DRONES: FRIEND OR FOE?

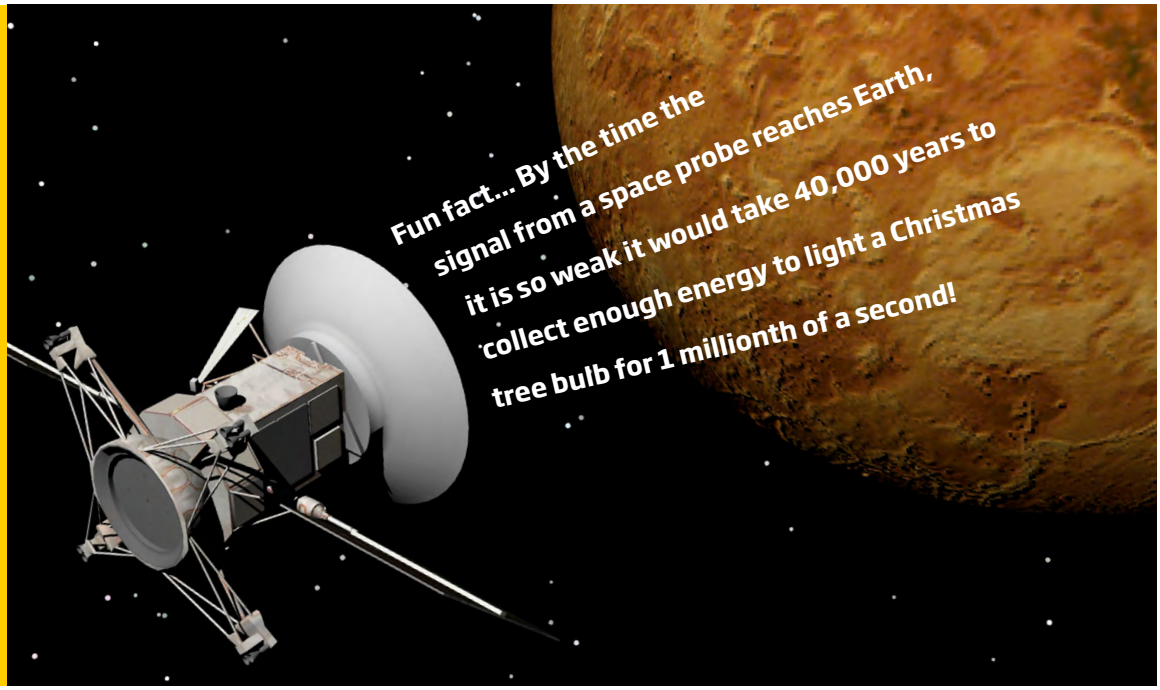
Remote data

ROYAL ACADEMY OF **ENGINEERING**

THIS IS ENGINEERING

This resource is based around how space probes send data they have collected back to earth.

How do space probes send data back to Earth?



Magellan spacecraft near Venus

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1. Microwaves

Space probes use microwaves for communications. Microwaves have a high enough frequency to pass through the atmosphere rather than being reflected by the ionosphere like lower frequency radio waves.

2. Binary

Space probes and computers only understand two states, on and off. We can represent that using binary numbers. Binary is a base-2 number system with only two digits, 1 or 0. A "1" or a "0" is called a bit.

Images that use binary to code a grid of coloured squares or pixels are called bitmap images. One bit of information per pixel can be used to create simple black and white images. If a pixel has the value 0, it is black. Then a pixel with the value 1 is white. For example, a 2 x 2 square bitmap with the values 1, 0, 0, 1 would look like this:

The first pixel has a value of 1, so is white. The second pixel has a value of 0, so is black. Starting on the next line, the value of the third pixel has the value 0, so is black. The fourth has a value of 1, so is white.

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There are 10 types of people in this world, those that understand binary and those that do not!

Activity 1 – Creating a black and white bitmap

In groups of four, each turn a different of binary code into an 11 x 11 bitmap using the grid from your teacher.

