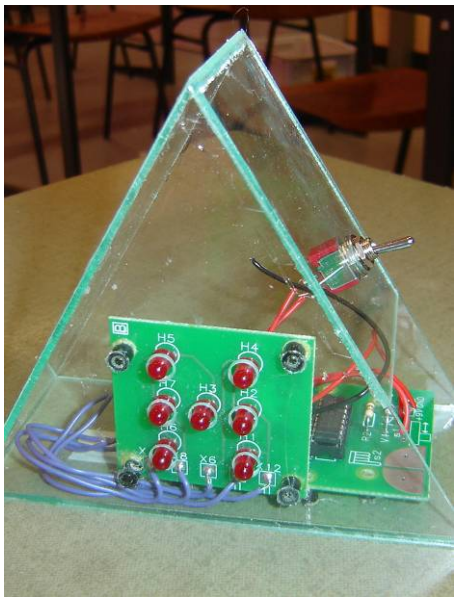
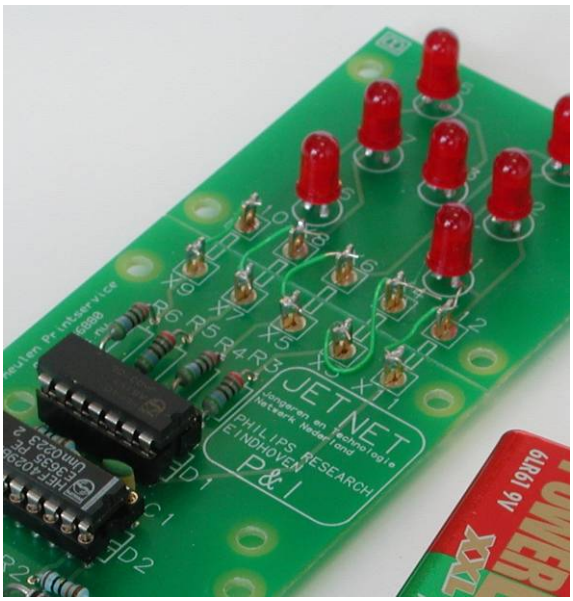
THE ELECTRONIC DICE

a technology project for secondary education





Name: _____

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Many parties were involved in making this lesson / project available for schools:

This technology project was originally developed by Philips (The Netherlands) for the Dutch Jet-Net-project and incorporated in the EU "Ingenious" project of European Schoolnet (EUN).

Jet-Net, the Netherlands Youth and Technology Network, is a partnership between companies, education and government. The aim is to provide higher general secondary school (HAVO) and pre-university school (VWO) pupils with a true picture of science and technology and to interest them in a scientific-technological higher education course.

European Round Table of Industrialists

ERT is a forum bringing together around 45 chief executives and chairmen of multinational industrial and technological companies with European heritage with sales volume exceeding € 1,000 billion and thereby sustaining around 6.6 million jobs in Europe. ERT advocates policies at both national and European levels which help create conditions necessary to improve European growth and jobs. ERT was the initiating force for the EU Coordinating Body (ECB), now called "Ingenious," to disseminate proven best practices of industry-school cooperation to stimulate interest in careers in science and technology throughout the European Member States.

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European Schoolnet (EUN) is a network of 30 Ministries of Education in Europe and beyond. EUN was created to bring innovation in teaching and learning to its key stakeholders: Ministries of Education, schools, teachers and researchers. The "Ingenious" project is coordinated by European Schoolnet.

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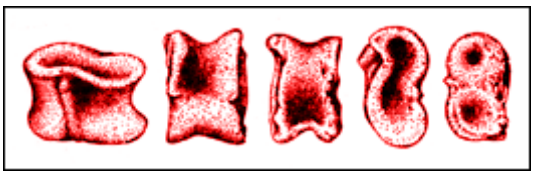
1. THE HISTORY OF THE DICE

You must have played with a dice at some time, for example when playing Yahtzee or Monopoly. Dice have existed for a very long time. The first known six-sided dice were found in Iraq and were made in 2750 B.C. They were made of terracotta, with small holes for the spots.

