Note Phy4 Midterm - Lecture notes 1

Physics 2 (Trường Đại học Quốc tế, Đại học Quốc gia Thành phố Hồ Chí Minh)

NOTE PHYSICS 4 - THEORY (Midterm)

1. Vibration. Resonance

a) In simple harmonic oscillation:

+ The restoring force: $F=-kx$

+ Displacement of simple harmonic motion:

$$x=A\cos(\omega t+\varphi)$$

with: $\omega=\sqrt{\frac{k}{m}}$

(k: string constant (N/m); m: mass of the object(kg))

+ The period: $T=\frac{2\pi}{\omega}$;

+ Frequency: $f=\frac{1}{T}=\frac{\omega}{2\pi}$

b) The physical pendulum:

+ Angular displacement: $\theta=\theta_0\cos(\omega t+\varphi)$

with: $\omega=\sqrt{\frac{mgd}{I}}$ (I: inertia moment; d: the distance from the rotating point)

+ The period: $T=2\pi\sqrt{\frac{I}{mgd}}$

+ In the simple pendulum: $T=2\pi\sqrt{\frac{L}{g}}$

c) Force Oscillation and Resonance:

+ In damped oscillation, the displacement is:

$x=Ae^{-\left(\frac{b}{2m}\right)t}\cos(\omega t+\varphi)$

with: $\omega=\sqrt{\frac{k}{m}-\frac{b^2}{4m^2}}$ (b: damping coefficient (kg/s))

+ In force oscillation:

$x=A\cos(\omega t+\varphi)$

with: $A=\frac{F/m}{\sqrt{\left(\omega^2-\omega_0^2\right)^2+\left(\frac{b\omega}{m}\right)^2}}$; $\omega_0=\sqrt{\frac{k}{m}}$

if $\omega=\omega_0 resonance$

2. Mechanical Wave

a) The wave function:

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

with: $\lambda=vT$ ($\lambda: wavelength\,; v: the\ speed\ of\ wave$)

and: $K=\frac{2\pi}{\lambda}$ (K: the wave number)

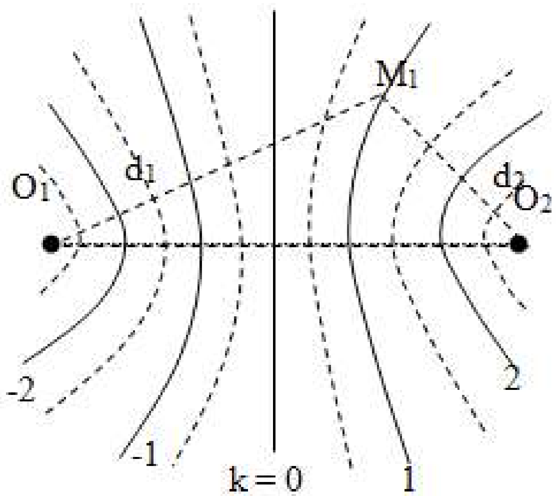
b) The speed of waves on strings:

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

with: T: tension of the string (N)

μ: mass per unit length (kg/m) $\left(\mu=\frac{m}{L}\right)$

c) Superposition and Interference:



The general function of interference;

$$x=2\,Acos\left(\frac{\phi}{2}\right)\sin\left(\omega t-K\,x_1+\frac{\phi}{2}\right)$$

For the phase difference:

$\phi = k2\pi$ constructive interference $(2A)$

$\phi = (2k+1)\pi$ destructive interfence (0)

For the path difference:

In case two waves are in the same phase

$\delta = d_1 - d_2 = k\lambda$ constructive interence

$\delta = d_1 - d_2 = \left(k + \frac{1}{2}\right)\lambda$ destructive interference

In case two waves are out of phase

$\delta = d_1 - d_2 = \left(k + \frac{1}{2}\right)\lambda$ constructive interence

$\delta = d_1 - d_2 = k\lambda$ destructive interference

d) Standing wave

The position of the nodes: $x = \frac{n\lambda}{2}$ (n = 1,2,3,…)

The position of the antinodes: $x = (n + \frac{1}{2})\lambda$ (n= 1,2,3,..)