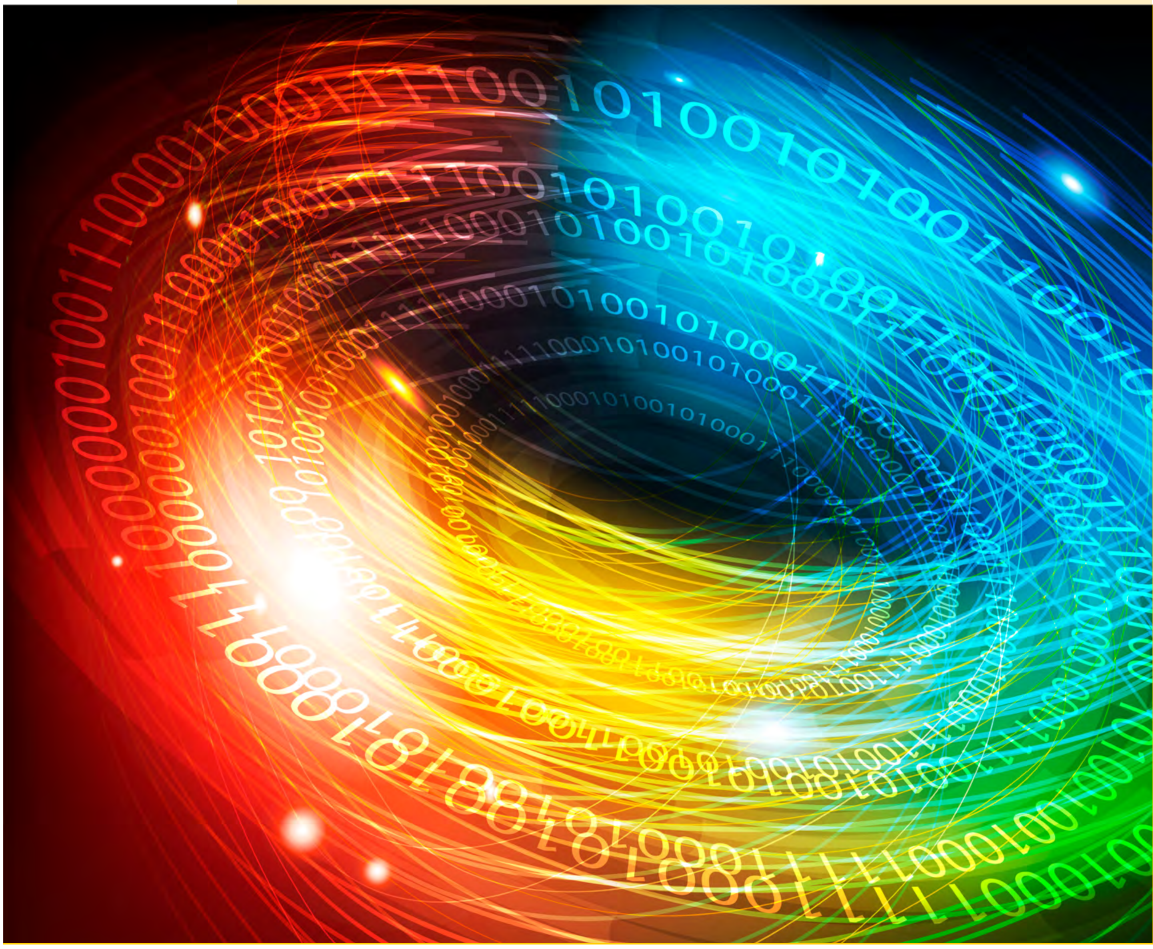
0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1, 1, 0, 0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1.

1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0.

1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.

1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.

Work out how to combine the four pictures into one 22 x 22 bitmap. What is in the picture?



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Activity 2 – Creating a grey scale bitmap

Images with better colour depth can be created using more information per pixel. For example a pixel can have two bits of information, meaning there are four colours available. The pixel could take the values 00, 01, 10 or 11 for black, dark grey, light grey, and white respectively. For example, a 2 x 2 square bitmap with the values 00, 01, 10, 11 would look like this:

The space probe has taken a second picture of the object from activity 1 with two bits per pixel. In groups of four, each turn a different of binary code into an 11 x 11 bitmap using the grid from your teacher.

