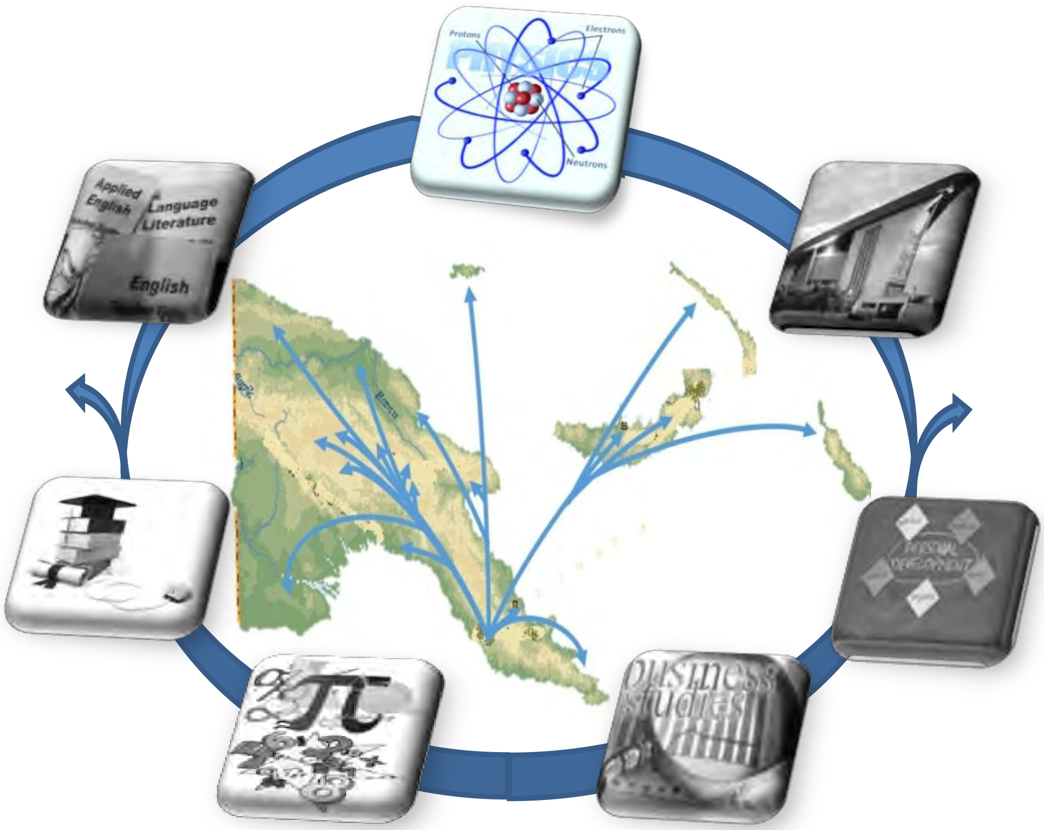
DEPARTMENT OF EDUCATION

GRADE 11

PHYSICS

MODULE 6



ELECTRONICS

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GRADE 11

PHYSICS

MODULE 6

ELECTRONICS

IN THIS MODULE, YOU WILL LEARN ABOUT:

11.6.1:	**SOLID STATE ELECTRONICS**
11.6.2:	**DIGITAL ELECTRONIC**
11.6.3:	**ELECTRONICS AND SOCIETY**

Acknowledgement

We acknowledge the contribution of all Lower and Upper Secondary teachers who in one way or another helped to develop this Course.

Our profound gratitude goes to the former Principal of FODE, Mr. Demas Tongogo for leading FODE towards this great achievement.

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DIANA TEIT AKIS
Principal-FODE

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SECRETARY'S MESSAGE

Achieving a better future by individual students, their families, communities or the nation as a whole, depends on the kind of curriculum and the way it is delivered.

This course is part of the new Flexible, Open and Distance Education curriculum. The learning outcomes are student-centred and allows for them to be demonstrated and assessed.

It maintains the rationale, goals, aims and principles of the National Curriculum and identifies the knowledge, skills, attitudes and values that students should achieve.

This is a provision by Flexible, Open and Distance Education as an alternative pathway of formal education.

The Course promotes Papua New Guinea values and beliefs which are found in our constitution, Government policies and reports. It is developed in line with the National Education Plan (2005 – 2014) and addresses an increase in the number of school leavers affected by lack of access into secondary and higher educational institutions.

Flexible, Open and Distance Education is guided by the Department of Education's Mission which is fivefold;

- To develop and encourage an education system which satisfies the requirements of Papua New Guinea and its people
- To establish, preserve, and improve standards of education throughout Papua New Guinea
- To make the benefits of such education available as widely as possible to all of the people
- To make education accessible to the physically, mentally and socially handicapped as well as to those who are educationally disadvantaged

The College is enhanced to provide alternative and comparable path ways for students and adults to complete their education, through one system, two path ways and same learning outcomes.

It is our vision that Papua New Guineans harness all appropriate and affordable technologies to pursue this program.

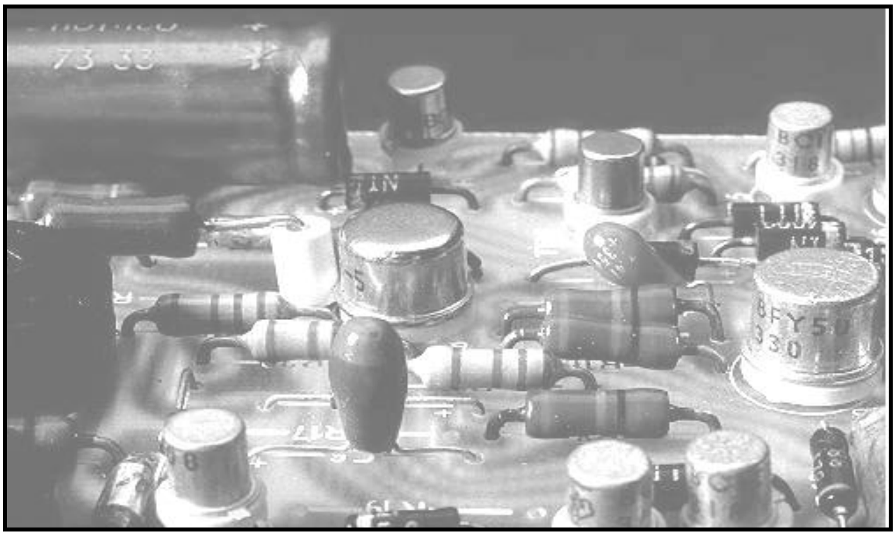
I commend all those teachers, curriculum writers, university lecturers and many others who have contributed so much in developing this course.

UKE KOMBRA, PhD
Secretary for Education

MODULE 11. 6: ELECTRONICS

Introduction

Today's world cannot function without using concepts in electronics and use of electronic components or devices. Some of these components are diodes, transistors, resistors and capacitors like those shown in the diagram below.



Transistors, resistors, capacitors, diodes, and inductors

What diodes are and how they are used in general applications will be learnt in this module. Your mobile phones, radios, computers and calculators all make use of electronic circuits and components like diodes to perform different functions.

Wikipedia says that electronics is the science of how to control electrical energy, energy in which electrons have a fundamental role. Electronics deals with electrical circuits that involve active electrical components like diodes, transistors and integrated circuits, and other associated passive electrical components and their interconnection. Passive components include resistors, capacitors and inductors.

In this module, you will not do a lot of technical stuff but enough to prepare you for other courses in Electronics (or that are related to Electronics) you might want to do in college or even university.

A close-up of a smoke detector's circuit board reveals its components, which include transistors, resistors, capacitors, diodes, and inductors. Rounded containers house the transistors that make the circuit work. Transistors are capable of serving many functions, such as amplifying and switching. Invented in 1948, transistors are a basic component in nearly all modern electronic devices. You will study it in detail in this module.

Learning Outcomes

After going through this module, you are expected to:

- define conductors, non-conductors and semiconductors and gives examples.
- differentiate intrinsic (pure) from doped semiconductors and gives examples explain how the conductivity of semiconductors can be increased by doping.
- briefly describe the atomic structure of some semiconductor elements such as silicon and germanium and explain why, in pure forms, they are non-conductors.
- define the two types of impurities (do- nor and acceptor) and give examples.
- describe the doping process of forming P- and N-type semiconductor materials.
- understand that doping can be used to make semiconductor devices such as diodes, transistors and integrated circuits (chips).
- describe how diodes are made from semiconductor materials specifies symbols for diode and explain the operating principle of the diode.
- explain what is meant by a diode being forward biased and reverse biased.
- understand the use of a diode as a switch and a rectifier with the aid of a circuit diagram.
- enumerate the advantages of transistors over other electrically operated switches.
- understand what happens to resistance, current and voltage when the transistor switch is ‘on’ or ‘off’.
- describe when a rheostat and a potential divider controls are used in transistor switching circuits.
- describe how transistors are made from semiconductor materials and specify symbols for transistors.
- explain the operating principle of the transistor and identify the three connections (base, collector and emitter) in transistors.
- interpret circuit diagrams understand the use of a transistor as a switch and an amplifier
- analyse and interprets circuit configurations for N-P-N and P-N-P junction transistor (common-base, common-emitter and common-collector).
- define logic gates, describes what they do, familiarize with the types of logic gates and remember their electronic symbols.
- understand that the signal levels used in electronic systems are expressed as ‘high’ and ‘low’ states and are represented as ‘1’ and ‘0’ signal levels respectively.
- analyse truth tables that describes the behaviour of each logic gate, describe logic gates and explain how some electronic control systems use logic gates.
- design and draws block diagrams to solve some logic control system problems in security, safety, heating and lighting.
- explain when a feedback is positive or negative and give the effects of positive and negative feedback.
- differentiate the two types of electronic devices and explain why electronics is having an ever-increasing impact in the society.

- give some areas in the society where electronics is having an impact
- identify social and economic consequences electronics bring to the society

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Time Frame

Suggested allotment time: **10 weeks**

This module should be completed within 10 weeks.

If you set an average of 3 hours per day, you should be able to complete the module comfortably by the end of the assigned week.

Try to do all the learning activities and compare your answers with the ones provided at the end of the unit. If you do not get a particular exercise right in the first attempt, you should not get discouraged but instead, go back and attempt it again. If you still do not get it right after several attempts then you should seek help from your friend or even your tutor.

DO NOT LEAVE ANY QUESTION UNANSWERED.

11.6.1 Solid State Electronics

You may remember from previous levels that an electrical **conductor** (or conductor) is a substance that allows electric currents (or electricity) to pass through it.

Metals are good conductors of electricity. Copper is a metal that is commonly used as a conductor in electrical circuits. Its atomic number is 29. Copper's electrons in an atom will occupy shells in this order: (2, 8, 18, 1) as shown in Figure 1 below.

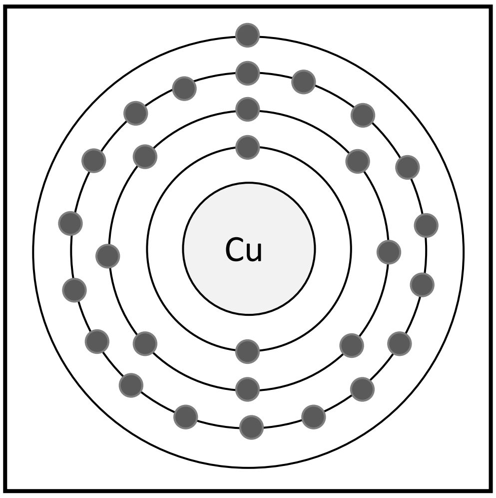


Figure 1 Arrangement of electrons in a copper atom

You can see in the outermost shell that there is only one electron. This electron is called the **valence electron** and is responsible for chemical changes. The electron is not only involved in chemical changes but can also conduct electricity. This electron is a bit loose and can move from one atom to another. When many of such electrons move freely across atoms, we get an electron flow or electric current. On the other hand, other substances like non-metals do not conduct electricity under normal conditions.

An **insulator** is said to be a substance that does not allow electricity to pass through it. Dry wood, pure water, plastic, and air are examples of insulators.

In electronics, another type of substance called a **semiconductor** is needed. A semiconductor acts like an insulator and at other times can also conduct electricity. A pure semiconductor acts as an insulator when very cold, and conducts only poorly at normal room temperatures.

Semiconductors can be made from silicon (atomic number 14) and germanium (atomic number 32). Both of these elements have four electrons in their outermost shell.

Silicon’s arrangement of electrons in its shell will be (2, 8, 4) as shown in the diagram below.

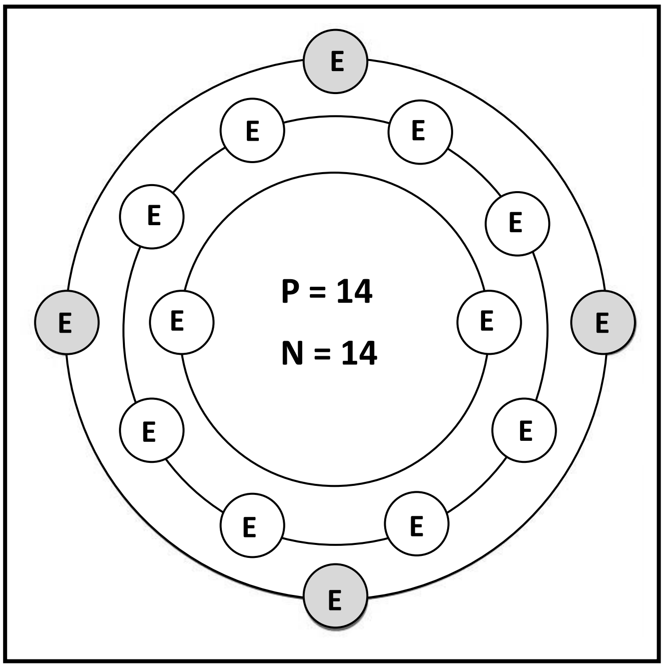


Figure 2. Arrangement of electrons in a silicon atom.

The most common semiconductor materials are silicon and germanium. In their pure state, both of these materials have certain properties. Although they are quite unique, they are not generally useful on their own. The important feature of a semiconductor material is the atomic structure of the atoms that make up the material. When you talk about the atoms of the material, then you should now reflect on your chemistry lesson. In chemistry, all atoms consist of a nucleus surrounded by orbiting electrons.

Intrinsic and Extrinsic

A semiconductor is labeled as **extrinsic** if conduction is dominated by donor acceptor impurities. Otherwise, it is known as an **intrinsic** semiconductor. Though either intrinsic or extrinsic conduction, semiconductors allow current to flow in either direction through the crystal.

Pure silicon or germanium semiconductors are **intrinsic semiconductors**. That is, they have semiconducting properties without having any other substances added to it. We can also say that, it is a semiconductor that does not have any impurities. Both silicon and germanium can be found in crystal form in nature.

At this point, it is important to note that an electric current is the ‘flow of electrons’ in a circuit. The electrons flow from the negative terminal of a power source (like a dry cell) and enter the positive terminal.

In electronics, we also talk about the ‘flow of holes’ in a circuit. A **hole** is the space left unfilled by an electron. We can think of a hole as a positive charge and it flows from the positive terminal of the power source to the negative side.

Often, scientists or technologists improve the conducting abilities of a semiconductor. To do that, the semiconductor material or crystals can be ‘**doped**’, meaning small amounts of other substances (or impurities) are added to it. The process of adding impurities to a semiconductor material is called **doping**. Semiconductors or crystals that have been doped are called **extrinsic semiconductors**.

The study of the microscopic view of the structure of solids, the atoms, the bonding between atoms and the number of valence and inner electrons of an atom is called **Solid State Electronics.** It also determines the conductivity of the solid. That is to say whether, the solid is a good conductor of electric current or not.

Conduction occurs as a result of the movement of charges or electrons. Electrons cannot be seen similar to a tennis ball flying over the net and across to the opposing players. However, we all have seen evidence of the movement of charges in nature through the air as when lightning strikes during a thunder storm. Air, which is normally an electrical insulator, is made to conduct large currents during lightning strikes due to the movement of ions and electrons created by the **ionisation** of air atoms. Ionisation is the removal of the outer electron of an atom, which is known as a **valence electron**. As the air in the atmosphere moves about, the electrons in the outer shell of the atoms are knocked off where they become separated and group themselves as positive and negative charges.

The energy required to remove this electron is usually supplied by the electric field during lightning. Generally, in our study, we are not interested in the exact motion of the charges. We just want to know whether there will be electrical conduction.

Semiconductors

The most important electronic components are made from semiconductors. Depending on certain conditions, the semiconductors can act like a conductor or an insulator.

There are many different semiconducting materials, but silicon is the most popular. It is the main ingredient of sand and forms about 28% of the Earth’s crust. It is never found in pure state and must be purified. Silicon and diamond share the same crystal structure.

Pure silicon is not always useful and so manufacturers spice up their silicon recipe with a dash of phosphorus, boron or other chemical elements. This is called **doping**.

Doping is the process of adding impurities semiconductors so that they can conduct electric current.

Let us briefly look at conductors and insulators to fully understand semiconductors.

Copper is a conductor, which means it allows electrons to move freely through it when a potential difference is applied. In the case of an insulator, all the electrons are locked up in bonding between atoms so that none are free to move at all.

Semiconductors are neither insulators nor conductors. Their behavior is somewhere in between that of a conductor and an insulator. Silicon and germanium are two elements that are semiconductors.

Some electrons in the valence band of a semiconductor will gain enough energy from the ambient thermal (heat) energy in the solid to jump up to the conduction band. This occurs readily at normal room temperature. Heating a semiconductor further increases the number of electrons jumping from the valence band to the conduction band, thereby making the solid more conducting.

A simple and abstract way of visualising whether there will be conduction in gas atoms can be shown using an energy level diagram as shown in Figure 3. The vertical axis is energy and the horizontal lines (levels) indicate the position an electron can have.

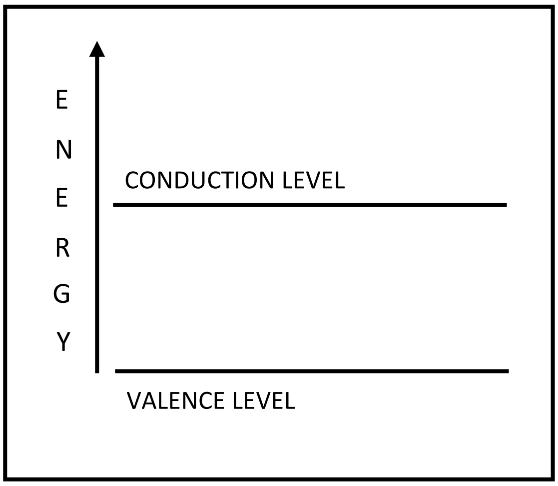


Figure 3 An energy level diagram

The lower line or level, known as the **valence level**, is the energy the electron has while bonding to the atom. The upper level, known as the **conduction level or band**, is the energy it must acquire to become free and contribute to electrical conduction.

For example, heating a piece of silicon will lower its resistance. At absolute zero (T = 0 Kelvins), there is no thermal energy available for the electrons, all of which remain in the valence band. Therefore, at absolute zero, the semiconductor behaves as an insulator. At normal room temperature (300K), the average kinetic energy of an electron is around 0.026eV (electron volt). However, the energy gap of silicon is 1.14eV. It would appear that the electrons do not have enough energy to jump to the conduction band.

The table below gives energy gaps in electron volts of some common semiconductors at room temperature.

Energy gaps in electron volts of common semiconductors at room temperature.

Semiconductor crystal	Energy gap (eV)
Silicon (Si)	1.14
Germanium (Ge)	0.67
Indium Phosphide (InP)	1.35
Galium Phosphide (GaP)	2.26
GaAs (Galium Arsenide)	1.43
Cadmium Sulphide (CdS)	2.42
Cadmium telluride (CdTe)	1.45
Zinc Oxide (ZnO)	3.2
(Zinc Sulphide) ZnS	3.6
Diamond (carbon)	5.4

Table 1 Energy gaps in electron volts of common semiconductors at room temperature.

So, why is it that silicon or any of the other semiconductors listed in Table 1, slightly conduct at room temperature? The answer is that 0.026eV is an average energy. This means there are some electrons that have a much lower energy and some that have a much higher energy. It is these higher energy electrons that make it across the gap. However, there are not many of them.

We will use silicon as an example, but similar explanations can be applied to all other semiconductors.

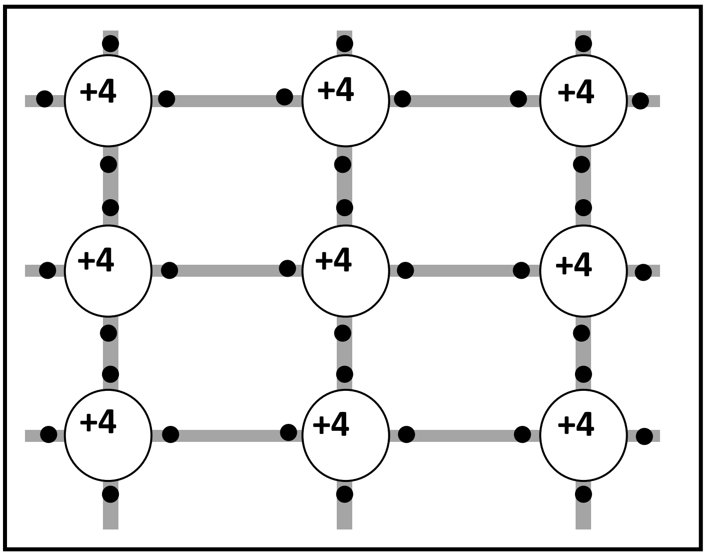


Figure 4. Pure silicon atoms with four electrons in the valence band.

