Wave motion

Waves

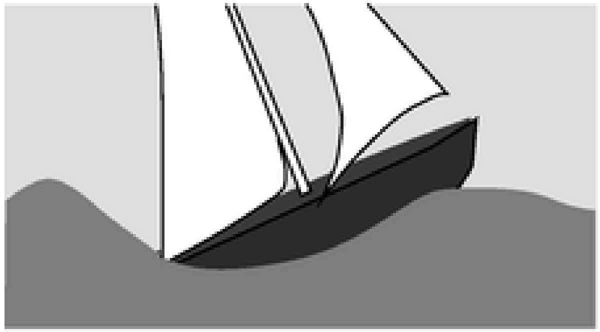
A vibrating tuning fork will force air within a pipe to begin vibrating back and forth in a direction parallel to the energy transport; sound is a longitudinal wave.

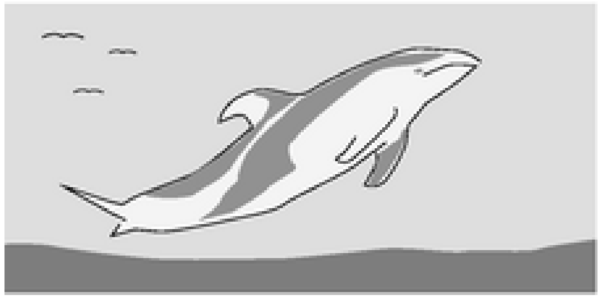
When a slinky is stretched, the individual coil assume an equilibrium or rest position.

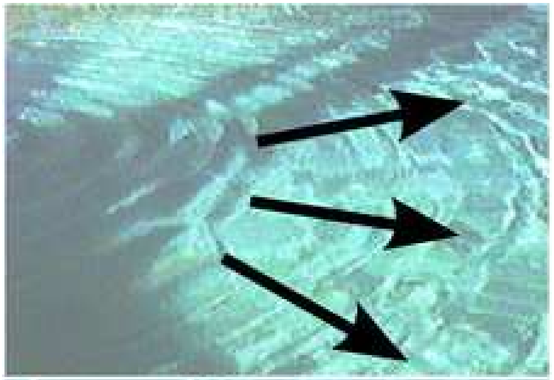
When the first coil of the slinky is repeatedly vibrated back and forth, a disturbance is created which travels through the slinky from one end to the other.

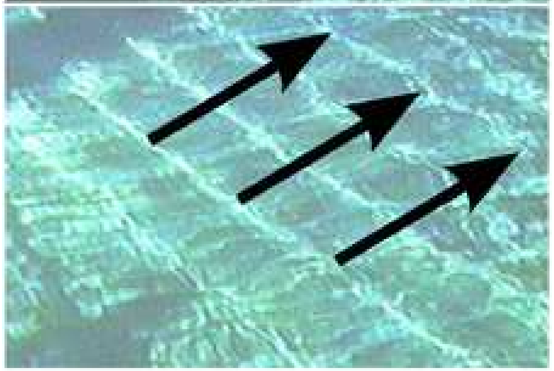
Condition: elastic media

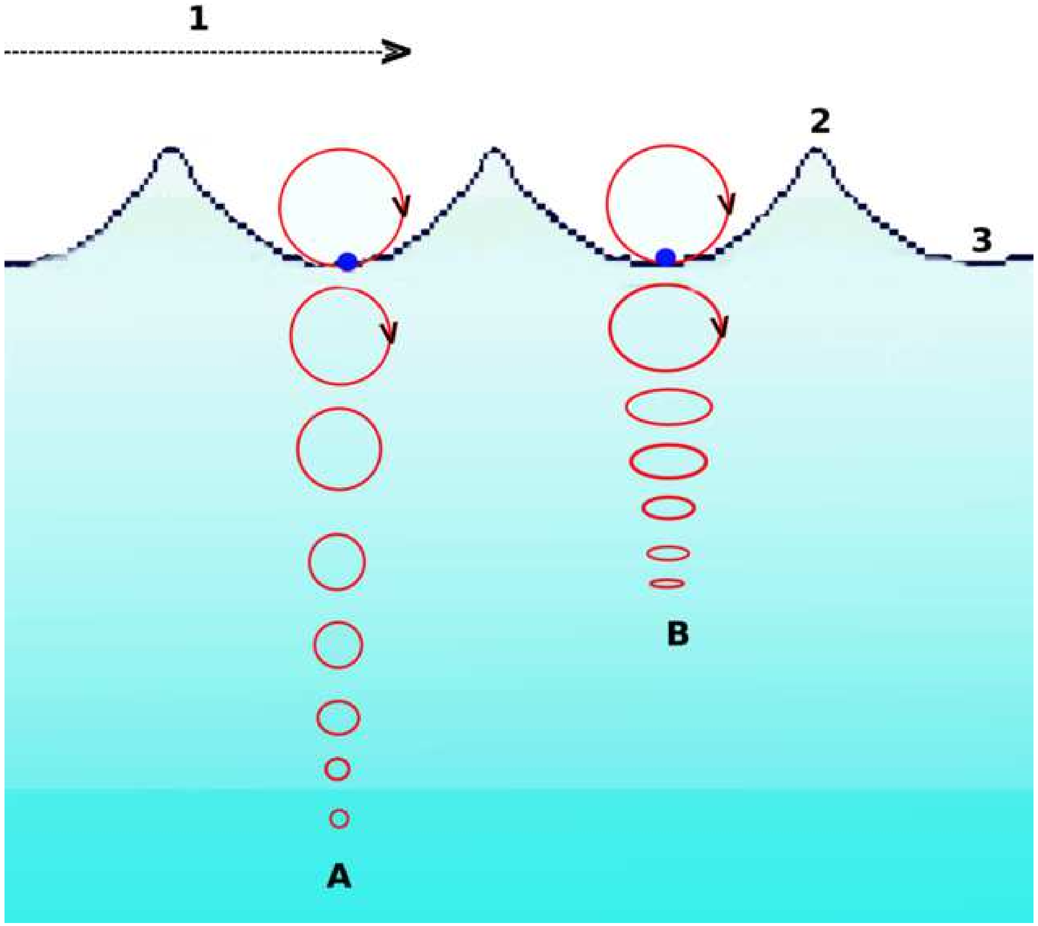
-Taut string, spring (slinky)
-Water surface, fluid
-Solid state
-Gas
-Etc.



