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PHYSICS

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Chapter # 16

INTRODUCTORY ELECTRONICS
COMPREHENSIVE QUESTIONS:

Give an extended response to following questions.

Q1. Why electrons are emitted from an electrically heated metal filament?

Ans: Electrons are emitted from an electrically heated filament due to the process of thermionic emission.

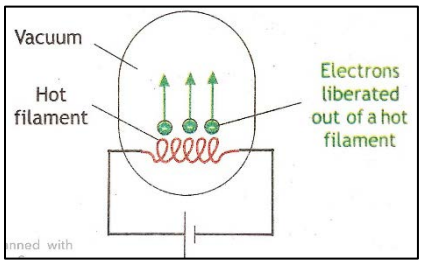
Thermionic emission:

The emission of electrons from certain metal due to heat is known as thermionic emission.

OR

The temperature induced electron ejection is called thermionic emission.

Explanation:



Metals conducts electricity, this indicates they contain some "free" electrons that are not bound to a particular atom. These free electrons are revolving in the outermost orbits of an atom in a certain metal. They can move freely through the metal and performs random motion. These free electrons are still bound to the material by a characteristics binding energy called the "work function" and it represents the minimum energy that must be imparted to an electron in order to escape from the metal i.e. this energy is used to break the metal bond.

When sufficient energy in the form of heat is given to the metal, the electrons taking this energy will be able to overcome the work function that causes electron to be emitted from the metal. If we increase the temperature of the metal, electrons start to move faster and some may have enough energy to escape from the metal. The higher the temperature, the higher will be the number of escaping electrons.

Thus, the same process of thermionic emission can also be achieved by passing electric current through tungsten filament as shown in figure where the electric current heats up the filament and electrons are emitted.

Q2. What are cathode rays? How are cathode rays produced?

Ans: Cathode Rays:

Electron beam produced by electron gun is also called cathode rays.

As cathode rays are produced from a negative electrode also termed as cathode.

Nature of Cathode Rays:

From the experiments of deflection of cathode rays by both electric and magnetic field, it is concluded that cathode rays are negatively charged electrons.

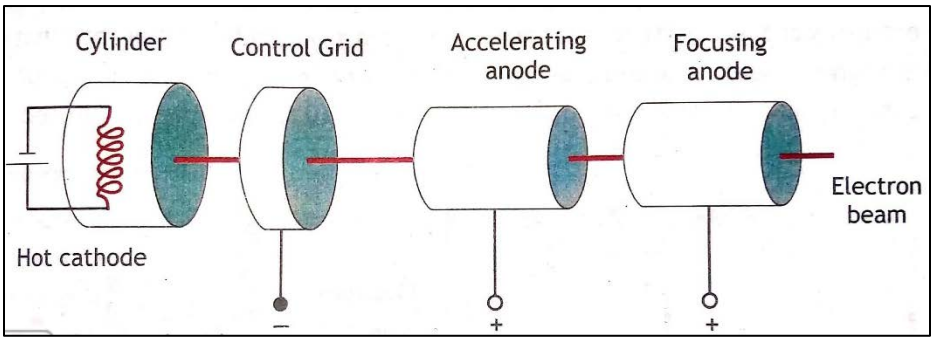
Production of Cathode rays:

For the production of electrons beam, we will examine an experiment performed by J.J Thomson in discovering the properties of electrons. For this purpose, an electron gun is used

through which the electrons are produced by the thermionic emission from a tungsten filament heated by 6V supply as shown in figure.

After exciting from the cathode, the electron passes through the control grid. The grid is connected to the negative potential which controls the flow of electrons in the beam. So, it is used to control the intensity (number of electrons) of electrons beam by increasing or decreasing its negative potential to allow the electrons towards the screen.

The electron which passes from the control grid is accelerated by the high positive potential which is applied across the accelerating anode. The electron beam is focused by the focusing anode as they are passing through it. This electron beam is also called as cathode rays.



Q3. Describe the construction and working of electron gun.

Ans: Electron Gun:

Electron gun is a source of focused and accelerated electron beam.

