$f' = f_0 \frac{1}{1 + \frac{v}{v_h}}$$



The Doppler effect:  
As the police car approaches the sound waves are compressed and the pitch rises.  
As it recedes the sound waves are stretched and the pitch decreases.



közeledik: kékeltolődás



nyugalomban (laboratórium)

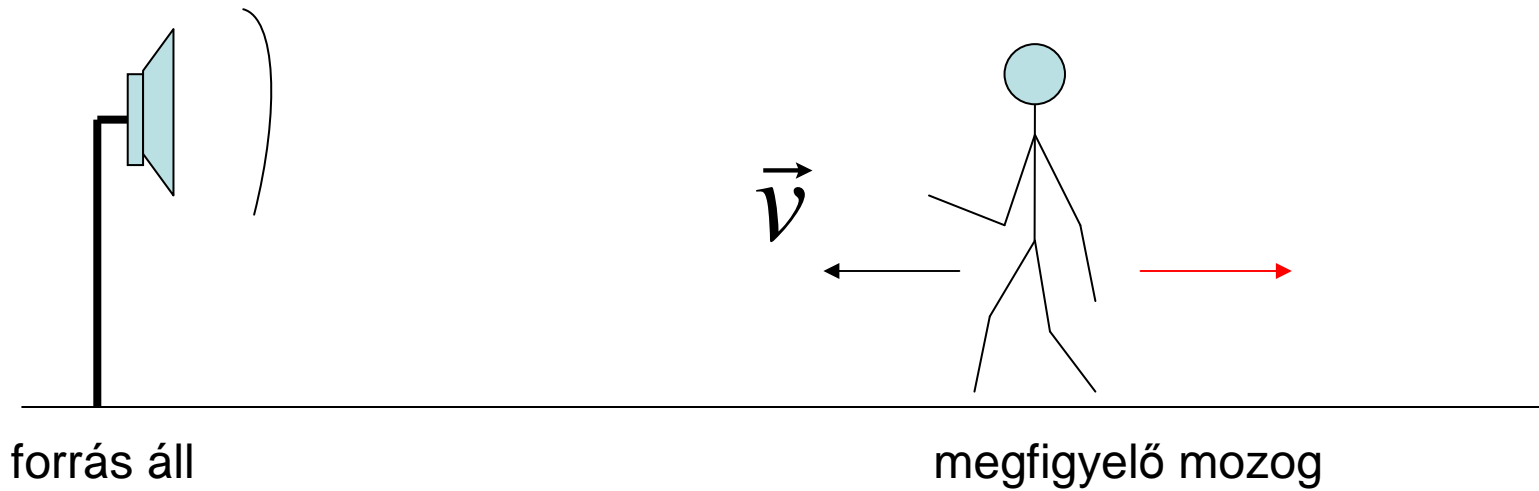


távolodik: vöröseltolódás

$$v = Hr$$

$H = \text{Hubble állandó}$

## Doppler effektus 2.



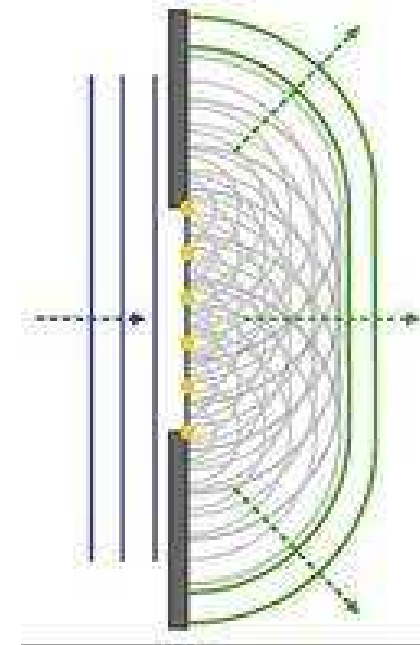
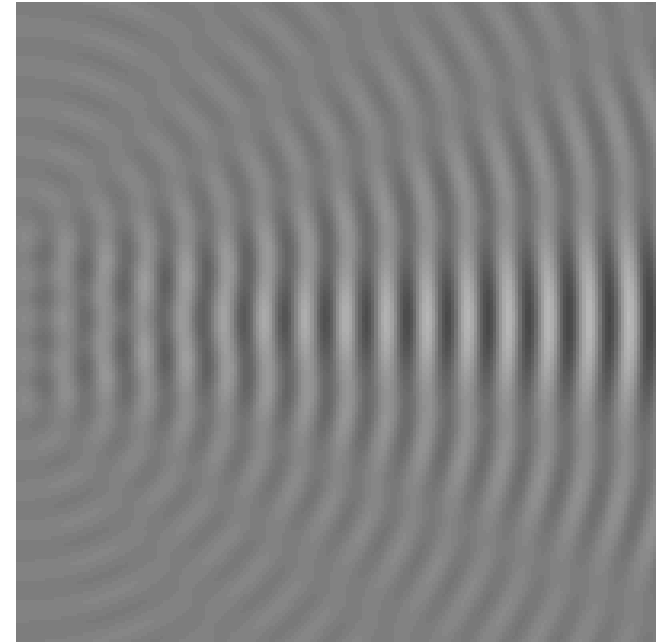
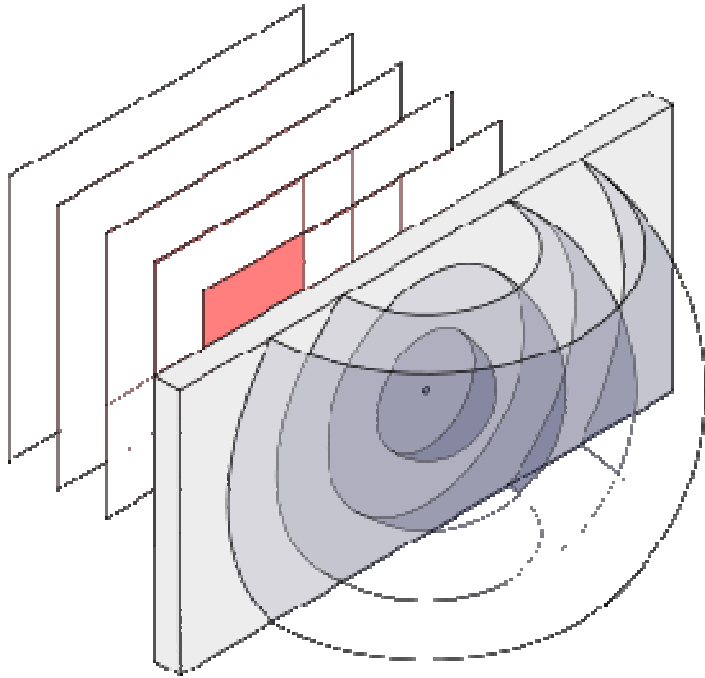
$$f' = f_o \left( 1 \pm \frac{v}{v_h} \right)$$

$$f' = f_o \frac{1 \pm \frac{v_m}{v_h}}{1 \mp \frac{v_f}{v_h}}$$

m: megfigyelő  
f : forrás  
h : hang

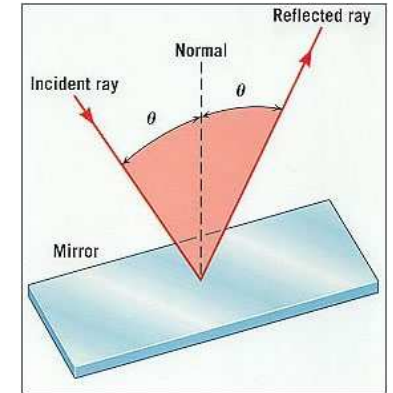
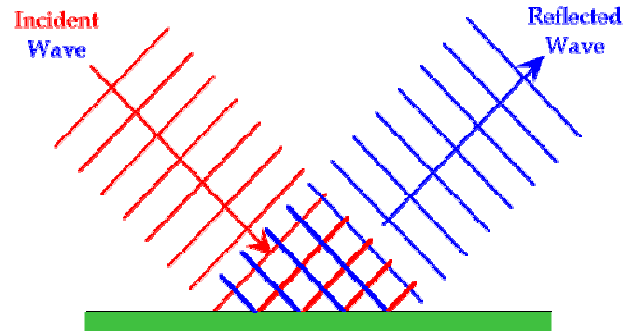
... és ha a szél fúj?

## *Huygens elv 1.*



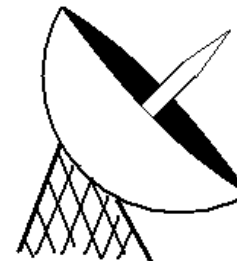
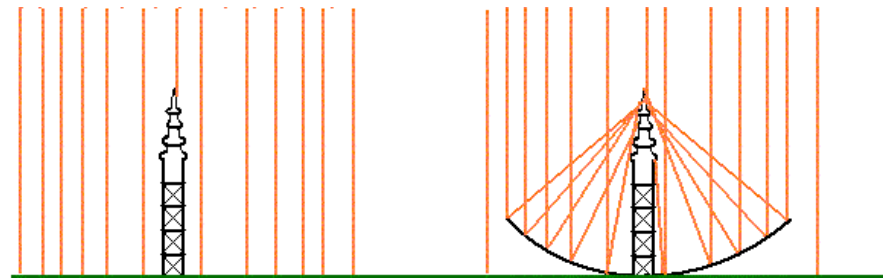
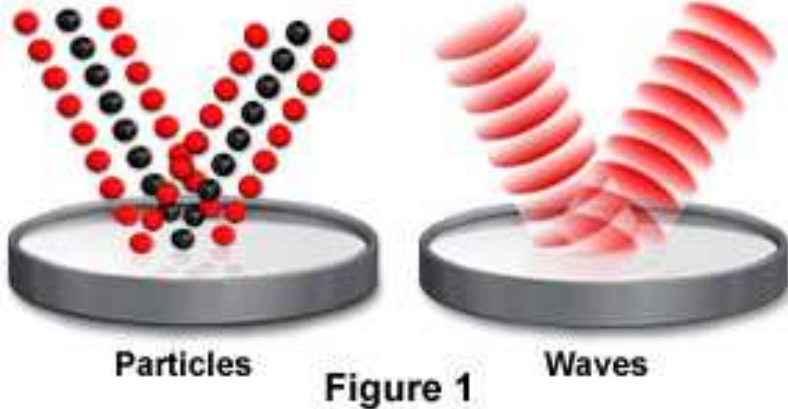
# Huygens elv 2.