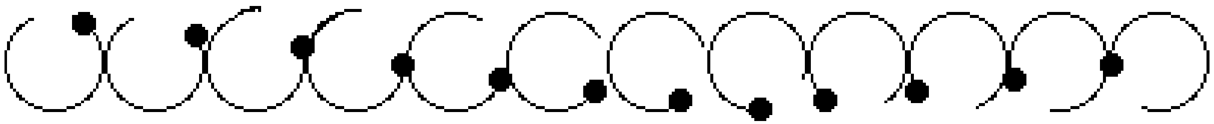






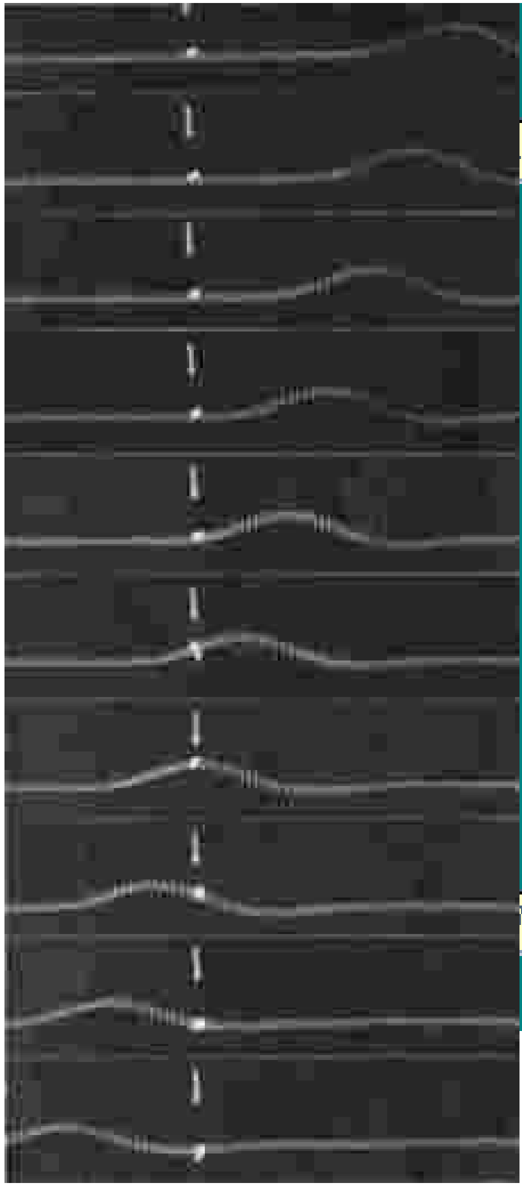


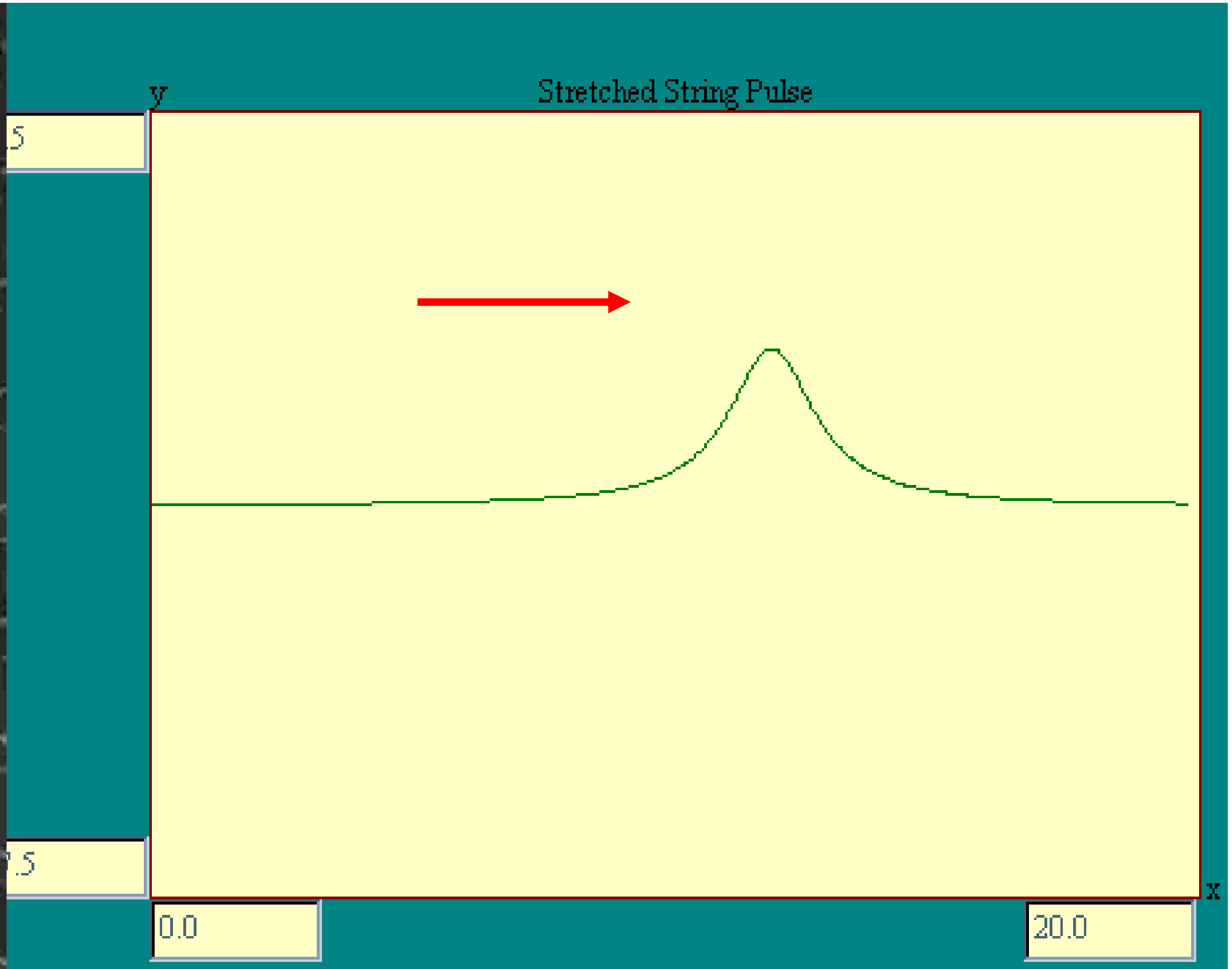
Surface Wave



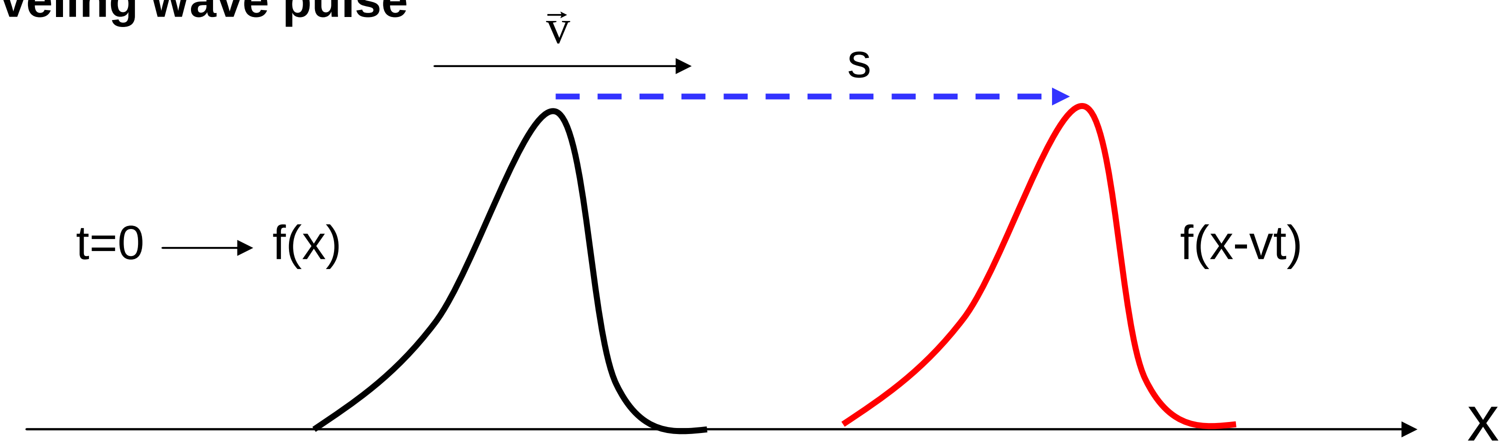
A surface wave is sometimes referred to as a circular wave since particles of the medium undergo a motion in a complete circle.