Originally dice were used for sorcery and to predict the future. A wise man from the village would roll the dice and, depending on the outcome, would predict what auspicious or inauspicious events were going to happen in the future. As time went on, however, dice were used more and more for gambling and playing games.

Besides dice, certain bones of animals, such as deer, calves, sheep and goats, were also used for this. These bones had four flat sides, each of which had a different appearance.



Since the sides were different, they did not need to be numbered. The highest throw was if you threw four bones at once and got four different sides showing. This throw was called *Venus*. Bones are still used in some primitive tribes. In Arabic the word for knucklebone is the same as the one for dice.

In several cultures cheating was known at an early stage: Roman dice with two fours have been found, for example!

After you have read the text thoroughly, answer the following questions.

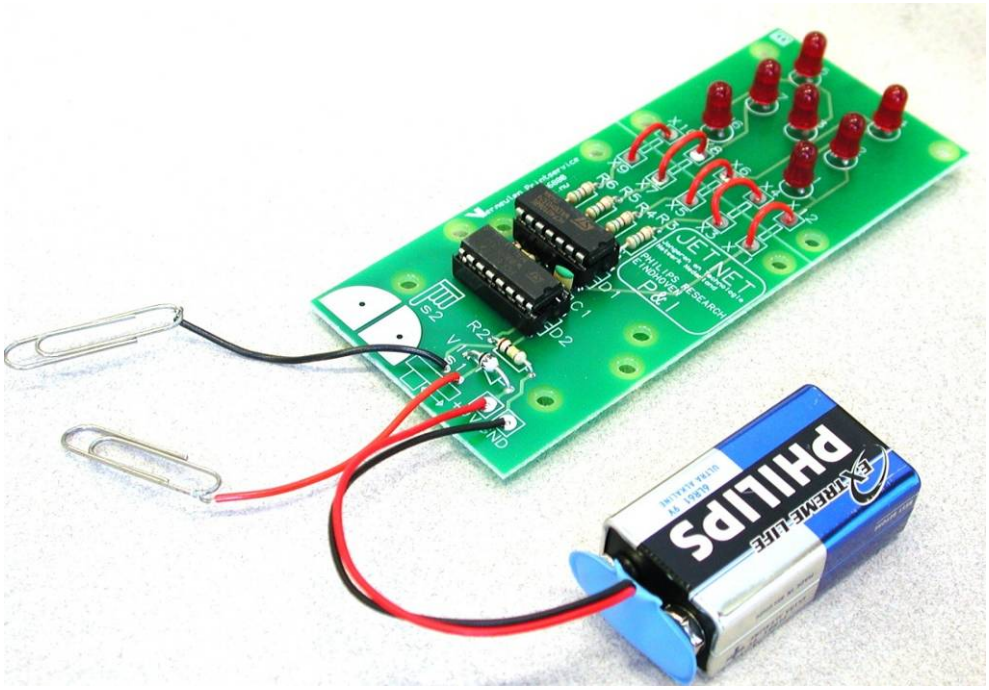
1. In which country were the first six-sided dice found?
2. For how many years have dice existed?

When you roll a dice, there are six possible outcomes (1, 2, 3, 4, 5 or 6). When you roll two dice, there are 6 x 6 = 36 possibilities.