You have seen the atomic structure of silicon in figure 4 on the previous page. Silicon belongs to Group IV of the periodic table, which means that the silicon atom has four (4) electrons available for bonding with other silicon atoms (see Figure 8). However, some electrons in the valence band can acquire enough thermal energy to jump across the small gap into the conduction band. The number of conduction electrons that result is much less than for a conductor, so a semiconductor is a much poorer conductor than a metal but a better conductor than an insulator such as plastic or glass.

A semiconductor is a much poorer conductor than a metal but, a better conductor than an insulator.

You will also note that copper is a good conductor of electricity. However, when heat is applied, they have high resistance and will not be able to conduct current efficiently. For semiconductor materials, they have high resistance and may not conduct current at normal room temperature. However, they become conductors when thermal energy is applied. Semiconductors can also conduct if impurities are added to them. We will discuss that in the next topic.

You have studied in the last unit that conductors that obey Ohm's Law are called **ohmic conductors**. Conductors that do not obey this law are called **non-ohmic conductors**. Electrical components such transistors, diodes and thermistors do not obey Ohm's Law. The voltage versus current graph for the two types of conductors are given below.

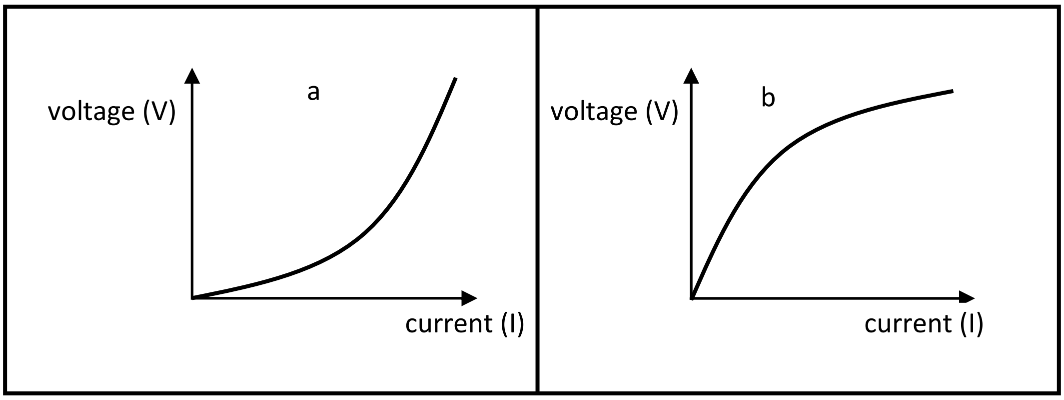


Figure 5. Graphs for non-ohmic conductors

For each of the two graphs, you will see that they do not obey ohms law therefore, they are non-ohmic conductors. As more current flows in (a), the device (thermistor) gets hotter and the resistance decreases so the graph gets steeper. In the second graph (b), you will see that as more current flows, the device gets hotter so the current increases.

Now check what you have just learnt by trying out the learning activity on the next page!

Learning Activity 1

30 minutes

Answer the following questions on the spaces provided.

1. Differentiate between a conductor and insulator.

____
____
____
____
____

2. Name at least three elements that contain 4 electrons in their outermost shell.

a) ______________________

b) ______________________

c) ______________________

3. List three elements that contain 5 electrons in their outermost shells.

a) ______________________

b) ______________________

c) ______________________

4. Name three elements that contain 3 electrons in their outermost shells.

a) ______________________

b) ______________________

c) ______________________

5. Name the two (2) factors that makes a semiconductor to conduct electric current.

a) ____

b) ____

6. Differentiate between intrinsic and extrinsic semiconductor? How can this be achieved?

____
____
____
____

7. Diffentiate between an ohmic and non-ohmic conductor.

____
____
____
____

8. What do we mean by “hole” in a semiconductor? How can this be achieved?

____
____
____
____

9. Explain the word “doping”.

____
____
____
____
____

Thank you for completing learning activity 1. Now check your work. Answers are at the end of the module.

P and N Type Semi-conductors

The common semiconductors include chemical elements and compounds such as silicon, germanium, selenium, gallium arsenide, zinc selenide, and lead telluride. The increase in conductivity with temperature, light, or impurities is due to an increase in the number of conduction electrons which are the carriers of the electrical current. In a pure or intrinsic semiconductor such as silicon, the valence electrons or outer electrons, of an atom are paired and shared between atoms to make a covalent bond that holds the crystal together. These valence electrons are not free to carry electrical current.

To produce conduction electrons, temperature or light is used to excite the valence electrons out of their bonds, leaving them free to conduct current. Deficiencies, or “holes”, are left behind that also contribute to the flow of electricity. These holes are said to be carriers of positive charges. This is the origin of the increase in the electrical conductivity of semiconductors with temperature. The energy required to excite the electron and hole pair is called the **energy gap**. The diagram below shows an ‘N’ and a ‘P’ type semiconductor.

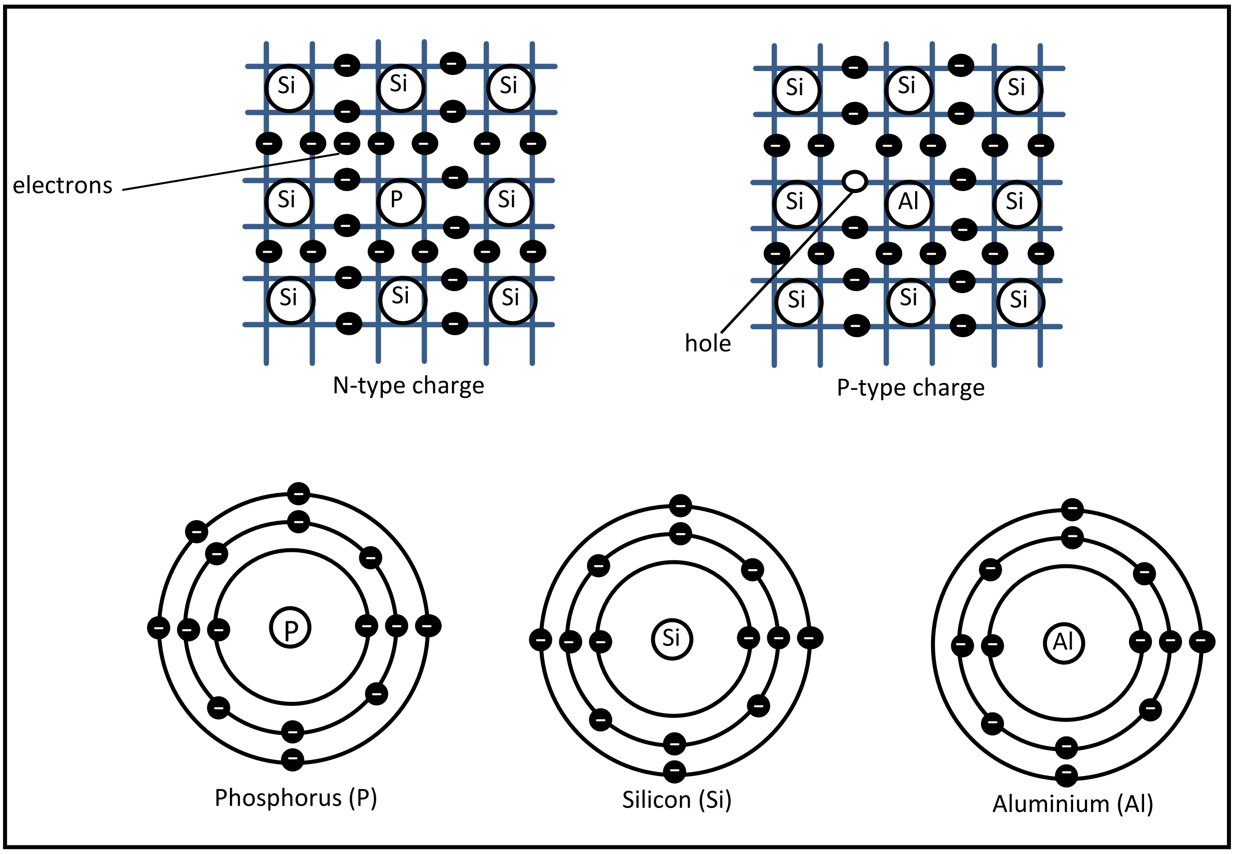


Figure 6. Shells of atoms with p-type and n-type semiconductor

Combinations of p- and n-type semiconductors have been used to make all modern electronic semiconductor devices, ranging from the simple remote control to the sophisticated computer **microprocessor**. The basis of this technology is a result of the properties of the junction between p- and n-type semiconductor materials.

When a material is doped, they can become either **n-type** or **p-type** semiconductors, depending on which substances were added.

Silicon and germanium atoms have 4 electrons in their outermost shells; that is, they have 4 valence electrons. To have complete shells they need 4 electrons from another atom. We will use silicon as an example, but similar explanations can be applied to all other semiconductors.

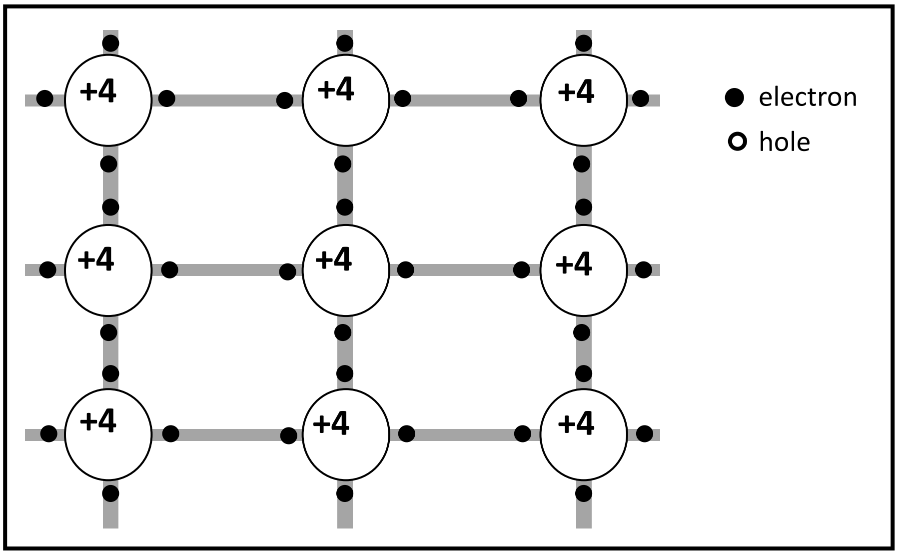


Figure 7 . The silicon lattice with 4 electrons that is shared completely among the silicon atoms.

To improve the conductivity of silicon, an atom that has one more or one less electron than the silicon atom in its outer shell is needed to dope the silicon atom. Silicon belongs to Group IV of the periodic table, which means that the silicon atom has 4 electrons available for bonding with other silicon atom. So, we need to dope the silicon atom with atoms that have 3 or 5 electrons in their outer shell. In this case, boron has 3 electrons and phosphorus has 5 electrons.

An atom that has 3 or 5 electron in its outer shell, which is used in doping, is called a dopan.

Dopan creates a spare electron to move about freely to cause current flow. At the same time, a dopan can create a vacant space (hole) that can be filled by an electron. The movement of electrons and the movement of holes result in the flow of current.

From the periodic table, we note that silicon can be doped with phosphorus (P) atom by replacing a silicon atom with a phosphorus atom or a boron (B) atom. This will result in an n-type and a p-type semiconductor respectively.

When an impurity with 5 valence electrons (like phosphorus) is added to silicon, 4 of the electrons will bond with 4 from the silicon atom while one will be free to move around as a conducting electron. The diagram below summarizes this process.

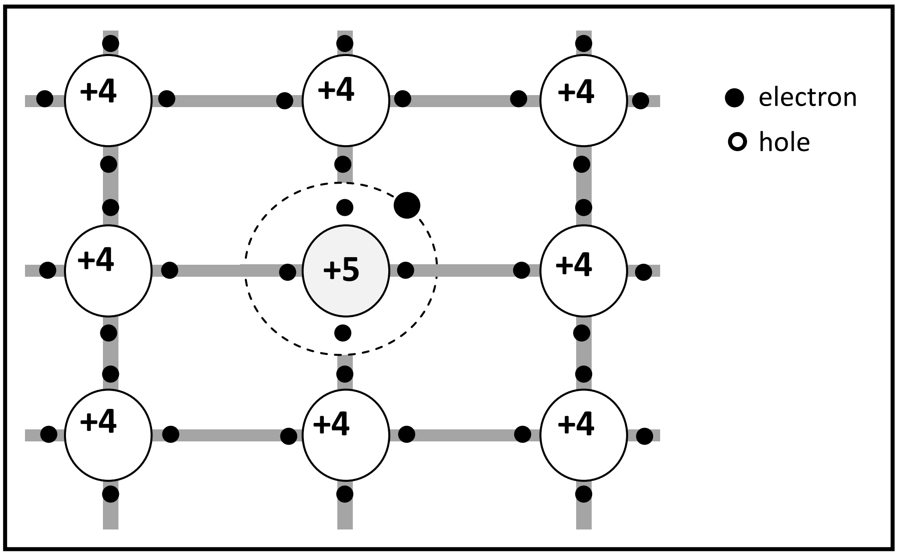


Figure 8. Silicon doped with Phosphorus to make an n-type semiconductor with surplus of electrons**.**

If more of the same impurities are added, we will have more free electrons in the material. The resulting semiconductor is called an **n-type semiconductor**. The particular impurity in this case, is one which has 5 valence electrons and is called a **donor impurity**.

Impurities that produce unbonded electrons are called donor impurities.

Phosphorus is in Group V of the periodic table and has 5 electrons available for bonding, but it can only bond with 4 atoms of silicon. It leaves **one electron** unbonded, (see Figure 8). This semiconductor is called an **n-type semiconductor.** The '**n'** represents the negative charge of the unbonded electron. Phosphorus is a donor impurity or dopan.

In a N type semiconductor, the conduction is by negative electrons

The energy-band diagram of an n-type semiconductor is shown in Figure 9. Note that a new energy level has been created in the energy gap just below the conduction band. This level is occupied by the unbonded electrons of the impurities and is called the **donor impurity energy level**. This level is very close to the conduction band. The difference in energy between the two levels is usually 0.026eV or less, and so most of the electrons in the donor level can jump up to the conduction band at room temperature, making the semiconductor much more conducting than the pure crystal without impurity

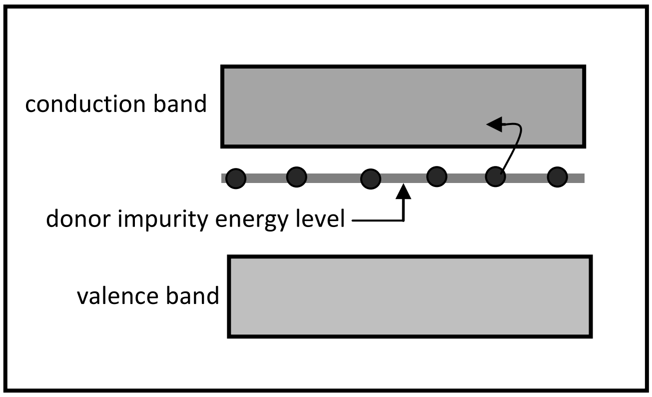


Figure 9. A donor impurity energy level

These unbonded electrons are weakly attached to their atoms near the conduction band and can easily be moved into the conduction band by ambient heat, and thus can contribute to an electrical current or conduction. In the same way, silicon can be doped with an element whose atom has three electrons in the valence band.

We find that group three elements in the periodic table have 3 electrons in the outer shell or valence band. Boron, which belongs to Group III therefore, has 3 electrons available for bonding with 3 electrons of the 4 silicon electrons, can be used as an impurity.

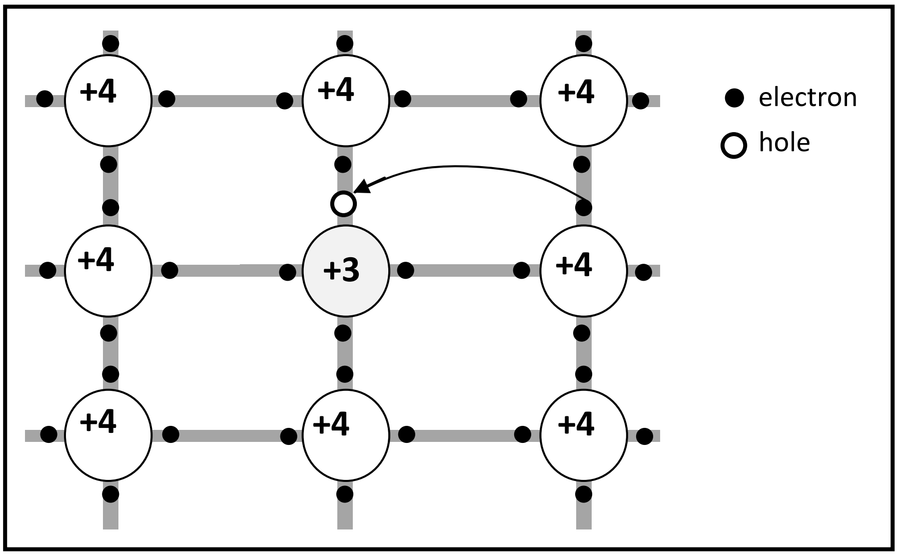


Figure 10. Silicon doped with boron to make a p-type semiconductor.

However, if silicon is doped with an element that has 3 valence electrons in an atom (like boron, aluminum or gallium); there will be a shortage of 1 electron to completely fill the outermost shell of the silicon atom. As a result, we will have a hole, having the absence of one electron, or the space left unoccupied by an electron.

The shortage of electrons can be further increased if more of the boron, the impurity, is added to silicon material. The resulting material is a **p-type semiconductor**. The '**p**' represents a positive hole. The main carriers of electric current in a p-type semiconductor are holes. The particular impurity in this case, which has 3 valence electrons, is called an **acceptor impurity.**

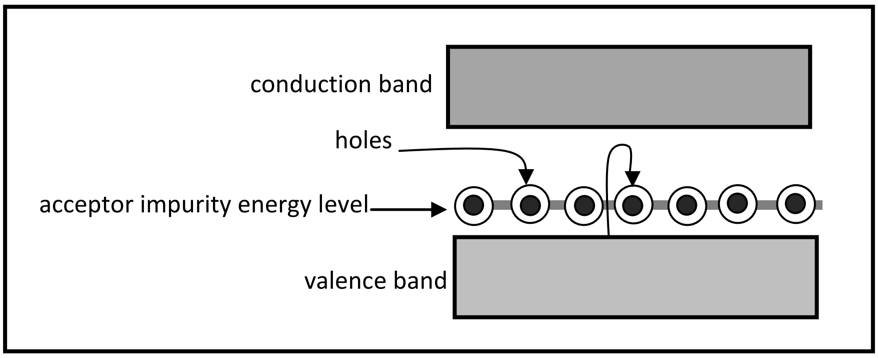


Figure 11. Diagram of a p-type semiconductor energy band showing acceptor impurity energy level.

The energy-band diagram for a p-type semiconductor in Figure 11 shows that there is an extra energy level, called an **acceptor energy level**, near the valence band. This level is full of vacancies (holes), allowing the valence electrons to jump up and occupy these vacancies and therefore contribute to an electrical current. The semiconductor behaves as though it has positive charge carriers and is therefore called a **p-type semiconductor**.

Impurities that produce a charge vacancy are called acceptor impurities.

Even though there is an unbonded electron or a vacancy created, we note that both the n-type and p-type semiconductors remain electrically neutral. It is because the neutral impurity atoms were added to an already neutral solid so, the net charge remains zero. Both n-type and p-type doping improve the conductivity of a semiconductor by creating an excess of negative and positive charge carriers respectively. The unbonded electrons in n-type semiconductors need a small amount of energy to move to a different location. Similarly, very little energy is required to cause a neighbouring electron to occupy the vacancy of a p-type semiconductor.

In a p- type semiconductor, the conduction is by positive charges.

Semiconductor materials can be used to make devices such as diodes, transistor and integrated circuits. We will look at these devices closely in the sub topic that will follows

Now check what you have just learnt by trying out the learning activity on the next page!

Learning Activity 2

30 minutes

Answer the following questions on the spaces provided.

1. What is a dopan?

____

____

____

2. What is a/an:

a) n-type semiconductor?

____

____

____

b) p-type semiconductor?

____

____

____

3. What are the majority carriers in each case?

____

____

____

____

4. Identify elements that can be used to make:

a) p-type semiconductor

____

____

____

b) p-type semiconductor

____

____

____

Thank you for completing learning activity 2. Now check your work. Answers are at the end of the module.

