ONDES ET SON

PGC-09

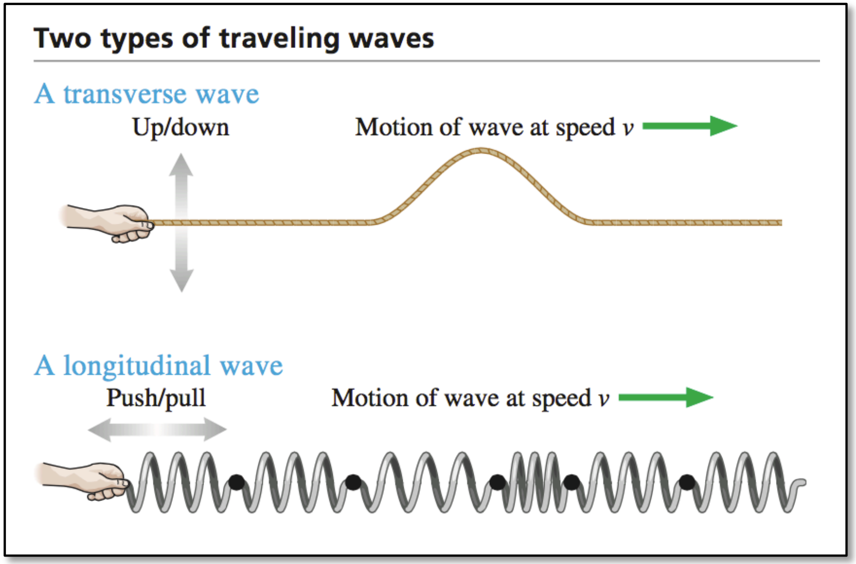


FIGURE 20.20 A plane wave.

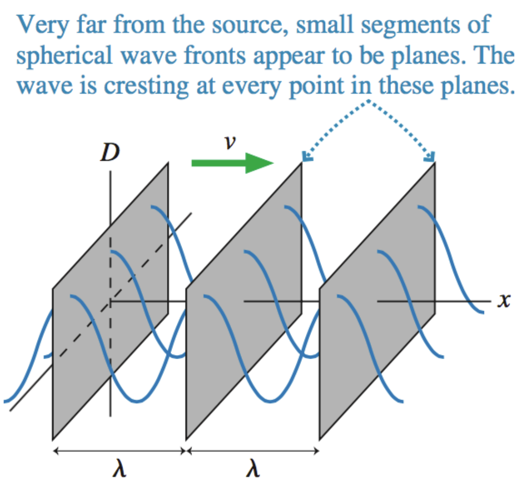
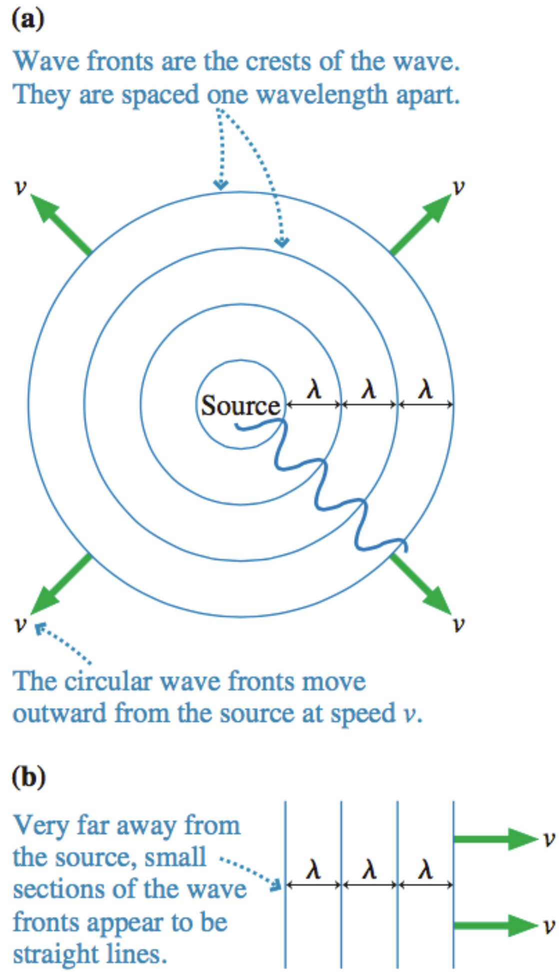
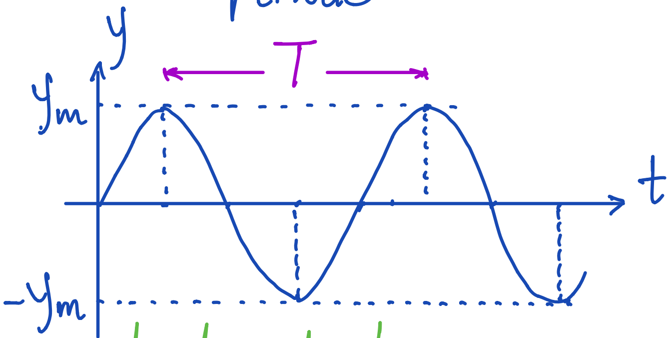


FIGURE 20.19 The wave fronts of a circular or spherical wave.



