Around the 1900s, many experiments on electrical discharges through rarefied gases in evacuated glass tubes were being performed. Voltages were applied across these discharge tubes by electrodes inserted into them. The negative electrode was called the cathode and the positive electrode the anode.

When the voltage across the tube was increased to high values, a dark space grew from the cathode, while the other end of the tube started to glow. When a screen with small holes in it was inside the discharge tube, the glow was restricted to tiny spots at the end of the tube. It appeared that something emanated from the cathode and so the rays were called cathode rays.

Initially it was unknown what these rays might be. From early experiments, some of the properties of cathode rays were consistent with a wave nature for the rays and at the same time these properties could be explained as a stream of particles.

Further experimental investigations of the conduction of electricity through rarefied gases in discharged tubes revealed the following properties of cathode rays:

1. They travel in straight lines.
2. They penetrate small thickness of material such as metal foils.
3. They carry considerable amounts of kinetic energy and momentum.
4. They are emitted perpendicular to the surface of the cathode.
5. They carry negative charge.
6. They are deflected by electric and magnetic fields.

Properties (5) and (6) show that the cathode rays to be negatively charged particles. This corpuscular nature was firmly established by J.J. Thompson in 1897 who measured the charge to mass ratio of the particles from their deflections in electric and magnetic fields. The results of his experiments provided strong evidence that cathode rays were electrons.
The cathode rays made up of electrons are mainly ejected from the cathode by the impact of positive ions with the cathode. The cathode is heated by an electric current so that electrons are more readily ejected. This is called thermionic emission. These ejected electrons while travelling down the tube occasionally strike an atom of the gas, knocking out one or more electrons creating positive ions. In general, the electrons and positive ions travel through the tube with few collisions because of the low gas pressures - the lower the pressure, then, the fewer the number of collisions. In a collision, a gas molecule may absorb energy and be left in an excited state. The excited molecule then emits a photon with a definite wavelength as in losses energy. The light observed in discharge tubes is due to the emission of electromagnetic radiation from excited atoms and molecules. The colour of the light depends upon the gas inside the tube and the gas pressure.

Spectral tubes: the light emitted from different gases at reduced pressure

If the air in a discharge tube is gradually pumped out and a high voltage is applied across the tube, then, as the pressure is reduced to a several mmHg, long, thin, violet streamers pass down the tube.

The streamers expand as the pressure is further reduced until the whole inside of the tube is filled with a soft violet/pinkish glow.
A still further reduction of pressure causes this glow to begin to retreat from the negative cathode with a blue glow around it and a positive striated column near the anode. The space between the cathode and negative glow region is called **Crookes dark space** and the region between the negative glow and positive column is known as **Faraday dark space**.

Further reduction in the pressure causes the illumination to almost disappear as the Crookes dark space fills the tube.

At still lower pressures, most of the cathode rays (electrons) are able to strike the end of the tube since there are very few collisions with the atoms of the gas, producing a fluorescence of yellowish-green colour on the glass.
**Technological applications**

Discharge charge tubes since their invention have been a most important technological device and has been used in many applications.

**Illuminated signs**

Illuminated signs which are referred to as neon signs are used extensively in advertising. The light is emitted from excited atoms and molecules inside the discharge tubes and the colour is determined by the gas pressure and the type of molecules inside the tube.

![Illuminated signs](image)

**Monitors in intensive care units**

Before plasma and LCD displays, cathode ray tubes were used in monitors to display vital patient parameters such as ECG, blood pressure, pulse rate, and blood oxygen levels.

![Monitors](image)
Television
A conventional television set comprises multiple internal electronic circuits, including those for receiving and decoding broadcast signals. A visual display device which lacks a tuner is properly called a video monitor, rather than a television. The video monitor is simply a cathode ray tube.

Electric and/or magnetic fields are used to scan the electron beam across the screen to produce the moving picture. In a coloured monitor, the screen is covered with red, blue and green phosphors. When an electron hits the screen, the phosphor produces a flash of light, either red, blue or green. Different combinations of red, blue and green produce the colour of the picture that is seen by the viewer.

Television is certainly one of the most influential “forces” of our time.
**X-ray tubes**

Cathode ray tubes are used to create X-rays where high speed electrons smash into a metal target (usually tungsten, molybdenum or copper). The electrons are decelerated upon impact with the target and lose energy by emitting X-rays. This X-ray photon-generating effect is generally called the Bremsstrahlung effect, a contraction of the German bremsen for braking, and strahlung for radiation. Also, these electrons transfer energy to the target atoms by knocking out the inner most electrons to produce excited atoms. The excited atoms then emit X-rays at characteristic wavelengths unique to the atoms of the metal target.

As with any vacuum tube, there is a cathode, which emits electrons into the vacuum and an anode to collect the electrons, thus establishing a flow of electrical current, known as the beam, through the tube. A high voltage power source, for example 30 to 150 kV, is connected between cathode and anode to accelerate the electrons.
Cathode ray oscilloscope
An cathode ray oscilloscope (CRO) is a type of electronic test instrument that displays varying signal voltages. Many measurements such as temperature, pressure, humidity, blood pressure, brain waves, etc, can be converted to voltages and displayed this way.

Oscilloscopes are used in the sciences, medicine, engineering, and telecommunications industry. General-purpose instruments are used for maintenance of electronic equipment and laboratory work. Special purpose oscilloscopes may be used for such purposes as analysing an automotive ignition system or to display the waveform of the heartbeat as an electrocardiogram.

The CRO is the most important electronic instrument used for measurements that vary with time.

An electron gun (also called electron emitter) is an electrical component that produces an electron beam that has a precise kinetic energy and is most often used in television sets and computer displays that use cathode ray tube (CRT) technology, as well as in other instruments, such as electron microscopes and particle accelerators. A direct current, electrostatic thermionic electron gun is formed from several parts: a hot cathode, which is heated to create a stream of electrons via thermionic emission, electrodes generating an electric field which focus the beam and one or more anode electrodes which accelerate and further focus the electrons. The large voltage between the cathode and anode accelerates the electrons.