00, 00, 00, 00, 00, 00, 00, 00, 01, 11, 11, 00, 00, 00, 00, 00, 00, 01, 01, 10, 11, 11, 00, 00, 00, 00, 01, 01, 01, 11, 10, 01, 01, 00, 00, 00, 01, 01, 01, 01, 01, 01, 01, 01, 00, 00, 01, 01, 01, 01, 01, 01, 01, 01, 01, 00, 01, 01, 01, 01, 01, 01, 01, 01, 01, 00, 10, 01, 01, 01, 10, 01, 10, 10, 10, 01, 00, 11, 01, 01, 01, 10, 01, 10, 10, 10, 01, 10, 01, 01, 01, 01, 10, 01, 01, 01, 01, 01, 11, 11, 01, 01, 01, 01, 01, 01, 11, 01, 11, 11, 11, 11, 11, 10, 01, 01, 01, 10, 11, 11.

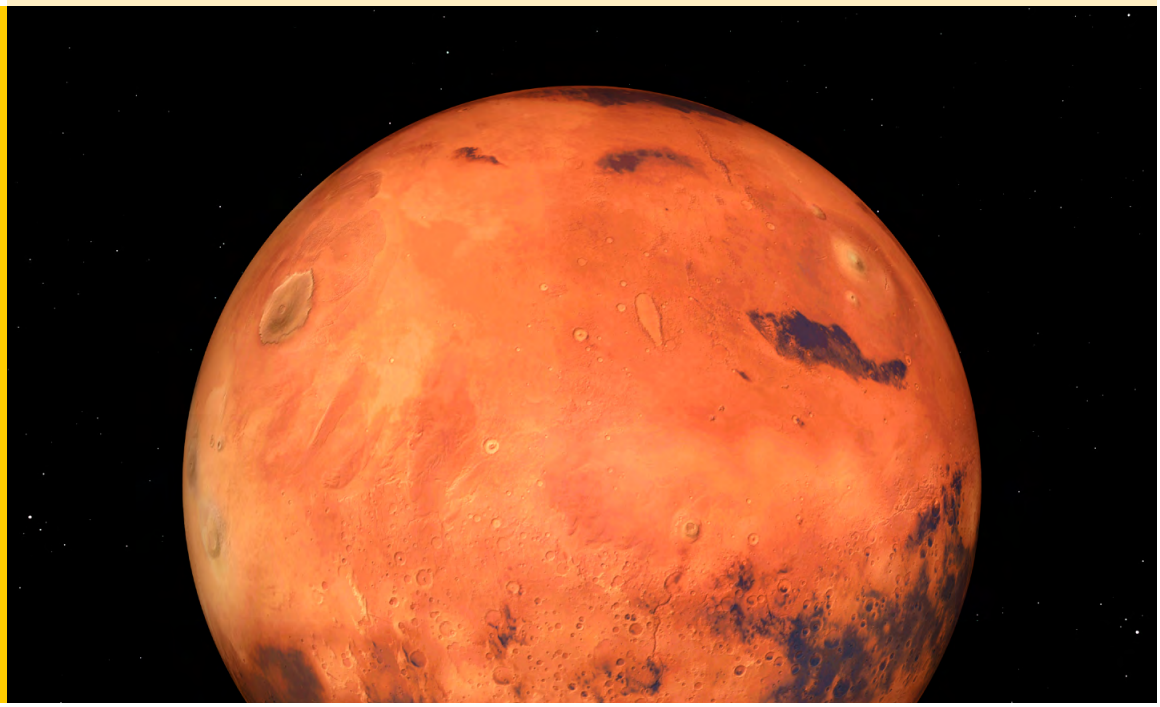
11, 01, 00, 00, 00, 00, 00, 00, 00, 00, 00, 01, 11, 11, 11, 10, 00, 00, 00, 00, 00, 00, 01, 10, 11, 11, 11, 11, 00, 00, 00, 00, 00, 01, 01, 11, 11, 11, 11, 11, 00, 00, 00, 00, 01, 01, 11, 11, 11, 01, 11, 11, 00, 00, 00, 01, 11, 11, 11, 11, 11, 01, 11, 11, 00, 00, 10, 11, 11, 11, 11, 11, 11, 11, 11, 00, 00, 01, 11, 11, 11, 11, 11, 11, 11, 11, 10, 00, 11, 01, 10, 01, 01, 10, 11, 01, 11, 10, 00, 01, 11, 11, 10, 01, 11, 01, 10, 01, 01, 00, 11, 11, 11, 11, 01, 01, 01, 11, 11, 10, 00.

