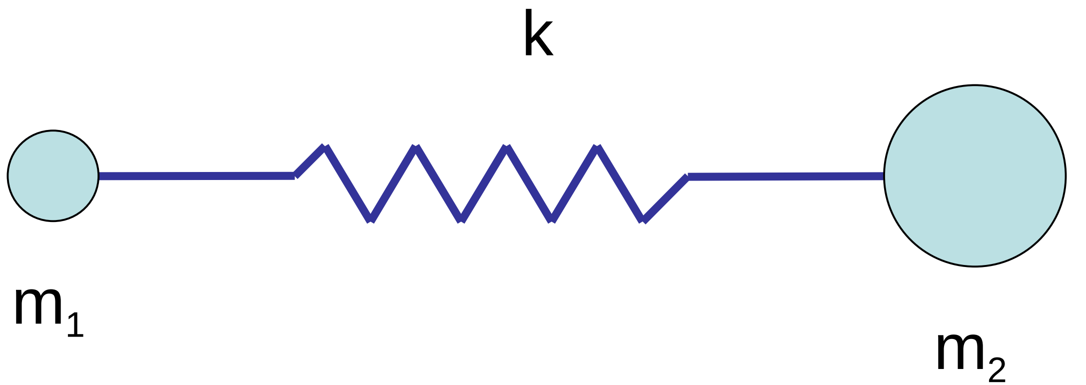
Fizika i

Rezgések, hullámok

Molekula rezgés:

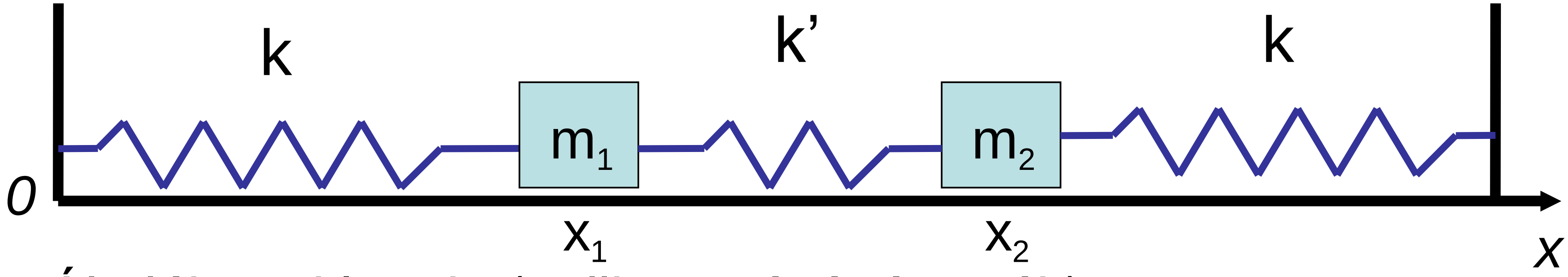


$\omega = ?$

$k' = ?$

$m' = ?$

Csatolt rezgés:



Általában: k' << k (nullhosszúságú rugók)

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

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

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

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

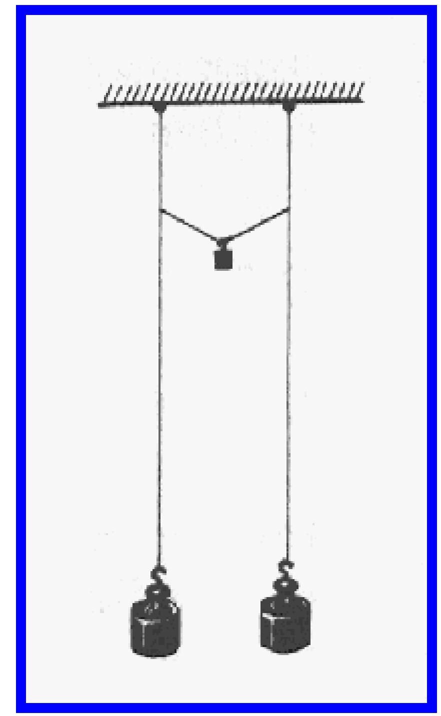
$$II. \quad \ddot{x}_2 = \omega_o^2(\ell - x_2) - \frac{k'}{m}(x_2 - x_1)$$

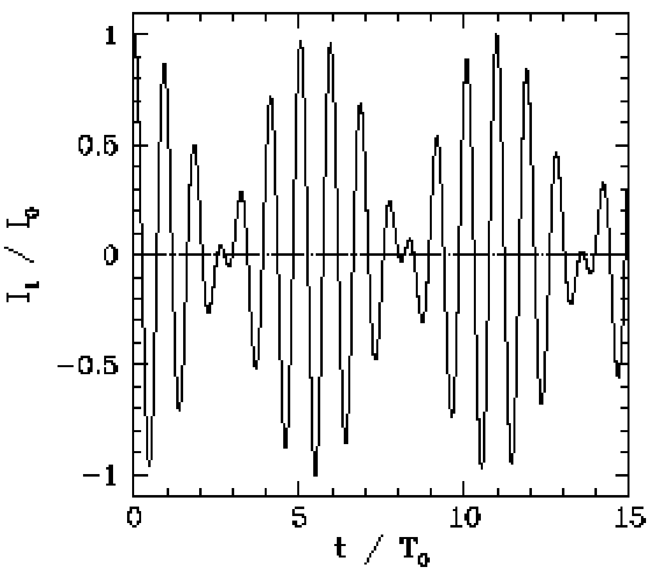
megoldás:

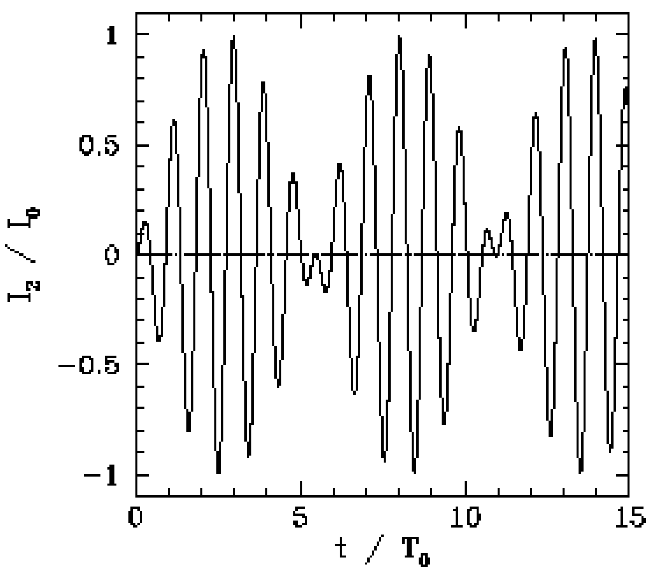
$$\omega = \sqrt{\omega_o^2 + 2\kappa} \quad \text{ahol} \quad \kappa = \frac{k'}{m}$$

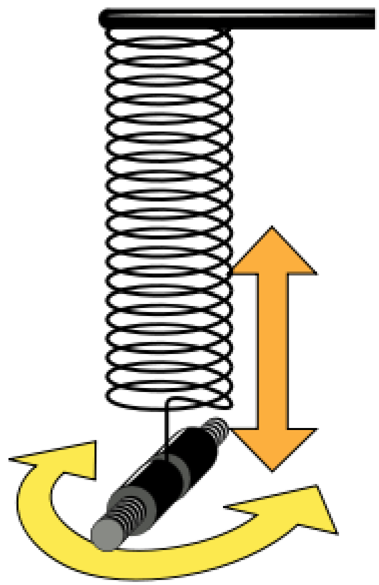
$$x_1 = C\cos\left(\frac{\omega - \omega_o}{2}t\right)\cos\left(\frac{\omega + \omega_o}{2}t\right)$$

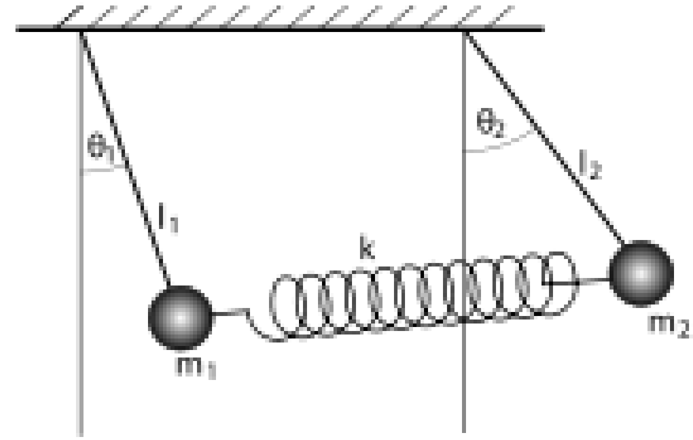
$$x_2 = C\sin\left(\frac{\omega - \omega_o}{2}t\right)\sin\left(\frac{\omega + \omega_o}{2}t\right)$$

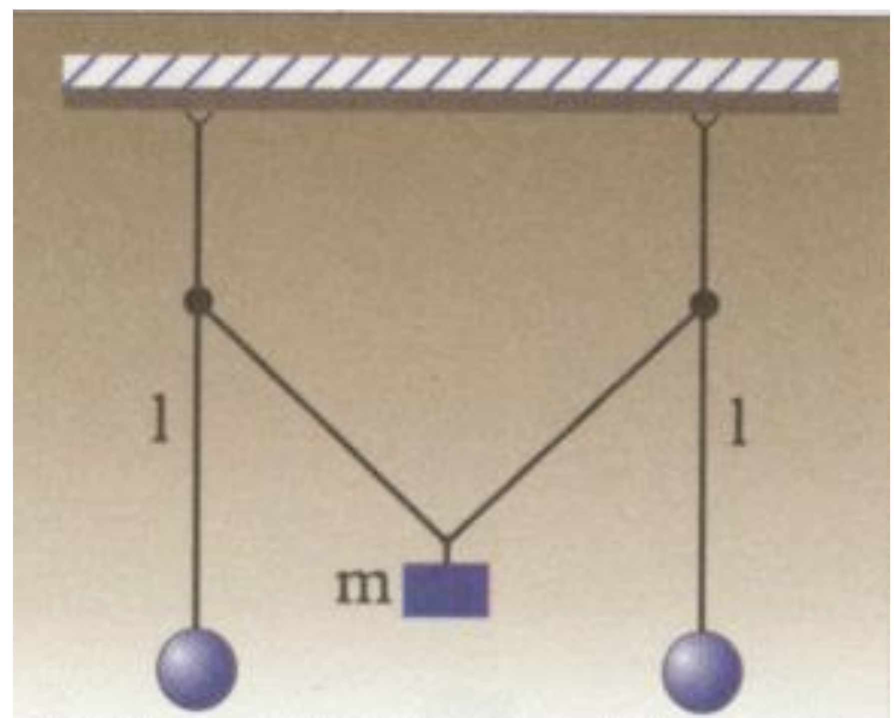




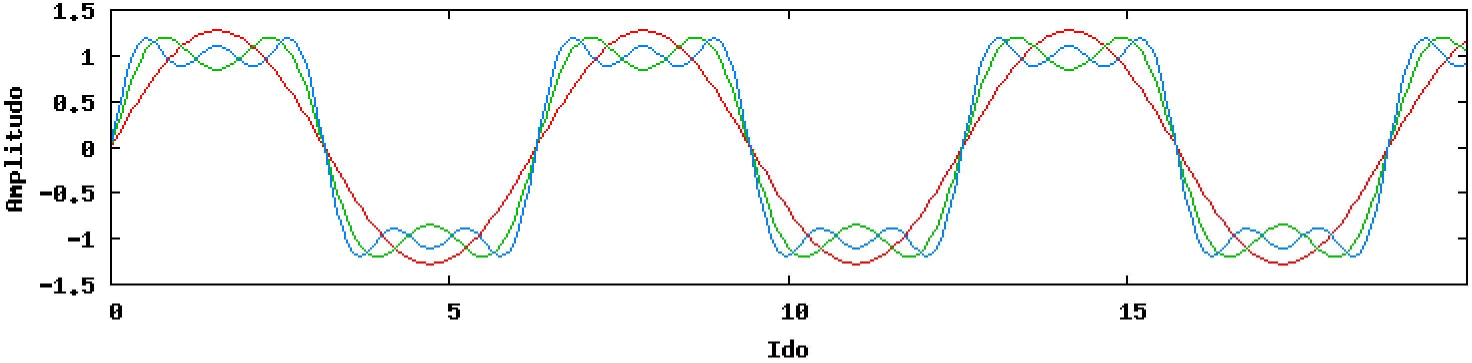





θ1
θ2
l1
l2
k
m1
m2


l
l
m

Rezgések Fourier-felbontása:

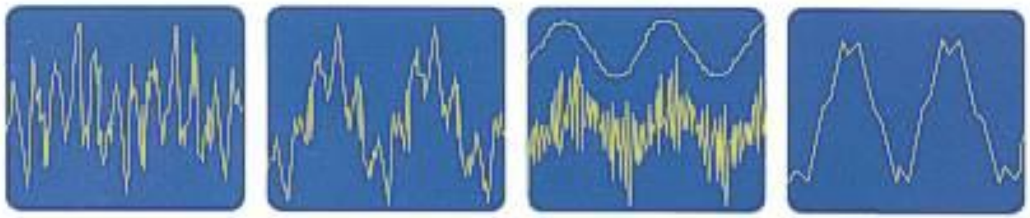


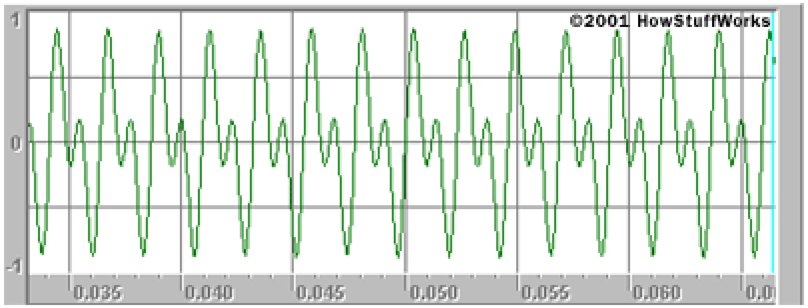
Tehát a Fourier transzformáció:

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

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

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





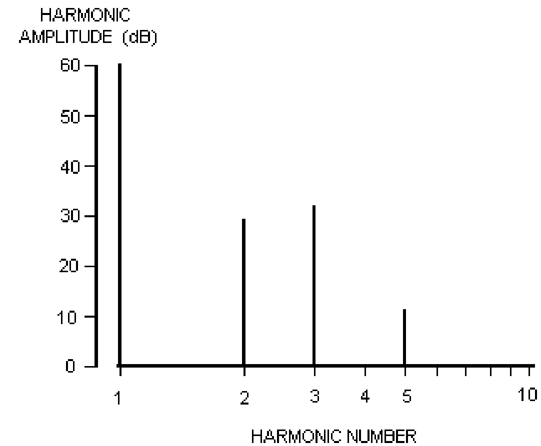
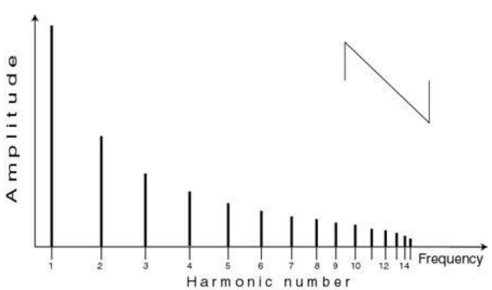
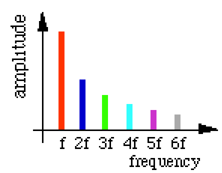
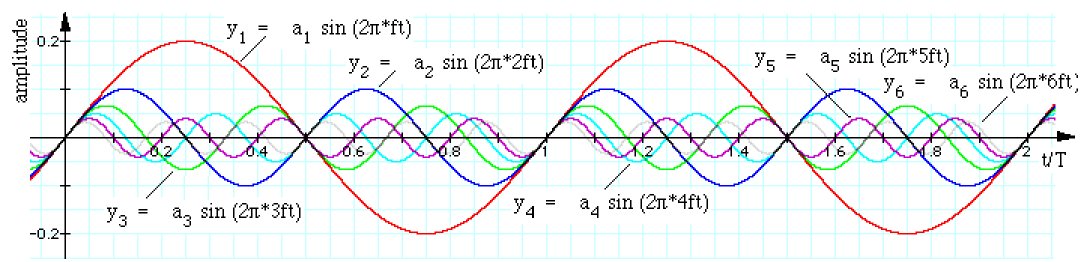
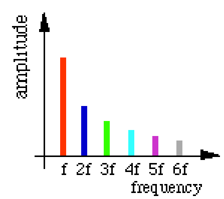


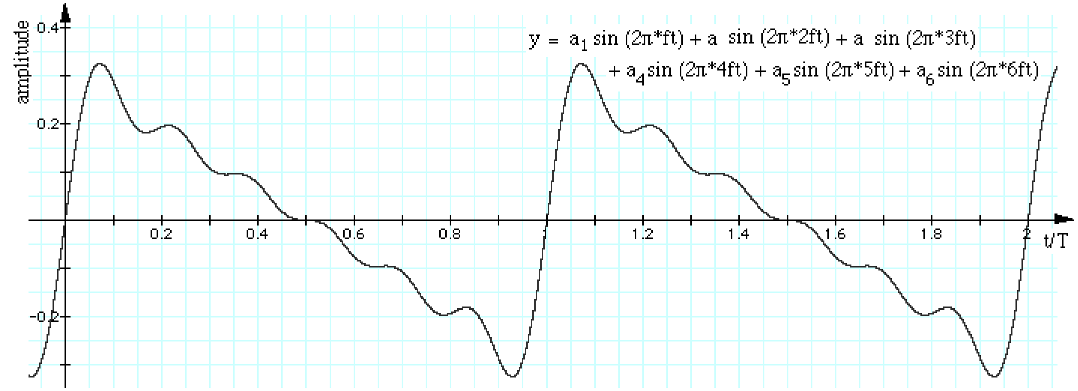
Figure 7 Harmonic Flute spectrum

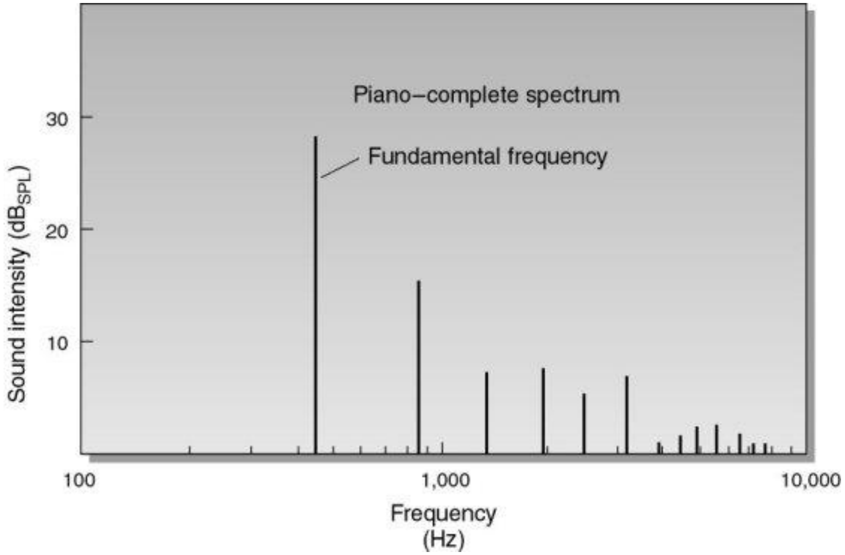


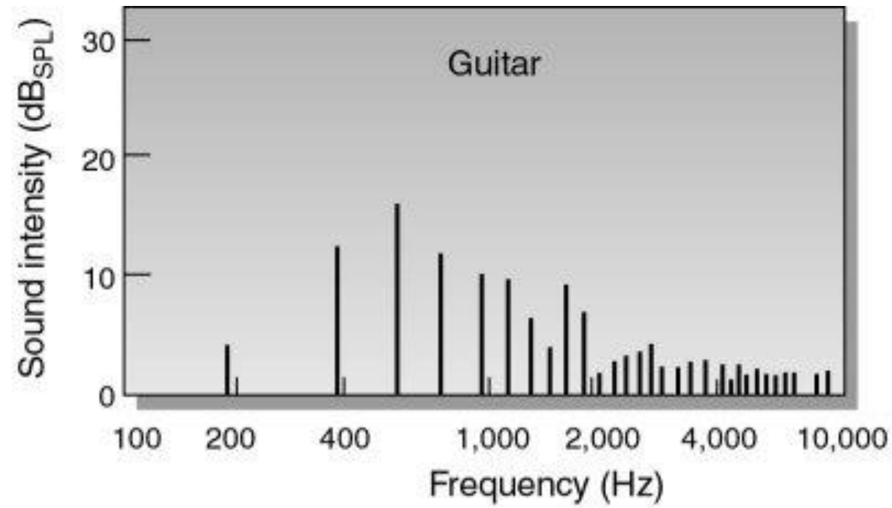












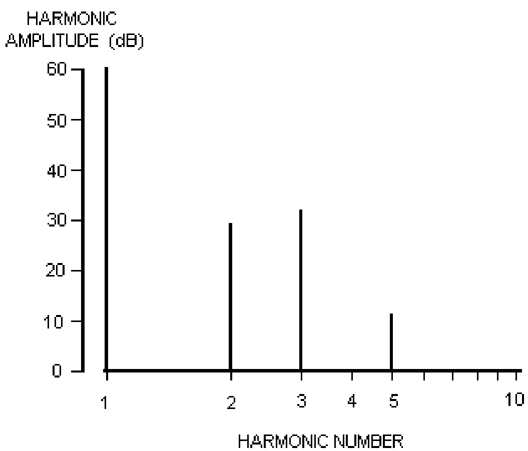
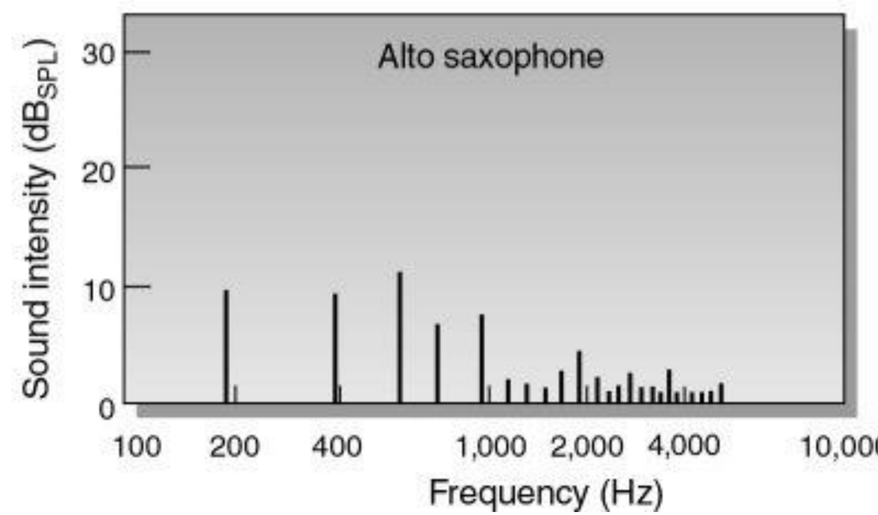


