International University,
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Physics 4

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Week 08

Review: theory

1. Mechanical waves

Wave Equation :

$$y = A\sin\left(\frac{2\pi}{T}t - \frac{2\pi}{\lambda}x\right) = A\sin\left(\omega t - Kx\right)$$

The **wavelength :** $\lambda = vT$ (T: period)

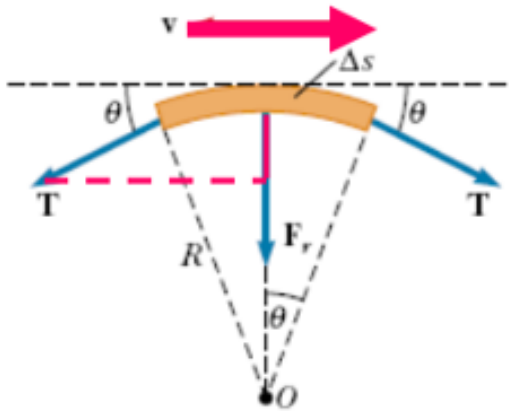
The **wave number :** $K = \dfrac{2\pi}{\lambda}$

Speed of wave on a string

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

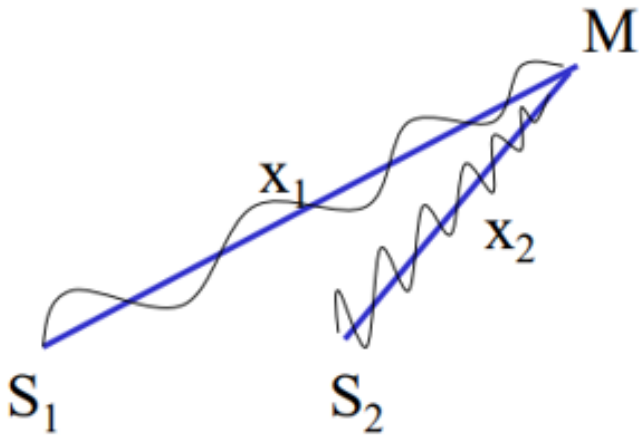
μ: linear mass density

T: string tension force



Superposition of waves

$$y = y_1 + y_2 = 2A\cos\left(\frac{\phi}{2}\right)\sin(\omega t - Kx_1 + \frac{\phi}{2})$$



$\phi = K(x_1 - x_2) = K\delta$: **Phase difference**

$\delta = x_1 - x_2$: **Path difference**

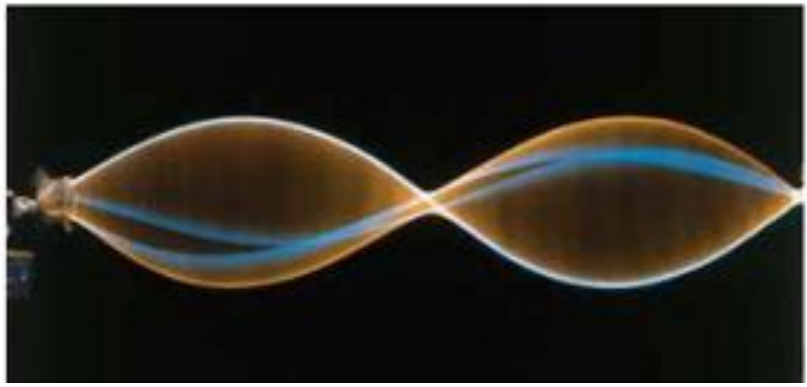
Constructive interference : $\phi = K\delta = k2\pi$; $\frac{2\pi}{\lambda}\delta = k2\pi$; $\boxed{\delta = k\lambda}$

Destructive interference : $\phi = K\delta = (2k+1)\pi$; $\frac{2\pi}{\lambda}\delta = (2k+1)\pi$;

$$\boxed{\delta = \left(k + \frac{1}{2}\right)\lambda}$$

2. Standing waves

General consideration



Position of nodes:

$$x = n\lambda / 2 \quad (n = 1, 2, 3, \ldots)$$

Position of antinodes:

