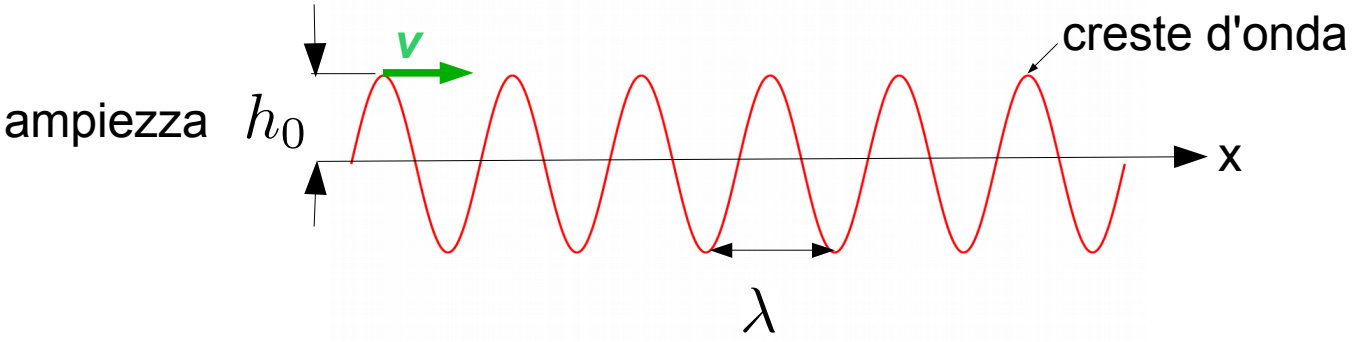
Lezione 16

- Onde in una, due e tre dimensioni
- Propagazione geometrica: fronte d'onda e raggio
- Onda sferica, onda piana
- Principio di Huygens
- Riflessione e rifrazione (riflessione totale)
- Interferenza e diffrazione

Onde in 1 dimensione

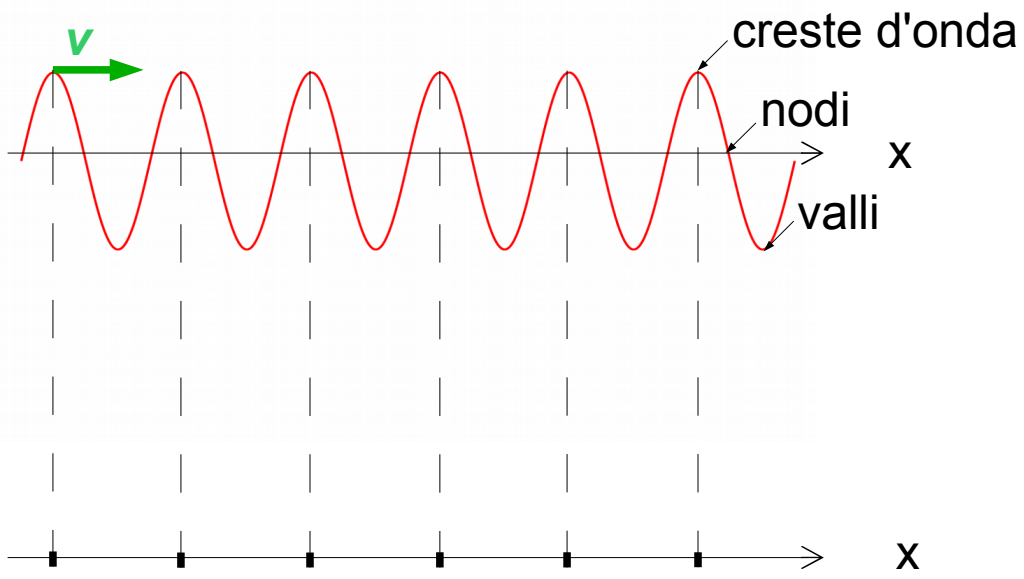


$$h(x,t) = h_0 \sin(\omega t - kx)$$

$$\omega = \frac{2\pi}{T} \qquad k = \frac{2\pi}{\lambda}$$

$$c = \frac{\lambda}{T} = \omega k$$

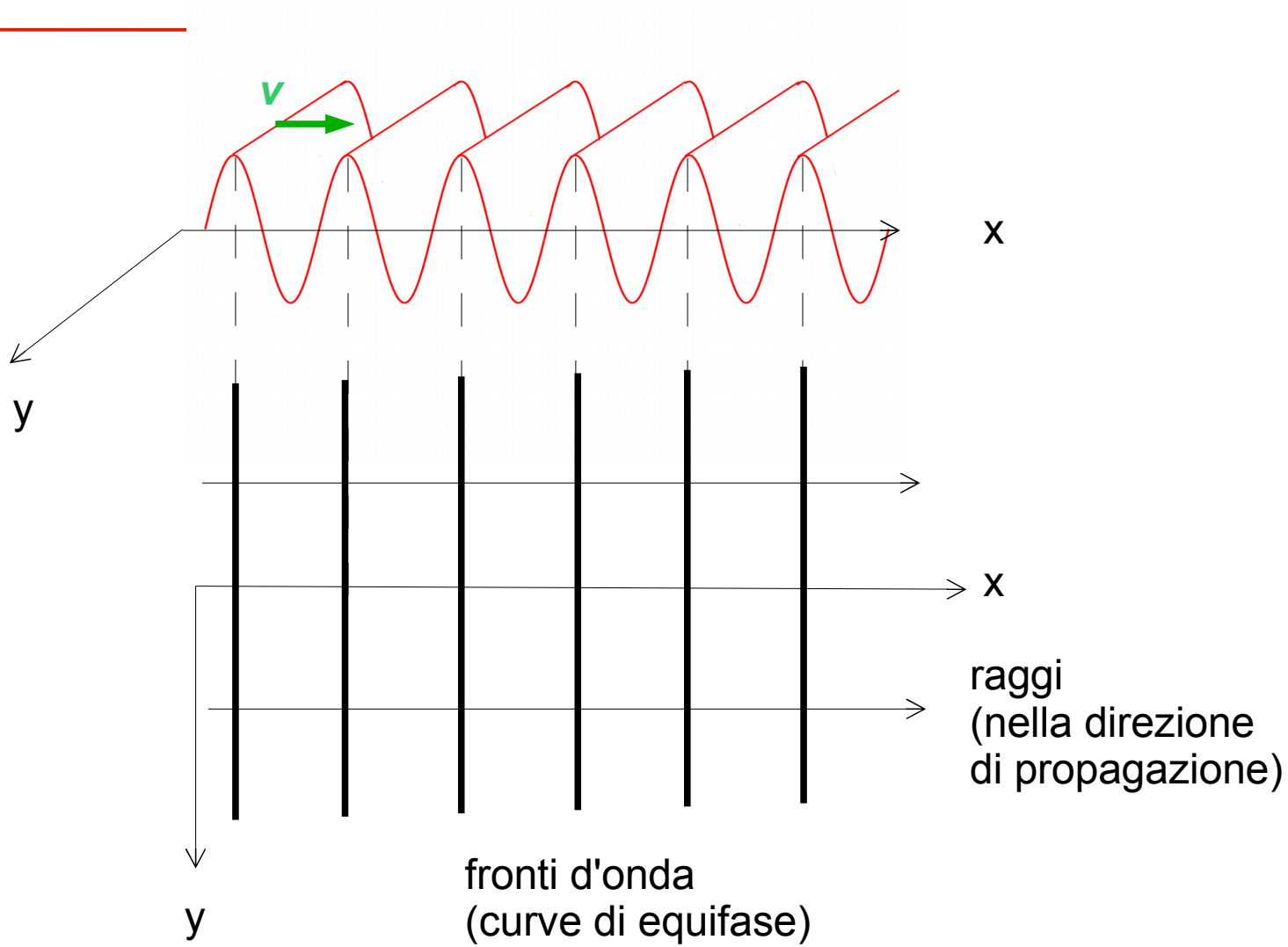
Onde in 1 dimensione



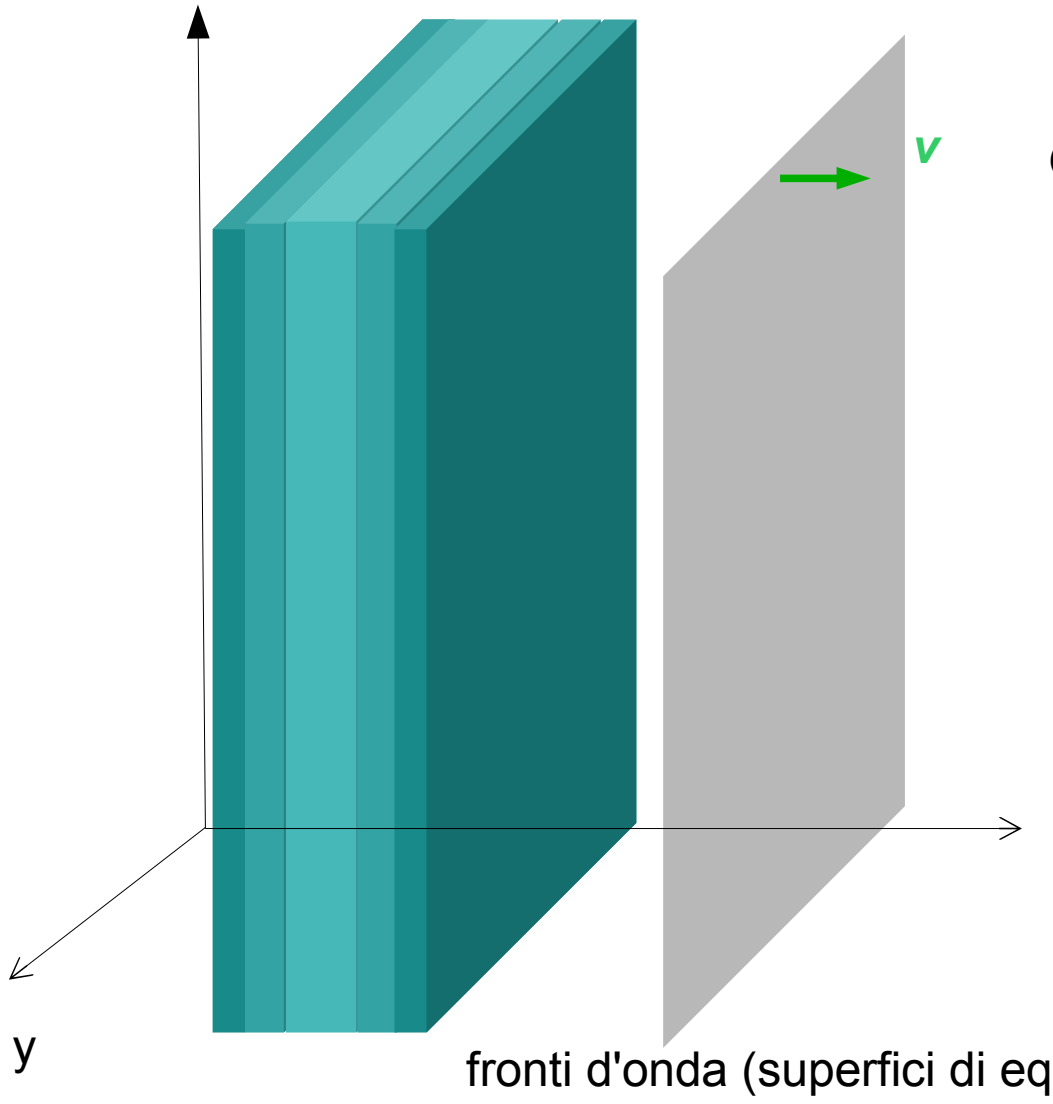
fronti d'onda
(punti di equifase)

raggio
(nella direzione
di propagazione)

