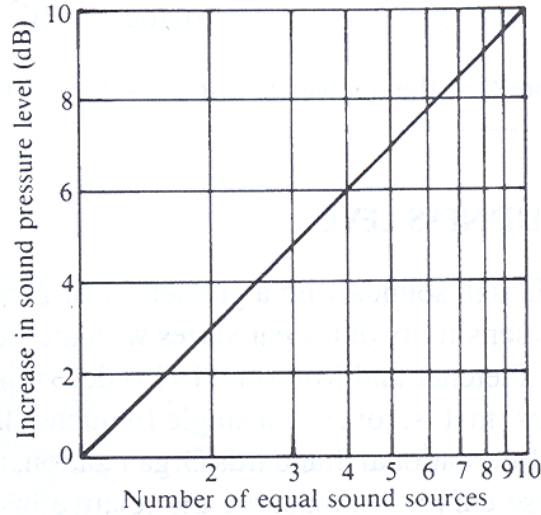


### Example: Adding $N$ Uncorrelated Equal Strength Sounds:

If  $N$  uncorrelated sound sources are superposed/added together, each with the same individual sound intensity  $I_1$ , the resulting loudness level is:

$$L_{sum} = 10 \log_{10}(N I_1/I_o) = 10 \log_{10}(I_1/I_o) + 10 \log_{10}(N) \Rightarrow \Delta L = 10 \log_{10}(N)$$



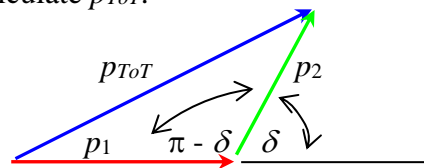
### Adding Correlated Sounds:

If sounds are correlated (*i.e.* have a stable phase relation to each other) then must add sounds together at the amplitude level

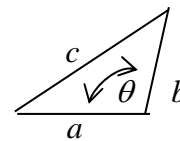
Suppose have two {RMS} over-pressure amplitudes  $p_1$  and  $p_2$

“ $p_{ToT} = p_1 + p_2$ ” but  $p_{ToT}$  actually depends on the phase relation between  $p_1 + p_2$

Use phasor diagram to calculate  $p_{ToT}$ :



$\delta$  = relative phase angle between  $p_1$  and  $p_2$



$$\theta = (\pi - \delta)$$

Use the law of cosines:

$$c^2 = a^2 + b^2 - 2ab \cos \theta$$

$$p_{ToT}^2 = p_1^2 + p_2^2 - 2p_1p_2 \cos(\pi - \delta) \text{ but: } \cos(\pi - \delta) = \underbrace{\cos \pi}_{=-1} \cos \delta + \underbrace{\sin \pi}_{=0} \sin \delta = -\cos \delta$$

$$\therefore p_{ToT}^2 = p_1^2 + p_2^2 + 2p_1p_2 \cos(\delta) \propto I_{ToT}$$

$$\text{or: } I_{ToT} = I_1^2 + I_2^2 + 2\sqrt{I_1}\sqrt{I_2} \cos \delta$$

$$p_{ToT} = \sqrt{p_1^2 + p_2^2 + 2p_1p_2 \cos \delta}$$