Lab 04

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Basic Oscilloscope Operation
Capacitor Time Constant

1. The Oscilloscope.

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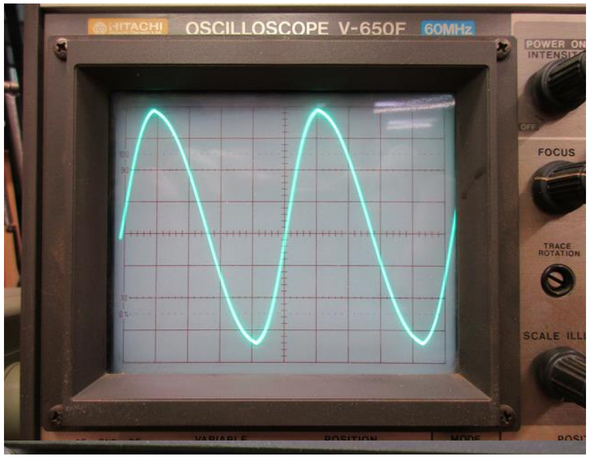
   a. As you can see from the oscilloscope screen ('face") the 'scope is nothing more than an x-y graph. The x axis (left-right) is calibrated in time and the y axis (up-down) is calibrated in voltage.

   b. In this "analog" 'scope, a beam of electrons is shot from a vacuum tube to a fluorescent screen inside of that tube. When those electrons hit the face of the tube, they light up the green fluorescent coating on the inside of the face of the tube. In this sense, the "cathode ray tube" in the 'scope is much like the old picture tube in black and white TV screens with a white fluorescent coating on the fact of the tube.

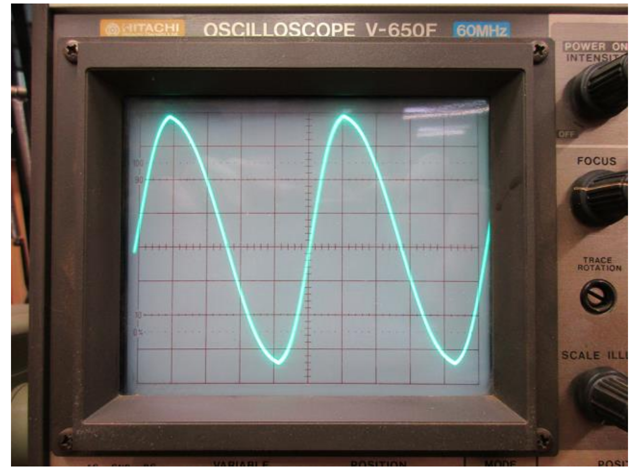


2. This is an image of a "sine wave", so named because it is a graph of the trigonometric "sine" function. To get this picture, we take the voltage output of a sine wave generator (like the one on the trainer) and put it into the vertical (y) input.

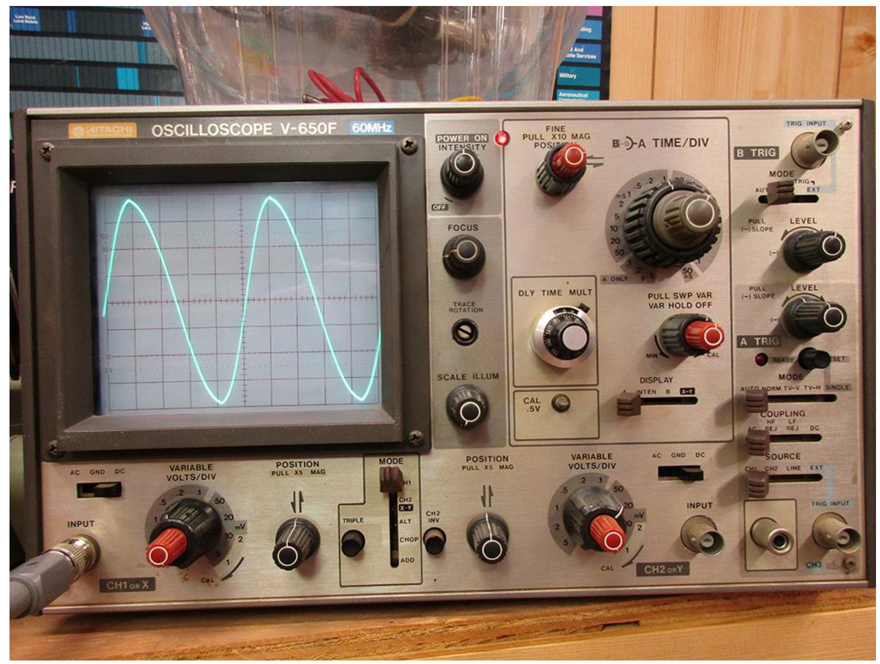
   The horizontal (x) input is internally generated by a very accurate "timebase" generator that moves the beam horizontally a precise number of seconds (or milliseconds, or microseconds) per division on the graph of the screen. So, up and down is the sine wave and left and right is how fast the sine wave is moving. This movement during some time period to complete one full up-down swing we call "frequency". If, for example (as this wave shows) we go up and down once every millisecond, the formula $f = 1/t$ gives us a frequency of 1000 Hz, or just a little below high C ("Soprano C") on the piano.