Onde in 2 dimensione



Onde in 3 dimensione

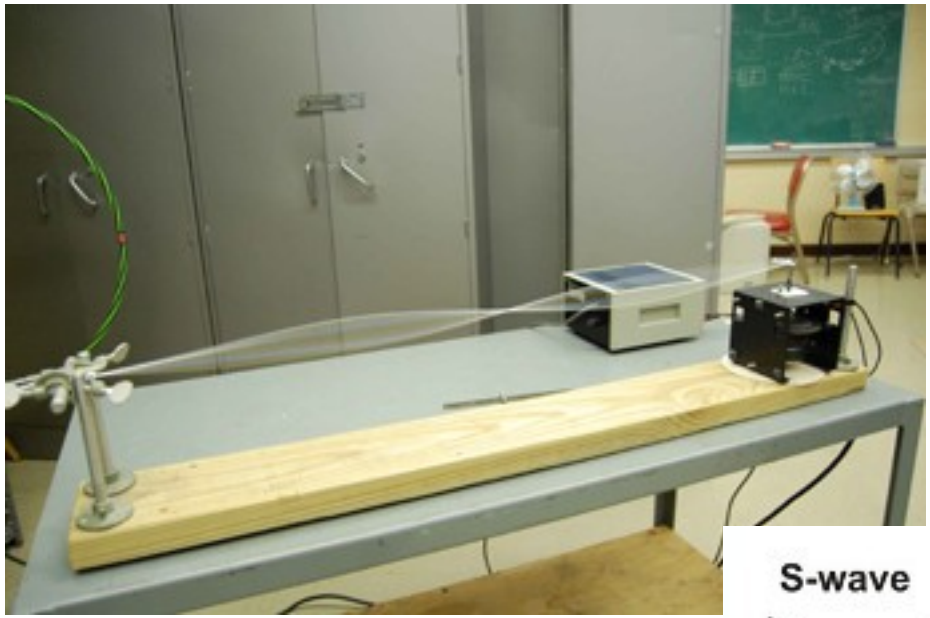


Onda piana

raggi
(nella direzione
di propagazione)

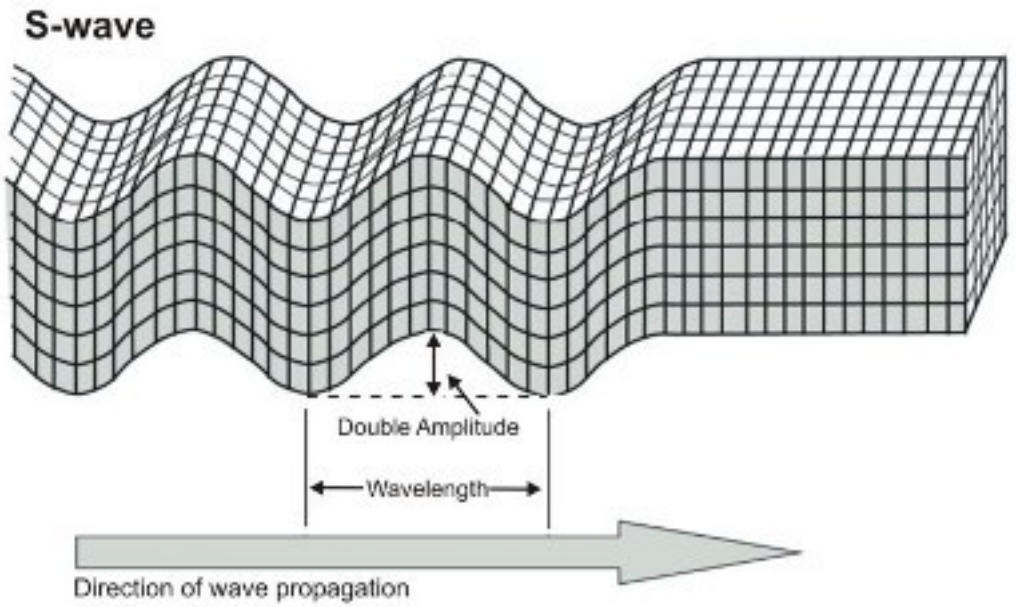
fronti d'onda (superfici di equifase)

Onde di superficie e di volume



Onda su una corda (stazionaria)

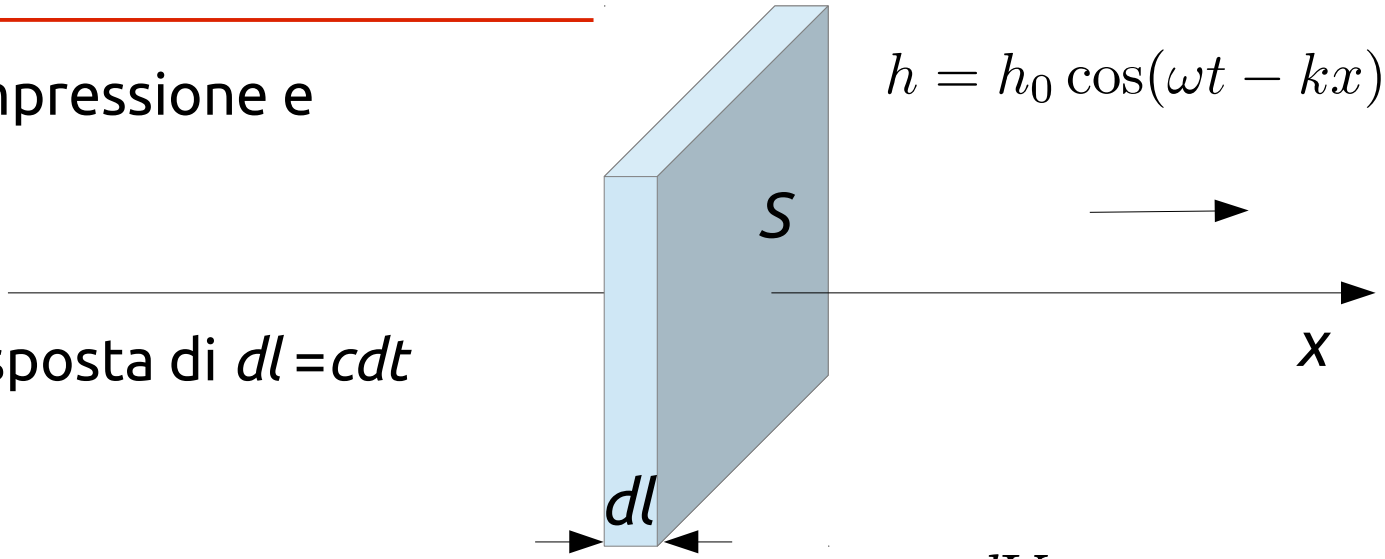
Onda di superficie
(e di volume) da terremoto



Potenza sonora trasmessa

onda di compressione e rarefazione

$$h = h_0 \cos(\omega t - kx)$$



La cresta si sposta di $dl = cdt$

il volume $dV = Sdl$ contiene energia U quindi $\frac{dV}{dt} = Sc$

Potenza

$$P = \frac{dU}{dt} = \frac{\frac{U}{V} dV}{dt} = u\,Sc$$

densità di energia per unità di volume

Potenza e intensità sonora trasmessa

$$P = uSc$$

$$u = \frac{1}{2}\frac{m}{V}v_0^2 = \frac{1}{2}\rho v_0^2$$

energia = energia cinetica massima
= energia potenziale massima

$$h = h_0 \cos(\omega t - kx)$$

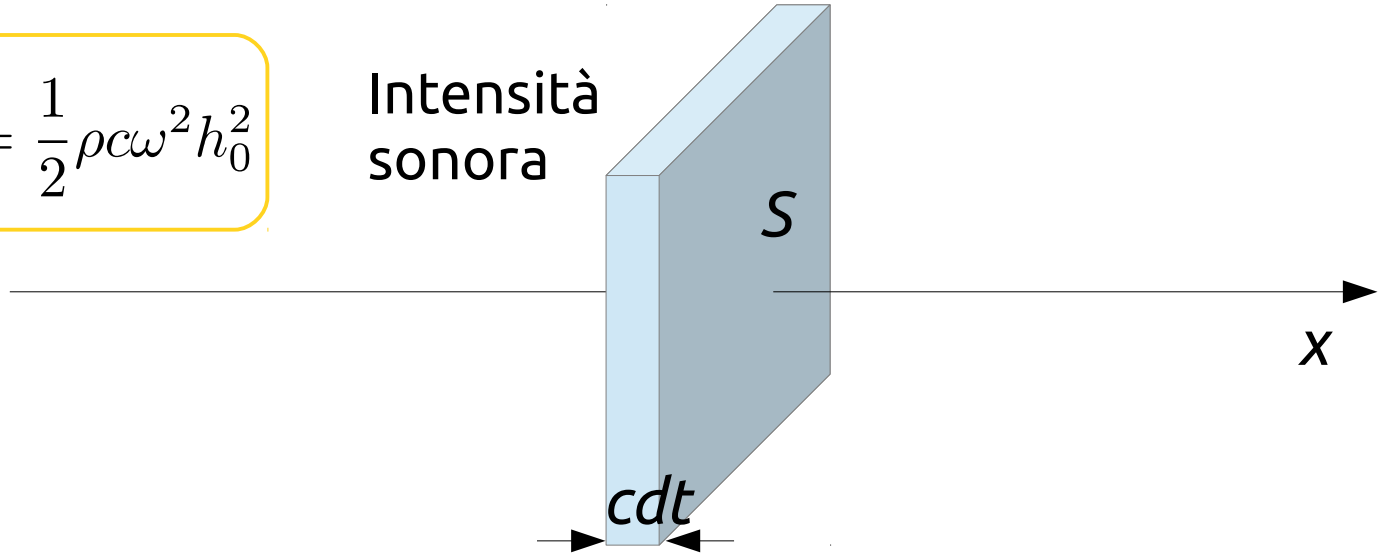
$$v = \frac{\partial h}{\partial t} \qquad v_0 = h_0\omega$$