OR

A system which produce electrons beam by thermionic emission of electrons is called electron gun.

An electron gun is used to investigate the properties of electrons beam. It is an essential part for the number of devices like television, 3D printers and SEM etc.

Construction and Working:

An electron gun consists of a glass tube at very low pressure, with negatively charged electrode as cathode and positively charged electrode as anode as shown in the figure. The electron gun consists of the following parts.

1. **Cathode cylinder (filament):**

It consists of a tungsten filament to which a 6.3 volt battery is connected. In front of the filament a cathode is placed, when current passes through the filament, the cathode is indirectly heated and many electrons are emitted from the cathode surface.

For getting high emission of electrons at the moderate temperature, the layer of barium and strontium oxide is applied at the end of the cathode.

2. **Control Grid:**

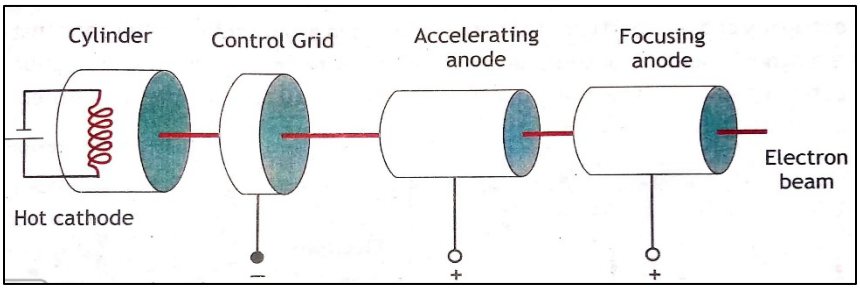
After exiting from the cathode, the electron passes through the control grid. The control grid is mostly made up of a nickel material. The grid is connected to the negative potential which controls the flow of electrons in the beam. It is used to control the intensity (number of electrons) of electron beam by increasing or decreasing its negative potential to allow the electrons towards

the screen. The number of electrons reaching the screen determines the brightness on screen light. So, the negative potential of the grid can be used as a brightness control.

3. **Accelerating and focusing anode:**

Third part is the presence of anode in front of the grid which are connected to positive potential that accelerate the electron and electrons are focused into a fine beam as they pass through the anode.

The beam after passing through the focusing anode passes through the deflection system and goes to the fluorescent screen.



Q4. What does an electric field and magnetic field have on the electron beam?

Ans: Investigating the properties of electrons:

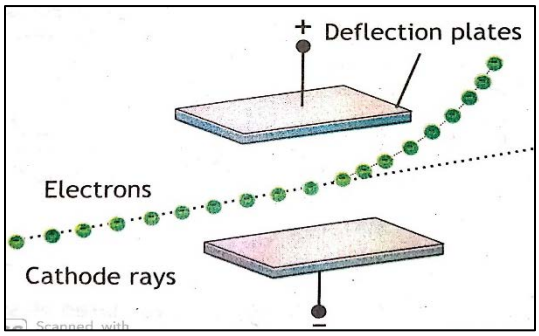
Electron gun is used to investigate the properties of electron beam. The electrons are produced by thermionic emission from a tungsten filament heated by cathode 6V supply. A high positive potential is applied to a cylindrical anode (+). The electrons are accelerated to a high speed and pass through the hole of the anode in the form of a fine beam of electrons. The whole setup is fitted in an evacuated glass tube. The electron beam produced by electron gun is also called cathode rays.

Effect of an electric and magnetic field:

When a narrow beam of electrons is passed through a uniform electric field and magnetic field, it is deflected by the presence of both electric and magnetic field as discuss below:

Deflection by electric field:

An electric field can be set up by applying a potential difference across two parallel plates placed horizontally some distance apart as shown in figure.