3. How many possible outcomes are there when you roll four dice? Explain your answer.

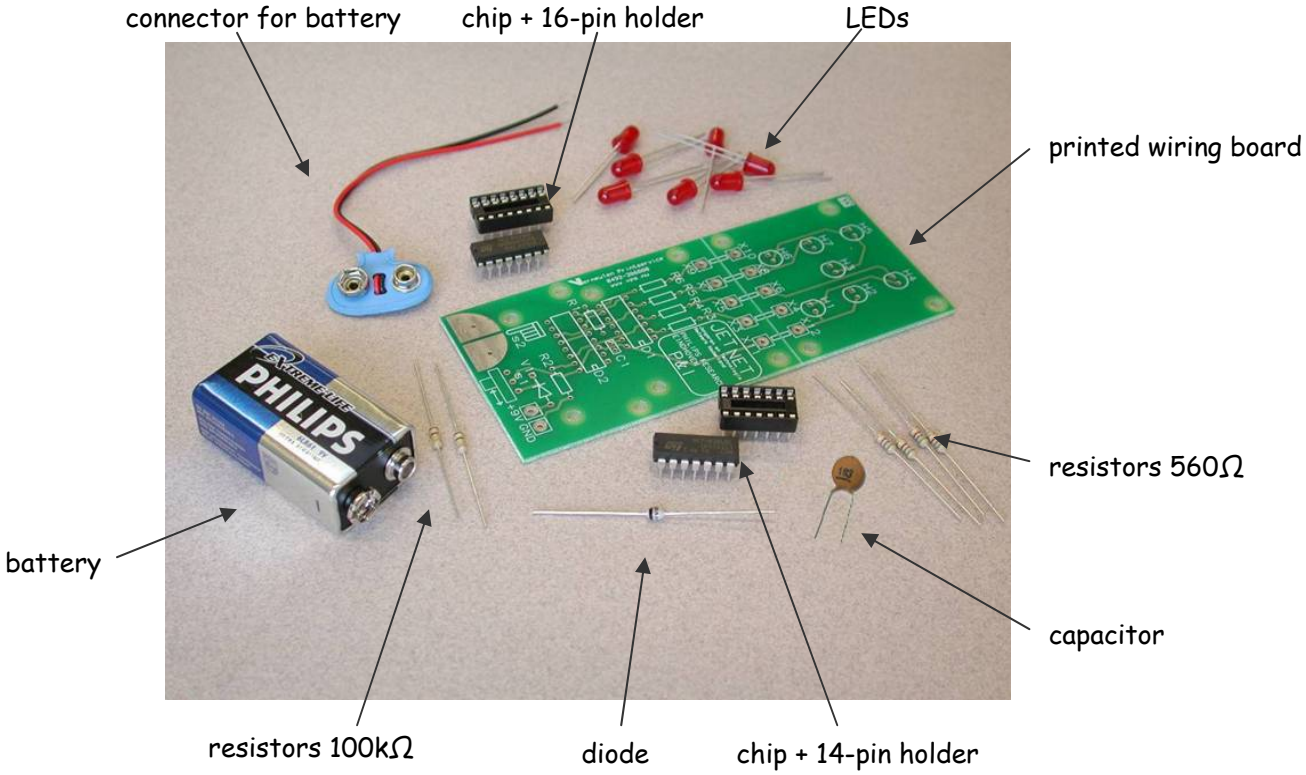
2. THE COMPONENTS OF THE ELECTRONIC DICE

This project involves building your own electronic dice. You can use it instead of an ordinary one. The picture shows you what it will look like when you have built it.



Using a switch developed by you, you can turn the battery on. After that you press the contact switch to 'throw' the dice. Some of the LEDs will light up. The LEDs are basically the spots on the dice. The number of LEDs that light up is unpredictable. Your own electronic dice!

Below you can see the various components you will need to build the electronic dice. The printed wiring board has a drawing on it showing where to solder the different parts.