$$P = \frac{1}{2}\rho S c \omega^2 h_0^2$$

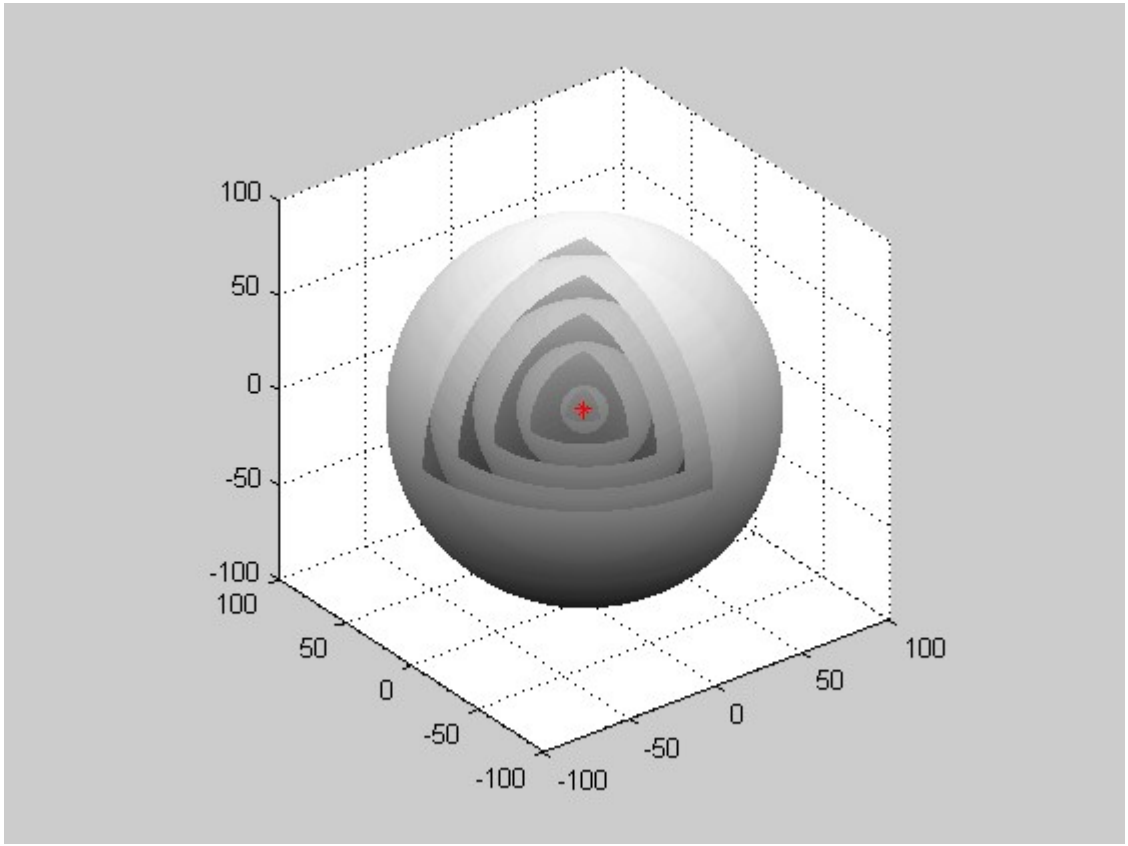
Potenza

$$I = \frac{P}{S} = \frac{1}{2}\rho c \omega^2 h_0^2$$

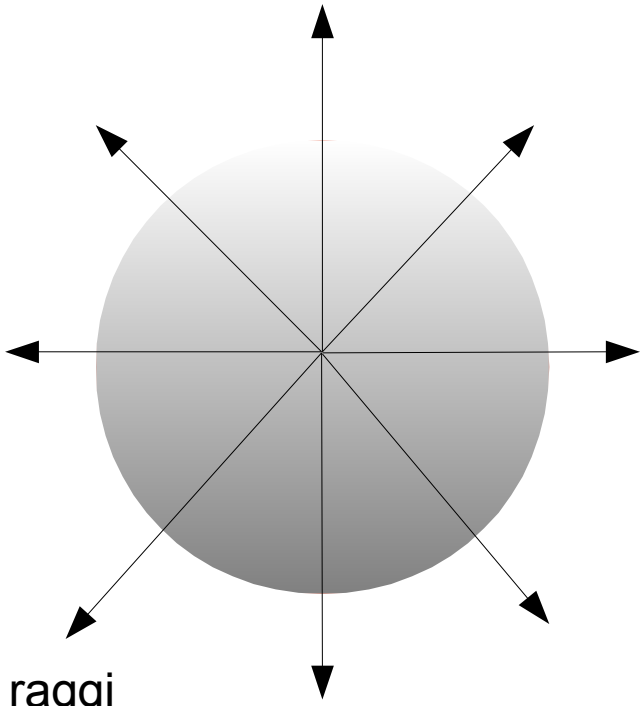
Intensità sonora



Onda sferica



fronte d'onda sferico

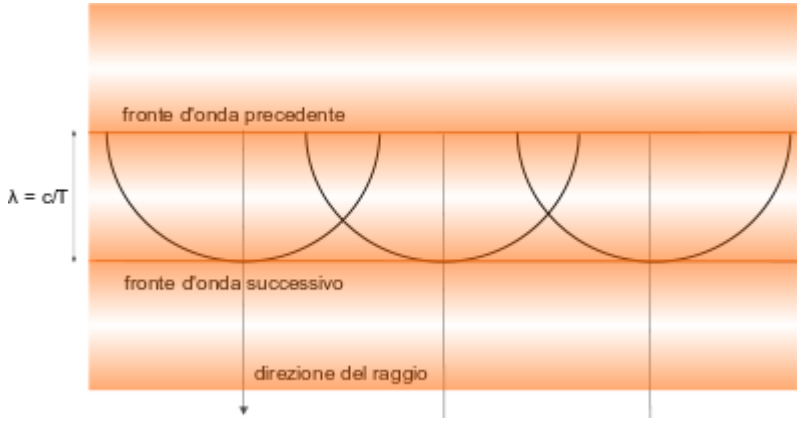


raggi

Principio di Huygens

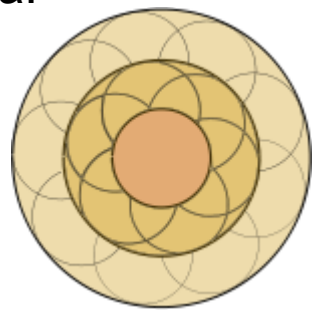
Christiaan Huygens
(1629-1695)

Principio di sovrapposizione: le onde si sommano

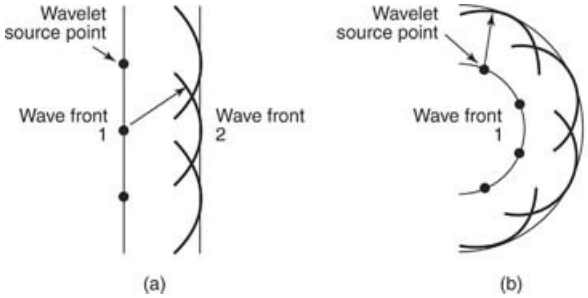


onda piana

Ciascun punto di un fronte d'onda è sorgente di un fronte d'onda sferico. L'onda ad un tempo successivo è la somma di questi nuovi fronti d'onda.



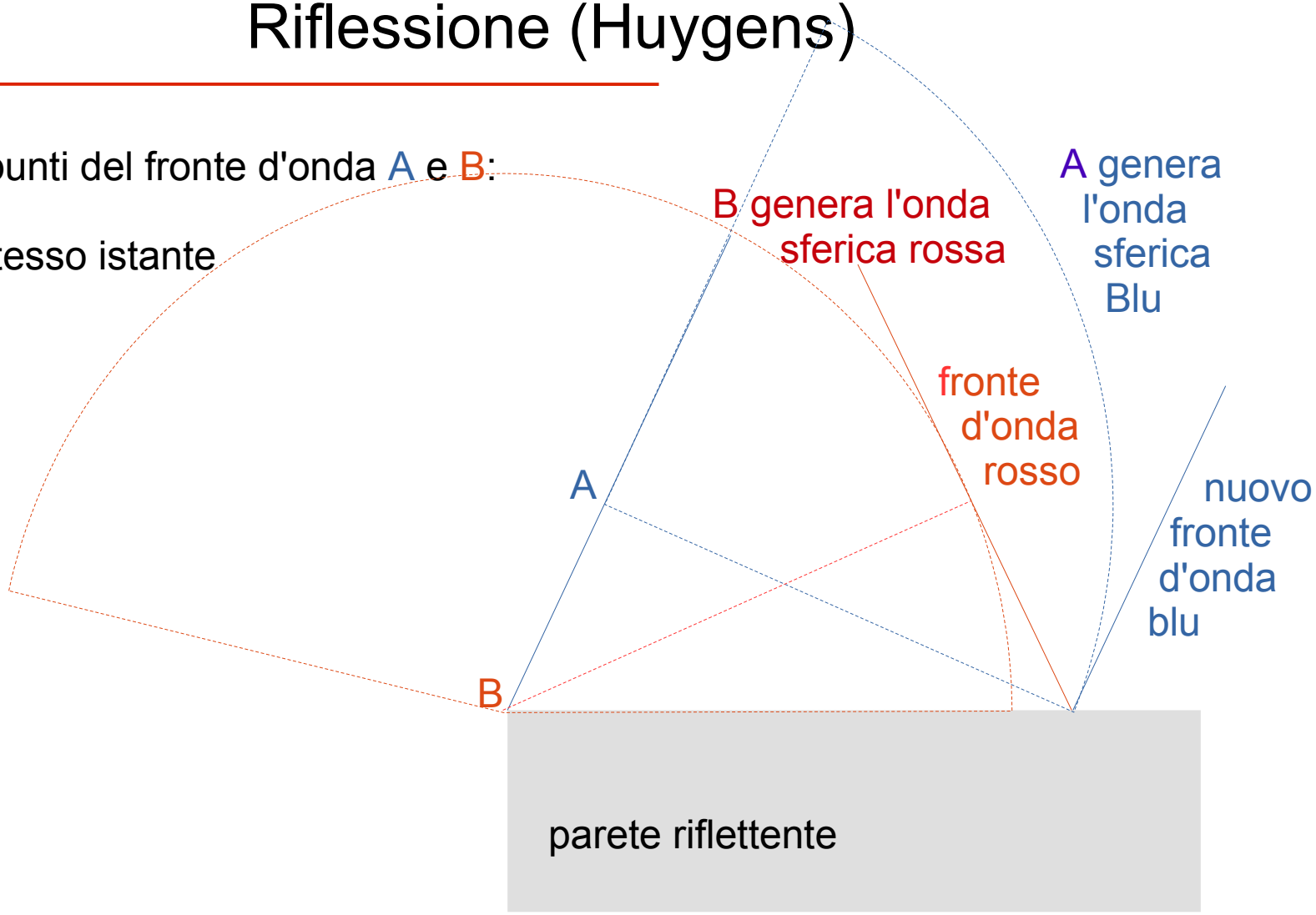
onda sferica



Riflessione (Huygens)