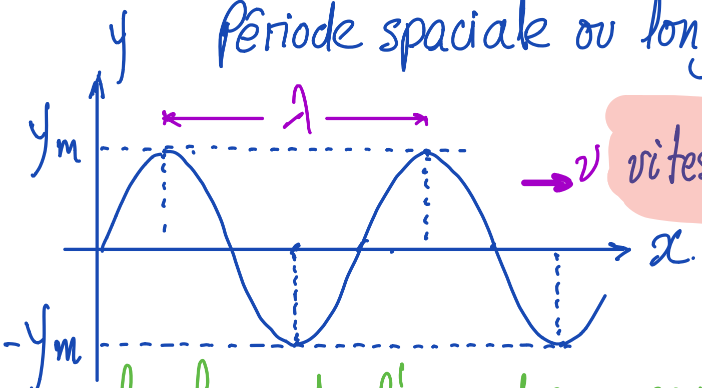
$$y(x,t) = y_m \sin(kx - \omega t + \phi)$$

Période



... le long du temps pour un point fixe x_0

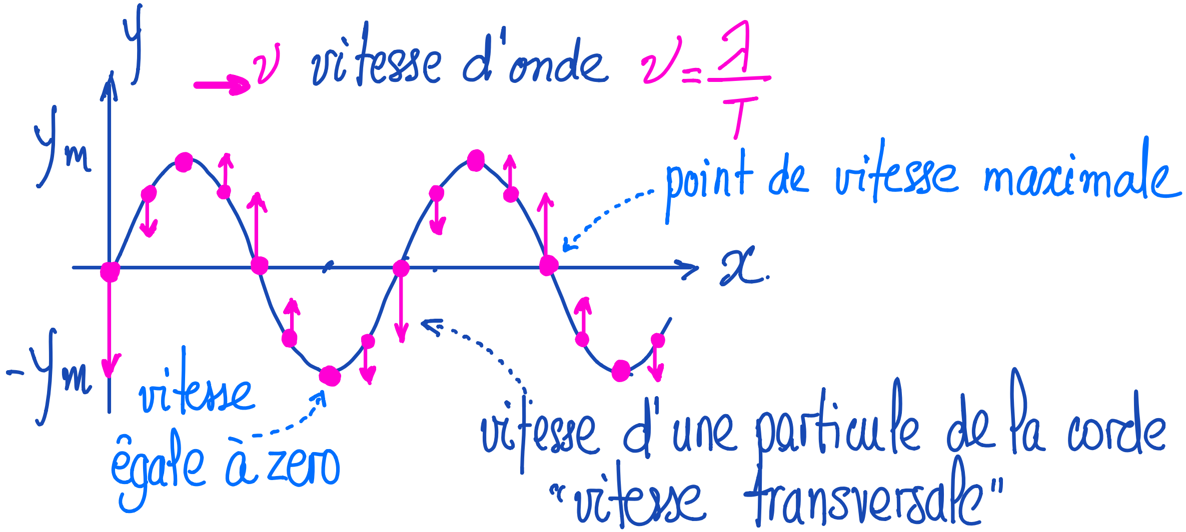
Période spaciale ou longueur d'onde



vitesse d'onde $v = \frac{\lambda}{T}$

... le long de l'axe des x pour un temps fixe t_0

VITESSE DU MOYEN

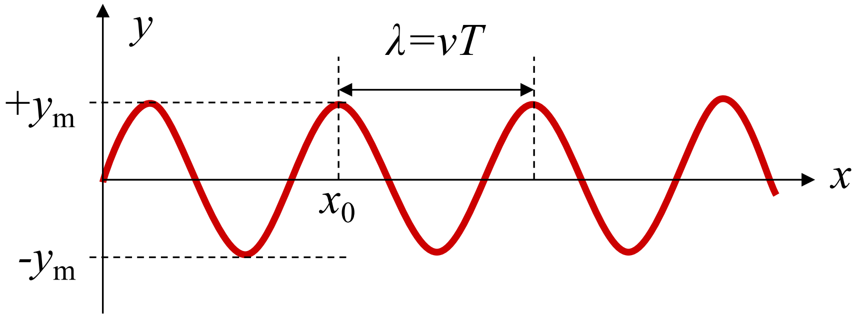


$$u = \frac{dy}{dt}$$

EXEMPLE

$y(x,t) = y_m \sin(kx - \omega t + \phi)$

Considérons une onde sinusoïdale le long d'une corde : $y(x, t) = 0.00327 \sin (72.1x - 2.72t)$