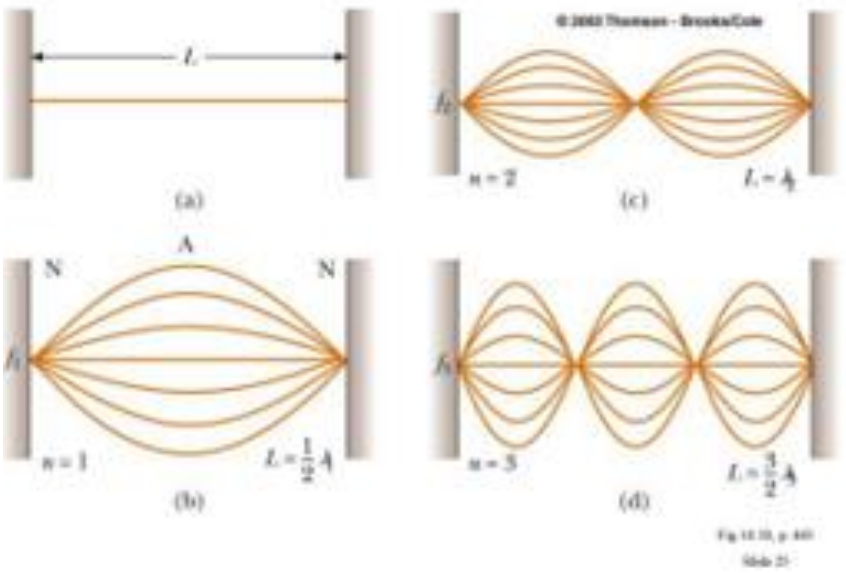
$$x = \left(n + \frac{1}{2}\right)\lambda / 2$$

String fixed at both ends

$$\lambda_n = \frac{2L}{n} \qquad n = 1, 2, 3, \ldots$$

$$f_1 = \frac{1}{2L}\sqrt{\frac{F}{\mu}}; \qquad f_n = nf_1 = \frac{n}{2L}\sqrt{\frac{F}{\mu}}$$

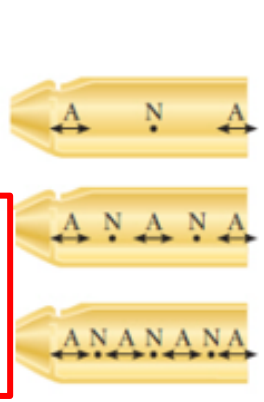
(Fundamental frequency)

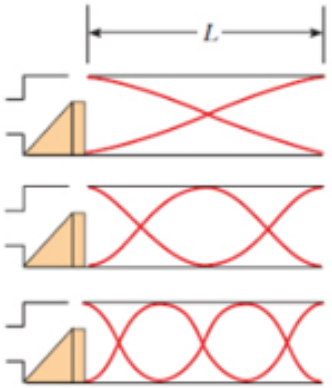


Air columns

Both open end

$$\lambda = \frac{2L}{n}, \quad n = 1, 2, 3, \ldots,$$





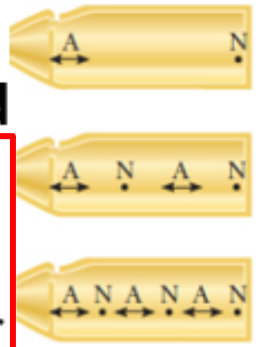
First harmonic: $\lambda_1 = 2L$, $f_1 = \frac{v}{2L}$

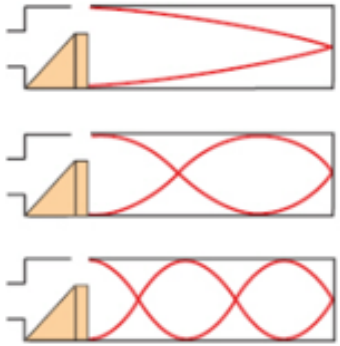
Second harmonic: $\lambda_2 = L$, $f_2 = 2f_1$