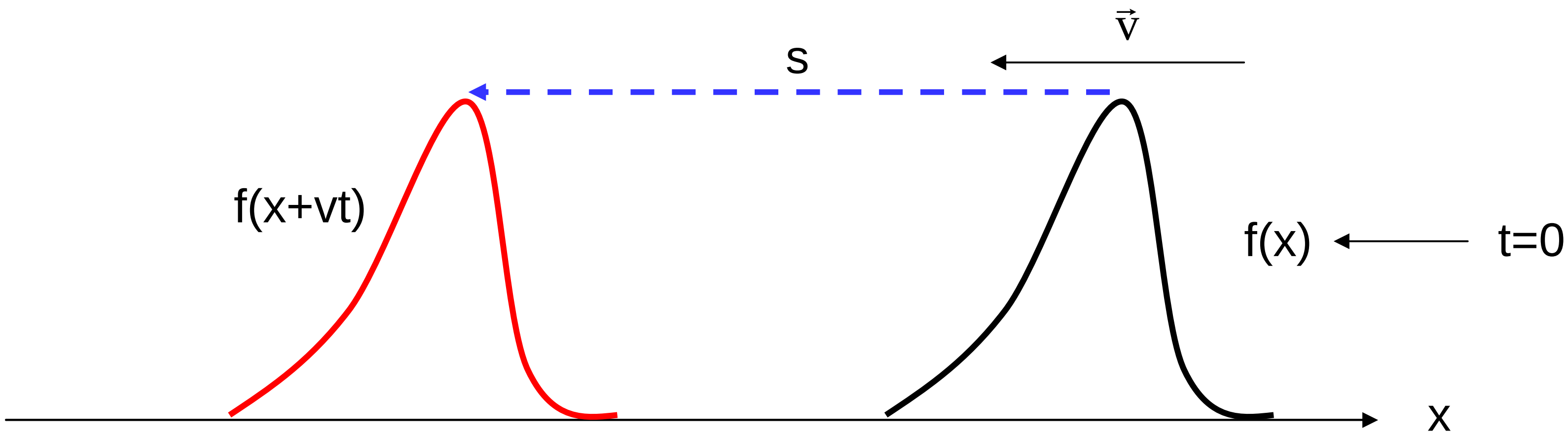
Wave pulse



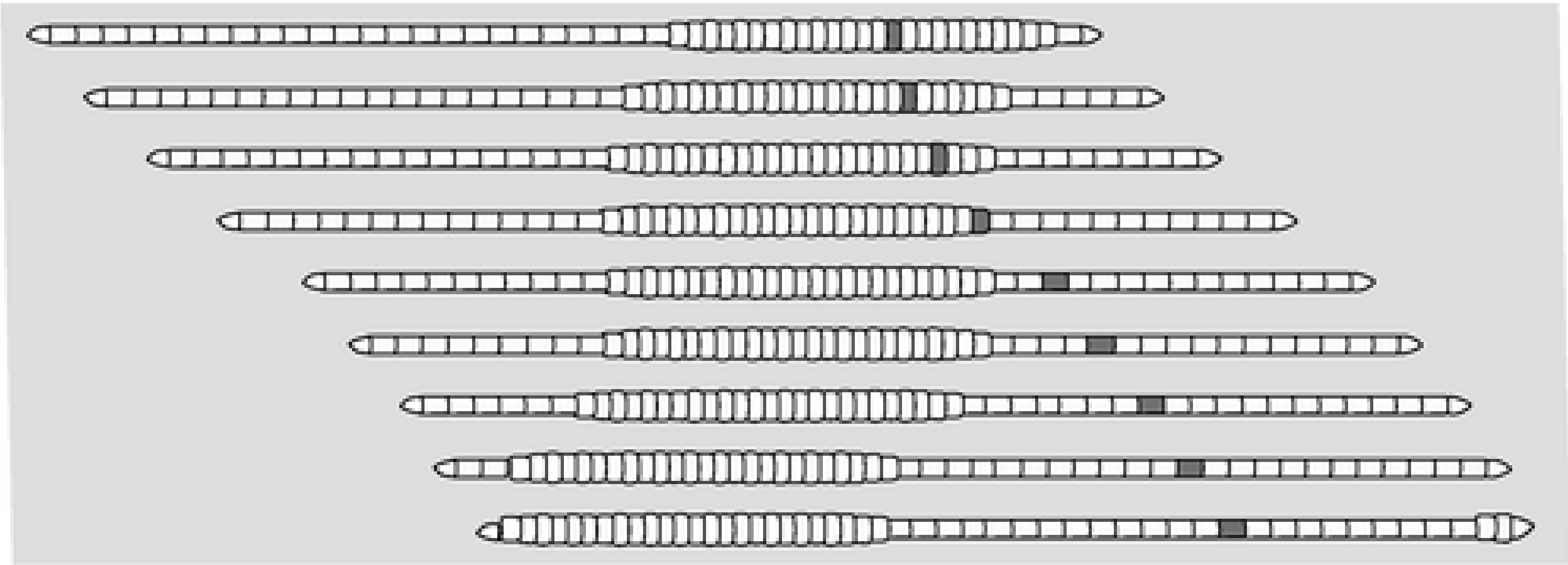


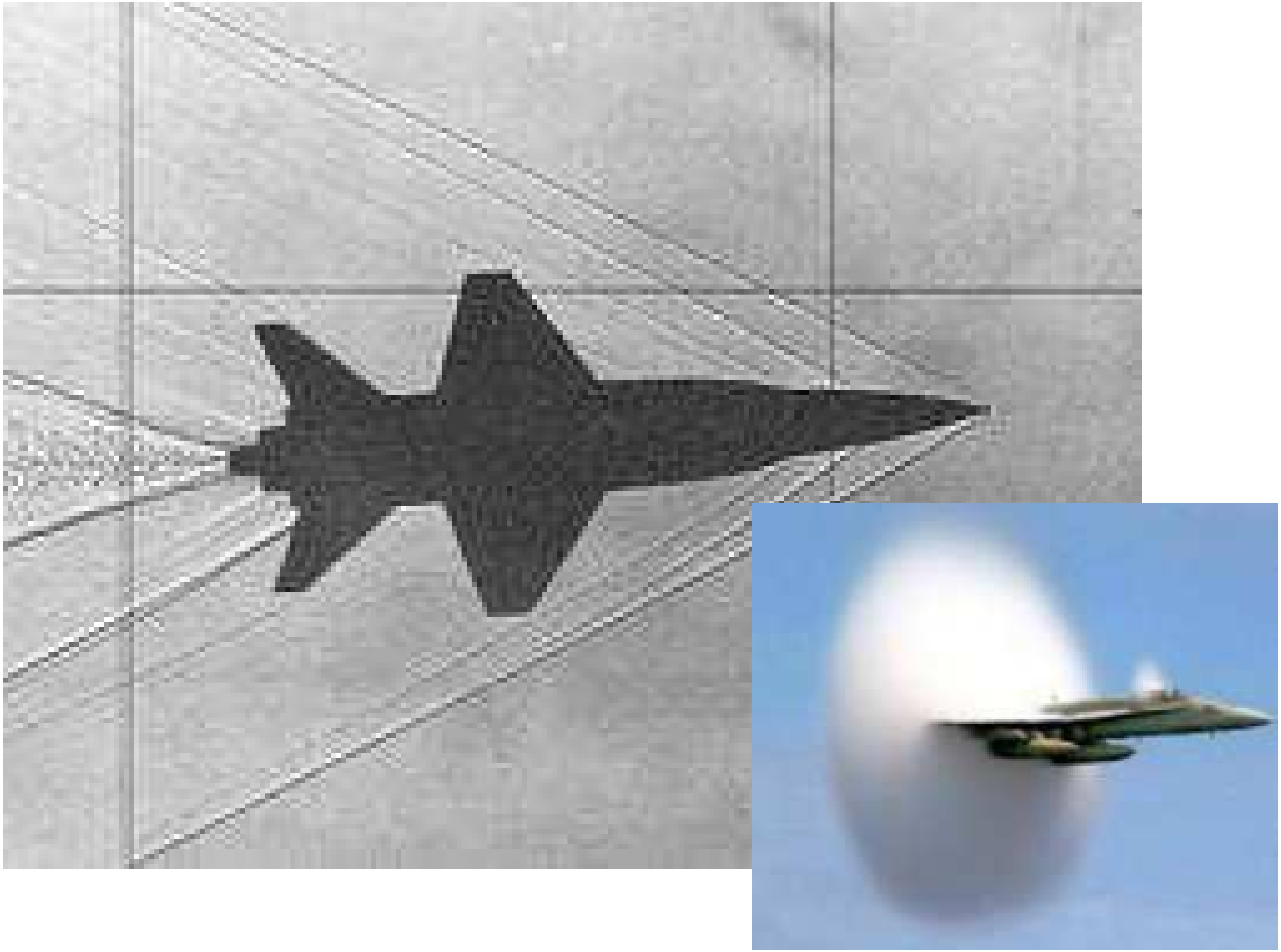
Traveling wave pulse

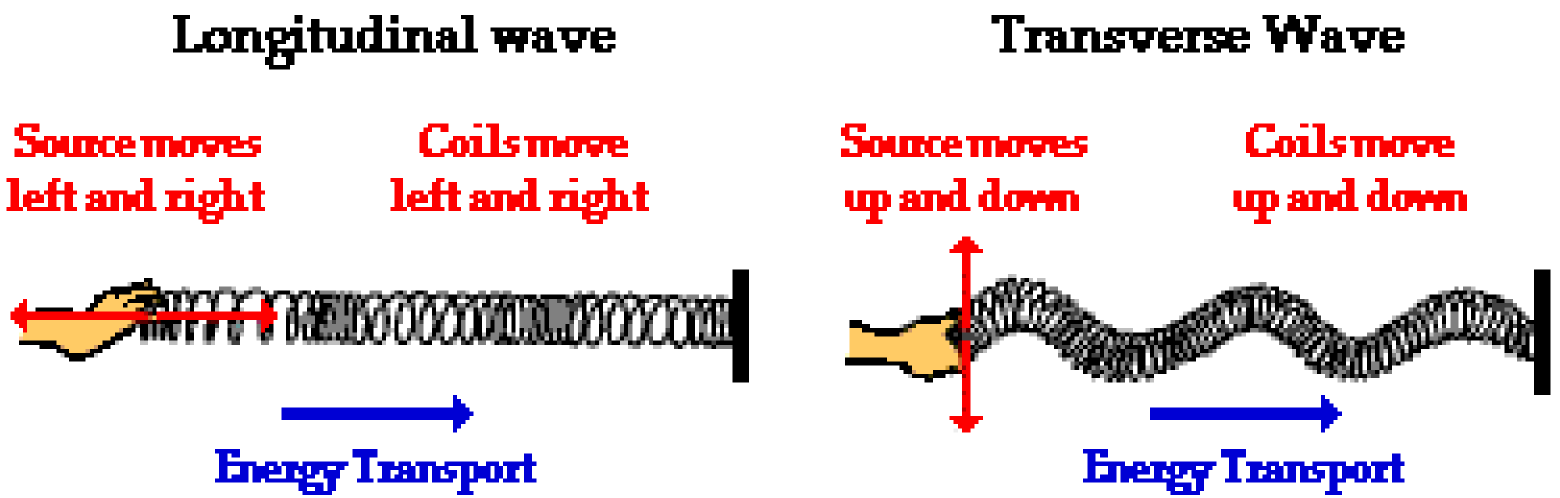




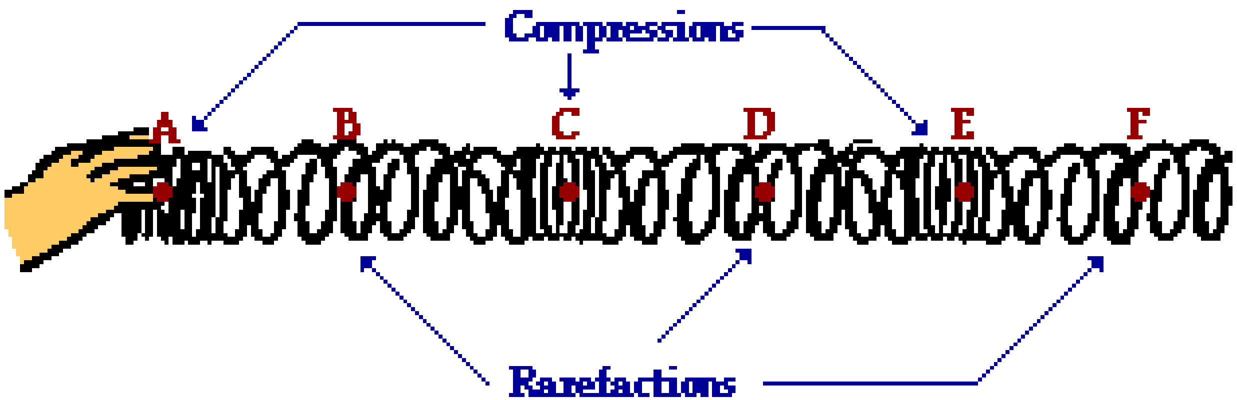
Wave – like motion of a worm

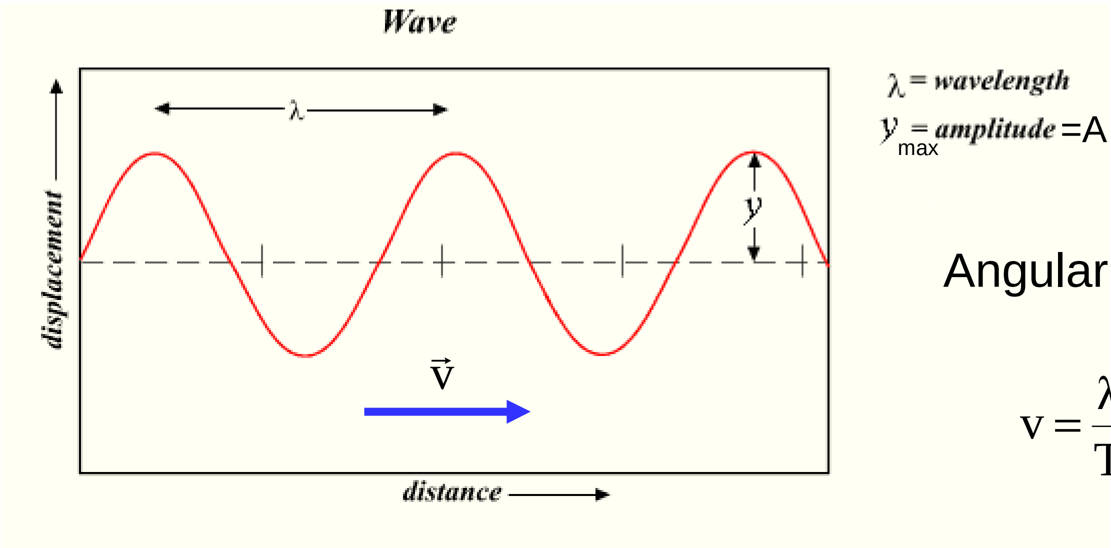






The subsequent direction of motion of individual particles of a medium is the same as the direction of vibration of the source of the disturbance.

