Electronics is that branch of applied physics which deals with the control of motion of electrons using different devices. Electronic devices being more effective and reliable have revolutionized the fields of telecommunication and information technology. This chapter aims at providing basic concepts of electronics

16.1   THERMIONIC EMISSION

In the 1850's, physicists started to examine the passage of electricity through a vacuum by putting two electrodes in a sealed vacuum tube. Some kind of rays were emitted from the cathode or the negative electrode. These rays were called cathode rays. J.J. Thomson in 1897 observed the deflection of cathode rays by both electric and magnetic fields. From these deflection experiments, he concluded that cathode rays must carry a negative charge. These negatively charged particles were given the name electrons.

The process of emission of electrons from the hot metal surfaces is called thermionic emission. Metals contain a large number of free electrons. At room temperature electrons cannot escape the metal surface due to attractive forces of the atomic nucleus. If the metal is heated to a high temperature, some of the free electrons may gain sufficient energy to escape the metal surface.
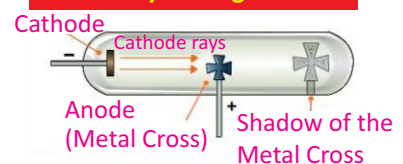
Thermionic emission can also be produced by electrically heating a fine tungsten filament. Typical values of the voltage and current used are 6 V and 0.3 A respectively. Now we examine some important experiments performed for discovering the properties of the electrons.
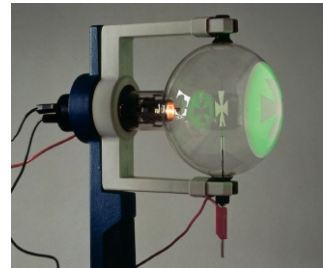
Phyics Insight

When an opaque object like a metal cross is placed in the path of cathode rays in a cathode-ray tube, a shadow of the metal cross is formed at the end opposite to the cathode. This is an evidence that rays of some kind are passing straight through the tube.

16.2 INVESTIGATING THE PROPERTIES OF ELECTRONS

An electron gun (Fig. 16.1) is used to investigate the properties of electron beam. The electrons are produced by thermionic emission from a tungsten filament heated by 6 V supply. A high positive potential (several thousands) is applied to a cylindrical anode (+). The electrons are accelerated to a high speed and pass through the hole of the anode in the form of a fine beam of electrons. The whole set up is fitted in an evacuated glass bulb.
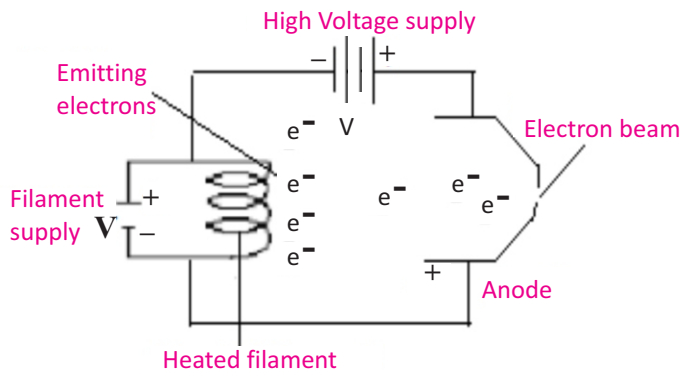

Fig. 16.1: Electron gun

Deflection of electrons by electric field

We can set up electric field by applying a potential difference across two parallel metal plates placed horizontally separated by some distance. When an electron beam passes between the two plates, it can be seen that the electrons are deflected towards the positive plate (Fig.16.2). The reason for this is that electrons are attracted by the positive charges and are repelled by the negative charges due to force $F=qE$, where 'q' is the electron charge and E is the electric field due to plates. The degree of deflection of electrons from their original direction is proportional to the strength of the electric field applied.
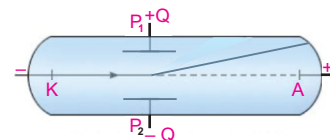
Deflection of electrons by magnetic field