Third harmonic: $\lambda_3 = \frac{2}{3}L$, $f_2 = 3f_1$

One closed end

$$\lambda = \frac{4L}{n}, \quad n = 1, 3, 5, \ldots$$





First harmonic: $\lambda_1 = 4L$, $f_1 = \frac{v}{4L}$

Third harmonic: $\lambda_3 = \frac{4}{3}L$, $f_3 = 3f_1$

Fifth harmonic: $\lambda_5 = \frac{4}{5}L$, $f_5 = 5f_1$

3. Sound waves

Intensity

$$I = \frac{\Delta E}{A\,\Delta t} = \frac{P}{A}$$ (W/m^2)

Audile range:
20 Hz – 20,000 Hz

Intensity sound level

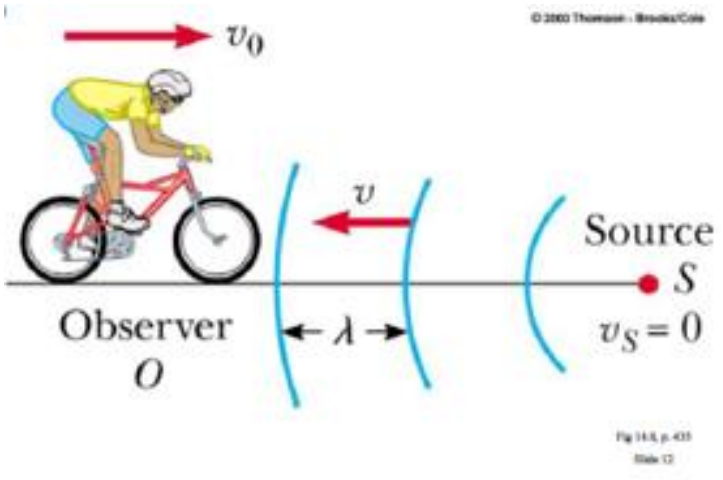
$$\beta = 10 \log \frac{I}{I_o}$$

Normal conversation's intensity level is about 50 dB.