Due punti del fronte d'onda A e B:

allo stesso istante

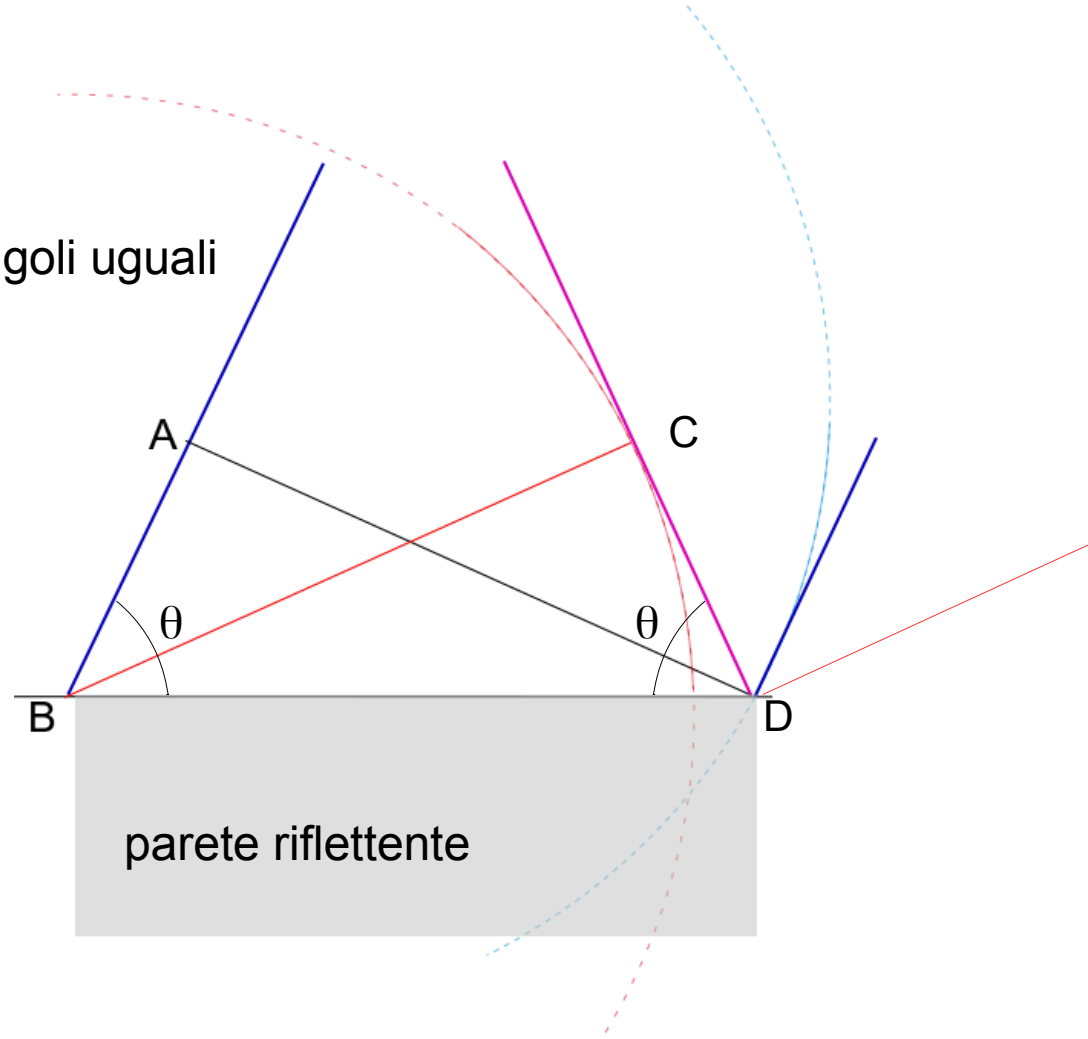


Riflessione (Huygens)

Triangoli ABD e BCD uguali:

Legge della rilessione:

i fronti si riflettono formando angoli uguali con la parete

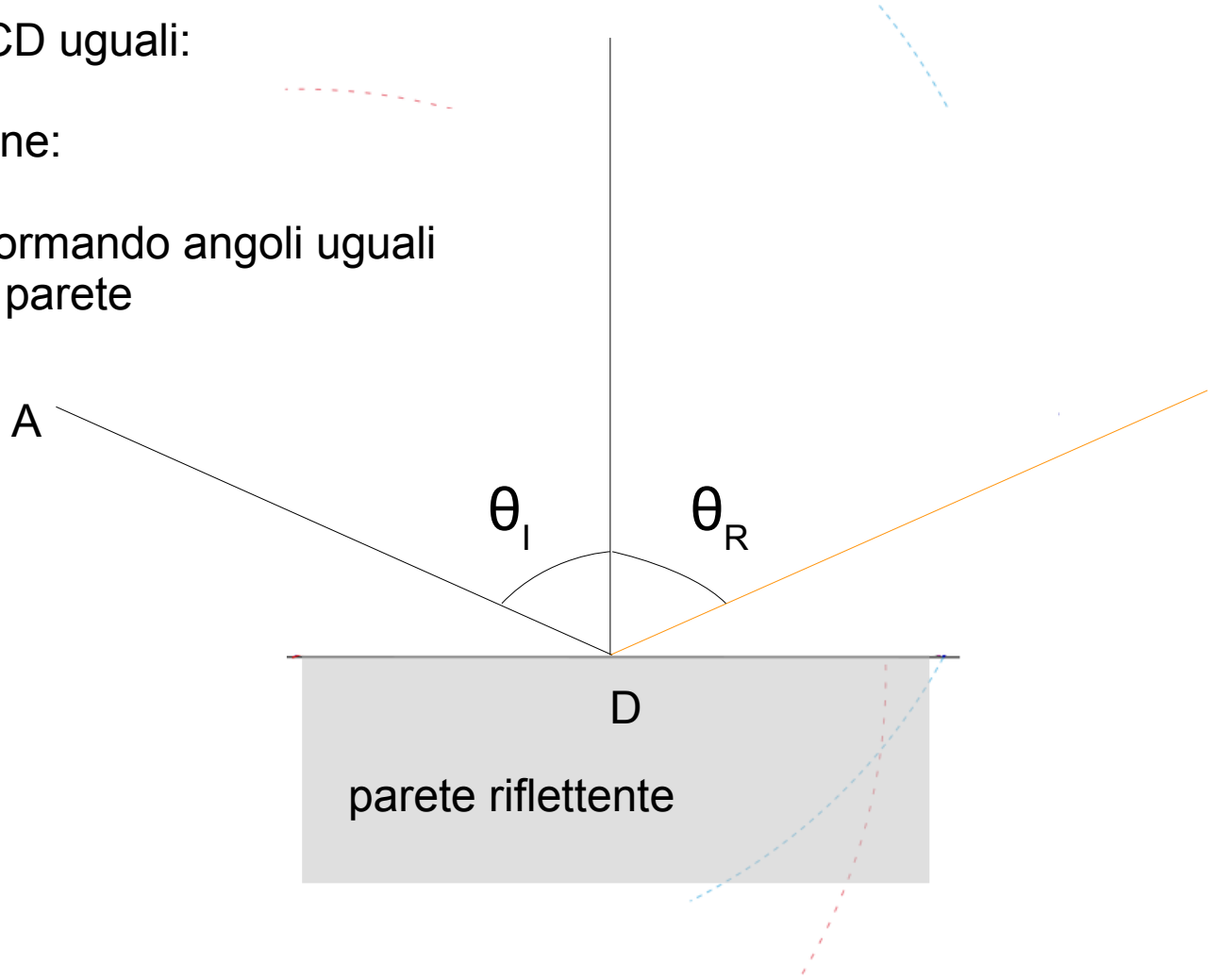


Riflessione (Huygens)

Triangoli ABD e BCD uguali:

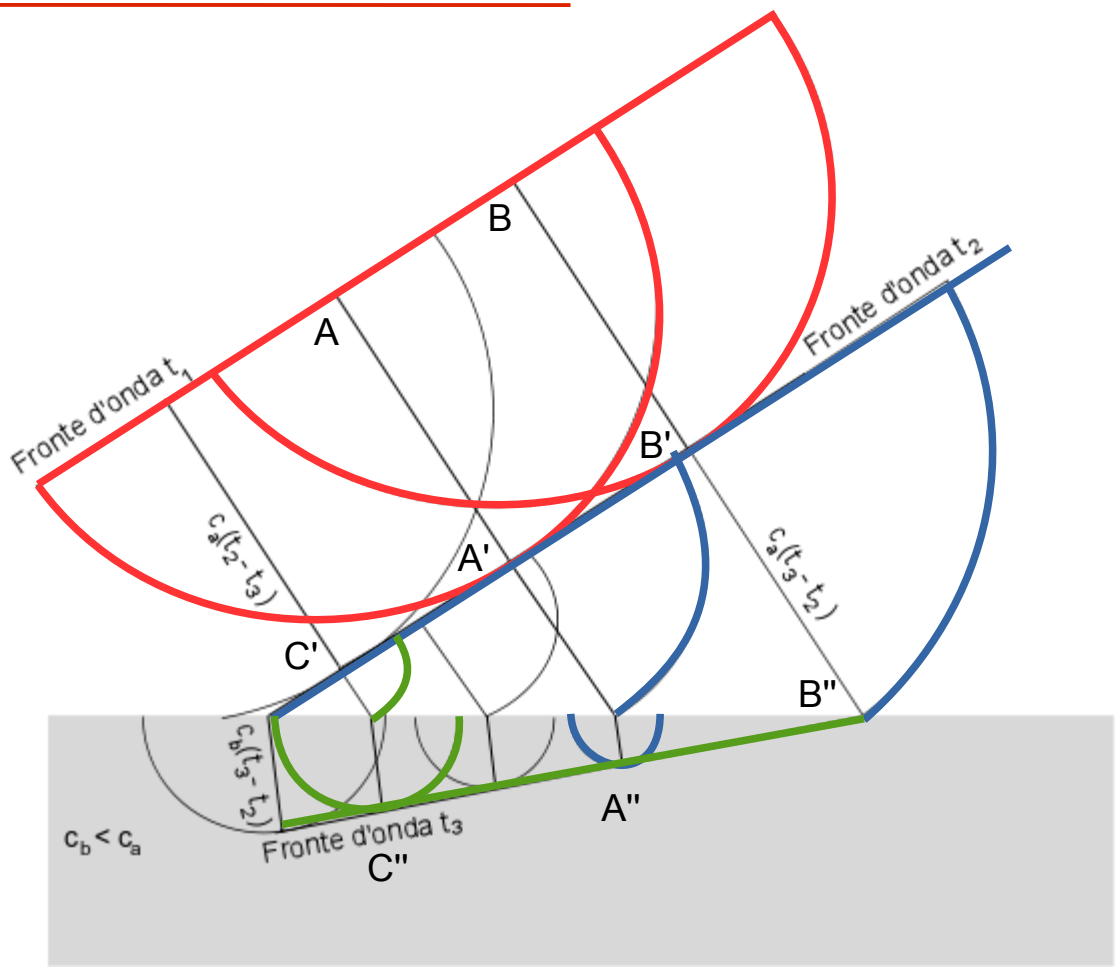
Legge della rilessione:

i raggi si riflettono formando angoli uguali con la normale alla parete

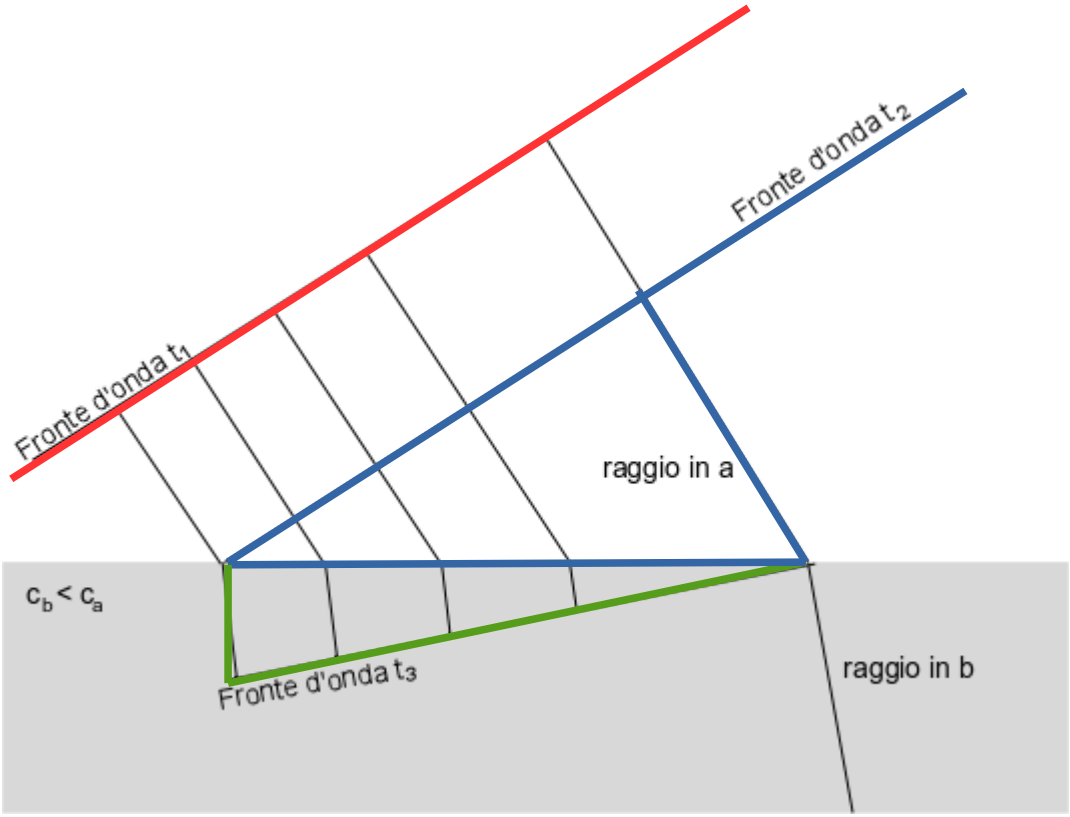


$$\theta_I = \theta_R$$

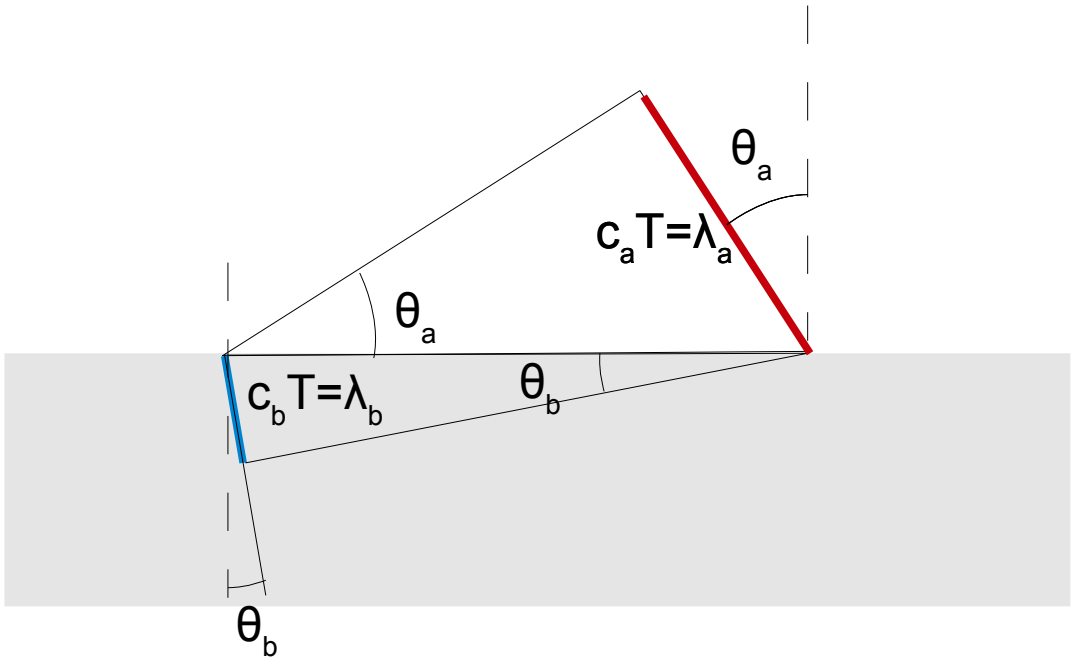
Rifrazione: Legge di Snell



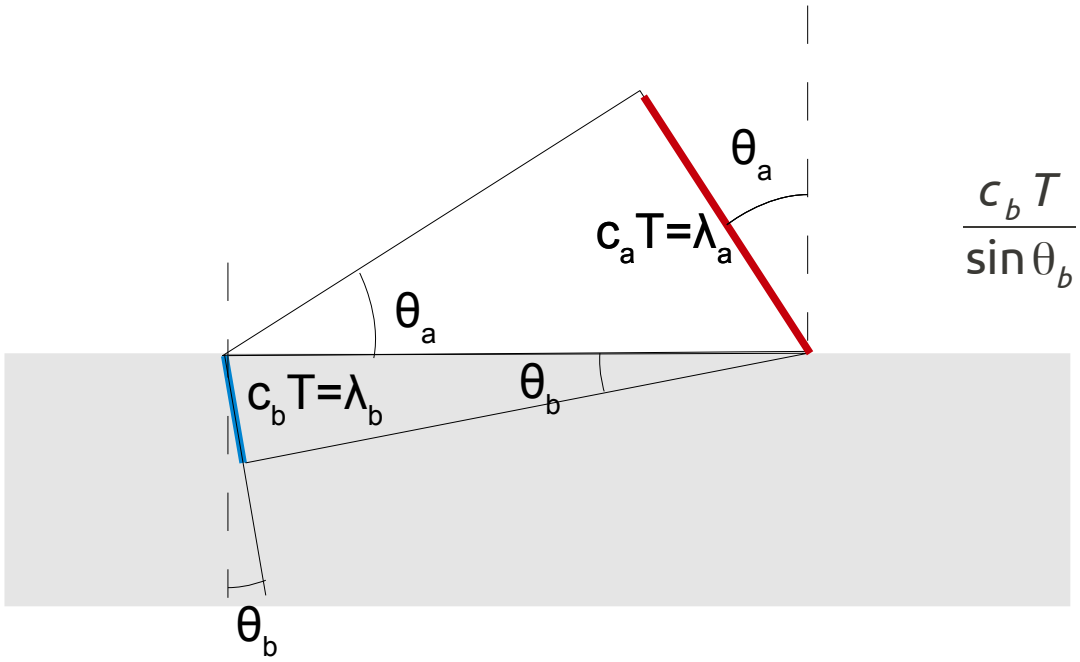
Rifrazione: Legge di Snell



Rifrazione: Legge di Snell



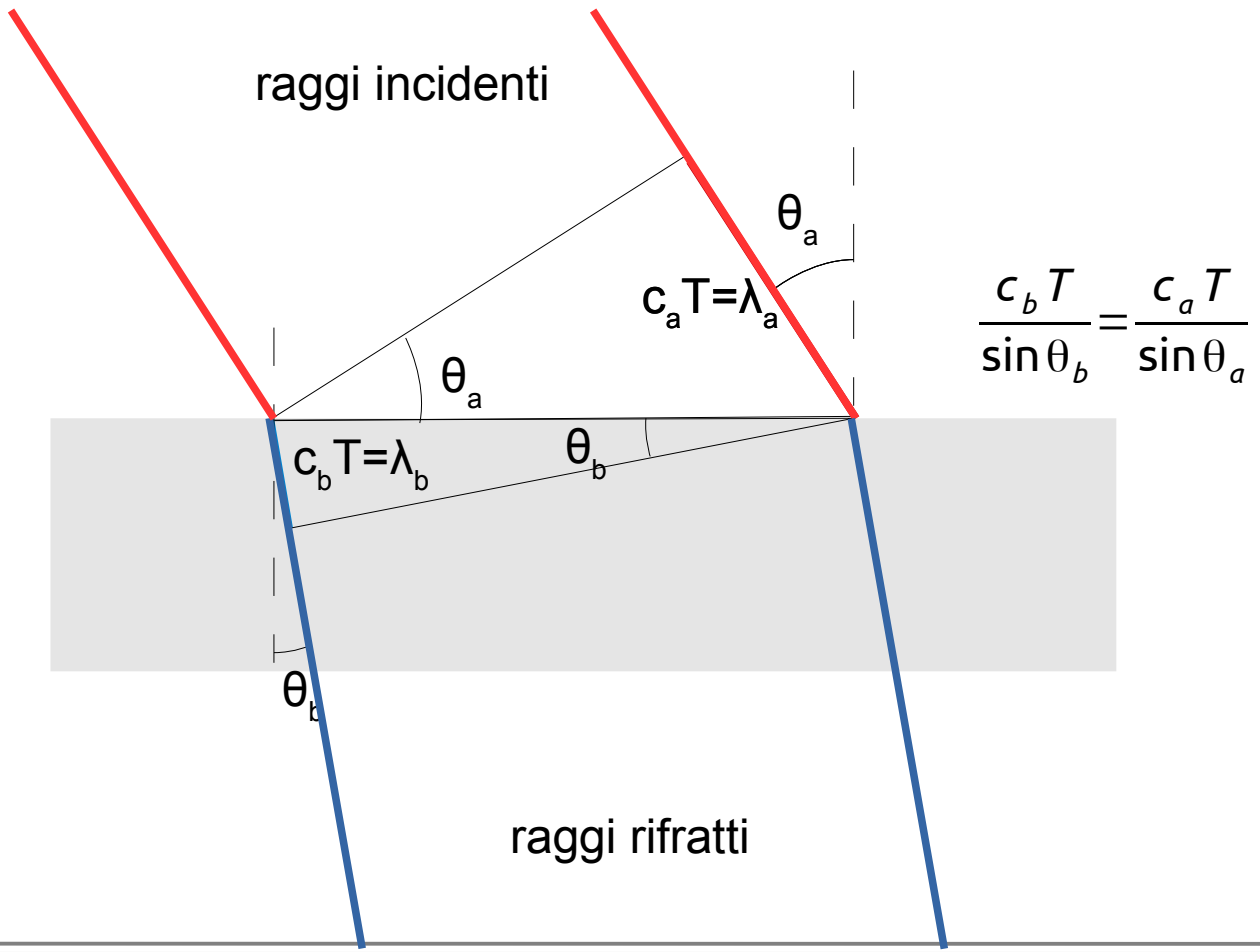
Rifrazione: Legge di Snell



$$\frac{c_b T}{\sin\theta_b} = \frac{c_a T}{\sin\theta_a}$$

Rifrazione: Legge di Snell

$$\frac{c}{c_b}\sin\theta_b = \frac{c}{c_a}\sin\theta_a$$

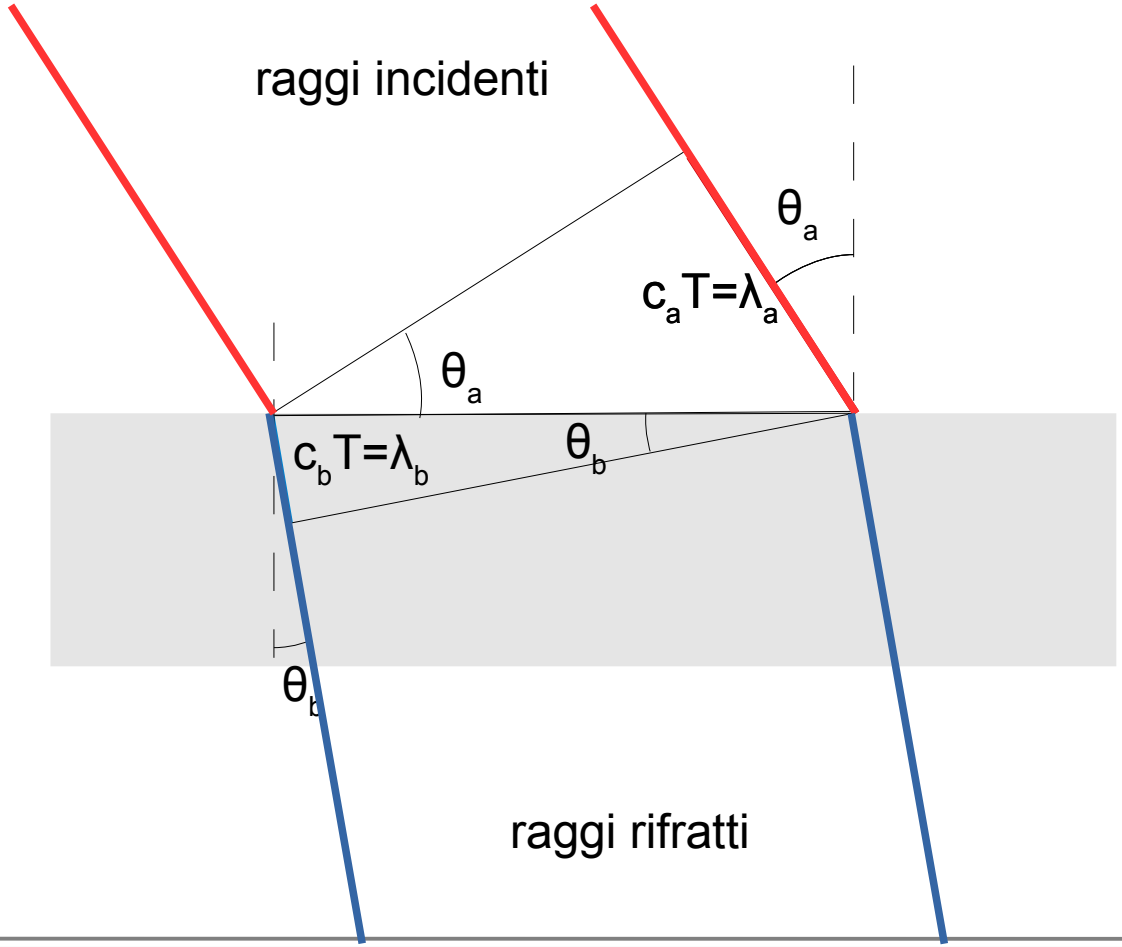


