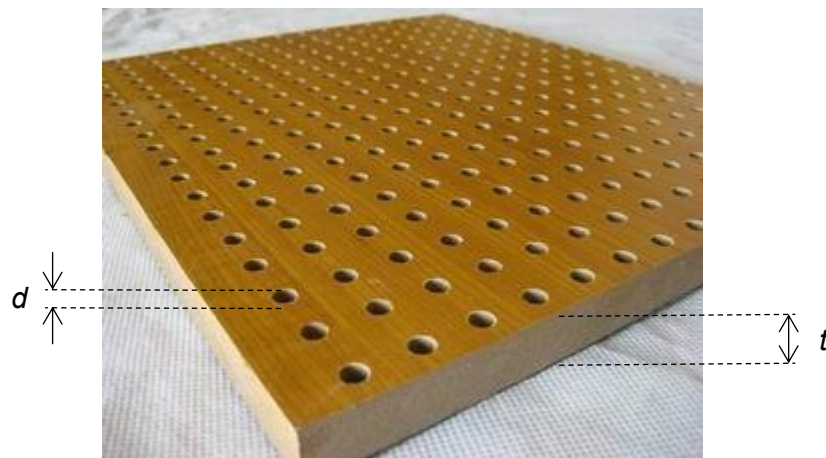


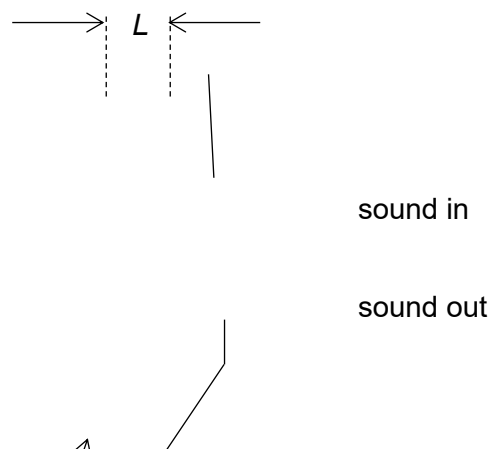
- 7 Echoes are produced by the reflection of sound waves from a surface such as a wall or a cliff. When the reflecting surface is far away from the source then the echo may be heard as a separate sound.

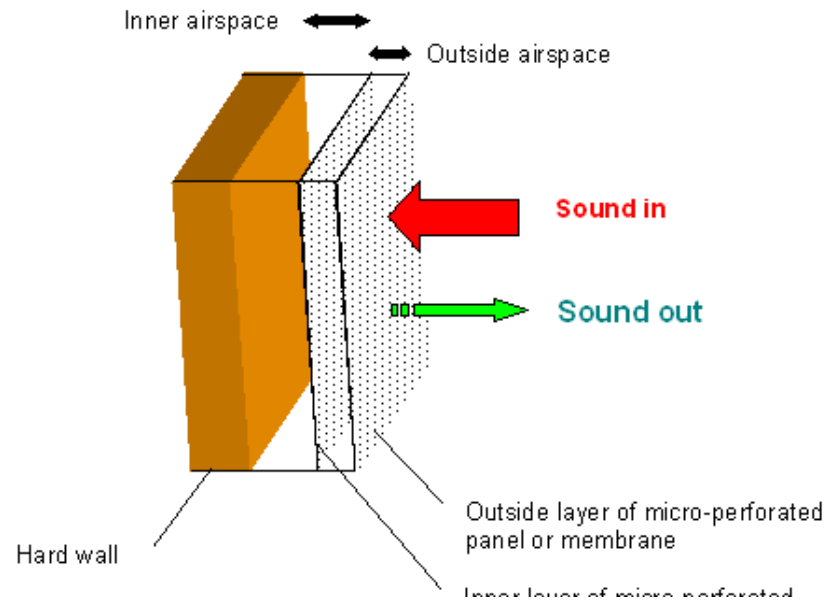
In an enclosed room, when a sound source ceases, the sound waves will continue to reflect off the hard wall, floor and ceiling surfaces until it loses enough energy and dies out. The prolongation of the reflected sound is known as reverberation. Reverberation time is the number of seconds it takes for the reverberant sound energy to die down to one millionth (or by 60dB) of its original value from the instant that the sound signal ceases.