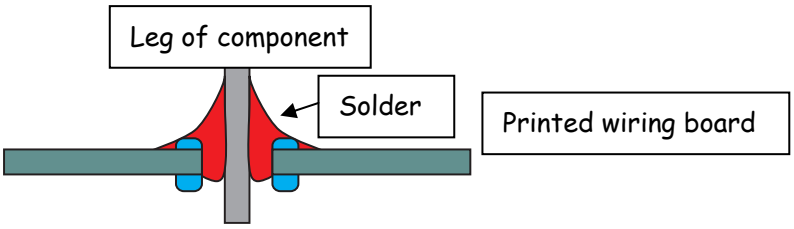
parts	symbol
1 circuit board	
7 LEDs (light emitting diodes)	
2 resistors 100kΩ	
4 resistors 560Ω	
2 integrated circuits (IC / silicon chips) – 1 x 14-pin, 1 x 16-pin	
2 IC holders – 1 x 14-pin, 1 x 16-pin	
1 capacitor	
1 diode	
1 battery (9-volt)	- +
1 battery clip	

3. BUILDING THE ELECTRONIC DICE

This assignment involves soldering various components, two integrated circuits (ICs) and metal wires to a given circuit board. Looking at the drawing, you can see how and where to attach the various items. You will also need a switch. The challenge for you is to develop one yourself and use it in your circuit.

Placing the components

The different components will be mounted at the front of the circuit board and soldered at the back. This means you have to bend the wires of the components in such a way that they fit through the holes. Do them one by one, starting with the smallest component. Solder each wire to the back of the circuit board and cut off the excess wire.



Be alert, though. Some components (the LEDs and the diode) must be mounted in a specific way. Check carefully the positive and the negative side before soldering these items. It is very important to mount them the correct way because otherwise your circuit will not work.

The *LEDs* are rounded flat at the bottom on one side. This is the negative side of the LED. The side where the flat part must go is indicated on the assembly diagram. You can also recognise the negative side by the shortest leg of the LED.

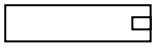
The black stripe on the diode should be on the same side as the stripe on the diode symbol on the PCB. See the assembly diagram for the correct position.

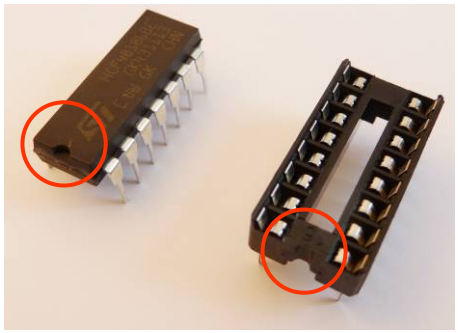
Placing the integrated circuits

ICs are very sensitive to static electricity (like the sparks you can sometimes feel when getting out of a car) and can break as a result. When mounting the ICs we therefore use IC holders. These IC holders will be soldered at the spot indicated on your circuit board.

<u>Make sure that you don't accidentally solder the legs of the chip base together or they will make a short circuit.</u>

If an IC breaks it can easily be replaced by taking it out and placing a new one. The IC holder has the same number of holes as the number of pins on the IC.

Both the IC and the IC holder should be placed the same way. You will find a semi-circle on one end of both of the items. On the circuit board this side is indicated by a small rectangle. It looks like this:  . Check before soldering the IC holder to the circuit board.



Placing the wires

A wire used in electronics is usually made of a conductive inner wire with a non-conductive shell around it. When soldering these wires you will have to remove some of the shell using a wire stripper.

- Remove the sheathing using stripping pliers.
- The wire inside consists of a bundle of very thin copper strands. Twist these strands together firmly.
- Now solder the bald copper wire at the right place.
- If the stripped end will not go through a hole, remove five or so of the twenty strands in the bundle.

The battery clip is also mounted using wires. The red wire is the positive one, the black one the negative or earth.
To connect the battery, solder the red wire in the +9V hole and the black wire in the GND hole (GND = ground = earth) on the PCB. This is also shown on the assembly diagram. The connector can be pressed onto the battery in only one way. The dice's control electronics is now ready for use.

To be able to connect the control panel to the LEDs you will have to solder five wires on each side. The wires may be of varying length, depending on the placement of the two sections of circuit board. Connect

- X3 to X4, X5 to X6, X7 to X8, X9 to X10 and X11 to X12.