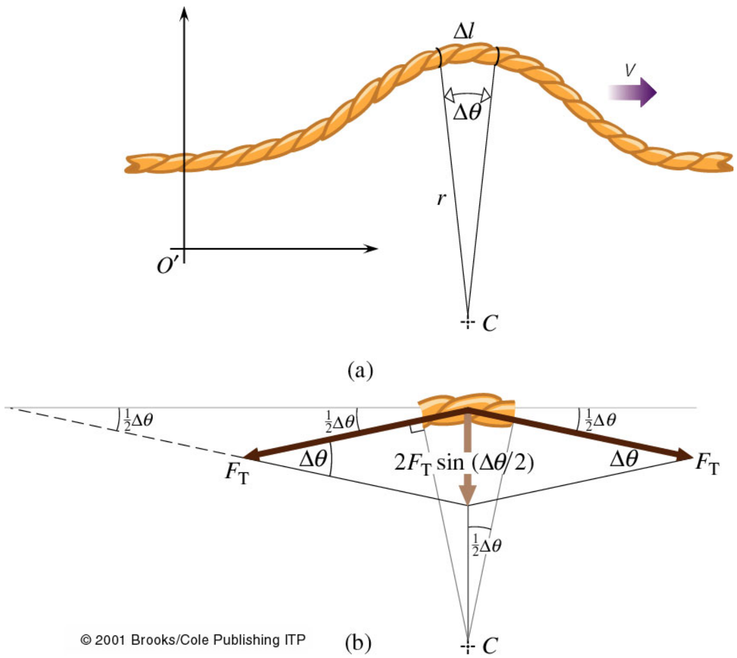
- Déterminez y_m, k, ▯, T, f et la vitesse de l'onde. –

- Calculez la vitesse et l'accélération transversales. –

$$u = \frac{dy}{dt} = -\omega y_m \cos(kx - \omega t)$$

$$a = \frac{du}{dt} = -\omega^2 y_m \sin(kx - \omega t)$$

ONDE SUR CORDE TENDUE



$$v = \sqrt{\frac{F_T}{\mu}}$$

μ : masse linéique

QUESTION

Si on double la tension d'une corde, la vitesse de l'onde est

(a) Doublée,

(b) multipliée par 4,

(c) multipliée par 1.414,

(d) divisée par 2,

(e) aucune de ces réponses.

$$v_1 = \sqrt{\frac{F_{T_1}}{\mu}}, \quad v_2 = \sqrt{\frac{F_{T_2}}{\mu}} \Rightarrow$$

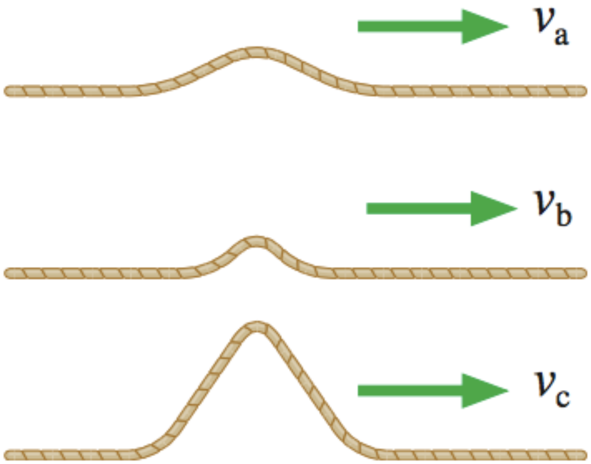
$$\frac{v_1}{v_2} = \sqrt{\frac{F_{T_1}}{F_{T_2}}}$$

QUESTION

$v = \sqrt{\frac{F_T}{\mu}}$

Trois ondes se propagent au long des cordes identiques. Quelle aura la plus grande vitesse:

(a) A
(b) B
(c) C
(d) Aucune de ces reponses



GENERATING A SINUSOIDAL WAVE

Une corde très longue avec μ = 2.0 g/m est tirée avec une tension de 5.0 N. À x = 0 m on connecte un moteur qui vibre à 100 Hz avec une amplitude de 2.0 mm. On considère t = 0 quand le deplacement vertical est maximal.

(a) Quelle est l'équation du deplacement pour l'onde progressive dans cette corde?

(b) À t = 5.0 ms, quel sera le déplacement de la corde à une position 2.7 m loin du moteur?

(a) $y = y_m \sin(kx - \omega t + \phi)$

$y_m = 2.0$ mm

$x, t = 0: \; y = y_m \Rightarrow y_m \sin\phi = y_m \Rightarrow \phi = \frac{\pi}{2}$

$\omega = 2\pi f \Rightarrow \omega = 200\pi$ rad/s

$k = 2\pi/\lambda = \omega/v$, $v = \sqrt{\frac{F_T}{\mu}} = 50$ m/s $\Rightarrow k = 4\pi \frac{\text{rad}}{\text{m}}$

$y = (2.0 \text{ mm}) \times \sin\left[2\pi\left[(2 \text{ m}^{-1})x - (100 \text{ s}^{-1})t\right] + \frac{\pi}{2}\right]$

$= (2 \text{ mm}) \cos\left[2\pi(\cdot\cdot\cdot)\right]$

(b) $t_1 = 5.0$ ms $= 5 \times 10^{-3}$ s

$x_1 = 2.7$ m

$y(t_1, x_1) = \dots = 1.6$ mm

LA VITESSE DE PROPAGATION DES ONDES

$$v = \sqrt{\frac{\text{facteur de force élastique}}{\text{facteur d'inertie}}}$$

$$v = \sqrt{\frac{F_T}{\mu}}$$

liquide : $v = \sqrt{\frac{B}{\rho}}$

solide : $v = \sqrt{\frac{E}{\rho}}$

gaz $v = \sqrt{\frac{P}{\rho}}$

ÉNERGIE TRANSMISE PAR UNE ONDE ÉLASTIQUE

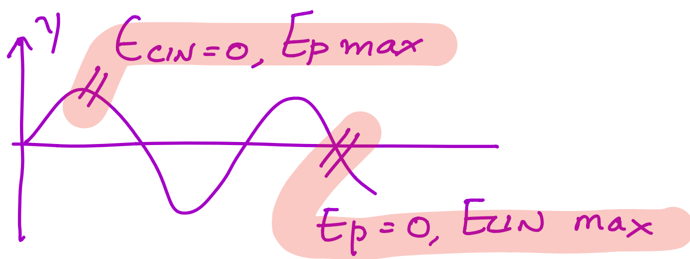
$$\bar{P} = \frac{1}{2}\mu v \omega^2 y_m^2$$

