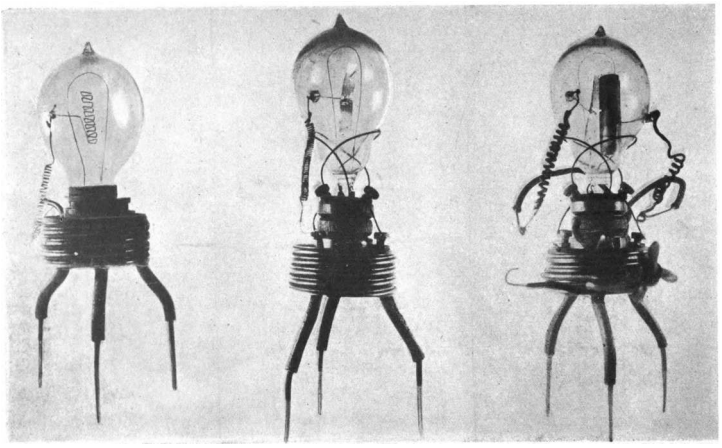
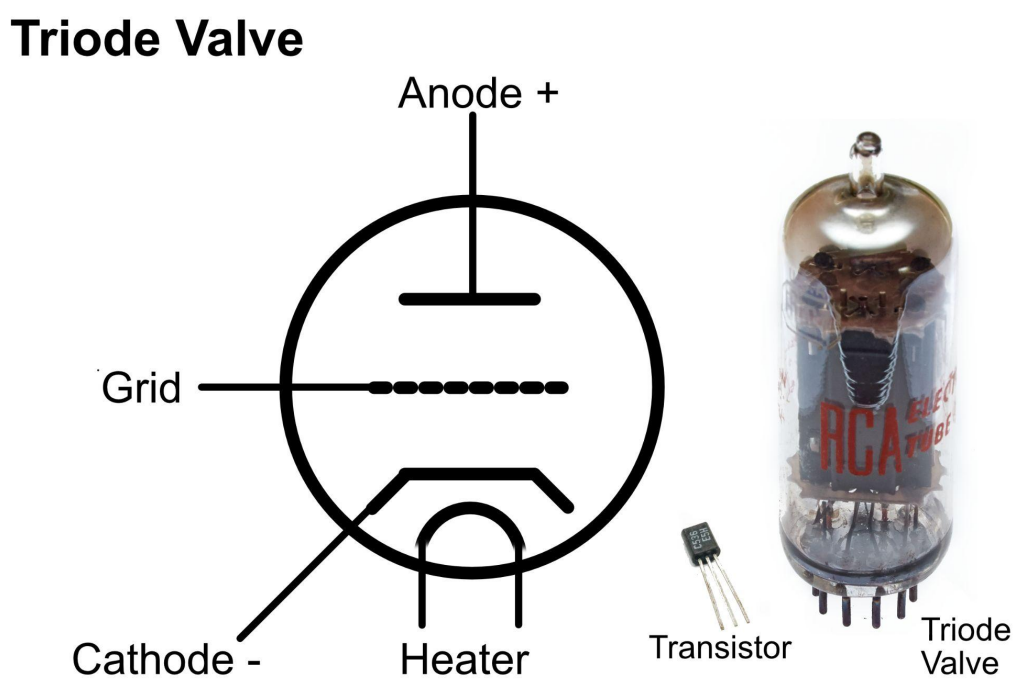
1001-act17 Introduction to Electronics

Activity	Electronic Switches
Student Guide	1001-act17-stg Electronic Switches: Student Guide tmt3Nngx
Teacher Guide	1001-act17-tcg Electronic Switches: Teacher Guide tmt3Nngw
Summary	Brief lesson on the history and advancement of transistors. A transistor is an electronic version of a mechanical switch that effectively connects two conductors together when it is turned on.
Principals Covered	• History of transistors and valves • Functions of a transistor • Look at the different types • Applications of transistors
Learning Outcomes	• Know that valves came before transistors • Valves are much bigger and more power hunger than transistors • Be able to identify a valve • Be able to identify the different types of transistor
Achievement Standards	
Equipment	Each student will need: • Student guide
Preparation	
Instructions	**1. Electric Valves for Vacuum Tubes** Before we look at transistors, it is worth taking a look back at vacuum tubes which were the earlier more fragile predecessor to transistors. These are glass enclosures that contain various parts that allow a current or voltage to be controlled. They were invented in 1904 and heavily used up to the mid 1960s. The electronic valve was first invented in 1904 by British engineer John Ambrose Fleming. The picture below shows the original valves invented in 1904.  Picture from Wikipedia.org

How Valves Work

Valves work by using a wire to control the amount of current that can flow between two wires. The diagram below shows the basic parts inside a triode valve made in the 1950's.

