Numbers, Shapes, Colours and Sounds

By John Foggitt

Numbers.

For those of you who didn't like maths or found it hard, you'll be pleased to hear that I'm not going to go into maths in detail, but I shall be covering some very simple maths. Numbers are very important in that anything we can measure from money to material for clothes, from temperature to voltage, from recipes to room dimensions, involves numbers. What I plan to do tonight is to show you some of the fascinating aspects of numbers when it comes to measuring colours and sounds and when creating interesting shapes for patterns, hence the title: Colours, Shapes, Sounds and Numbers.

Shapes.

We are all familiar with some of the regular geometric shapes such as triangles, squares, hexagons, etc., but there are many more interesting shapes that are easily created using tools such as a Spirograph or a computer. The nice things about a computer generated curve is that the pen and wheel never slip and once a curve has been created, it can be printed off as many times as required.

Here we have to look at some simple maths, trigonometry and polar coordinates, both very simple concepts. What do we call a 6 sided shape? What do we call an 8 sided shape? What do we call a 5 sided shape? What should we call a 3 sided shape? A trigon. Metry means measurement so trigonometry is simply measurement based on triangles, right angled triangles to be precise.

If we take a right angled triangle and divide the vertical line by the longest side, the result will depend only on the angle between the horizontal line and the longest line. If you double the length of one side but keep the angles the same, the other 2 sides will also double in length. This division results in a number called the sine of the angle. If we consider the horizontal line and divide that by the longest line, the result is called the cosine of the angle. That's basic trigonometry and you may be surprised at the patterns we can generate using sine and cosine. Now a word about polar coordinates. You can specify a position on a sheet of paper or a screen by how far across it is and how far up from the bottom left hand corner. But there's another way - we can say how far the point is from the bottom left hand corner and what angle a line drawn from the point to the corner makes with the horizontal. We still need 2 numbers or coordinates. The across and up system is known as x-y or Cartesian Coordinates and the distance and angle system is known as r-theta or Polar Coordinates. As angles are involved in Polar Coordinates, it immediately has something in common with sines and cosines and let me show you some patterns that this relationship can generate.

Colours.

Our retinas contain 3 types of colour receptors primarily sensitive to Red, Green and Blue. The red sensors cover a range of colours from red to green with peak sensitivity to red but also picking up at the violet end of the spectrum. The green sensors cover everything from red to blue with peak sensitivity to green and the blue sensors cover green to violet with peak sensitivity to blue. When we see a colour such as yellow, a colour midway between red and green, both the red and green sensors are equally sensitive to yellow so the brain interprets a colour which stimulates the red and green sensors equally as yellow. This means that a video display whether television or a computer monitor doesn't have to reproduce all the colours; it merely has to fool the eye/brain into believing that it sees a full range of colours. This is done by stimulating the red, green and blue sensors to different degrees as happens with real colours. In practice if you look closely at a colour video display you will see the red green and blue sections which are each so small that you can't see them individually at normal viewing distances; you see what appears to be a full spectrum of colours.

Computers and domestic cameras and camcorders use 24 bit colour. This means 2 times itself 24 times giving a total of 16 777 216 colours, of which there are many instances where the human eye cannot distinguish between 2 or more similar colours. Each component, red, green and blue can be any of 256 different brightness levels from 0 (black) to full brightness. When all are at full brightness, all colour receptors in our eyes are equally stimulated which gives us the impression of white.

Note that this is very different from mixing paint colours in that with a video display we are adding the component colours whereas with paint we are subtracting the component colours so the primaries for video are red, green and blue whereas the primaries for paint and printing are cyan, a light blue which reflects green and blue light, yellow which reflects red and green light and magenta which reflects red and blue light. Mix yellow and cyan (blue) and you get green because the cyan absorbs red and the yellow absorbs blue so the only colour reflected by both is green. We are subtracting red from the yellow and blue from the cyan.

Only about 3% of the colour receptors - known as cones because of their shape - in the retina are blue sensitive and scientists were puzzled when they started studying the eye because initially they only found red and green sensors. This situation also gives rise to the fact that blue makes a negligible contribution to brightness perception and since the eye focusses on edges between two areas of different brightness, with two adjacent colours differing only in the amount of blue, the eye has difficulty focussing. So on a computer screen, you should never have such colours adjacent. Typical combinations are blue on black or yellow on white - very difficult to see clearly.

Another rule for computer displays is, "Don't put colours far apart in the spectrum together. This means red and blue should never be adjacent. The reason for this is that the lens in the eye, as with all lenses unless they are specifically designed to avoid this, focusses differently for different colours. With ordinary living it's not a problem because we rarely encounter pure colours, except on computer screens

Sounds.

These are vibrations in the air ranging from 20 to 20000 vibrations per second or Hertz although as we get older, our ability to hear the higher frequencies deteriorates. When I was at school in the sixth form my upper limit was about 17,200 Hertz. Some asthmatics can hear as high as 30000 Hertz which is of the same order as a dog whistle. The number of vibrations per second is known as the frequency. A qualitative description of the frequency is known as pitch. What is interesting about sounds is the shape of the sound waves which determine the timbre or tonal quality of the sound. Here I'm going to introduce a simple branch of maths relating to triangles and angles. What do we call a six sided shape? What do we call an eight sided shape? What do we call a many sided shape? What should we call a three sided shape? A trigon. The branch of maths relating to measurements based on triangles is known a trigon-o-metry or trigonometry and the basics are very simple but have some surprising consequences.

The sine of an angle is the opposite side of a right angled triangle divided by the hypotenuse. Now if we plot a graph of the sine of an angle against the size of the angle we get a wave, known as a sine wave for an obvious reason. If we take the sine of double the angle it is known as the first harmonic in Britain but the second harmonic in the USA, a bit like floors in a building - what we call the first floor the Americans call the second floor, etc.

As we add whole number multiples of a frequency, usually at reduced volume, to the fundamental frequency, the tonal quality or timbre of the sound changes.