$$\frac{c_b T}{\sin\theta_b} = \frac{c_a T}{\sin\theta_a}$$

Rifrazione: Legge di Snell

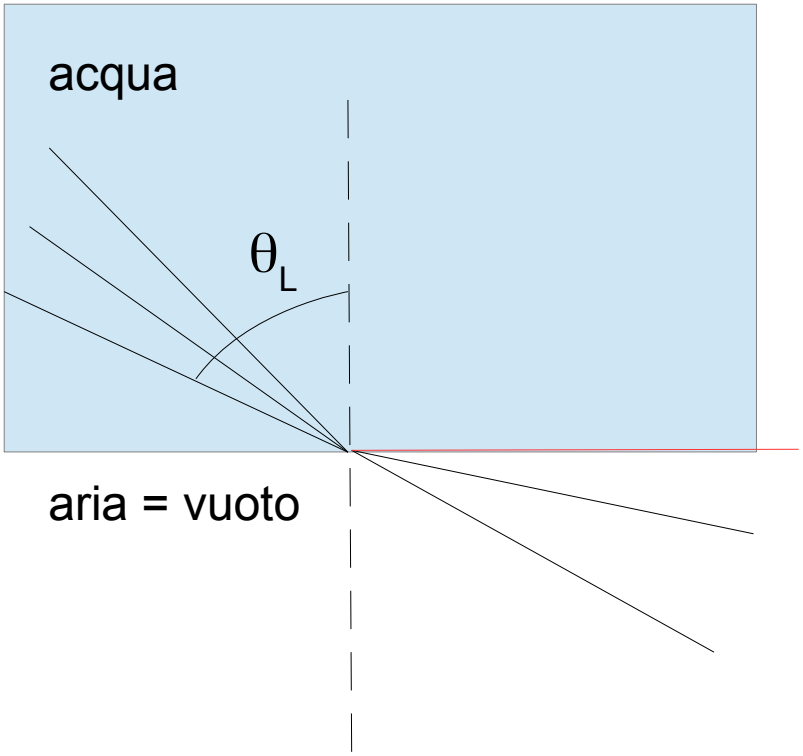
$$n_b \sin\theta_b = n_a \sin\theta_a$$

$$n_a = \frac{c}{c_a}$$



Riflessione totale

angolo limite



$$c_a < c$$

$$n \sin \theta_L = 1$$

Ondoscopio: Interferenza

Ondoscopio @ http://www.falstad.com/ripple/

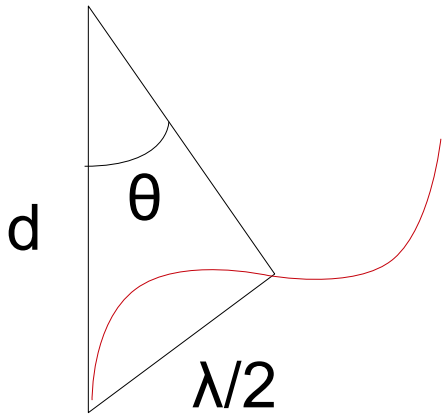
1 single source
2 double source
3 double slit } interferenza
4 single slit diffrazione

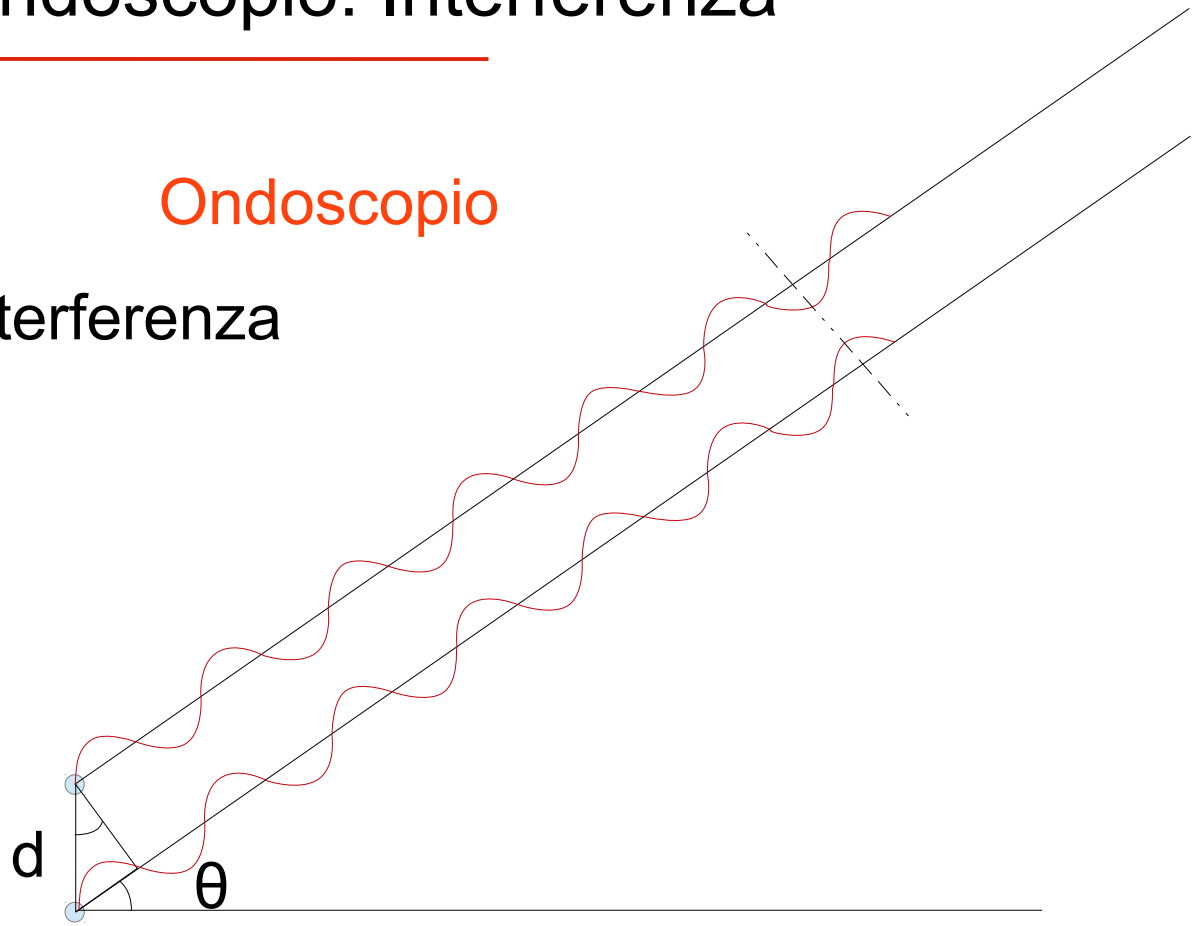
(ricordarsi di abilitare java)