Developing the switch

A switch is used to switch the battery to the e-dice circuitry on so that the current will flow and make your circuit work. You will have to design your own switch using simple materials. You must stick to the following specifications (requirements):

- the switch has two possible positions: open or closed
- you must be able to see clearly if the circuit is on (closed) or off (open)
- the switch should be made out of simple and cheap materials that can be found in the technology room.

4. Design you own switch. Make clear drawings and explain them using annotations. Have your teacher check it before making the switch and connecting it to your circuit.

4. TESTING THE ELECTRONIC DICE

You have finished your e-dice.
Now it gets exciting: we're going to test whether it works!

ATTENTION:
To avoid irreparable damage to the chips, first check again whether the marks on both chips are in the correct position (see page 7 – mounting chips)!

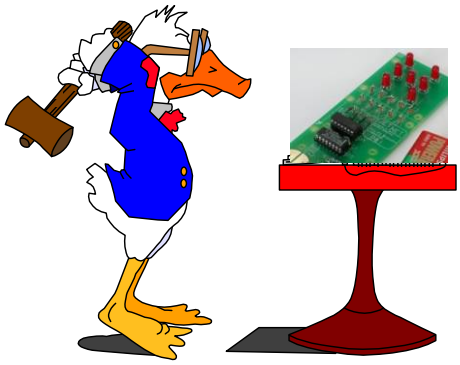
Test 1 – Does it work?

Switch your circuit on using the switch you have developed yourself. Use your index finger to press the contact switch (the one on the circuit board or your own design) several times. Do the LEDs light up in various combinations?

YES→ Congratulations! Go further to Test 2
NO → Check the following…

1. Wet your finger a little and try again.
2. Is the battery connected the correct way? Check positive and negative.
3. Are the LEDs mounted the correct way? Check positive and negative (= flat side).
4. Is the diode connected the right way? Check positive and negative here as well.
5. Check all the connections you have made (the soldering work).
6. Have you answered yes to all of the above? Does your circuit still not work?

Now ask for help!



Test 2 – Is the dice you created a fair one?

There is really only one way to find out if your dice is fair to play with, and that is by using it a lot. According to statistics a fair dice will show all possibilities in equal amounts after throwing it a certain number of times.

5. How many times do you think you should throw the dice to test your electronic dice properly?

Use your own e-dice and an ordinary one and throw them the number of times you stated in question 5.

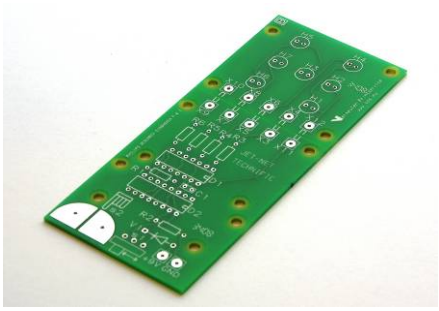
6. Enter the outcomes in the tables on the answer sheet
7. Is your electronic dice fair? Explain your answer.
8. Give three advantages of the electronic dice over the ordinary dice.

A. EXPLANATION OF THE COMPONENTS

We explain what each component is for and how it works.

PCB

A PCB (printed circuit board) is a plastic board which has conductive wires (*tracks*) on the front and back. The tracks make the connections between the components of a circuit. This makes it possible to connect a large number of components quickly and easily in a small space.



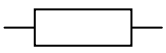
LEDs (lamps)

LEDs (light emitting diodes) are small electronic lamps. The electric current can flow through an LED in only one direction and for this reason it is important to be very careful how you connect the LEDs.

