General Certificate of Education
Advanced Subsidiary Examination
June 2012

Use of Mathematics UOM4/1PM

Applying Mathematics Paper 1

Preliminary Material

Data Sheet

To be opened and issued to candidates between Thursday 10 May 2012 and Thursday 17 May 2012

REMINDER TO CANDIDATES

YOU MUST **NOT** BRING THIS DATA SHEET WITH YOU WHEN YOU SIT THE EXAMINATION. A CLEAN COPY WILL BE MADE AVAILABLE.

Making a noise

Figure 1 *A crowd listening to loud live music*

What is a safe sound level?

We are surrounded by sound, some we want to hear and some we don't. Perhaps you use a personal music player for some of the day to listen to music or radio programmes. Have you ever wondered whether there is a level of sound that is unsafe? What effect might loud music have on your hearing?

Experts agree that listening to music louder than 85 decibels (dB) for prolonged periods can damage hearing. What are decibels, and what does a sound level of 85 decibels sound like?

Humans hear sounds when their ears detect pressure waves in the surrounding air.

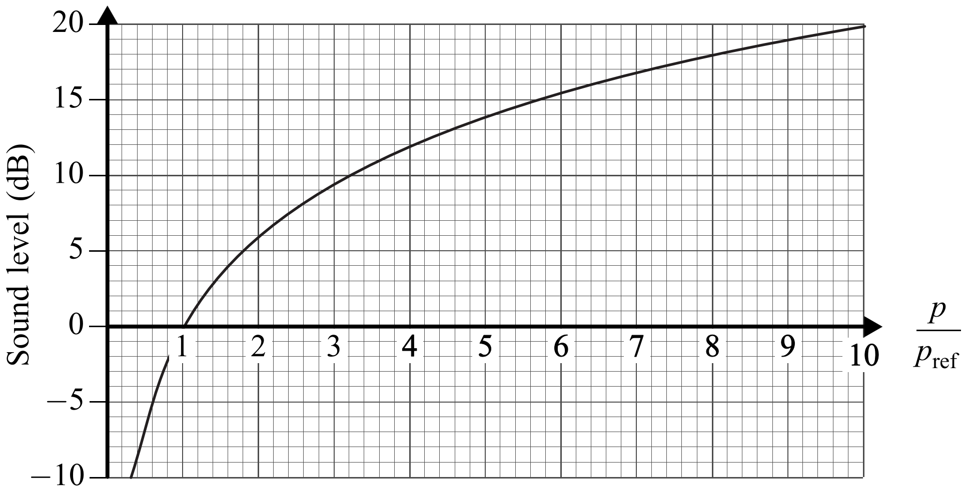
The sound level, L decibels, due to a pressure, p, is given by $L = 20\log_{10}\left(\dfrac{p}{p_{\text{ref}}}\right)$ where p_{ref} is a reference value of pressure.

The decibel unit is named after the scientist and inventor Alexander Graham Bell, who is credited with inventing the first telephone. It is usual to quote values to the nearest integer, because a change in sound level of less than 1 dB is very hard to detect.

For sound pressure, the reference level in air, p_{ref}, is usually chosen to be 20 micropascals (μ Pa) or 20×10^{-6} Pa. This is very low, as standard atmospheric pressure at sea level is usually about 101 325 Pa or 101.325 kPa. This very low value is chosen because such a pressure would give rise to a sound that could just be heard.

A graph showing how the sound level varies for small ratios of pressures, $\dfrac{p}{p_{\text{ref}}}$, is shown in **Figure 2**.

Figure 2 *Graph showing how sound level varies with pressure ratio*



A sound level of 85 dB, quoted as being dangerous, therefore, results from a pressure, p, that is given by

$$20\log_{10}\left(\frac{p}{p_{\text{ref}}}\right) = 85$$

This pressure, p, is 17 800 times greater than that of the reference level.

The table in **Figure 3** gives the sound pressures and the resulting sound level in dB that result from a few sound sources.

Figure 3 *Pressures and levels associated with different sound sources*

Source of sound	**Sound pressure Pa**	**Sound level dB**
Rifle being fired at 1 metre	5000	168
Jet engine at 30 metres	632	150
Vuvuzela at 1 metre	20	120
Normal conversation at 1 metre	2×10^{-3}	40
Calm breathing	6.32×10^{-5}	10

As the data in **Figure 3** suggest, the sound level is dependent on how far away you are from a source. This is because as you move away from a sound source the pressure diminishes. The pressure and distance follow an inverse relationship $p \propto \frac{1}{r}$ or $p = \frac{k}{r}$, where p is the pressure at distance r.

So a sound which produces a pressure of p_1 at a distance of r_1 produces a pressure of p_2 at a distance of r_2 such that $\frac{p_2}{p_1} = \frac{r_1}{r_2}$.

For example, suppose you are 10 metres away from a noise source and the pressure is p_1. If you then move so that you are 20 metres away, the pressure, p_2, will be such that $p_2 = \frac{10}{20} p_1$. That is, the pressure will be half of what it was, resulting in a fall of 6 dB in the sound level.

Figure 4 *Vuvuzelas being blown after a 2010 world cup football match*

A number of experiments have considered the subjective loudness of sounds. In one experiment, it was found that a sound that appears to be twice as loud as another has a difference of 10 dB in sound level. This contrasts with the 6 dB that would be recorded for sounds that give rise to pressures that are in the ratio 2 : 1. A difference of 20 dB in sound level is caused by a sound that appears to be four times louder and so on.

In general, therefore, for this experiment, the loudness ratio, x, for two sounds that give rise to a change in sound level of ΔL is given by

$$x = 2^{\frac{\Delta L}{10}}$$

This means that if we consider a sound level of 85 decibels, this will sound $x = 2^{\frac{85}{10}} = 362$ times louder than something we can barely hear.

END OF DATA SHEET

ACKNOWLEDGEMENT OF COPYRIGHT-HOLDERS AND PUBLISHERS

Figure 1: © Getty Images

Figure 4: © Getty Images