Puissance moyenne transmise

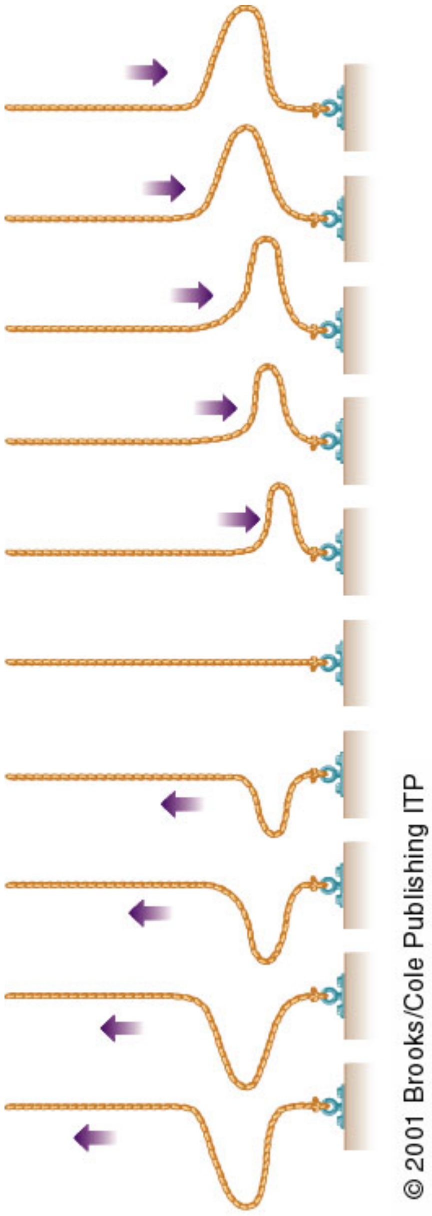
$$v = \sqrt{\frac{F_T}{\mu}}$$

$$\bar{P} = \frac{1}{2}\sqrt{\mu F_T}\,\omega^2 y_m^2$$

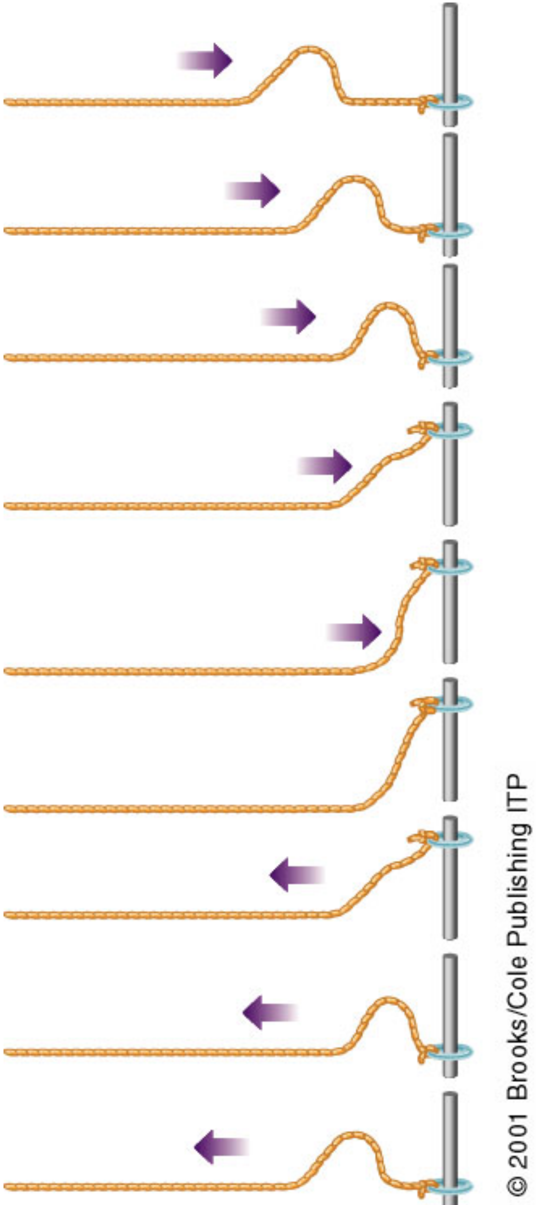
Energie transportée $\propto \omega^2, y_m^2$