Now we apply magnetic field at right angle to the beam of electrons by using a horseshoe magnet (Fig. 16.3). We will

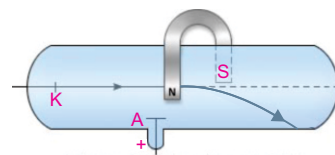**Fig 16.2:** Deflection of cathode rays by an electric field

Fig.16.3: Deflection of cathode rays by a magnetic field

notice that the spot of the electrons beam on the screen is getting deflected from its original direction. Now change the direction of the horseshoe magnet. We will see that spot on the fluorescent screen is getting deflected in the opposite direction.

16.3   CATHODE-RAY OSCILLOSCOPE (C.R.O)

The cathode-ray oscilloscope is an instrument which is used to display the magnitudes of changing electric currents or potentials (Fig. 16.4). The information is displayed on the screen of a "cathode-ray tube". This screen appears as a circular or rectangular window usually with a centimetre graph superimposed on it. For example, the picture tube in our TV set and the display terminal of most computers are cathode-ray tubes.
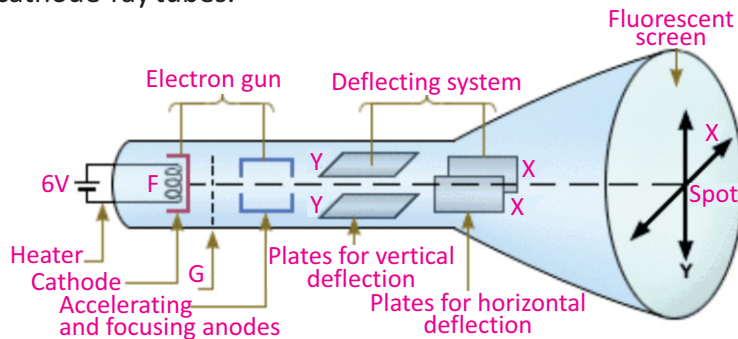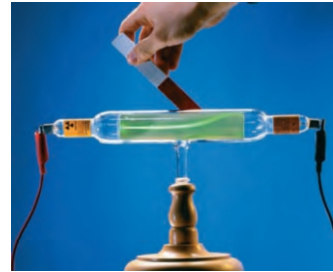
A cathode ray will deflect as shown when it is under the influence of an external magnetic field.

Fig. 16.4: Cathode-Ray Oscilloscope

The cathode-ray oscilloscope (C.R.O) consists of the following components:

- The electron gun with control grid
- The deflecting plates
- A fluorescent screen

Point to ponder!

When a magnet is brought near to the screen of a television tube, picture on the screen is distorted. Do you know why?

The Electron Gun

The electron gun consists of an electron source which is an electrically heated cathode that ejects electrons. Electron gun also has an electrode called grid G for controlling the flow of electrons in the beam. The grid is connected to a negative potential. The more negative this potential, the more
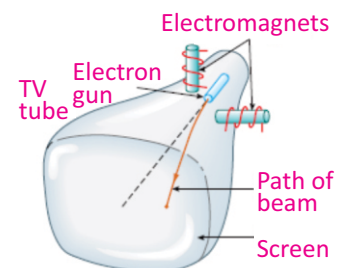
Do you know?

Electromagnets are used to deflect electrons to desired positions on the screen of a television tube.

electrons will be repelled from the grid and hence fewer electrons will reach the anode and the screen. The number of electrons reaching the screen determines the brightness of the screen. Hence, the negative potential of the grid can be used as a brightness control. The anode is connected to positive potential and hence is used to accelerate the electrons. The electrons are focused into a fine beam as they pass through the anode.

The Deflecting Plates

After leaving the electron gun, the electron beam passes between a pair of horizontal plates. A potential difference applied between these plates deflects the beam in a vertical plane. This pair of plates provides the Y-axis or vertical movement of the spot on the screen. A pair of vertical plates provides the X-axis or horizontal movement of the spot on the screen.