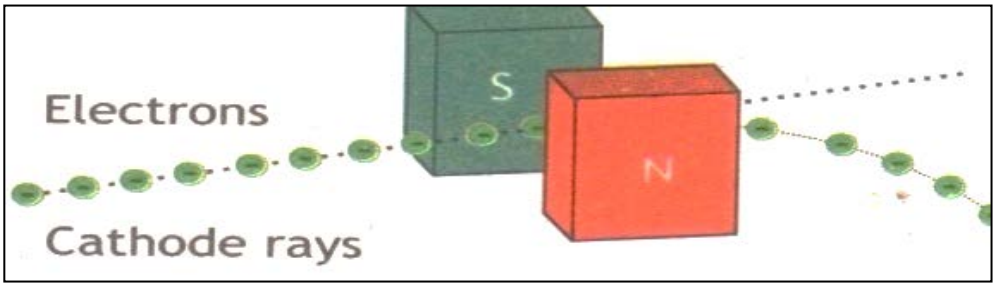


When an electron beam passes between the two plates, it can be observed that the electrons are deflected towards the positive plate. The reason is that the cathode rays are composed of negatively charged electrons; therefore, the cathode ray beam (electrons) is attracted by positive charges and repelled by the negative charges. Thus, we can say that cathode rays are affected by the presence of an electric field.

Deflection by magnetic field:

A magnetic field is applied at right angle to the beam of electrons by using a magnet as shown in the figure. It can be observed that the electrons beam is deflected by the magnetic field. The reason is that the electrons are negatively charged and a magnetic field exerts forces on electrically charged particles that are in motion in any direction other than that of magnetic field. To determine the direction of force and thus the deflection of electron beam, the Fleming left hand rule can be used.

Therefore, due to deflection of cathode rays by both electric and magnetic field (experiments), it is concluded that cathode rays are negatively charged particles.



Q5. Describe the working principle of Cathode Ray Oscilloscope (CRO) and make list of its uses.

Ans: Cathode Ray Oscilloscope (CRO):

The cathode ray oscilloscope (CRO) is an electronic test instrument that is used to observe the waveforms of repetitive electric signals.

OR

It is an instrument which is used to display the magnitudes of changing electric currents or potentials.

Construction and working:

The CRO works on the principle of deflection of electron beam in electric and magnetic field.

Cathode Ray Tube (CRT):

The main part of CRO is a highly evacuated glass tube and the information is displayed on the screen of a cathode ray tube. The cathode ray tube is used in computer monitors, TV sets and oscilloscope tube.

Components of Cathode Ray Oscilloscope (CRO):

The C.R.O consists of the following components.

1. The electron gun
2. Deflection system
3. The fluorescent screen

Their working is explained below:

1. Electron gun:

The electron gun emits the electrons and forms them into a beam. The electron gun of C.R.O consists of the following parts.

- In front of the filament, a cathode is placed. When current passes through the filament, the cathode is indirectly heated and many electrons are emitted from the cathode surface.
- A grid which is connected with a negative potential is placed in front of the cathode. It is used to control the concentration of electrons emitted by cathode. Only few electrons can pass through the opening of the grid in the form of a beam.
- Third part is the presence of anode which is at positive potential that accelerates the electrons and electrons are focused into a fine beam as they pass through the anode.

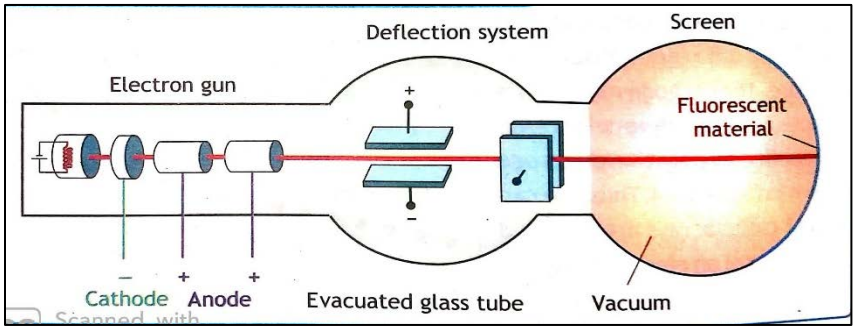
2. Deflection system:

After the beam exits from the electron gun, it travels to the electron beam deflector where two pairs of plates are fitted in C.R.O and voltages are applied to these plates to deflect the electron beam.

