Measurement of sound velocity in a liquid by acousto-optics diffraction experiment

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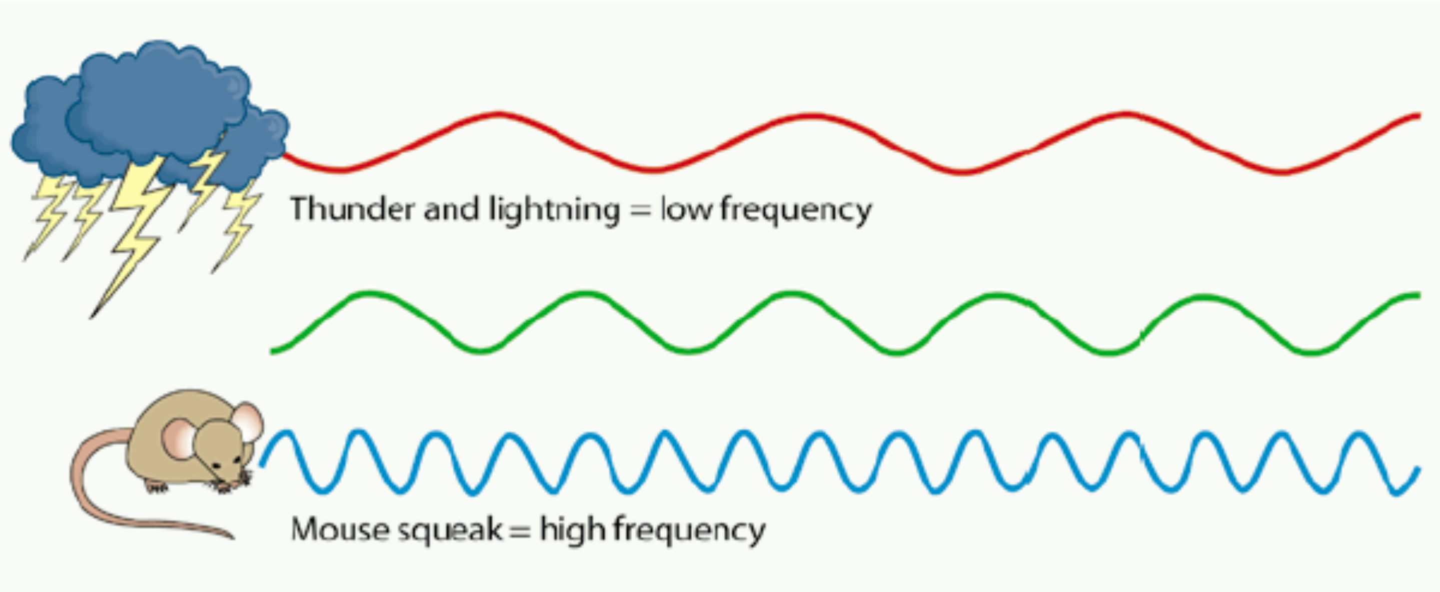
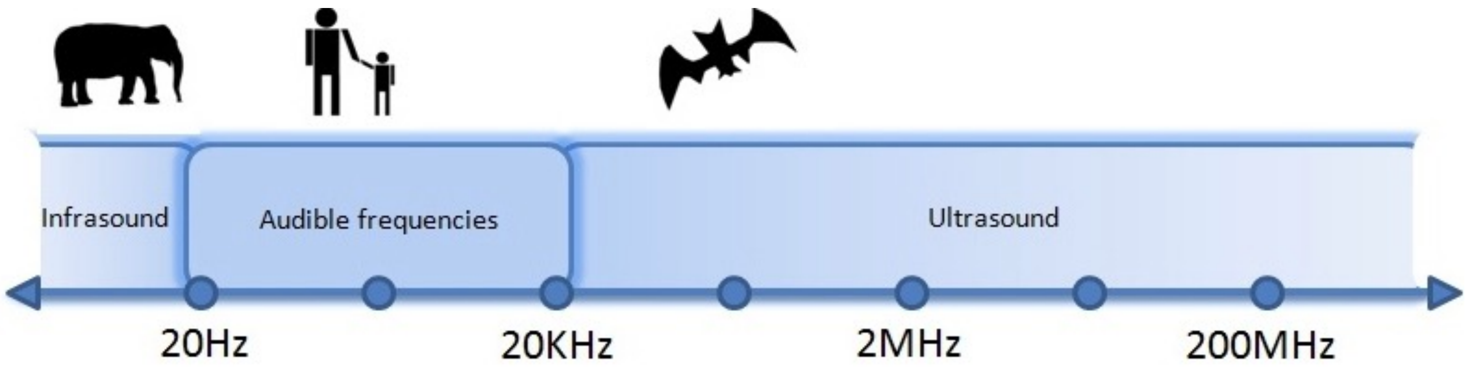
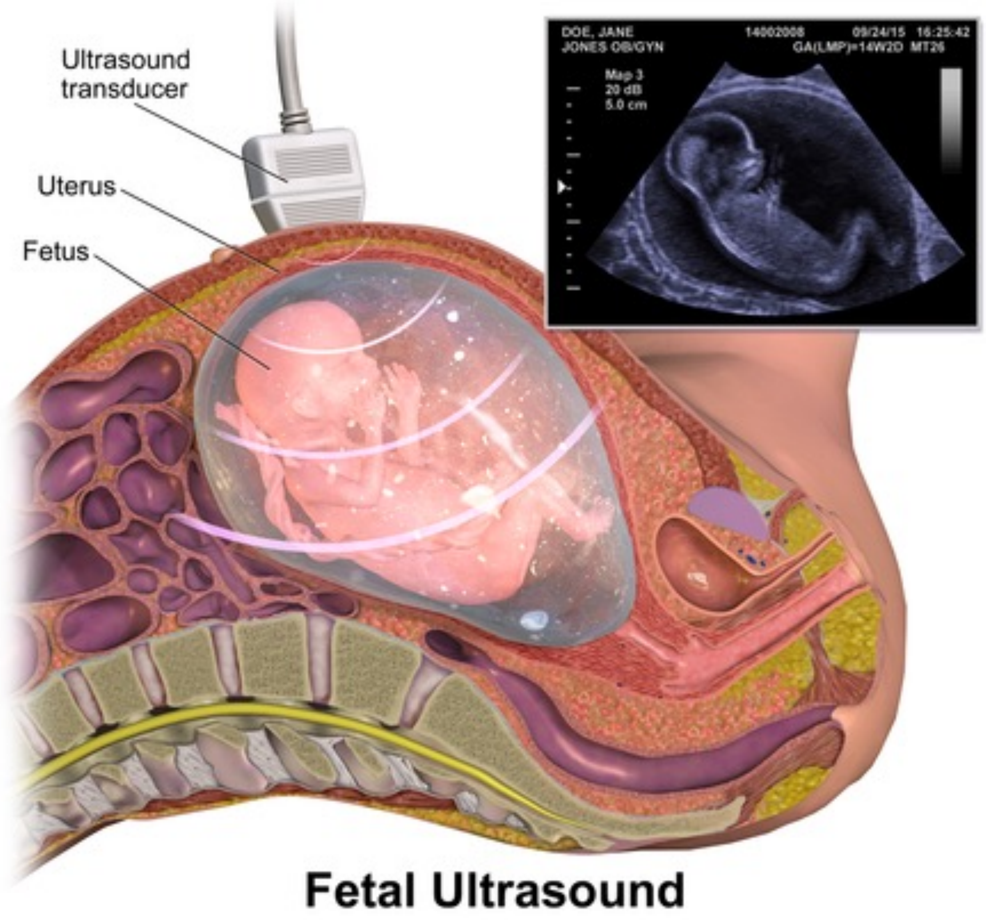
Sound wave