$I_o = 1 \times 10^{-12}$ W/m^2

Doppler effect

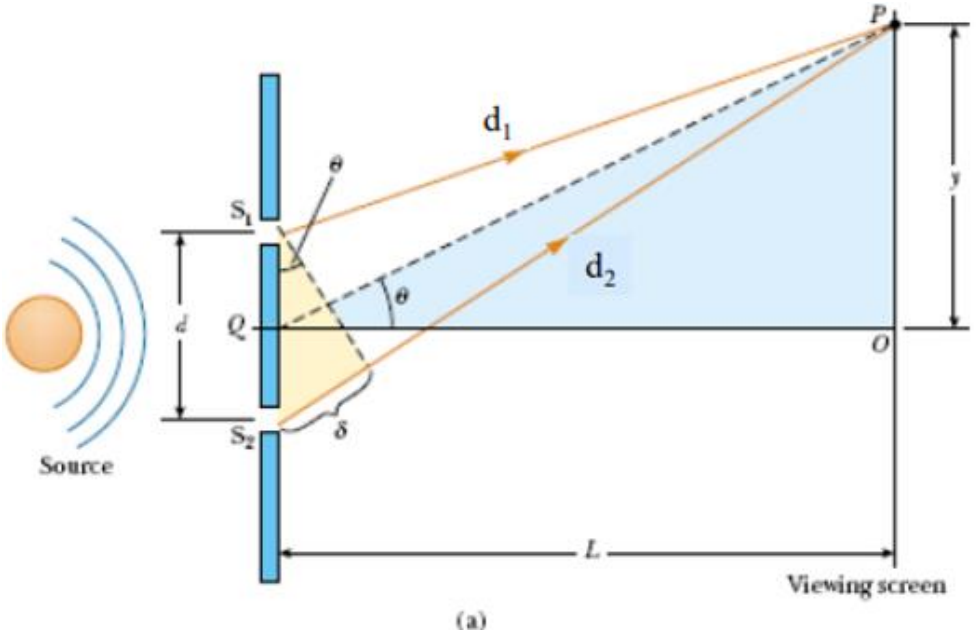
$$f' = \frac{V + V_O}{V - V_S} f$$



v_s, v_o > 0 observer and source move towards together
v_s, v_o < 0 observer and source move far away each other

4. Light

Young's double-slit interference



(a)

Path difference:

$$\delta \approx d \sin\theta$$

$$\delta \approx d \frac{y}{L}$$

Bright region:

$$\delta = d \sin\theta = k\lambda$$

$$y_{BRIGHT} = k \frac{L}{d} \lambda = ki$$

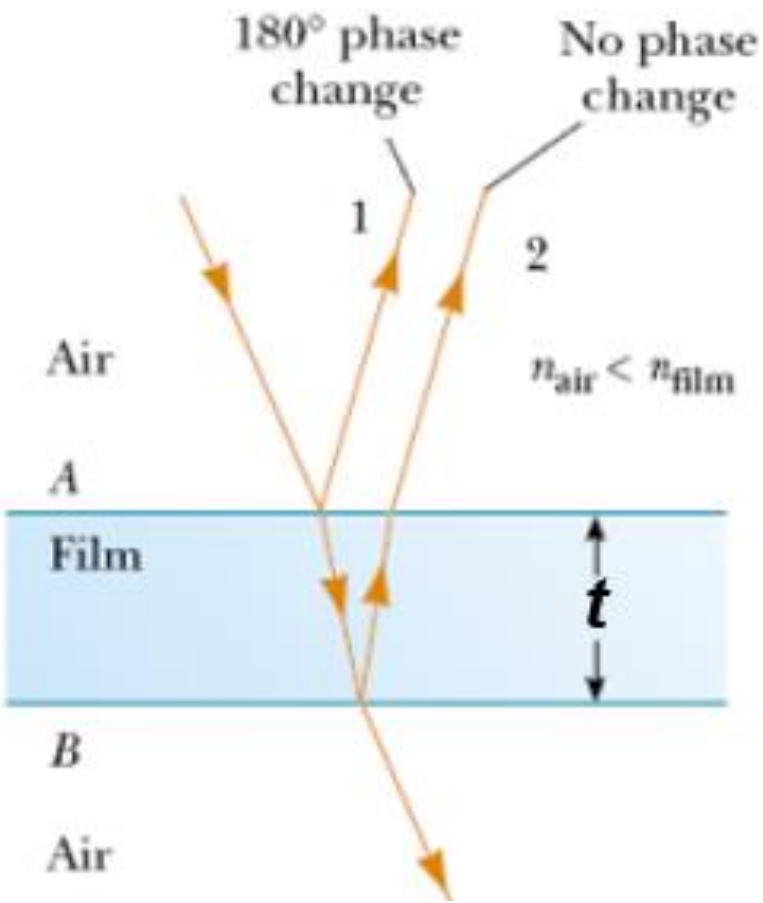
$$i = \frac{L}{d} \lambda$$

Dark region:

$$\delta = d \sin\theta = (k + \frac{1}{2})\lambda$$

$$y_{DARK} = \left(k + \frac{1}{2}\right) i$$

Thin-film interference



Refraction index: $n = \frac{c}{v}$

$$\lambda_n = \frac{v}{f} = \frac{c}{nf}; \quad \boxed{\lambda_n = \frac{\lambda}{n}}$$

