a) A capacitor in a source-free series RC circuit has stored energy due to the initial voltage \( v(0) \) across it. The natural response takes the familiar form:

\[
v(t) = v(0) e^{-t/\tau}
\]

where \( \tau \) is the time constant. A convenient way to experimentally determine the time constant of a circuit is to measure the time it takes for the voltage to decrease from \( v(0) \) to one-half of \( v(0) \) [since one-half is often easy to identify on the screen of an oscilloscope]. Suppose we measure this time and call it “\( t_{50}\% \)”. Use the properties of the exponential function to solve for \( \tau \) when \( t_{50}\% = 20 \) ms.

b) Determine the voltage as a percentage of \( v(0) \) when \( t = 1, 2, 3, 4 \) and 5 time constants (i.e. \( \tau, 2\tau, 3\tau, 4\tau \) and \( 5\tau \)).
Purpose: At the end of this experiment, you will be able to determine time constants of networks with first-order differential equations.

Theoretical Basis: For a more detailed discussion, consult appropriate sections of your textbook.

Task 1. Stopwatch Method  (Work in pairs for this experiment (Task 1 only))

a. Construct the circuit in Figure 1 without the short from A to B. Using the DC power supply, establish a 10V capacitor voltage, verifying it on the NI4060 multimeter. Allow time for the network to reach a steady state. Connecting a short circuit from terminal A to B will allow us to observe the natural response of a series RC by watching the decaying voltage level in the NI4060 multimeter. Try this once or twice to get a rough feeling for the discharge rate of the network. Remove the short and allow the network to recharge fully to 10V each time before continuing.

b. Using a stopwatch, time the fall from 10V to the voltage values found in Table I. Repeat this several times to estimate the uncertainty of your measurements. Each student should enter the data into their own table for future reference. Note how the voltage values selected are related to a multiple of the time constant. Determine the measured time constant of the network. Be able to discuss what effect the voltmeter resistance produces in this circuit. Will this effect always be a practical concern?

Figure 1: Test circuit for Task 1

Task 2. Oscilloscope Method
Practical electrical networks are characterized by very small time constants, usually considerably less than one-hundredth of a second. The stopwatch method would not be useful in such cases. To observe the natural response, we must use the oscilloscope.

a. Connect the signal generator to the RC circuit, as shown in Figure 2. Although the output resistance of the source is not explicitly shown, it may be important.

![Figure 2: RC test circuit.](image)

b. Establish a 10kHz square wave from the signal generator. On the oscilloscope you should see a waveform similar to Figure 3. Adjust settings for horizontal and vertical scale until you observe one full decay cycle in detail. Adjust the magnitude of the function generator to 6V p-p.

c. Complete Table II. Using the CRT cursors, determine the time required for the voltage to fall to 50%, 37% and 5% of the initial value. [Hint: using the horizontal position control, slide the display left or right until the desired discharge value is touching a vertical grid reference.] Estimate the uncertainty of your readings by using the oscilloscope error specifications for “ΔT”.

![Figure 3: RC Natural Response used to determine τ](image)
Complete all entries in Tables I and II.

Table I. Stopwatch time constant measurements; \( R = \) __________, \( C = \) __________

<table>
<thead>
<tr>
<th>Time to fall from 10V to:</th>
<th>( t ), seconds</th>
<th>Estimated uncertainty, ( ) s</th>
<th>Possible range for ( \tau ), s</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.07V = 10 x ( e^{-t/2} )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.68V = 10 x ( e^{-t} )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.35V = 10 x ( e^{-t} )</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table II. Oscilloscope time constant measurements.

<table>
<thead>
<tr>
<th>Time to fall from 6V to:</th>
<th>( t ), ( \mu )s</th>
<th>Estimated uncertainty, ( \mu )s</th>
<th>Possible range for ( \tau ), ( \mu )s</th>
</tr>
</thead>
<tbody>
<tr>
<td>50% of 6 = 3.0V</td>
<td>( t = 0.693 x \tau )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>37% of 6 = 2.2V</td>
<td>( t = 1 x \tau )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5% of 6 = 0.3V</td>
<td>( t = 3 x \tau )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Postlab Assignment**

Explain which method is the most reliable for determining \( \tau \). By noting the published input impedances of the NI4060 multimeter, the oscilloscope, the signal generator and the DC power supply, fully explain why the measured time constants are not the simple product of \( R \) and \( C \). What is the Thevenin resistance as viewed by the capacitor in each case?

*Use paragraph headings to add structure to your discussion. Include any pertinent tables or equations in the body of the text. With care and thought, you should be able to make a convincing argument using 150-200 words.*