Recording studios and music halls are acoustically designed to cover the walls with sound absorbing surfaces such as a perforated panel as shown in Fig. 7.1. In many cases it is necessary to absorb certain frequencies more than others, and one way to do this is to use the resonances of these perforated panels attached to the wall as shown in Fig. 7.2.



**Fig. 7.1**





**Fig. 7.2**

It is found that a panel made of hardboard resonates at a particular frequency sound of that frequency more than other frequencies. An approximate expression for the resonant frequency is given by

$$f = 5000 \sqrt{\frac{P}{L(t + 0.8d)}}$$

Where  $f$  = resonant frequency

$L$  = depth of airspace

$t$  = thickness of panel

$d$  = hole diameter

$P$  = percentage of open area

(all measurements are made in mm)

**(a)** State a difference between echo and reverberation.

.....  
..... [1]

**(b)** Explain why reverberation is not desirable for a conference room.

.....  
..... [1]

**(c)** The panelling of walls can reduce the reverberation time more significantly at certain frequencies.

**(i)** Explain why paneling the walls reduces reverberation time.

.....  
.....  
.....[1]

**(ii)** Explain why the reduction of reverberation time is more significant at certain frequencies.

.....  
.....

.....

.....

.....

.....[2]

(d) State two other factors which would affect the reverberation time of a room.

.....

.....

.....

..... [2]

(e) A perforated panel with 10% open area, with various hole diameters are tested. The resonant frequencies  $f$ , together with values of  $\frac{1}{f^2}$  obtained are shown in Fig. 7.3.

$d/\text{mm}$	$f/\text{Hz}$	$\frac{1}{f^2}/10^{-6} \text{ s}^2$
1.0	1600	0.39
2.0	1480	0.46
3.0	1350	0.55
4.0	1280	
5.0	1180	0.72
6.0	1140	0.77

**Fig. 7.3**

(i) Complete Fig. 7.3 for the resonant frequency of 1280 Hz. [1]

(ii) Fig. 7.4 is a graph of some of the data in Fig. 7.3.

On Fig. 7.4,

1. plot the point corresponding to  $f = 1280$  Hz, [1]

2. draw the line of best fit for all the points. [1]

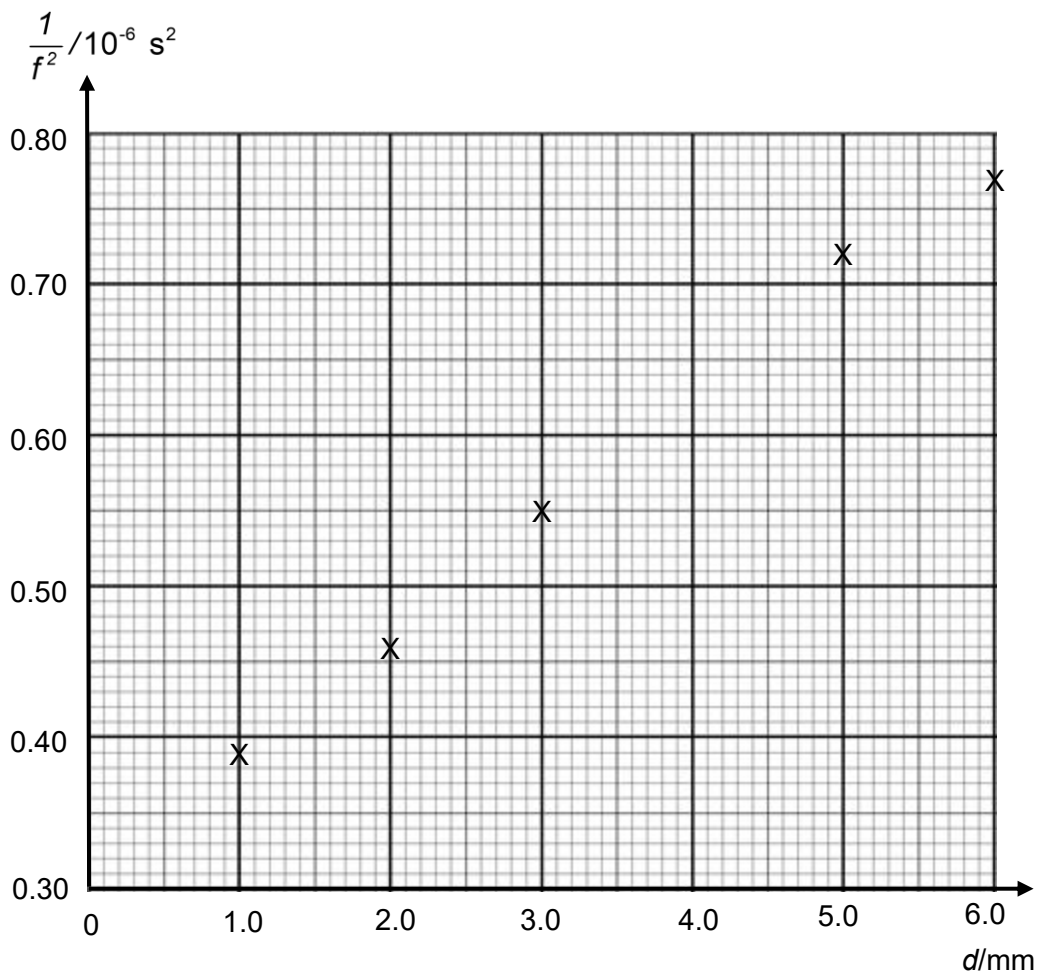
(iii) Use Fig. 7.4 to determine for the line drawn in (e)(ii)