11, 11, 11, 11, 01, 10, 10, 10, 10, 01, 11, 11, 11, 10, 10, 01, 10, 01, 01, 01, 10, 11, 10, 11, 01, 10, 01, 10, 01, 01, 01, 11, 11, 00, 11, 11, 11, 11, 01, 10, 11, 11, 11, 11, 00, 11, 11, 11, 11, 11, 11, 11, 11, 11, 11, 00, 00, 11, 11, 11, 11, 10, 10, 11, 10, 11, 00, 00, 00, 11, 11, 10, 11, 11, 10, 11, 11, 00, 00, 00, 00, 11, 11, 11, 11, 11, 11, 11, 00, 00, 00, 00, 00, 00, 01, 11, 11, 11, 11, 11, 00, 00, 00, 00, 00, 00, 00, 00, 11, 11, 11, 00, 00, 00, 00, 00, 00, 00, 00, 00, 00.

11, 01, 11, 11, 11, 01, 01, 11, 11, 10, 00, 11, 11, 01, 11, 11, 10, 10, 11, 11, 10, 00, 11, 11, 11, 10, 11, 10, 10, 11, 11, 11, 00, 11, 11, 11, 11, 10, 10, 10, 10, 11, 00, 00, 11, 10, 10, 11, 11, 10, 11, 11, 11, 00, 00, 11, 11, 11, 11, 11, 11, 11, 11, 00, 00, 00, 11, 11, 11, 11, 11, 11, 11, 00, 00, 00, 00, 11, 11, 11, 11, 11, 11, 00, 00, 00, 11, 11, 11, 11, 01, 00, 00, 00, 00, 00, 00, 11, 01, 00, 00, 00, 00, 00, 00, 00, 00, 00, 00, 00, 00, 00, 00, 00, 00, 00, 00, 00, 00, 00, 00, 00, 00.

Put these four images together, what does the picture now show?

Colour image of Mars



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Activity 3

To create colour images, the space probe takes pictures through different coloured filters. Each filter will only let through a certain colour; for example a blue filter will let through only blue light. So the blue-filtered picture will show the brightness of blue as a grey scale bitmap. If you had a red, green and blue bitmap and combined the pixel data, you could create a colour image.

Investigate what different objects look like through different filters.

- What does a white object look like through a red filter, a green filter and a blue filter?
- Why does the white object appear black if you look at it through all three filters?

Investigate how different colours combine.

In groups, put the three filters in front of different torches or ray boxes. Shine the different coloured lights onto a white surface.

What colour does the light appear to be when using the following combinations:

- Red and blue?
- Red and green?
- Blue and green?
- Red, blue and green?

3. Phase modulation

To send information back to Earth in the form of binary, space probes use phase modulation; changing the phase of the radio wave to represent a 1 or a 0. Digital phase modulation is called phase shift keying or PSK. The simplest form of PSK is binary phase shift keying, BPSK, which uses two phases that are separated by 180°.

All data is transmitted by a wave with a particular wavelength and amplitude known by both the probe and the receiver on Earth; this is called the carrier wave. The space probe will instantaneously change the phase of the wave transmitted to Earth to represent a 1 or a 0. A wave received 0° out of phase (or in phase) with the carrier wave represents 1. A wave 180° out of phase with the carrier wave is a 0.