reflexió



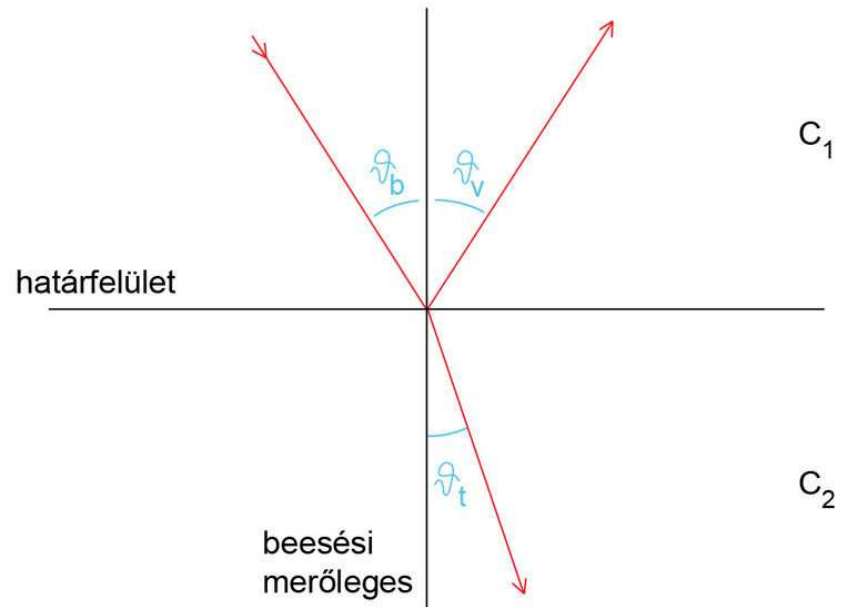
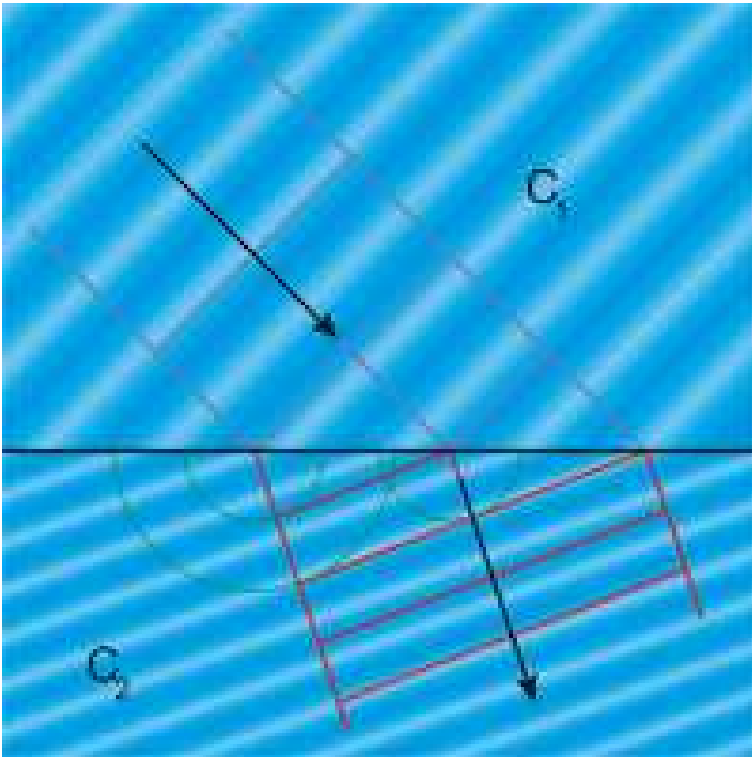
Magyarázat!!!

## Particles and Waves Reflected by a Mirror



This is the reason for this characteristic shape for items that receive radio waves or other transmissions from space. This particular radio receiver is pointed at a certain part of the sky so it can receive transmissions from a particular satellite.

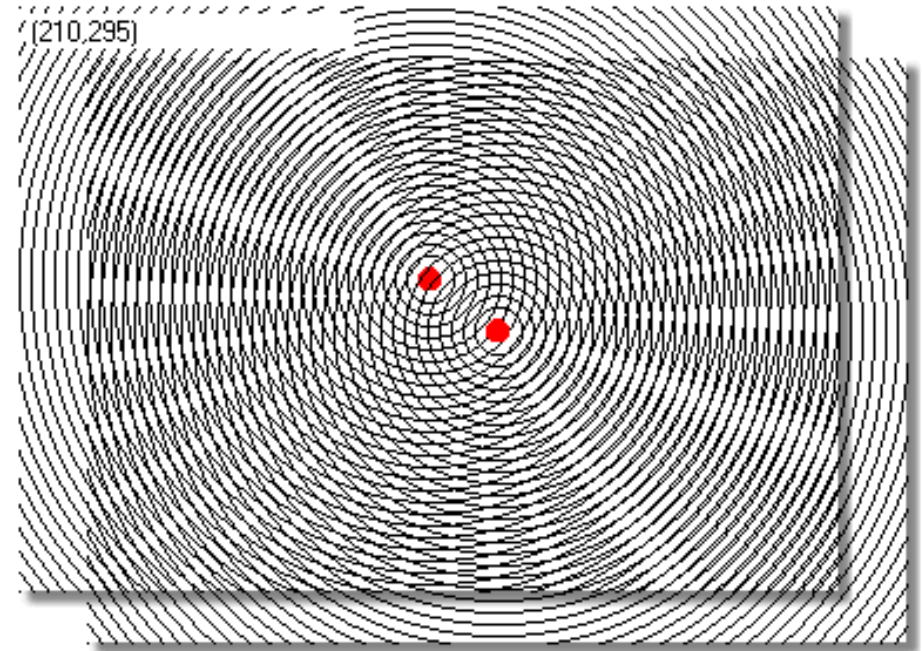
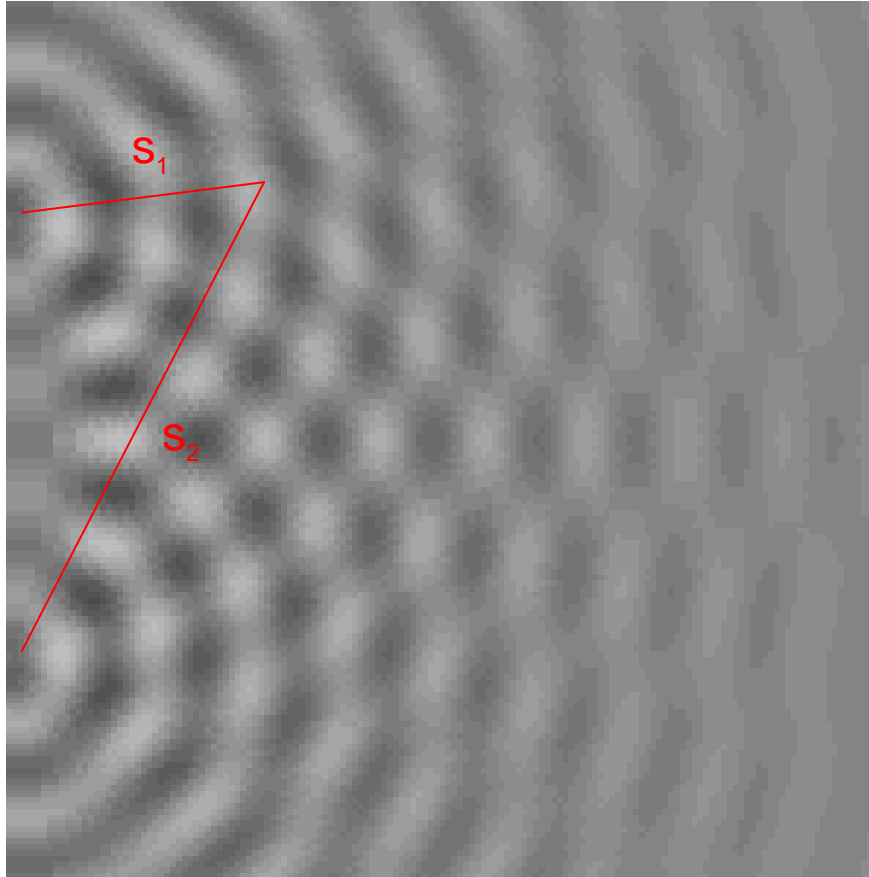
## Huygens elv 3.



Fénytörés (hullámtörés)

**Magyarázat!!!**

# Interferencia



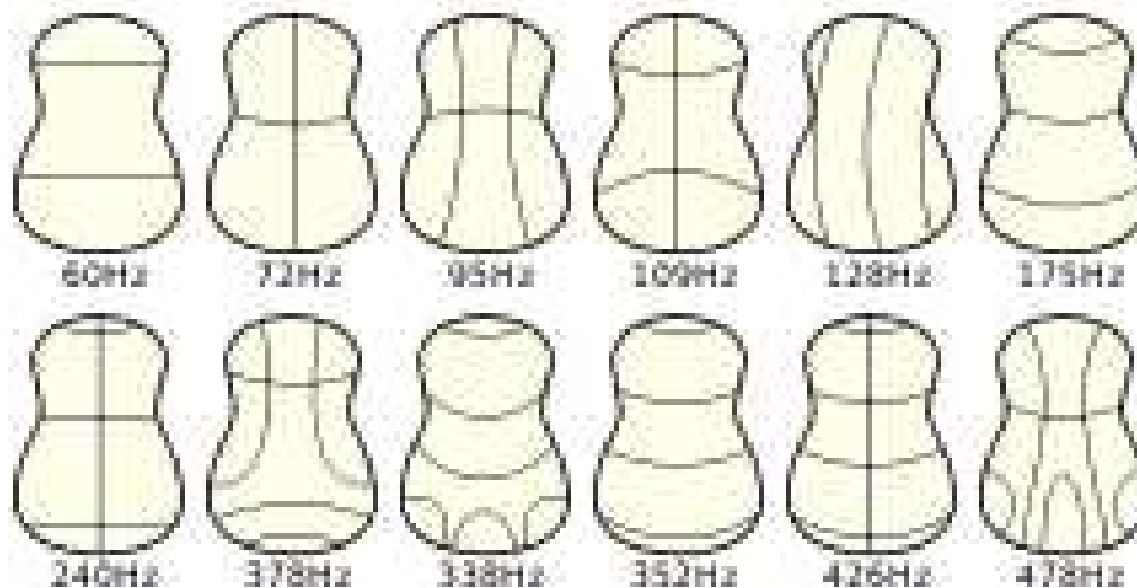
Erősítés:  $\Delta s = s_2 - s_1 = n\lambda$   
 $\Delta\varphi = n(2\pi)$

Kioltás:  $\Delta s = s_2 - s_1 = (2n + 1)\frac{\lambda}{2}$   
 $\Delta\varphi = (2n + 1)\pi$   
 $n = 1, 2, 3 \dots$





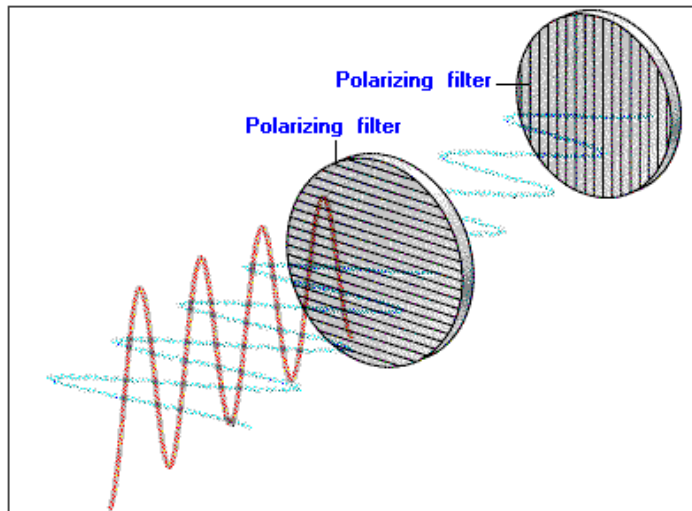
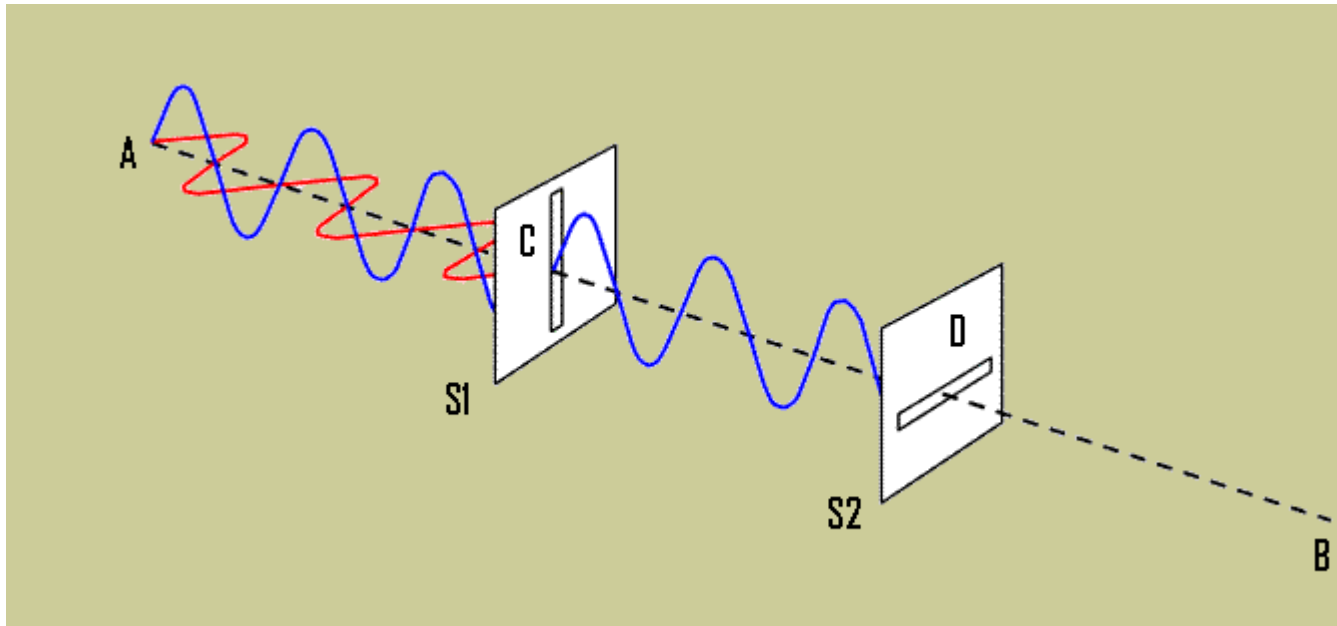
## Chladni ábrák