Diodes

If a p-type and an n-type material are joined together, we get a useful device called a **p-n junction diode**. Both p-type and n-type silicons conduct electricity. The resistance of both is determined by the amount of holes or surplus electrons. Therefore, both types can function as resistors and will conduct electricity in any direction. By forming some p –type silicons in n-type silicons, electrons will flow through the silicon in only one direction. This is the principle of diode. The P-N interface is called the **PN junction**.

How does the diode work? Here is a simplified explanation of how a diode conducts electricity in one direction (forward) while blocking the flow of current in the opposite direction(reverse).

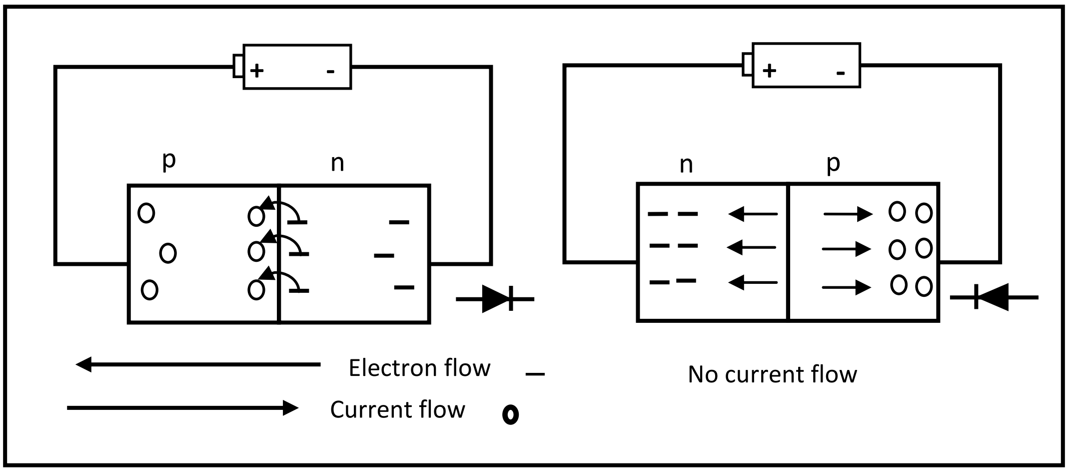


Figure 12. Electron and current flow in a diode

Here the charge from the battery repels holes and electrons toward the junction and if the voltage exceeds 0.6 volts, then electrons will cross the junction and combine with holes. This makes the current flow.

In diagram on the next page, the charge from the battery attracts holes and electrons away from the junction. Therefore, there would not be any current flowing.

The diode allows the current to flow one way. The arrow on the diode symbol shows the direction in which conventional current can flow. The diode is then said to be forward biased. If the diode is reversed biased the current is nearly zero.

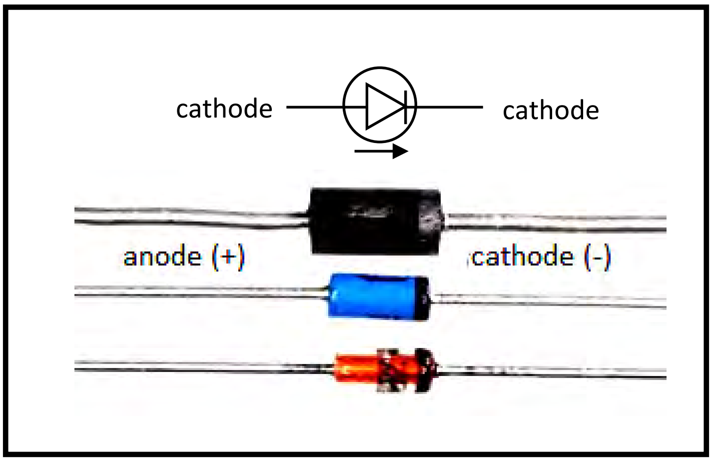


Figure 13. Types of diodes and their positive and negative terminals.

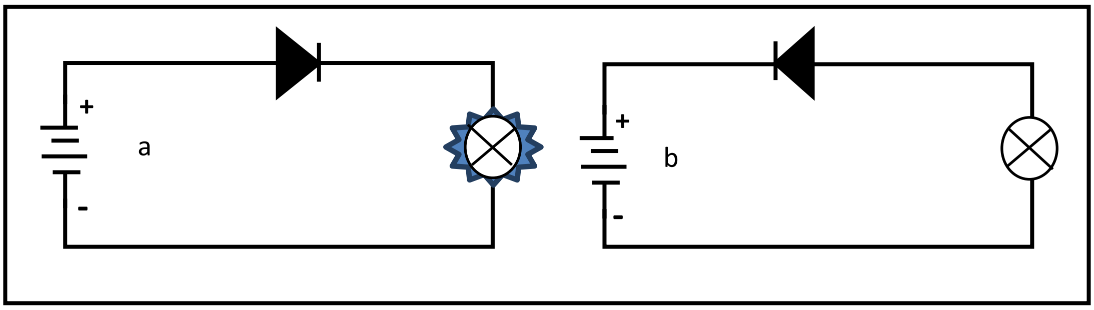


Figure 14. Forwards biasing and reverse biasing in a diode

You already know that a diode is like an electronic one way valve. It is also important for you to know some additional aspects of diode operation.

1. A diode will only conduct until the forward voltage reaches a certain threshold point. For silicon diode, the voltage it would reach is about 0.6 volts.

2. If the forward current becomes excessive, the semiconductor chip may crack or melt. This will make the contact separate. If the chip melts, the diode may suddenly conduct in both directions and cause heating which can vapourise the chip.

3. Too much of reverse voltage will cause a diode to conduct in the wrong direction. Since the voltage is high, the sudden current may zap the diode. The graph on the next page sums up the operation of the diode.

N

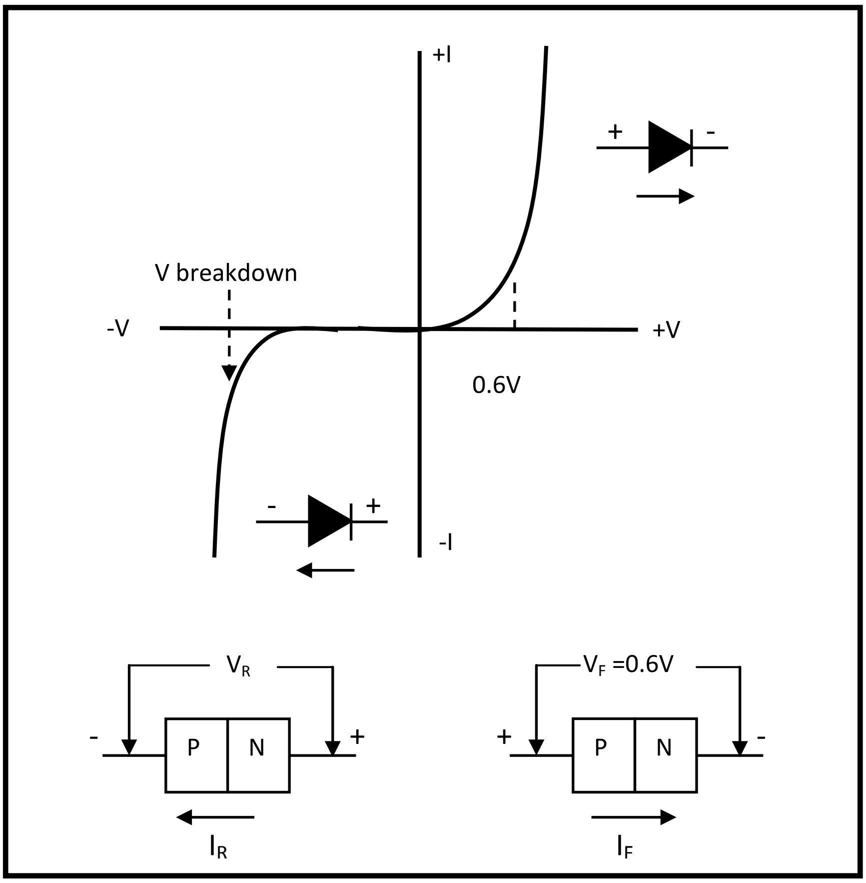


Figure 15. Graph showing the operation of a diode

Types of Diodes

There are many different types of diodes available. Some common ones and their function are listed below.

Figure16. Different types of diodes

Small signal diode

The small signal diodes are used to transform low current AC (alternating current) to DC (direct current) and to detect (demodulate) radio signals. They also multiply voltage, perform logic and absorb voltage spikes.

Power rectifier

The function is identical to small signal diodes. The power rectifiers can handle more current. They are installed in large metal packages that soak up excess heat and transfer it to metal heat sink mainly used in power supplies.

Zener diode

The zener diode is designed to have a specific reverse breakdown (conduction voltage. This means zener diodes can function like a voltage sensitive switch. There are many zener diodes which can have a breakdown voltage ranging from 2 to 200 volts.

Light emitting diode

All diodes emit some electromagnetic radiation when forward biased. Diodes that are made from certain semiconductors like gallium, arsenide and phosphide emit more radiation than silicon diodes. They are called light emitting diodes (LED). LEDs can be used as indicator lamps. They are small, reliable, need only a small current and last much longer than filament lamps.

LEDs are sometimes used in seven segment displays in digital clocks, cash registers and calculators. Each segment is a LED and depending on which have voltage across them. The displays light up the numbers 0 to 9. Look at an example below. The number eight (8) has seven segments but other numbers can be formed from this.

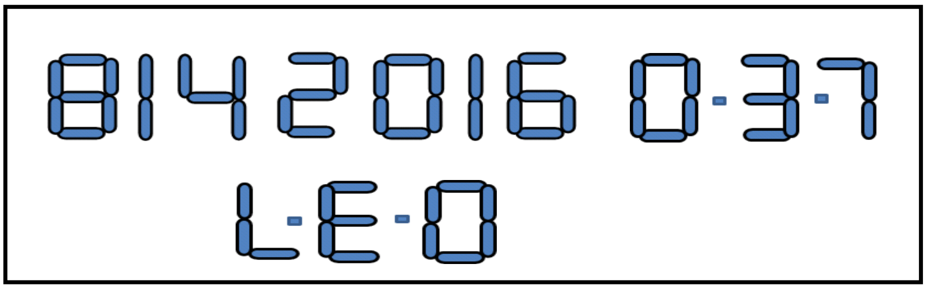


Figure 17. Seven segment display on digital devices

Photodiode

All diodes respond to some certain stage when illuminated by light. Diodes designed specifically to detect light are called photodiodes. The photo diode is a normal semiconductor diode with a glass or a plastic window through which light can enter. It works in a reverse bias and the tiny reverse current with the light intensity. Photodiodes are used as fast counters which produce a current pulse every time a beam of light is interrupted. They often have a large exposed junction region. Silicon makes good photo diodes.

Uses of diodes

Diodes are used for:

1. Protecting equipment,
2. Switching stand by batteries and
3. Rectification.

Diodes can be used to change AC (alternating current) to DC (direct current). The process is called **rectification**. The diodes that do this are called **rectifiers**. A simple circuit is shown below. The diode let the forward parts of the alternating current through, but blocks the backward parts so, the current through the resistor flows one way only.

A CRO (cathode ray oscilloscope) can be used to show how the circuit changes the AC input. As you can see, the bottom half of the output wave front is missing. The current is flowing in surges, with short periods of no current in between. In other words, you will only see short pulses.

The pulsing current from the rectifier can be smoothed by connecting a capacitor across the output. The capacitor collects charges during the surges and releases it when the current from the rectifier falls. More complicated circuits with extra diodes give an even smoother current. This makes it more like a steady DC from a battery.

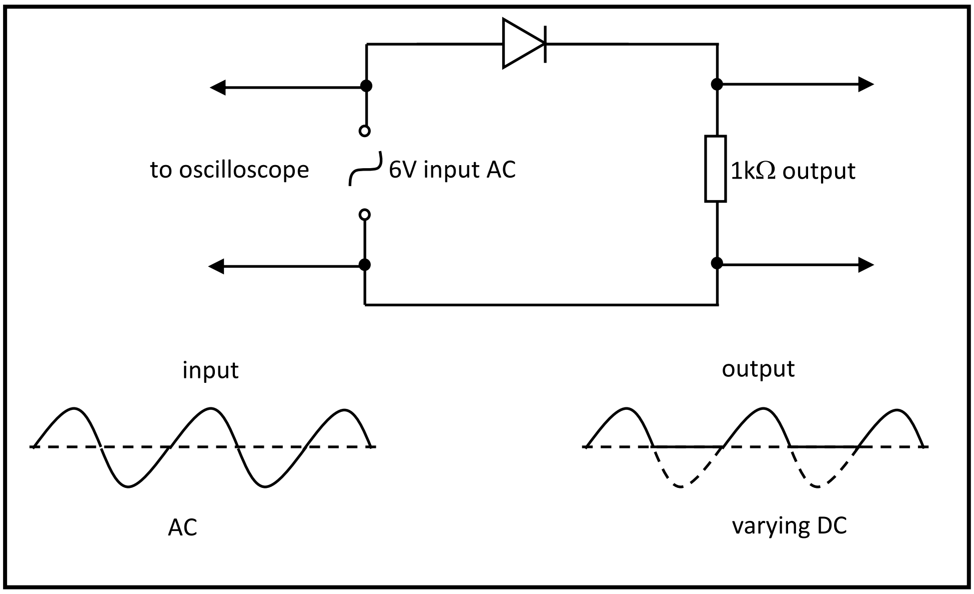


Figure 18. A diode being used as a rectifier.

The p-n junction has the property of allowing current to flow in only one direction at a time when the p-terminal is positive or forward biased and does not allow current flow when the p-terminal is negative or reverse biased. It is a very useful characteristic in electronic applications because most electronic circuits only operate on direct current (DC). The p–n junction diodes are used in rectifiers to convert alternating current (AC) to direct current (DC). AC or alternating current outputs contain both negative and positive voltage signal.

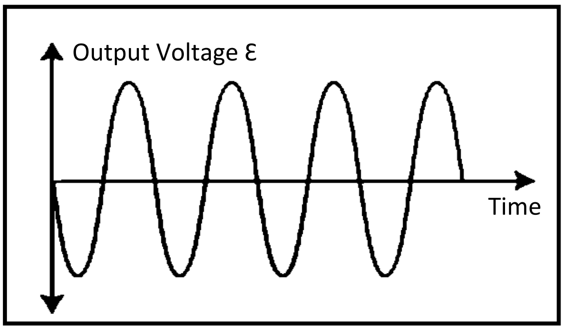


Figure 19. An oscilloscope display of an AC voltage signal

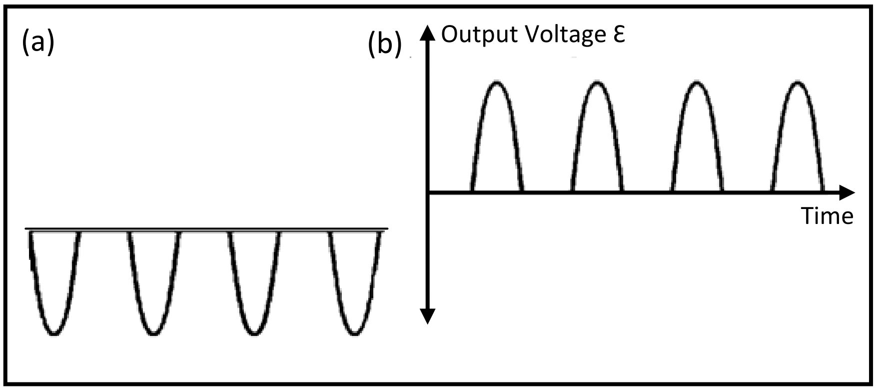


Figure 20. (a) Negative component of AC; (b) Positive signal is allowed to pass through the diode

This property has significant application in converting alternating current (AC) to direct current (DC). Using a network circuit of diodes, the cut off negative cycle (Figure 20) can be made positive. This process is called rectification. As we have studied previously, alternating current (AC) is the main power source in our homes but direct current (DC) is the common powering source in all electronic circuits.

If we now re-arrange four diodes as shown in Figure 21 (a), the negative cycle will also conduct current as shown. This is called the full-wave rectification. The diodes combine in pairs to allow conduction through the load resistor during both positive and negative swings of the input sine wave.

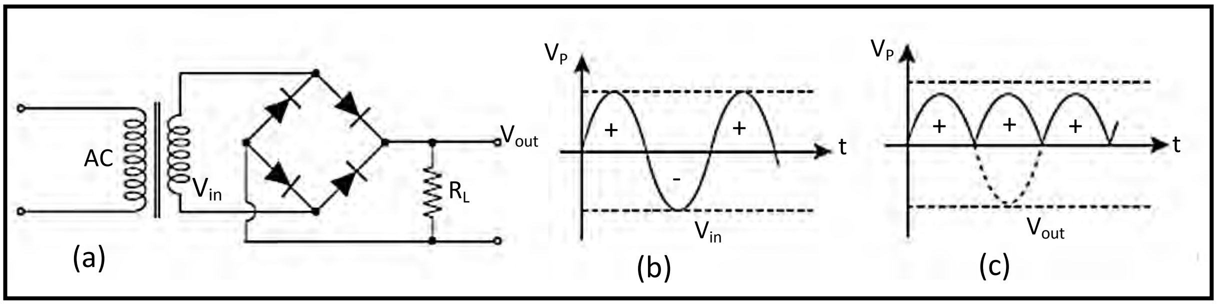


Figure 21. (a) Full-wave Rectifier, (b) AC sine wave input, (c) Full-wave rectified positive output

Potential divider

A potential divider is an arrangement that delivers only a portion of the voltage from the battery (or other sources). The circuit below shows this principle.

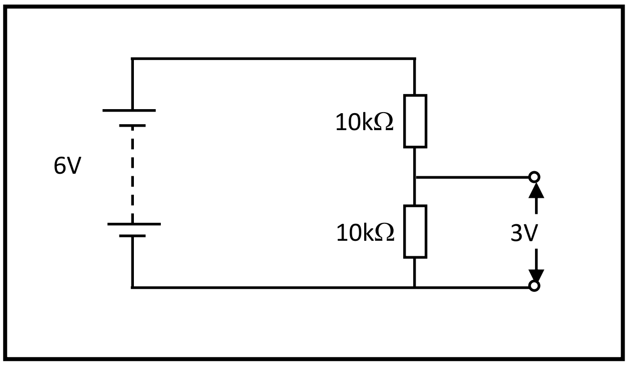


Figure 22. Arrangement of a potential divider

In this potential divider the lower resistor has half of the total resistance of the two resistors. You will see that its share of battery voltage is halved.

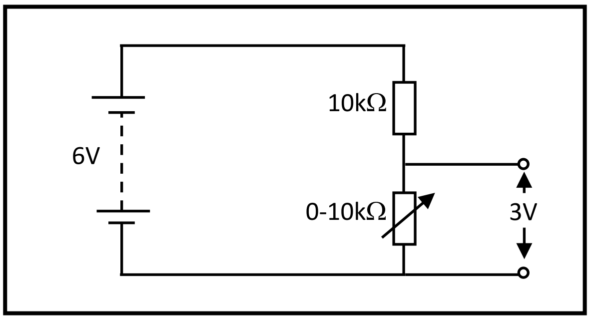


Figure 23. Potential divider with resistor

Now, you will see that one of the resistors is being replaced by a variable resistor. The output voltage is being varied. You will also note that the voltage can range from (0V to 3V) depending on the setting of the variable resistor. This circuit could be used as a volume control knob on a radio.

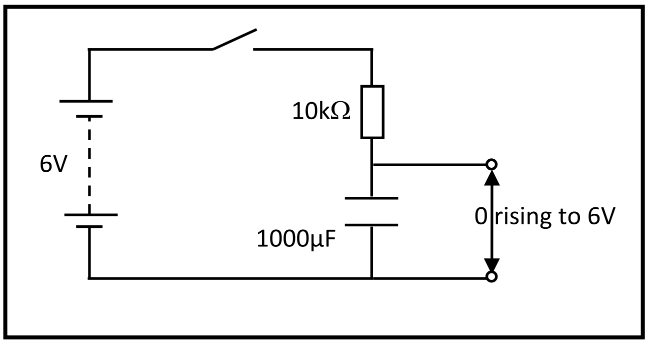


Figure 24. A potential divider with a capacitor

In figure 24, the variable resistor has been replaced by a capacitor. If you close the switch, the output voltage takes half a minute to rise from (0V to 6V) as the capacitor charges up.

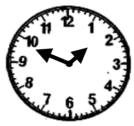
Some electronic circuits are designed to switch on when a voltage reaches a set value. Let us say, if a variable resistor in the second circuit was to be replaced by an LDR (light dependent resistor), then the circuit controlling the lamp would switch on when it got dark. Similarly, a fire alarm will be switched on by a potential divider containing a thermistor (temperature dependent resistor).

The third circuit has a capacitor that would be used in a time relay circuit. For example, a circuit that switches on a light or a buzzer after a set time.

A reed switch is operated by a magnetic field. The contact closes if the magnetic field is brought near to it and opens when the magnet is moved away. Burglar alarm systems often contain reed switches. The magnet is attached to the moving parts of windows and doors. With a coil around it, a reed switch becomes a relay. The current in one circuit through the coil switches on another circuit through the contacts.