Ultrasound

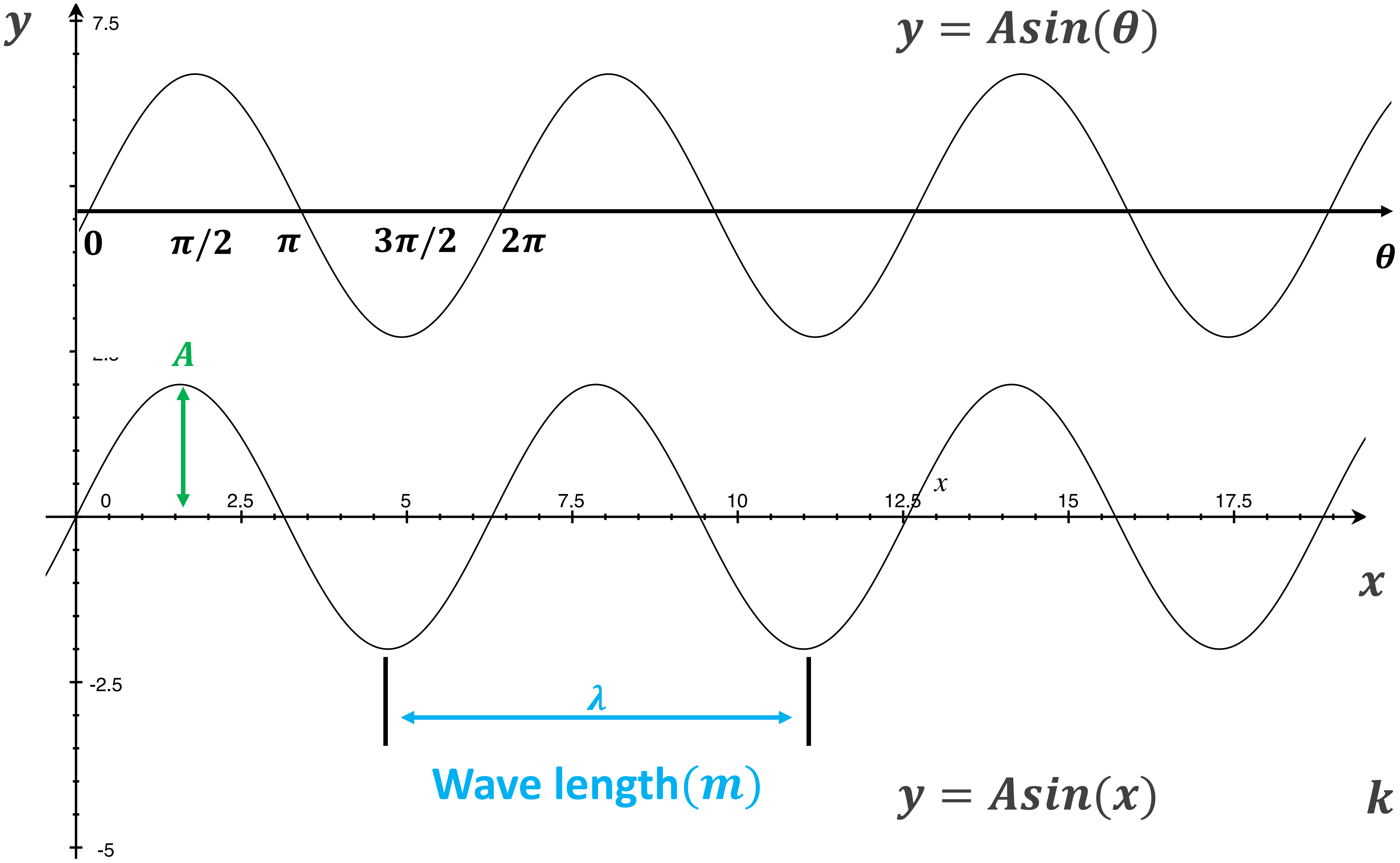






$$f > 20\ KHz$$

Sound wave



$$\frac{\theta}{x} = \frac{2\pi}{\lambda}$$

$$\begin{aligned} y &= A\sin(\theta) \\ &= A\sin\left(\frac{2\pi}{\lambda}x\right) \\ &= A\sin(kx) \end{aligned}$$

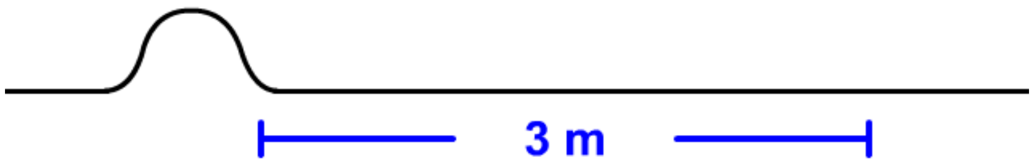
$$k = \frac{2\pi}{\lambda}$$

k : Wave number (m^{-1})

