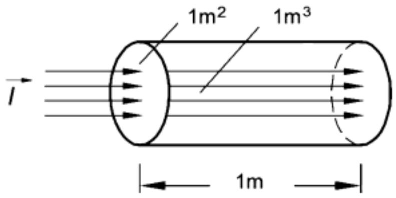
1 Intensity of a ray bundle

Let's first consider the sound in the room is the superposition of an infinity of ray bundles (plane waves).



The energy density in the bundle traveling a distance of 1 m (during time interval $1/c$) is

$$w_{ray} = \frac{W_{ray}}{V} = \frac{P_{ray}\frac{1m}{c}}{1m^3} = \frac{\vec{I}_{ray}.\vec{S}.1m}{c.1m^3} = \frac{I}{c} \tag{1}$$

where V =1 m^3 is the volume of the unitary cylinder of cross-section 1 m^2 and length 1 m. In the following, we will assume that all rays traveling the room are incoherent (they don't interfere then). Then, at any position in the room, the "diffuse" sound intensity I_d is the sum of all intensities from all directions :

$$I_d = \int\int_{4\pi} ||\vec{I}(\Omega)||d\Omega = w_d c \tag{2}$$

where w_d is the energy density of the diffuse field (assumed constant all other the volume).

2 Sound power on walls

Now let's focus on the power hitting the walls of the room. Let's consider a small element of surface dS of a wall.

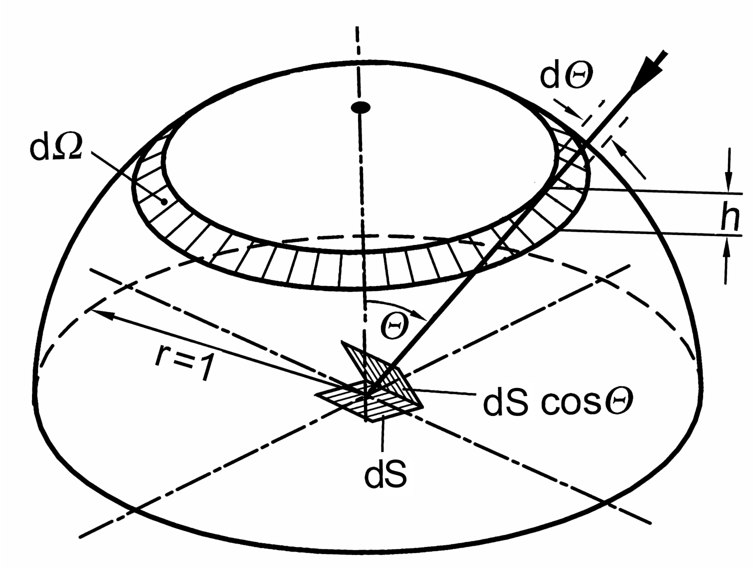
The intensity hitting the wall is the integral of infinitesimal intensities coming from solid angles $d\Omega = 2\pi \sin\theta d\theta$. Since the energy density in this solid angle is $dw = \frac{w_d}{4\pi}d\Omega = \frac{w_d c}{2}\sin\theta d\theta$, the elementary intensity transported in $d\Omega$ and hitting the wall is $dI_{wall}(\theta) = dw.c = \frac{w_d c}{2}\sin\theta d\theta$.

Then the total intensity hitting the wall is :

$$I_{wall} = \int_{\theta=0}^{\pi/2} dI(\theta)\cos\theta = \frac{w_d c}{4} \tag{3}$$

Then the total power hitting the whole walls of the room (total surface area S) is

$$P_{walls} = \frac{w_d c}{4} S \tag{4}$$



3 Mean free-path time

The energy that hits the wall every second is $W_{1s} = P_{walls}.1s$ whereas the total energy in the room of volume V is $W = w_d V$.

The rays transport this energy to wall in average N times per second, then $N w_d V = \frac{w_d c}{4} S.1s$, which leads the average number of reflections per second :

$$N = \frac{cS}{4V} \tag{5}$$

Finally the mean free-path time is the average time between two reflections on walls :

$$t_m = \frac{1}{N} = \frac{4V}{cS} \tag{6}$$