In a string fixed at both ends:

- The wavelength: $\lambda_n = \frac{2L}{n}$ (n = 1,2,3,…)
- The frequency: $f_n = \frac{v}{\lambda_n} = \frac{nv}{2L} = \frac{n}{2L}\sqrt{\frac{T}{\mu}}$ (n = 1,2,3,…)

⇨ The fundamental frequency: $f_1 = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$ and $f_n = nf_1$

In a pipe opened at both ends:

- The wavelength: $\lambda_n = \frac{2L}{n}$ (n = 1,2,3,…)
- The frequency: $f_n = \frac{v}{\lambda_n} = \frac{nv}{2L} = \frac{n}{2L}\sqrt{\frac{T}{\mu}}$ (n = 1,2,3,…)

⇨ The fundamental frequency: $f_1 = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$ and $f_n = nf_1$

In a pipe closed at one end:

- The wavelength: $\lambda_n = \frac{4L}{n}$ (n = 1,3,5,...)
- The frequency: $f_n = \frac{v}{\lambda_n} = \frac{nv}{4L} = \frac{n}{4L}\sqrt{\frac{T}{\mu}}$ (n = 1,3,5,...)

⇨ The fundamental frequency: $f_1 = \frac{1}{4L}\sqrt{\frac{T}{\mu}}$ and $f_n = nf_1$

(n is odd number)

e) Sound wave:

+ Normal human can hear from 20Hz to 20000Hz

+ The intensity of sound wave: The rate at which the energy flows through a unit area

$I = \frac{P}{A} = \frac{P}{4\pi r^2}$

with: P is the power

+ The intensity of sound level:

$\beta = 10\log\frac{I}{I_0}$

I_0: threshold of hearing ($I_0 = 10^{-12} W/m^2$¿

f) Doppler effect:

$f' = \frac{v + v_0}{v - v_s} f$

v: the speed of sound

v_0 : the speed of the observer

v_s : the speed of the source

$v_0, v_s > 0$ ⇨ The motion is toward ⇨ Higher frequency

$v_0, v_s < 0$ ⇨ The motion is away ⇨ Lower frequency

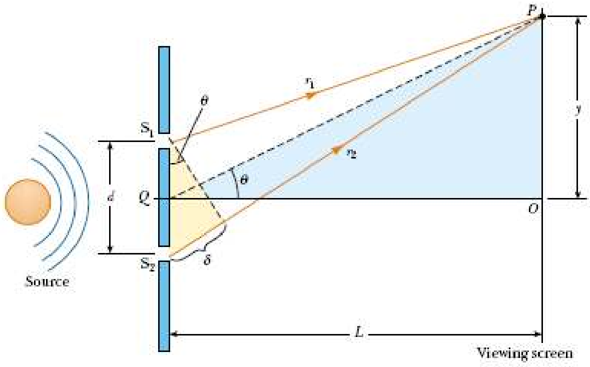
3) Wave Optics:

a) The nature of light: The photon energy:

$$\varepsilon = hf = \frac{hc}{\lambda}$$

$$h = 6.63 x 10^{-34} J.s$$

b) Interference of light wave:



(a)

The path difference:

$$\delta = d_1 - d_2 \approx dsin\theta \approx dtan\theta = d\frac{y}{L}$$

- Bright fringe:

$$\delta = d\frac{y}{L} = k\lambda \; y_{bright} = k\frac{L}{d}\lambda = ki$$

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

Angular position: $\delta = dsin\theta = k\lambda$

- Dark fringe: $\delta = d\frac{y}{L} = \left(k + \frac{1}{2}\right)\lambda \; y_{dark} = \left(k + \frac{1}{2}\right)i$