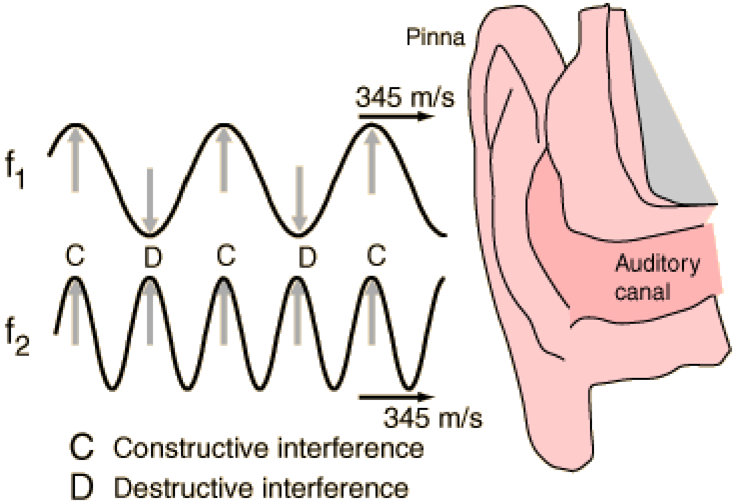
Figure 7 Harmonic Flute spectrum

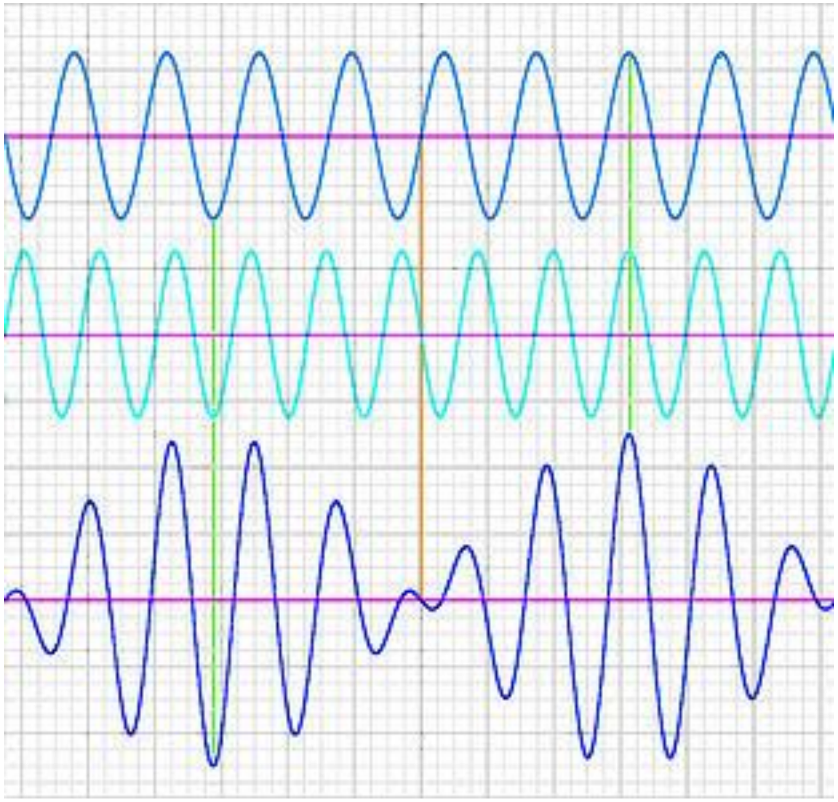


A lebegés jelensége:

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

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





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

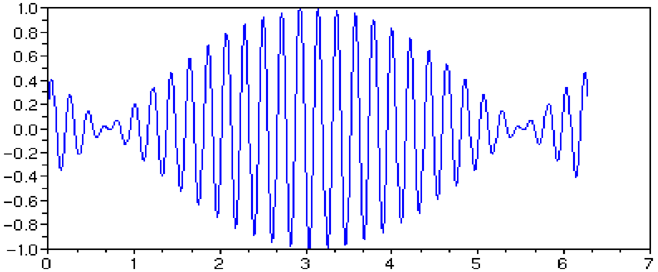
$$y(t) = A\cos(\omega_1 t) + A\cos(\omega_2 t)$$

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

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

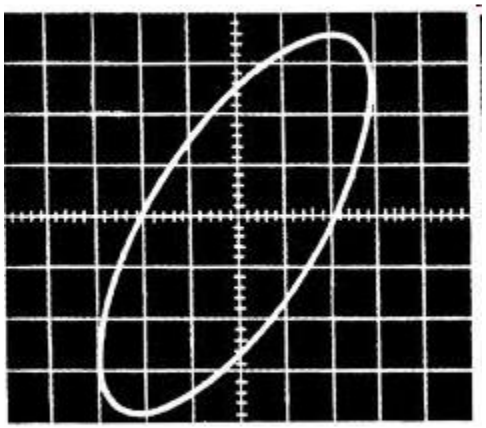
$$f_{lebegés} = \Delta f$$

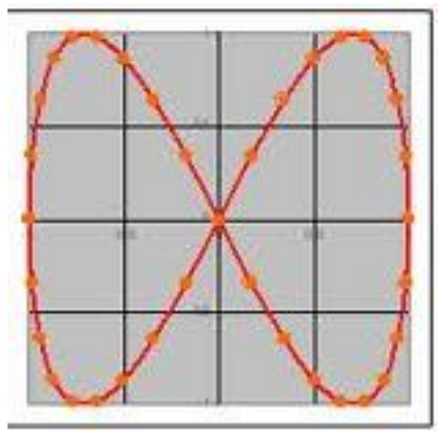
!

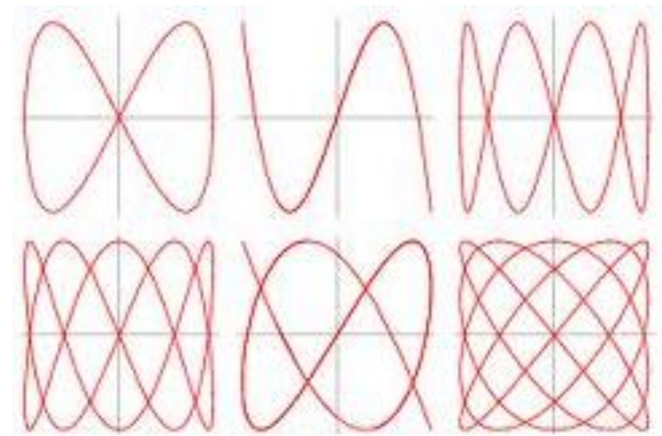


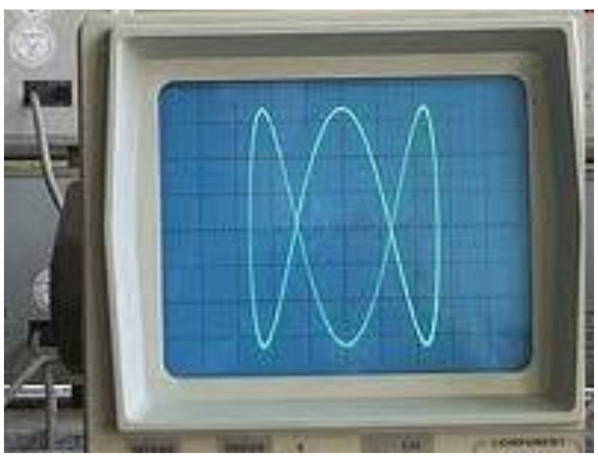
Egymásra merőleges rezgések összetétele – Lissajou görbék

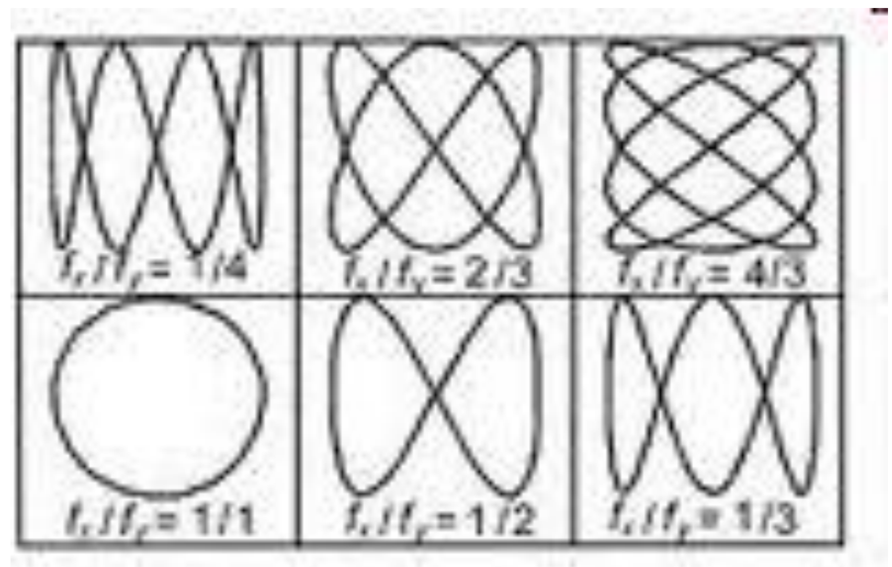
$$x(t) = A\sin(\omega t) \qquad y(t) = A\sin(\omega t + \varphi)$$



