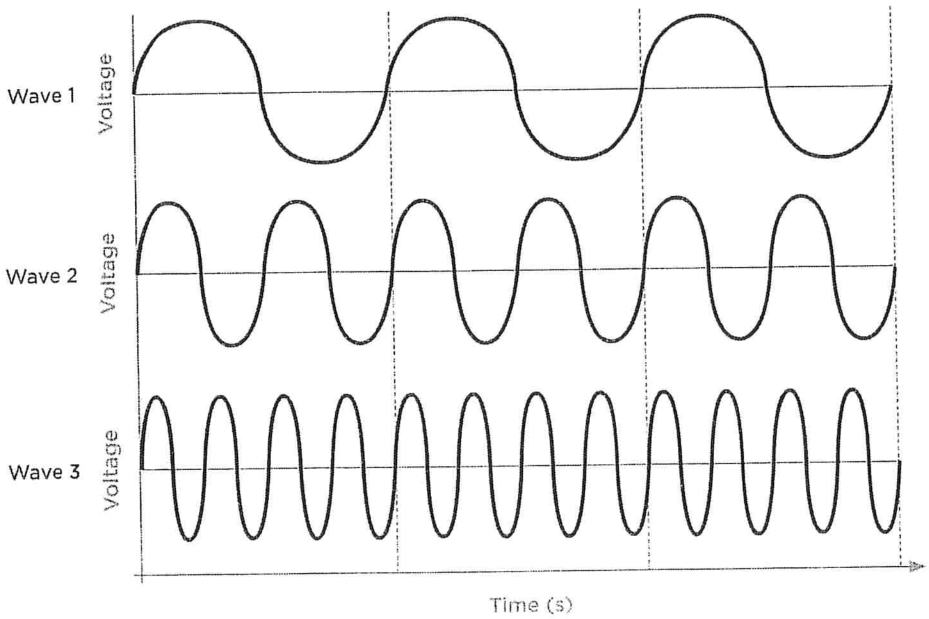
Formulas:	**Topic Link**
1.	
2.	
3.	
4.	
5.	
6.	

Question 9

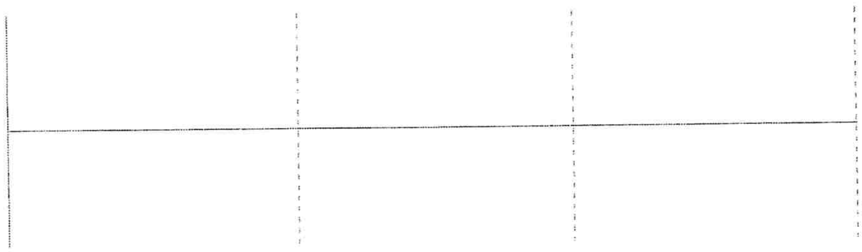
Numeracy and calculations

The frequency of wave 1 below is 100Hz.



a. Label the amplitude of wave 1. (1)

b. Draw a wave that is 180 degrees out of phase with wave 1. (2)



c. Identify what you would hear if you played wave 1 and the wave you have drawn in part (b) at the same time, at the same amplitude. (1)

....

d. Calculate the period of wave 1. Show your working. (2)

period .... s

e. Calculate the frequency of both waves below. Show your working.

i. Wave 2 (2)

frequency of wave 2 ________ Hz

ii. Wave 3 (2)

frequency of wave 3 ________ Hz

iii. Identify the musical relationship between waves 2 and 3. (1)

____

f. Calculate the frequency of a wave that is a perfect 5th above wave 1.
Show your working. (2)

frequency ________ Hz

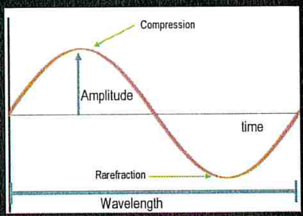
g. Calculate the frequency of the sixth harmonic of wave 1. Show your working. (2)

frequency ________ Hz

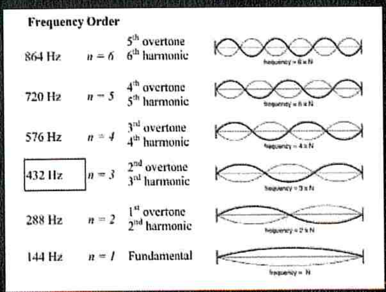
Total for A Level: 15 marks

SOUND RECAP

Label the waveform



HARMONICS AND OVERTONES



An OVERTONE is any frequency greater than the fundamental frequency of a sound. The fundamental and the overtones together are called partials.

HARMONICS, or more precisely, harmonic partials, are partials whose frequencies are numerical integer multiples of the fundamental.

