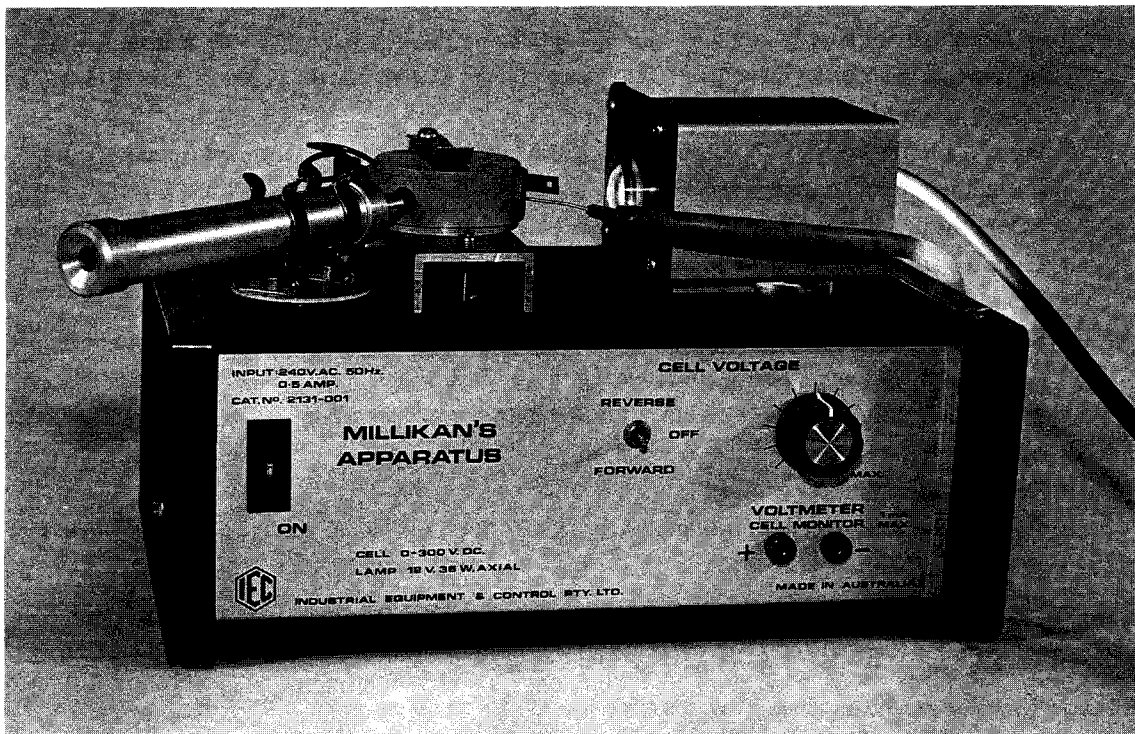


MILLIKAN'S OIL DROP



This equipment has been designed to enable students to calculate the charge on an electron in a similar way to that devised by Millikan in 1912.

It consists of a transformer which supplies a high voltage to two metal plates located inside the chamber which is mounted on top. A small telescope is fixed to focus into the middle of the chamber and an atomiser mounted so that an attached needle can be inserted into the side of the chamber.

Using this equipment the value of the charge on the electron can be determined by balancing the gravitational and electric forces on small charges particles of latex which have been injected from the atomiser into the cavity.

SETTING UP AND USING MILLIKAN'S OIL DROP

C It is worth checking the following items before setting up an experiment

- Ensure that the needle used to inject the latex mist is not blocked with hardened latex. It can easily be cleared with a piece of thin wire.
 - Ensure that the tubing and neck of the atomiser is cleared of hardened latex.
 - Check that the consistency of the latex solution is a fine fluid suspension. If it is too thick, dilute with water. If the fine particles of latex are clumped together they cannot be used.
- NOTE: The latex is supplied in a concentrated form and needs to be diluted 1 in 10 parts with water (5 ml of latex solution made up to 50 ml with water).
- Always wash the equipment thoroughly before putting it away.