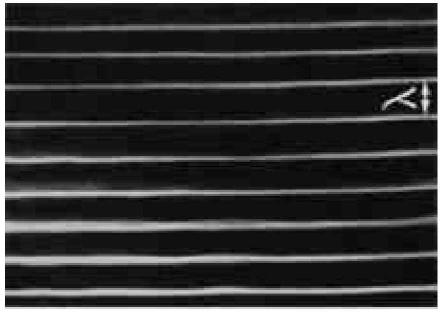




Angular wave number: $k = \frac{2\pi}{\lambda}$

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

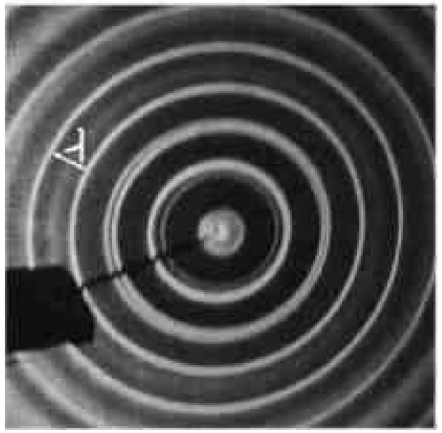
$$v = \frac{\omega}{k}$$



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

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

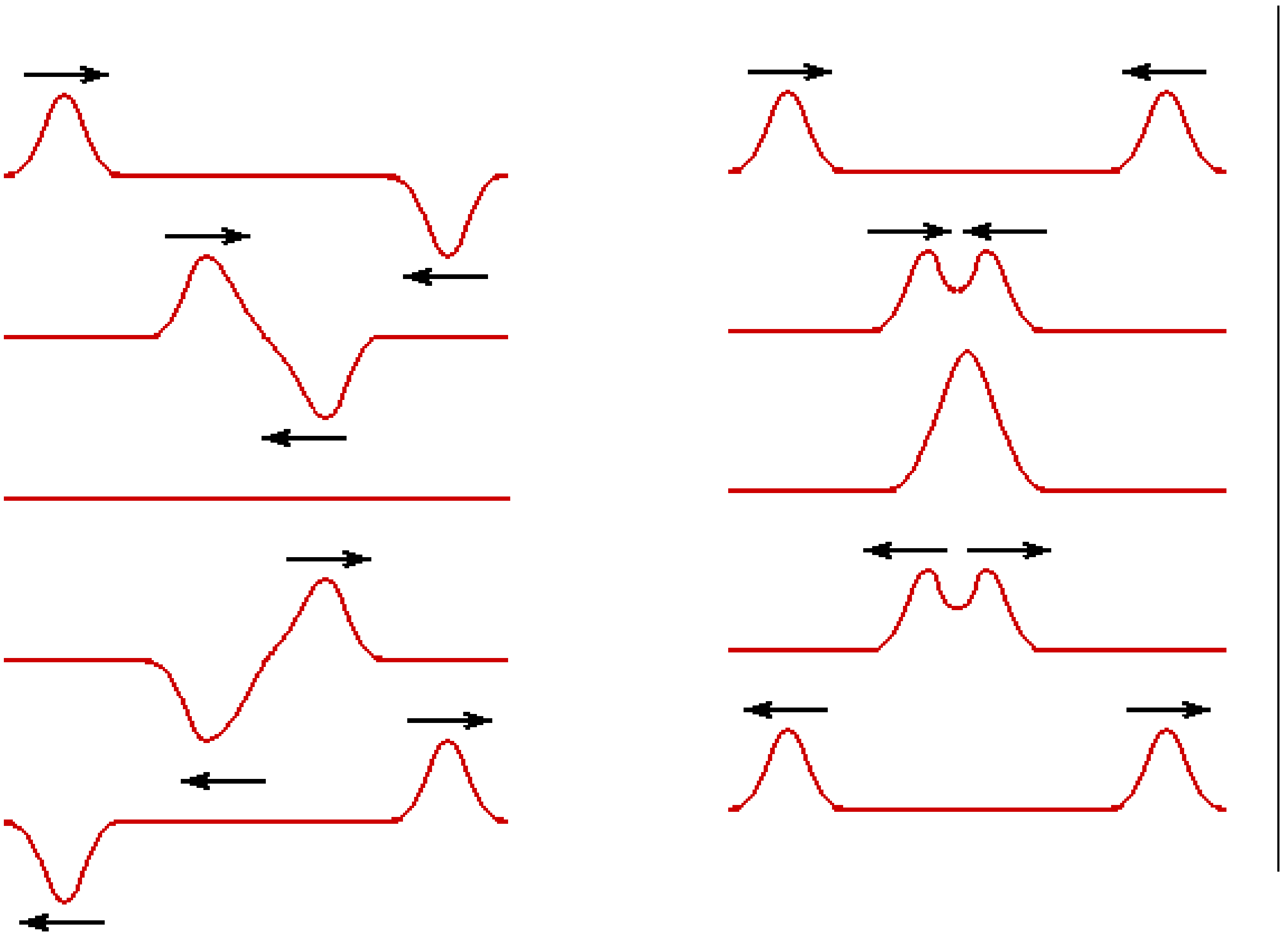
$$\frac{2\pi}{\lambda} vt = \frac{2\pi}{\lambda/v} t = \frac{2\pi}{T} t = \omega t$$