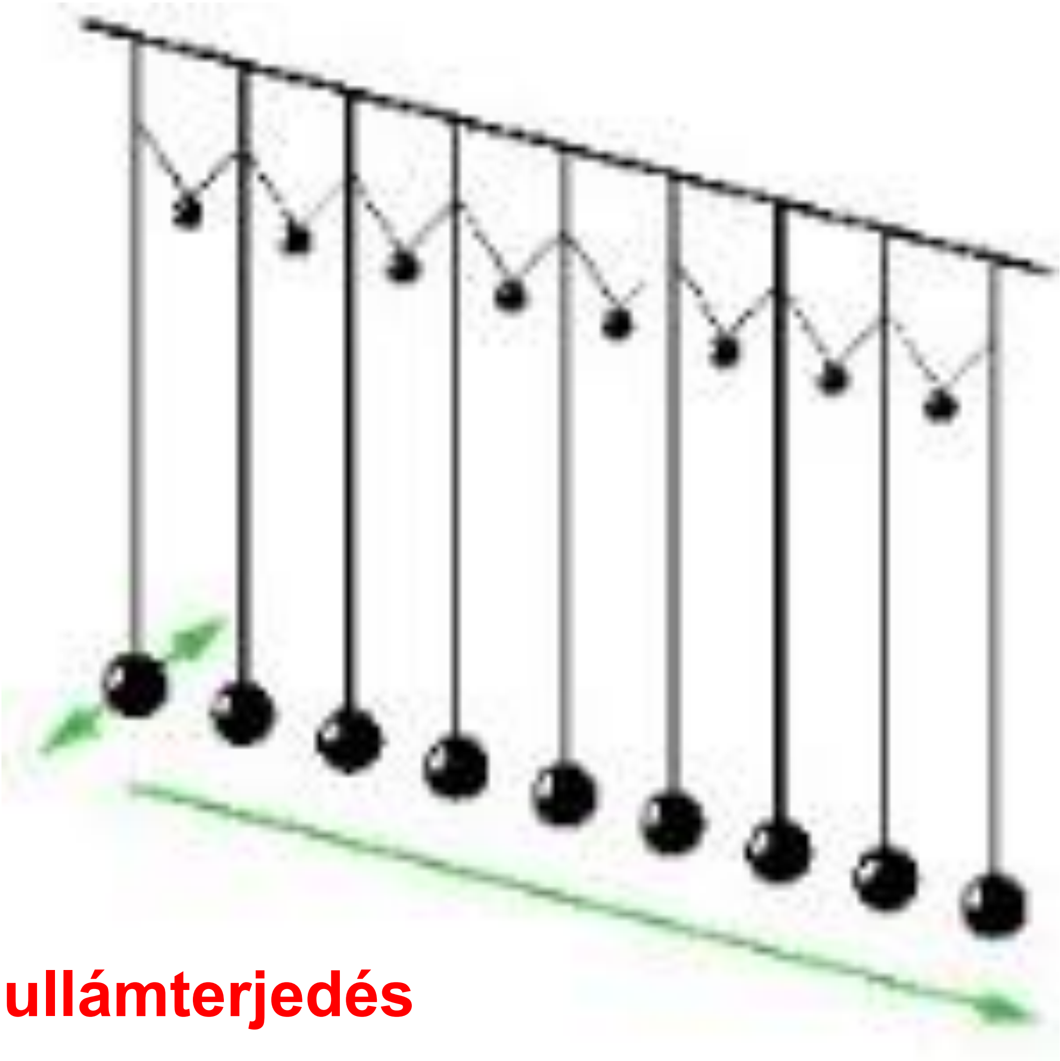








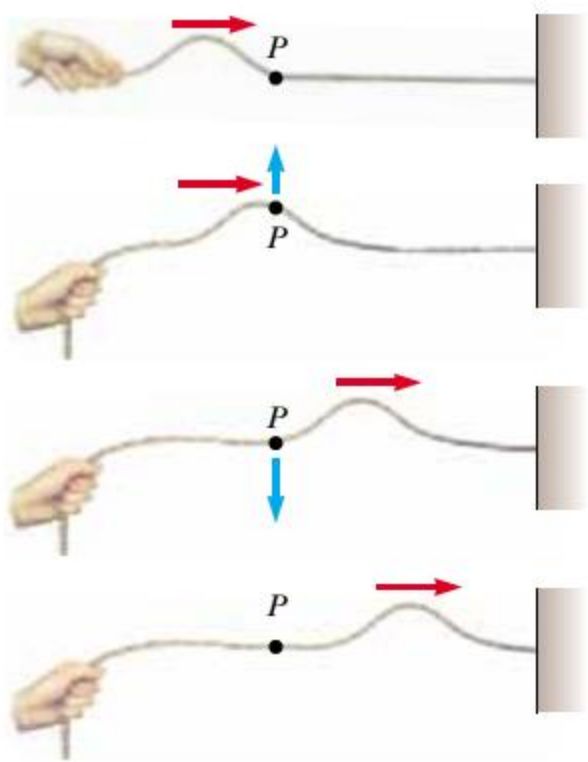
Csatolt rezgés még egyszer

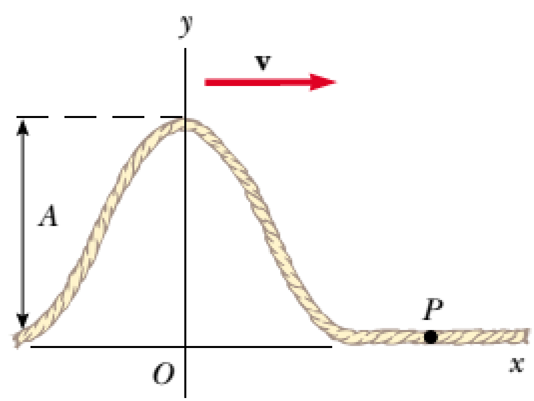


Hullámterjedés

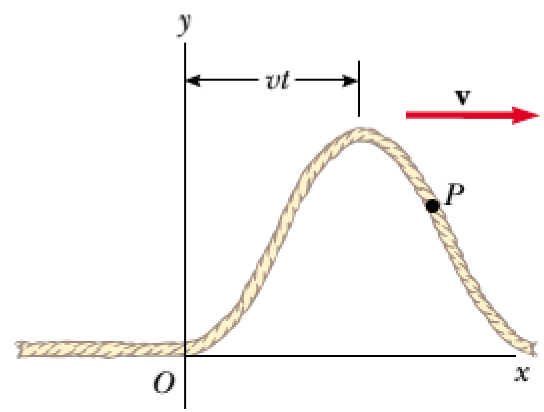
Hullámterjedés

(Hullámmozgás)





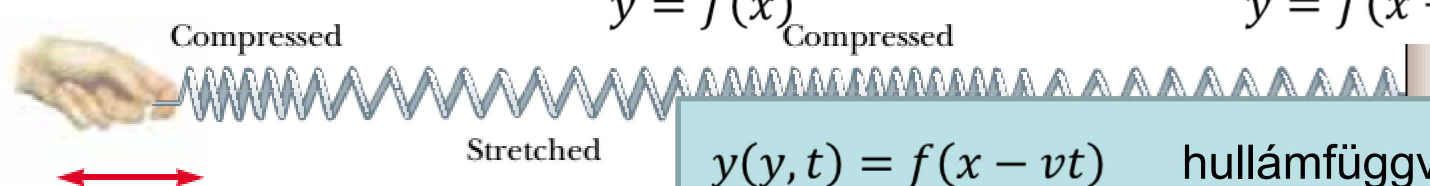
t = 0



t = *t*

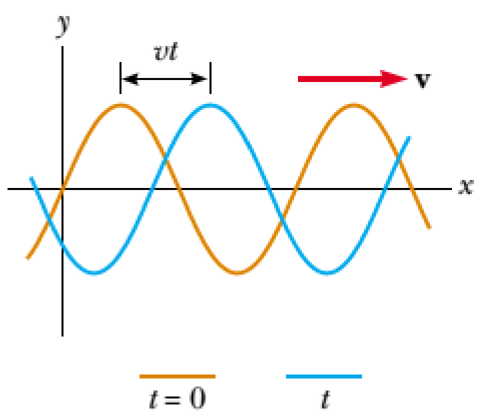
$y = f(x)$

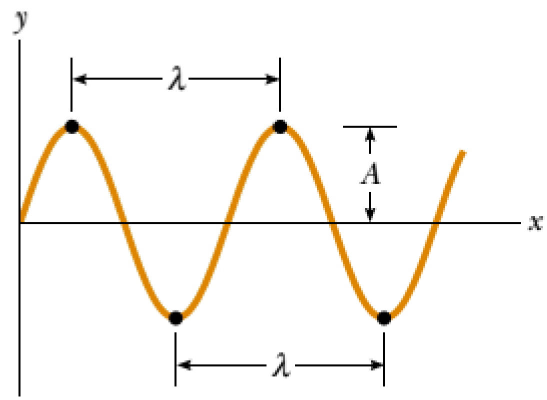
$y = f(x - vt)$

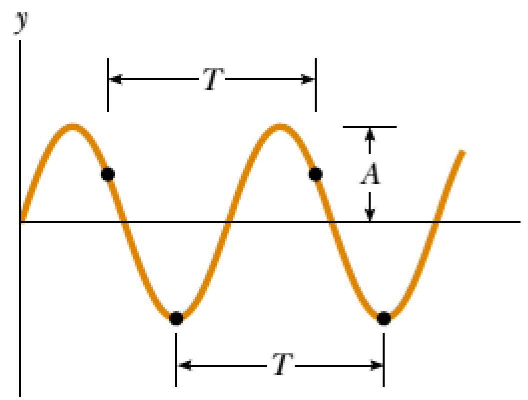


$y(y,t) = f(x - vt)$ hullámfüggvény

Szinusz(os) hullám







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

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

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

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

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

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

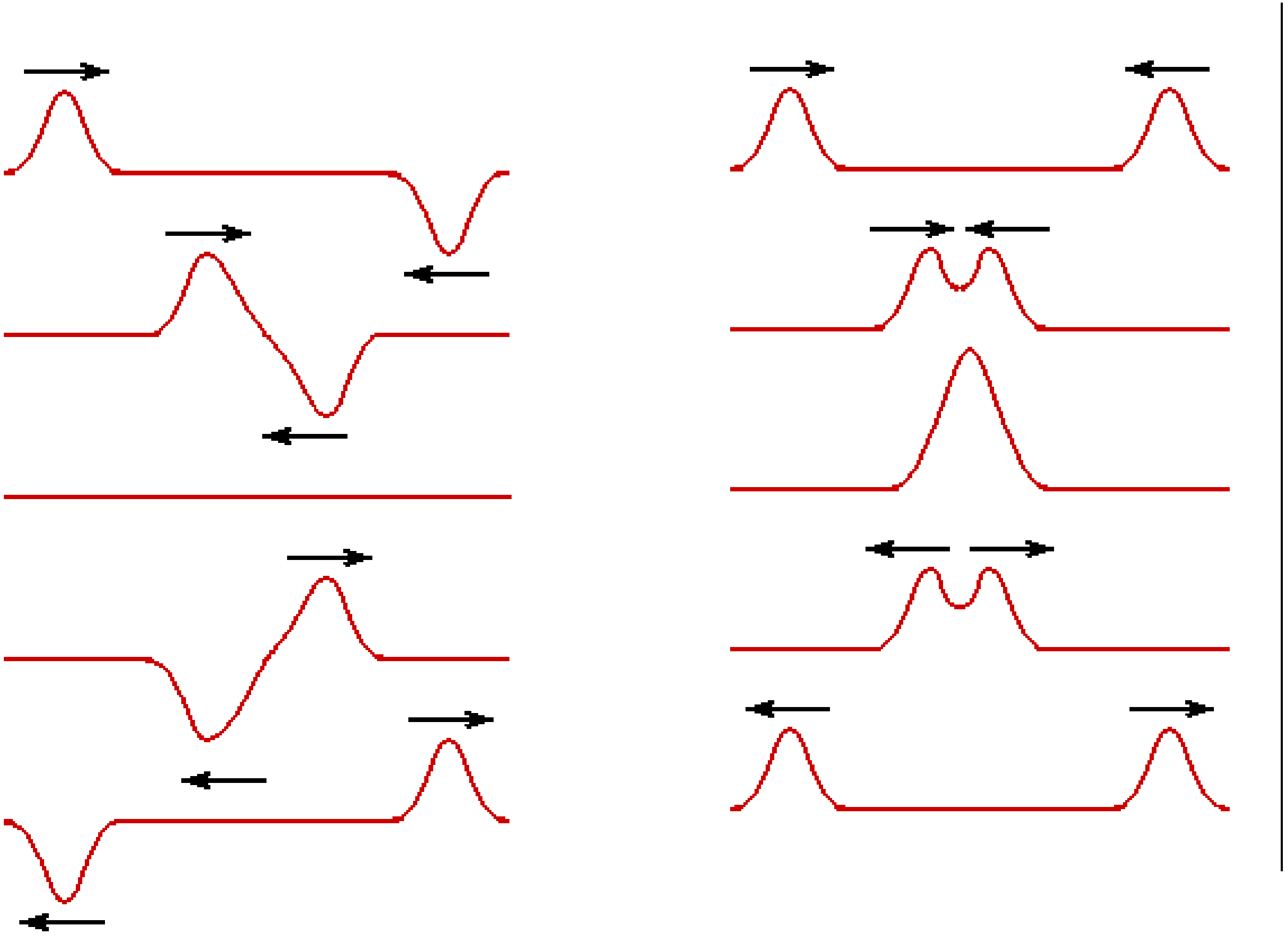
$$y(x,t) = A\sin(kx - \omega t + \varphi)$$

