The Physics of Sound

Absorption coefficient

Absorption coefficients of common materials [edit]

Absorption coefficients of common materials[3]

Materials	Frequency (Hz)				
	125	250	500	1,000	2,000
Acoustic tile (ceiling)	.80	.90	.90	.95	.90
Brick	.03	.03	.03	.04	.05
Carpet over concrete	.08	.25	.60	.70	.72
Heavy curtains	.15	.35	.55	.75	.70
Marble	.01	.01	.01	.01	.02
Painted concrete	.10	.05	.06	.07	.09
Plaster on concrete	.10	.10	.08	.05	.05
Plywood on studs	.30	.20	.15	.10	.09
Smooth concrete	.01	.01	.01	.02	.02
Wood floor	.15	.11	.10	.07	.06

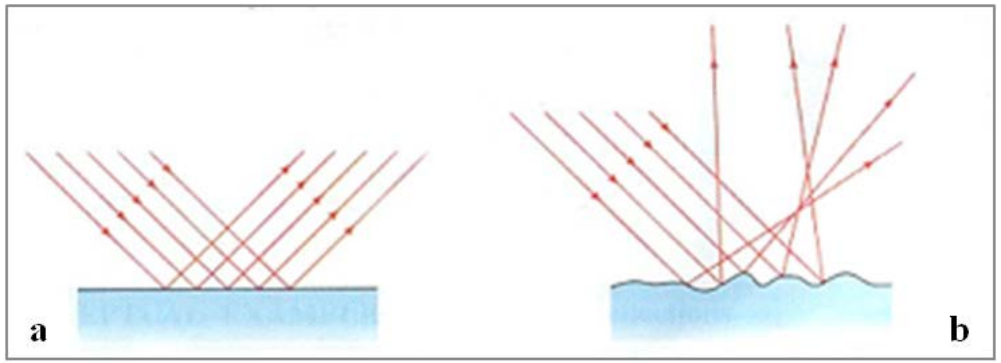
- The sound **Absorption Coefficient** "a" of a material is defined as the ratio of sound energy absorbed by it to the total sound energy incident on it
- Absorption coefficient

a = Sound energy absorbed by the surface / Total sound energy incident on it

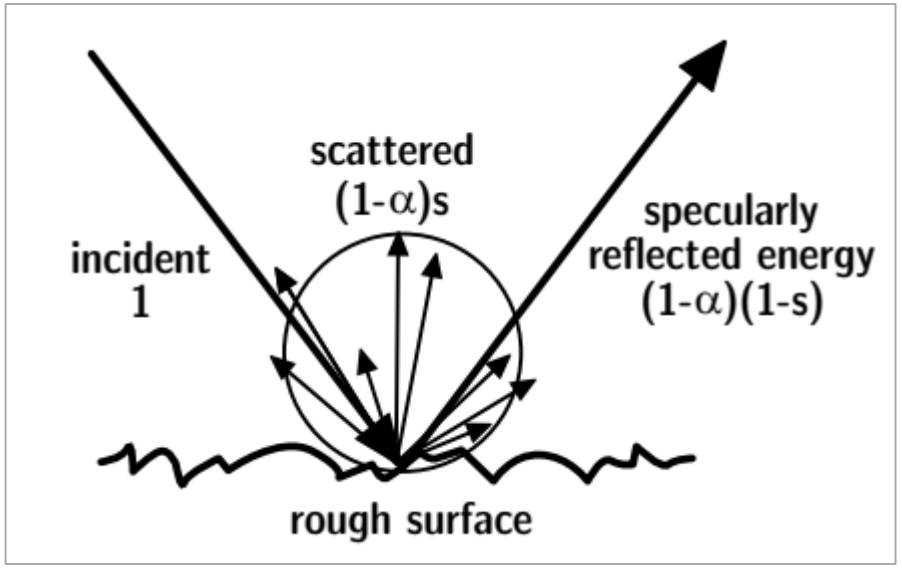
- Expressed as a value between
  - 1.0 = perfect absorption (no reflection) and
  - 0 = zero absorption (total reflection)