The Fluorescent Screen

The screen of a cathode-ray tube consists of a thin layer of phosphor, which is a material that gives light as a result of bombardment by fast moving electrons.

The CRO is used in many fields of science; displaying waveforms, measuring voltages, range-finding (as in radar), echo-sounding (to find the depth of seabeds). The CRO is also used to display heartbeats.

16.4   ANALOGUE AND DIGITAL ELECTRONICS

The quantities whose values vary continuously or remain constant are known as analogue quantities. For example, the temperature of air varies in a continuous fashion during 24 hours of a day. If we plot a graph between time and temperature recorded at different times, we get a graph (Fig.16.5-a). This graph shows that temperature varies continuously with time. Therefore, we say that temperature is an analogue quantity. Similarly, time, pressure, distance, etc. are analogue quantities.

Do you know?

Cathode Rays

The beam of electrons was called a cathode ray, because the electron had not yet been discovered. The old terminology survives in electronic engineering where a cathode-ray tube is any tube constructed along Thomson's lines whether in a computer monitor, a television, or an oscilloscope.

Do you know?
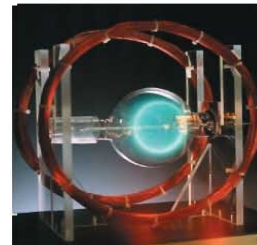
The glow in the tube is due to circular motion of electron in the magnetic field. The glow comes from the light emitted from the excitations of the gas atoms in the tube.

The branch of electronics consisting of circuits which process analogue quantities is called analogue electronics. For instance, the public address system is an analogue system in which the microphone converts sound into a continuously varying electric potential. This potential is an analogue signal which is fed into an amplifier. Amplifier is an analogue circuit which amplifies the signal without changing its shape to such an extent that it can operate a loudspeaker. In this way, loud sound is produced by the speaker. Radios, televisions and telephones are a few common devices that process analogue signals.

The quantities whose values vary in non-continuous manner are called digital quantities. Digital version of analogue signal is shown in Fig.16.5 (b). Digital quantities are expressed in the form of digits or numbers. The branch of electronics which deals with digital quantities is called digital electronics. Digital electronics uses only two digits '0' (zero) and '1' (one) and the whole data is provided in binary form due to which processing of data becomes easy.

Fig 16.6 shows an analogue and digital signal. A continuously varying signal is called an analogue signal. For example, an alternating voltage varying between the maximum value of +5V and the minimum value of -5V is an analogue signal (Fig. 16.6-a). A signal that can have only two discrete values is called a digital signal. For example, a voltage with square waveform is a digital signal (Fig.16.6-b). This signal has only two values i.e., +5 V and 0 V. The High voltage is +5 V and the low voltage is 0 V. It can be seen that digital signal provides the data by a maximum and a minimum voltage level. The changes occurring in the digital signal are not continuous. For quite a long period, the use of digital electronics was limited to computers only, but now-a-days its application is very wide spread. Modern telephone system, radar system, naval and other systems of military importance, devices to control the operation of industrial machines, medical equipments and many
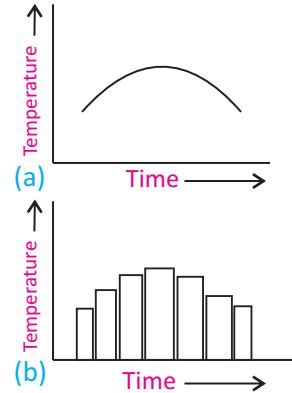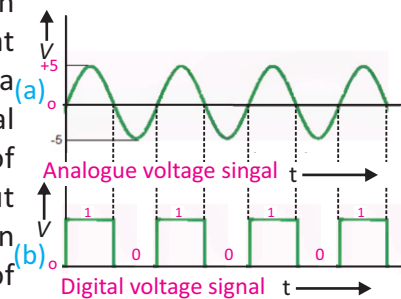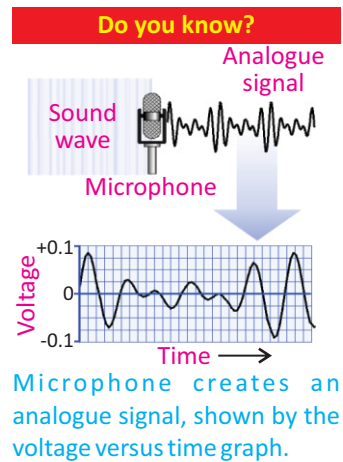
Fig.16.5: An analogue signal