One is the X- plates that deflects the electron beam in the horizontal direction and second is the Y-plates that deflects the electron beam in the vertical direction when voltage is applied across them.

3. The fluorescent screen:

The screen of C.R.O is coated with phosphor (Zinc sulphide) which is a fluorescent salt. When the electrons hit the screen, it will cause the phosphor to produce a flash of light and a bright spot appear on the screen.



Uses of C.R.O:

The cathode ray oscilloscope (C.R.O) is used in many fields of science, some uses are given below.

1. It is used to display different types of waveform.
2. It is used to measure the voltage and frequency of the wave.
3. It can be used to estimate the small time intervals.
4. The C.R.O is used in television and computer monitors.
5. It can also be used to check newly designed circuitry in order to avoid bad voltage level, electrical noise etc.

Q6. What is the difference between analogue and digital electronics?

	Analogue Electronics	Digital Electronics
1	**Definition**	
	The branch of electronics which deals with the study of analogue quantities are called analogue electronics.	The branch of electronics which deals with the study of digital quantities are called digital electronics.
2	**Signal**	
	Analogue electronics is based on continuous signal which represent physical measurements.	Digital electronics is based on discrete time signals which process data in the form of digits i.e. 0 and 1.
3	**Representation**	
	It uses continuous range of values to represent information.	It uses discrete or discontinuous values to represent information in form of numbers, letters or symbol.
4	**Waves**	
	Analogue signals are denoted by sine waves.	Digital signal are denoted by square waves.
5	**Memory**	
	In analogue electronics, data is stored in the form of wave signal.	In digital electronics, data is stored in the form of binary bit (0, 1).
6	**Power**	
	Analogue instruments draw large power.	Digital instruments draw only negligible power.
7	**Cost**	
	Analogue is low cost.	Digital is of high cost.
8	**Technology**	
	Analogue technology records waveforms as they are.	Samples analog waveforms into a limited set of numbers and records them.
9	**Response to noise**	
	Analogue signals are affected by noise, reducing accuracy.	Digital signal is less affected by noise.
10	**Uses**	
	It is best used in audio and video transmission and also used in analogue devices.	It is best used for computing and digital electronics.
11	**Examples**	
	Microphone, electric iron, manual watches and thermometer etc. are based on analogue electronics.	Computers, calculators, digital cameras, mobile phones etc. are based on digital electronics.

Q7: Define logic gates. Describe the operation of AND, OR, NOT, NAND and NOR logic gates by drawing their symbols and truth tables.

Ans: Logic Gate:

Logic gate are basic building block for forming digital electronic circuitry.

Explanation:

Logic gates plays an important role in digital electronics. A logic gate has one output and one or more input terminals. Logic gate are electronic circuits that implement the basic functions of Boolean algebra. Variables used can have only two binary values i.e. "0" and "1", these variables are called Boolean variables. Logic gates works on digital signals only and there are two states of these signals i.e. "0" as low or off and "1" as high or "ON". Generally, these logic level can be understand as "ON" and "OFF" states. Truth table is used to represent the operation of a logic gate or circuit in the form of table

Types of logic gates:

Some important types of logic gates are described below along with their Boolean equation and truth table.

1. AND Gate:

The AND gate is an electronic circuit that gives a high output (1) only, if all its inputs are high (1). In other words, we can say that the output will be ON only, if both inputs "A" and "B" are "ON". Whereas the output will be low (0) if both inputs or any one input (A or B) is low (0). AND operation is represented by a symbol of dot(.).