A LED is indicated on the PCB by the symbol: 

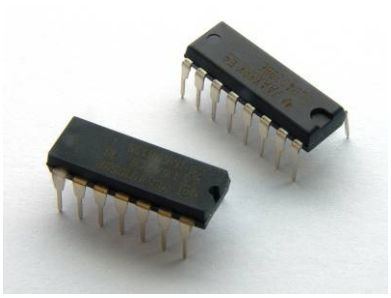
Resistors

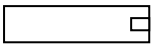
Resistors are used to reduce the voltage in a circuit. For the electronic dice we use two types of resistor. There are two 100 kΩ resistors and four 560 Ω resistors.

A resistor is indicated on the PCB by the symbol: 

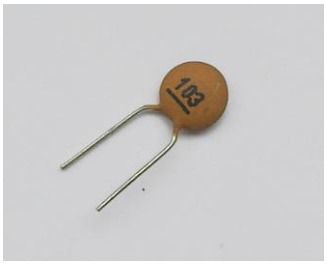
Chips

Chips contain a large number of circuits on a very small board. They can be programmed to perform various tasks. When making the electronic dice we use two different types of chip, one with 14 legs – this one is programmed to generate electrical pulses – and one with 16 legs – this one is programmed to count electrical pulses. From now on we will call these chips the 14-leg chip and the 16-leg chip.



A chip is indicated on the PCB by the symbol: 

Capacitor



A capacitor can temporarily store electricity. Charging is slower than discharging.

The capacitor is indicated on the PCB by the symbol: 

Diode

A diode conducts electric current very well in one direction, but hardly at all in the other direction. So it is important to connect the diode correctly.

The diode is indicated on the PCB by the symbol: 

B. READING THE COLOUR CODING ON RESISTORS

Resistors have colour coding indicating the value of the resistance. This colour coding was introduced years ago, in the days when it was not possible to print legible numbers on such small areas.

However, colour coding also has its advantages. If one printed digit is rubbed off, the value of a resistor can no longer be read. But it is highly unlikely that the entire ring of a particular colour will disappear. Nowadays a small number of modern components do have the value printed on them. If you had to sort a dish full of those little things you'd wish you had the colour coding back!

A resistor also usually has a gold or silver band. This gold or silver band is the last ring of the code and indicates the tolerance. This is because resistors never have the exact value indicated by the colour coding. The tolerance gives the possible deviation from the value indicated. A gold band means that the value of the resistor may deviate from the indicated value by 5%; a silver band means that the tolerance is 10%.

To work out the value of a resistor from the colour coding, first look where the gold or silver band is located. You then start reading from the other side. The table below shows the values represented by a particular colour.

First and second colour bands	Value	No. of zeros (third colour band)
BLACK	0	none
BROWN	1	0
RED	2	00
ORANGE	3	000 (=1k)
YELLOW	4	0,000 (=10k)
GREEN	5	00,000 (=100k)
BLUE	6	000,000 (= 1M)
VIOLET	7	0.000,000 (= 10M)
GREY	8	00.000,000 (= 100M)
WHITE	9	000,000,000 (= 1G)

Write down the figure represented by the first colour band and then the figure represented by the second one. Place after them the number of zeros that corresponds to the third colour band as shown in the table.
The value is in ohms (Ω).

An example:

The first line/band is brown, meaning a 1;
The second band is black, representing a 0;
The third band is red, which means you must add two zeros;

The value of the resistor is 1 0 00 = 1,000Ω (or 1kΩ).

9. Calculate the value of the following resistors:

Resistor A

Resistor B

10. Calculate the values between which these two resistors may lie according to the tolerance.

11. Work out the colour bands of resistors with a value of 100 kΩ and 560 Ω, each with a tolerance of 5%.

C. HOW THE ELECTRONIC DICE WORKS

But just how does the electronic dice work? In the following section we discuss the various components in the electronic dice.

Fill in the answers on the answer sheet.

Pulse generator

The 14-leg chip, the capacitor and a 100 kΩ resistor together make up the pulse generator.
A pulse generator switches between a high (9-volt) and a low (0-volt) voltage. If you connect a pulse generator to, say, a lamp, the lamp will blink at a certain frequency.
The frequency of the pulse generator in the electronic dice is 1111 Hz.