Wave velocity

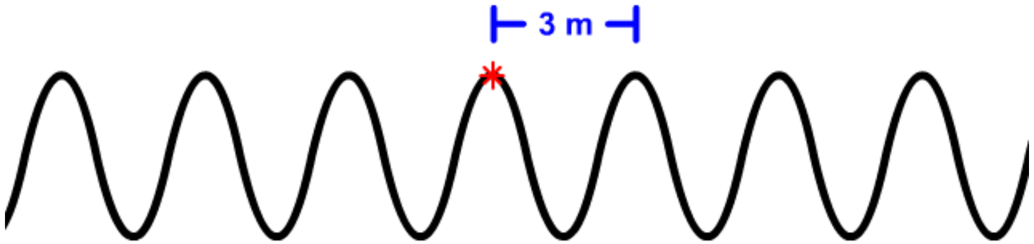
Time: 0 s

$$v = \frac{x}{t}$$



3 meters traveled
in 2 seconds

$$v = (\lambda)(f)$$



3 meters per wave
2 waves per second

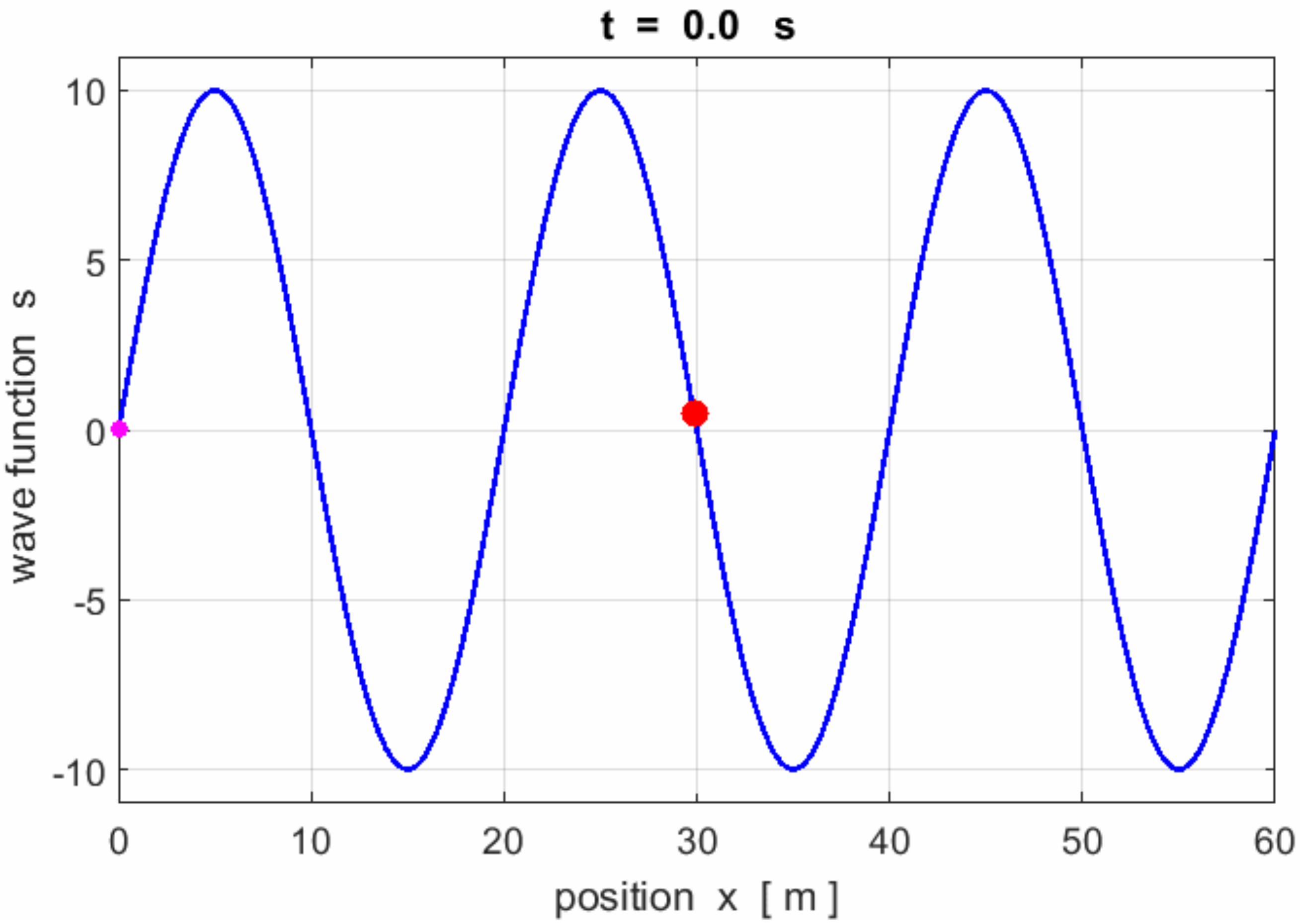
T_p : Period(s) λ : wave length (m)

$f = 1/T_p$: Frequency(Hz)