Do you know?

Microphone creates an analogue signal, shown by the voltage versus time graph.

Fig.16.6

Not For Sale – PESRP

household appliances are using digital technology.

In our daily life, the quantities that we perceive by our senses are usually analogue quantities which cannot be processed by digital circuits. To overcome this problem, a special circuit has been designed which converts in binary form the analogue signal into a digital one in the form of digits in binary form. This circuit is known as analogue to digital converter (ADC). This binary output is then processed by a computer which also gives output in digital form. The output of the computer is again converted into an analogue form by a circuit known as digital to analogue converter (DAC). As the output of DAC is an analogue signal, it can be readily sensed by us. Thus, electronic systems used at present consist of both analogue and digital type circuits.

16.5 BASIC OPERATIONS OF DIGITAL ELECTRONICS – LOGIC GATES

A switch has only two possible states. It could be either open or closed. Similarly, a given statement would be either true or false. Such things which can have only two possible states are known as binary variables. The states of binary variables are usually represented by the digits '0' and '1'.

Suppose we form a circuit by connecting a lamp to a battery using a switch S (Fig. 16.7). We call state of switch as input and state of current or lamp as output. When the switch is open no current passes through the circuit and lamp is OFF. In other words, when input is zero output is also zero. When the switch is closed current passes through the circuit and lamp is ON. Thus, the output current is also a binary variable. In case, the current is passing, we can say the value of the output is '1' and it is '0' when no current is passing. The possible combinations of input and output states of this circuit are shown in Table 16.1.

These states are also called logic states or logic variables. Now the question arises that if the values of input variables of
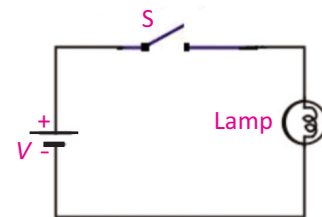
Fig. 16.7

Table 16.1	
S	Lamp
Open	OFF
Closed	ON

a circuit or a system are known, then how can we determine the value of output? To answer this question, George Boole invented a special algebra called Boolean algebra also known as algebra of logics. It is a branch of mathematics which deals with the relationships of logic variables. Instead of variables that represent numerical quantities as in conventional algebra, Boolean algebra handles variables that represent two types of logic propositions; 'true' and 'false'.

Boolean algebra has become the main cornerstone of digital electronics. It operates with two logic states, '1' and '0', represented by two distinct voltage levels. Boolean algebra's simple interpretation of logical operators AND, OR, and NOT has allowed the systematic development of complex digital systems. These include simple logic gates that perform simple mathematical as well as intricate logical operations. Logic operations may be thought of as a combination of switches.

Since a logic gate is a switching circuit (i.e., a digital circuit), its outputs can have only one of the two possible states. either a high voltage '1' or a low voltage '0' − it is either ON or OFF. Whether the output voltage of logic gate is high '1' or low '0' will depend upon the condition at its input.

Now we discuss some basic logic operations and logic gates that implement these logic operations.

16.6 AND OPERATION

In order to understand the logic AND operation see the Fig 16.8 in which a lamp is connected to a battery using two switches S_1 and S_2 connected in series considered as two inputs. There are four possible states of these two switches which are given below:

(i) When S_1 and S_2 are both open, the lamp is OFF.
(ii) When S_1 is open but S_2 closed, the lamp is OFF.
(iii) When S_1 is closed but S_2 open, the lamp is OFF.
(iv) When both S_1 AND S_2 are closed, the lamp is ON.