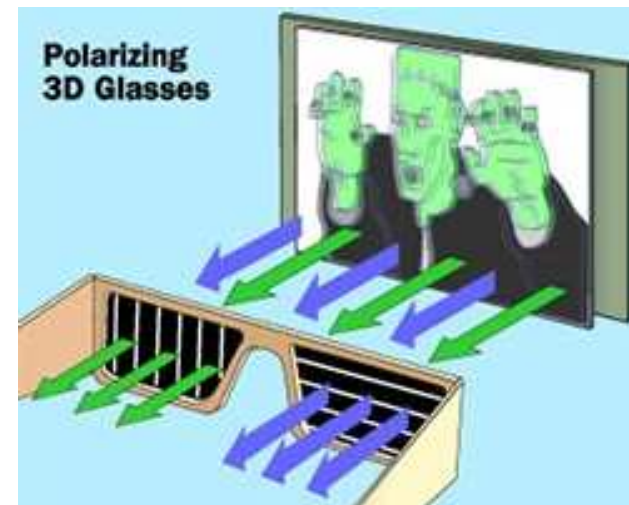
gitár

# Polarizáció (hullám)

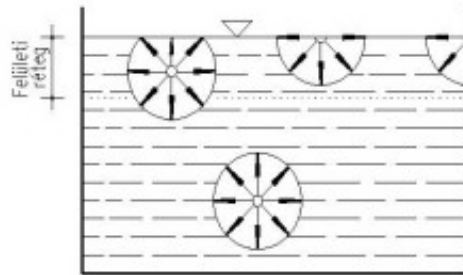
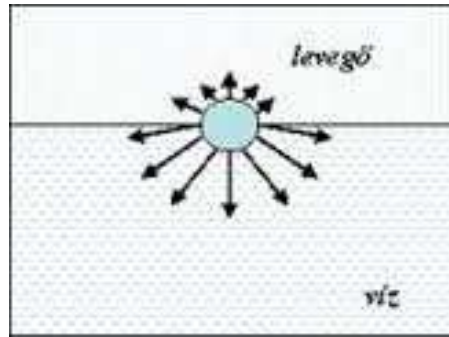
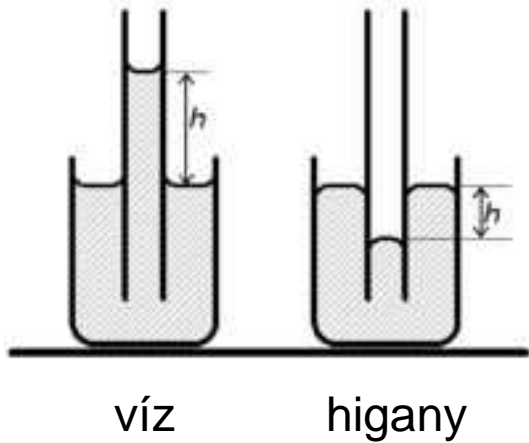
kötél:



fény

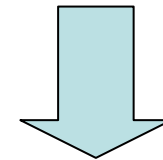
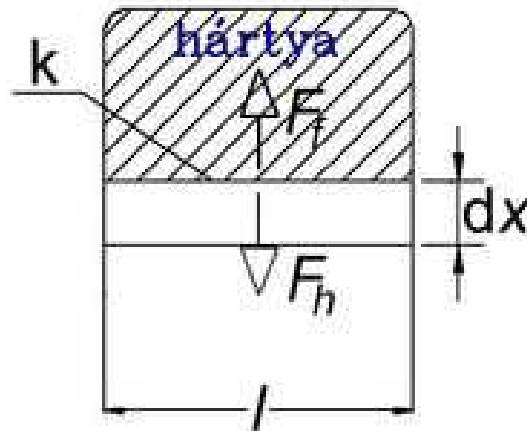
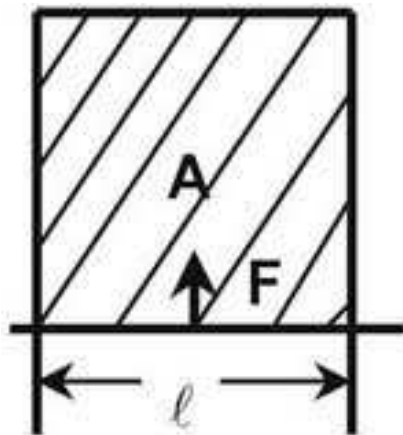


# Felületi feszültség I.



$$F = \alpha l$$

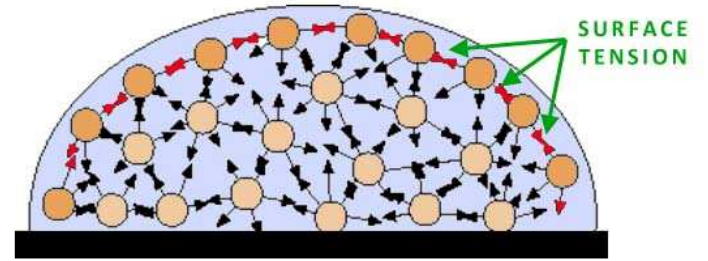
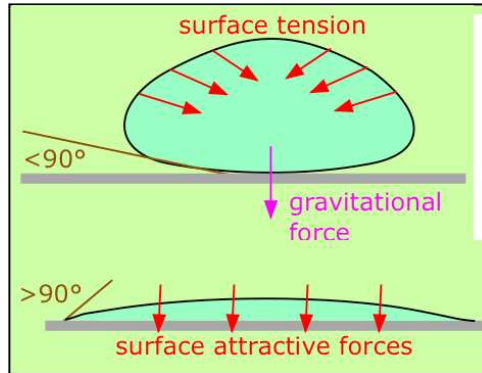
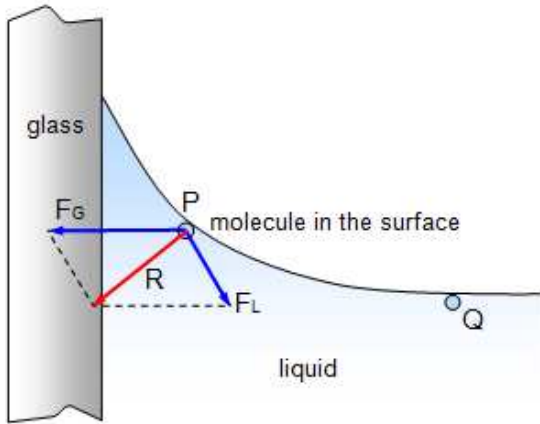
$$dW = F dx = \alpha l dx = \alpha dA$$



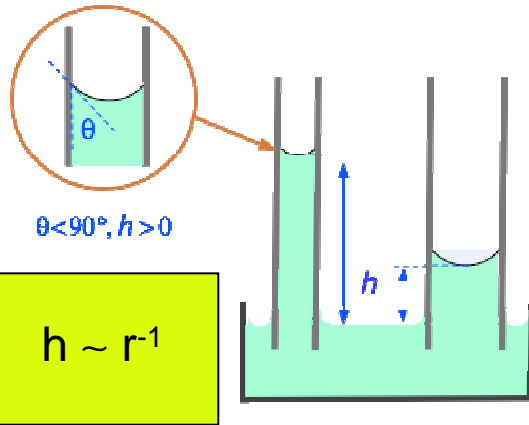
**Felületi energia:**

$$E = W = \alpha A$$

# Felületi feszültség II.



$$E = W = \alpha A$$



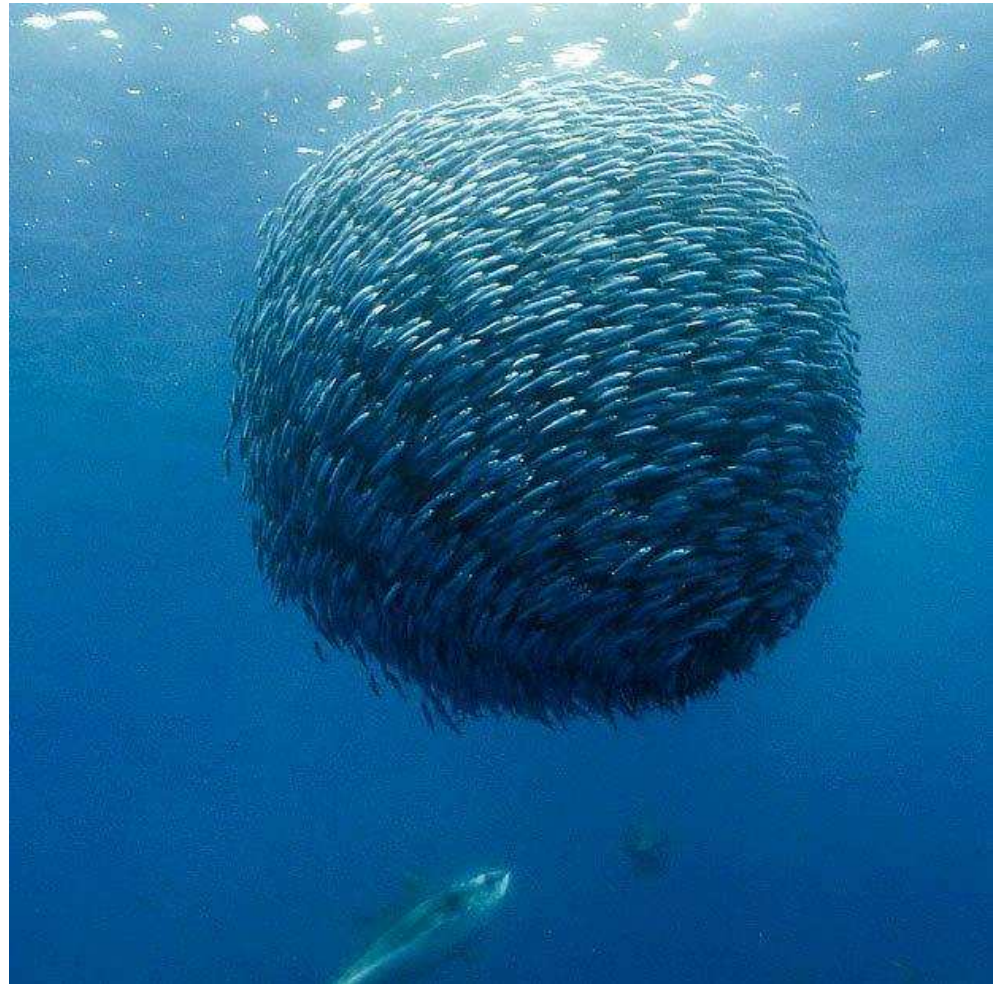
**Falak nedvesedése  
(kapilláris hatás)**