Ondoscopio: Interferenza

Ondoscopio

Minimi dell'interferenza



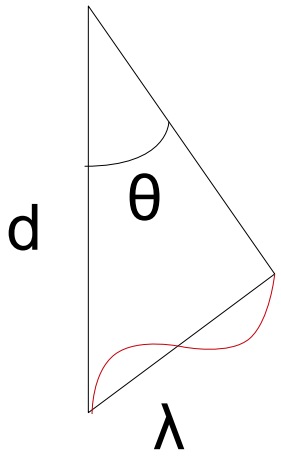


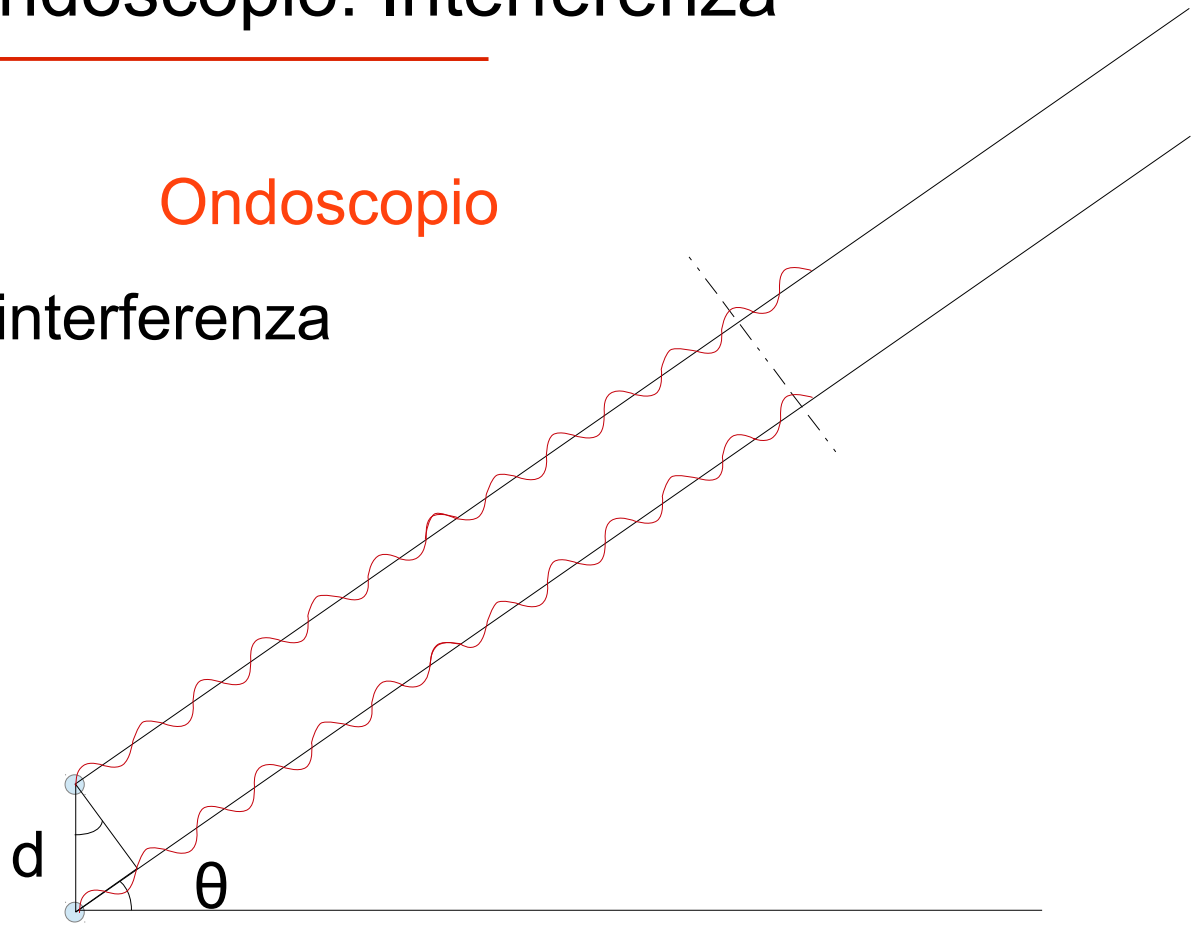
$$d \sin\theta = \left(n + \frac{1}{2}\right)\lambda$$