Do you know?

TV and telephone signals once travelled as analogue signals. Electrical signals in copper wires would interfere with each other and give poor quality sound and vision. Today, everything is going digital. The big advantage of digital is quality. There is no interference or loss of strength in digital signal travelling in an optical fibre.

Introduction to Boolean Algebra

The algebra used to describe logic operations by symbols is called **Boolean Algebra.** Like ordinary algebra, English alphabets (A, B, C, etc.) are used to represent the Boolean variables. However, Boolean variable can have only two values; 0 and 1.

Digital circuits perform the binary arithmetic operations with binary digits '1' and '0'. These operations are called logic function or logical operations.
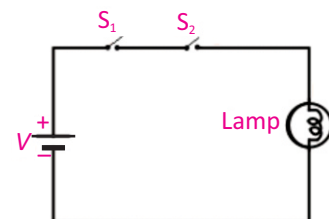

Fig. 16.8

The four possible combinations of switches S_1 and S_2 are shown in the Table 16.2. It is clear that when either of the switches (S_1 or S_2) or both are open, the lamp is OFF. When both switches are closed, the lamp is ON.

Symbol for AND operation is dot (.). Its Boolean expression is: $X = A . B$ and is read as **" X equals A AND B"**.

Set of inputs and outputs in binary form is called truth table. In binary language, when either of the inputs or both the inputs are low (0), the output is low (0). When both the inputs are high (1), the output is high (1). The truth table of AND operation is shown in Table 16.3, where X represents the output. Therefore, AND operation may be represented by switches connected in series, with each switch representing an input. When two switches are closed i.e., the inputs of the AND operation are at logic '1', the output of the AND operation will be at logic '1'. But when two switches are open i.e., the inputs of AND operation are at logic '0', the output of AND operation will be at logic '0'. For any other state of two switches (i.e., the input of AND operation), the output will be '0'.

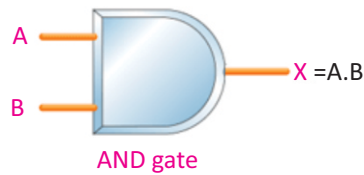| Table 16.2		
S_1	S_2	Lamp
Open	Open	OFF
Open	Closed	OFF
Closed	Open	OFF
Closed	Closed	ON

AND gate

Fig. 16.9

The circuit which implements the AND operation is known as AND gate. Its symbol is shown in Fig. 16.9. AND gate has two or more inputs and only one output. The value of output of AND gate is always in accordance with the truth table of AND operation. It means output of AND gate will be '1' only when all of its inputs are at logic '1', and for all other situations output of AND gate will be '0'.

Table 16.3		
A	B	X = A.B
0	0	0
0	1	0
1	0	0
1	1	1

16.7   OR OPERATION

In order to understand the logic OR operation see the circuit shown in Fig.16.10. A lamp is connected to a battery using two switches S_1 and S_2 connected in parallel considered as

two inputs. There are four possible states of these two switches which are given below:

(i) When S_1 and S_2 are open, the lamp is OFF.

(ii) When S_1 is open and S_2 closed, the lamp is ON.

(iii) When S_1 is closed and S_2 open, the lamp is ON

(iv) When both S_1 and S_2 are closed, the lamp is ON.

As evident from the circuit in Fig. 16.10, the lamp will glow if at least one of the switches is closed. In the language of Boolean algebra, we say the lamp will glow at least one of the values of S_1 and S_2 is at logic '1'.

Table 16.4 describes all possible states of the switches for the 'OR' operation.