$$E \rightarrow E_{\min}$$



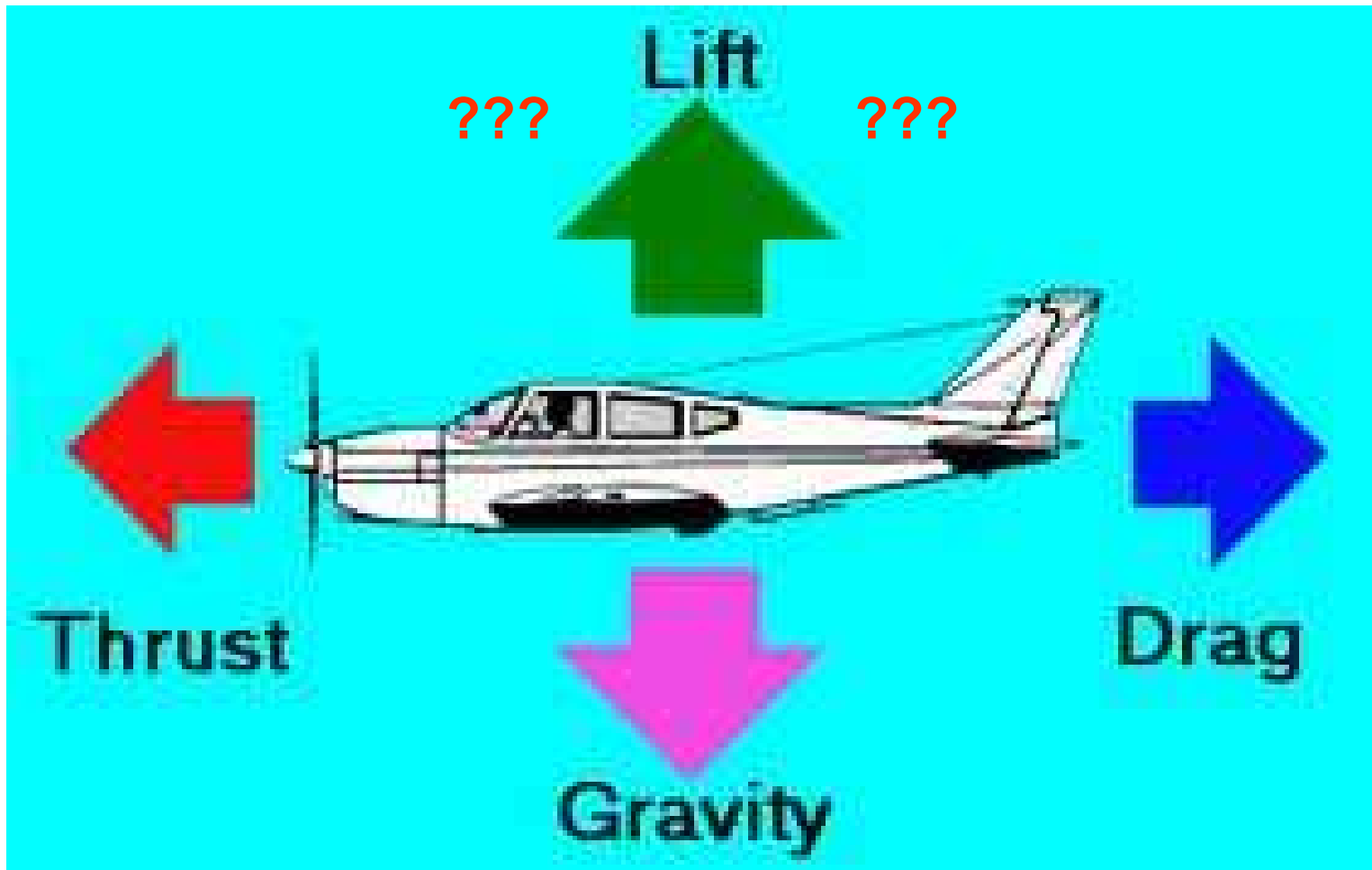
## Felületi feszültség III.

*Szappanbuborék, halraj*



# Folyadékok (gázok) mechanikája

*Hogyan repül a repülő ( $F_{lift}$ )???*



Def.: nyomás  $P = \frac{F}{A} \left[ \frac{N}{m^2} = Pa \right]$

Víznyomás:

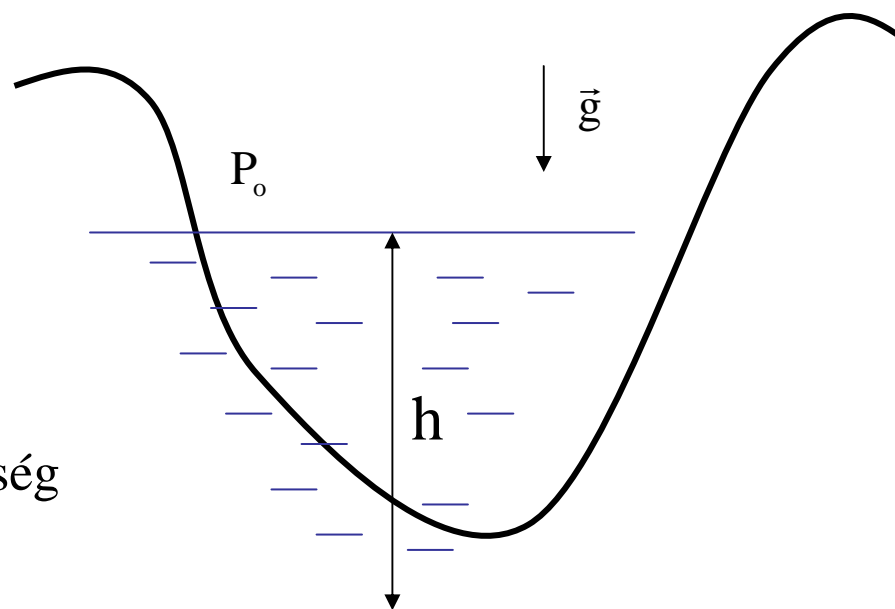
A mérhető nyomás

$$P = P_0 + \rho gh$$

légköri nyomás

sűrűség

mélység



Vízcsepp v. szappanbuborék, felületi feszültség:

$$r \rightarrow r + dr$$

$$P = FA$$

$$dW = \alpha dA = \alpha 8\pi r dr \quad dV = 4\pi r^2 dr$$

$$dW = P 4\pi r^2 dr = \alpha 8\pi r dr$$

Energiasűrűség:  $\omega = \frac{dW}{dV} = \frac{2\alpha}{r}$

$$P = \frac{2\alpha}{r}$$

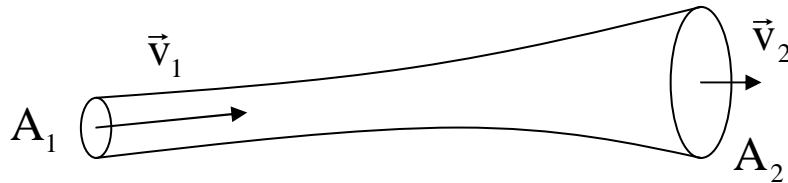
# Felhajtóerő (Archimedes):

$$F_f = \rho_{foly.} g V'$$

(„úszó” test)

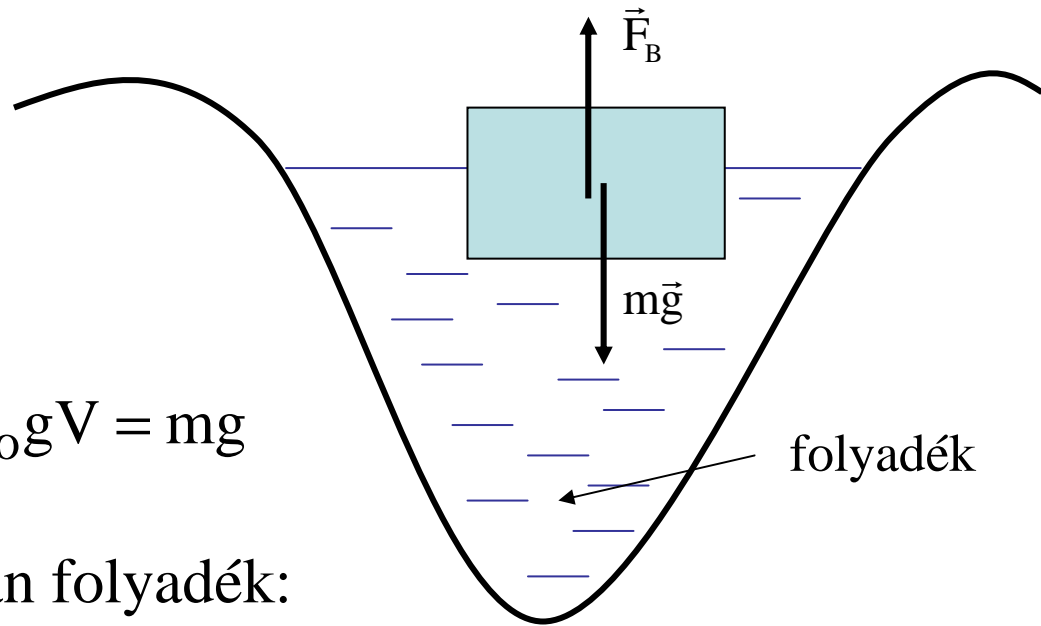
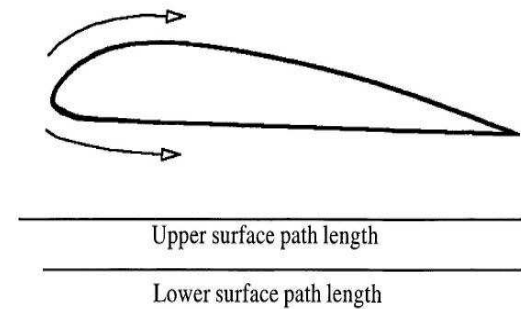
$$F_f = \rho_{foly.} g V' = \rho_o g V = mg$$

Összenyomhatatlan folyadék:



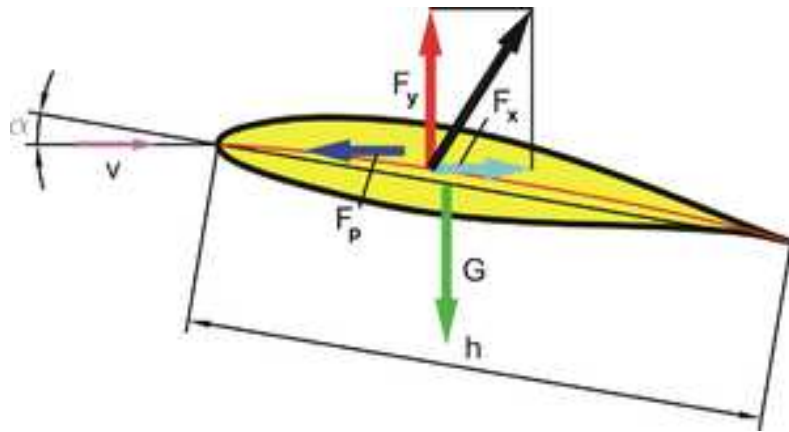
$$A_1 v_1 = A_2 v_2$$

Bernoulli egyenlete: 
$$P + \frac{1}{2} \rho v^2 + \rho g y = \text{const}$$



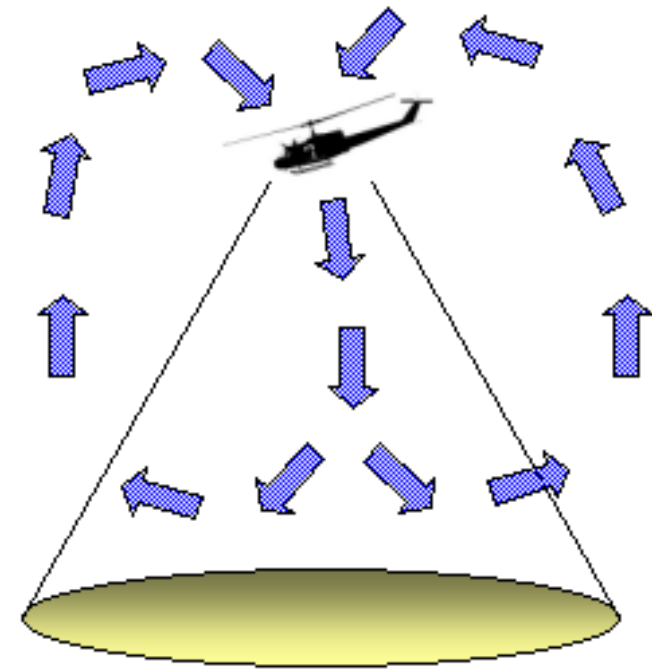
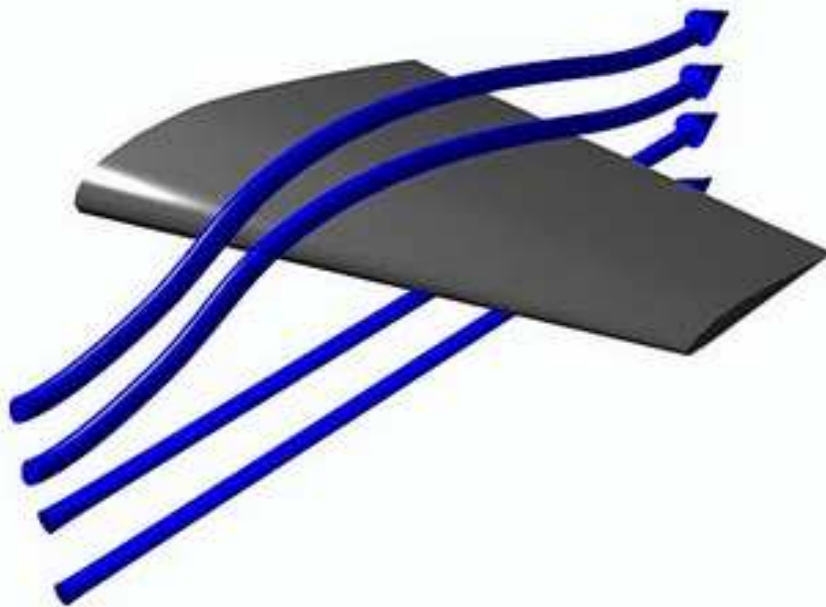


# Zsukovszkij-féle szárny profil



Nyikolaj Ivanovics  
Zsukovszkij  
1847-1921

1902-1904 az első  
szélcsatorna építése

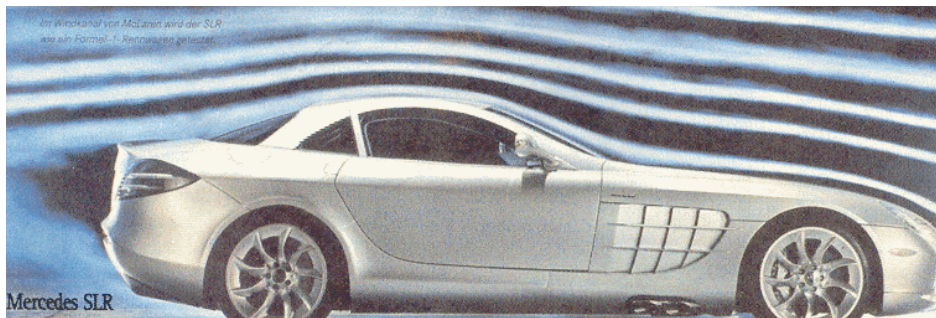




Közegellenállás:

$$F = \frac{1}{2} c_w \rho A v^2$$

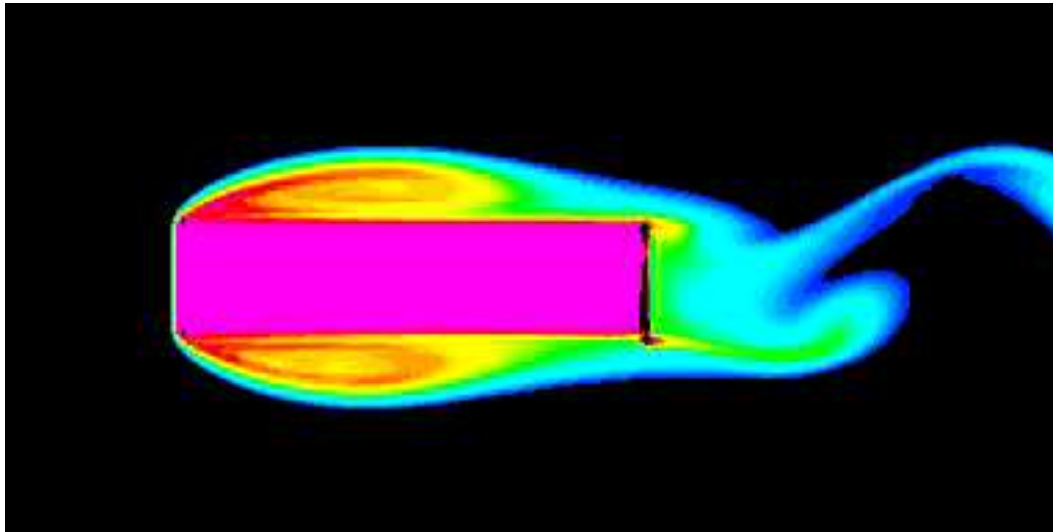
$$c_w = 0,26 - 0,29$$



$$c_w = 0,26$$



## Kármán-féle örvénysor:



Kármán Tódor

1881-1963

1898-1902

Királyi József Műegyetem  
(BME)

USA: Szuperszónikus

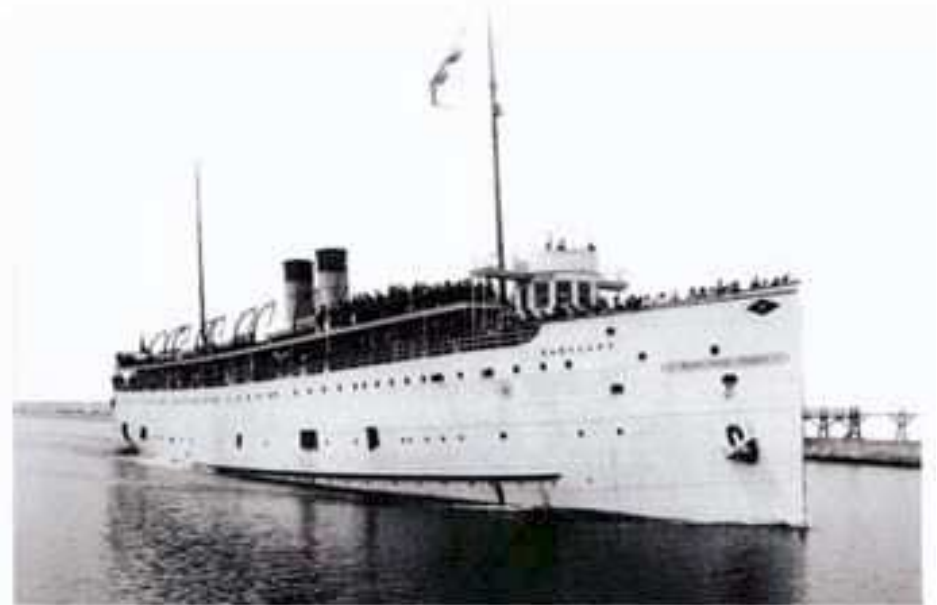
aerodinamika és

1944 után *Jet Propulsion  
Laboratory* (Sugárhajtás-  
laboratórium)

## Nem túl jó döntések, avagy amikor a fizika fölülírja a gazdasági folyamatokat

**Az ország mellékvonali közlekedése teljesen megbénult tíz évvel ezelőtt egy, az előző évben történt baleset kivizsgálása nyomán.**

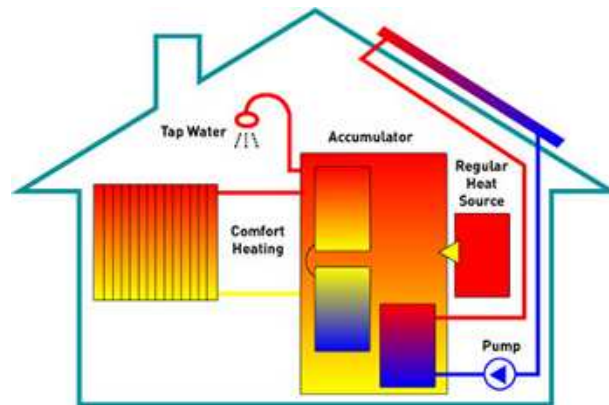
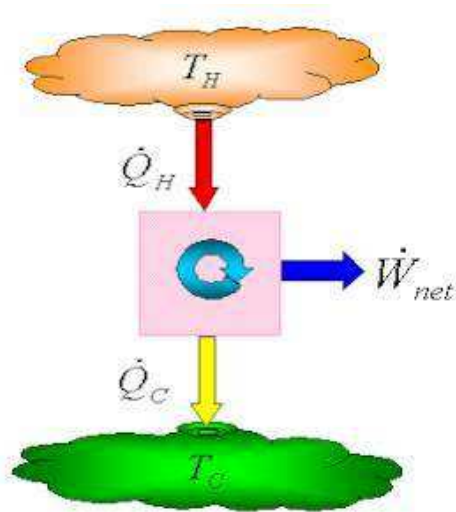
A kezdet: Ukk és Jánosháza között 2002. november 13-án, a Bzmot 277 pályaszámú motorkocsi tengelytörés miatt kisiklott. A baleset körülményeinek tisztázása során később ultrahangos vizsgálatnak vetették alá e csehszlovák gyártmányú típus kerékpártengelyeit. Ennek eredményeképpen 2003. január 23-án a 259-ből 219 motorkocsi közlekedését függesztették fel, ugyanis úgy ítélték meg, a sikláshoz vezethető repedések veszélyeztették az utasok biztonságát.



**The Eastland**



# Termodinamika (és statisztikus mechanika)



???