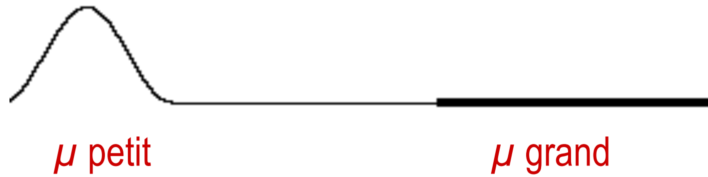
RÉFLEXION, ABSORPTION ET TRANSMISSION

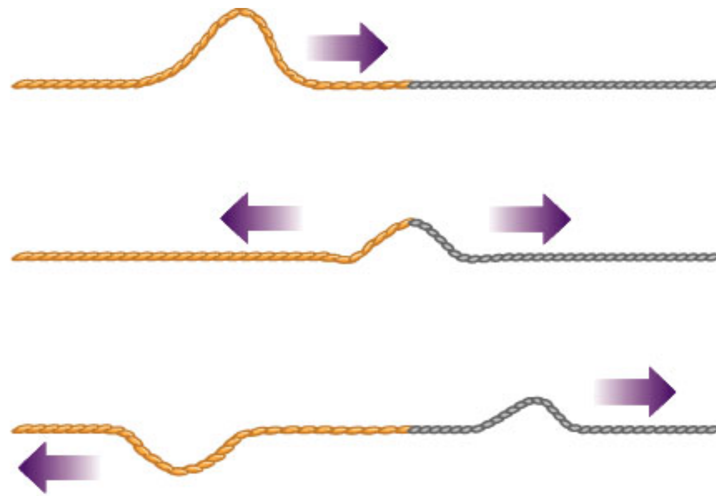


RÉFLEXION, ABSORPTION ET TRANSMISSION



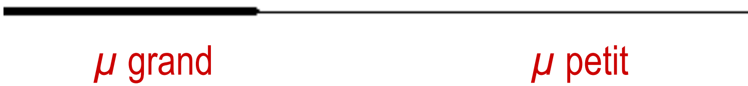
RÉFLEXION, ABSORPTION ET TRANSMISSION

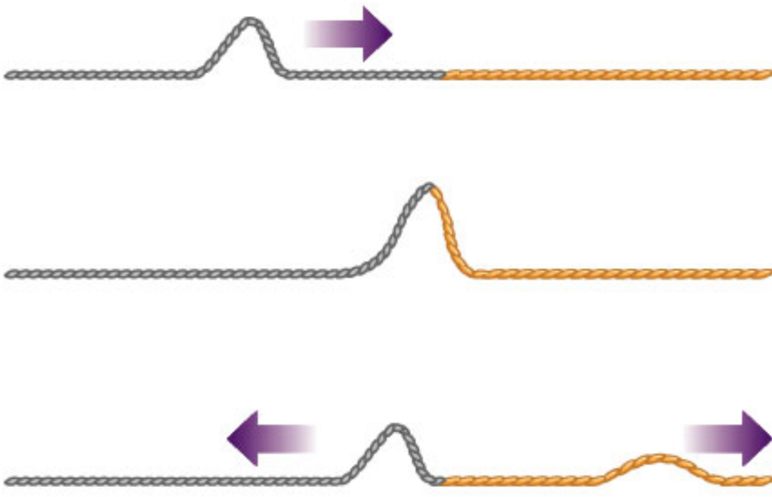




(a)