OR operation is represented by the symbol of plus (+). Boolean expression for OR operation is : X = A + B and is read as " X equals A OR B". Truth table of OR operation is shown in Table 16.5. An OR operation may be represented by switches connected in parallel, since only one of these parallel switches need to turn on in order to flow current in the circuit.
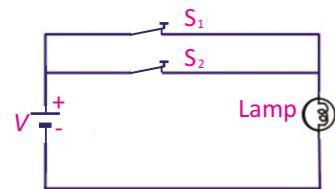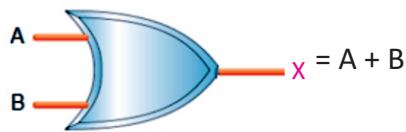

Fig. 16.10

OR gate

Fig.16.11

The electronic circuit which implements the OR operation is known as OR gate. Symbolically, OR gate is shown in Fig. 16.11. It has two or more inputs and has only one output. The values of output of OR gate are always in accordance with the truth table of OR operation. It means, the value of output of OR gate will be '1' when anyone of its inputs is at '1'. The output will be '0', when all inputs are at '0'.

Table 16.4		
S_1	S_2	Lamp
Open	Open	OFF
Open	Closed	ON
Closed	Open	ON
Closed	Closed	ON

16.8 NOT OPERATION

In order to understand NOT operation, see the circuit shown in Fig. 16.12. A lamp is connected to a battery with a switch S, in parallel When the switch is open, current will pass through the lamp and it will glow. When switch is closed, no current

Table 16.5		
A	B	X = A+B
0	0	0
0	1	1
1	0	1
1	1	1

will pass through the lamp due to large resistance of its filament and it will not glow. States of the switch and the lamp are shown in Table 16.6.

NOT operation is represented by a line or bar over the symbol i.e., $X = \overline{A}$ and is read as "X equals A NOT ".

It means NOT operation changes the state of a Boolean variable. For example, if the value of a Boolean variable is 1, then after NOT operation its value would change to '0'. Similarly, if its value before NOT operation is 0, then after NOT operation it would change to '1'. Thus NOT operation inverts the state of Boolean variable. Truth table of NOT operation is given in Table 16.7.

The electronic circuit which implements NOT operation is known as NOT gate. Symbol of NOT gate is shown in Fig. 16.13. It has only one input and one output terminal. NOT gate works in such a way that if its input is 0, its output would be '1'. Similarly, if its input is '1', then output would be '0'.
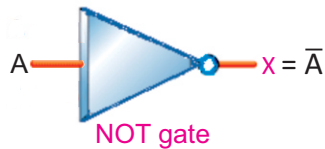
Lamp

Fig. 16.12

Table 16.6	
S	Lamp
Open	ON
Closed	OFF

NOT gate

Fig. 16.13

NOT gate performs the basic logical function called inversion or complementation. NOT gate is also called inverter. The purpose of this gate is to convert one logic level into the opposite logic level. When a HIGH level is applied to an inverter, a LOW level appears on its output and vice versa.

Table 16.7	
A	$X = \overline{A}$
0	1
1	0

16.9   NAND GATE

NAND operation is simply an AND operation followed by a NOT operation.   For example, NAND gate is obtained by coupling a NOT gate with the output terminal of the AND gate (Fig. 16.14-a).
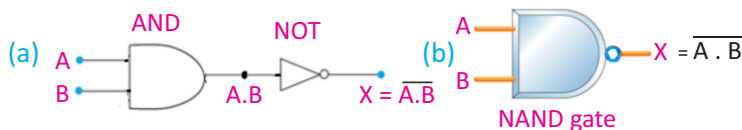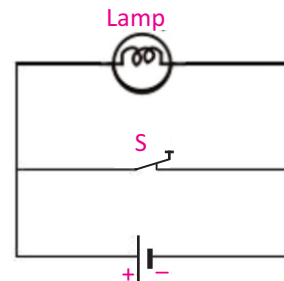

(a)   A   B   AND   A.B   NOT $X = \overline{A.B}$ (b)   A   B $X = \overline{A \cdot B}$ NAND gate

Fig.16.14

The NOT gate inverts the output of the AND gate. The output of the NAND equals $\overline{A.B}$ and is written as $X = \overline{A.B}$. It is read as X equals A AND B NOT. Symbol of NAND gate is shown in Fig. 16.14-b. As shown in the figure, the NOT gate has been replaced with a small circle. In the symbol of NAND gate, this small circle attached at the output of NAND gate given NOT operation. Truth table of NAND gate is given in Table 16.8.