Distance traveled by one period T_p is λ

$$v = \lambda/T_p = \lambda f$$

Traveling Wave



$$y = A\sin(kx - \omega t)$$

At time t=0

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

At time t>0

Wave has traveled a distance of vt

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

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

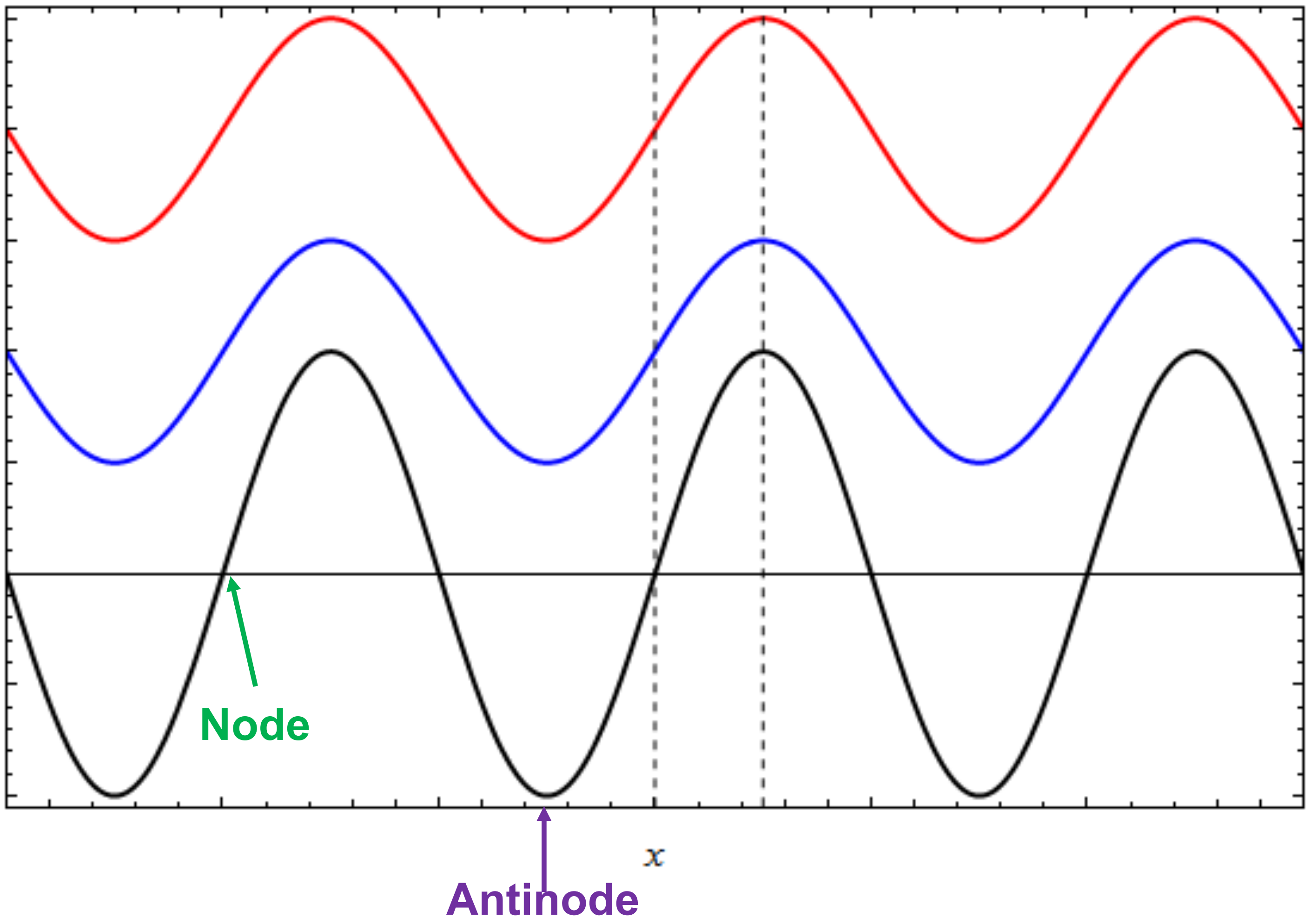
$$\frac{2\pi}{\lambda}v = \frac{2\pi}{\lambda}\frac{\lambda}{T} = \frac{2\pi}{T}$$

Angular frequency: $\omega = \frac{2\pi}{T}$

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

Standing Wave

Standing Wave formed by two counter propagating waves



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

$$y_2 = A sin(kx + \omega t)$$

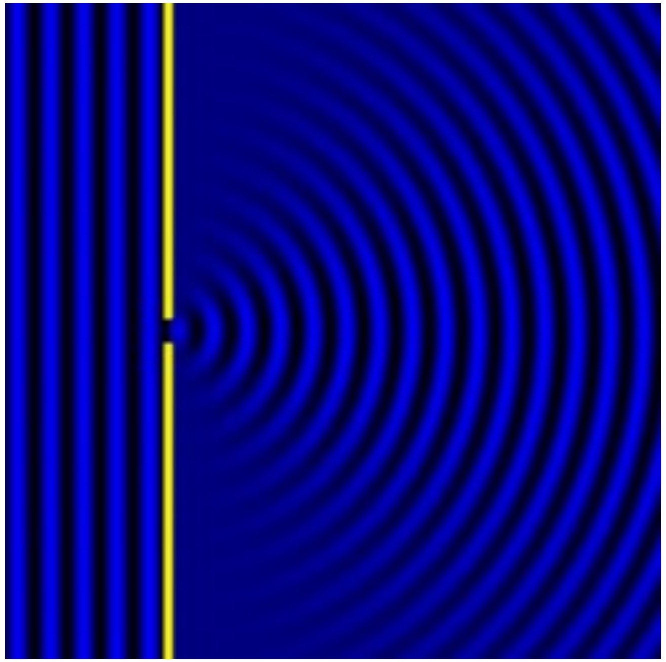
$$y = y_1 + y_2 = 2A sin(kx) cos(\omega t)$$

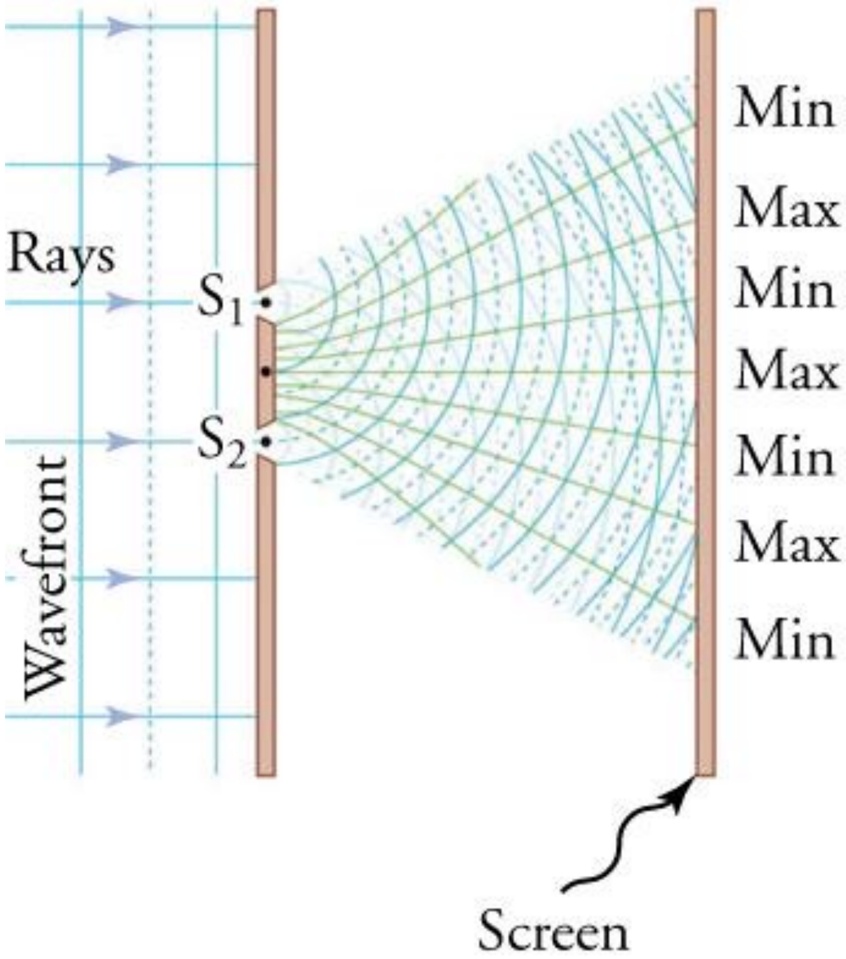
$$nodes: x = 0, \pm\frac{1}{2}\lambda, \pm\lambda, \pm\frac{3}{2}\lambda, \ldots$$