12. Calculate how long the lamp lights up when connected to a pulse generator with a frequency of 1111 Hz. Explain your answer.

Pulse counter

The 16-leg chip and four 560 Ω resistors together make up the pulse counter. As the name suggests, the pulse counter counts the number of pulses it receives. The pulse counter in the electronic dice is set in such a way that it counts from 1 to 6.

13. Say the pulse counter in the electronic dice is connected to the pulse generator for one second.
Calculate how often the pulse counter counts to 6 in this second.

Binary numbers

The pulse counter in the electronic dice is a binary counter. This means that it counts in zeros and ones. There is a relationship between various combinations of ones and zeros and the decimal figures that we normally use for counting (0, 1, 2, 3, 4, 5, 6, 7, 8 and 9).

A decimal number is made up of *powers of 10*. For instance, the number 406 is equal to $6 \times 10^0 + 0 \times 10^1 + 4 \times 10^2$. Just work it out. You will see that from right to left the digits in the number 406 are multiplied by increasing powers of 10.

A number in the binary system is made up of *powers of 2*. For instance, the number 110 is equal to $0 \times 2^0 + 1 \times 2^1 + 1 \times 2^2$. If you calculate this you get 6.

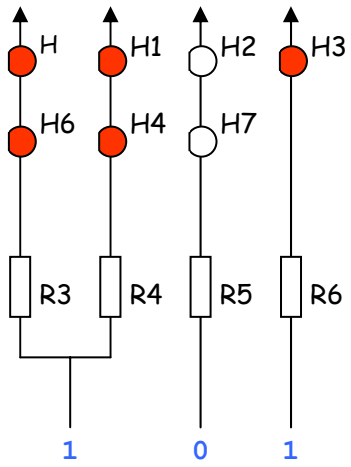
14. Calculate the decimal number represented by the following four binary numbers:

01010
10001
01111
11111

The pulse counter in the electronic dice can count from 1 to 6.

15. You already know that 6 = 110.
Now convert the decimal numbers 1 to 5 to binary numbers consisting of three figures.

The pulse counter in the electronic dice has three outputs (legs), which are connected via the four resistors to the seven LEDs. Via these three outputs the pulse counter counts in binary form from 1 to 6. When an output is on "1" the connected LEDs light up and when an output is on "0" they are off. In the diagram below you can see how the three outputs are connected to the seven LEDs. The outputs are shown at the bottom of the diagram. You can see that five lamps do indeed light up for the number 5 (101).



16. In the diagram on your answer sheet you can see how the lamps are arranged on the PCB.
In the diagram on the answer sheet, colour in the lamps that will light up in the case of the decimal number 3. Explain how you arrived at this.

Combination of the pulse generator and the pulse counter

You will build the electronic dice in such a way that the pulse generator and the pulse counter are connected when you press the touch switch (the silver-coloured area on the PCB).

Since the pulse generator has such a high frequency, the pulse counter will start counting very rapidly. As a result, different combinations of LEDs will light up in very quick succession. So it will look as if all seven LEDs are permanently lit up. As soon as you take your finger off the touch switch the pulse counter stops counting (it is impossible to say in advance what number it will stop at - it is simply going too fast). The LEDs stop in a certain combination. You have rolled the electronic dice!

D. SOLDERING

What is soldering and what is it used for?

Soldering is joining two metals by means of another metal. With soldering the two parts to be joined do not melt. Soldering is actually a kind of gluing with molten metal as the adhesive. Soldering is used for example to join metal wires to electronic components and to fasten components on a PCB.
Soldering requires a soldering iron and tin solder.

How do I solder a component to the PCB in 10 steps?

1. Switch the soldering iron on.

Be careful: soldering irons get hot (~ 350° C)!

