

GAS DISCHARGE TUBES

This section contains information about the discharge tubes available for use in most school laboratories. It includes the set of three Crooke's tubes, the six tubes for vacuum scale and the spectrum tubes. The induction coil has been included as it provides the high input voltage required to operate the tubes. Although the different discharge tubes are used to demonstrate a variety of principles many of the safety aspects are common.

SAFETY PRECAUTIONS

- The induction coil itself does **NOT** produce X-rays. However, X-rays are produced in the discharge tubes when they are connected to the induction coil. The X-rays are emitted when the cathode rays are stopped suddenly by hitting glass or metal surfaces. When the equipment is set up using a *minimum operating voltage* from the induction coil the X-rays produced are of low energy and are significantly attenuated through the glass.
- Remove all metal jewellery and watches before using the induction coil.
- *Keep one hand behind your back when operating the apparatus.* This helps to ensure that you do not provide a short circuit for the high voltage electric current.
- Do not handle the glass tube while it is in operation.
- Do not leave this equipment on for longer than is necessary to perform the desired experiment.

X Extra equipment for **ALL** the suggested learning experiences using the discharge tubes includes:

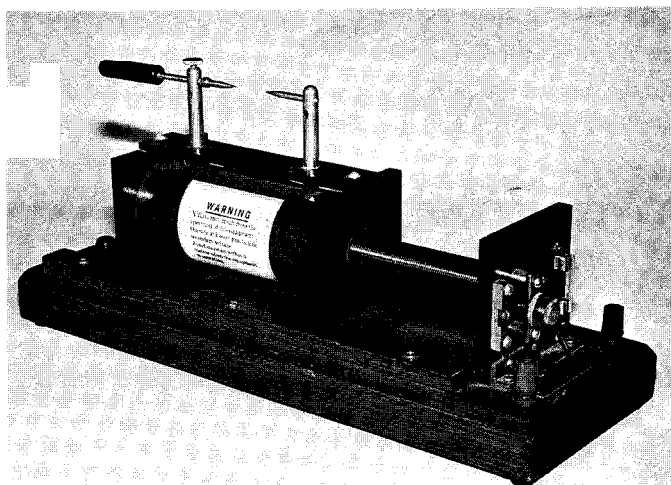
- induction coil
- two long leads with alligator clips
- power pack
- black cardboard
- two leads with banana plugs
- spare fuses for the induction coil

HANDY HINT

For impressive results, darken the laboratory or set up in a large darkroom.

1) INDUCTION COIL

The induction coil is used as a high voltage power source because it produces by electro-magnetic induction a very high voltage in its secondary coil. It pulsates a small direct input voltage of 6V in the primary coil to produce a variable output in the order of 15 000 volts in the secondary coil. The two electrodes, mounted on the secondary coil, are used as a high voltage supply.



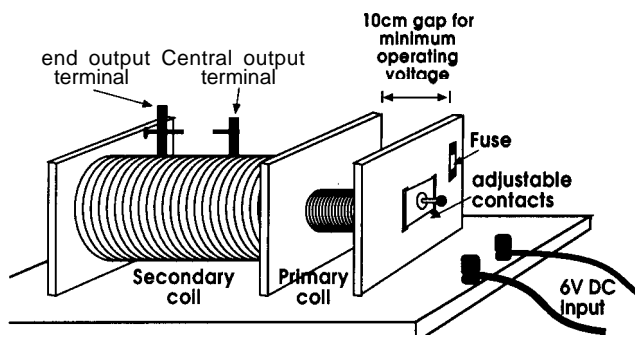
SETTING UP AND USING THE INDUCTION COIL

C It is worth checking the following before setting up the equipment.

- Make sure the contacts are clean and free of carbon deposits. If not, clean them with fine sandpaper.
- Use the screw to adjust the gap between the contacts so there is a very small space between them, and when turned on, there is a continuous oscillation and a spark jumping between the contacts.
Turn the power off before readjusting the screw.
- Check to see that the fuse is unbroken.

S Setting up the Induction Coil

- Make sure that the induction coil is connected only to 6V DC current (middle setting on the power pack).
- Connect the positive terminal of the induction coil to the positive terminal of the DC power supply and the negative terminals similarly.



- Pull the terminals on the secondary coil apart before connecting to a discharge tube.