Now check what you have just learnt by trying out the learning activity below!

Learning Activity 3



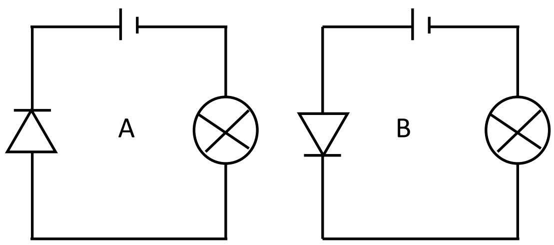
20 minutes

Part A: Answer the following questions on the spaces provided.

1. What is the function of the rectifier in the circuit?

____
____
____

Refer to circuit A and B below to answer Question 2.



a) In which of the two circuits will the bulb light?

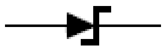
____

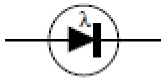
b) In which circuit would no current flow?

____

Part B: Research Activity

1. Carry out a research on the following types of diodes:

   a) Zener, 

   b) Light Sensitive 

   c) Light emitting 

   In your research, describe what they are and what they are used for in electronics. Write your answers on the spaces provided below.

   (a) Zener diode

   (b) Light Sensitive diode

   (c) Light emitting diode

Thank you for completing learning activity 3. Now check your work. Answers are at the end of the module.

Transistors

Transistors are used in television, CD players and other pieces of electronic equipment. This electronic device can join electric circuits so that a small current in one transistor controls a larger current in the other. Most transistors form part of the integrated circuits in microchips.

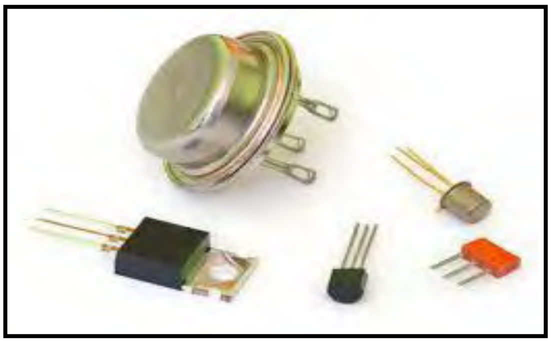


Figure 25. Different types of transistors

They can also be produced as separate components. The transistor shown below is an **npn transistor.** It has three (3) terminals called the **emitter, the base and the collector.**

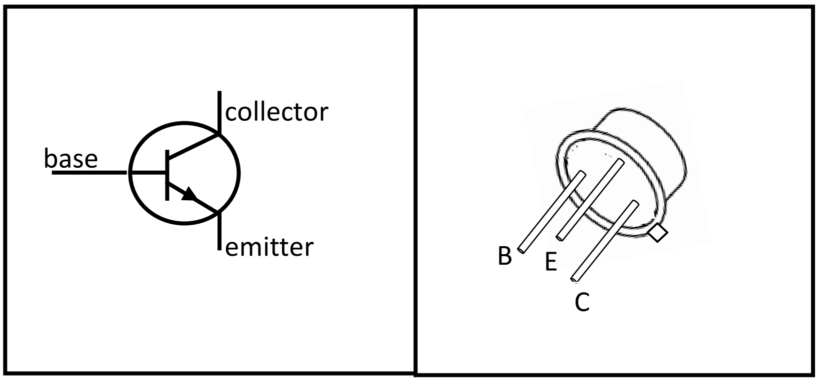


Figure 26. A transistor and its parts.

The arrow in the transistor symbol shows how conventional current will flow through it when **C** and **B** are connected to battery (+) and **E** to (-). The outer circle of the transistor symbol is not always included.

There are two current paths through the transistor. One is the **base- emitter** path and the other is the **collector- emitter** path through the base. The transistor is very useful because of the fact that it can link circuits connected to each part, so that the current in one controls the current in the other. The transistor works just like a relay.

The circuit diagram below shows the action of a transistor.

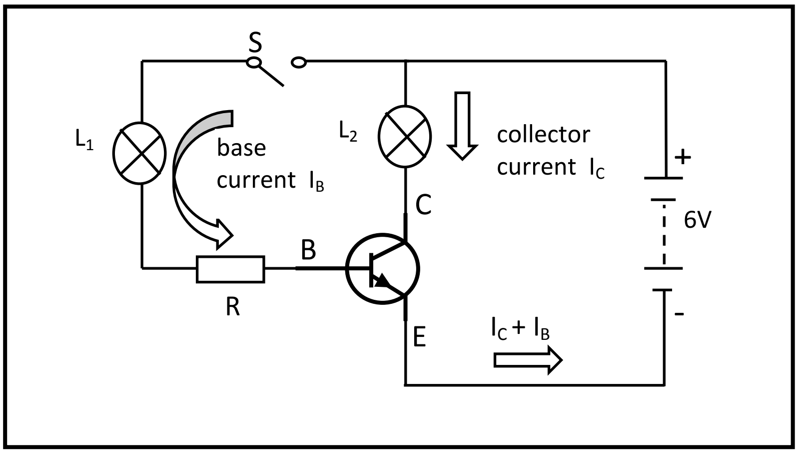


Figure 27. A transistor workings in a circuit.

When the switch (S) is open, the base current (I_B) is zero and lamp (L_1 and L_2) will not light up. This shows that the collector current (I_C) is also zero even though the battery is correctly connected across the current – emitter (CE) path.

When the switch (S) is closed, the base (B) is connected through the resistor(R) to battery (+) and so L_2 lights up and not L_1. This shows that there is now collector current (which passes through L_2) and that is much greater than the base current. The current that passes through L_1 is much smaller and therefore it is impossible to light lamp (L_1).

In a transistor, the base current I_B switches on and controls the much greater collector current I_C.

Resistor (R) must be in the circuit to limit the base current which would otherwise create a large collector current and may destroy the transistor by overheating.

Transistor as a switch

Transistors have many advantages over other electronically operated switches such as relays. They are small, cheap, reliable, have no moving parts, their life is almost indefinite (in well-designed circuits) and they can switch on and off millions of times a second.

A transistor is considered to be 'off' when the collector current is zero (0) or may be small. It is on when the collector current is larger. The resistance of the collector emitter path is large when the transistor is 'off' (as this would be for a normal mechanical switch) and small when it is 'on'. To switch a transistor 'on' requires the base voltage and of course the base current to exceed a minimum value of about + 6 volts.

In diagram (A) of figure 28 below, the transistor has a blocking effect. In other words, it is switched off. There is no current flowing through it and the bulb does not light. Diagram (B) shows what happens when a small battery is connected between the base and the emitter. A tiny current flows through the base and this alters the way transistors behave. The blocking effect disappears, the transistor conducts and the bulb lights up. You must remember that the transistor will only switch on like this if the positive (+) and the negative (-) terminals of the power source are connected the right way.

You must also know that in the base and collector circuits, the conventional current direction must match the arrow direction in the transistor symbol.

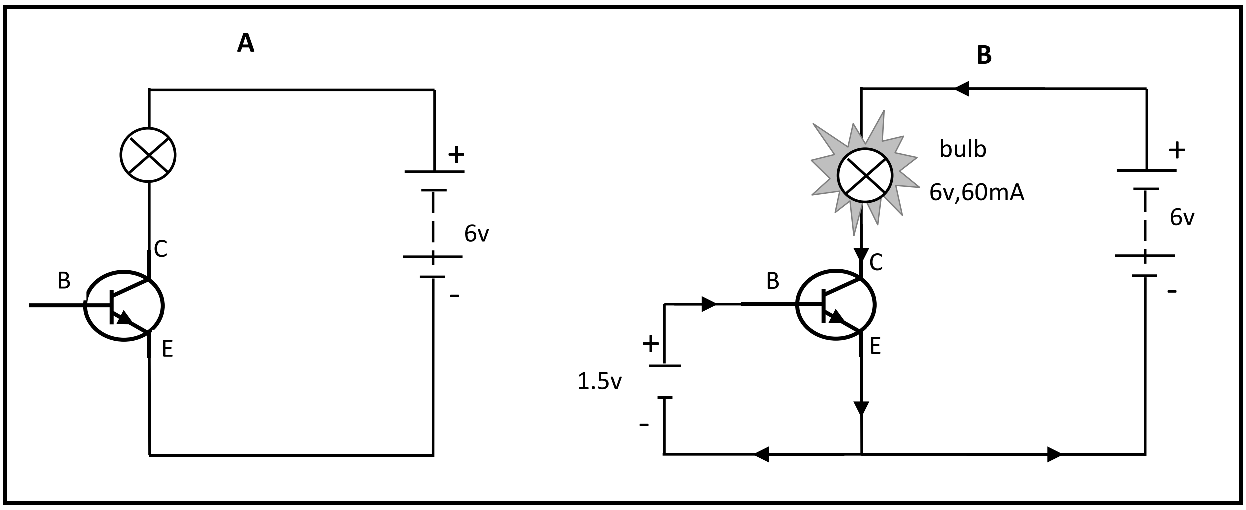


Figure 28. The behavior of a transistor in a circuit

You do not need an extra battery to switch on a transistor. The task can be done using proportion of the main battery voltage instead. This can be supplied by a potential divider.

In diagram(C) of figure 29, the resistor and a variable resistor are being used as a potential divider. You should know that the variable resistor has no resistance. The voltage across it is zero and the transistor stays switched off. Now that the resistance of the variable resistor is increased, its share of the battery voltage also increases. When it passes about 0.6 volts the transistor switches on and the bulb lights. This principle is used in transistor switching circuits.

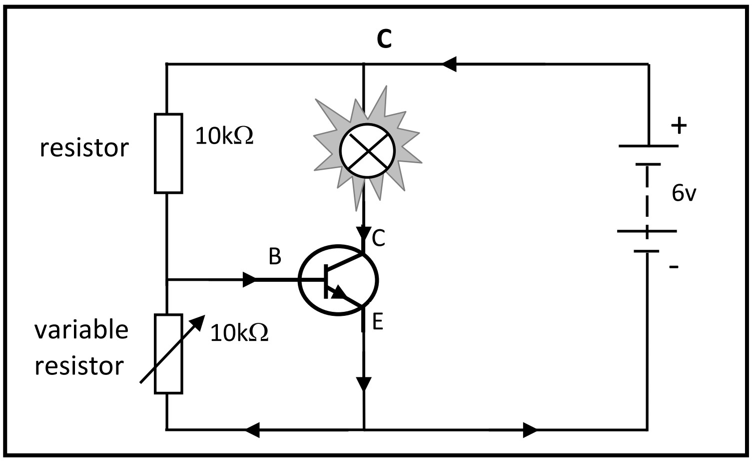


Figure 29. A transistor as a switch

Transistor are used as switches in devices such as alarms computers, digital watches on calculators, on weighing machines and telecommunication equipment.

Here are some circuits which used transistor to switch things on and off.

Turning on light in the dark

In daylight an LDR has a resistance of about 500Ω. So when it is light, the voltage across BC is very small. This is because the resistance of an LDR is much smaller than the 20kΩ resistor. The voltage at B is close to zero. The transistor is switched off and the bulb is out. When it is dark, the resistance of the LDR is very high about 1MΩ (1000 000Ω). The voltage across the 20 kΩ is much smaller compared with the voltage across the LDR. Now the voltage at B is nearly 6V. The transistor is switched on and the lamp lights.

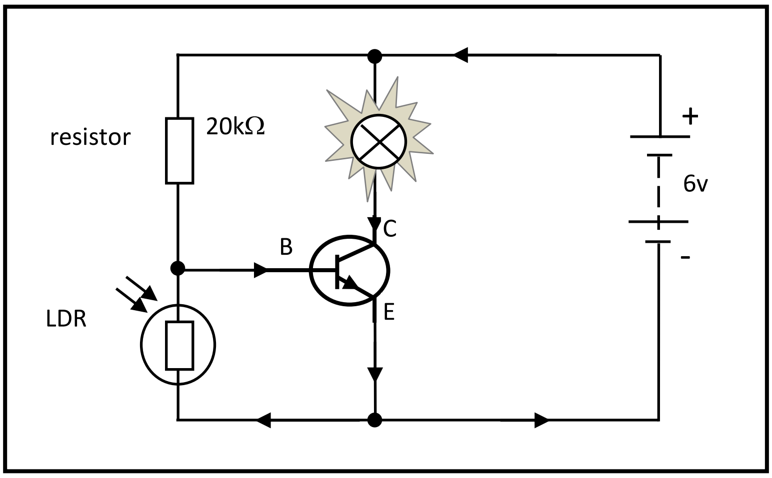


Figure 30. A transistor used to switch on light in the dark.

A time delay switch

When the main switch is closed as shown in the diagram below, there will be a delay before the bulb lights up. This happens because of the capacitor in the potential divider. The capacitor charges up slowly and in several seconds before the voltage across it is high enough to switch on the transistor. The delay can be increased by increasing the capacitance or increasing the resistance of the upper resistor.

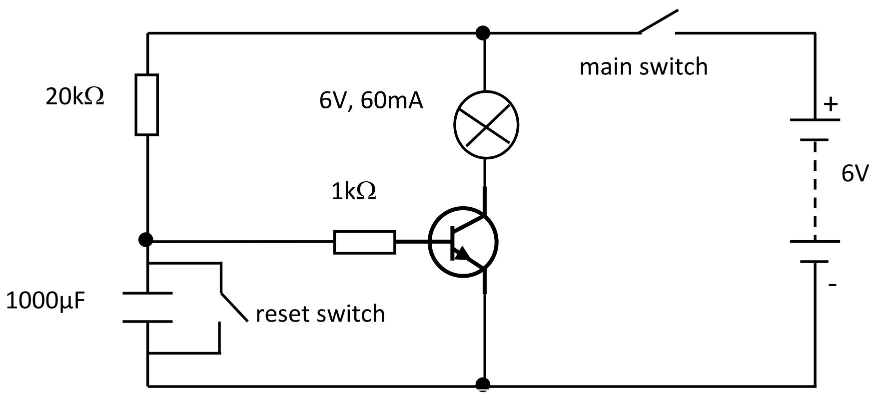


Figure 31. A capacitor used in a circuit to control time.

An automatic garden waterer

The circuit shows how a garden gets watered when the owner is away on holiday. The soil contacts are placed in the soil around the garden. When the soil is wet, it conducts electricity well. This means that there is a short circuit between the base and the emitter of the transistor so the transistor is switched off. When the soil dries out, the resistance between B and C becomes large. This makes the voltage at B rise and the transistor is switched on. Now you will see that the current through the transistor energizes the relay. The magnetic field from the coil makes the switch S close. Again this will now switch on the pump. We need a relay to switch on the pump because it needs a current of 2A. This is a far larger current that can flow through the transistor.

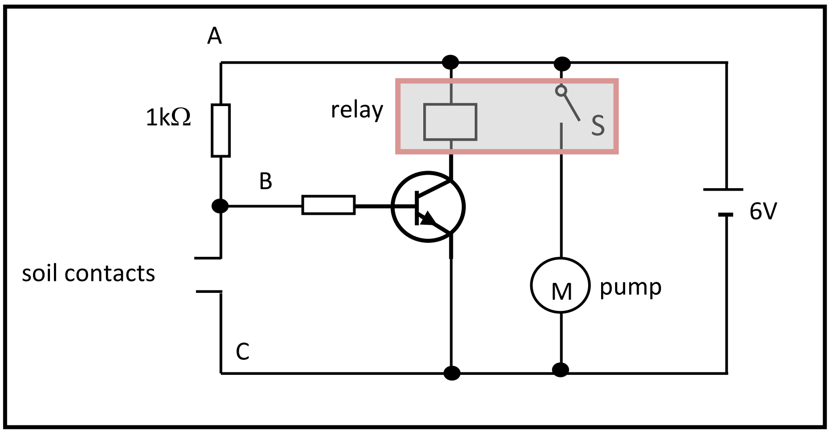


Figure 32. High power switch is put on by a relay

The two examples as shown in the diagram show how a transistor can act as a switch.

Now check what you have just learnt by trying out the learning activity below!

Learning Activity 4

30 minutes

Answer the following questions on the spaces provided.

1. Give a practical use of a;

   a) light sensitive switch.

   ____
   ____
   ____

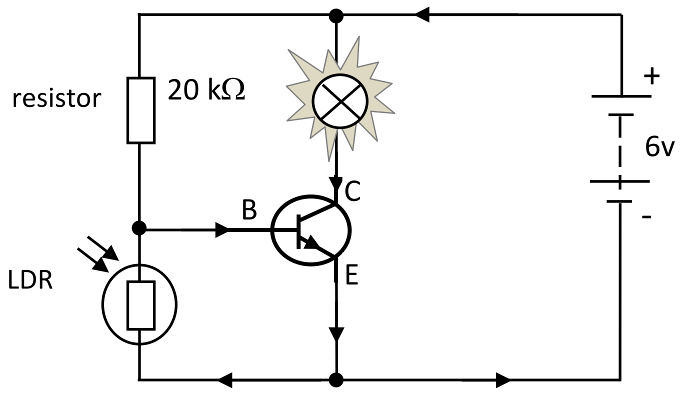
   b) temperature sensitive switch.

   ____
   ____
   ____

2. Why is a relay often used with a transistor switch?

____
____
____
____

3. A light sensitive switch is shown in the diagram below. What would be the effect of changing the LDR and the 10kΩ resistor so the LDR is at the bottom?



____
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____
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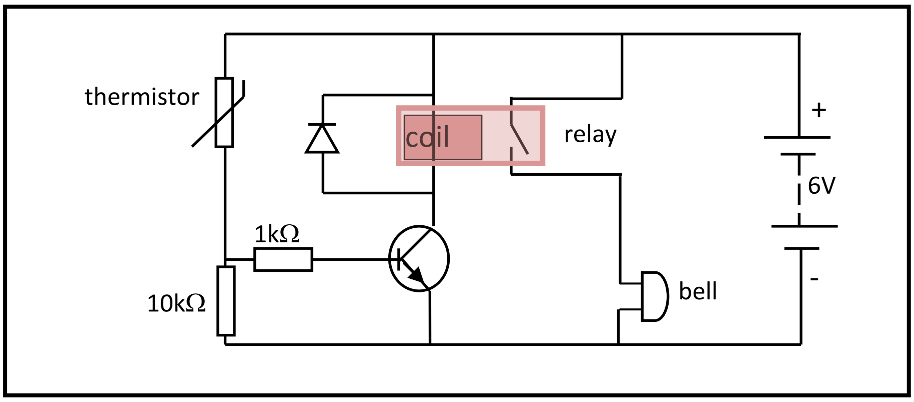
____

Refer to the temperature sensitive switch below to answer Question 4.



4. a) What would be the effect of replacing the 10kΩ resistor with one of the lower value?

____
____
____
____

b) What changes would be made to the circuit so that you will vary the temperature at which the bell sounds?

____

____

____

Thank you for completing learning activity 4. Now check your work. Answers are at the end of the module.

Transistor as an Amplifier

Transistors are semiconductor devices with three leads. A very small current or voltage at one lead can control a much larger current flowing through the other two leads. This means transistors can be used as amplifiers and switches. There are two main types of transistors: bipolar and field effect. If we will add a second junction to a PN junction diode we will get a three(3) layer silicon sandwich The sandwich can be NPN or PNP either way. The middle layer acts like a gate that controls the current moving through three layers.

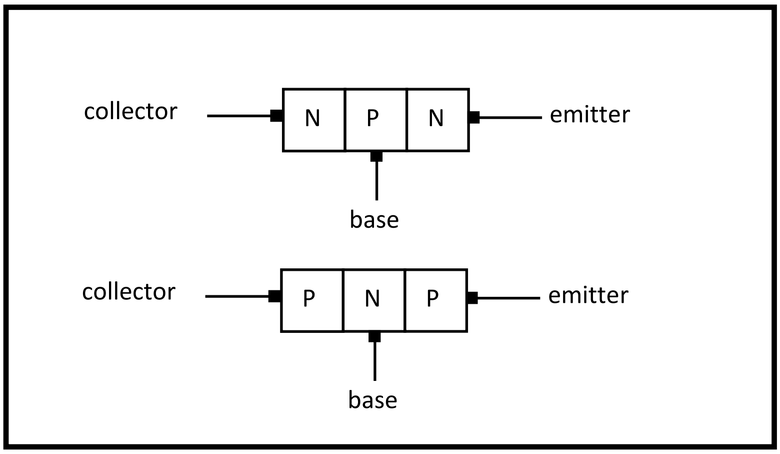


Figure 33. A PN junction diode being fused to form a transistor.

The three layers of a bipolar are the emitter, the base and the collector. The base is very thin and has fewer doping atoms than the emitter and the collector. Therefore, a smaller base current will cause a much larger emitter-collector current to flow.

Amplification is the strengthening of a weak electric current to produce a stronger one. A device which does this is called an **amplifier**. In general, amplifiers produce an output voltage which is larger than the input voltage. They can also be used as current amplifiers and power amplifiers. The voltage gain (A) of an amplifier is the ratio of the output voltage to the input voltage.

$$\text{Voltage gain (A)} = \frac{V_{out}}{V_{in}}$$

Most amplifiers manufactured today use transistors to amplify signals. Transistors are often small, three terminal, semiconductors which have revolutionised electronics. Transistors are made as separate devices or as part of an integrated circuit (IC) whereby thousands can be packed on a silicon chip.