Sound Physical Phenomenon – Reflection

- When a sound wave strikes a plane surface, part of the sound energy is reflected back into the space.
  - **Specular Reflection (a)**: If the wavelength of the sound wave is **small** enough in respect to the dimensions of the reflecting object and **large** compared with possible irregularities of the reflecting surface, a specular reflection occurs (**the angle of reflection is equal to the angle of incidence**)
  - **Diffuse (or Scattering) Reflection (b)**: if the sound wavelength is **comparable** with the corrugation dimensions of an irregular reflection surface, **the incident sound wave will be scattered in all directions**. In this case, the phenomenon is called diffuse reflection



Specular and Diffusion (or Scattering) coefficient



- Energy reflected from a corrugated surface into:
  - scattered and
  - specularly reflected portion
- $E_{spec} = (1-\alpha)(1-s) \equiv (1 - a)$, $E_{total} = (1- \alpha)$
- Definition of the total reflected energy $(1 – \alpha)$, the scattered energy $(1 – \alpha)s$ and specularly reflected energy $(1 – \alpha)(1 – s)$,

where **a** is the specular absorption coefficient and **s** is the scattering coefficient

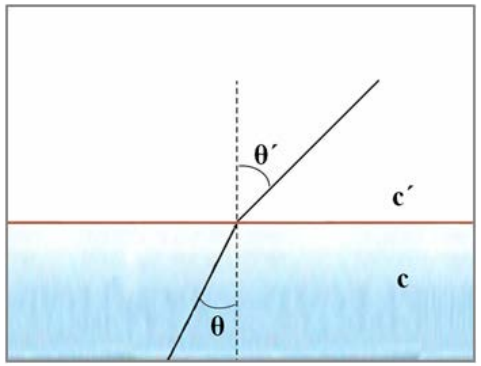
(*Vorländer and Mommertz 2000*)

Sound Physical Phenomenon – Refraction

- Refraction is the **change in the propagation direction** of waves when they cross obliquely the boundary **between two mediums** where their speed is different
- For transmission of a plane sound wave from air into another medium, the refraction index (n) is calculated from the below equation, for calculating the geometric conditions

$$n = c'/c = \sin\theta'/\sin\theta \,,$$

where c' and c the sound speed in the two media, θ the angle of incidence and θ' the angle of refraction.