TASK-CALCULATE THE HARMONIC/OVERTONE

The fundamental frequency is 200Hz

1. Calculate the 1st overtone
2. Calculate the 2nd harmonic
3. Calculate the 4th harmonic
4. Calculate the 3rd overtone
5. Calculate the 6th harmonic

The fundamental frequency is 200Hz

1. f= nx2 400Hz
2. f= nx2 400Hz
3. f= nx4 800Hz
4. f= nx4 800Hz
5. f= nx6 1200Hz

DIGITAL NUMERACY

- You will need to convert a binary into a decimal number
- The conversion should be fairly simple as you cannot use a calculator
- This will more than likely be a MIDI analysis question which requires you to use your list editor, followed by a conversion
- MIDI is 8 bit(1 byte) and you should draw a table to make the process easier

Bits	8	7	6	5	4	3	2	1
Cal	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Value	128	64	32	16	8	4	2	1
Example code	1	0	0	0	0	0	0	1

Example binary code conversion: 128+1=129

CALCULATE THE FOLLOWING

The note of a C Maj7 chord is played a different velocities. Complete the table below

Note	Velocity	Binary Code
C	73	1001001
E	64	1000000
G	48	110000
B	9	1001

Bits	8	7	6	5	4	3	2	1
Cal	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Value	128	64	32	16	8	4	2	1
Example code	1	0	0	0	0	0	0	1

TASK

Component 4 Numeracy

Using the delay time formula, calculate the quarter note(crotchet), eighth note(quaver) and 16^{th} note(semiquaver) delay times for a song that's in 4/4 time at 100bpm

60000ms in 1 minute

Delay Formula 60000/BPM

Mastering

Mastering is the final process of preparing a track for release after mixing. Since the mix has already taken place, mastering can't change things such as the balance. 'Remastering' is a process that often takes place with older mixes that prepares them for playback on newer equipment, or to conform to more modern and up-to-date stylistic conventions.

- **Mastering** processes depend on how the track will be delivered and listened to
- Modern masters are completed on **DAWs**, whereas pre-1990, this process would have been completed using **analogue** multitrack tape
- Mastering best takes place in an acoustically treated room, in which the mix is compared on multiple sets of speakers – this is called checking the 'translation'
- Certain speakers are well-known by engineers and often used for this process, for example the Yamaha NS-10
- Radio edits may be created to remove lengthy introductions or solos.

Mastering processes

- **Noise** reduction can be used to reduce hiss; this is often used on **analogue** recordings pre-2000
- The stereo width can be adjusted; this is a common issue with 1960s tracks which have extreme/polarised panning. The tracks are often re-released in **mono**
- **Reverb** can be used to glue mix elements together or to add a sense of stereo width. You would control the wet/dry mix in order to select an appropriate amount of reverb
- EQ can be used to adjust the volumes of particular frequencies in the recording
  - 1970s masters tended to be 'warmer', with less upper-mids and high frequencies
  - 1980s masters had more upper mids and high frequencies
  - More modern masters are low and high **frequency** heavy
- A **high pass filter** with a cutoff set below 35Hz can be used on the whole mix to remove rumble. and other inaudible sub-bass
- A high shelf boost can be used on the whole mix to add brightness
- Compression is used to reduce the dynamic range and increase the average volume/perceived loudness

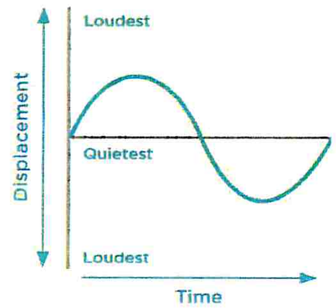
- Limiting is used to prevent **distortion** or peaking. A brickwall **limiter** (with a **ratio** of ∞:1) is normally used at the end of the chain to prevent **clipping** and to increase average volume
- It is good practice to match the volumes and EQs between different album tracks
- Equally, fades in and out are used at the beginning and end of the tracks to avoid a click or cutting off the tail.

Technical numeracy

In addition to the technical numeracy content outlined in this chapter, you should also make sure that you are clear about the graphs used throughout the book, for example for compressor responses, EQ curves and envelopes.

Waveform graphs

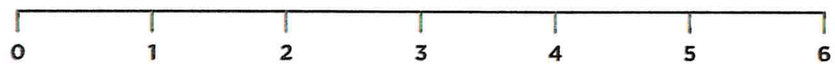
- A graph of a **waveform** shows us how the displacement changes over time, between its maximum positive and maximum negative values and around a zero line
- You may also see waveform graphs that show you a change in voltage over time.