A transistor is made of three (3) layers N, P, N semiconducting material. In an N, P, N transistor, a small base current causes a larger current to flow through the collector to the emitter. This effect is called current amplification or current gain. Current gain equals the collector current divided by the base current.

$$\text{Voltage gain (A)} = \frac{I_C}{I_B}$$

The values for the emitter current I_E, base current I_B and the collector current I_C through a transistor are shown above. As the current flowing out of the transistor must equal the total current in: $I_E = I_B + I_C$

$I_E = I_B + I_C$
20 mA = 0.1 mA + 19.9mA

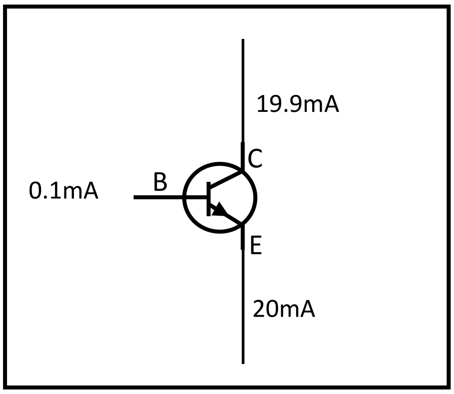


Figure 34. Current flow in a transistor

Once the transistor is conducting, a small change in the base current causes a much larger change in the collector current. This means that, the transistor can be used to amplify signals.
If I_C is 19.9mA and I_B is 0.1mA, then the current gain = $\frac{4}{0.04}$=199

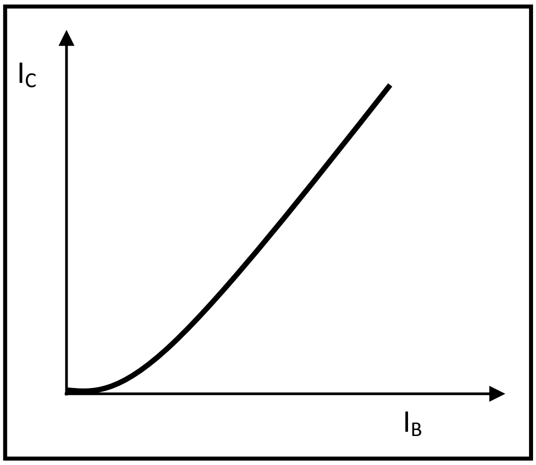


Figure 35. Current transfer characteristics for a NPN transistor

The collector current is proportional to the base current

From the graph, we can say that when the base current increases, the collector current increases. This simply means that, a small current in the base circuit causes a larger current to flow in the collector circuit.

There are two paths that the current can flow through a transistor as seen in figure 36 below. For a NPN transistor, the collector and the base must be positive with respect to the emitter. Such transistors can be damaged if they get too hot by carrying too much current. The transistor can amplify current and can also amplify voltage.

Suppose there was a resistor (up to 10kΩ) connected in the collector circuit, and as the current increases, the voltage will also increase. According to Ohm's law, V=IR.

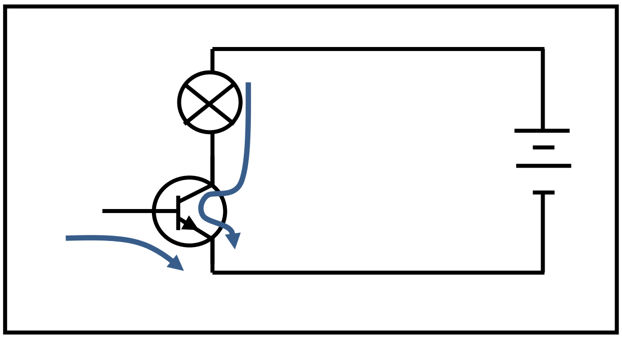


Figure 36. The two paths that current can flow through a transistor

Making an amplifier

The diagram below shows how make a simple amplifier. A microphone is used to pick up the speaker's voice and the loud speaker relay what is said to the audience.

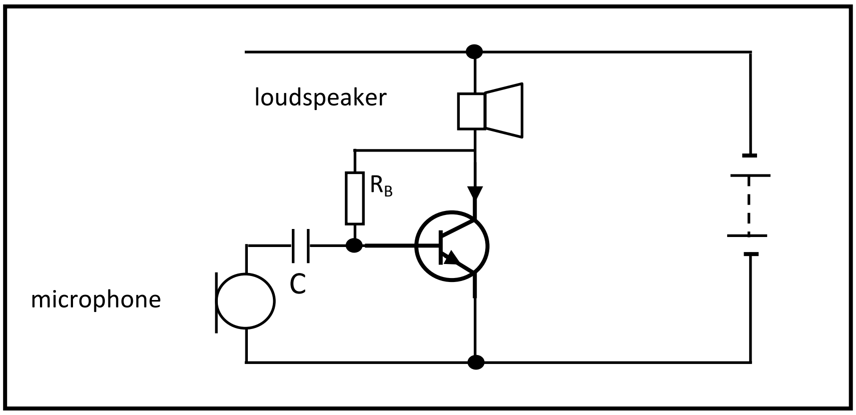


Figure 37. A transistor being used to amplify current

- The base resistor R_B is there to allow a small current to go into the base. This will switch on the transistor. We call this **biasing the transistor**.

- When someone speaks into the microphone, a small changing voltage is produced across it. This signal passes through the capacitor and makes changes to the base current.
- The small changes to the base current are amplified by the transistor. The current is now loud enough to drive the loud speaker.
- It is important to have a capacitor in the circuit. The capacitors allow alternating current through but not direct currents. This means that the signal can get through to the transistor. Without the capacitor, the biasing of the transistor would be upset. This is because the direct current would go from the base through the microphone. Now the base would be at the wrong voltage and the transistor will not work properly.

Now check what you have just learnt by trying out the learning activity below!

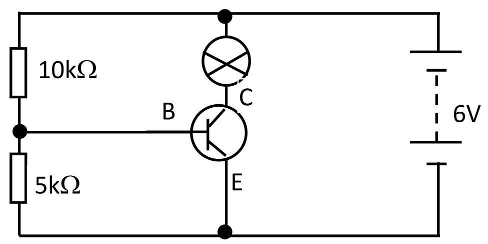
Learning Activity 5

40 minutes

Answer the following questions on the spaces provided.

Refer to the circuit diagram below to answer Question 1.

1. a) What do the letters E, B and C represent in the diagram?



Letter E ______________________
Letter B ______________________
Letter C ______________________

b) What do the two resistors do?

____
____
____
____

c) Is the bulb going to light up or not?

____
____
____

d) What is the effect of replacing the lower resistor with a short piece of wire?

____
____
____
____

2. If the circuit in Question 1 has a base current of 0.02mA and a collector current of 1.9mA, what is the

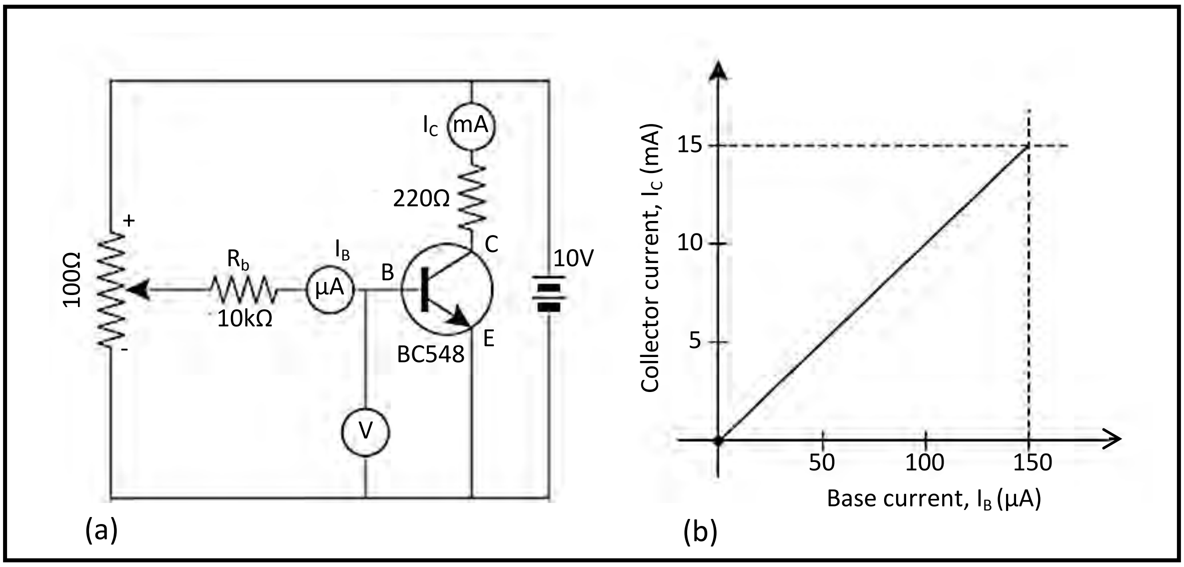
a) emitter current?

____
____
____
____

b) the current gain?

____
____
____
____

Refer to the circuit and graph below to answer Question 3.



(a) Circuit diagram, (b) Graph of collector current I_C, versus base I_B, current

3. What voltage should register on the base–emitter voltmeter when a small collector current I_C begins to be measured?

---

4. Use the data of the graph supplied to calculate the current gain of the BC548 transistor in this circuit.

---

5. An operating transistor has the following parameters: $\beta = 200$, $I_b = 15\ \mu A$.

What are the values of I_C and I_e?

I_c = ____
____

I_e = ____
____

---

6. Explain the operating conditions that are necessary to make a transistor function as a switch.
____
____
____
____

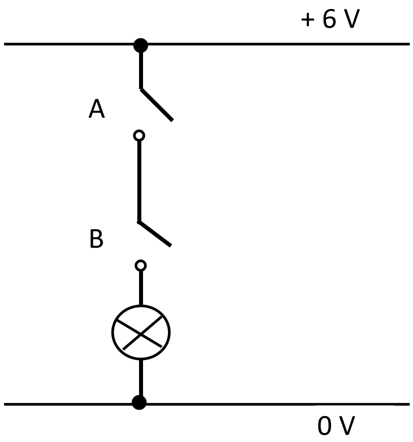
Thank you for completing learning activity 5. Now check your work. Answers are at the end of the module.

11.6.2 Digital Electronics

The computer is a very important piece of electronic equipment used today. The building blocks all computers use today are the logic gates. Logic gates are switching circuits used in digital electronic systems like computers. All the decision making processes within a computer is done by gates. Storage and timing task can be done on a digital computer by a group of devices called **multi-vibrators**.

Logic Gates

Logic gates are widely used in computers and other electronic systems. They collect and display information. A very simple logic gate is shown in figure 38 below.



State of switch		State of bulb
A	B	
open	open	off
closed	open	off
open	closed	off
closed	closed	on

Figure 38. Two –state system – the bulb is on or off

To turn on the light bulb you have to press both switches. It will not be good to just press only one switch and the behavior can be summarized in a table. The simple table can collect information about your fingers. When two fingers press switch A and switch B, the bulb lights. A similar circuit can work with relays. This time the circuit collects information about voltages. The relay switches in the circuit are normally open. However, if the voltage of A is high (for example above 3V) the top switch is closed. When switch A and B are above 3V, the bulb will switch on.

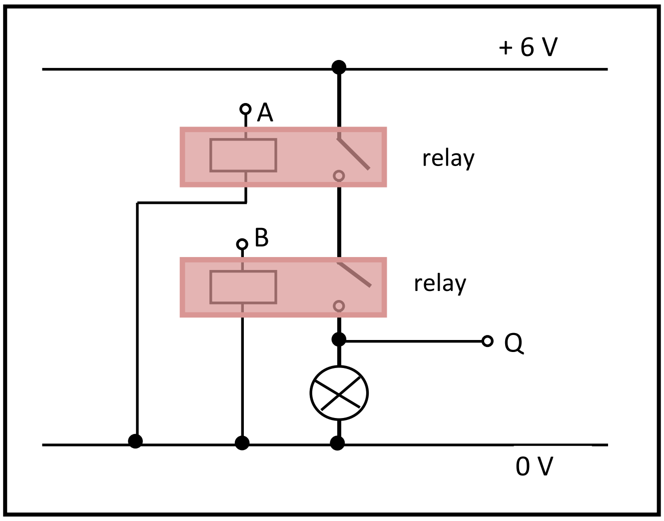


Figure 39. A relay is used to turn on the switch

Logic gate is a switching circuit in which the output at any instant depended on the inputs. In the decision making process, a gate is usually given voltage level at one (1) or two (2) inputs. It will then produce a single output signal.

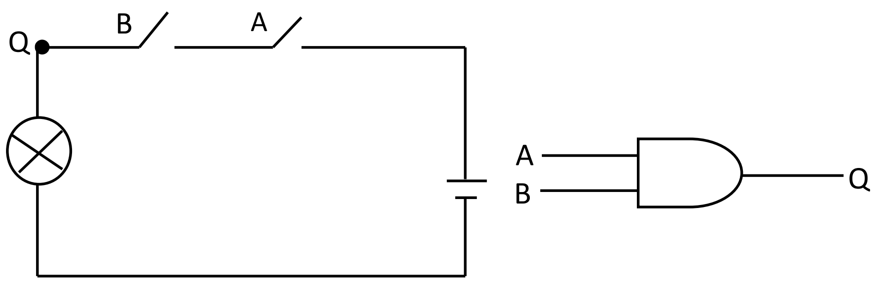
Logic gates today are made up of integrated circuits (IC). In this part of the topic, we will look at different types of logic gates.

The three main types of gates that we will look at are **AND**, **OR** and **NOT** gates. These three gates can be used to construct any other logic gates. Another important gate is a single input called the **INVERTER** which we will look at later in the course. This gate gives an output signal that is opposite to that at its input. We will also look at the other two gates which are the NAND and NOR gates. The truth table describes the behavior of logic gates. It also shows the output of all possible inputs.

High outputs and inputs for example +5 volts are represented by logic level 1.
Low outputs and inputs for example 0 volts are represented by logic level 0.

The AND gate

A simple mechanical switching circuit is shown in figure 40 below. It can help us to understand how the AND gate works. To determine the decision made by this type of gate, we look at the behavior of point Q. When point Q is at zero potential, the bulb will be off (logic 0). When it is at higher potential, the bulb will be on (logic 1). You will notice that when A or B, or both switches are off (logic 0), Q will be off. Q is on only when both A and B are both on (logic 1). The information is described in a **truth table**. A truth table is used to represent the input and output information of any logic gate or circuit to give a visual representation of the switching function of the system. A logic gate truth table shows each possible input combination to the gate or circuit with the resultant output depending upon the combination of these input(s).



input		output
A	**B**	**Q**
0	0	0
0	1	0
1	0	0
1	1	1

Figure 40. AND gate with its truth table

Output Q is high if inputs A and B are high

Use of AND gate

An AND gate can be used for a bank security system. The bank opens when a switch at the band vault and the bank manager's desk are pressed. An AND gate can also be used on a motor vehicle. This means that the car can only be started when door 1 and door 2 are closed. It can also be used on an automatic water system. The automatic water heater is on only when there is water in the water container and that the water is cold. The thermistor and the contacts are placed inside the water container. When the water is cold (input A is high) and the contacts are immersed in water (input B is high), the reed relay is on. The circuit is shown below.

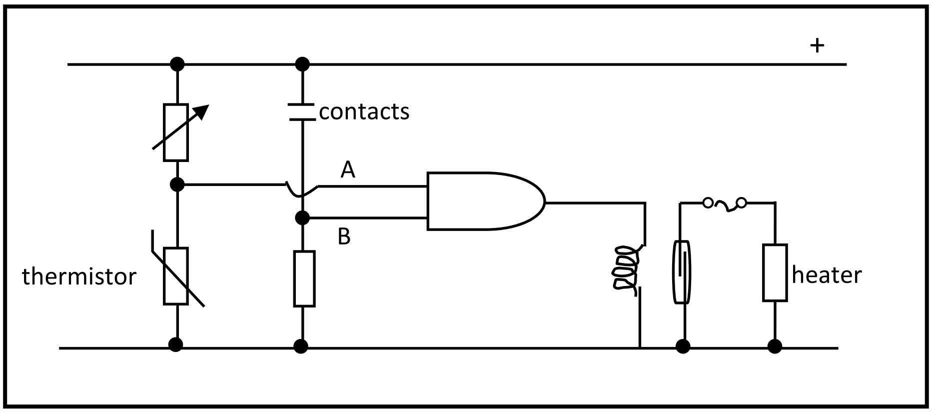
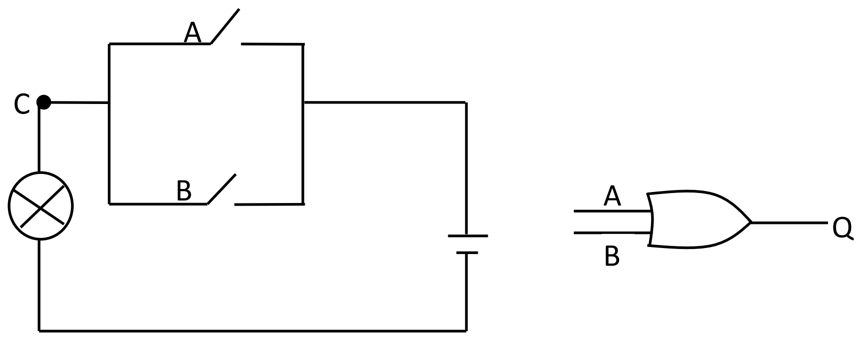


Figure 41. Hot water heating system

The OR gate

The diagram below shows how an OR gate works. Study the truth table given next to the diagram.



inputs		**output**
A	**B**	**Q**
0	0	0
0	1	1
1	0	1
1	1	1

Figure 42. OR gate with its truth table

The truth table for the OR gate shows that the output **Q** is 1 if input **A** or **B** or both are 1.

Output Q is high if input A or B (or both) is high.

Use of OR gate

The OR gate is used in car warning signal. Each switch is installed in the car door. When either door is open, the input is not connected and behaves as it is high. The output is high and the LED warning light glows.

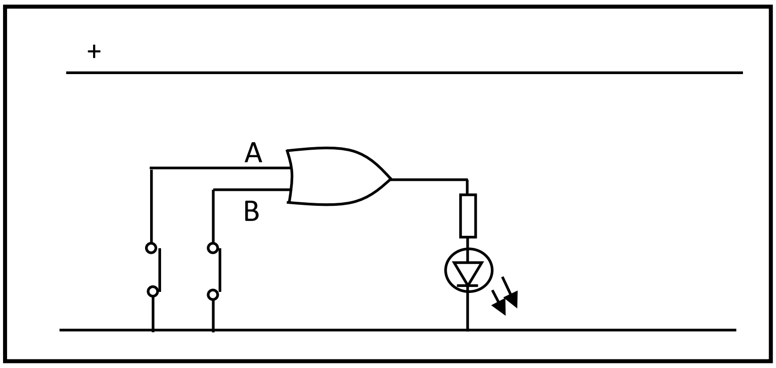
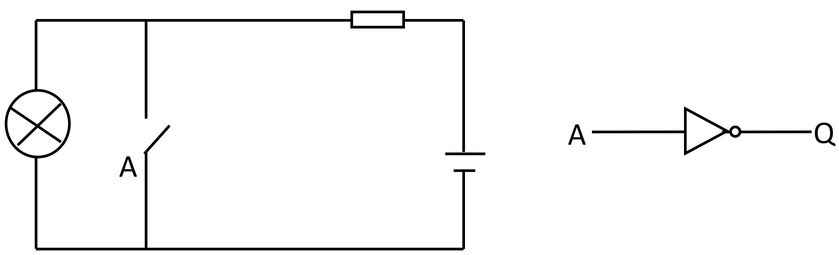


Figure 43. A OR gate used in car warning system

The NOR gate

The NOR gate or the inverter has only one input. The main function of this gate is to always produce an output which is the opposite of its input. That is, a (1) at the input results in a (0) at the output or a (0) at the input and a (1) at the output.



input	output
A	**Q**
0	1
1	0

Figure 44. NOR gate and its truth table

You will see from the diagram that the output is not the same as the input. If the lamp glows or lights up, the switch is off. However, when the switch is closed, the lamp does not glow.

Output Q is high if input A is NOT high

Use of NOT gate

This gate can be used in fire alarm systems. The buzzer in the circuit will sound an alarm when the temperature of the thermistor reaches a certain point. The sensitivity of the circuit can be changed by adjusting the variable resistor. The diagram below shows how the alarm system works.