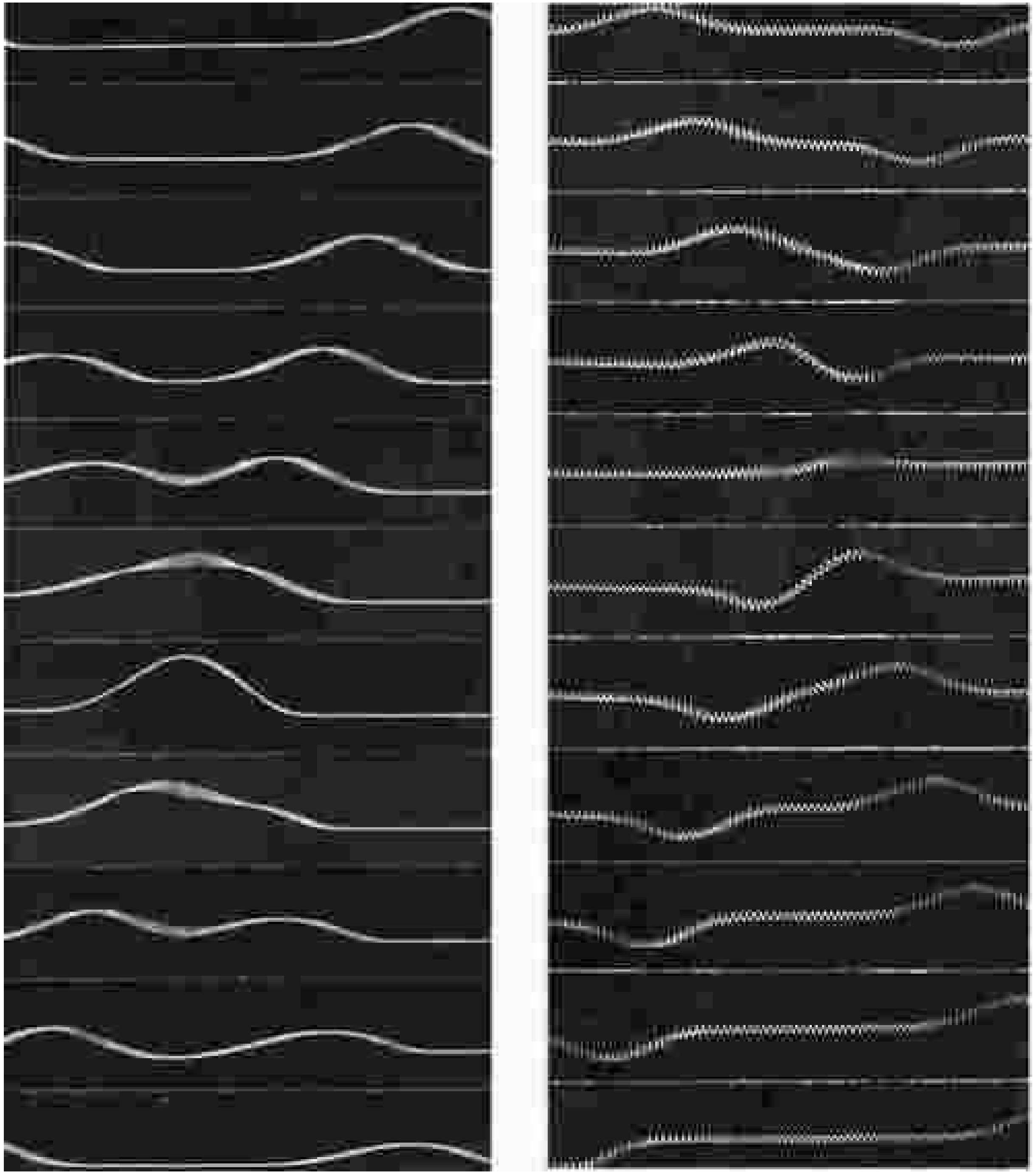


$$y(x, t) = A \sin(kx - \omega t + \varphi)$$

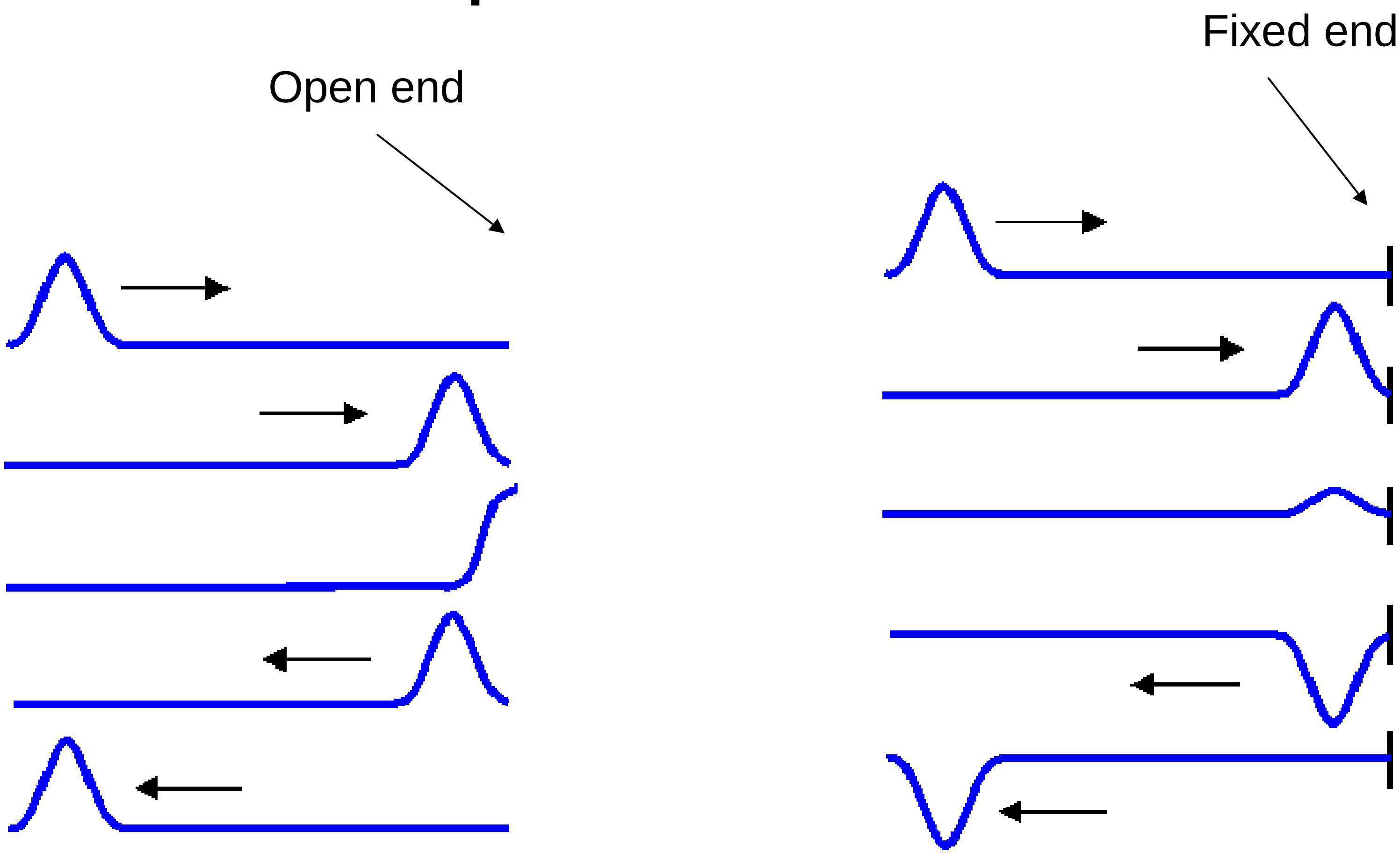
Superposition

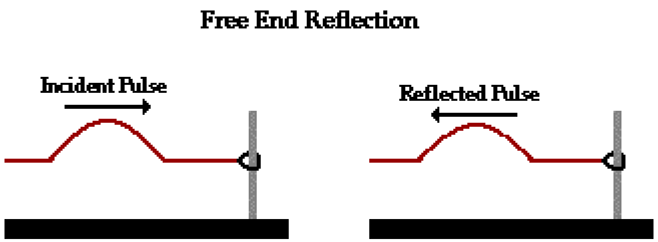
Linearity

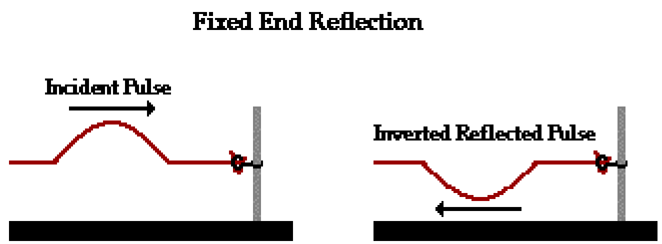


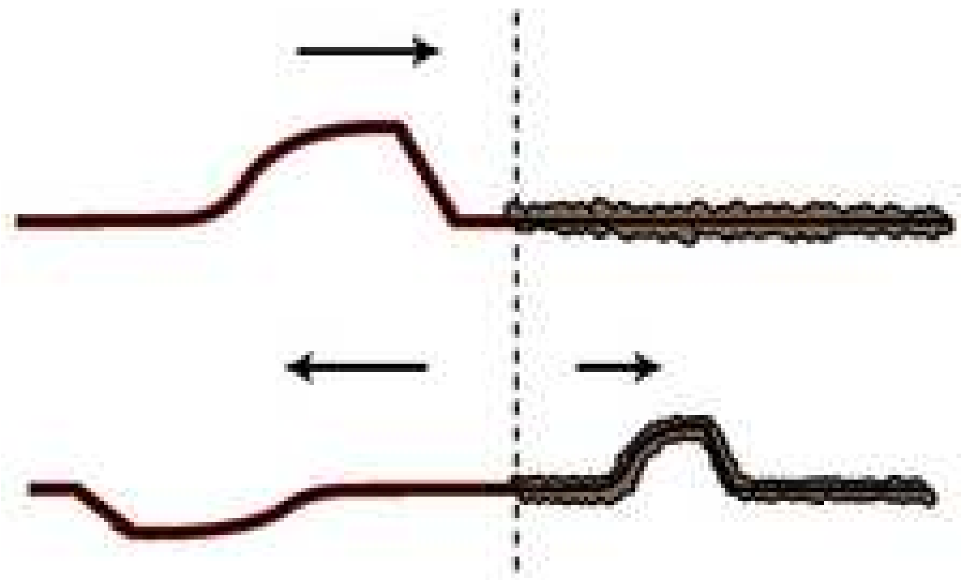


Reflection of wave pulse



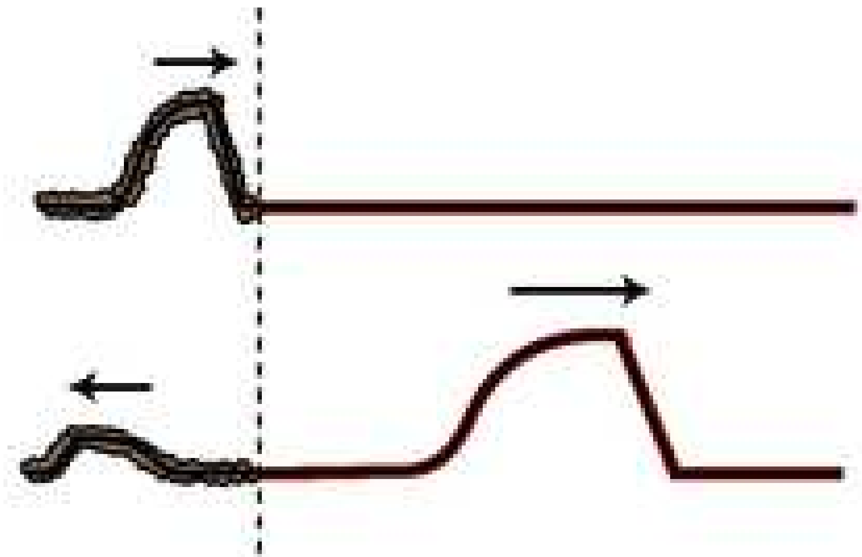




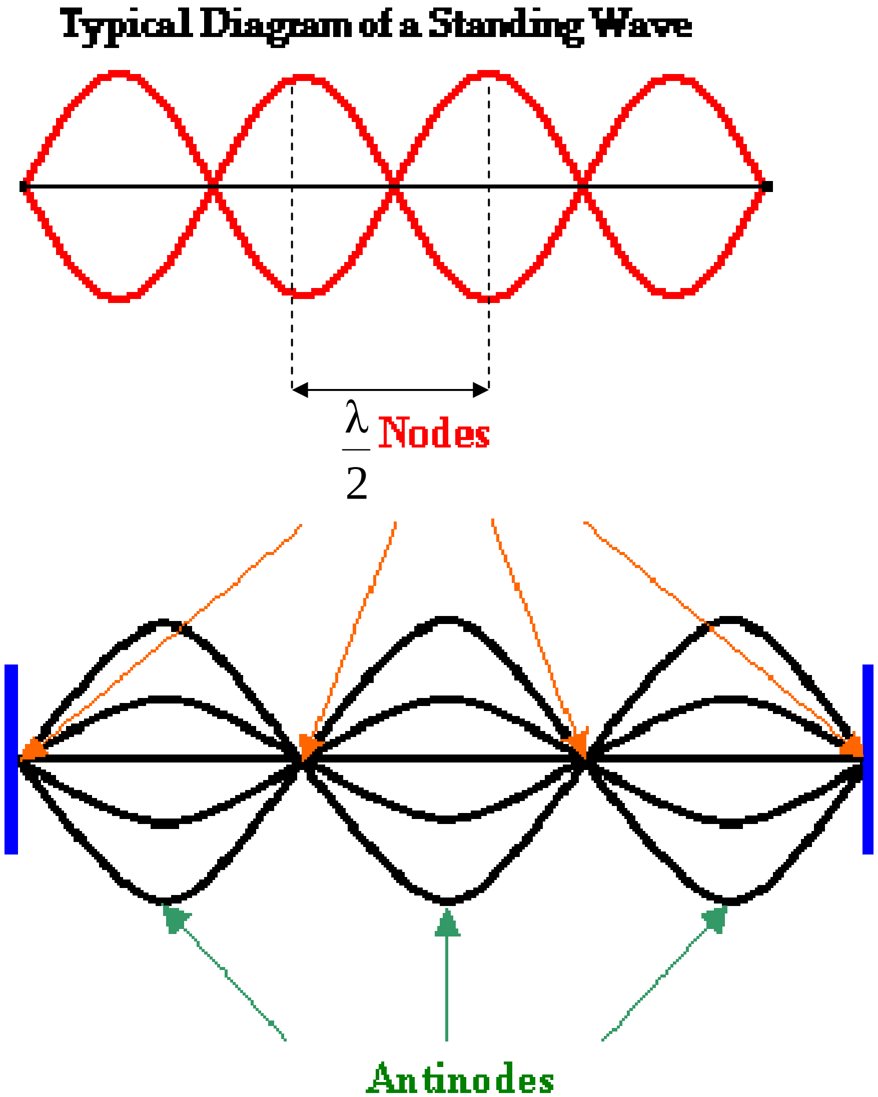


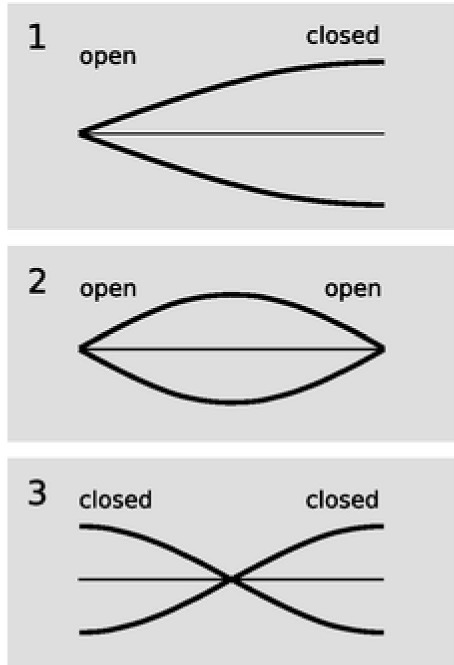
inverted

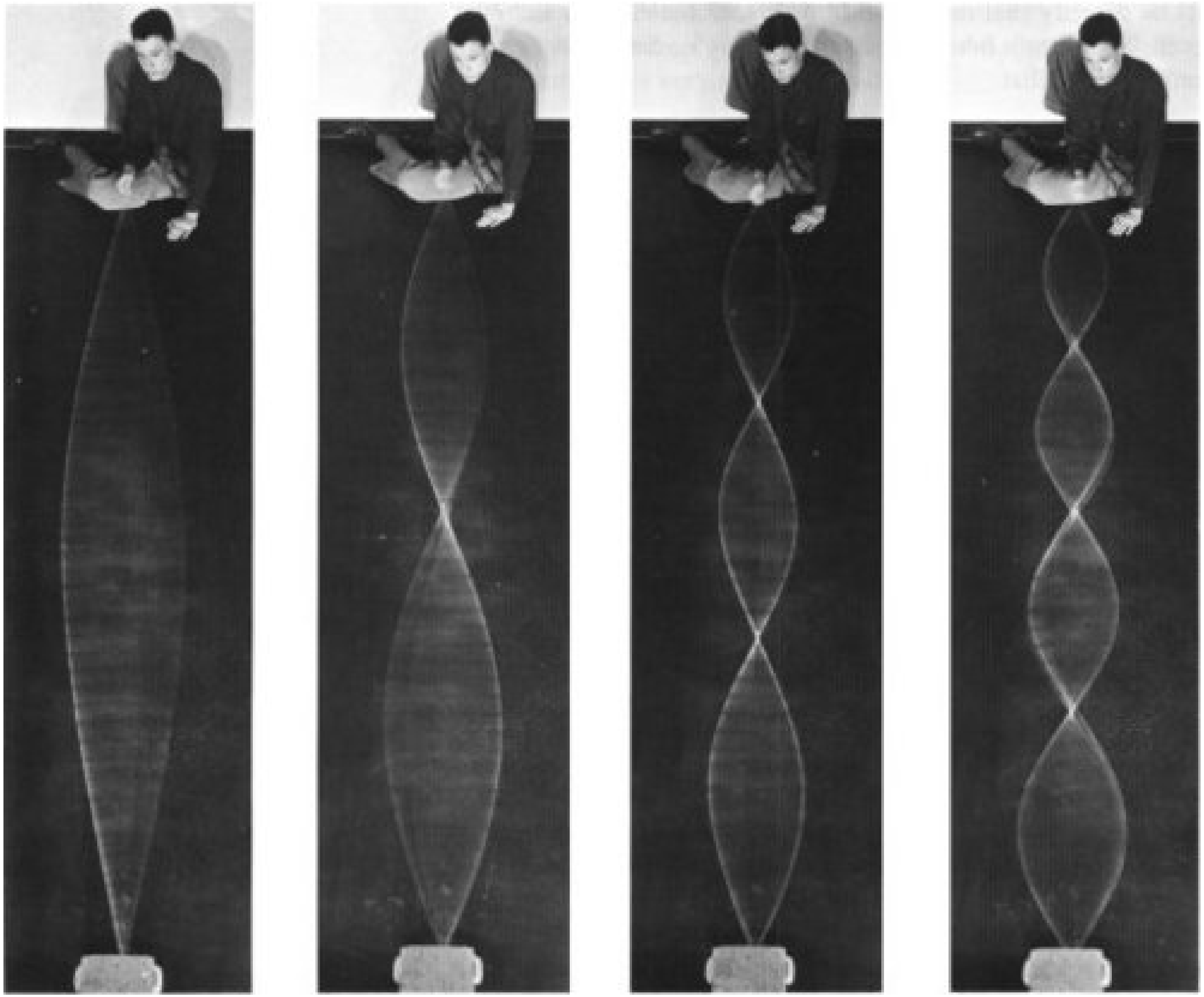
uninverted



Standing waves







Standing waves

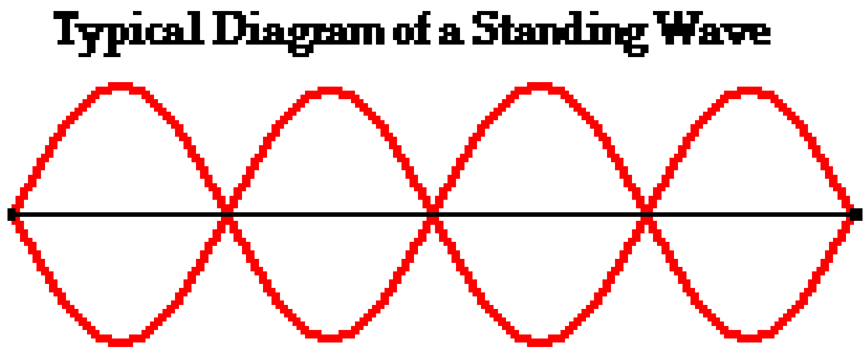