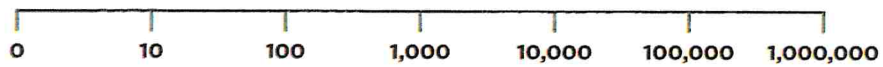
Logarithmic scales

- A **logarithmic** scale is used to represent orders of magnitude as a linear change

Linear scale



Logarithmic scale (base 10)



- The decibel scale and the **frequency** values on a filter or EQ graph are examples of logarithmic scales

- EQs are organised in this way because of our greater sensitivity to lower frequencies, and because doubling a frequency means moving an octave higher. For example, from 1000Hz to 2000Hz is a movement of one octave, but 1Hz to 1000Hz contains many octaves
- The decibel is a unit of sound pressure level. It uses a logarithmic scale because our ears don't respond to sound pressure in a linear way. Our ears hear logarithmically; a chainsaw is many times louder (when measuring pressure and power) than a conversation, but we don't perceive it like that
- When we use **dB** to measure sound pressure level, we can normally set meters to **Peak** or **RMS** mode

Peak	- A transient measure of loudness - The meter will give a momentary measure of the highest volume of the signal - Useful for setting input gains to avoid **distortion**, or to create pumping effects on compressors.
RMS	- Stands for Root Mean Square, an average measure of loudness - This is a much slower analysis than **peak** and is useful if you are looking for the average volume of something - Useful for measuring the overall volume of audio and is often used to gauge the volume of a track during the **mastering** process.

- Because of the way we perceive sound, we will hear sounds with a consistently higher level as louder than those with a loud peak but no sustained volume
- This type of **psychoacoustics** is why we sometimes hear a whole drum kit playing a beat as louder than a single cymbal hit.

Period

- **Frequency** (measured in Hz), is the number of **waveform** cycles per second
- The **period** of an oscillation is the amount of time a single cycle takes
- The frequency of an oscillation is directly related to the period of the oscillation:

Where frequency = f and period = T

$$f = 1 \div T$$

$$T = 1 \div f$$

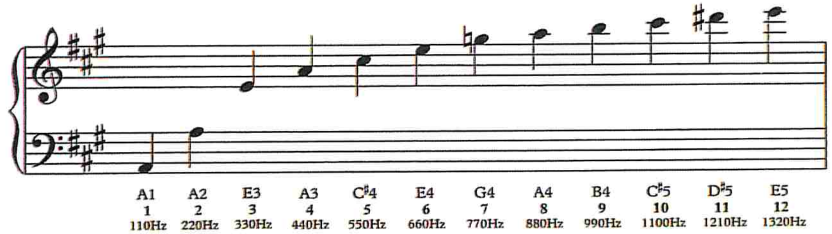
Frequency and musical intervals

In an exam, you don't have a calculator available to you to work out **frequency**/musical interval calculations; therefore, the maths needed will be something you can work out in your head.

Interval	Relationship	Equation
Octave higher	The octave higher is always double the frequency of the original.	$f = n \times 2$
Octave lower	The octave lower is always half the frequency of the original.	$f = n \div 2$
Perfect 5th higher	The perfect 5th higher is the mid-point between the original and octave higher.	$f = n \times 1.5$
Perfect 4th lower	Same note name as the perfect 5th above, but an octave lower.	$f = n \times 0.75$

Frequencies from the harmonic series

- If you know (or can work out) the fundamental frequency, you can approximate the frequency of a note in the harmonic series



- The fundamental frequency is also referred to as the first harmonic
- We can calculate the frequency of higher harmonics by using the calculation:

f_h = harmonic frequency

f_f = fundamental frequency

n = number of harmonic

$$f_h = f_f \times n$$

Calculating delay time from BPM

- To calculate the delay time of a crotchet at 100BPM in seconds:

  Delay time (s) = 60s ÷ crotchet beats per minute

  Delay time (s) = 60s ÷ 100

  Delay time (s) = 0.6s
- Sometimes it might be easier to use milliseconds. If you need to convert, remember that there are 1000 milliseconds in a second, so a delay time of 0.6s is equal to 600ms
- The delay time is for a crotchet (1/4). For a quaver (1/8), the delay time would be half as much, so 0.3. For a minim (1/2), the delay time would be twice as long, so 1.2 seconds
- Remember that you don't have access to a calculator in an exam, so the maths will always be doable in your head.