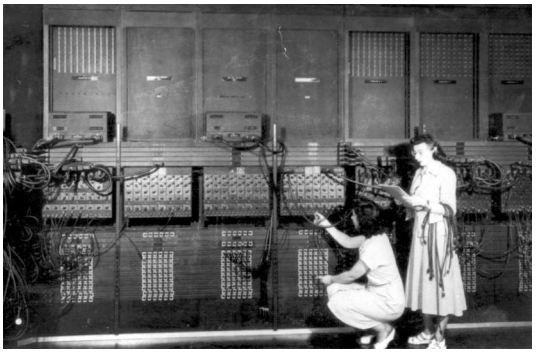


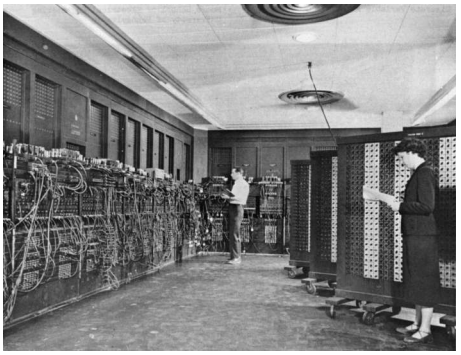
The inside of a valve is shown on the left. First we have the Anode, at the top, which is connected to the positive power supply. Below that we have the Grid which is used to control the amount of current that can flow between the Anode and the Cathode. The Cathode connects to the negative power supply.

Finally we have the Heater which provides a source of electrons that the valve needs to work. This heater is a special filament of wire like that in old tungsten light bulbs. It glows red and gets very hot which is how it generates the required electrons. As you can see from the picture below the valves glow a lot and get hot.

The heat generated by these valves made their use in computers, as switches, very problematic because they would fail after a short time. One of the original valve computers called ENIAC, built in 1946, used 17,468 valves, 70,000 resistors, 10,000 capacitors, 1,500 relays and 6,000 manual switches. It weighed 27 tons, occupied 1,500 square feet of floor space and used 150,000W of electricity.

In terms of speed ENIAC could perform 5,000 additions, 357 multiplications, or 38 divisions each second. By comparison a modern Raspberry Pi computer board is around 150,000 times faster than ENIAC and has hundreds of millions of transistors in it all while fitting into the palm of your hand. The picture below shows part of the ENIAC computer. The women are the first programmers.





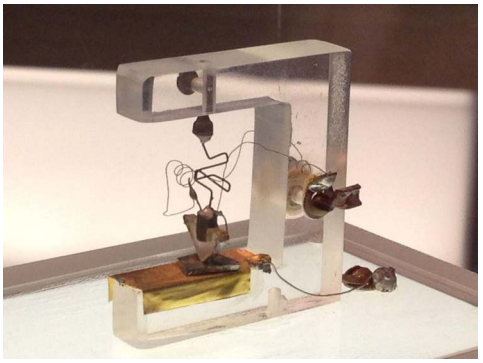
The problem however, was that aside from their large size, power needs, valves being made of glass are very fragile and break easily. This limited their use in portable applications or in places where vibration was a problem.

2. Find Other Valve Computers
As an exercise ask the students to see if they can use Google on their devices to find any other valve computers. Some examples of valve computers are listed below:

- Colossus https://en.wikipedia.org/wiki/Colossus_computer
- Whirlwind https://en.wikipedia.org/wiki/Whirlwind_I

A comprehensive list of valve based computers can be found on Wikipedia at:
https://en.wikipedia.org/wiki/List_of_vacuum-tube_computers

3. Transistors
Transistors were invented in 1947 at Bell Labs and essentially form the basis of all modern day electronics, including computers. They are semiconductor devices made from silicon and either amplify a signal or act as a switch. Transistors used in computers are almost exclusively used as switches, this is because computers use binary ones and zeros to operate.



As mentioned above valves are made from glass and thus fragile, they are also very big and consume a lot of electricity. Transistors by comparison are small, robust and consume very little power. And almost as importantly they could switch a lot faster than even the best valves.

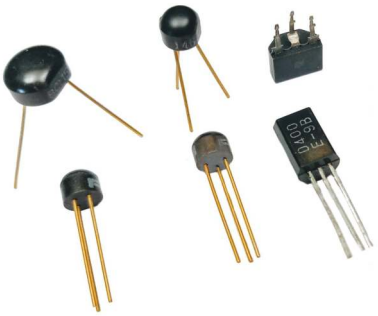
The first transistor is shown above.