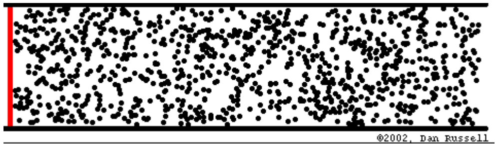
RÉFLEXION, ABSORPTION ET TRANSMISSION

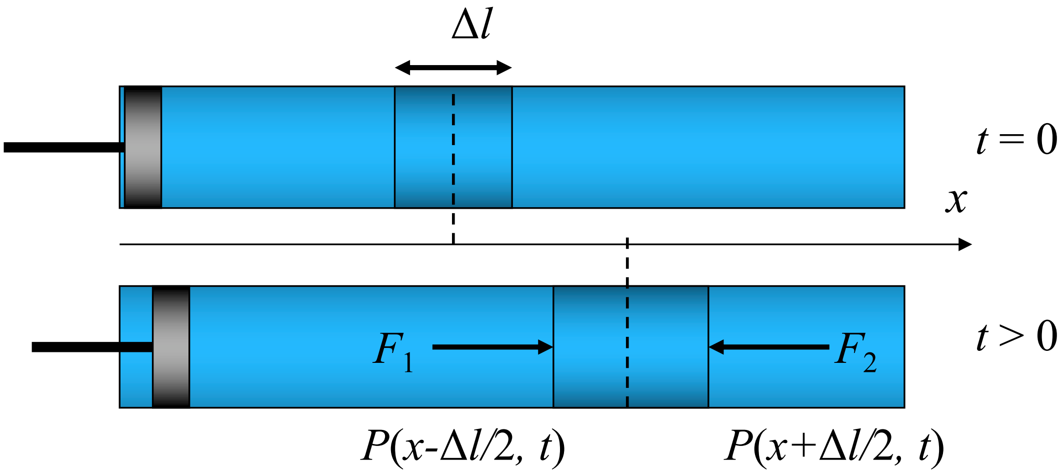


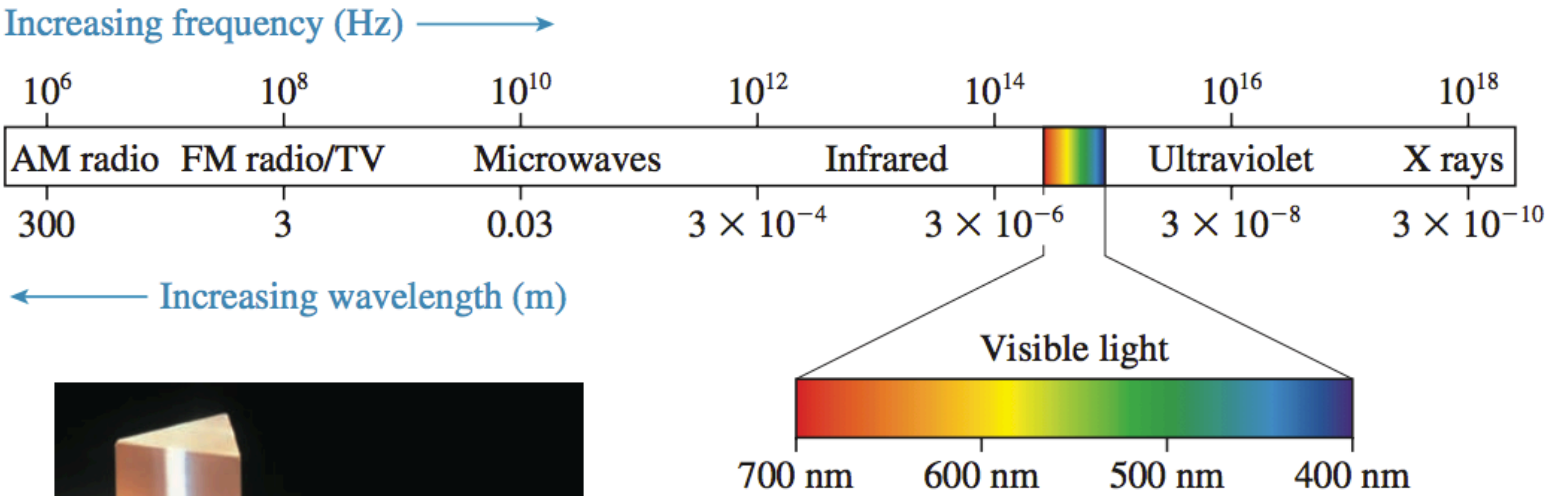


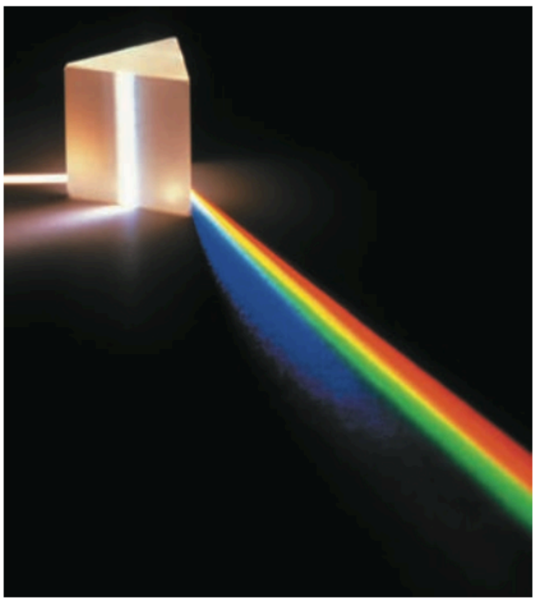
(b)

ONDE DE PRESSION









White light passing through a prism is spread out into a band of colors called the *visible spectrum.*