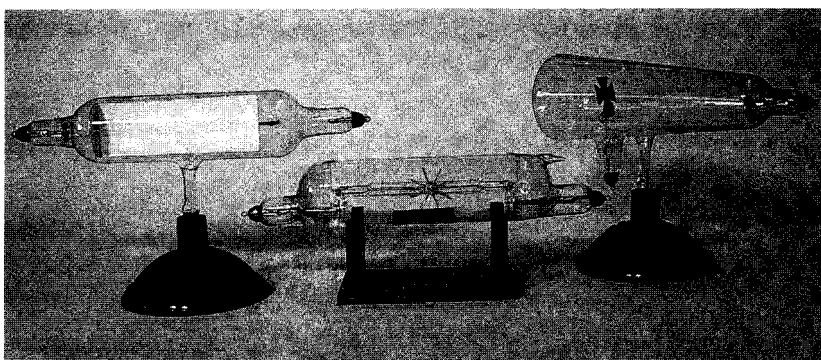
- To achieve a *minimum operating voltage*, move the position of the secondary coil so there is a gap of 10cm between the front section of the primary and secondary coils as shown in the diagram.

figure 1

2) CROOKE'S TUBES

Crooke's tubes are a set of 3 discharge tubes which, when connected to a high voltage power supply such as the induction coil, demonstrate the existence and some of the properties of 'cathode rays'.

They are all clear glass evacuated tubes with a plate cathode (-) and nipple-shaped anode (+). The magnetic deflection tube has a vertical fluorescent screen in the tube to highlight the path of the cathode rays. The Maltese cross tube has a metal cross in the tube which can be flipped up



into the path of the cathode rays. The paddlewheel tube sits horizontally in a wooden cradle with a glass paddlewheel positioned to turn in the path of the cathode rays.

SETTING UP AND USING CROOKE'S TUBES

C It is worth checking the following before setting up the equipment.

- Use a large horseshoe magnet or electromagnet for deflecting the beam.
- Position the discharge tube to point towards the wall so that the student is one metre away and any X-rays produced when the cathode rays hit the glass will be absorbed by the wall.

S Setting up Crooke's Tubes

- Connect up the induction coil to the power packs described in the section on the induction coil.
- For the magnetic deflection and Maltese cross tubes connect the central output terminal on the induction coil (*see figure 1*) to the cathode plate electrode in the tube, and the end terminal of the induction coil to the nipple-shaped anode in the tube. If a green fluorescence is not clearly visible at the 'cross' end of the tube opposite the cathode then change the polarity of the connections.
- Position the paddlewheel tube exactly horizontally on the wooden cradle. The paddlewheel should be resting at one end of the tube. Connect this end, as the cathode, to the central terminal of the induction coil. Connect the end terminal to the anode.

SUGGESTED LEARNING EXPERIENCES

TOPIC: Atomic Physics - History of the Atom

1. Use the *Maltese cross tube* to demonstrate the following characteristics of cathode rays:

- that they are emitted at right angles to the cathode
- that they travel in straight lines in a vacuum (since they form a shadow of the cross on the glass)
- that they are interrupted by a thin piece of metal.

Set up the experiment as described earlier with the cross down to view the fluorescence on the end of the tube, switch it off, flip the cross up into the path of the cathode rays and switch it back on. HINT

- with a black piece of material, provide a dark background at the end of the tube to see the fluorescence more easily.

2. Demonstrate that cathode rays are deflected by a magnetic field and therefore carry charge, by using the *magnetic deflection tube*. Set up the equipment as described earlier and place a large horseshoe magnet over the tube so the magnetic field is at right angles to the path of the cathode rays. Reverse the polarity of the magnet and discuss the results.

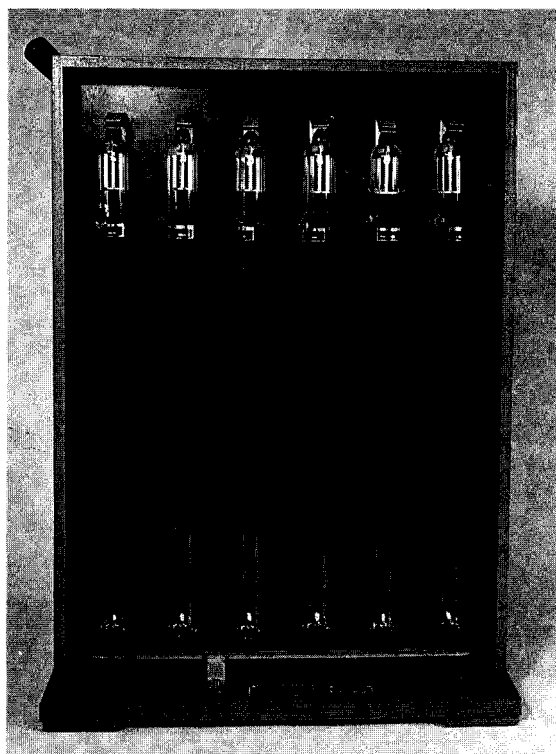
3. Demonstrate that cathode rays have momentum and therefore mass, by using the *paddlewheel tube*. Set up the equipment as described above and switch it on. The paddles on the wheel are painted with fluorescent paint to show when the cathode rays are hitting them. The paddlewheel is propelled along by the impact of collisions with the cathode rays, revealing that they must have mass.

3) TUBES FOR VACUUM SCALE

These tubes are used to demonstrate the concept of mean free path of electrons and to display the results of early physicists in their quest to discover the nature of cathode rays.