$$antinodes: x = \pm\frac{1}{4}\lambda, \pm\frac{3}{4}\lambda, \pm\frac{5}{4}\lambda \ldots$$

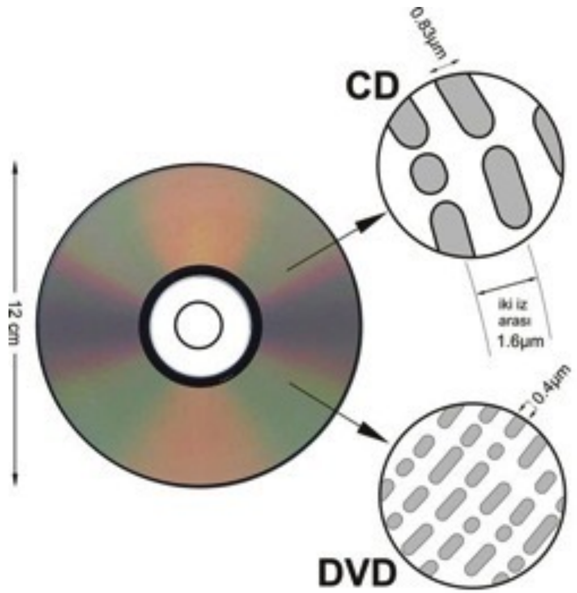
Standing wave oscillates in time, but has a stationary spatial dependence.