Hullámegyenlet:

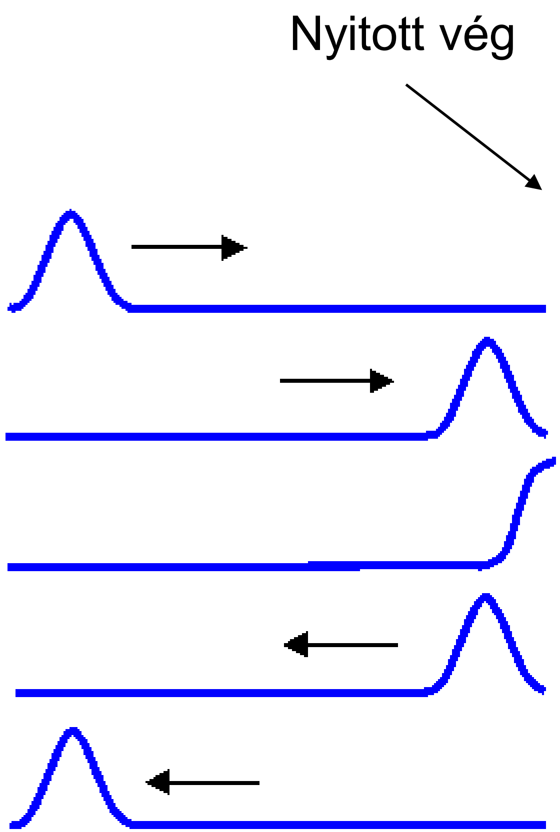
$$\frac{\partial^2 y(x,t)}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y(x,t)}{\partial t^2}$$

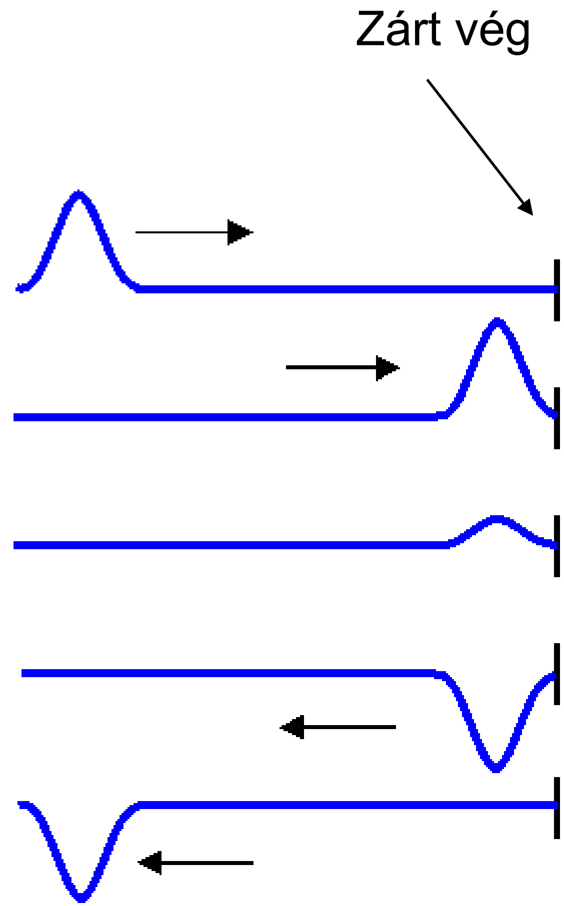
Szuperpozíció

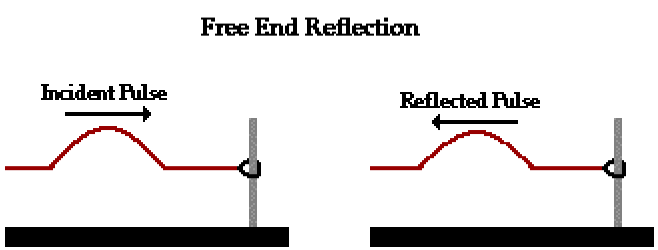
Linearitás!!!

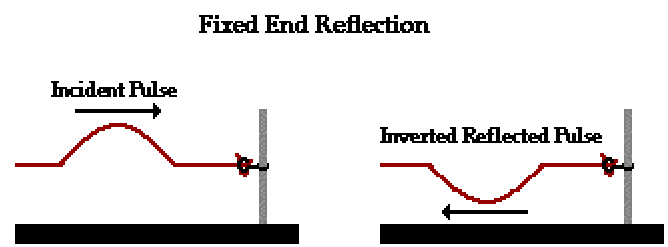


Hullámok visszaverődése, reflexiója:









Állóhullám

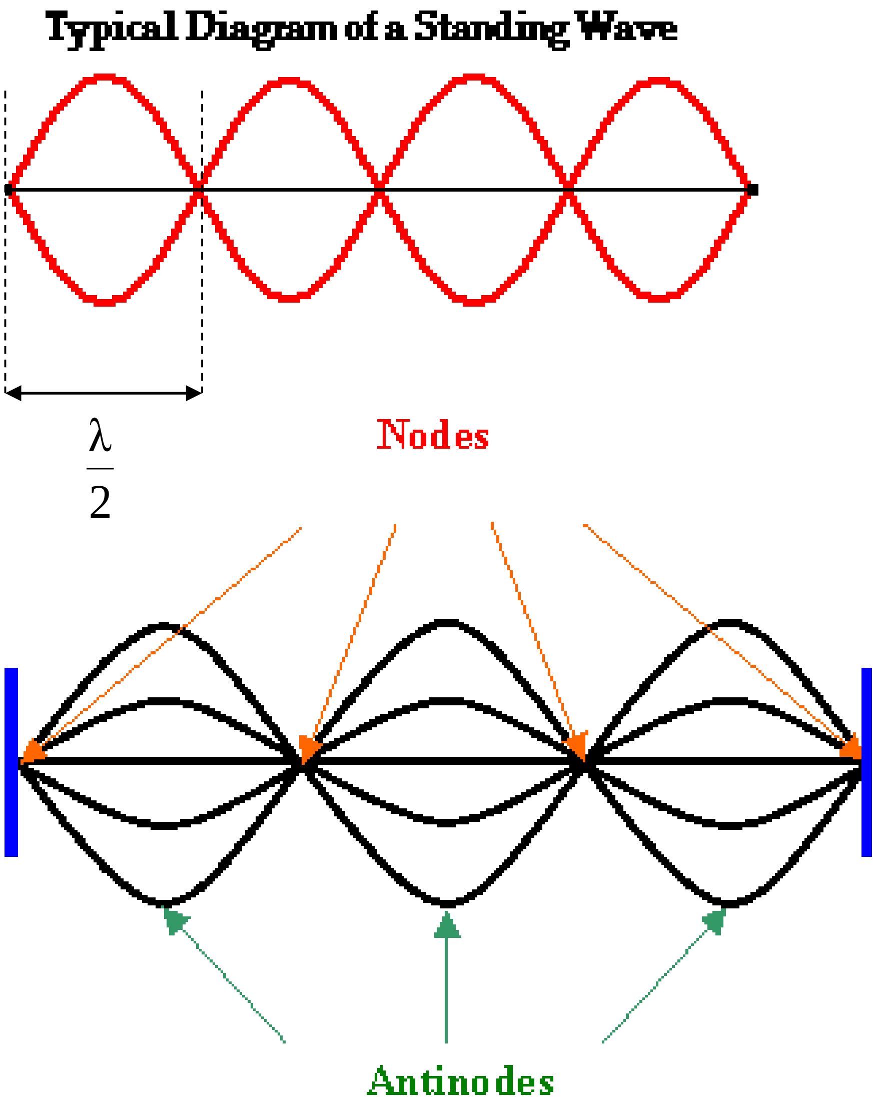
$$y_1(x,t) = A\cos(kx - \omega t) \qquad y_2(x,t) = A\cos(kx + \omega t)$$

$$y = y_1 + y_2$$

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

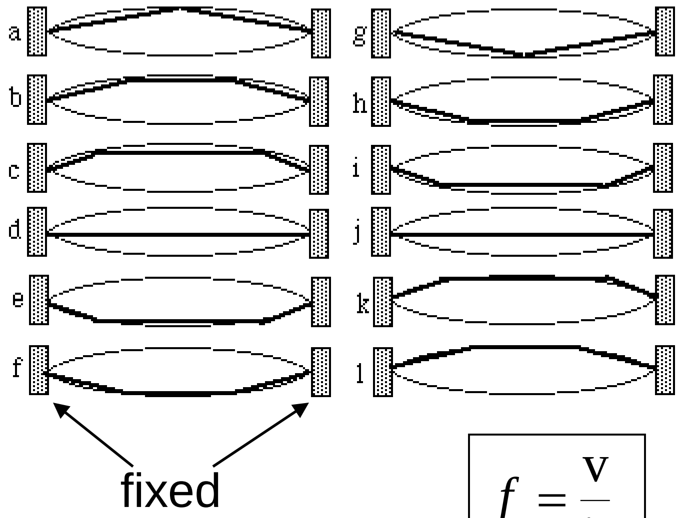
$$\omega = \frac{2\pi}{T} \qquad \mathrm{k} = \frac{2\pi}{\lambda}$$