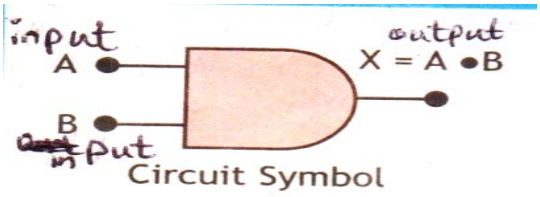
Boolean equation for AND Gate:

The Boolean equation for AND gate can be written as:

X=A.B

Or X=AB

Symbol of AND gate:



Truth Table:

TRUTH TABLE		
Input		Output
A	B	X = AB
0	0	0·0=0
0	1	0·1=0
1	0	1·0=0
1	1	1·1=1

2. OR Gates:

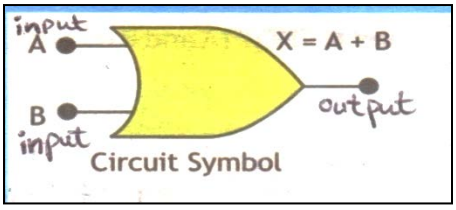
The OR gate is an electronic circuit that gives a high output (1), if both inputs or any one of its input is high (1). In other words, the output will be "ON", if both inputs or any one input is "ON". The output of an OR gate will be low (0), when both the inputs are low (0). OR operation is represented by symbol of plus (+).

Boolean Equation for OR gate:

The Boolean equation for OR gate can be written as:

X=A+B

Symbol of OR gate:



Truth Table:

TRUTH TABLE		
Input		Output
A	B	X = A+B
0	0	0+0=0
0	1	0+1=1
1	0	1+0=1
1	1	1+1=1

3. NOT Gate:

NOT gate is used to complement or invert a digital signal. Therefore, it is also called inverter. In NOT gate, the output is always opposites to the input i.e., when input is low (0), the output will be high (1) and when the input is high (1), the output will be low (0). In other words, it changes ON to OFF and OFF to ON.

Boolean equation for NOT Gate:

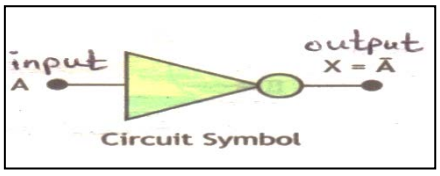
Boolean equation for NOT gate can be can be written as:

$X=\overline{A}$

Or x= NOTA

Where bar over "A" is an inversion bar, used to signify the complement.

Symbol:



Truth table:

TRUTH TABLE	
Input	Output
A	$X = \overline{A}$
0	1
1	0

4. NAND Gate:

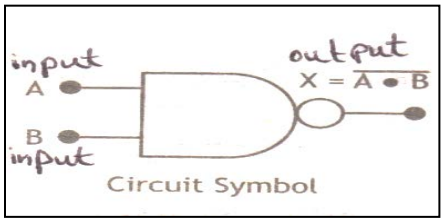
The operation of NAND gate is the same as the AND gate except that its output is inverted. So, it is an AND gate with an inverter at its output. The output of all NAND gate are high (1), if any of the input is low (0) and the output will be low (0), if both inputs are high (1). In other words, the output will be "ON", if any one of the input is "OFF".

Boolean equation for NAND gate:

Boolean equation for NAND gate can be written as:

$X=\overline{AB}$

Symbol:



Truth table:

TRUTH TABLE		
Input		Output
A	B	$X = \overline{AB}$
0	0	1
0	1	1
1	0	1
1	1	0

5. NOR Gate:

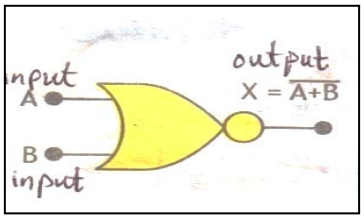
NOR gate is an OR gate with an inverter at its output. The outputs of all NOR gates are low (0), if any of the input is high (1) and the output will be high (1), if both inputs are low (0). In other words, the output will be "ON", if both inputs are "OFF".