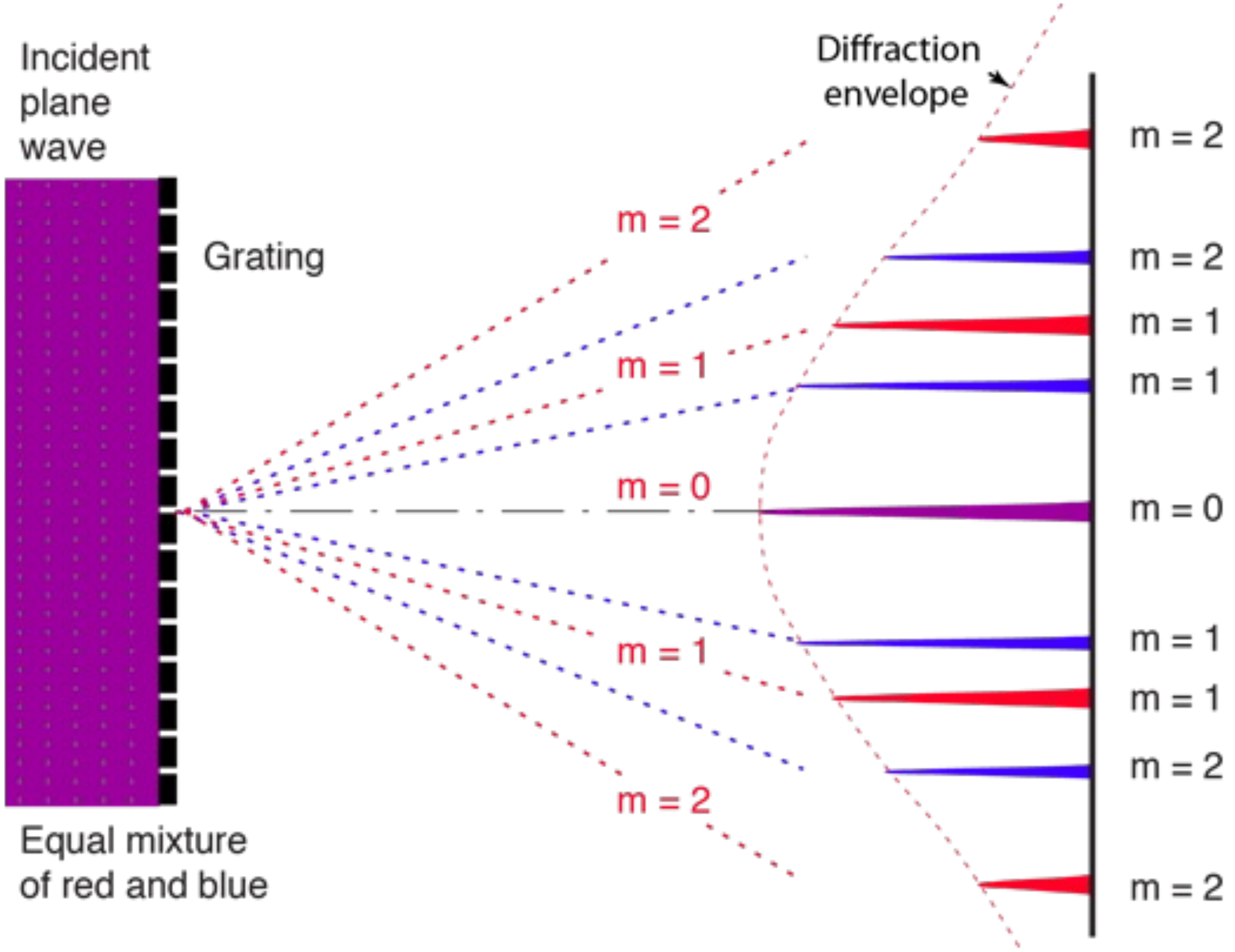
Diffraction and Interference



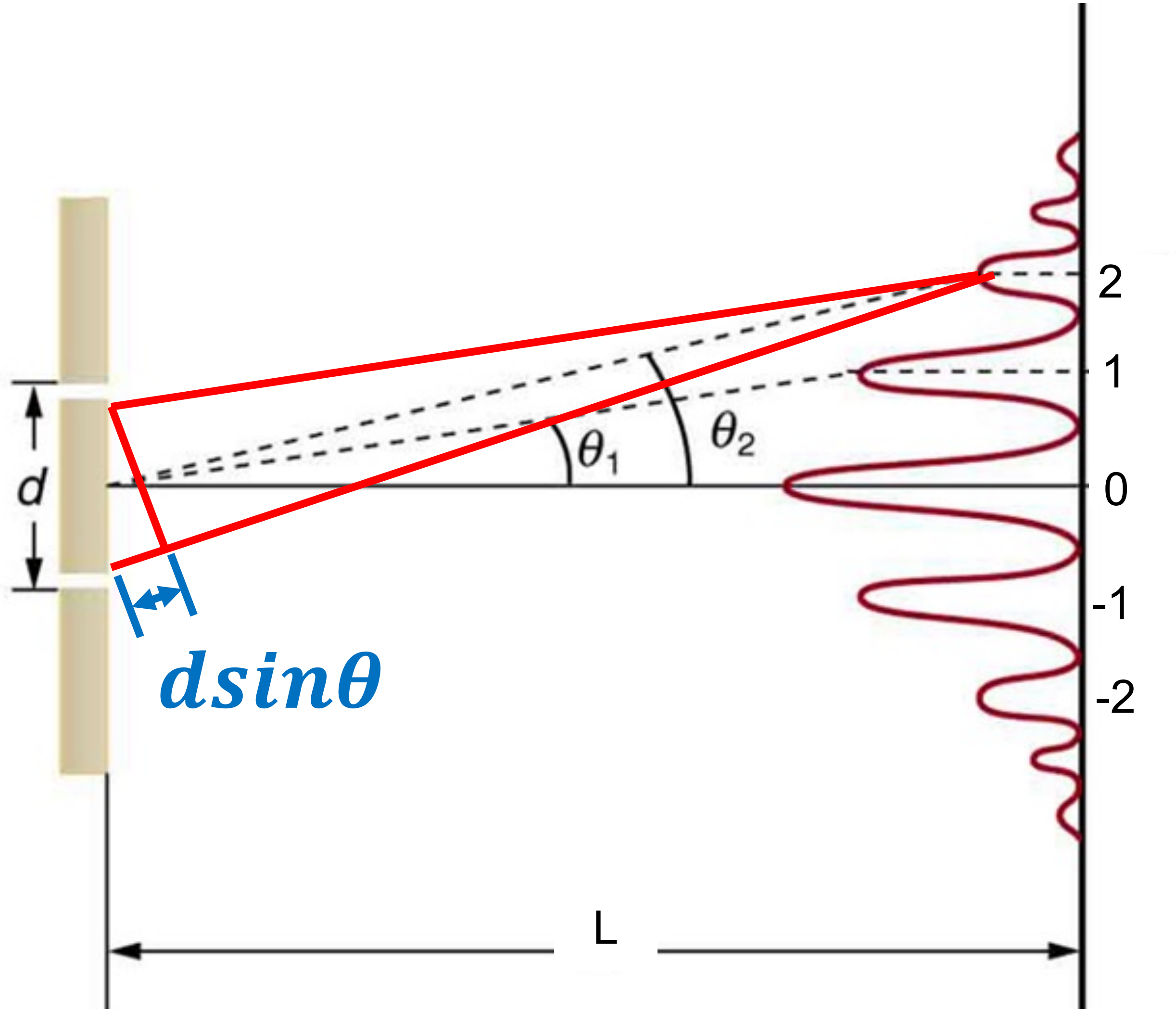


Diffraction and Interference

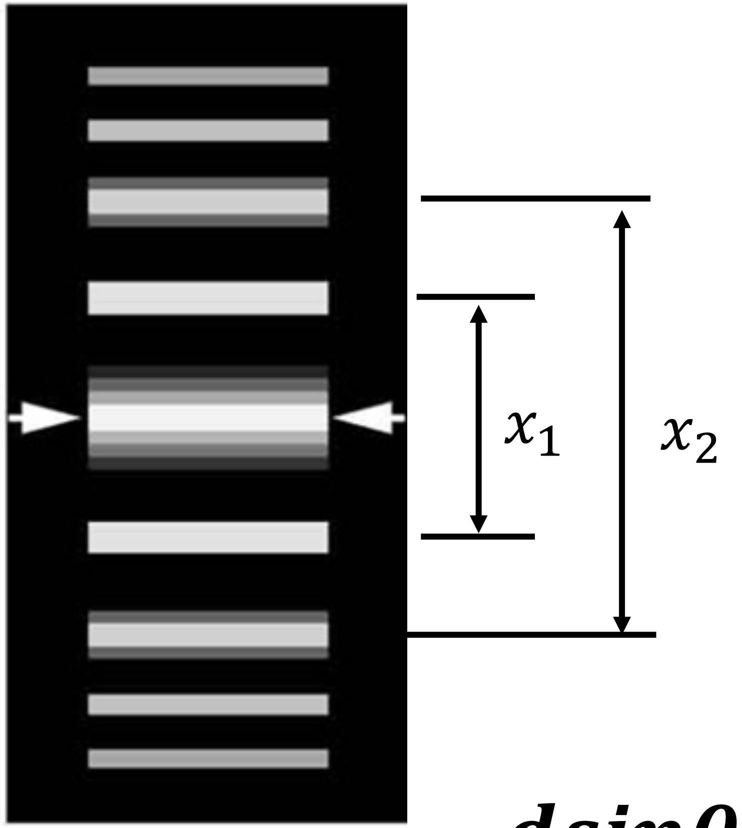




Diffraction and Interference



$dsin\theta$

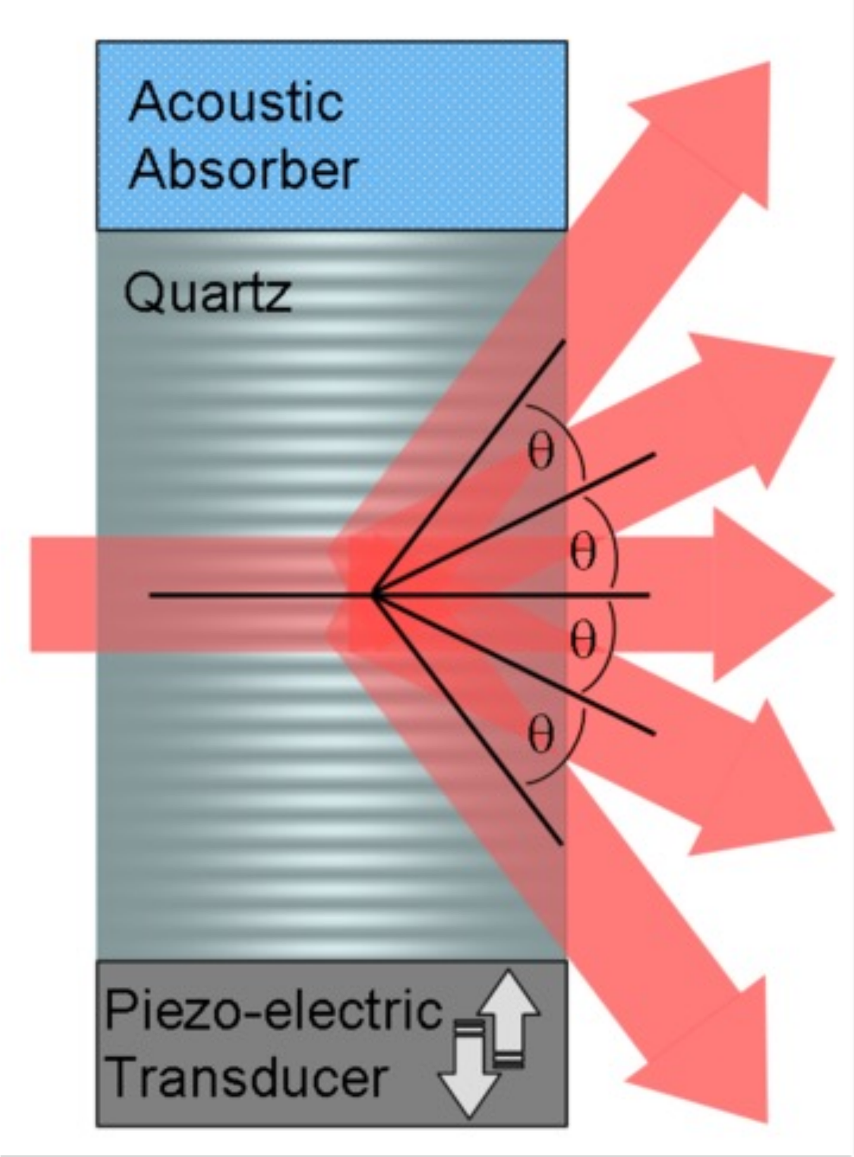


$$dsin\theta_m = \pm m\lambda_l$$

$$sin\theta_m \approx \frac{X_m/2}{L}$$

λ_l Wave length of light

Acousto-optic diffraction



$$d\sin\theta_m = \pm m\lambda_l \qquad \sin\theta_m \approx \frac{X_m/2}{L}$$

$$d = ? \qquad d = \lambda_s$$