This equipment consists of a set of six glass tubes evacuated to decreasing levels of gas pressure. Only one tube is connected at a time to a high voltage power source such as the induction coil.

Varying patterns of fluorescence and dark spaces are observed as the pressure in the tubes decreases.



SPECIFIC SAFETY PRECAUTIONS

- Always hold the moveable connection at the back of the equipment by its plastic insulating handle.
- Switch the apparatus off while changing the moveable connecting arm.
- Keep one hand behind your back when touching the equipment while it is turned on.**

SETTING UP AND USING THE TUBES FOR VACUUM SCALE

Setting Up the Equipment

- Connect the induction coil to the power pack *as described in the section on the induction coil*.
- Connect the central output terminal of the induction coil (see figure 1) to the moveable handle at the back of the discharge tubes (connects to the cathodes) and the end output terminal of the induction coil to the bottom connection at the front of the discharge tubes (connects to the anodes).

SUGGESTED LEARNING EXPERIENCES

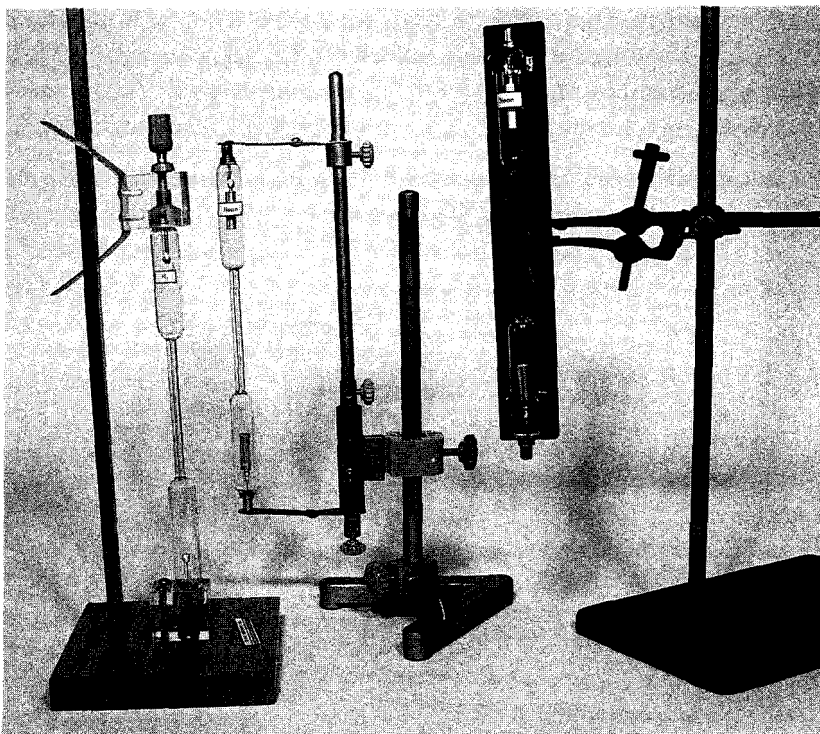
TOPIC: Atomic Structure

1. Observe the nature of cathode rays as Crookes would have seen them and discuss your observations in the light of your knowledge of electrons today. *Refer to Activity 17.1 page 94 Essential Physics.*
2. Discuss how the concept of the mean free path of electrons explains the dark spaces appearing in some of the columns.
3. Use the lower pressure tubes to demonstrate the effect of an aurora and discuss the concept of ionisation.

4) SPECTRUM TUBES

This equipment consists of a number of glass discharge tubes which can be mounted individually in a stand.

The tubes contain different gases, including hydrogen, neon, helium, and sodium vapour. When connected to a high voltage power source they emit a fluorescence which is peculiar for the particular element contained in the tube. They are ideal light sources to use with the hand spectroscope or spectrometer (see *pages 43 and 46*).



SETTING UP AND USING THE SPECTRUM TUBES

C It is worth checking the following before setting up the equipment.

The hydrogen gas discharge tubes have a lifetime of the order of five years, after which a significant proportion of the gas has diffused through the glass container. Each tube should be tested annually and more tubes ordered as required.

S Setting up the Spectrum Tubes

1. Connect the induction coil to the power pack *as described in the section on the induction coil, page 28.*
2. Connect the output terminals of the induction coil to the terminals of the discharge tube - the polarity does not seem to matter.

SUGGESTED LEARNING EXPERIENCES

TOPIC: Atomic Physics

1. **Observe the spectral lines of hydrogen** using a diffraction grating spectrometer and the hydrogen gas spectrum tube. Take measurements of the angular positions of the lines and calculate the wavelength and frequency of each visible line. *Refer to activity 17.2 page 96 Essential Physics.*
2. **Using a collection of different discharge tubes with their labels covered, ask students to identify the gases within them** by observing their emission spectra and comparing these with known charts.