Boolean Equation for NOR gates:

The Boolean equation for NOR gate can be written as:

$X=\overline{A+B}$

Symbol:



Truth table:

TRUTH TABLE

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

Q8: Explain simple uses of logic gates in

a) Automatic light bulb switching
b) Textile coloring plant

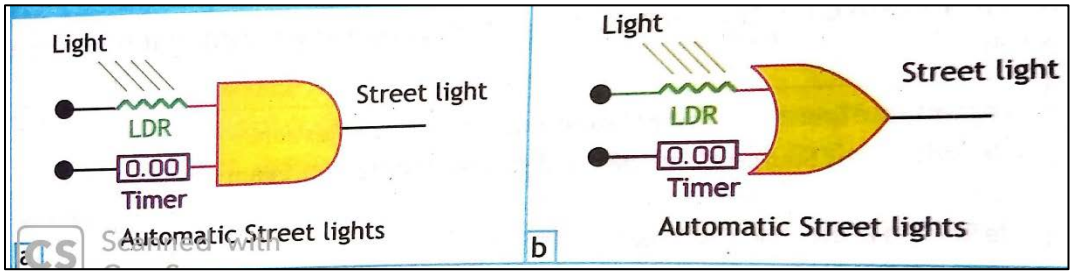
Ans: Uses of logic gates:

Logic gates are use in electronic circuits to do useful tasks. Equipment and devices could be turned on and off automatically by using logic gates and their combinations. The use of logic gates in automatic light bulbs switching and textile coloring plant are given below.

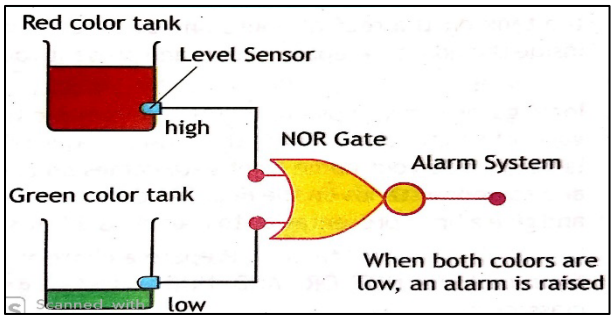
Automatic light bulb switching:

If you want to automatically switch the street lights on and off after appropriate time and light level, you can use an AND gate. During day, when light shines on Light Dependent Resistor (LDR), the resistance is high and current in the wire is low (0). In the evening, when light fades out, the resistance of LDR decreases and it turns to high (1). But the light will not glow until the timer time is not reached after which it would also turn high (1). When both the terminals are high, the street light will turn up.

On the other hand, if we want to turn the light on, when either light is low or timer is reached, we can use an OR gate. The schematic representation is shown in figure below.



Textile coloring plant:



A textile coloring plant uses two tanks to store red and green color. Each tank has a sensor that detects when the color levels drops to 25% of full. The sensors produce a high level of 5V, when the tanks are more than one-quarter full. When the volume of color in a tank drops to one-quarter or less, the sensor put a low level of 0V. A Manufacturer requires that an alarm is raised when both tanks are more than one quarter empty. So, a NOR gate with its

two inputs are connected to the tank level sensors and its output connected to the indicator alarm system as shown in figure. Such that if red color tank and green color tank are above one quarter full, the signal is low (0V). As soon as both sensor outputs are low (0V), indicating that both tanks are less than one-quarter full. Thus, the NOR gate output is high (5V) and alarm is raised. Here NAND gate circuitry can be used to indicate by a green light that both tanks are full.

CONCEPTUAL QUESTIONS:

Give a brief response to the following questions.

Q1: What are free electrons?

Ans: The electrons that are free to move through the metal are called free electrons. A free electron is an electron that is not connected to an atom in a structure. Free electrons make substance conductive. They are the outermost valence electrons which are loosely attached to the nucleus of an atom. When small amount of external energy (in the form of heat) is supplied to the valence electrons, then they get pulled away from the atom and become free. So, materials that contain free electrons conduct electricity such as metals.

Q2: What is the function of an accelerating anode in an electron gun?

Ans: The main function of the accelerating anode in an electron gun is to accelerate the electrons towards the fluorescent screen. As we know that electrons are emitted from the filament by thermionic emission. These electrons are then directed towards the screen at a high speed with the help of accelerating anode in order not to lose any electrons in its way. So, the electrons hitting the screen produce fluorescence for creating images on it.