$$y_1(x,t) = A\cos(\omega t - kx)$$

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

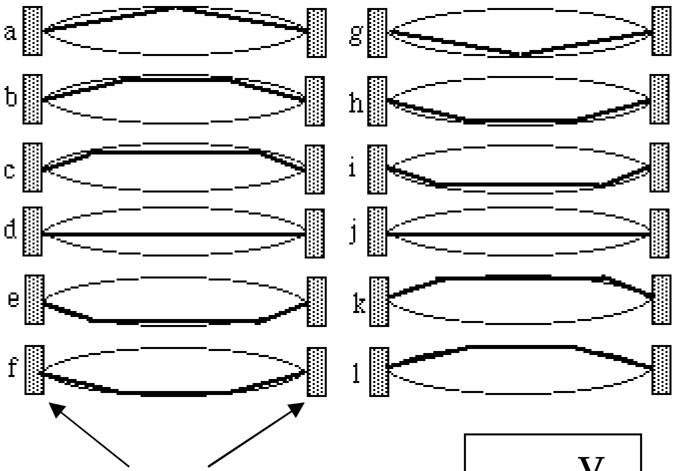
Standing wave: $y(x,t) = y_1(x,t) + y_2(x,t)$

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

/ φ: $y(x,t) = 2A\sin(\omega t)\sin(kx)$ /



Harmonics



fixed

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

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

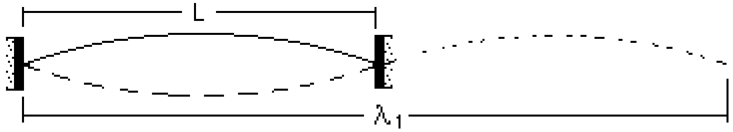
$$f_2 = \frac{v}{\lambda_2} = 2 \cdot \frac{v}{2L} = 2 \cdot f_1$$

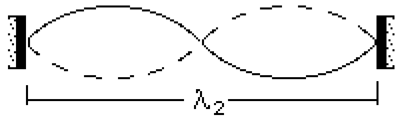
$$f_3 = \frac{v}{\lambda_3} = 3 \cdot \frac{v}{2L} = 3 \cdot f_1$$