Converting between decimal and binary

- To convert a decimal number to binary we must work out what each place of the binary number is 'worth'. We will use an 8 bit binary number to demonstrate this
- The decimal number we will convert is 150. To do this we need to find the largest value that will fit into 150, drawing the table below. 128 is the largest number that fits into 150, so we put a 1 in that column

128	64	32	16	8	4	2	1
1							

- We then have 22 left over. 64 or 32 cannot fit into 22, but 16 can. So, we put 0s in the 64 and 32 columns, and 1 in the 16 column

128	64	32	16	8	4	2	1
1	0	0	1				

- This leaves us with 6 left over. 8 cannot fit into 6, but 4 can. This leaves 2 left over. 2 can fit into 2 exactly, leaving nothing left over. When this happens, we can fill all of the remaining columns with 0, as we don't have anything left over

128	64	32	16	8	4	2	1
1	0	0	1	0	1	1	0

- Therefore, 150 in binary is 10010110
- To convert between binary and decimal, you total up the numbers with a one in their column. So, in the example above, we add 2, 4, 16 and 128 to get a total of 150.

The sound of popular music

As you develop your skills in the practical tasks, you are also developing your critical and analytical listening skills – in fact, every time you listen to a piece of music you are doing this!

This section concisely covers the styles you need to know for your A Level in terms of:

- A brief outline of the style: dates, instruments and influences
- Main artists and their significant recordings
- The features of each style's technology and production.

It is useful to think of Music Technology as being divided up into five 'eras'.

c. 1930–1963	Direct to tape mono recording	■ Recordings often feature hiss due to the poor **signal-to-noise ratio** ■ Indistinct balance and **EQ** due to the limited number of tracks.
c. 1964–1969	Early multitrack recording	■ The balance could still be poor because of restricted tracks, especially on drums ■ A time of experimentation with effects.
c. 1969–1995	Large-scale analogue multitrack	■ Increased clarity of parts ■ More tracks meaning further chances to experiment and record with multiple microphones.
c. 1980–present day	Digital recording and sequencing	■ Repetitive loops in sequenced parts ■ Less hiss in digital recording ■ Brighter mixes.
c. 1996–present day	Digital audio workstations (DAW) and emerging technologies	■ Lots of editing ■ Flawless performances ■ Flex-Time and pitch/Auto-Tune.

To put this into context, turn to the styles and eras timeline on page 200.

A LEVEL COMPONENT 4

MUSIC TECHNOLOGY NUMERACY

LISTENING TASK-IDENTIFY THE FREQUENCY AND PITCH

Frequency (Hz) →	65	73	82	87	98	110	123	131	147	165	175	196	220	247	262	294	330	349	392	440	494	523	587	659	698	784	880	987	1047
Note →	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C

Keyboard →

THE RELATIONSHIP BETWEEN FREQUENCY AND MUSICAL INTERVALS

We observed in the listening task that an octave above a known frequency is twice the original frequency and an octave below is half the frequency.

We can therefore use the following calculations:

$f=n \times 2$ OCTAVE HIGHER e.g. original frequency 100Hz $f=100x2$, **f=200Hz**

$f=n / 2$ OCTAVE LOWER e.g. original frequency 100Hz $f=100/2$, **f=50Hz**

Calculating a perfect 5th (7 semitones):

$f=n \times 1.5$ PERFECT 5TH HIGHER e.g. original frequency 100Hz $f=100x1.5$, **f=150Hz**

The same note is a Perfect 4th (5 semitones) below:

$f=n \times 0.75$ PERFECT 4TH LOWER e.g. original frequency 100Hz $f=100x0.75$, **f=75Hz**

TASK-CALCULATE THE FOLLOWING FREQUENCIES

1. 845Hz an octave higher
2. 200Hz a Perfect 5th higher
3. 262Hz an octave lower
4. 400Hz a Perfect 4th lower
5. 349Hz an octave higher

1. 1690Hz
2. 300Hz
3. 131Hz
4. 300Hz
5. 698Hz

Listening:
The first note is 440Hz(A)
What is the frequency of the next note?

Challenge: What are the frequencies of a C major chord starting on Middle C(just the triad)

262Hz C
330Hz E
393Hz G

THE RELATIONSHIP BETWEEN FREQUENCY AND PERIOD

The PERIOD is the time it takes to complete one cycle

For example, 100Hz is a 100 cycles per second therefore it takes 100th of a second to complete 1 cycle(or 0.01s)

T=period

f=frequency

We therefore can calculate the frequency and period(and visa versa):

$f = 1/T$ if the period is 0.1s $f = 1/0.1$ f = 10Hz

$T = 1/f$ if the frequncy is 1Hz $T = 1/f$ T = 1sec

TASK-CALCULATE THE FOLLOWING FREQUENCIES

1. 0.0001s
2. 0.02s
3. 0.5s
4. 0.05s
5. 1s

1. 10kHz
2. 50Hz
3. 2Hz
4. 20Hz
5. 1Hz