Q3: If the electron beam in a television tube striking just one point on the screen at a time, how can we get a full picture? Explain

Ans: The electron beam (negatively charged particles) is controlled by electromagnets inside the tube. This beam moves back and forth across the screen line by line painting a picture on the screen. The electron beam moves so quickly that we do not see it building up the picture. It does not actually paint but produce a bright spot on the screen where it hit the screen. The screen is coated with phosphor (i.e. ZnS) which produces light when electron hit it. By switching the electron beam ON and OFF, the video circuit builds up the entire picture on the screen by lightening up some spots and leaving others dark.

Q4: Why image is distorted when a magnet is brought close to old television screens or monitors with cathode ray tube (CRT) inside?

Ans: When a bar magnet is brought close to the screen of old television or monitors with CRT inside, it distorts the picture as it distorts the path of electrons flowing from the electron gun towards the screen of the TV. As electrons are negatively charged particles, their motion is greatly affected by the magnetic force of magnet. In old TV sets, this damage may occur permanently if the magnet is brought very close to the screen. Because magnetic field diverts the electrons from

where they should go and so, the wrong phosphor spots give a distorted image. Modern flat panel television i.e. plasma, LCD etc. do not suffer from this effect.

Q5: Assuming that cathode rays are a beam of charged particles, how could you demonstrate that these particles are negatively charged? Explain

Ans: We can easily demonstrate that cathode rays are negatively charged by passing these rays through an electric and magnetic field.

When cathode rays are passed through an electric field, they are attracted towards the positive plate which shows that they have negative charge. Similarly, by applying the magnetic field, these rays are deflected and start moving in a circle. By applying right hand rule, we can prove that they have a negative charge.

Q6: If there are four inputs in any logic gate, how many combinations are possible?

Ans: The number of input state possibilities increases by adding more input terminals to a logic gate. With a single input gate such as inverter, there can be only two possible input states, either the input is high (1) or it is low (0). A two-input gate has four possibilities for input states and so on. Hence, the number of possible input states is given by the formula. i.e.

No. of possible input states = 2^n

Or **$N = 2^n$**

Where n= number of inputs

If n = 4, then

$N = 2^4$

$N = 16$

So, there will be sixteen input possibilities if there are four inputs in any logic gate.

Q7: What conditions produce a high (1) output for an AND gate and NOR gate?

Ans: The output of AND gate will be high i.e.1 only when both of its inputs are high (1). In other words, if A=1 and B=1, then according to Boolean equation

X= A.B

X= 1

It is also clear from the truth table of AND gate as shown below.

Input	**Input**	**Output**
A	**B**	**X=A.B**
0	0	0
0	1	0
1	0	0
1	1	1

The output of NOR gate will be high (1), if both of its inputs are low (0). In other words, if A=0 and B=0, then according to Boolean equation

$X = \overline{A+B}$

i.e. X= 1

It is also clear from the truth table of NOR gate as shown below.

Input	Input	Output
A	**B**	**X=A.B**
0	0	1
0	1	0
1	0	0
1	1	0

Q8: What are the algebraic Boolean expressions to represent the output of AND, OR, NOT, NAND and NOR gates?

Ans: The algebraic Boolean expressions to represent the output of different logic gates are given below.

1. **Boolean expression for AND gate:**

The Boolean equation for AND gate can be written as:

X= A.B

Or

X= AB

This equation can be read as "X equals A and B".

2. **Boolean expression for OR gate:**

The Boolean equation for OR gate can be written as:

X= A+B

It can be read as "X equals A or B".

3. **Boolean expression for NOT gate:**

The Boolean equation for NOT gate can be written as:

$X = \overline{A}$

It can be read as "X equals NOT A".

4. **Boolean expression for NAND gate:**

The Boolean equation for NAND gate can be written as:

$X = \overline{AB}$

It can be read as "X equals NOT (A and B)".

5. **Boolean expression for NOR gate:**

The Boolean equation for NOR gate can be written as:

$X = \overline{A+B}$

It can be read as "X equals NOT (A or B)".