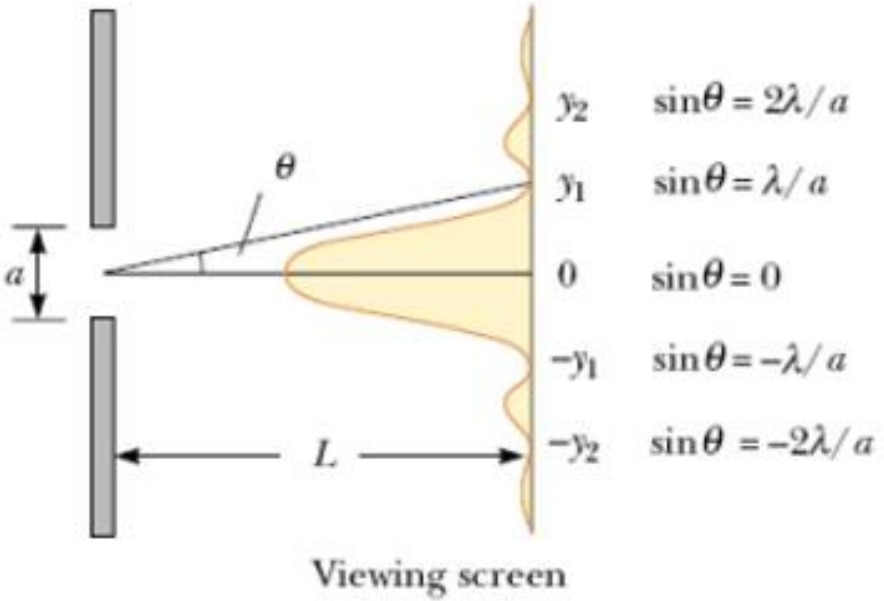
Constructive interference:

$$\boxed{2nt = (m + \frac{1}{2})\lambda}$$

Destructive interference:

$$\boxed{2nt = m\lambda} \qquad m = 0; 1; 2; 3; \ldots$$

Single-slit diffraction



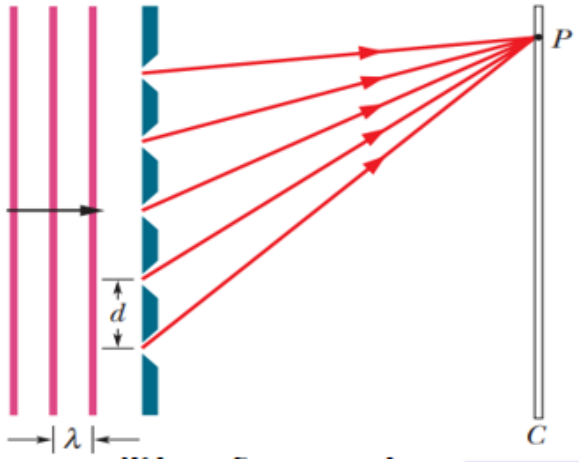
Condition for destructive interference:

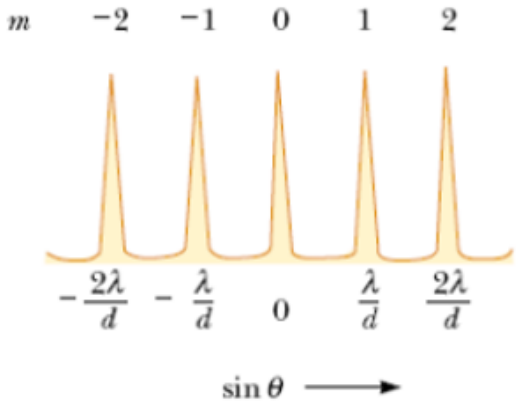
$$\sin\theta = m\frac{\lambda}{a}; \quad m = \pm 1; \pm 2; \pm 3; \ldots$$

Position of dark fringes:

$$y_m = m\frac{L\lambda}{a}; \quad m = \pm 1; \pm 2; \pm 3; \ldots$$

Grating





Condition for maxima: $d\sin\theta = m\lambda \quad m = 0; 1; 2; \ldots$