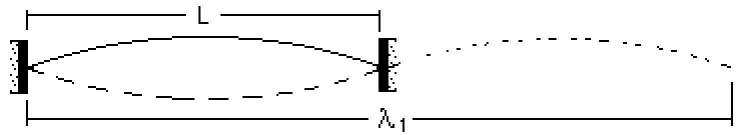
Állóhullám:



Typical Diagram of a Standing Wave
$\frac{\lambda}{2}$
Nodes
Antinodes

Alap és felharmónikusok (mindkét vég zárt)

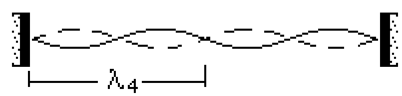




$$\lambda_1 = 2L$$

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

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



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

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

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

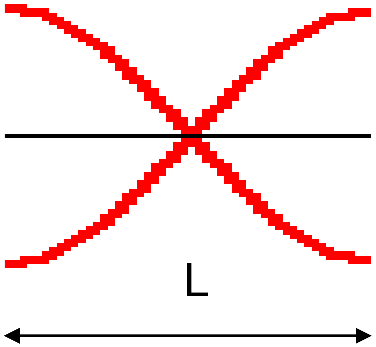
$$f_2 = \frac{v}{\lambda_2} = 2 \cdot \frac{v}{2L} = 2 \cdot f_1$$

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

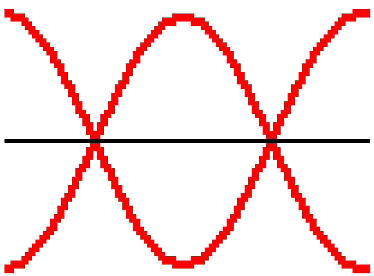
∘
∘
∘

$$f_n = n \cdot f_1$$

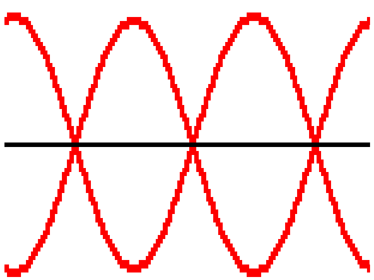
Mindkét vég nyitott



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



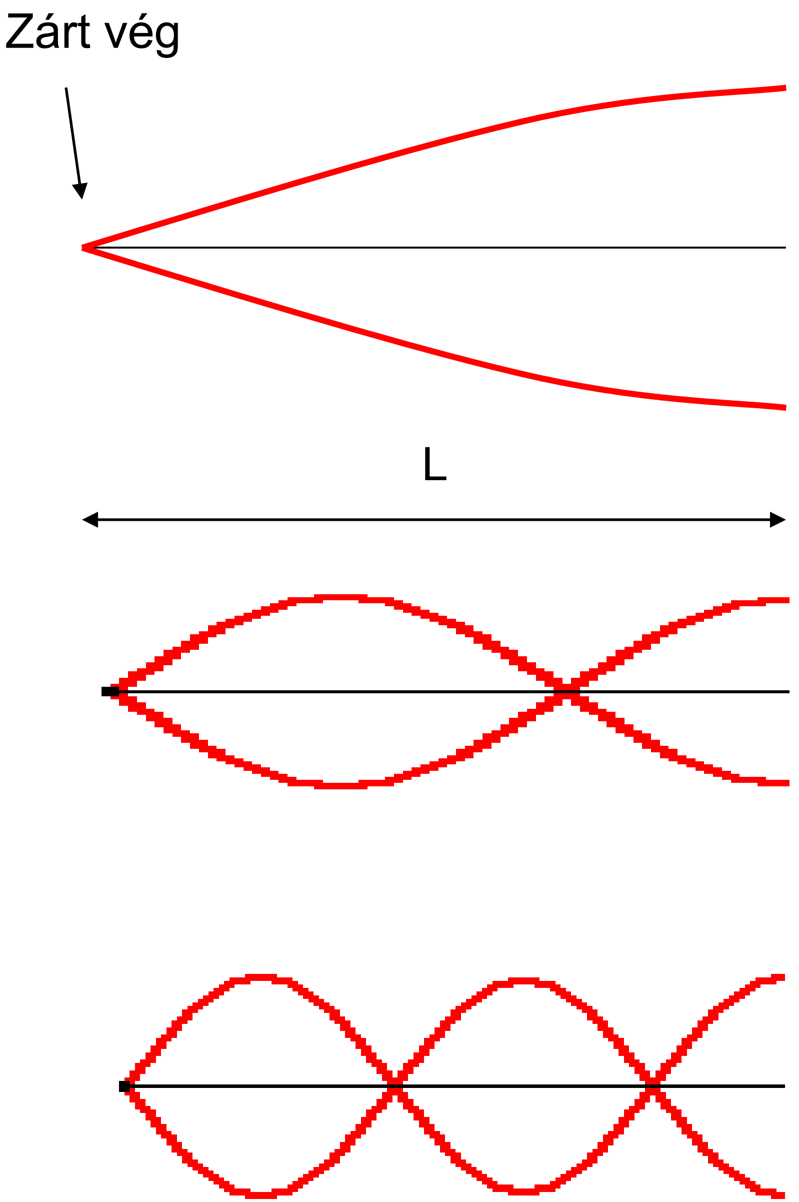
$$\lambda_2 = \frac{2L}{2} \qquad f_2 = \frac{v}{\lambda_2} = 2 \cdot \frac{v}{2L} = 2 \cdot f_1$$



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

$$\boxed{f_n = n \cdot f_1}$$

Egyik vég nyitott



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

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

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

∘

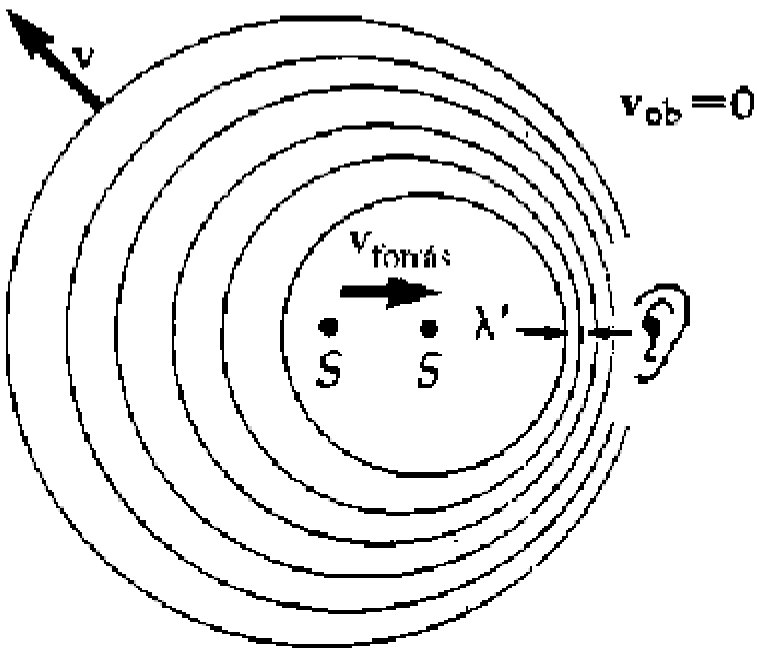
∘

∘

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

Doppler effektus 1.

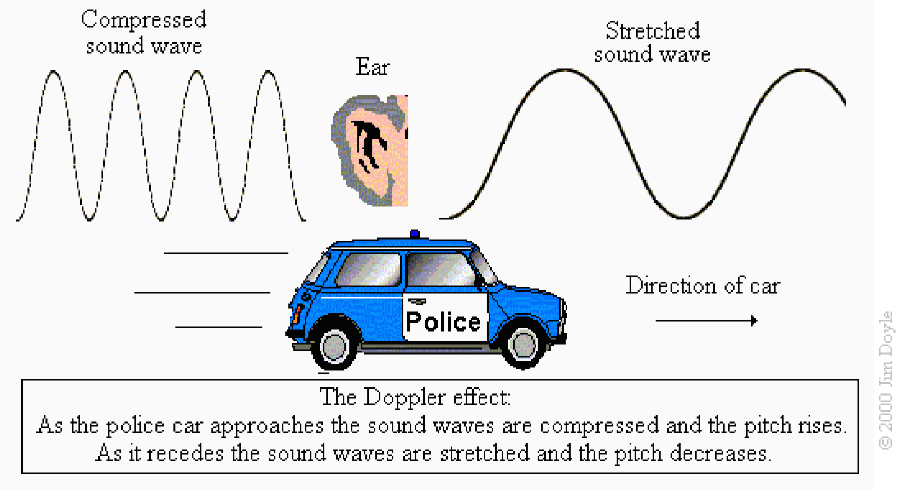
Forrás mozog, a megfigyelő áll



Egy másodperc alatt a $(v-v_{forrás})$t hosszú távolságon f rezgés.

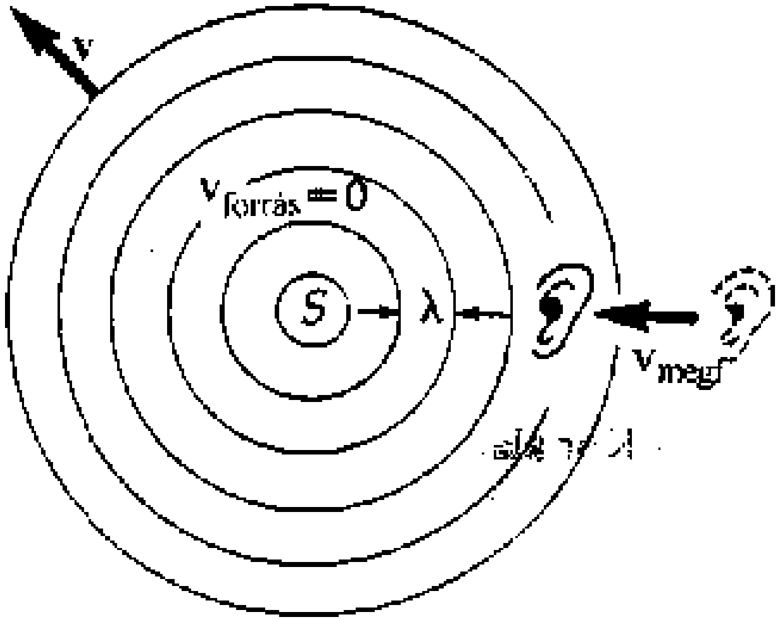
$$\lambda' = \frac{(v - v_{forrás})}{f}$$

$$f' = \frac{v}{\lambda'} = f\left(\frac{v}{v - v_{forrás}}\right)$$



Doppler effektus 2.