2. If possible, secure the PCB.
3. Check that the PCB and the component are quite clean.

The soldering iron must be clean as well. Do this as follows:

4. When the soldering iron is hot, melt a small amount of tin solder on the tip.
5. Wipe the tip clean with a wet sponge.

Once the iron is clean you can start soldering.

The order is: iron on – add soldering tin – melt soldering tin - iron off.
How exactly you should do this is explained in points 6, 7 and 8.

6. Heat up the soldering area on the PCB and on the component at the same time with the tip of your soldering iron.

Note: both elements must be the same temperature
Note: solder quickly, do not let the components get too hot!

7. Keep the tip of the iron firmly against the soldering area while you melt a thin film of tin solder on the soldering area. Use a small amount of soldering tin as the legs of the components often have to be close together.

Note: apply the solder to the soldering area, not to the iron!
Note: two different soldered joints must not touch one another (otherwise a short-circuit will result)!

8. Remove the soldering iron and allow the joint to cool down for a few seconds.

Note: do not move the joint until the solder is cold!

9. Check that your joint is firm enough.
10. When you have finished soldering wash your hands with soap and water.

ANSWER SHEET

1. The first six-sided dice were found in ……

2. Dice have existed for …… years.

3. When you roll four dice there are …… possible outcomes.
   Explanation: ……

4. Make a drawing (here or on a separate sheet of paper) and show your teacher

5. You should throw the dice …… times to test the electronic dice properly.

6. Enter the outcomes in the tables below.
   - Write down how often you threw each number.
   - Calculate the percentage that each number was thrown (example: if you threw a 2 9 times out of the 100, then 9% of the throws were 2s).
   - Then calculate the deviation for each number: this is the difference between the 'ideal percentage' (this is the percentage if every number were thrown with the same frequency) and the percentage you actually threw.

ELECTRONIC DICE			
Number of spots	**Thrown ? times**	**percentage**	**difference**
1			
2			
3			
4			
5			
6			
total		100%	

ORDINARY DICE			
Number of spots	**Thrown ? times**	**percentage**	**difference**
1			
2			
3			
4			
5			
6			
total		100%	

7. My electronic dice is / is not fair.

   Explanation: ……

   ……

8. Three advantages of the electronic dice over the ordinary dice are

   1 ……

   2 ……

   3 ……

9. The value of resistor A is ……

   The value of resistor B is ……

10. The value of resistor A lies between

    …… and ……

    The value of resistor B lies between

    …… and ……

11. The colour bands are

	100kΩ	560Ω
First band:	……	……
Second band:	……	……
Third band:	……	……
Fourth band:	……	……

12. The lights up for ……

    Explanation: ……

    ……

13. The pulse counter counts …… **times to 6 in this second.**

14. The decimal number represented by 01010 is ……

The decimal number represented by 10001 is ……

The decimal number represented by 01111 is ……

The decimal number represented by 11111 is ……

15. The decimal number 1 is represented by ……

The decimal number 2 is represented by ……

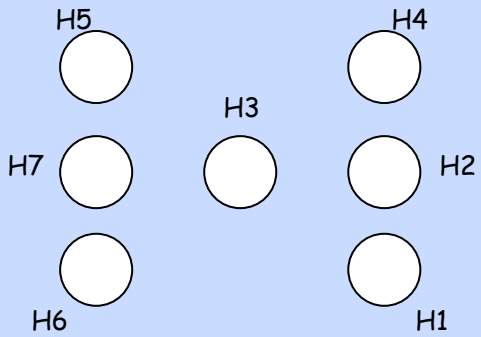
The decimal number 3 is represented by ……

The decimal number 4 is represented by ……

The decimal number 5 is represented by ……

The decimal number 6 is represented by 110

16.



In the case of the decimal number 3 the lamps coloured in above will light up because ……

……

……

……

……

……

……

ASSEMBLY SCHEME