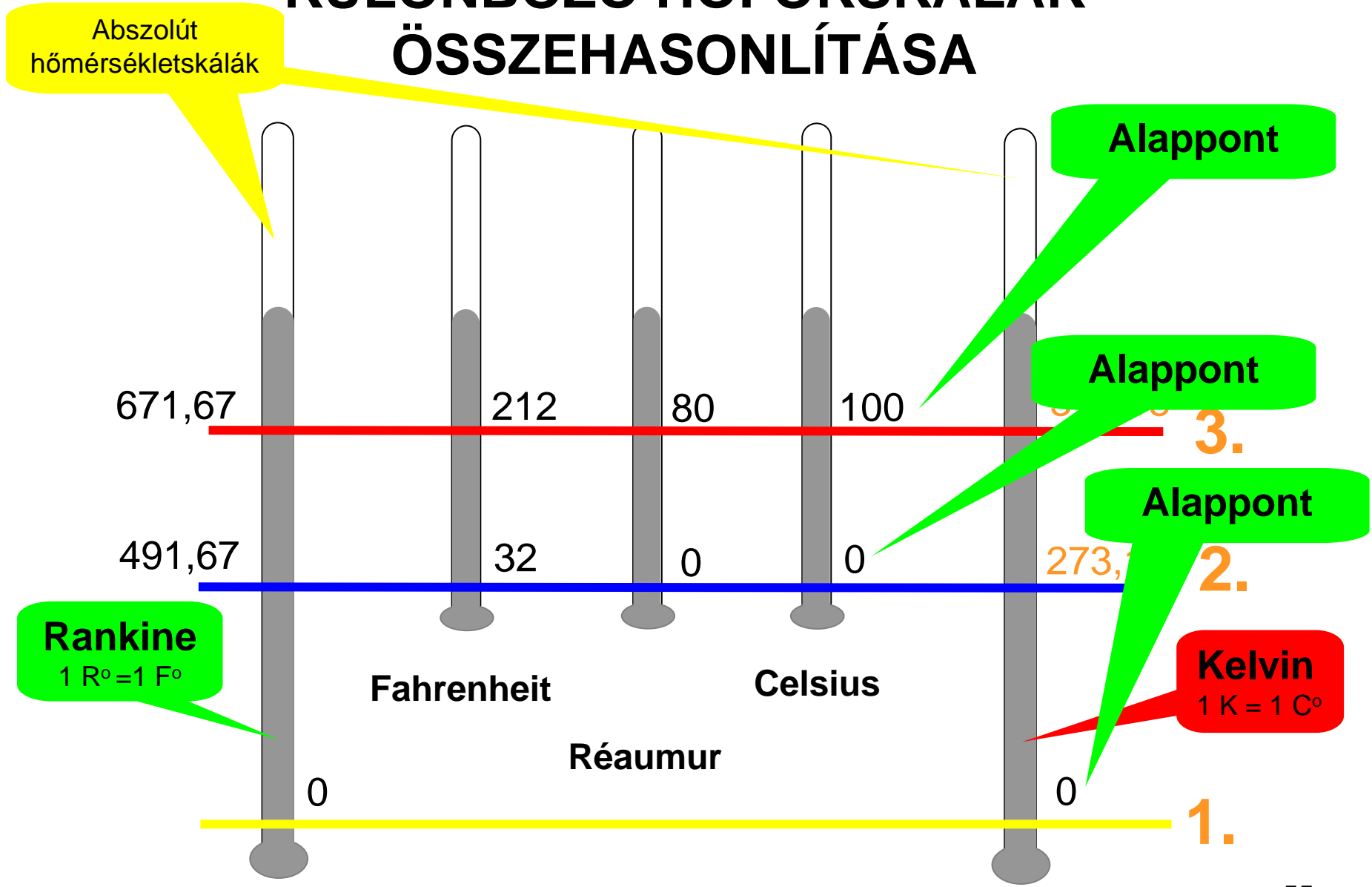
# Hőmérséklet

**Andres Celsius** (1701-1744)

1737-ben tervezte meg a ma is általánosan használt (100 fokos beosztású) hőmérsékletskálát, melynek azóta is megőrizte nevét, sőt az egyik leggyakrabban elhangzó névvé tette világszerte. Ötlete, amelyet 1742-ben ismertetett a Svéd Akadémián tartott előadásában, leegyszerűsítette a hőmérsékletmérést, és a kapcsolódó számításokat.

Celsius azonban a forráspontot jelölte 0-val, s a fagyáspontot 100-al, a két számot 1750-ben Stromer svéd tudós cserélte fel.

# KÜLÖNBÖZŐ HŐFOKSKÁLÁK ÖSSZEHAISONLÍTÁSA



# Hőtágulás

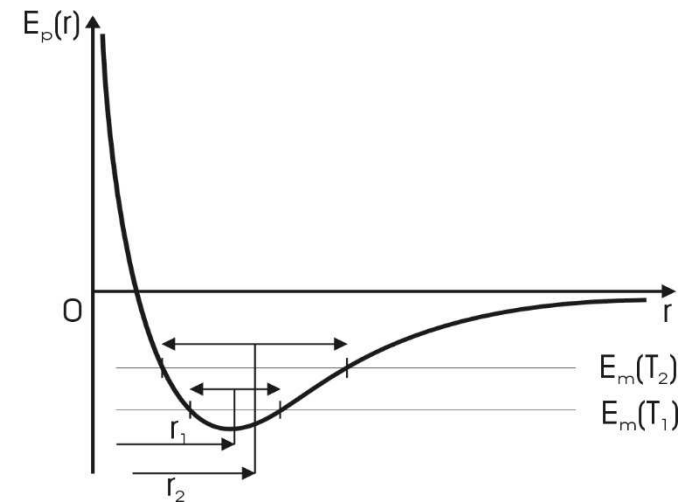


Szilárd testek:  
Lineáris hőtágulás.

$$l = l_0(1 + \alpha \Delta T)$$

Térfogati hőtágulás

$$V = V_0(1 + \beta \Delta T)$$



$$\Delta T = T - T_0$$

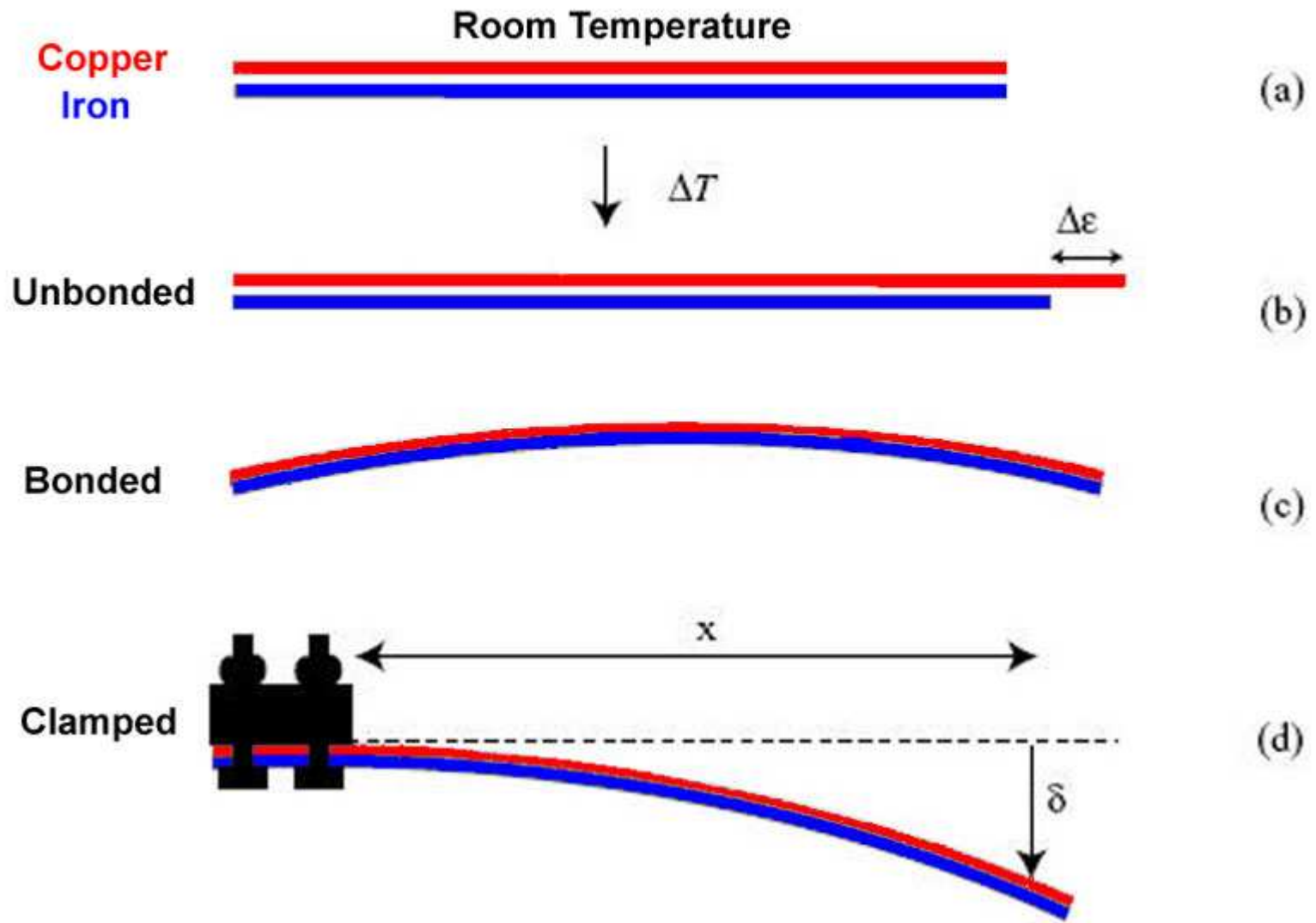
$$\Delta T = T - T_0$$





# Bimetal Strip

Two Metals Bonded Together with Different Coefficients of Expansion



Folyadékok termodinamikája.

Térfogati hőtágulás.

$$V=V_0(1+\beta\Delta T)$$

$$\Delta T=T-T_0$$

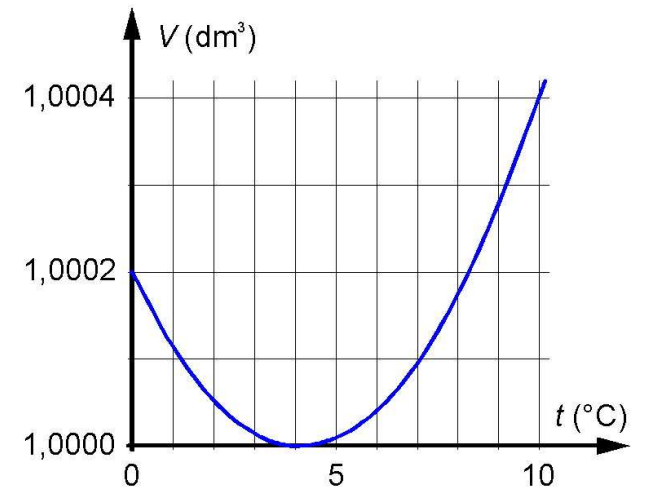
$\beta$  a térfogati hőmérsékleti együttható:

$$?? \quad \beta=3\alpha \quad ??$$

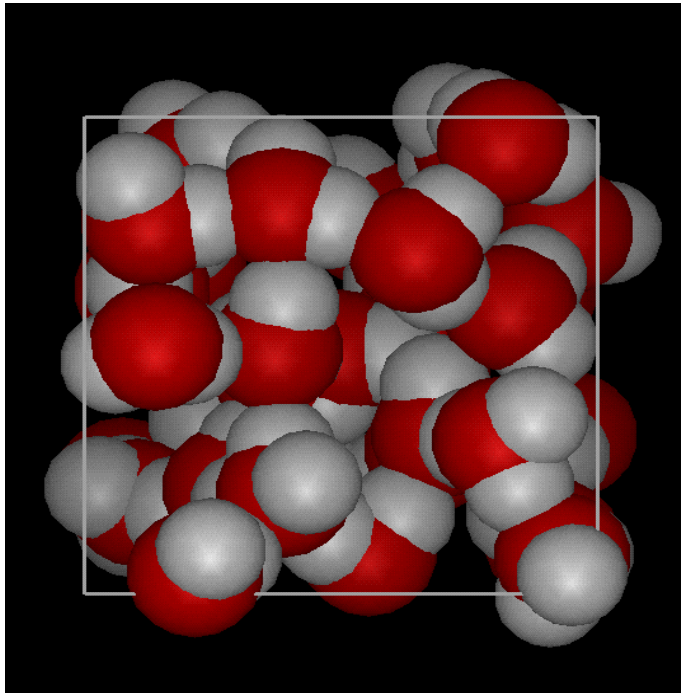
*Gázolaj, benzin:  $\beta \approx 0.001 \text{ 1/}^\circ\text{C}$*