Refraction coefficient

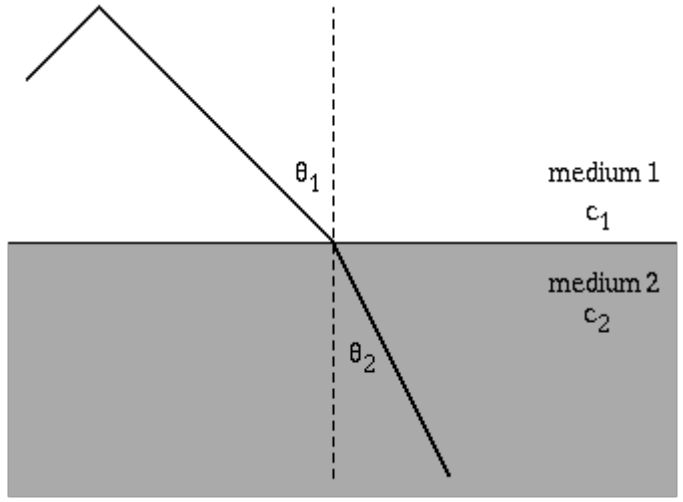


Figure: https://www.acs.psu.edu/drussell/Demos/refract/refract.html

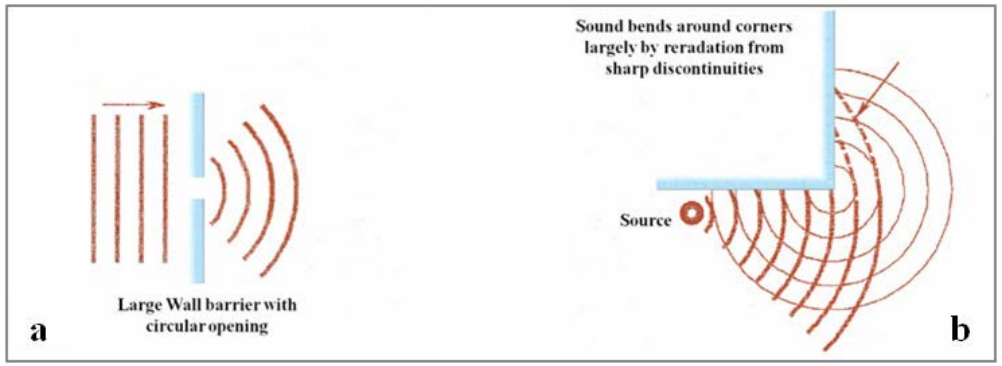
- The sound travels faster in some materials than others
- Sound waves travel outward in straight lines from their source until something interferes with their path
- When sound changes mediums (enters a different material) at an angle other that 90 degrees, it is bent from its original direction
- This change in angle of direction is called refraction
- **Snell's law** relates the directions of the wave before and after it crosses the boundary between the two media

$$\frac{\sin\theta_1}{c_1} = \frac{\sin\theta_2}{c_2}$$

- The wavefronts cross the boundary the **wavelength changes**, but the **frequency** remains **constant**.

Sound Physical Phenomenon – Diffraction

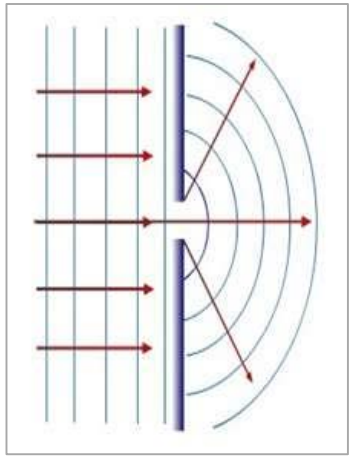
- Diffraction is the spread of waves around corners (b), behind obstacles or around the edges of an opening (a)
- When diffraction occurs:
  - Wave direction changes
  - Wave velocity, v, changes
  - Wavelength, λ, is unchanged
  - Frequency, f, is unchanged
  - Speed unchanged

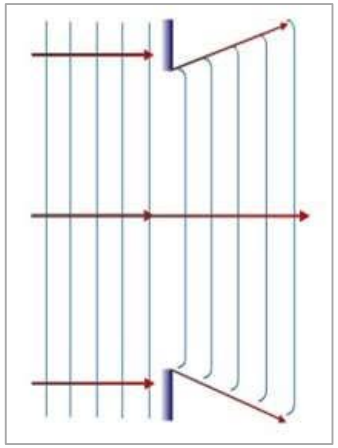


Diffraction coefficient

- When the width of the opening is **smaller** than the wavelength, **λ**, the wave will be **well diffracted**

When the opening is very **narrow**, the wave is very **well diffracted**

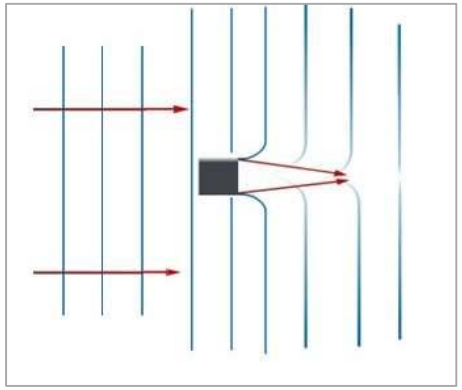


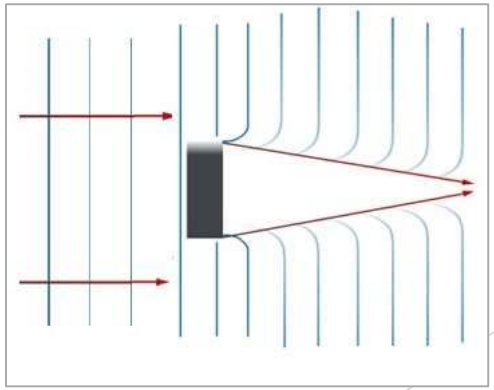


The size of the opening is too **big**, the wave is **not well diffracted**

- When **the size of the obstacle** is **smaller** than the wavelength, **λ**, the wave will be **well diffracted**