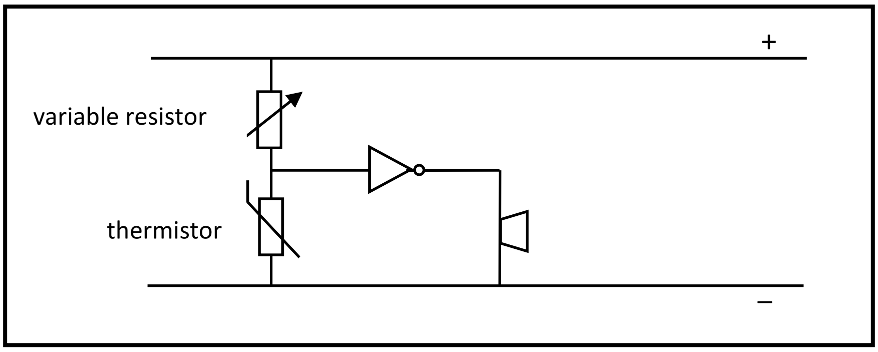
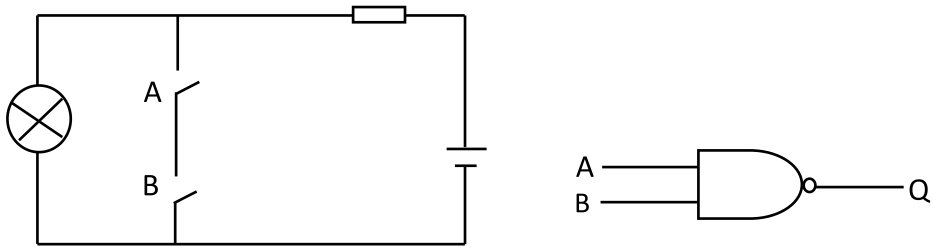


Figure 45. Fire alarm system

The NAND gate

Gates can be combined so that the output of one becomes the output of the other. Other logic circuits are combinations of three basic gates AND, OR and NOT. A NAND can be made by connecting an AND gate to an INVERTER. The output of a NAND is opposite to that of an AND gate. (NAND stands for Not AND). Therefore, for a NAND gate, the output is 1 if the input A and B are not both 1.



AND input		NOT input	NAND output
A	**B**	**C**	**Q**
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

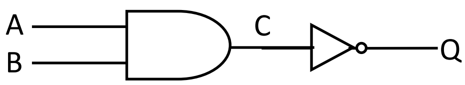


Figure 46. NAND gate and its truth table

A NAND circuit, circuit symbol for a NAND logic gate, A NAND truth table and a NAND gate combined with a NOT gate. A NAND gate can be made by combining an AND gate and a NOT gate.

Output Q is high if inputs A AND B are NOT both high.

Use of NAND gate

A simple burglar alarm system can be made using a NAND gate. The buzzer will sound when the light dependent resistor (LDR) is illuminated by the (burglar's torch) or the switch is closed by the burglar's foot stepping on the pressure mat.

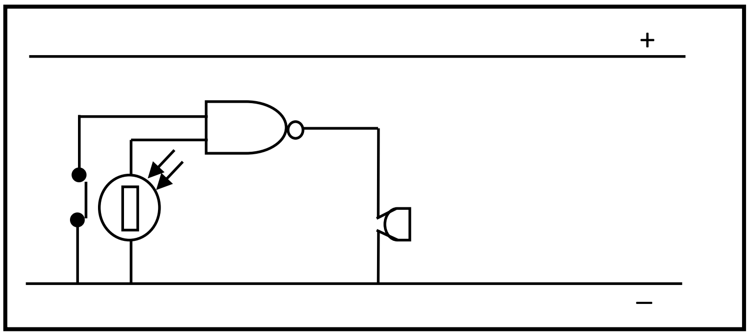
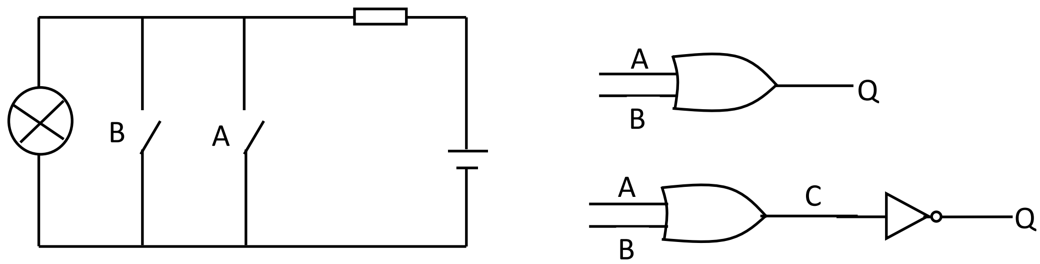


Figure 47. A burglar alarm system using NAND gate.

The NOR gate

A NOR gate is made by connecting OR gate to an INVERTER. The output of a NOR gate is 1 if neither input A nor B is 1 (NOR stands for Not OR).



OR input		NOT input	NOR output
A	**B**	**C**	**Q**
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

Figure 48. NOR gate and its truth table

Output Q is high if neither input A nor input B is high.

Use of NOR gate

The NOR gate can be made by combining OR gate to NOT gate. The NOR gate can be used as an automatic lighting system such as the one shown in the diagram. When neither the switch is pressed, nor the light dependent resistor is under the bright light, the bulb is turned on automatically. The lights come on automatically when it is dark.

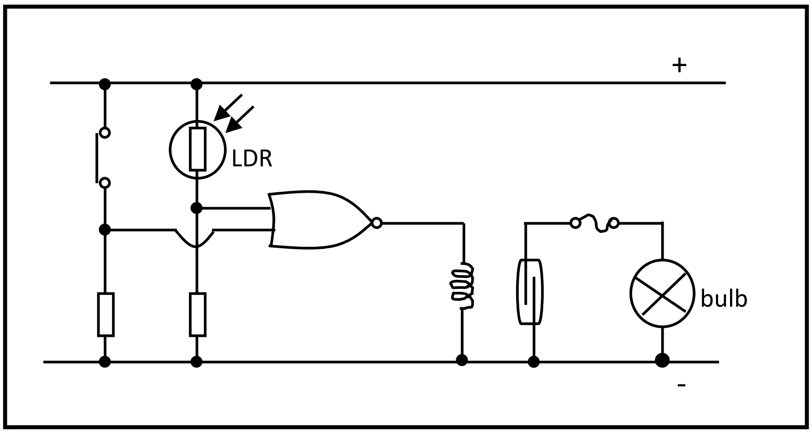


Figure 49. Automatic lighting system

One logic gate has limited use. However, they can be linked together to have multiple uses. Computers use thousands of logic gates linked together. The output of one logic gate is connected to another gate and the process continues.

Bistable

The bistable or a flip- flop can be flipped from one state to another. For example, if the top is made high, the bistable flips to another output state. One pulse can be enough to make the change. The bistable will remember its new output state. These features make it useful in computers where data is stored in binary codes as a series of (0's) and (1's). The two inputs are called S and R because one is used to set the system (change the output from low to high) while the other is to reset it.

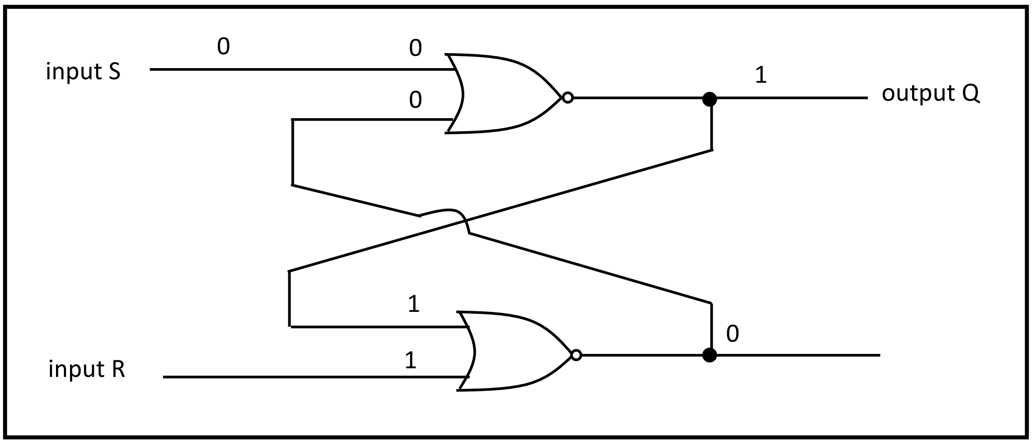


Figure 50. Input S is connected to logical 0 which sets the bistable.

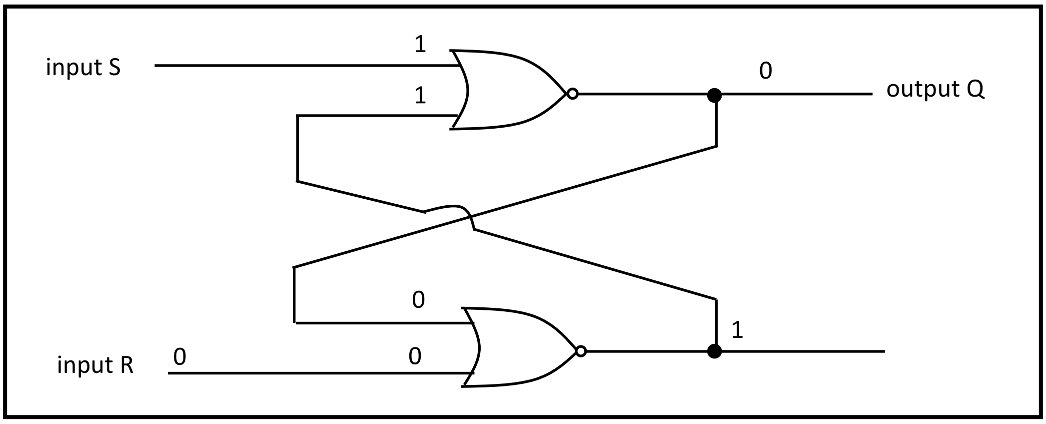


Figure 51. In put R is connected to logical 0 which resets the bistable

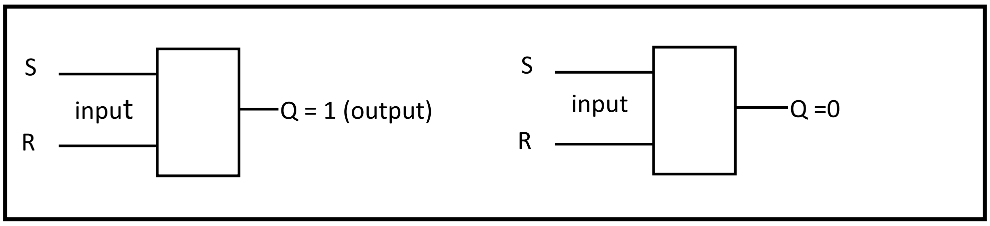


Figure 52. Stable SET state and stable RESET state

The arrangement above is called bistable. Two NOR gates have been cross-coupled so that the output of each is fed back to one input on the other. This means that, with both inputs low (0) there are two possible output states: the input can be low (0) or high (1). This is shown in the diagram.

Now check what you have just learnt by trying out the learning activity below!

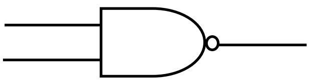
Learning Activity 6

40 minutes

Answer the following questions on the spaces provided.

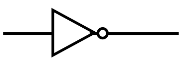
1. What do the symbols A – E represent?

A



____

B



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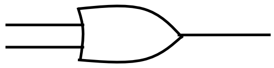
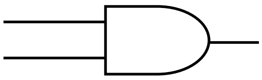
C



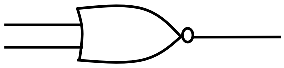
____

D



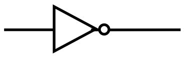
____

E



____

2. Write down the name of the logic gate in the diagram.

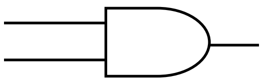


____

Complete the truth table for this logic gate

input	output
0	

3. a) What is this type of logic gate?



____

Complete the table.

Input A	Input B	Output
0	0	
1	0	
0	1	
1	1	

4. Where is logic gates used? Name the three main types of logic gates.

____

____

____

____

5. Give the truth table and the symbol for an OR gate.

Draw your symbol here.

---

6. Under what input conditions, is the output of

   a) an AND gate high?

   ____
   ____
   ____
   ____

   b) a NOT gate high?

   ____
   ____
   ____
   ____

Thank you for completing learning activity 6. Now check your work. Answers are at the end of the module.

Logic Gate Control System

Logic gates are used in computer microprocessors, security and safety systems to control electronic systems to perform tasks in places where it is unsafe for humans to operate. For example, a heavy duty high tension electrical switch within the high tension area can be controlled and operated by a logic gate from a safe area. Logic gates control systems are the main control system in most electronic systems today. Using an LDR connected to a NOT gate, an alarm system can be activated when a light beam directed to the LDR is broken.

Many of these can be demonstrated by connecting together commercial modules. Some examples are shown in the diagram below**.** Any electronic system can be considered to consist of three parts:

i) An input sensor or a transducer

ii) A processor

iii) An output transducer

The table below shows the input and output transducers.

input transducers	**output transducers**
microphone	loudspeaker
record player pickup	buzzer lamp
thermistor	relay
light dependent resistor	bell
mechanical switch	electric motor
reed switch	lamp

Table 2. Input and output transducers

Security system

Shown in figure 52 is a block diagram for a simple system that might be used by a jeweler to protect an expensive jewelry from being stolen. The jewelry sits on a push which sends a (1) to the **NOT** gate unless a clock is lifted when a (0) is sent. In that case the output from the NOT gate is a (1) which rings the bell.

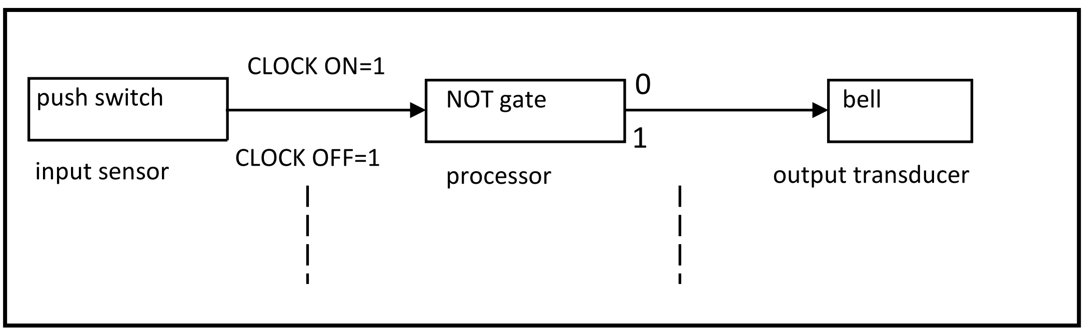


Figure 53. A block diagram for a security system.

Safety system for a machine operator

The system could prevent a machine (e.g electric motor) being switched on before another switch had been operated by a protective safety guard being in the correct position. You will see in the diagram that when switches A and B are pressed, they supply a (1) to each input of the AND gate which can then start the motor.

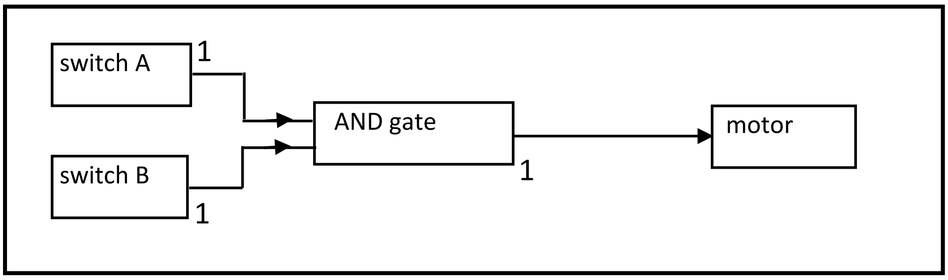


Figure 54. A block diagram for a safety system

Heater control system

The heater control has to switch on the heating system when it is:

i) cold - the temperature is below a certain value and the output from the temperature sensor is (0).

ii) daylight – the light sensor output is (1).

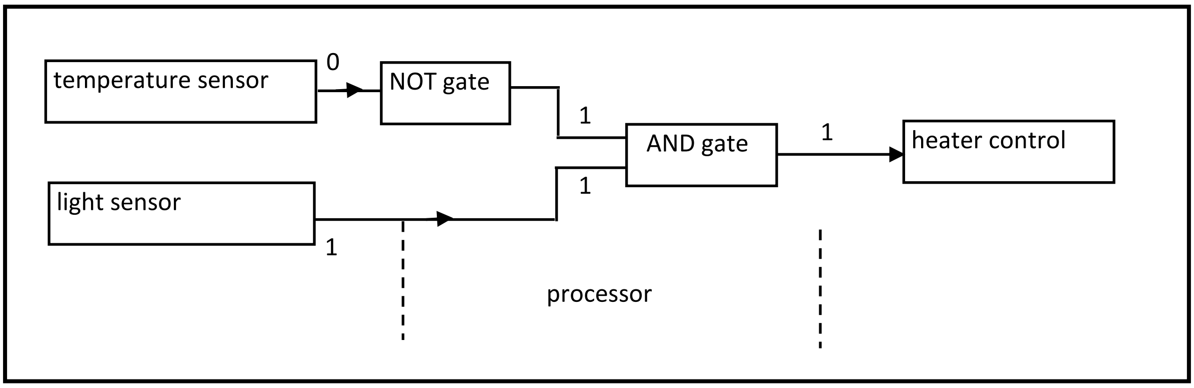


Figure 55. A block diagram for a heating system

You will note that with these outputs from the sensors applied to the processor, an AND gate has two (1) inputs. The output from the AND gate is then (1) and will turn on the heater control. Any other combination of sensor outputs produces a (0) output from the AND gate, as you can check.

Street lights

A system is required which allows the street lights either to be turned on manually by a switch at any time or automatically by a light sensor when it is dark. The arrangement that you see in the diagram achieves this since the OR gate gives a (1) when either or both of its inputs are (1).

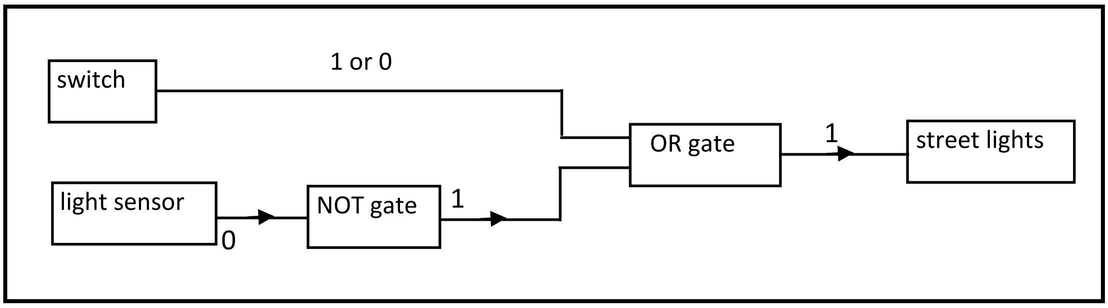


Figure 56. A block diagram for street lighting system

Feedback and Control

Feedback refers to a system, process, or machine in which part of the output is fed back to the input to regulate the operation. The returned part of the output is called feedback. When the feedback signal reinforces the trend of the system, it is said to be positive. When it opposes the trend of the system, it is called negative feedback.

Negative feedback is employed to stabilize systems. The negative feedback system can be said to maintain an output equal to the desired value. It does this by comparing measurements of input and output and using the results of the comparison to control input. Negative feedback is used in amplifiers and is basic to automation and process control. Positive feedback finds an application in oscillators, which we will study in further Electronics studies.

In many kinds of system, electronics and others, all or part of the output (or information about it) is **feed back** to the input and affects the output.

Feedback is **positive** if it acts in the same direction as the input and increases the output. It is used to produce A.C. in electrical oscillators and in bistables which are the basic memory elements in computers. Too much positive feedback can cause instability in a system. Thus, may happen in a public address system if the sound (output from a loudspeaker) is picked up by the microphone and fed back to the amplifier and then on to the speaker where it produces howls (distorted sound).

Feedback is **negative** if it acts in the opposite direction to the input and reduces the output. In an amplifier, though it decreases the gain, it makes for stability, better control and less distortion.

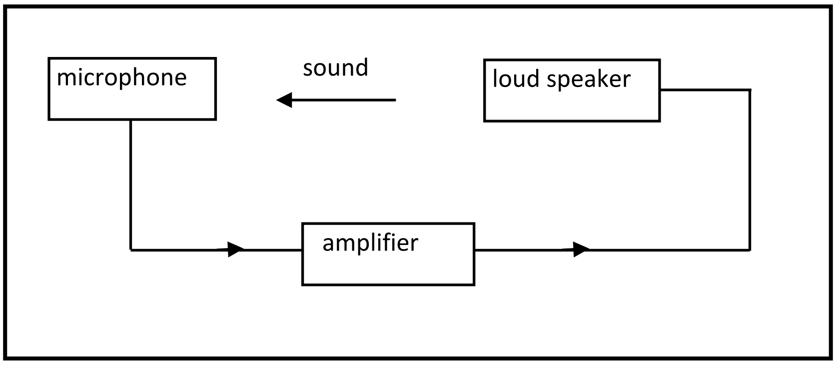


Figure 57. A block diagram for negative feedback

a) **Control of the body temperature**

Feedback plays an important part in this process. If the body temperature rises above normal, the blood and temperature sensors in the skin feedback information to a part of the brain which responds in two ways. First, it increases the rate of flow of blood in the skin capillaries so increasing the rate at which the blood is cooled. Second, sweating starts, producing cooling of the body by evaporation .If the temperature fall below normal, feedback reduces the blood flow to the skin and no sweating occurs, and shivering is activated to generate heat in the muscles.

b) Control of a heater

A block diagram of a system to regulate the temperature of a room is shown in Figure 58. The required is set by hand on the thermostat. If the setting is above room temperature, the **thermostat** switches on the **electrical supply** to the **heater**. The room warms up and when its temperature reaches the one selected, the thermostat responds to this information, which is fed back to it from the **air in the room**, by switching off the electrical supply.