Angular position: $\delta = dsin\theta = (k + \frac{1}{2})\lambda$

The intensity:

$$\frac{\pi dsin\theta}{\lambda}$$

$$\frac{\pi dy}{L\lambda}$$

$$(¿)$$

$$(¿) = I_0 \cos^2 ¿$$

$$I = I_0 \cos^2 ¿$$

c) Interference in a thin film

+ Change of phase due to reflection

- $n_1 < n_2$ ⇨ 180^0 phase change
- $n_1 > n_2$ ⇨ no phase change

+ The wavelength of light in a medium

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

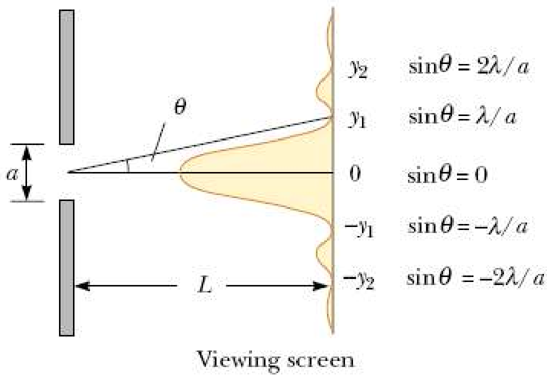
+ The interference in a thin film

- **Constructive interference:** $2nt = (m + \frac{1}{2})\lambda$
  - (m = 1,2,3,..)
- **Destructive interference:** $2nt = m\lambda$ (m = 1,2,3,…)

(t: the thickness of the film; n: refraction index of the film)

d) Light diffraction:

+ The general condition for destructive interference



$$\sin\theta = m\frac{\lambda}{a}$$ (m = 1,2,3,…)

(a: the width of the split)

+ Position of dark fringe

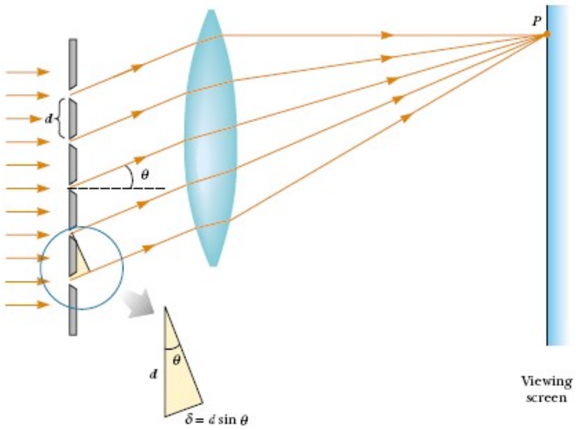
$$y_m = m\frac{L\lambda}{a}$$

+ The intensity at each point on the screen

$$I = I_{max}\left[\frac{\sin\left(\frac{\pi a \sin\theta}{\lambda}\right)}{\frac{\pi a \sin\theta}{\lambda}}\right]^2$$

- If $a \gg \lambda$ ⇨ all the light concentrate at the geometrical focus
- If a < λ ⇨ The central maximum spread over 180^0 ⇨ Cannot see the fringe

e) Diffraction grating: consider a large number of splits, all with the same width a and spaced equal distances d between centers



The condition for maximum intensity:

$d\sin\theta = m\lambda$ (m =1,2,3,...)

(d: grating spacing)

For grating spacing d: d = $\frac{Length}{Number\ of\ splits}$

f) Diffraction of X-rays by crystal

The Bragg equation (for the path difference)

$\delta = d_1 - d_2 \approx 2d\sin\theta$

(θ : the incident angle; d: the distance between adjacent planes)

g) Polarization:

The intensity of the light transmitted through the analyzed:

$$I = I_{max} \cos^2 \phi$$

(ϕ : the angle between two polarizer axis¿

For the unpolarized light passing through a polarizer:

$$I = \frac{I_{max}}{2}$$

4) Geometric Optics

a) Refraction and Reflection

+ Index of refraction:

$$n = \frac{c}{v}$$

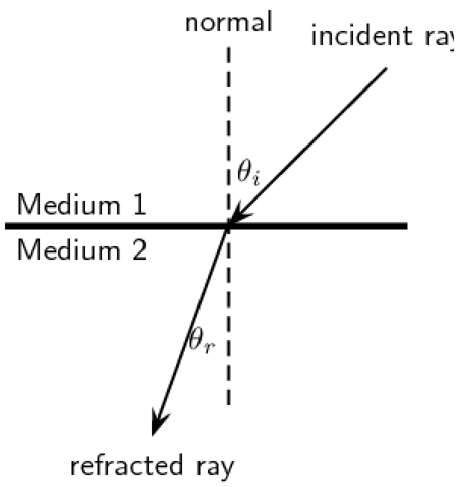
(v : the speed of light in a medium)

