Experimental Activity 17

Relaxation Oscillations: Neon Bulb

Comment: This activity should not take more than one hour to complete.

Reference: Section 7.2

Object: To investigate the relaxation oscillations produced by a constant voltage source applied to a circuit that contains a neon glow lamp wired in parallel with a capacitor.

Theory: Stable periodic oscillations that are caused by autonomous (time-independent) forcing functions are known as limit cycles. If the dependent variable exhibits fast changes near certain time values, with relatively slowly varying regions between, the oscillator is said to exhibit relaxation oscillations. In this experimental activity the negative resistance characteristic of a neon glow bulb in conjunction with a capacitor and constant voltage power supply is used to produce relaxation oscillations.

Figure 17.1 is a sketch of a neon glow lamp. The small bulb is about 1.0 cm long and contains two vertical metal electrodes which are separated by approximately 2 mm. The electrodes are surrounded by a moderately low pressure neon gas and when a potential difference is applied across the electrodes an electric field is created. This electric field accelerates the electrons and neon ions inside the bulb. If the electric field is large enough, the electrons reach a speed that is sufficient to start an avalanche of electrons. The avalanche is caused by an
electron knocking out of the neon atom a second electron, thereby providing two electrons for the next collision, and four for the next collision, and so on until saturation is reached.

Accordingly, a neon glow lamp is considered to have a very high resistance until the correct potential difference exists across the electrodes. At the critical potential difference—the firing voltage ($V_f$)—the presence of a seed electron creates an avalanche and the bulb begins to conduct. This conduction reveals itself by making the lamp glow. Once the neon bulb is glowing, its resistance decreases, so a current-limiting resistance is usually placed in series with the bulb. The current-limiting resistance is normally selected to have a value that permits the bulb to stay glowing without burning it out. This happens because as the current through the bulb increases and the potential drop across the bulb decreases, the potential drop across the resistance increases. If the correct resistance is selected, the bulb stays lit. If the current-limiting resistance is very large, the bulb turns off. If the current-limiting resistance is too small, the current can continue to increase until the bulb burns out. Because neon bulbs consume very little power and have a very long life they are often used to indicate if a device such as a power supply is turned on.

The neon bulb in this activity is used a little differently than that given in the description above. The circuit shown in Figure 17.2 produces relaxation oscillations. When the switch (S) is closed, the capacitor slowly (relatively) charges through the large resistance ($R$). The potential drop across the capacitor increases until the bulb's firing voltage ($V_f$) is reached and the bulb turns on. As soon as the bulb turns on, its resistance drops and the capacitor rapidly discharges through the bulb. As the capacitor discharges, the potential drop across the capacitor (bulb) decreases until the extinction voltage is reached and the bulb turns off. When the bulb turns off, its resistance rapidly regains its large initial value (infinity), the capacitor begins to recharge and the limit cycle is in operation.

Figure 17.3 shows the same cycle as a function of the voltage and the current. Be careful not to assume that the lengths of the line segments ($DA$, $AB$, $BC$, $CD$) are proportional to the time. As the voltage across the bulb increases from 0 to $A$, no (or very little) current flows through the bulb. Once the firing voltage ($V_f$) is reached, the bulb's resistance drops dramatically and the bulb begins to conduct. This reduction in the bulb's resistance allows for a rapid increase in the current through it. This is represented by the movement from point $A$ to point $B$. Now the circuit relaxes as the capacitor discharges and the