$$\Rightarrow \lambda_s = \frac{2L\lambda_l}{X_m/m}$$

$$\Rightarrow V_s = \lambda_s f_s = \frac{2L\lambda_l f_s}{X_m/m}$$

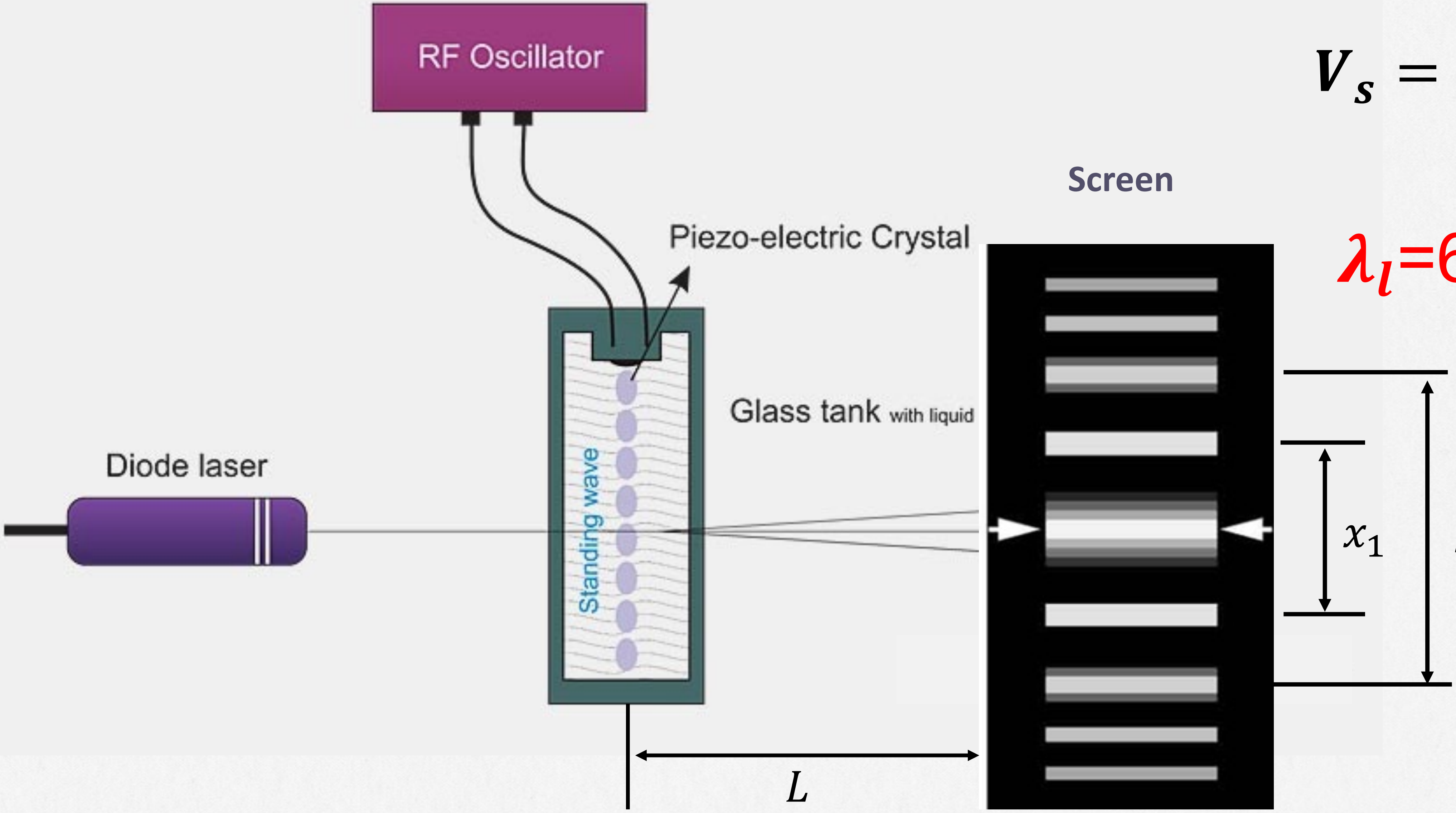
λ_l Wave length of light

λ_s Wave length of sound

f_s Frequency of sound

V_s Sound velocity

Acousto-optic diffraction



$$V_s = \frac{2L\lambda_l f_s}{X_m/m}$$

λ_l=650.4 nm

Acousto-optic diffraction

Time for fun!

1.Safety

- **Do not look into the laser beam directly.**
- **Do not touch the Piezoelectric ceramic piece directly.**