The size of the obstacle is **small**,
the waves are **well diffracted**

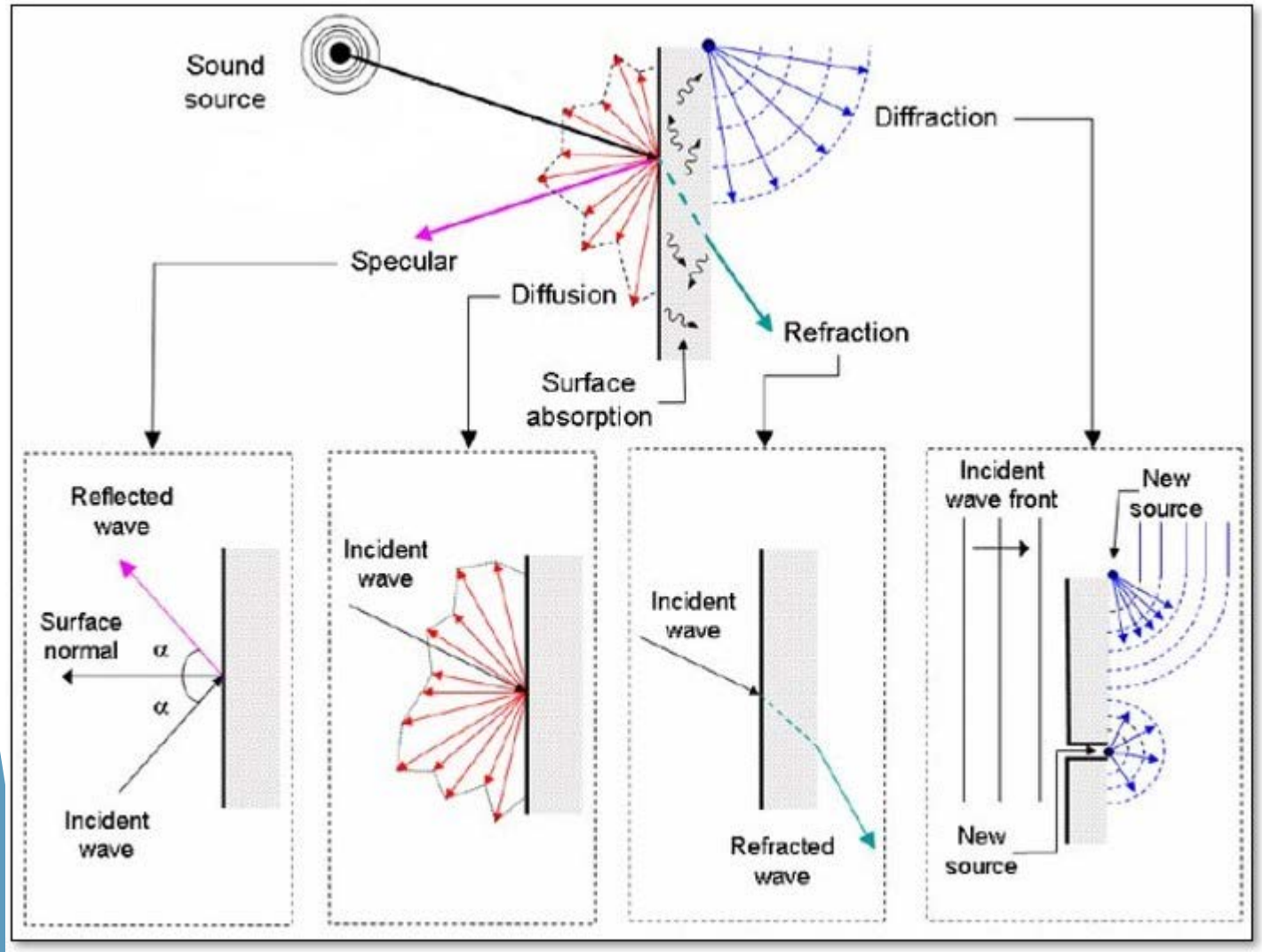




The size of the obstacle is too **big**,
the waves are **not well diffracted**

Figures: Diffraction, Nurul Fadhilah, Working at MRSM kuala klawang

Sound Propagation Phenomena



- **absorption** coefficient
- **specular** coefficient
- **diffusion** coefficient
- **refraction** coefficient
- **diffraction** coefficient