Forrás áll, a megfigyelő mozog

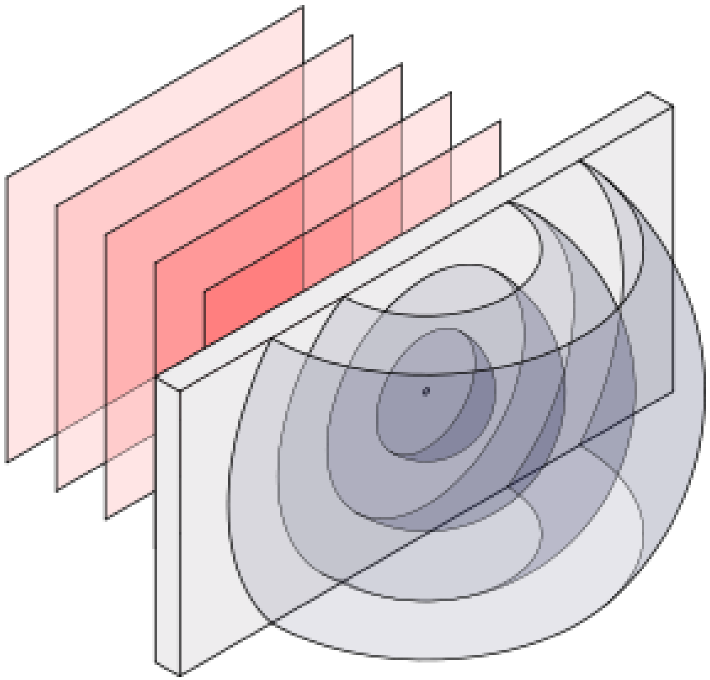


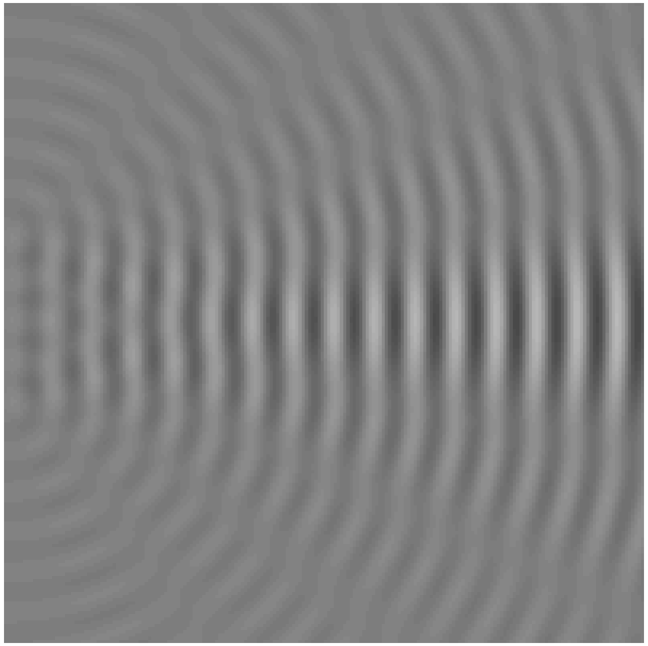
$$f' = \left(\frac{v}{\lambda} + \frac{v_{megf}}{\lambda}\right) = f\left(\frac{v + v_{megf}}{v}\right)$$

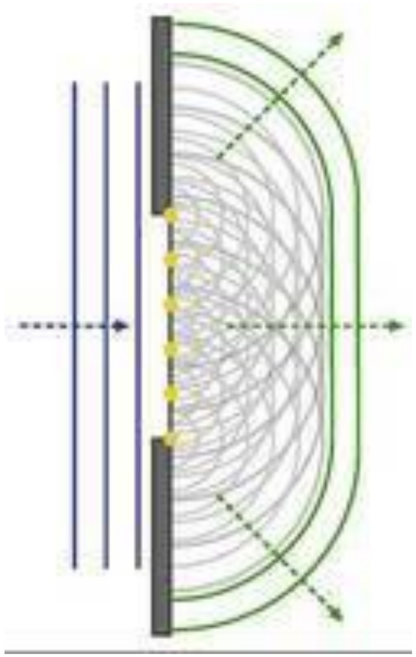
$$f' = f\left(\frac{v \pm v_{megf}}{v \mp v_{forrás}}\right)$$

… és ha a szél fúj?

Huygens elv 1.

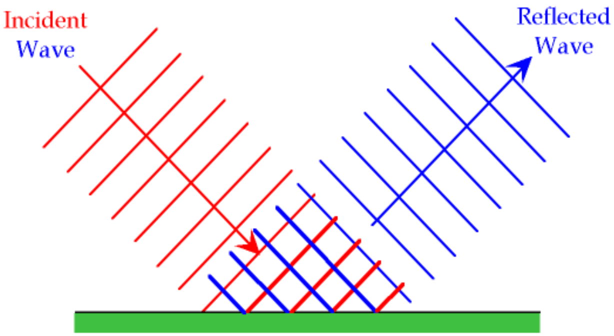


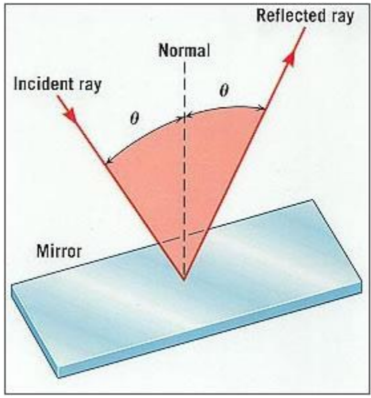


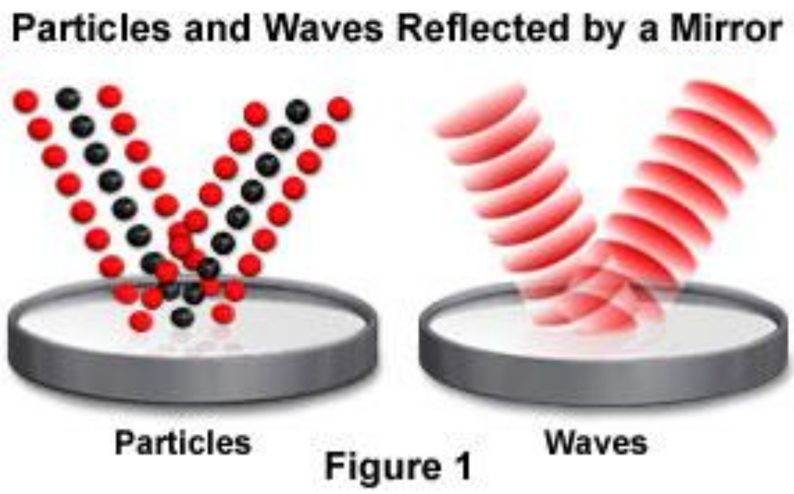


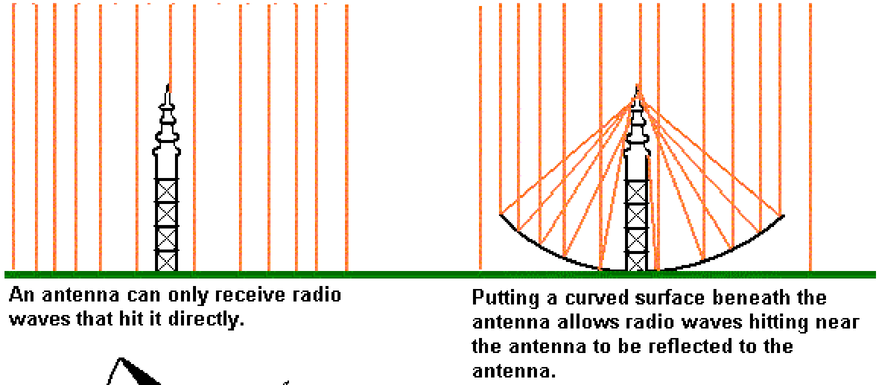
Huygens elv 2.

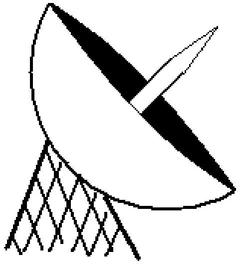
reflexió





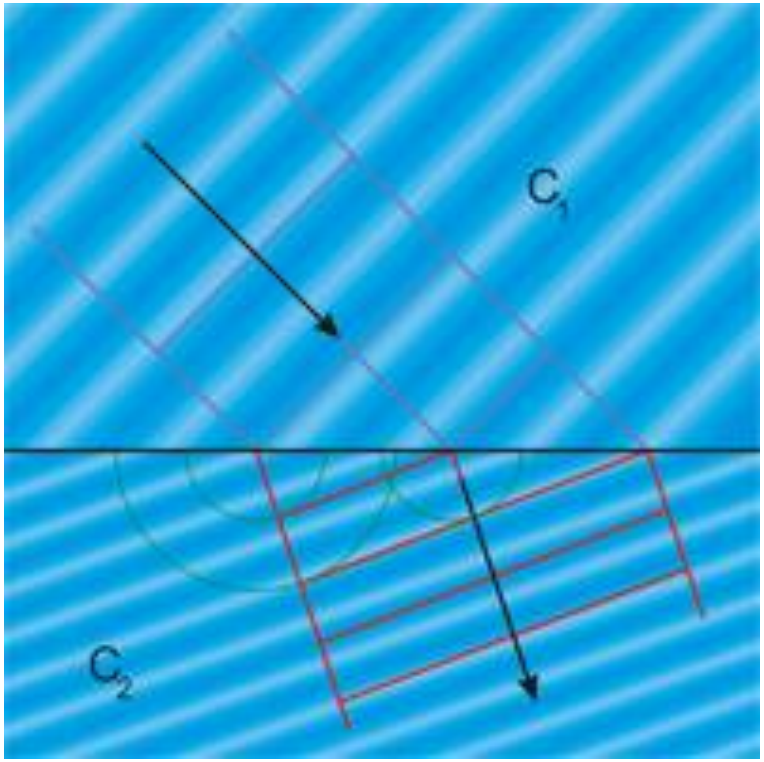


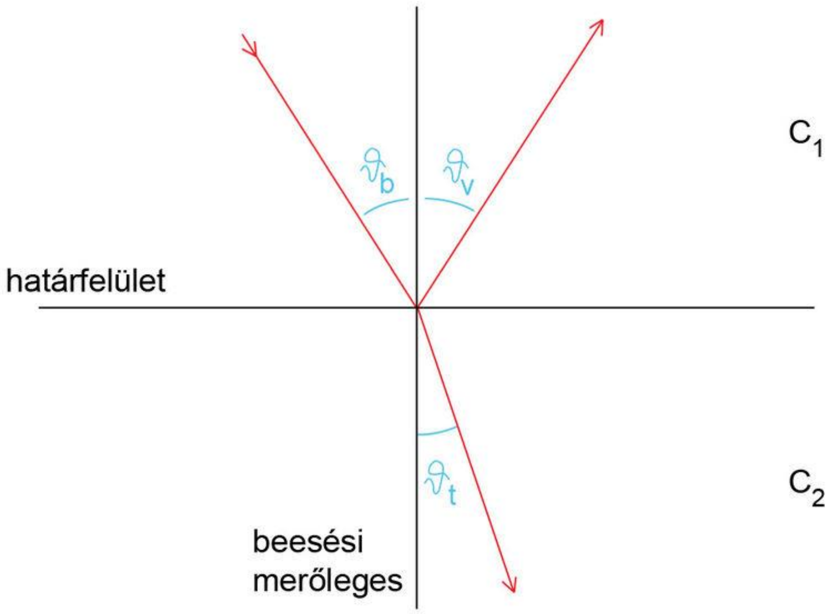




This is the reason for this characteristic shape for items that receive radio waves or other transmissions from space. This particular radio receiver is pointed at a certain part of the sky so it can receive transmissions from a particular sattelite.