Ondoscopio: Interferenza

Ondoscopio

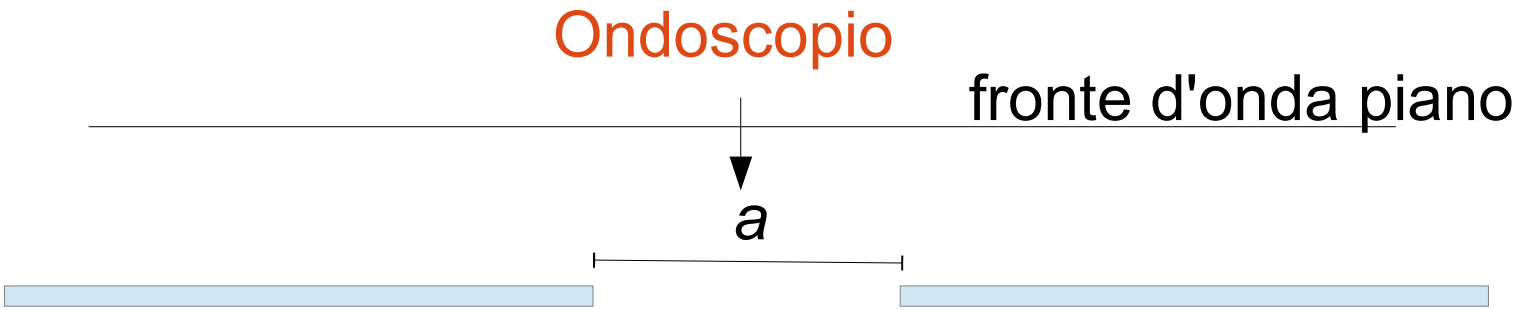
Massimi dell'interferenza





$$d \sin\theta = n\lambda$$

Ondoscopio: diffrazione, fenditura*

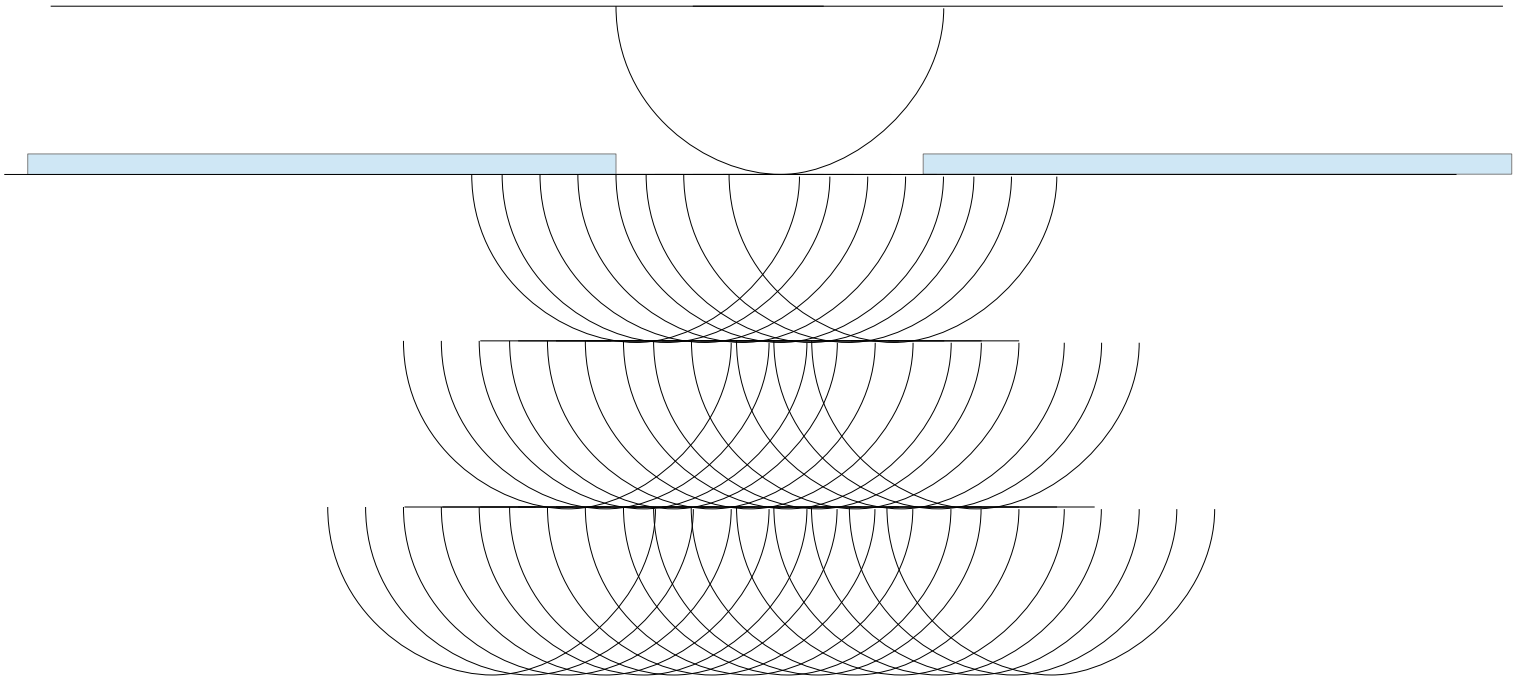


Larghezza *a* confrontabile con λ

* single slit

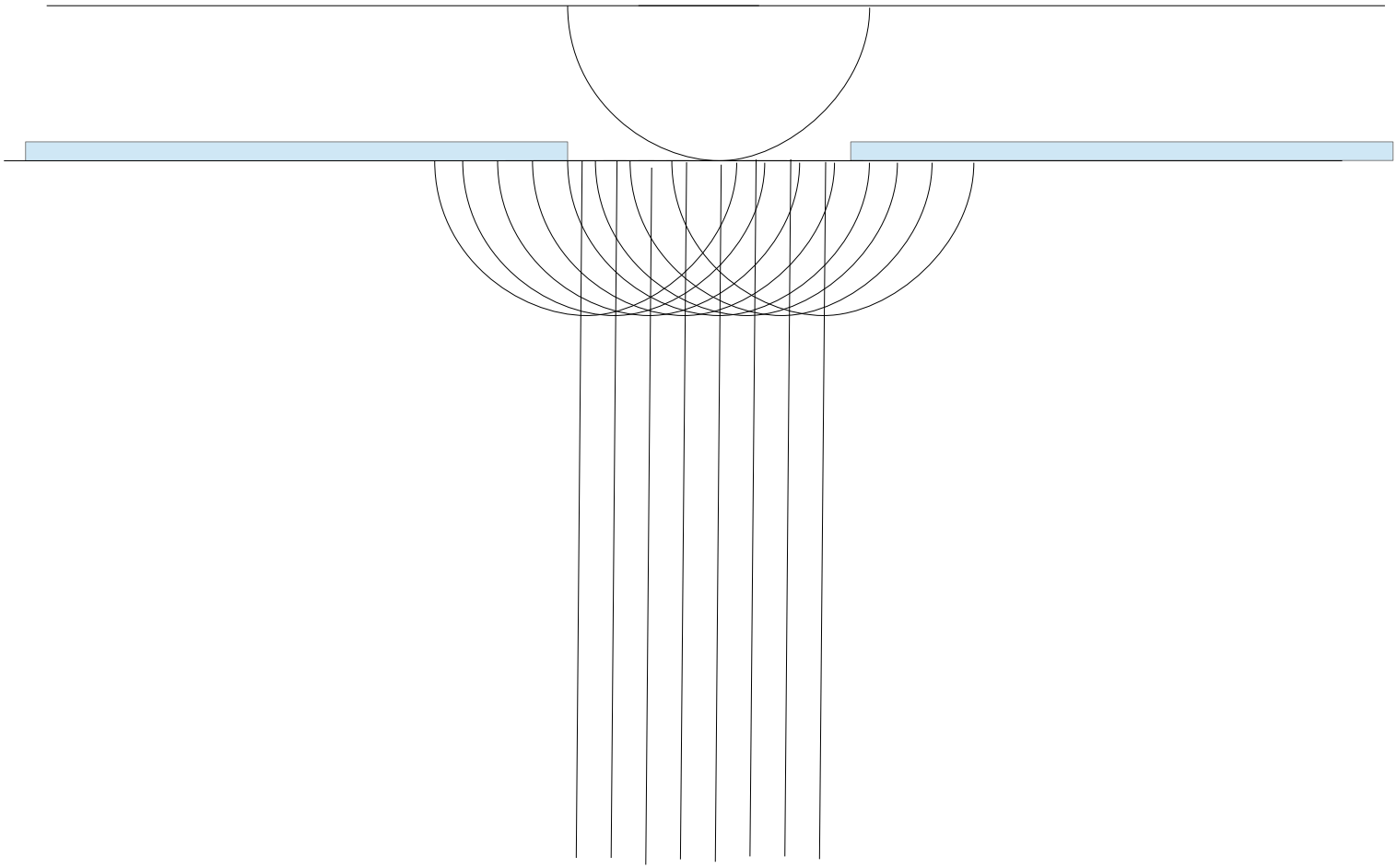
Ondoscopio: diffrazione

Huygens: le onde aggirano gli ostacoli



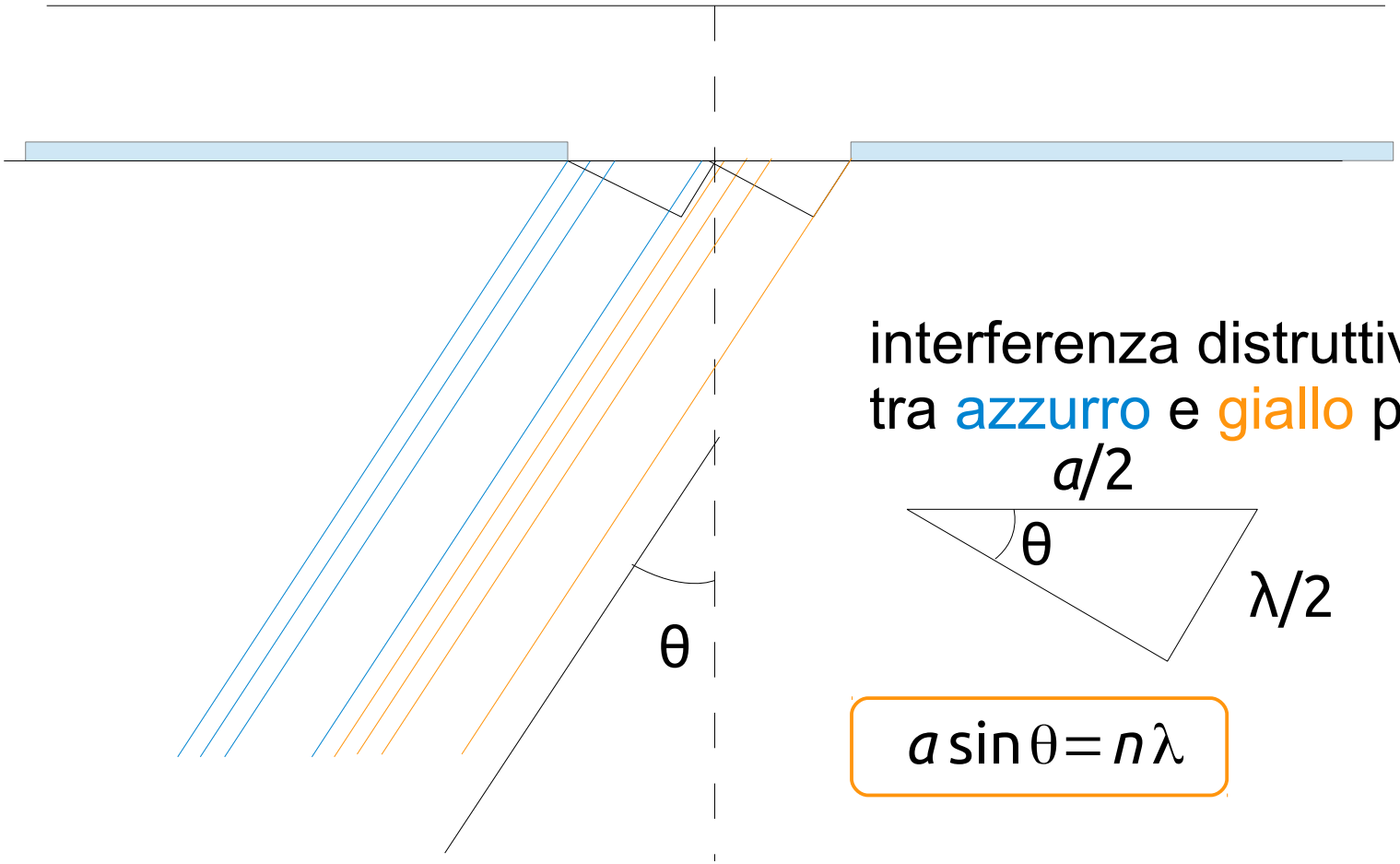
Ondoscopio: diffrazione

Huygens: In avanti, stesso cammino, si sommano in fase



Ondoscopio: diffrazione

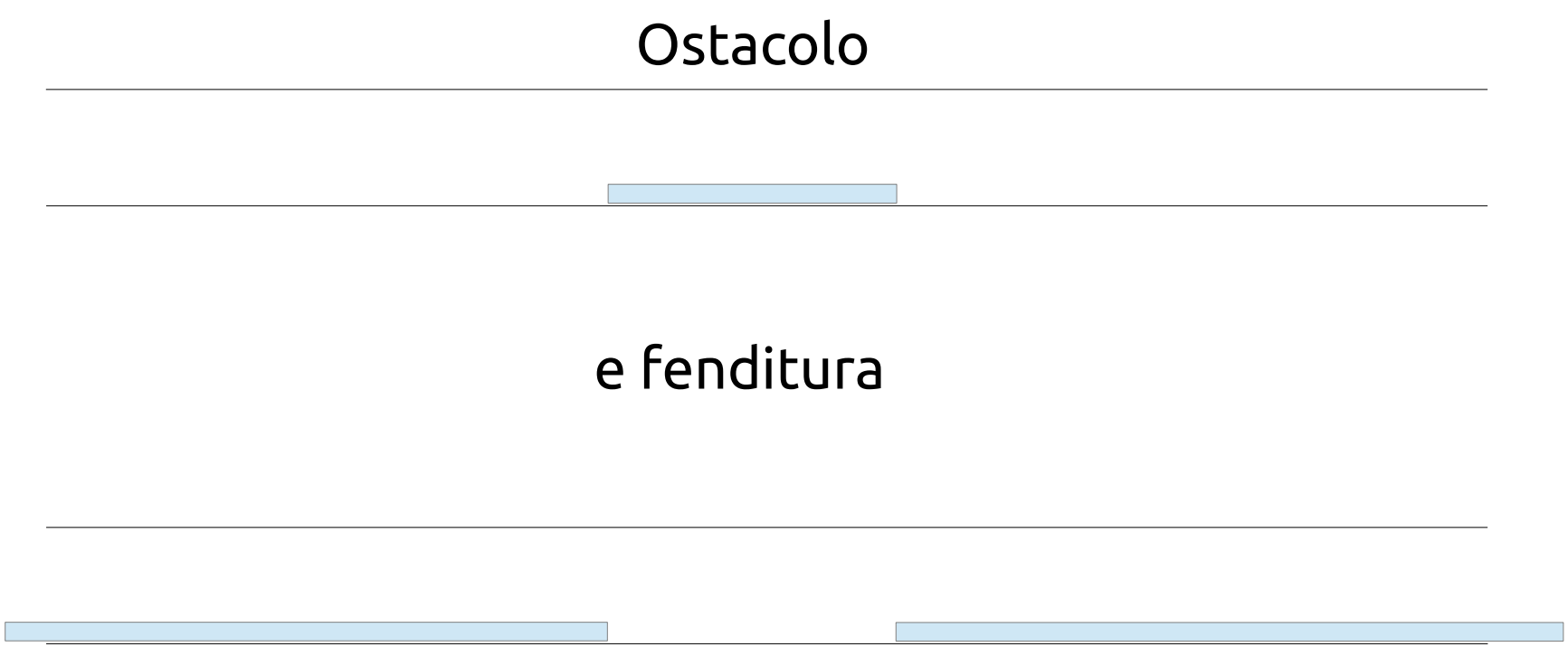
Huygens: di lato diffferenza di cammini,



interferenza distruttiva tra azzurro e giallo per

$$a \sin\theta = n\lambda$$

Ondoscopio: diffrazione ostacolo



Riassunto

Le onde di propagano secondo il principio di Huygens

Si riflettono come particelle elastiche $\theta_I = \theta_R$

Subiscono la rifrazione $\frac{1}{c_b}\sin\theta_b = \frac{1}{c_a}\sin\theta_a$

Inteferiscono:

$d\sin\theta = \left(n + \frac{1}{2}\right)\lambda$ minimi

$d\sin\theta = n\lambda$ massimi

Diffrangono: $a\sin\theta = n\lambda$ minimi