+ The law of reflection: The angle of reflection is equal to the angle of the incident light

$$\theta_i = \theta_r$$

+ Snell's Law of Refraction:

$$n_i \sin\theta_i = n_r \sin\theta_r$$



+ The critical angle for total internal reflection:

$$\sin\theta_{crit} = \frac{n_r}{n_i} \quad \text{(if } n_i > n_r \text{¿}$$

b) Thin lenses:

+ The focal length f (the lens maker's equation):

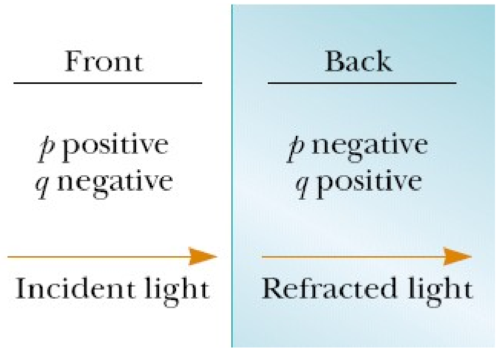
$$\frac{1}{f}=(n-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

- If $f>0$ ⇨ converging lens
- If $f<0$ ⇨ diverging lens

+ Thin-lens equation:

$$\frac{1}{f}=\frac{1}{p}+\frac{1}{q}$$

- If: $p>0$ ⇨ Real object;
  $p<0$ ⇨ Virtual object
- If: $q>0$ ⇨ Real image;
  $q<0$ ⇨ Virtual image

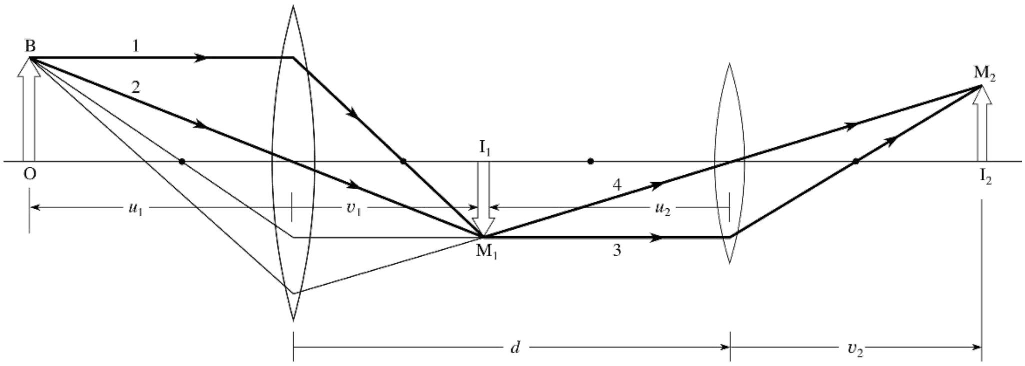


+ Magnification:

$$M=\frac{h'}{h}=\frac{-q}{p}$$

- If $M>0$ ⇨ The image is the same direction as the object (erect image)
- If $M<0$ ⇨ The image is opposite direction to the object (inverted image)

+ For the two lenses system:



- Thin-lens equation for lens 1:

$$\frac{1}{f_1}=\frac{1}{p_1}+\frac{1}{q_1}$$

- The distance between lens 1 and lens 2:

$$d=q_1+p_2$$

- Thin-lens equation for lens 2:

$$\frac{1}{f_2}=\frac{1}{p_2}+\frac{1}{q_2}$$

- Total magnification:

$$M=M_1.M_2=\frac{q_1}{p_1}.\frac{q_2}{p_2}$$

c) Prism (optional)

$$sini=nsinr$$

$$\sin i'=nsinr'$$

$$A=r+r'$$

$$D=i+i'-A$$

For minimum deflection:

$$i=i'$$

$$r=r'=\frac{A}{2}$$

$$D_m=2i-A$$

d) Mirrors (optional)

$$\frac{1}{f}=\frac{1}{p}+\frac{1}{q}$$

$$f=\frac{R}{2}$$