⋮

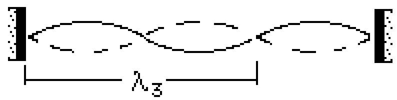
$$f_n = n \cdot f_1$$

$$\lambda_1 = 2L$$

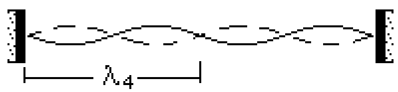




$$2 \cdot \frac{\lambda_2}{2} = L \rightarrow \lambda_2 = L$$

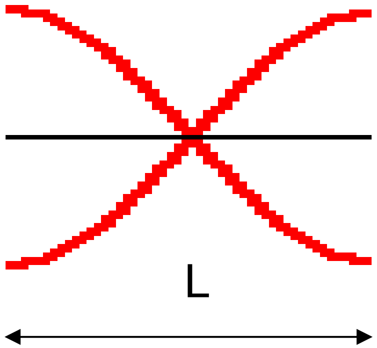


$$3 \cdot \frac{\lambda_3}{2} = L \rightarrow \lambda_3 = 2 \cdot \frac{L}{3}$$



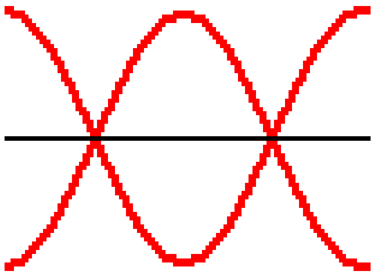
$$4 \cdot \frac{\lambda_4}{2} = L \rightarrow \lambda_4 = 2 \cdot \frac{L}{4}$$

Open ends



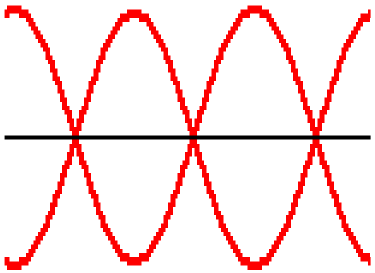
$$\lambda_1 = 2L \quad \longrightarrow \quad f_1 = \frac{v}{\lambda_1} = \frac{v}{2L}$$