- **Charge the Piezoelectric ceramic piece after inserting it into water.**

2.Data recording

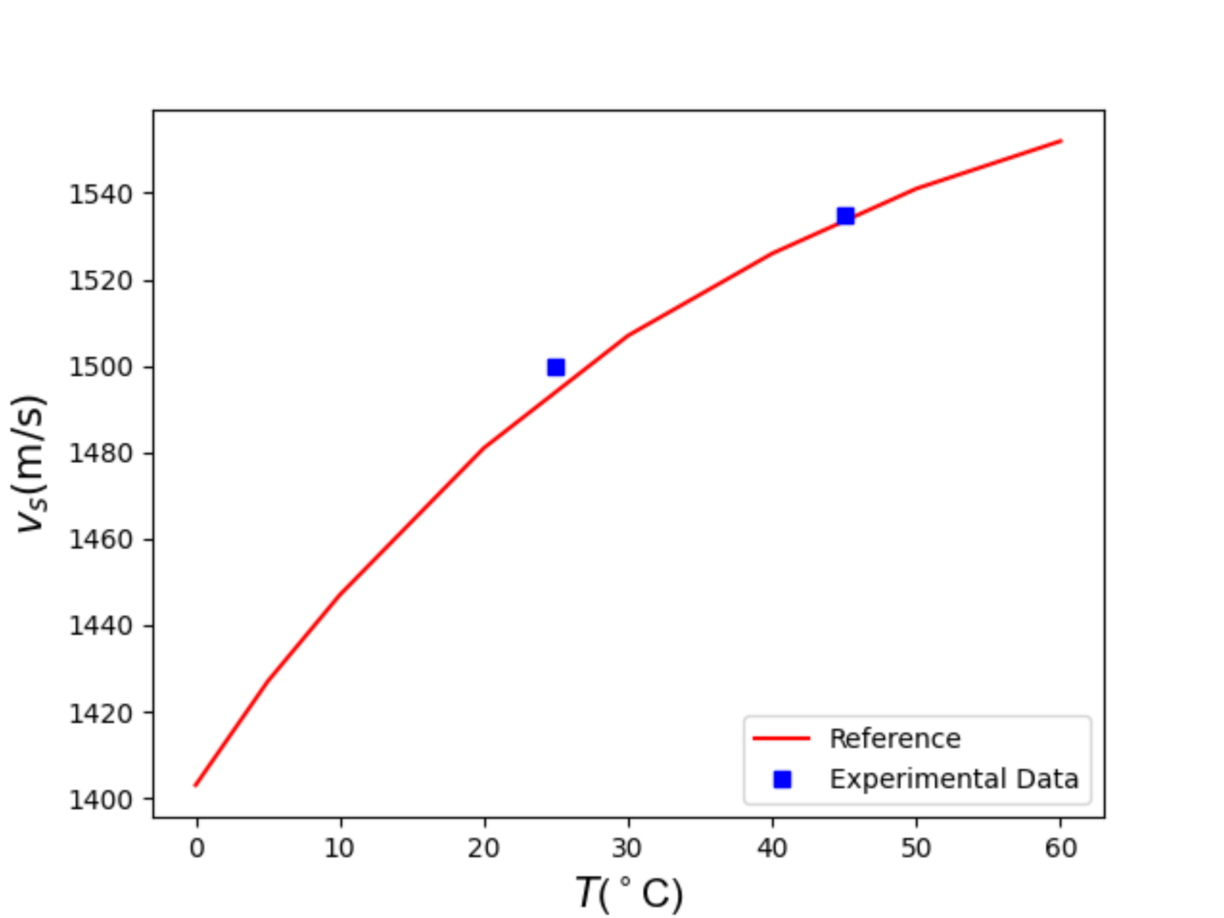
Appendix Table I: Experimental Raw Data

T(°C)	f_s(Hz)	λ_l(nm)	L(mm)	$x_1/1$(mm)	$x_2/2$(mm)	$x_3/3$(mm)	$\overline{L}$(mm)	$\overline{x_m/m}$(mm)

Acousto-optic diffraction

T(℃)	Speed of sound V_s (m/s)
0	1403
5	1427
10	1447
20	1481
30	1507
40	1526
50	1541
60	1552
70	1555
80	1555
90	1550
100	1543

Reference data



Calculate the relative error!

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THANK YOU !