X Extra equipment for the suggested learning experience includes:-

- a DC voltmeter (0-300 volts) OR a multimeter
- connecting leads
- a piece of black material as a hood for the apparatus.
- a strip of black plastic
- thin wire to focus the telescope

Setting up Millikan's Oil Drop

- Darken the room or place a piece of black material over the apparatus and the person viewing the particles. The voltages can be read by a second person outside the hood.
- Turn on the lamp and position it to illuminate the inside of the chamber. For some models without an **inbuilt** power supply you will need to connect a 12 volt power supply to operate the lamp.
- Ensure that the transformer switch is in the middle position so that the plates inside the chamber are not charged.
- Insert a small piece of thin wire into the middle of the chamber through the injection hole.
- Focus the telescope by sliding it in and out, so that the edges of the wire can be clearly seen.
NOTE: the image in the viewer is inverted and will appear on the side opposite the insertion point.
- Place a strip of black plastic at the back of the chamber to act as a screen.
- Remove the wire and insert the needle.
- Squeeze the atomiser a couple of times. The latex particles should be seen as tiny pin points of light drifting slowly upwards, because the image is inverted.
- If the latex particles cannot be seen adjust the light source by sliding it in its mount towards the chamber.
- Re-focus the telescope viewer.
- Connect the voltmeter or multimeter to the transformer, so that the voltage across the plates can be read.

SUGGESTED LEARNING EXPERIENCE

This equipment is used exclusively to determine the charge on an electron.

These results may then be used, in conjunction with Thomson's charge/mass ratio equipment, to determine the mass of the electron.

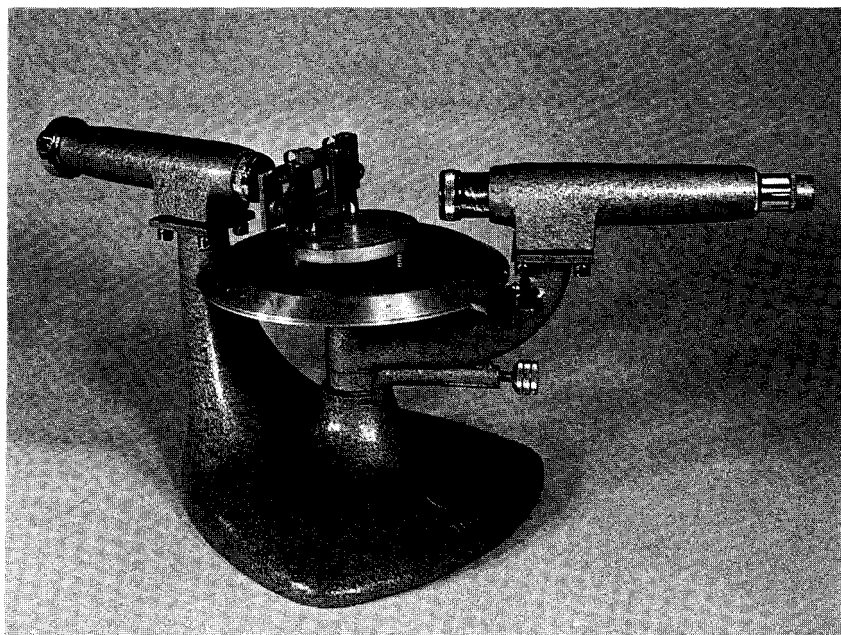
Procedure

- Set up the equipment as described, with the telescope focused on the latex particles which are seen to drift upwards. Set the voltage to about 200 volts by rotating the 'cell voltage' control knob in a clockwise direction.
- Reverse the polarity of the plates a couple of times using the switch on the front of the transformer. This will cause the fast moving particles to move from the field of view.
- Concentrating on one of the slowly moving particles, adjust the voltage until the particle stops moving.
- Record the voltage. This is the voltage required to balance the particle against the force of gravity exerted on it.
- Obtain readings of the balancing voltage for a large number of particles (approximately 50).
NOTE: Any particle which is balanced with a voltage less than 50 volts should be ignored, as its own charge is caused by too large a surplus or deficit of electrons. This means that the chance of getting readings which differ from each other by the equivalent of 1 electron is very small. Some readings in excess of 200 volts should be obtained.
- This number of readings may take several periods to collect.

Analysis

- The results should seem to clump together in groups. Calculate an average value for each of the 3 or 4 groups with the highest voltages.
- Convert these values to $1/V$ and list them in order. The charge on the particles is proportional to these $1/V$ values.
- The actual values of the charges are calculated by multiplying the $1/V$ values by the mass of the spheres, the acceleration due to gravity and the distance between the charged plates,
where $e^- = mgd/V$
- The mass of the particles is calculated from the average volume and density of the latex. The manufacturer has specified the average diameter of the latex particles to be 1 micron and the density of the latex as between 0.94 and 0.98 gcm^{-3} . The charged plates are 5 mm apart.

SPECTROMETER



The bench spectrometer is an instrument used for measuring the wavelengths of light.

The most important application of the bench spectrometer is to determine the individual wavelengths present in atomic emission spectra.

The spectrometer comprises three parts; the central circular table, the collimator and the telescope. A prism or diffraction grating is mounted in the centre

of the table which is graduated in degrees. With the aid of the vernier scale, angular measurements to 0.1° are easily made.