16.10 NOR GATE

The NOR operation is simply an OR operation followed by a NOT operation. The NOR gate is obtained by coupling the output of the OR gate with the NOT gate (Fig.16.15-a). Thus, for the same combination of inputs, the output of a NOR gate will be opposite to that of an OR gate. Its Boolean expression is $X = \overline{A + B}$. It is read as X equals A OR B NOT. Symbol of NOR gate is shown in Fig. 16.15(b). Table 16.9 is the truth table of NOR gate.
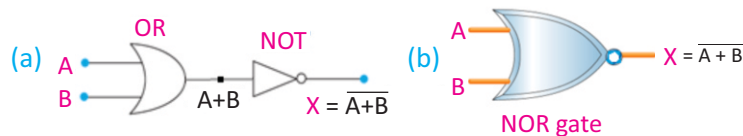
Table 16.8

A	B	$X = \overline{A.B}$
0	0	1
0	1	1
1	0	1
1	1	0

Table 16.9

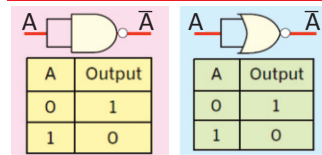| A	B	$X = \overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

Fig. 16.15

16.11 USES OF LOGIC GATES

We can use logic gates in electronic circuits to do useful tasks. These circuits usually use light depending resistors (LDRs) to keep inputs LOW. An LDR can act as a switch that is closed when illuminated by light and open in the dark.

House Safety Alarm

We can use single NAND gate to make burglar alarm. This can be done by using NAND gate, an LDR, a push-button switch S and an alarm (Fig. 16.16). Connect LDR between NAND gate

input B and the positive terminal of the battery. The LDR will cause a HIGH level input '1' at B when in light because of its Low resistance. The LDR will cause a Low level input '0' at B when light is interrupted and causes high resistance in LDR. A LOW level signal is also caused at A when burglar steps on switch S. So this burglar alarm sounds when either burglar interrupts light falling on LDR or steps on switch S.
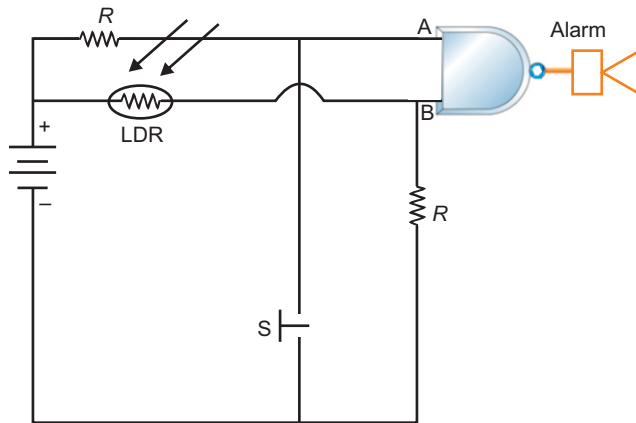
Fig. 16.16: Burglar alarm schematic circuit

Quick Quiz

Assume you have an OR gate with two inputs, A and B. Determine the output, C, for the following cases:

(a) A = 1, B = 0

(b) A = 0, B = 1

If either input is one, what is the output?

For your information

Most of today's technologies fall under the classification of digital electronics.

Digital electronics devices store and process **bits** electronically. A **bit** represents data using 1's and 0's. Eight bits is a **byte** – the standard grouping in digital electronics.

Digitization is the process of transforming information into 1's and 0's.