LE SON COMME UNE ONDE

VITESSE DU SON - EXEMPLE

$v = \lambda f$

$v \Uparrow$

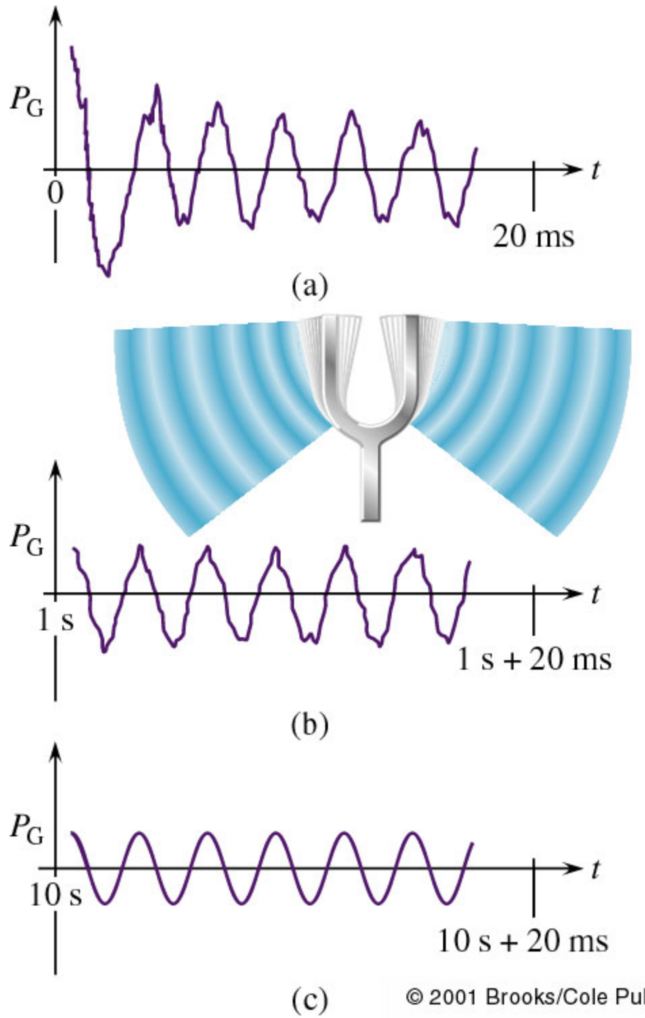
$\lambda \Uparrow$

Milieu	Vitesse (m/s)
Air (0^oC)	331
Air (20^oC)	343
Helium (0^oC)	970
Ethyl alcohol	1170
Eau (20^oC)	1480
Granite	6000
Aluminium	6420

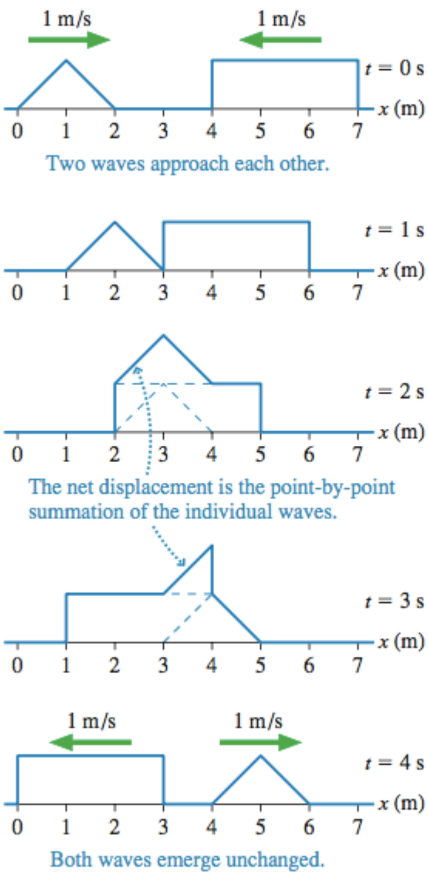
Tableau 18.1: La vitesse du son.

Pour comparer: la vitesse de la lumière est 3.00 x 10^8 m/s

LE DIAPASON



LA SUPERPOSITION DES ONDES



$y_{fin} = y_1 + y_2$

ANALYSE FOURIER

$$y'(x,t) = a_1 \sin(\omega t + \phi_1) + a_2 \sin(2\omega t + \phi_2) + a_3 \sin(3\omega t + \phi_3) + \dots$$

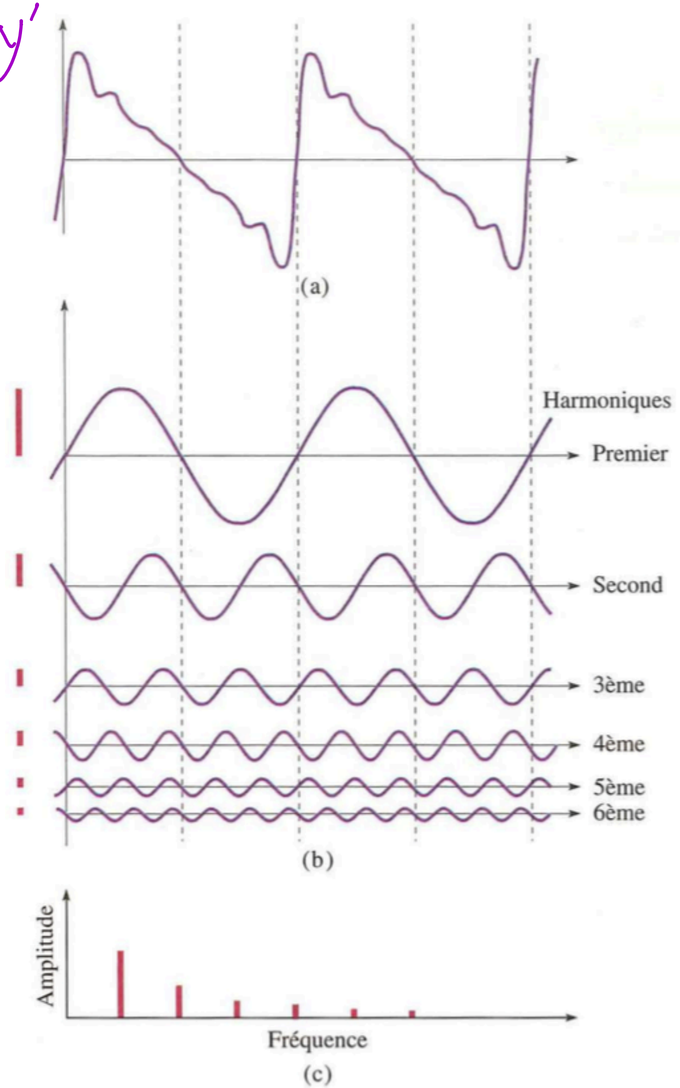
$$= y'(x,t) = \sum_n a_n \sin(n\omega t + \phi_n)$$

$$\omega = 2\pi f$$

$n = 1$: fondamentale

$n = 2, 3 \dots$ harmonique

y'