The collimator is a fixed arm with an adjustable slit at one end and a lens at the other for focusing the image of the slit.

The telescope is a moveable arm with an achromatic lens at one end and an eye-piece with cross-hairs at the other.

SETTING UP AND USING THE SPECTROMETER

C It is worth checking the following items before an experiment is set up

Ensure you have the box of accessories which includes:

- a screw-threaded post with a spring clip for holding the flint glass prism firmly on the circular table
- an L-shaped bracket with 2 spring clips for holding the diffraction grating.
- an optically worked 60° flint glass prism. (This is a very expensive prism and not to be confused with the crown glass prisms used in the junior school.)
- a replica diffraction grating mounted in black cardboard with 3 small glass windows labelled in lines/inch.

I Extra equipment for the suggested learning experiences (numbers refer to appropriate experiences) includes:

- 2 metres of thick black cloth for covering the instrument and your head.
- a tungsten light bulb and desk lamp mounting (1)
- a sodium vapour lamp with mounting and power supply (2,3,4,5)
- a mercury vapour lamp with mounting and power supply (6)
- a 'long-life' light bulb and appropriate mounting (6)
- a kit of spectral tubes including hydrogen, helium and neon, induction coil, power pack and leads (6,7) - See *instructions for setting up spectral tubes on page 30*.

Setting up the Spectrometer

- 1. Look through the eye-piece and adjust until the cross-hairs are sharp and clear.
- 2. Point the telescope at some distant object like a building or a tree and adjust the achromatic lens until the inverted image is in sharp focus. The telescope is now focused at infinity and should not be adjusted again throughout the experiment.
- 3. Place any bright light source at the slit end of the collimator and swing the telescope into line so that a bright vertical image of the slit can be seen.
- 4. Adjust the achromatic lens at the end of the collimator until the image of the slit comes into sharp focus. It is this step which is repeated during the course of any experiment. That is, the slit-width adjusted and the collimator lens re-focused to give a sharp image of the slit.
- 5. Depending on the experiment, mount either the prism or the diffraction grating on the central circular table and place the appropriate light source at the adjustable slit.
Remember: apart from adjusting the slit-width, the ONLY focusing adjustment made during the course of an experiment is re-focusing the lens at the end of the collimator. The telescope always remains focused at infinity.

HANDY HINT

Set the spectrometer up in a darkened laboratory or cover the instrument and your head with a piece of thick black cloth.

SUGGESTED LEARNING EXPERIENCES

1. **View a continuous spectrum from red to violet** using a 12 volt tungsten filament bulb as the light source and a 60° prism on the table. Moving the telescope aside, try looking directly through the prism to obtain the best orientation for seeing the spectrum (*see figure 2*).
2. **View the sodium emission spectrum** using the sodium vapour lamp and 60° prism.
3. **Calculate the refractive index of the prism** using the sodium vapour light and the 60° flint glass prism. First determine the refracting angle of the prism (*see figure 1*) by positioning the prism so that the incident light falls on one of the vertices. Position the telescope to receive the reflected light from each of the faces either side of the edge of the prism. Read off the angular displacement from the vernier scale on the turntable and the angle between the two readings is twice the refracting angle (A) of the prism.