1. the gradient

gradient = .....  $\text{s}^2 \text{ mm}^{-1}$  [2]

2. the y-intercept

y-intercept = ..... s<sup>2</sup> [2]



**Fig. 7.4**

(iv) Use your answers to (e)(iii) to determine

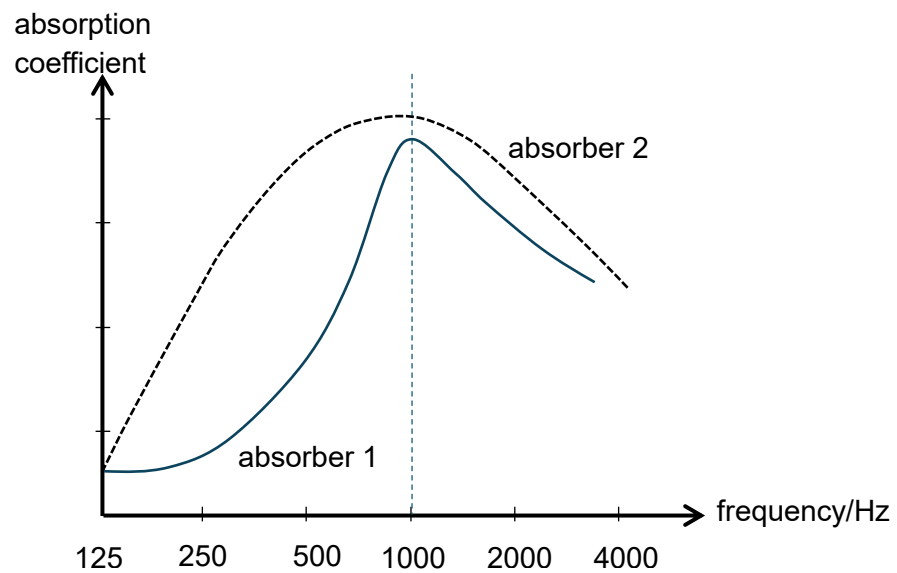
1. the depth  $L$  of the airspace

$L = \dots\dots\dots$  mm [2]

2. the thickness  $t$  of the panel

$t = \dots\dots\dots$  mm [1]

- (f) The panel with 5.0 mm holes is selected and tested with its airspace filled with absorber 1 and absorber 2 separately. The absorption characteristics shown in Fig. 7.5 were obtained, where the absorption coefficient is the ratio of energy absorbed to energy incident on the absorber.



**Fig. 7.5**

- (i) With reference to Fig. 7.3 and Fig. 7.5, state the effect absorbers have on the resonant frequencies when they were inserted in the airspace.

.....

..... [1]

- (ii) State and explain the absorber that is more suitable for use in a recording studio.

.....

.....

.....

..... [2]

[Total: 20]