If the room cools and its temperature falls below the setting ,the thermostat will again respond and switch on the heater. This is how the temperature control by feedback is achieved.

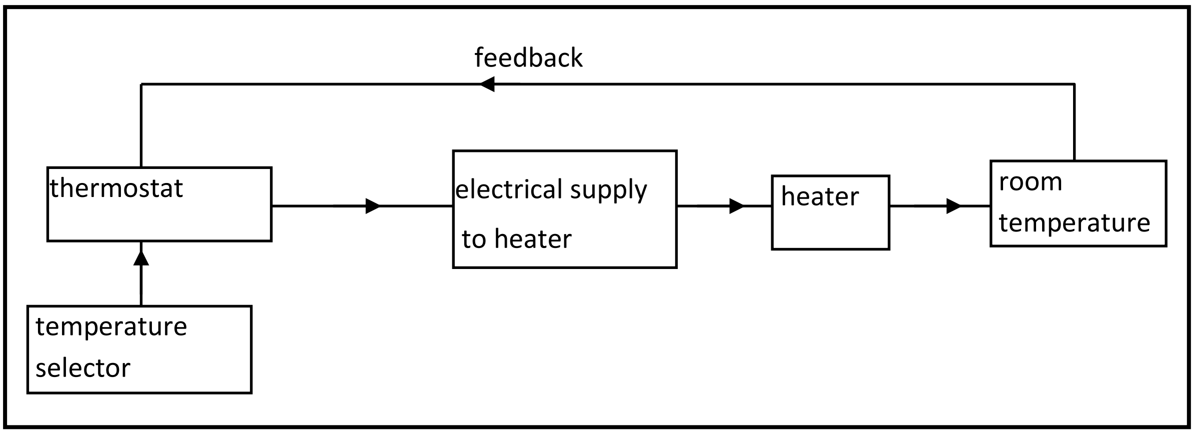


Figure 58. Feedback for temperature in the room

Control of a car exhausts system

Many cars are fitted with a feedback system to minimize and control exhaust gases. You will now see in figure 59 that the oxygen sensor in the exhaust pipe feeds back information about the emission gases to the electronic control unit (a microprocessor). This adjusts the air and the fuel mixture to the cylinder. This will then optimize the efficiency of the catalytic converter in changing harmful gases into carbon dioxide, nitrogen and water.

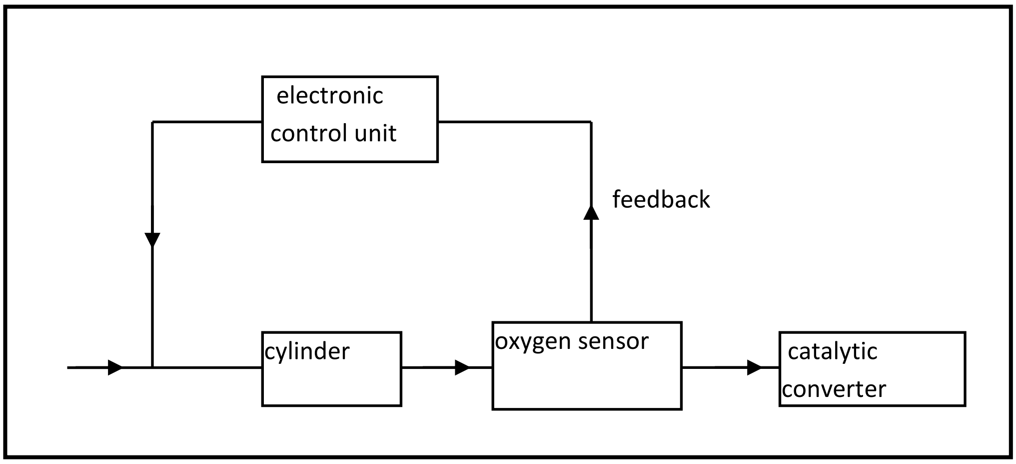


Figure 59. Controlling a car exhaust system

Burglar alarm

The burglar alarm system demonstrates the use of bistable latch as processor control system. The alarm operates when an intruder breaks a light (infrared) beam and cuts of the illumination to the light sensor. This changes the input to the latch (an SR bistable) making it go high and activates the transistor switch which operates the alarm. The alarm is kept on by the latch even when the light beam is no longer interrupted until the latch is reset**.**

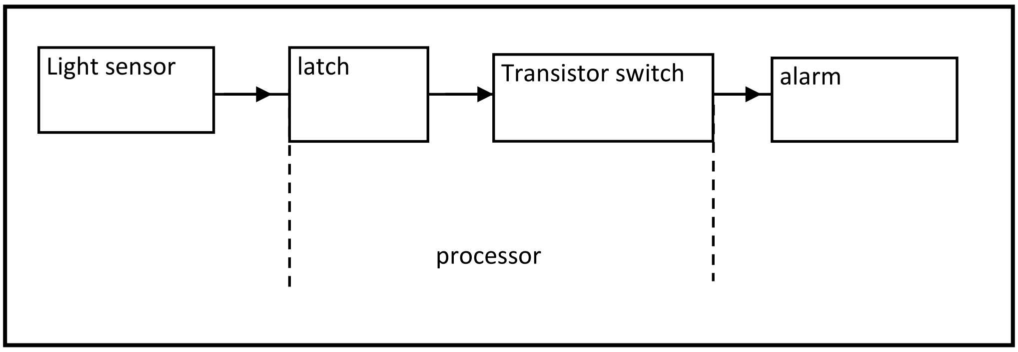


Figure 60. Light sensitive alarm using a latch

Now check what you have just learnt by trying out the learning activity on the next page!

Learning Activity 7

40 minutes

Answer the following questions on the spaces provided.

Design and draw block diagrams for the logic control system to indicate how the following task could be done.

1. Allow a door bell to work only during the day.

2. To switch on a water pump if a house plant is too dry.

3. Give warning when the temperature of a domestic hot water system is too high.

4. To switch on a heater if a fish tank gets too cold.

5. To switch an anti-burglar device to switch on your house lights when you are out of the house.

6. Draw a block diagram to of an electronic that might be adapted to switch on a street lamp when the sky goes dark.

Thank you for completing learning activity 7. Now check your work. Answers are at the end of the module.

Electronics and Society

The making of integrated circuits (ICs) or microchips have further revolutionized the field of electronics. Integrated circuits can be made by forming individual transistors, diodes and resistors on a small chip of silicon. The components are connected to one another with aluminium wires deposited on the surface of the chip. This forms an integrated circuit (IC).

Integrated circuits can contain few or several hundreds or thousands of transistors. In that way, electronic devices that once took up a lot of space now take up very little space. You may have noticed that popular electronic devices such as video games, digital watches, mobile phones and computers can be made smaller and more portable.

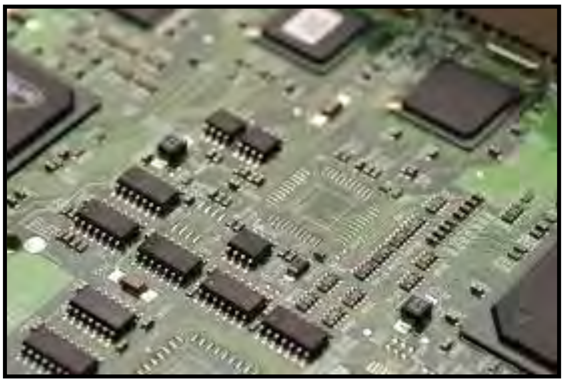


Figure 61. Integrated circuits or microchips on a circuit board of a device.

The picture above shows an integrated circuit. The actual circuit or chip is very small but can easily contain more transistors, resistors and capacitors. Nowadays, integrated circuits have more than a million components on one chip.

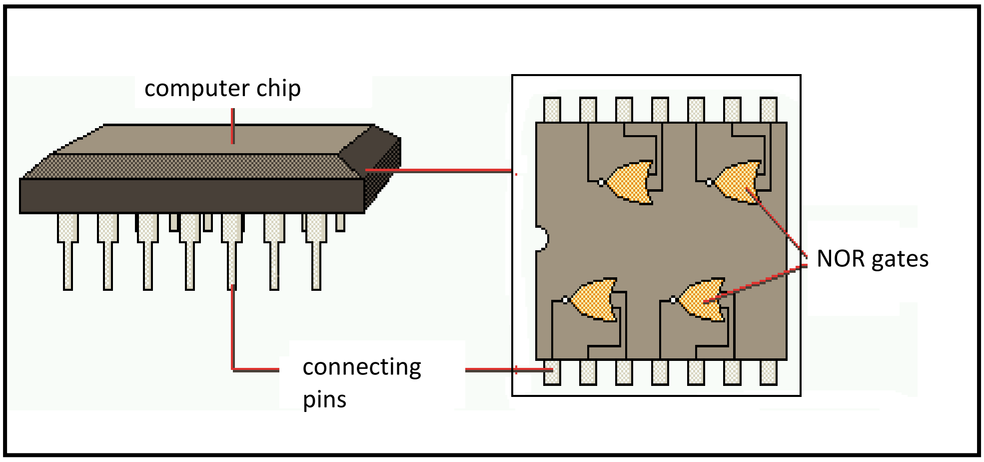


Figure 62. A computer chip and logic gates

There are two types of integrated circuits. Analogue signals are commonly used in audio, video and television systems while digital signals are used widely in computers and a microprocessor or microcontroller-based consumer devices.

Figure 63. An analogue and a digital meter.

1. **Analogue** (or linear) integrated circuits produce, amplify or respond to variable voltages. Analogue IC includes many kinds of amplifiers, timers, oscillators and voltage regulators.

2. **Digital** (or logic) ICs respond to or produce signals having only two voltage levels. Digital ICs include microprocessors, memories, microcomputers and many kinds of simpler chips.

The diagram below shows an analogue (linear) system. The voltage can vary smoothly and can have any voltage between the lowest and the highest. The digital system can only have certain definite values usually on or off. The transistor switch and the logic gate are digital systems. Both analogue and digital systems can be built into an integrated circuit as shown earlier in the diagram.

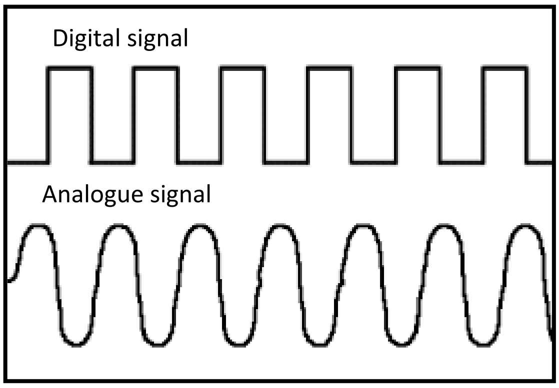


Figure 64. An analogue and digital signal

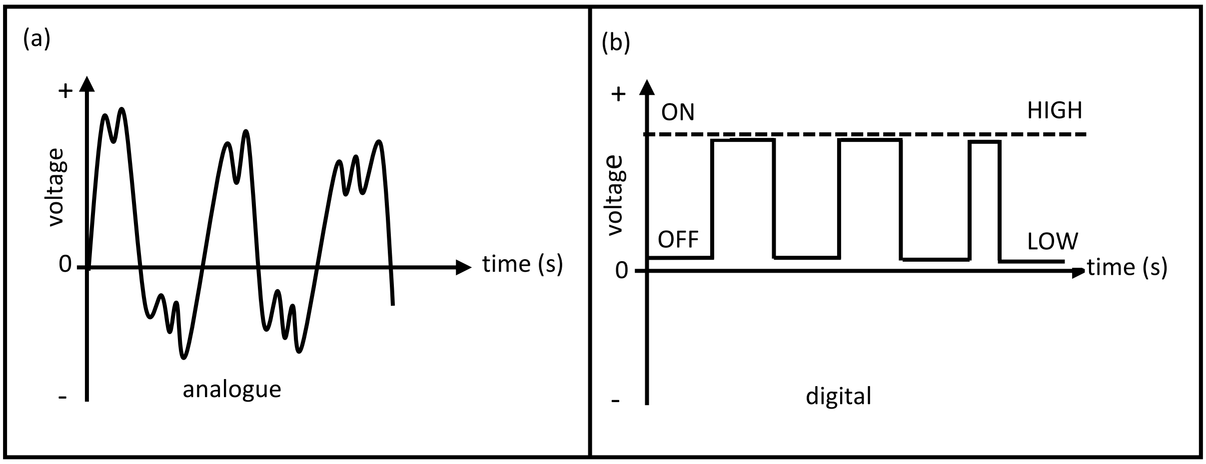


Figure 65. (a) An analogue electrical signal (b) a digital electrical signal

Electronics has an impact in all our lives. Work and leisurely activities are changing as a result of the social, economic and environmental influences of new technology. Electronics has changed almost all aspect of life and society from television and computers, to mobile phones and medical diagnosis and treatment. The discovery of p-n junction diodes led to the development of photovoltaic cells or solar cells opening a window to electricity in rural life.

People in the modern society, as well as those in the western worlds and cities become too dependent on technology, including electronics technology that they become lazy. Even cars today are becoming computerized with the use of many electronic devices. And with these many electronic devices, that means more electrical energy can be drawn from the car battery to power them.

Electronic systems tend to be cheaper, smaller, more reliable, less wasteful, and much faster and can respond to a much wider range of signals than other systems.

Areas of Impact

In homes devices such as washing machines, burglar alarms, telephones, cookers and sewing machines contain electronic components. Some office doors heating systems may also have automatic electronic control. Video recorders, CD players, interactive digital television or computers are making their way into homes and are used for entertainment. Internet connections and electronic games are also found in homes in modern urban societies.


Figure 66.Computers used at homes and video games played on computer.

Medical services have benefited greatly in recent years from the use of electronic instruments and appliances. Electrocardiograph (ECG) recorders for monitoring the heart, ultrasonic scanners for checks during pregnancies, gamma ray scanners for detecting tumors, deaf aids, heart pacemakers, artificial kidneys, limbs and hands with electronic control and key hole surgeries are some of the many devices operated electronically.

Figure 67. Ultra sound scanning in a hospital controlled by an electronic system

In industry, microprocessor controlled equipment are being used to control robots. These robots are used in car assembly and to do other jobs such as welding and spray painting. In many cases production lines and factories are entirely automated. Computer aided design (CAD) of products are also increasing at a fast rate.

Figure 67. Computer aided design used by electronic system.

In offices, banks and shops, computers are used for word processing, data control and communication through emails. Using electronic means text, numbers and pictures can be transmitted by high speed digital links. Cash dispensers and other automated services used by banks have made life easier for customers. Bar codes found on packages of products are often used by shops for stock control with the help of a bar code reader and the data recorder connected to the computer. A similar system is used by libraries to record the issue and return of books.

Figure 68. Automated telling machine used in banking industry and an automated circulation system in a library

Communication has been transformed by electronics. Satellites help us to be aware of events that are happening on one side of the world. This can be made possible through telephone links, mobile phones and on emails.

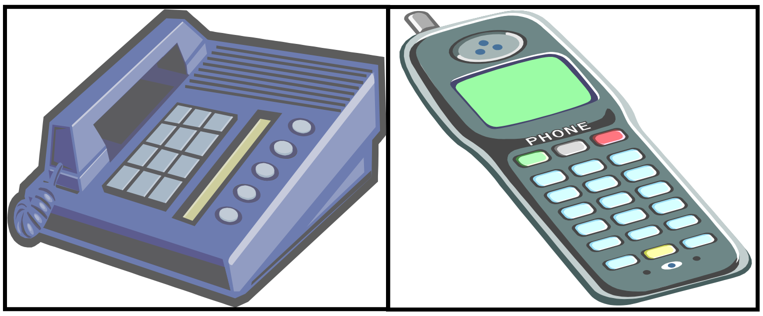


Figure 69. Telephone and mobile phones used in communication

Leisure activities have been affected by electronic developments. Some people participate or attend sporting activities where the electronic scoreboard is an evidence of increase in electronic age. Other people can listen to music whose production and recordings has been transformed by digital revolution. Some popular music recordings have been electronically synthesized. The sound effects and lighting on stage can also be programmed by a computer. For someone who loves going to cinemas, the special effects in film production have been greatly improved by computer generated animated images.

In transportation, electronically controlled traffic lights can control the flow of traffic in a busy town or city. Even the cars that are being driven can have central locking system that provides safety for the driver and the passengers. Most of the controls and instruments on an airplane have electronic control systems that assist the pilot in flying and landing the airplane.

Figure 70. A busy traffic in a city is being controlled by electronic system

Consequences of impact

Most of the economic consequences of electronics are beneficial, but only a few can cause problems. The reliability of electronic systems can improve the quality of life by increasing life expectancy, assuring more leisure time. Those that are in the workforce do not have to do dull and repetitive jobs by which the electronic system can do the task. It has also made the world a better place.

The Public is better informed because of better communication. News can be reported to our homes by radio and television. The influence of information systems such as text messages, social media, you-tube and the internet has made it easier for people to be well informed of what is happening in and around them.

Electronic data bases have been developed recently. This is the development of memories which can store huge amounts of information for rapid transmission from one place to another. For example, police can obtain information in seconds by radio, the details of a car they may be following. On the other hand, data bases can raise a question of invasion of privacy for individuals or for organizations.

Employment is affected by the demand for new equipment. New industry and jobs are created to make and maintain it. However, if electronic systems replace mechanical ones, then some people in the workforce may find themselves being laid off or become redundant. On the other hand there can also be retraining of workers. Conditions of employment and long term job prospects can also be affected for many people, especially for those doing manual or clerical work. For example, one industrial robot can replace four factory workers.

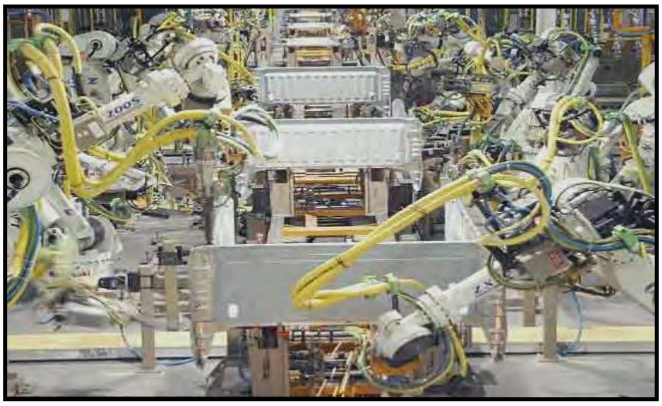


Figure 71. Robots replacing human by doing repetitive and dull jobs in an assembly line.

The public attitude to the electronics revolution is not always positive. This is because modern electronics is a hidden technology with parts that are enclosed in a tiny package and do not move. It is also a throw away technology. This means that the whole lot can be discarded and replaced. An expert will be the only person to fix it if any problem arises or the part fails. At times, these parts are not readily available. For this reasons, it may be regarded as mysterious or unfriendly.

Future

The prediction about the future is that new technologies will be developed. Just like the present one, they will continue to have influence on our lives. Today, the development of intelligent computers is being pursued with great determination. Voice recognition techniques are already being used on some computers. Optical system that is more efficient than the electronic ones are increasingly being developed. They are being used in data transmission storage and processing of information.

Now check what you have just learnt by trying out the learning activity below!

Learning Activity 8

40 minutes

Answer the following questions on the spaces provided.

List two advantages and disadvantages of using electronic system in the society.

Advantages

____

____

____

____

____

____

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Disadvantages

Thank you for completing learning activity 8. Now check your work. Answers are at the end of the module.

NOW REVISE WELL USING THE MAIN POINTS ON THE NEXT PAGE.

Summary

You will now revise this module before doing **ASSESSMENT 6**.
Here are the main points to help you revise. Refer to the module topics if you need more information.