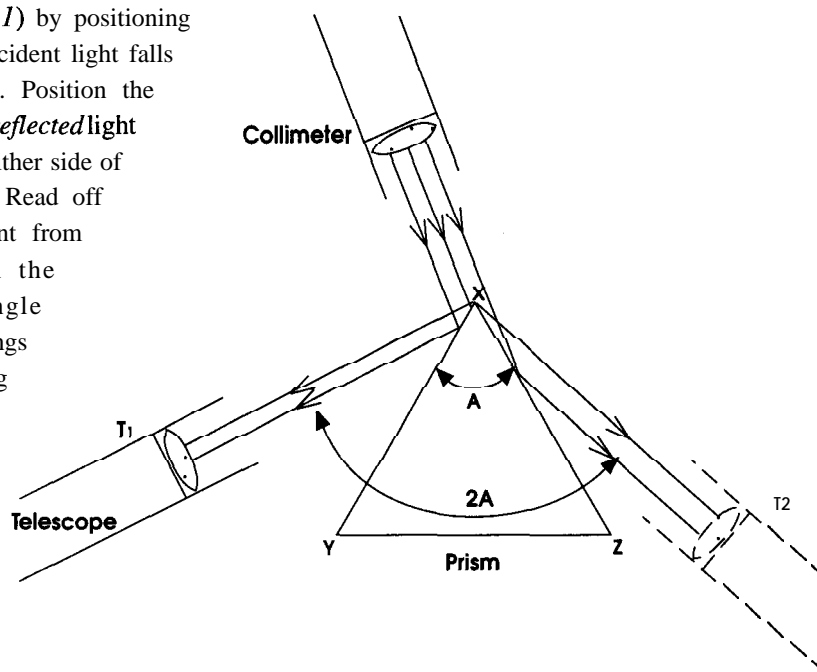


figure 1

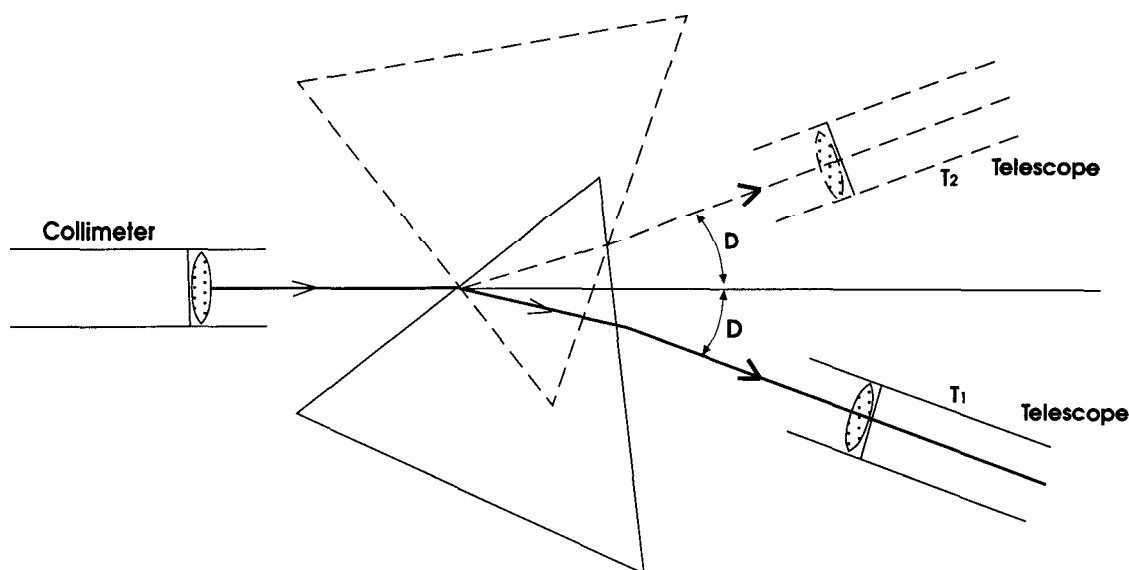


figure 2

The angle of minimum deviation can be found by positioning the prism (*see figure 2*) so that the light is incident at about 45° to one of the refracting faces and the telescope set up to receive the *refracted* light through the prism. Rotate the prism table slowly, reducing the angle of incidence till the refracted beam is on the point of reversal. Read off the **angle** from the vernier scale. Rotate the prism to bring the other refracting face toward the collimator and repeat the procedure. The angle between the two readings taken is twice the angle of minimum deviation (D). Calculate the refractive index of the prism using the following formula

$$n = \frac{\sin(A+D)/2}{\sin A/2}$$

4. **Calibrate the diffraction gratings** for an accurate measurement of the lines present in atomic emission spectra. Use the sodium lamp as the light source as it emits an orange monochromatic light at 589 nm. Observe the first and second order images on both the right and left and hence calibrate the grating accurately. *For further details, refer to Year 12 Senior Physics Prac Manual, Experiment C8.*
5. **Determine the wavelength of the sodium light**, as a corollary to the previous experiment. If the grating value is accurately known, then the wavelength of the sodium line is easily calculated using much the same procedure as in the previous experiment. Note: the sodium line is actually 2 lines 0.5 nm apart, but it is almost impossible to resolve with this equipment.
6. **Observe and estimate the wavelength of the line spectra** emitted from various light sources, including the mercury vapour lamp, the neon spectrum tube and even the 'long-life' light bulbs. Compare the estimated values for the wavelengths with the published ones. *Refer to the colour plate on page 14 in the front section of Science for High School Students - most other texts also have information on the wavelengths of the common spectral lines.*
7. **Observe and measure the 4 emission lines in the visible region for hydrogen.** Set up the spectrometer with the hydrogen spectrum tube and diffraction grating. Allow students to participate in this exciting phase of historical scientific discovery as they verify the empirical formula for the Balmer series of spectral lines, first proposed in 1885 by J.J.Balmer.