Carrier wave **1** **0**

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Very Large Array (VLA) radio astronomy observatory, New Mexico USA. In 1989 the VLA was used to receive communications from the Voyager 2 spacecraft as it flew by Neptune


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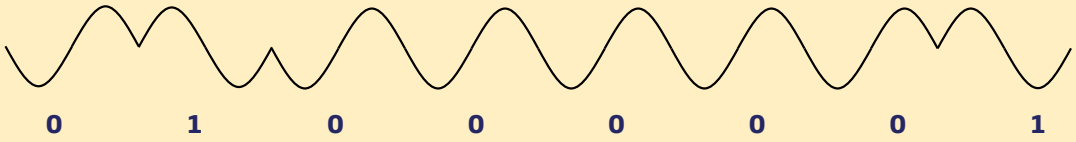
Activity 3 – Sending a message

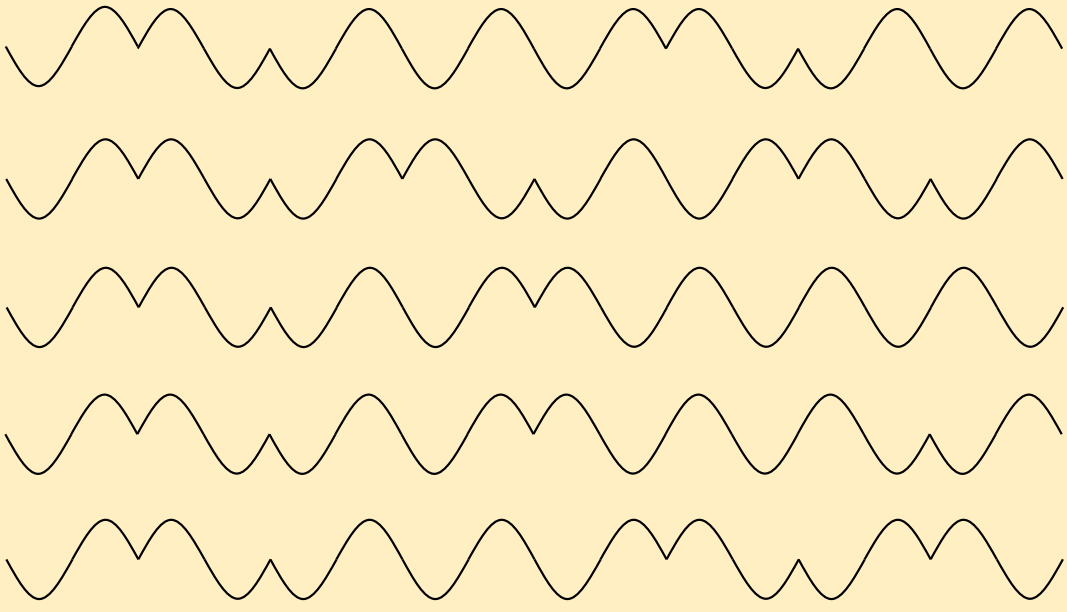
Binary can be used to send words and numbers as well as pictures. This is similar to how mobile phones send and receive text messages.

Letter	Binary code	Letter	Binary code
A	01000001	N	01001110
B	01000010	O	01001111
C	01000011	P	01010000
D	01000100	Q	01010001
E	01000101	R	01010010
F	01000110	S	01010011
G	01000111	T	01010100
H	01001000	U	01010101
I	01001001	V	01010110
J	01001010	W	01010111
K	01001011	X	01011000
L	01001100	Y	01011001
M	01001101	Z	01011010

The table shows the alphabet in binary code, so if the letter A were to be sent as a signal to Earth with one wavelength representing one bit of information the waveform would look like this:



Can you work out what this message says?