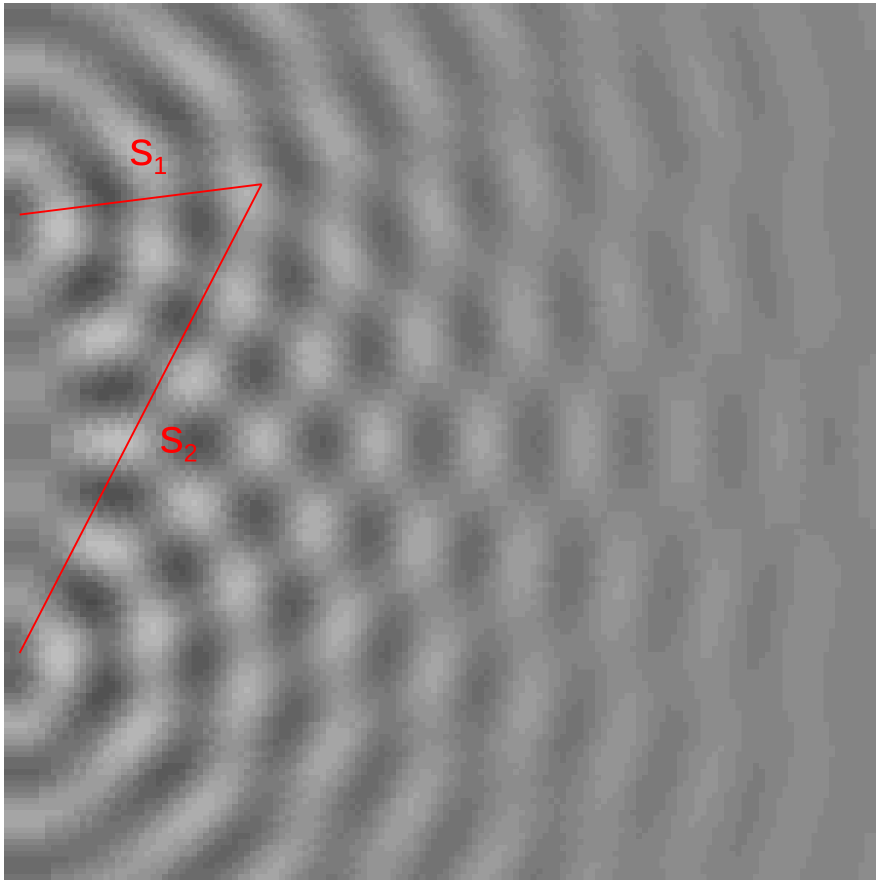
Huygens elv 3.

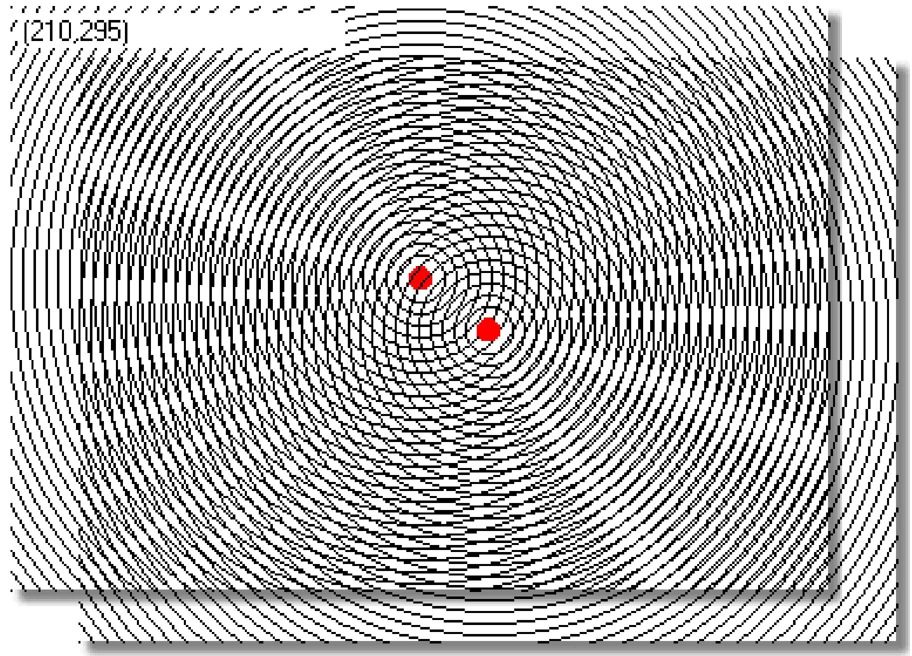




Fénytörés (hullámtörés)

Interferencia





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

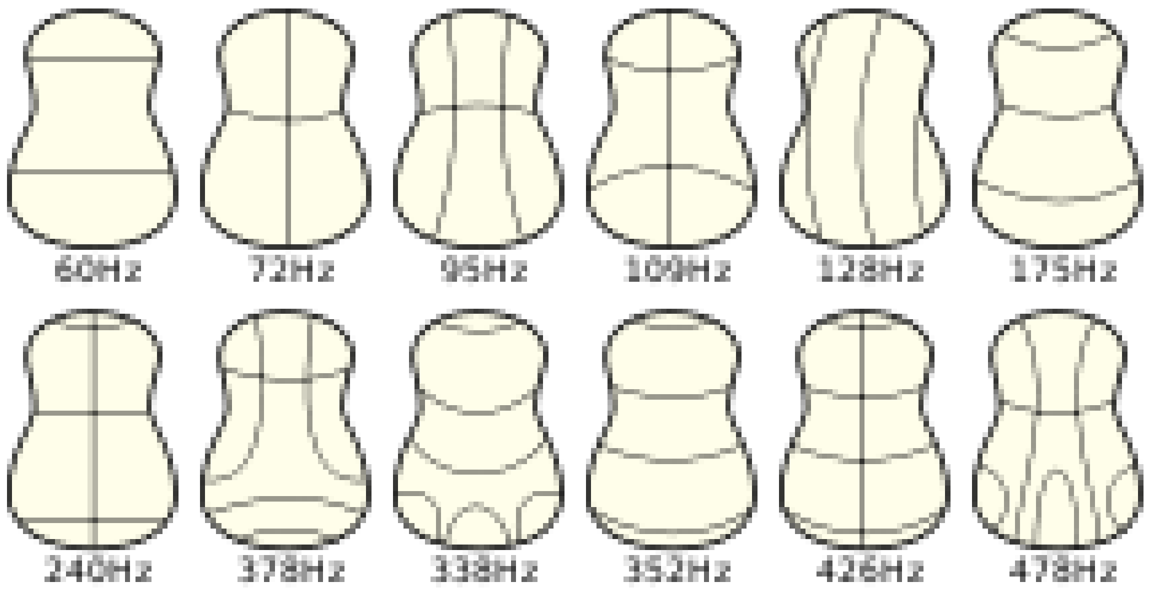
$$\Delta\varphi = (2n+1)\pi$$

Erősítés: $$\Delta s = s_2 - s_1 = n\lambda$$

$$\Delta\varphi = n(2\pi)$$

$$n = 1, 2, 3 \ldots$$

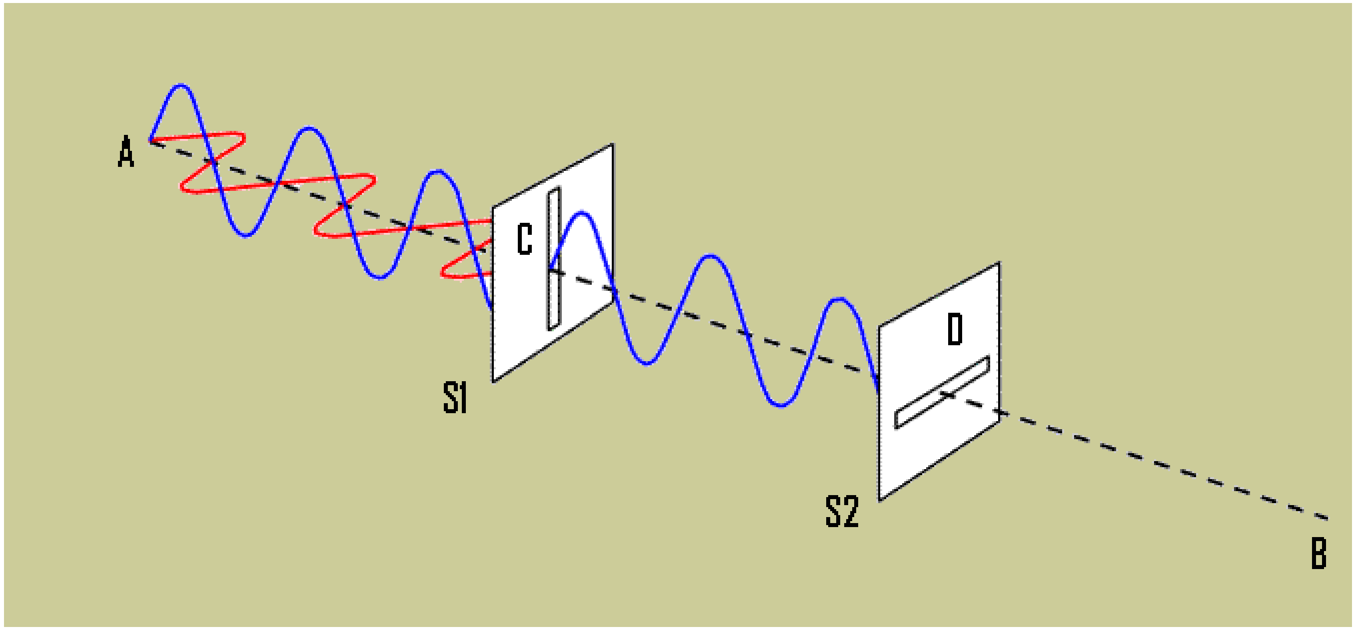
Chladny ábrák

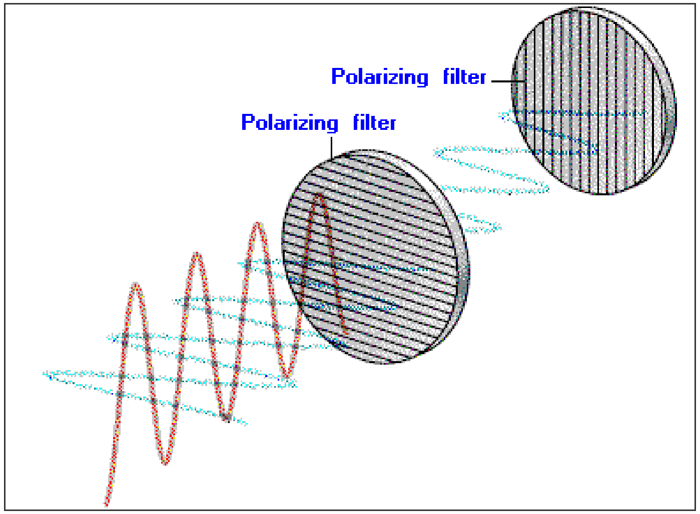


gitár

Polarizáció (hullám)

kötél:





fény