*Példa*

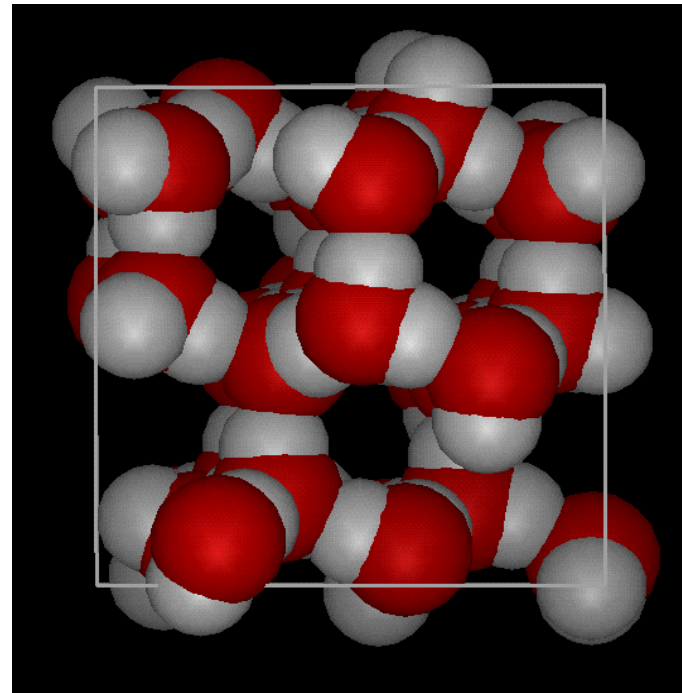
# Víz térfogatváltozása



víz



jég



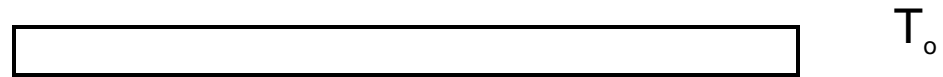
# Hőtágulás (még egyszer)

Hőtágulás:

$$T_C = T - 273,15$$

↑      ↑  
[°C]    [K]

$$T_F = \frac{2}{5} T_C + 32^\circ F$$

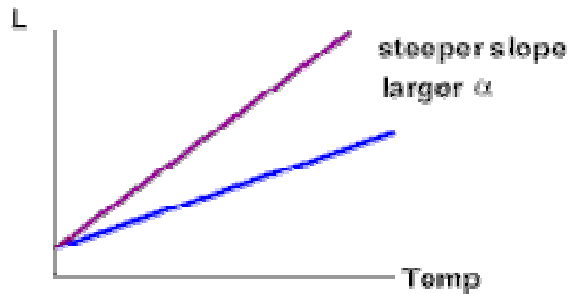


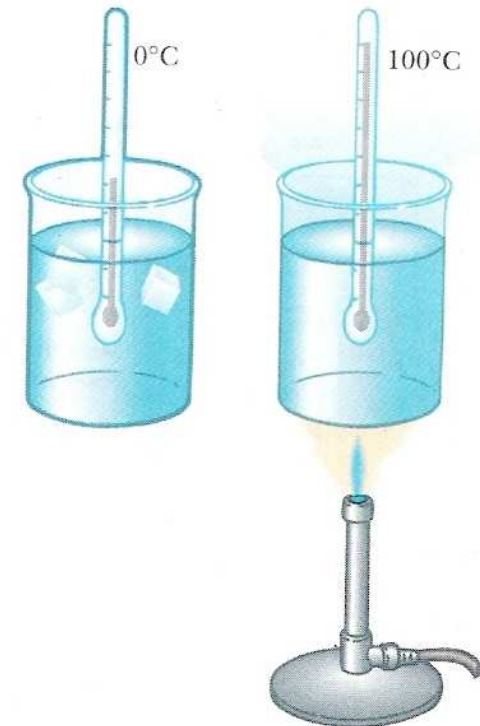
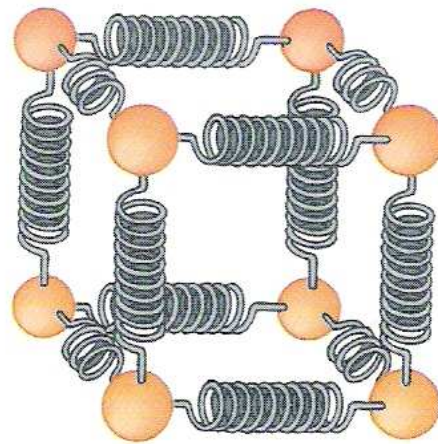
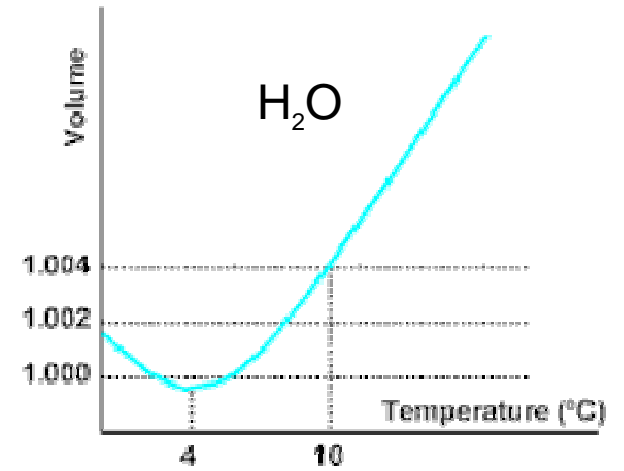
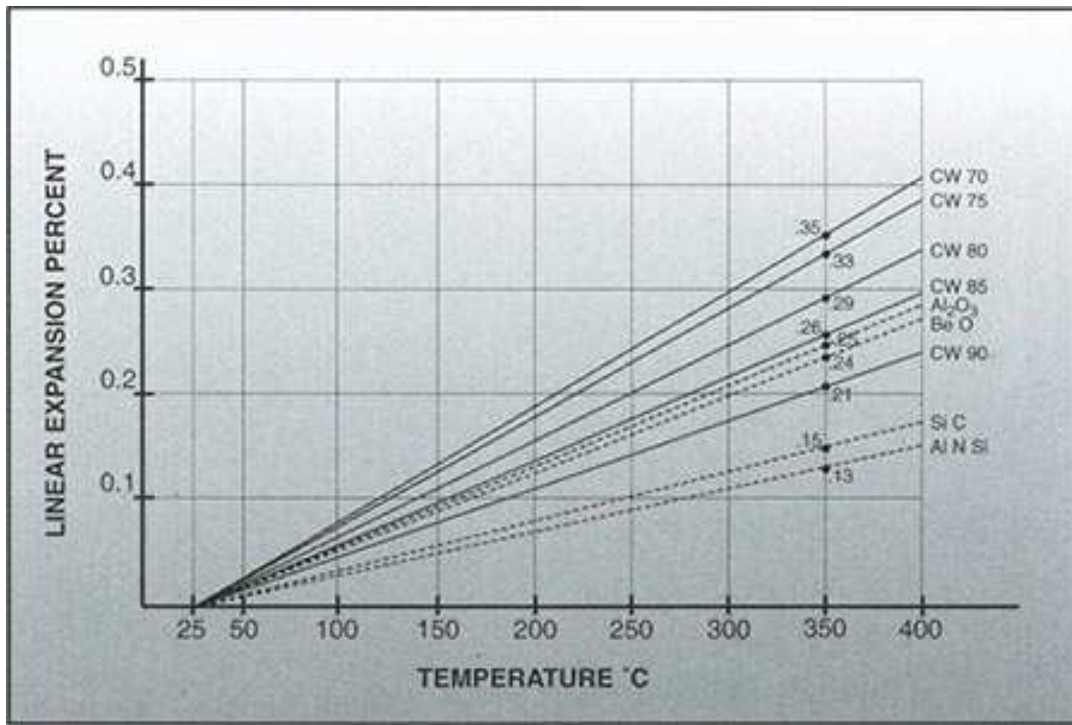
$$\Delta L = \alpha L_0 \Delta T$$

$$L - L_0 = \alpha L_0 (T - T_0)$$

$\alpha$  : átlagos hőtágulási együttható

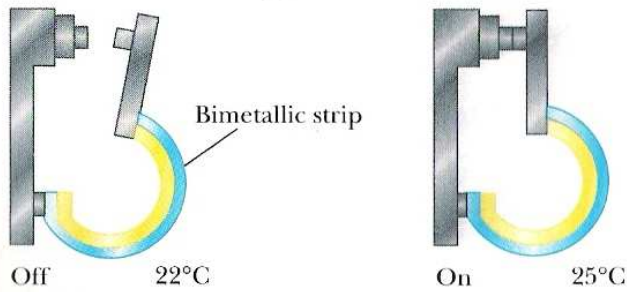
[1 / °C]



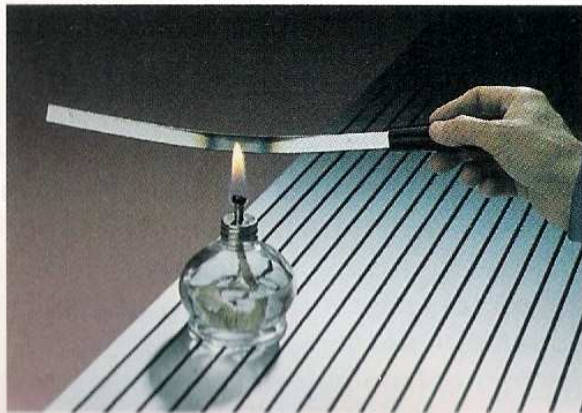




(a)



(b)



(c)

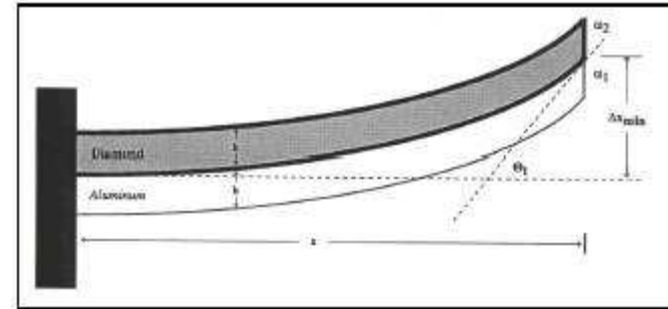
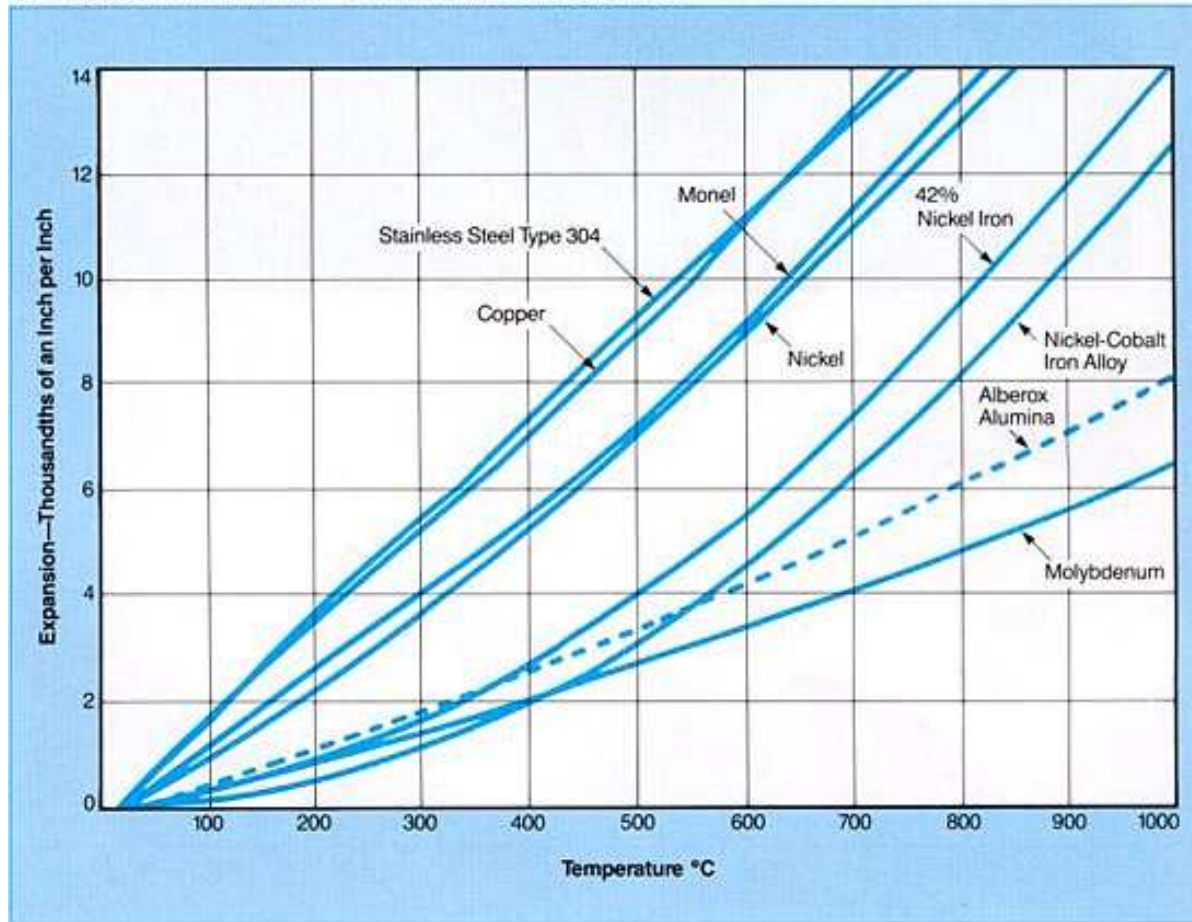