Notes for teachers

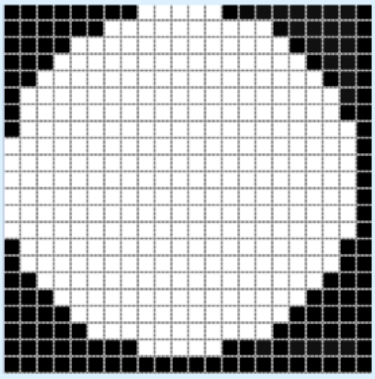
Working in groups

It is advised that for activities 1 and 2 the students work in groups of four to create the bitmap image.

Using the grids provided students should colour in the squares according to their bitmap and fit together the four corners to produce pictures of the moon.

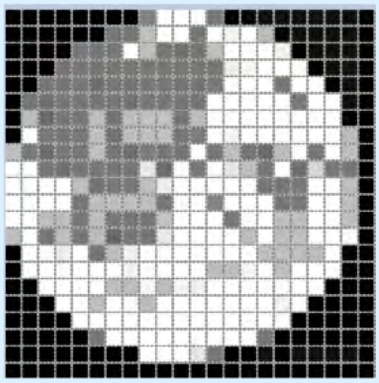
Activity 1

The picture should look like this:



Activity 2

The picture should look like this:



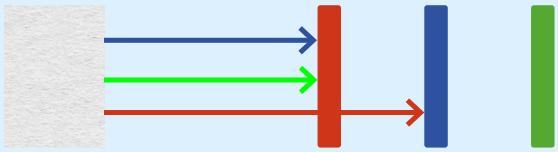
From the first image, the probe could have taken a picture of anything round. With the second image, we can start to see the craters of the moon.

The resolution of a bitmap image can be improved by having a higher pixel density. Resolution is measured in dots per inch (dpi). Images on websites usually have a resolution of 72 dpi. This means that a 1-inch square contains a grid of pixels that is 72 pixels wide by 72 pixels high.

Activity 3

Filters work by blocking all wavelengths of light except for the colour of the filter. This means a red filter will only let red light through, making everything appear red; a blue filter will only let blue light through, making everything appear blue and a green filter will only let green light through, making everything appear green.

Objects will appear black when observed through all three filters as no light is able to pass through.



The red filter blocks the blue and green light, the blue filter then blocks the red light so no light can reach or be transmitted through the green filter.

Red and blue light combine to make magenta
Red and green light combine to make yellow
Blue and green light combine to make cyan

Red, blue and green light combine to make white

Activity 4

The word is DRONE.

You could extend this by asking the students to write their own binary message and send it as a signal to other students.

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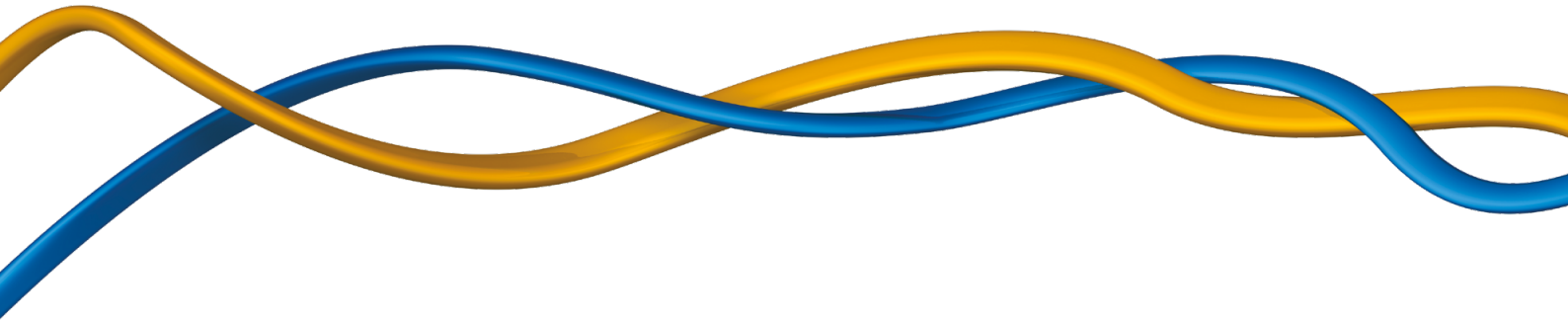

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