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



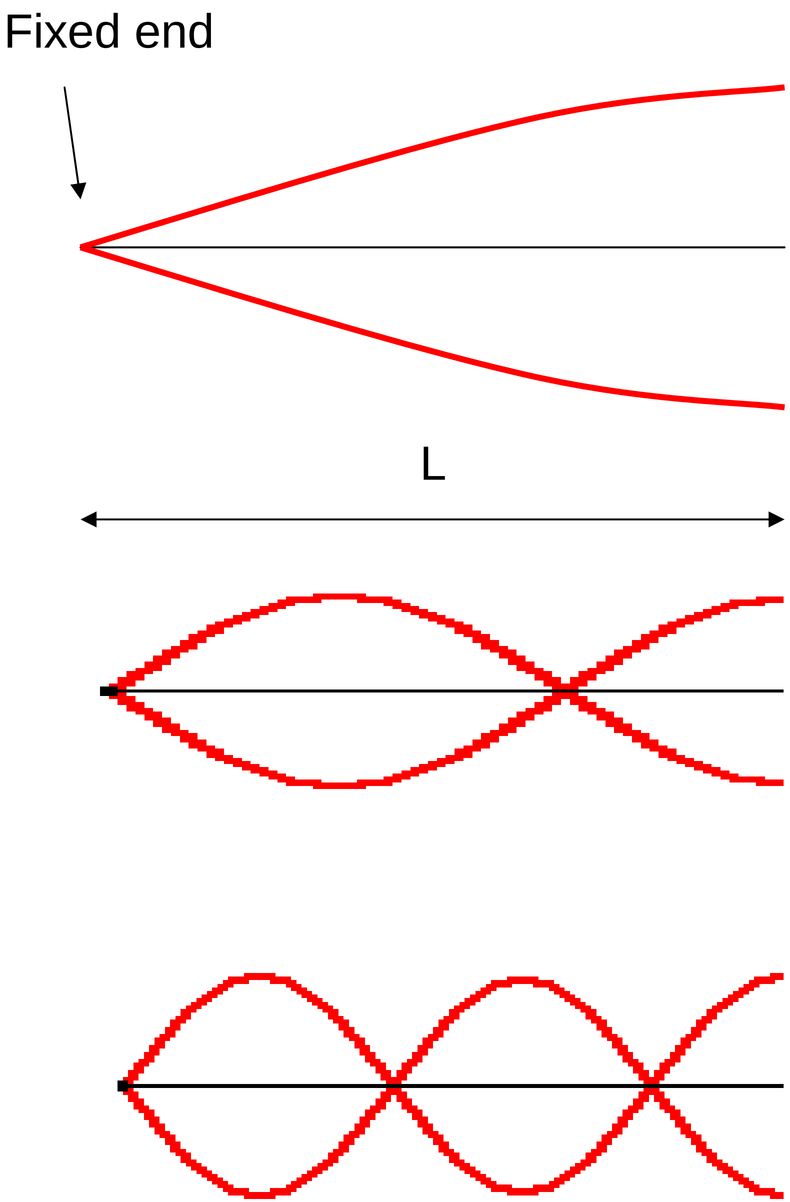
$$\lambda_2 = \frac{2L}{2}$$

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



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

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



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

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

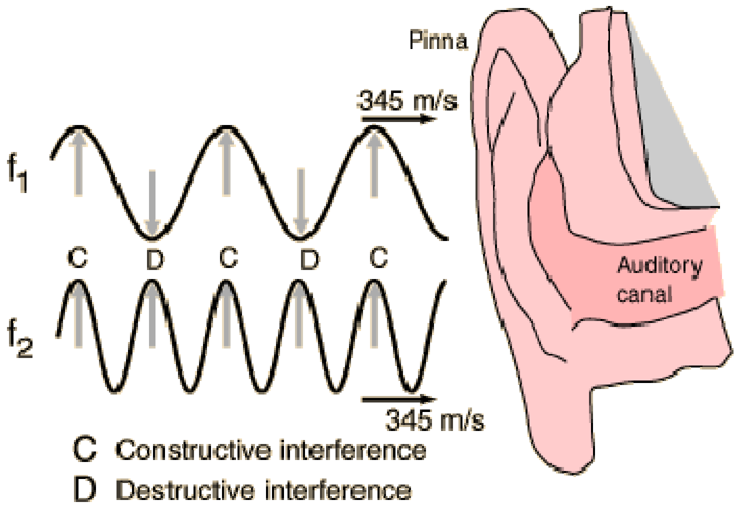
$$5 \cdot \frac{\lambda_3}{4} = L \rightarrow \lambda_3 = \frac{4L}{5} \longrightarrow f_3 = \frac{v}{\lambda_3} = 5 \cdot \frac{v}{4L}$$

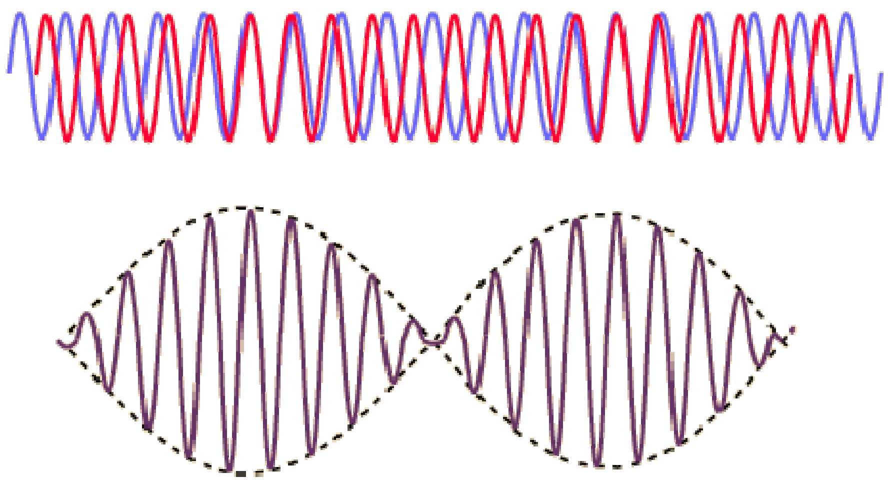
∘
∘
∘

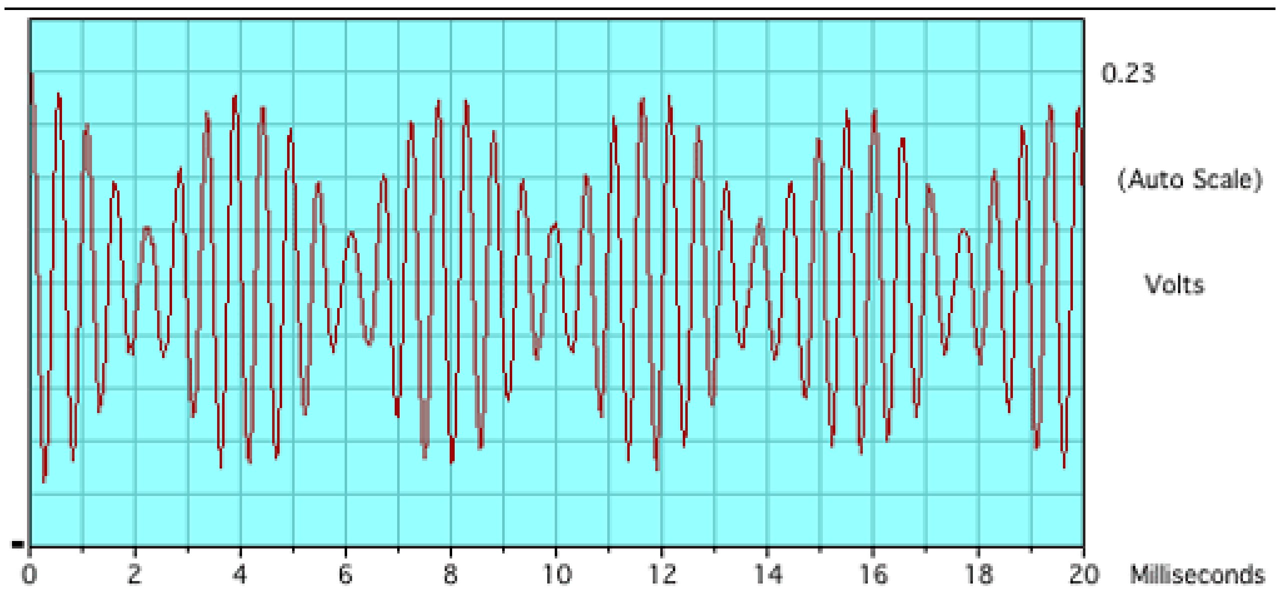
$$f_n = (2n - 1) \cdot f_1$$

Ultrasound

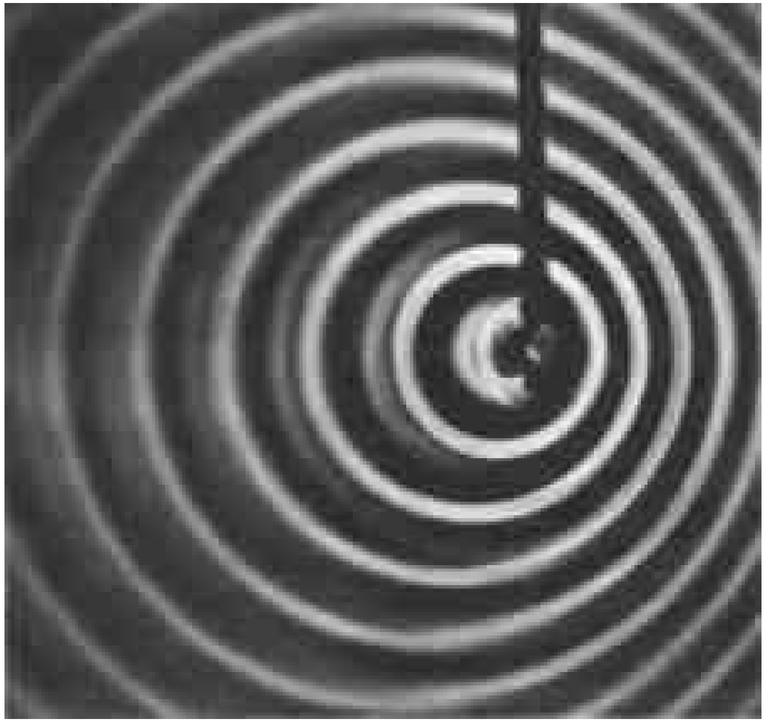
Beat frequency







Doppler-effect



Sound source: at rest
Observer: moving at v

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

Sound source: moving at v
Observer: at rest

$$f = \frac{f_o}{\left(1 \mp \frac{v}{v_s}\right)}$$

$$f = f_o \frac{\left(1 \pm \frac{v_1}{v_s}\right)}{\left(1 \mp \frac{v_2}{v_s}\right)}$$

Sound source: moving at v_2
Observer: moving at v_1