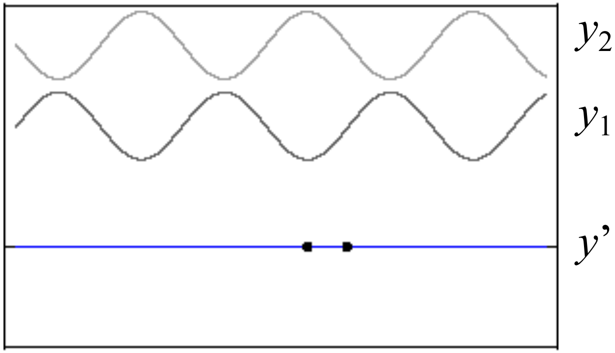
$$\sin a + \sin\beta = 2\sin\left(\frac{a+\beta}{2}\right)\cdot\sin\left(\frac{a-\beta}{2}\right)$$

INTERFÉRENCE D'ONDES

$$y_1 = y_m \sin(kx - \omega t)$$

$$y_2 = y_m \sin(kx - \omega t + \phi)$$

$$y'(x,t) = y_1(x,t) + y_2(x,t)$$



$$y' = y_1 + y_2 =$$

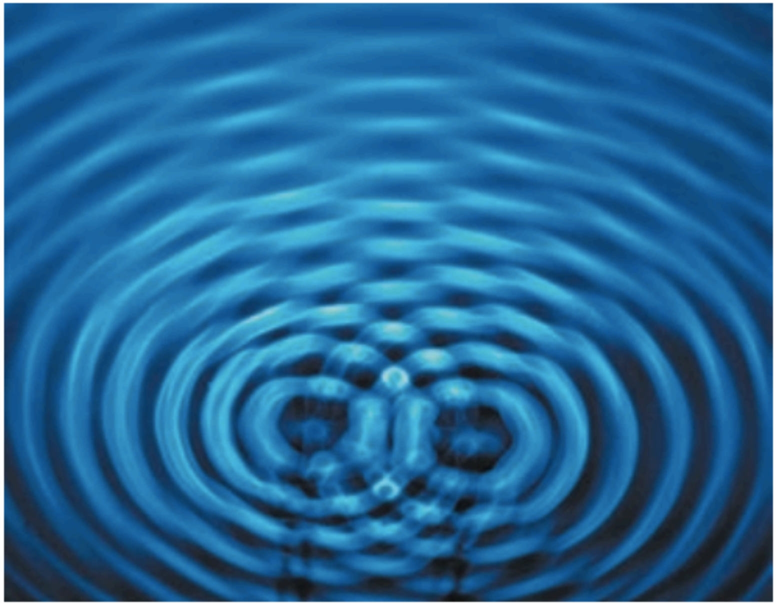
$$= y_m\left[\sin(kx - \omega t) + \sin(kx - \omega t + \phi)\right]$$

$$= 2y_m \cos\frac{\phi}{2} \cdot \sin\left(kx - \omega t + \frac{\phi}{2}\right)$$

Pour $\phi = 0$: inter. Constructive

$\phi = \pi$: inter Destructive

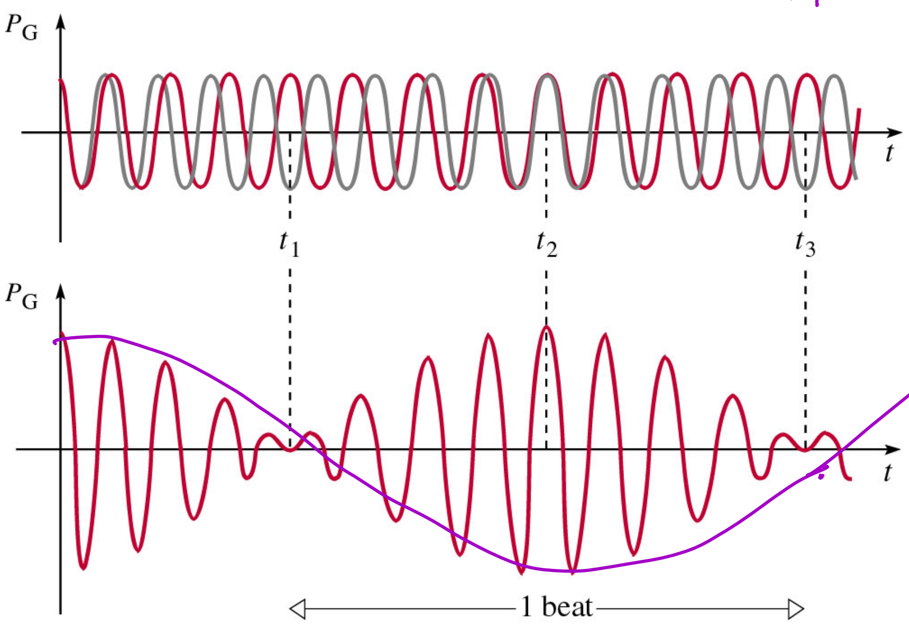
INTERFÉRENCE D'ONDES



Two overlapping water waves create an interference pattern.

BATTEMENTS

$f_1 \simeq f_2$



$f = f_1 - f_2$