- Substances that conduct electric current are known as conductors.
- Substances that do not conduct electricity are called insulators.
- Semiconductors are substance that may behave like a conductor or an insulator.
- Conductivity of semiconductors can be improved by heating or doping.
- Elements like copper are good conductors of electricity because they have free electrons.
- Solid state electronic devices like diodes, thermistor, LEDs and LDRs are semiconductors
- Pure semiconductors like Silicon and Germanium are called intrinsic semiconductors.
- A semiconductor is labeled as extrinsic if conduction is dominated by donor acceptor. Impurities.
- The conductivity of semiconductors can be improved by introducing impurity atoms into the crystal lattice and this is called doping.
- A diode allows current to flow one way only. The flow of current is due to movement of electrons (negative charges) and holes (positive charges).
- In a diode current flows when forward bias and does no flow when it is reversed biased.
- Diodes can be used as rectifiers (to convert alternating current to direct current).
- A semiconductor with impurities that introduce extra electrons into the lattice is known as an n-type semiconductor.
- A semiconductor with impurities that introduce a vacancy in the bonding is known as a p-type semiconductor.
- The impurities in semiconductors introduce extra holes or electrons and so improve the conductivity of semiconductors.
- The resistance of and LDR (light dependent resistor) decreases if illuminated .The resistance of a thermistor when oit is heated. An LDR, a transistor and a reed switches are input transducers.
- A relay and a LED (light emitting diode)are output transducers
- A transistor amplifies small current .A transistor or (op-amp) can be used as an electronic switch.
- In a reed relay, a large current through the relay contacts can be controlled by a much smaller current through the relay coil.
- Semiconductor devices can be made by using the properties of the junction between p- and n-type semiconductors, and include the diode, the solar cell and the transistor.
- Transistors replaced thermionic valve triodes used in the control of electrical current.
- Transistors have the advantage of being faster, smaller and more energy efficient than thermionic valve triodes, and thousands can be produced on a small silicon wafer to make complicated integrated circuits.
- A variable voltage can be obtained from a potential divider circuit.
- A logic gate is a switching circuit in which the state of the output depends on all the present state of input. The output is high only for certain input combinations.
- There are several kinds of logic gates; AND, OR, NOT, NAND, NOR.

- Amplifiers produce an output voltage which is larger than the input voltage.
- In an NPN transistor a small base current causes are larger current to flow through the collector to the emitter. This is called current amplification.
- Capacitors are devices used in electronic circuits to store charge and energy.
- Rectifiers use diodes to convert Ac signals to DC signals.
- The output of a rectifier can be smoothed by a capacitor across the load input.
- The output of a flip-flop changes (from 1 to 0 or from 0 to 1) when a pulse of electricity is applied to its input.
- Block diagrams are used to show how a logic gate works.
- Electronic systems have many advantages and disadvantages in modern society.
- Many different types or transistor are built into an integrated circuit (IC).

We hope you have enjoyed studying this module. We encourage you to revise well and complete assessment 6.

NOW YOU MUST COMPLETE ASSESSMENT 6 AND RETURN IT TO THE PROVINCIAL CENTRE CO-ORDINATOR.

Answers to Learning Activities 1 - 8

Learning Activity 1

1. A conductor is a substance that allows electricity to flow through it easily and an insulator does not allow electricity to flow through it easily
2. Carbon (C), Silicon (Si) and Germanium (Ge)
3. Phosphorus (P), Arsenic (As) ,Antimony (Sb)
4. Aluminium (Al), Gallium (Ga), Indium (In)
5. By doping it or by heating the semiconductor
6. Intrinsic conductors are semiconductors that are not being doped and extrinsic semiconductor are those semiconductors that have been dope. By adding impurities
7. Ohmic conductor obeys ohms law while a non ohmic conductor does not follow ohms law.
8. A space left unfilled by an electron .Holes are the positive charges on a semiconductor
9. Doping is a way of adding impurities to the semiconductor so that it can conduct current

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Learning Activity 2

1. An atom that has either 5 or 3 electrons on its outer shell which may be used in doping.
2. a) An n-type semiconductor is a semiconductor that has negative charges or electrons.

   b) A p-type semiconductor is a semiconductor that carries positive charges or holes.
3. Majority of carriers n-type semiconductors are electrons and in a p-type semiconductor are the holes.
4. a) Phosphorus (P), Germanium (Ge), Arsenic (Ar)

   b) Boron (B), Aluminum (Al) ,Gallium(Ga) ,Indium (In)

Learning Activity 3

Part A.

1. The function of the rectifier is to convert alternating current (AC) to direct current (DC)

2. a) Curcuit B will light up.

   b) No current will flow in circuit A.

Part B.

1. (a) (i) A zener diode is a semiconductor component that functions as a voltage regulator. When current is passed through the device in the forward biased direction, it behaves much like any other semiconductor diode. When current is passed through the device in the reverse biased direction, the normally high reverse resistance suddenly becomes very low when the applied voltage exceeds a specified minimum level called the Zener breakdown voltage, which can be selected to be from about three volts to hundreds of volts. This characteristic has the effect of regulating the applied voltage to the level of the Zener breakdown voltage.

   (ii) Zener diodes are commonly used to protect sensitive electronic circuits and components from excess voltage

   (b) (i) A Light-sensitive diode is a device that is activated by electromagnetic energy in the form of light waves. It is also called the light dependent resistor.

   (ii) Widely used to put automatically on and off street lights. They serve as counting devices on production lines, and can be employed in various alarm systems. They are also familiar in supermarkets as the sensor that scans codes on grocery items at checkout counters. Also in photography, they are designed as the light meters used to measure the intensity of illumination (see ACTINOMETER).

   (c) (i) A light emitting diode gives out light at very low current. Commonly called the photo emissive shell

(ii) Such cells are familiar as the "electric eyes" that trigger the automatic opening of doors when a person intercepts a beam of light. They may also be used in ways similar to those of photoconductive cells in other automated and control systems. In the form of photomultiplier tubes, they are used in astronomy to measure electromagnetic radiation from celestial objects.

Learning Activity 4

1. a) A light sensitive switch can be used to turn on a street light by automatically turning on a light sensor. The resistance of the resistor falls when light shines on it. When the LDR is put in the dark, the bulb lights up.

   b) A temperature sensitive switch can be used in a heater control system. When the temperature is below a certain value and the output of the temperature sensor is zero (0).The resistance falls when temperature rises. When the thermistor is heated the bell rings.

2. A relay has diode across it which will protect the transistor from voltages (generated by magnetic induction) when the relay coil is switched on and off.

3. The bulb comes on when it is light and goes off when it is dark.

4. a) This will make the temperature high enough which will make the bell ring.

   b) Replace the resistor with a variable reistor

Learning Activity 5

1. a) (E)emitter current, (B)base current, (C)collector current

   b) They act as potential dividers by controlling the base current. When the resistance is zero, no current passes through the base. If the resistance is high, the current passes and the bulb lights up.

   c) The bulb is going to light up.

   d) The bulb is not going to light up.

2. a) emitter current = base current + collector current
   $I_E = I_B + I_C =$ 0.02 mA + 1.9mA = 1.92mA

   b) Current gain = collector current /base current
   1.9m A/0.02mA =95mA

3. Milli-ammeter (mA), is measuring collector current I_C, will not show any working current until, base-emitter voltage v_{be} reads at least 0.6 V as this is the switch-on voltage for the transistor.

4. $\beta = \frac{I_C}{I_B} = \frac{15mA}{150\mu A} = 100$

5. I_c = 3mA, I_e = 3.015 mA

6. Below a point known as saturation or cutoff, the ratio of the base current to the emitter-collector current is constant. At saturation, the transistor reaches its highest possible conductivity, and further increases in base current fail to increase the emitter-collector current. A small base current easily saturates a transistor into full conduction and causes it to act as a solid-state on-off switch. This mode of operation has many uses, particularly in digital electronic circuits.

Learning Activity 6

1. A. NAND gate
   B. NOT gate
   C. NOR gate
   D. AND gate
   E. OR gate

2. NOT gate

input	output
0	1
1	0

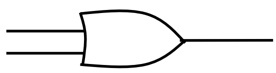
3. a) AND gate

Input A	Input B	Output
0	0	0
1	0	0
0	1	0
1	1	1

4. Logic gates are used in electronic circuits .The three main gates are AND, NOT and OR gate .

5.

Input A	Input B	Output
0	0	0
0	1	1
1	0	1
1	1	1

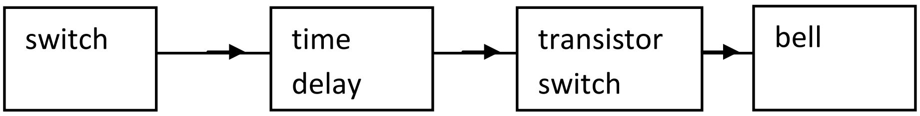


6. a) When both inputs are high.

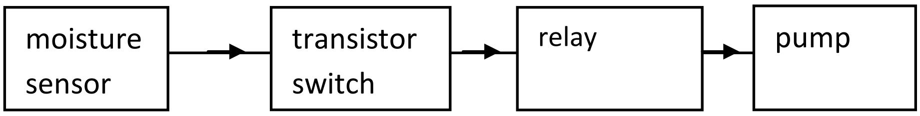
   b) When the input is low.

Learning Activity 7

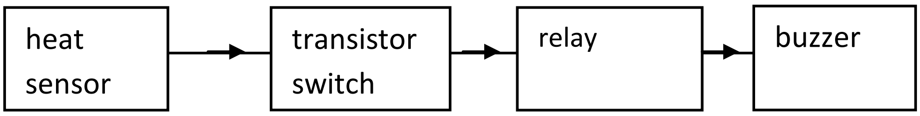
1. Allow a door bell to work only during the day



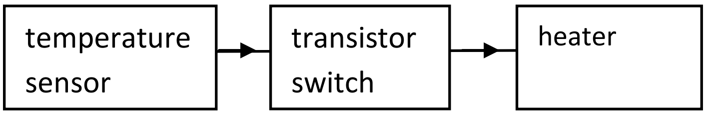
2. To switch on a water pump is a house plant is too dry



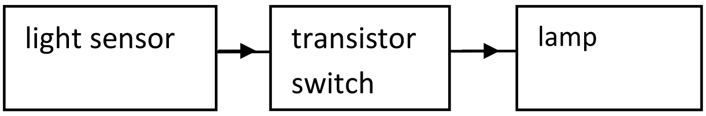
3. Give warning when the temperature of a domestic hot water system is too high.



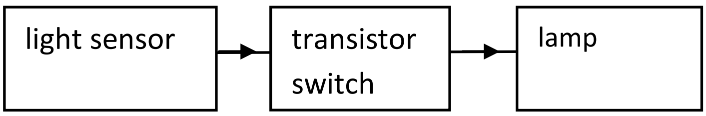
4. To switch on a heater if a fish tank gets too cold.



5. To switch an anti-burglar device to switch on your house lights when you are out of the house.



6. Draw a block diagram to of an electronic that might be adapted to switch on a street lamp when the sky goes dark.



Learning Activity 8

Advantages

a) Used in medical services

b) Controlling robots

c) Fast processing of data and controlling

d) Electronic systems can control traffic

Disadvantages

a) Loss of job for people.

b) Replacing parts in an electronic system is costly and expensive.

If you have queries regarding the answers, then please visit your nearest FODE Provincial Centre and ask a distance tutor to assist you.

References

1. Alan Storen, Ray Martine, (1987), *Physics For Senior Students.* 1st ed. Thomas Nelson Australia.
2. Barnaal, D., (1982), *Analogue and Digital Electronics for Scientific Application.* from Encarta, The New Grolier Multimedia Encyclopaedia.
3. Bishop Owen, (1983), *Beginners Guide to Electronics,* 4th ed, from Encarta, The New Grolier Multimedia Encyclopaedia.
4. Byers, T. J., *Solar Shells* (1982); Hamakawa, Y., (April, 1987) *Photovoltaic Power*, Scientific American.
5. Christian, D., Crossley, W. (1992) *Essential Physics*. Book Two, 2nd ed. McGraw Hill Book Company Australia Pty Ltd.
6. Driscoll, Frederick F., and Coughlin, Robert F., (1975), *Solid State Devices and Applications*, from Encarta, the New Grolier Multimedia Encyclopaedia.
7. Duncan Tom, Heather Kenneth. (2001), *GCSE physics*, 4th ed. John Murray Publishers Ltd.
8. England Nick .,(1989) Physics Matters.1st Edition. Hodder and Staugton.
9. Geoff Cackett, Ron Kennedy, Alastair Steven, (1979), *Core Physics.* 1st ed. Oxford University Press.
10. Getrew, I. E. (1978) *Modelling the Bipolar Transistor*, from Encarta, the New Grolier Multimedia Encyclopaedia.
11. Harding, J. R., Burrows, R., Del Balso, S., Forward, K., (1996) *PHYSICS Concepts & Applications. VCE Units 1 & 2*, McMillan Education Australia Pty Ltd.
12. Harding, J. R., Burrows, R., Del Balso, S., Forward, K., (1997) *PHYSICS Concepts & Applications. VCE Units 3 & 4*, McMillan Education Australia Pty Ltd.
13. John Wilkinson (1994) *Essential Physics* Book one, 1st ed. McGraw Hill Book Company Australia Pty Ltd.
14. Johnson Keith (1987),Revised edition. GCSE Physics For You .Hutchinson Ltd
15. Kaiser, W. A., (1980), ed., From *Electronics to Microelectronics*; from Encarta, The New Grolier Multimedia Encyclopaedia
16. Microsoft Encarta. 1993-2006. Encyclopedia Microsoft Corporation.
17. Pollack, Harvey. (1982), *Transistor Theory and Circuits Made Simple* from Encarta, the New Grolier Multimedia Encyclopaedia.
18. Pople Steven ,(2010) Complete Physics for Cambridge IGCSE, Oxford University Press.
19. Roden, Martin. (1979) *Analogue and Digital Systems*, from Encarta, the New Grolier Multimedia Encyclopaedia.

20. Richard Walding, Greg Rapkins, Glenn Rossiter (2004*), New Century Senior Physics,* 2nd ed, Oxford University Press 253 Normanby Road, South Melbourne, Australia

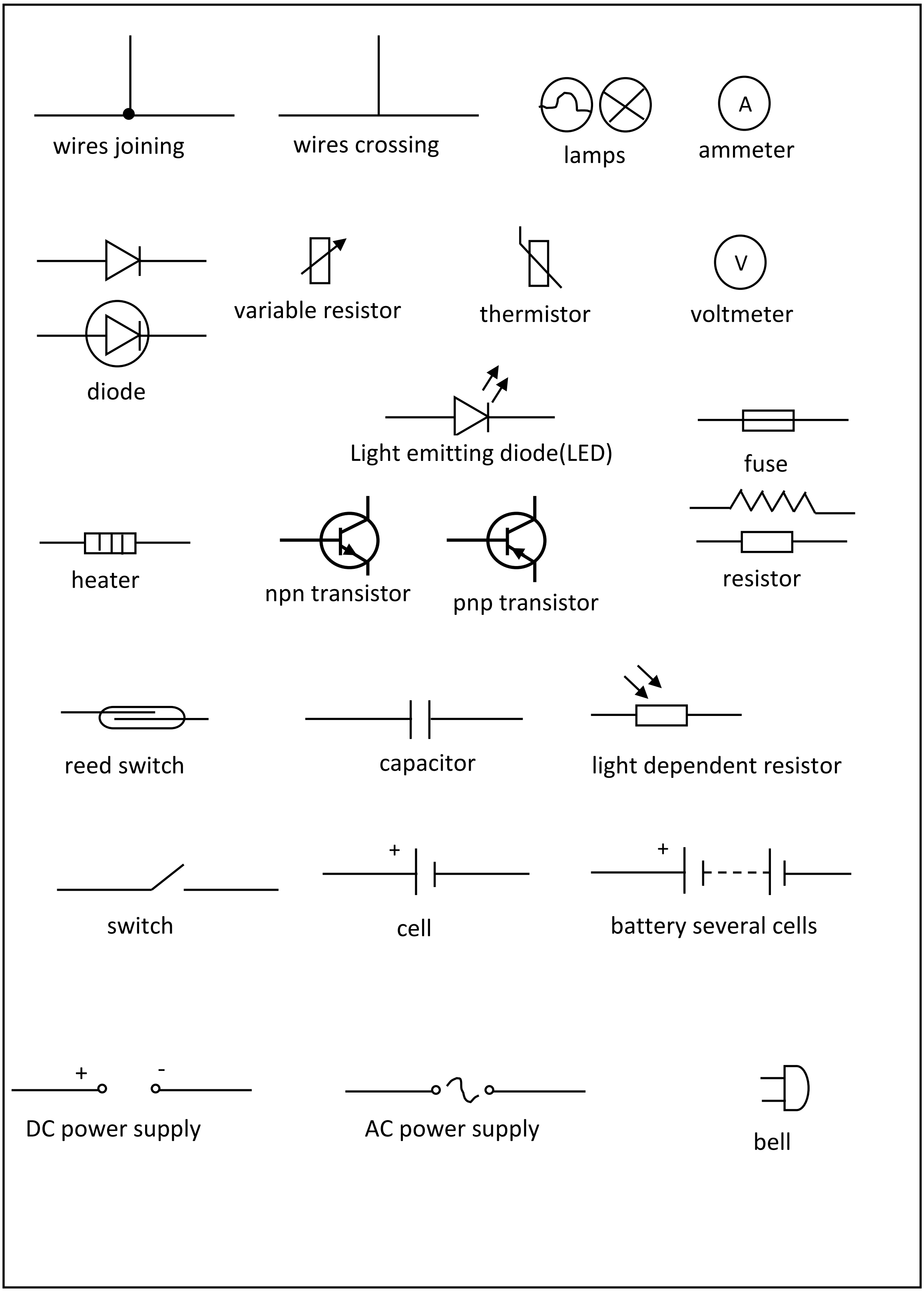
21. Rutkowski, George B. (1972), *Solid-State Electronics*, from Encarta, the New Grolier Multimedia Encyclopaedia.

22. Stanley, George C. (1975), *Transistor Basics*, 2nd ed. from Encarta, the New Grolier Multimedia Encyclopaedia.

23. Trevor Castle, (2000), *Physics Year 12*. 1st ed. New House Publishers Ltd. New Zealand.

24. Waters, Earl J., (1987), *ABC's of Electronics,* 4th ed, from Encarta, The New Grolier Multimedia Encyclopaedia.

Electronic symbols and codes



Some components used in electronic circuits

Resistors keep currents and voltages at the levels needed for other components to work properly

Capacitors store small amounts of electric charge. They are used in smoothing circuits and time -delay circuits in the tuning circuits in radios an TVs and for passing on signals from one circuit to another. If two capacitors are connected across the battery the one with the higher capacitance (in microfarads) will store more charge.

Diodes let current flow through in one direction only. Most are made from doped crystals of silicon which is a semiconductor.

Light emitting diodes (LED) glow when a small current pass through them. They are used as indicator (on /off) lights in alphanumeric (letter and number displays like those in a digital clock.

Transistors are used for amplifying signals and for switching. Most are made from doped silicon and are joint together

Integrated circuits (ICs) or microchips contain many complete circuits, with resistors, transistors, other components and connections all formed in a tiny chip of silicon only a few square millimetres .

Relays are electromagnetic switches .The relay can switch on or off a high power circuit by a tiny current from an electronic circuit.

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2	KEREMA	P. O. Box 86, Kerema	6481303	72228124	The Coordinator	Senior Clerk	72229049
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9	MT HAGEN	P. O. Box 418, Mt. Hagen	5421194 / 5423332	72228148	The Coordinator	Senior Clerk	72229057
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14	KIMBE	P. O. Box 328, Kimbe	9835110	72228150	The Coordinator	Senior Clerk	72229065
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16	KAVIENG	P. O. Box 284, Kavieng	9842183	72228136	The Coordinator	Senior Clerk	72229069
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FODE SUBJECTS AND COURSE PROGRAMMES

GRADE LEVELS	SUBJECTS/COURSES
Grades 7 and 8	1. English
	2. Mathematics
	3. Personal Development
	4. Social Science
	5. Science
	6. Making a Living
Grades 9 and 10	1. English
	2. Mathematics
	3. Personal Development
	4. Science
	5. Social Science
	6. Business Studies
	7. Design and Technology- Computing
Grades 11 and 12	1. English – Applied English/Language& Literature
	2. Mathematics - Mathematics A / Mathematics B
	3. Science – Biology/Chemistry/Physics
	4. Social Science – History/Geography/Economics
	5. Personal Development
	6. Business Studies
	7. Information & Communication Technology

REMEMBER:

- For Grades 7 and 8, you are required to do all six (6) subjects.
- For Grades 9 and 10, you must complete five (5) subjects and one (1) optional to be certified. Business Studies and Design & Technology – Computing are optional.
- For Grades 11 and 12, you are required to complete seven (7) out of thirteen (13) subjects to be certified.

Your Provincial Coordinator or Supervisor will give you more information regarding each subject and course.

GRADES 11 & 12 COURSE PROGRAMMES

No	Science	Humanities	Business
1	Applied English	Language & Literature	Language & Literature/Applied English
2	Mathematics A/B	Mathematics A/B	Mathematics A/B
3	Personal Development	Personal Development	Personal Development
4	Biology	Biology/Physics/Chemistry	Biology/Physics/Chemistry
5	Chemistry/ Physics	Geography	Economics/Geography/History
6	Geography/History/Economics	History / Economics	Business Studies
7	ICT	ICT	ICT

Notes: You must seek advice from your Provincial Coordinator regarding the recommended courses in each stream. Options should be discussed carefully before choosing the stream when enrolling into Grade 11. FODE will certify for the successful completion of seven subjects in Grade 12.

CERTIFICATE IN MATRICULATION STUDIES		
No	**Compulsory Courses**	**Optional Courses**
1	English 1	**Science Stream:** Biology, Chemistry, Physics
2	English 2	**Social Science Stream:** Geography, Intro to Economics and Asia and the Modern World
3	Mathematics 1	
4	Mathematics 2	
5	History of Science & Technology	

REMEMBER:
You must successfully complete 8 courses: 5 compulsory and 3 optional.