4. Transistors Versus Valves
The table below compares transistors and valves.

Property	**Valve**	**Transistor**
		
Size	big	Very small
Voltage	400V to 500V	<1V
Power needed	Very high	Very low
Heat generated	Lots	Very little
Reliability	average	Very high

5. Early Transistors
The very first transistors used in electronics were all made from metal in contrast to modern transistors which are generally made of plastic. The picture below shows some old style transistors next to modern ones.

Early metal transistors.

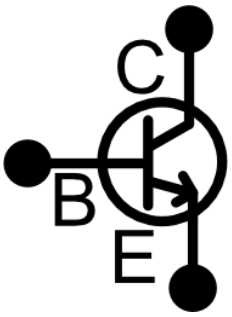
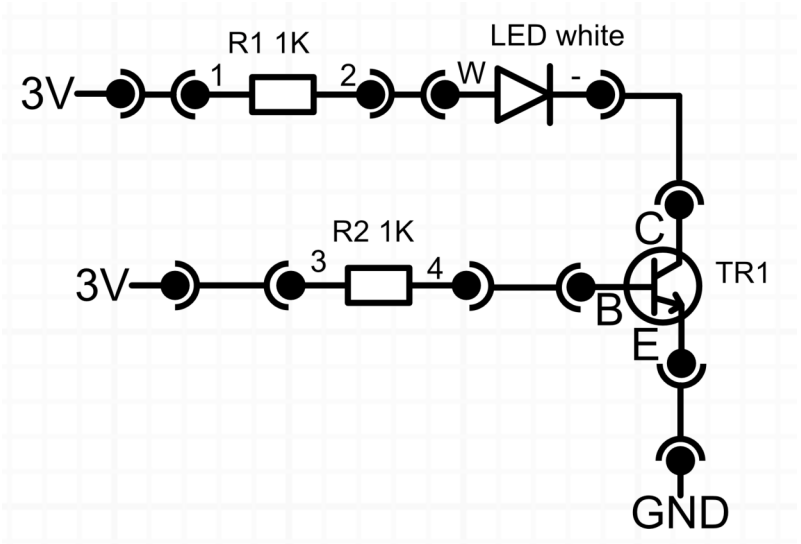


Early plastic transistors.

In the old days transistors were handmade by hundreds of women at microscopes as shown below, they would have to assemble the various parts after which the transistor would be sealed and tested.

6. Modern Transistor Types
There are many types of modern transistor as shown in the table below. Each type has a specific job to do.

Picture	Type
	**Small signal transistor** This is used to amplify or switch small signals in devices like pocket radios and small toys. These generally handle currents below 1A.
	**Medium power transistor** This is a medium size power transistor. These are designed to handle higher currents in things like small motors and smaller appliances. They can handle currents from 1 to ~20A.
	**Power transistor** These are high power types designed for applications in which high currents >10A need to be handled. They are made from metal so they can get rid of the heat they generate.

	Plastic transistors are cheaper to make and are used in applications where high currents don't need to be handled. A modern CPU (Central Processing Unit) of a computer can contain billions of transistors. **7. Parts of a Transistor** Just about all transistors have 3 legs like the ones shown below:   The pins are also shown on a transistor on the right that is the same as the ones on the TOP. The pins are: • **C** Collector This is the positive pin • **B** Base This is the base which turns the transistor on and off • **E** Emitter This is the negative pin Basically power flows through the collector and emitter pins when a voltage >= ~0.6V is applied to the base pin. When this happens the collector and emitter pins will conduct, almost as if they were a switch. A simple transistor circuit in which the transistor is used to turn an LED on and off is shown below. You will build this circuit in the next activity.  In the circuit the transistor is TR1 and is used to supply power to the LED when the transistor is turned on. To turn it on we apply 3V to the transistors base as shown above. In the next activity we will use a transistor to control an LED.
Notes	
Extension	• Comparison of the ENIAC vs modern devices https://www.deviceplus.com/raspberry-pi/raspberry-pi-tech-vs-computers/ • The Mullard Story: manufacturing values in the early days.

	https://www.youtube.com/watch?v=-GgWIlvyEL8&t=1288s ● Philco manufacturing transistors: https://www.youtube.com/watch?v=BillR7xtTxc&t=107s ● Semiconductor Museum: http://semiconductormuseum.com/Museum_Index.htm ● Russian Transistors: http://vintage-technics.ru/Eng-First_transistors_ussr.htm