Fig. 4.8. Thermal expansion temperature sensor (schematic representation only).

Material	Linear expansion Coeff. $\alpha$ ( $1/^\circ\text{C}$ )
Aluminum	$24 \cdot 10^{-6}$
Brass & bronze	$19 \cdot 10^{-6}$
Copper	$17 \cdot 10^{-6}$
Glass	$9 \cdot 10^{-6}$
Glass (Pyrex)	$3,2 \cdot 10^{-6}$
Steel	$11 \cdot 10^{-6}$
Concrete	$12 \cdot 10^{-6}$

## APPROXIMATE THERMAL EXPANSIONS



$$\Delta L = \alpha L \Delta T \quad \frac{F}{A} = Y \frac{\Delta L}{L}$$



$$F = YA\alpha\Delta T$$

Y: Young (rugalmassági) modulus (acél: 200 GPa)



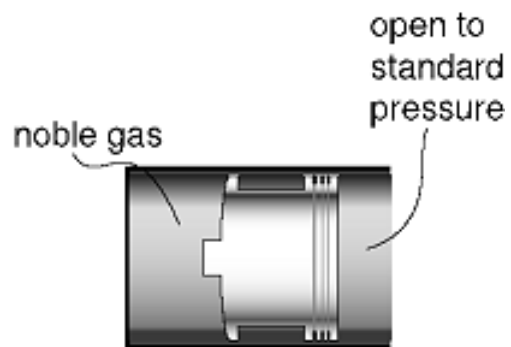
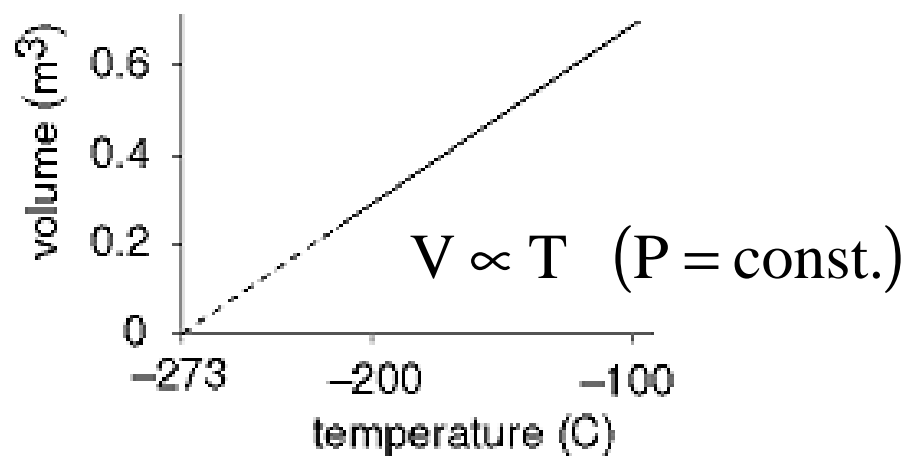
Hőtágulás 2D-ben:

$$\Delta A = 2\alpha A \Delta T$$

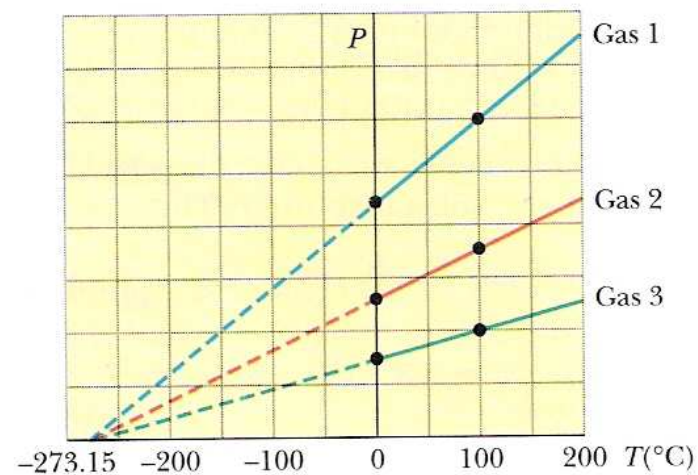
Hőtágulás 3D-ben:

$$\Delta V = \beta V \Delta T \rightarrow \beta = 3\alpha$$

### Gáz thermométer (kísérlet)



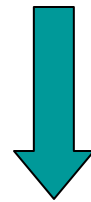
$$P \propto T \quad (V = \text{const.})$$



## Ideális gáz:

$$\left. \begin{array}{l} P \propto T \quad (V = \text{const.}) \\ V \propto T \quad (P = \text{const.}) \end{array} \right\}$$

$$PV \propto T \quad (m = \text{const.})$$



$$P \text{ [Pa]}$$

$$V \text{ [m}^3\text{]}$$

$$T \text{ [K]}$$

$$PV = nRT$$

Ideális gáz törvény

mól  
szám

$$n = \frac{m}{M}$$

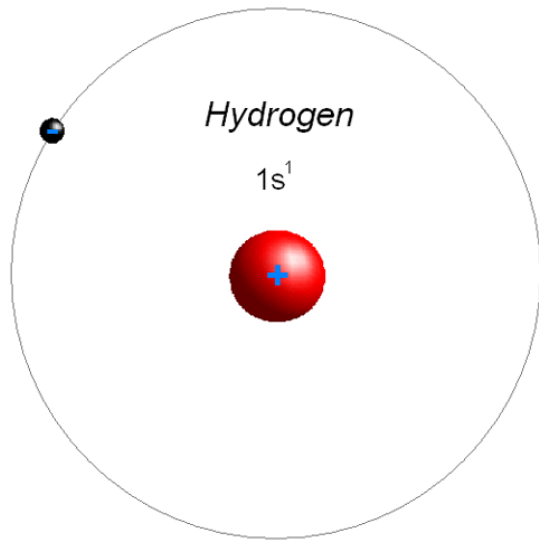
A gáz tömege

Moláris  
tömeg

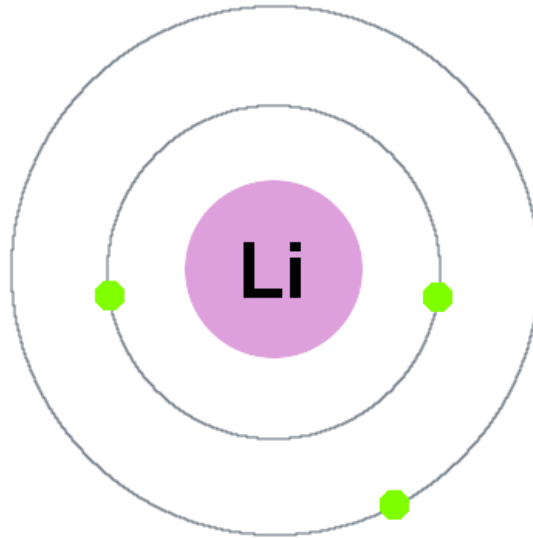
Ideális gáz állandó:  $R = 8.31 \frac{\text{J}}{\text{mol} \cdot \text{K}}$

1 mól:  $N_A = 6,022 \cdot 10^{23}$

# Moláris (mólnyi) tömeg

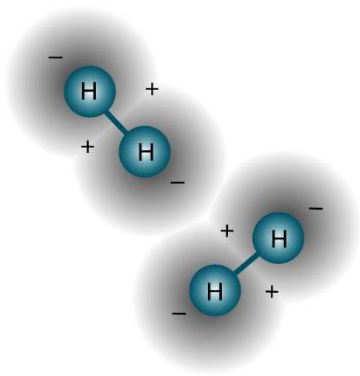
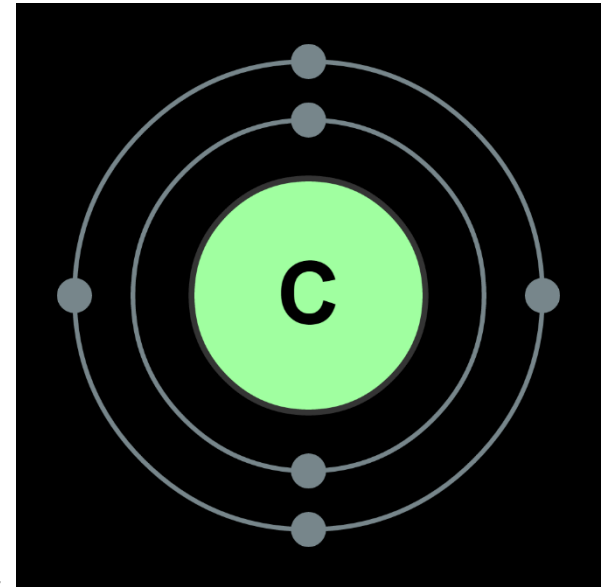


??  $H^1$  ??

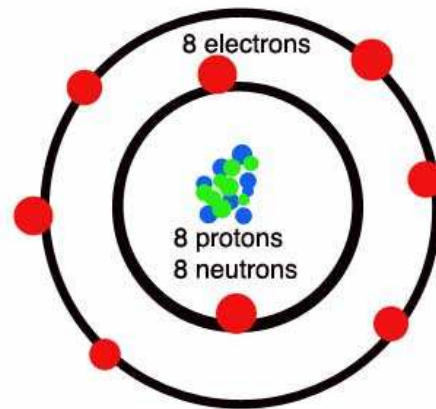


$Li^6$

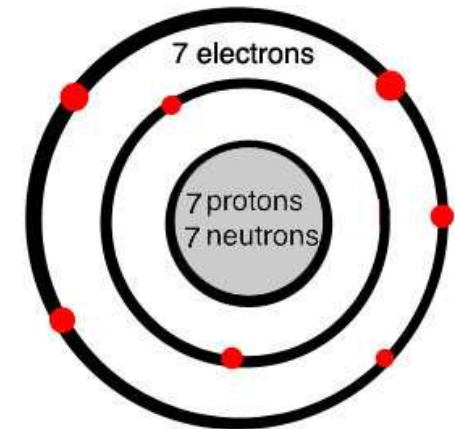
$C^{12}$



$H_2 \rightarrow M_{H_2} = 2g$



$O_2 \rightarrow M_{O_2} = 32g$



$N_2 \rightarrow M_{N_2} = 28g$