3. We can also measure the voltage of this sine wave. Note that the vertical "y" axis is calibrated as 2 volts per division, so from the center zero volts line we go UP 4 divisions (8 volts) and DOWN 4 divisions (-8 volts) or a "peak to peak" voltage of 16 volts.

   Of course, we aren't limited to sine waves. We can have square waves, triangle waves, pulses, noise, in fact we can have any voltage source you wish INCLUDING dc if you want a very expensive battery tester.



4. The problem with the analog oscilloscope is that you didn't see the wizard behind the curtain. Here is the ENTIRE front panel of the oscilloscope, and each one of those knobs and switches had to be in EXACTLY the right position and adjustment for this sine wave image to show correctly.



   In particular, the "trigger" adjustments on the right side of the oscilloscope have to be adjusted "just so" to get a stable image on the screen. Otherwise you get a "spaghetti screen" that really doesn't mean anything to you or to I because it conveys absolutely no information other than I don't have the trigger adjustments set properly.

5. Enter the new kid on the block. The DIGITAL oscilloscope. Fairly devoid of all the knobs and switches of the analog oscilloscope. The tradeoff? That analog oscilloscope in the first couple of pages can be had for a $$ couple of hundred bucks.

   The Tektronix digital scope goes for $1500 new, $650 used. About 3x to 4x the price.

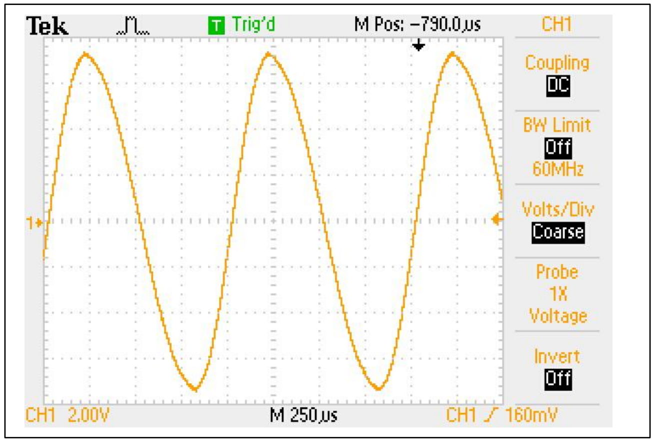
   But here is what it can do that the analog scope never dreamed of…

Plug it in. Push the power button. Push the Autoset and Autorange buttons and the trace appears on the screen without you having to adjust anything. Bingo, it pops right up.

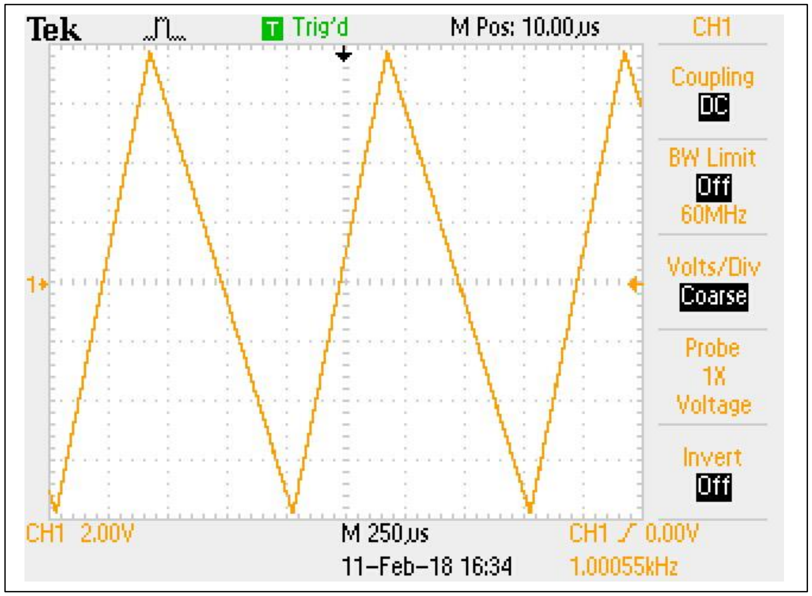
   MOREOVER, to take a picture on the analog 'scope it is necessary to get the camera just so, with exactly the right f-stop, the right aperture, and the right exposure.

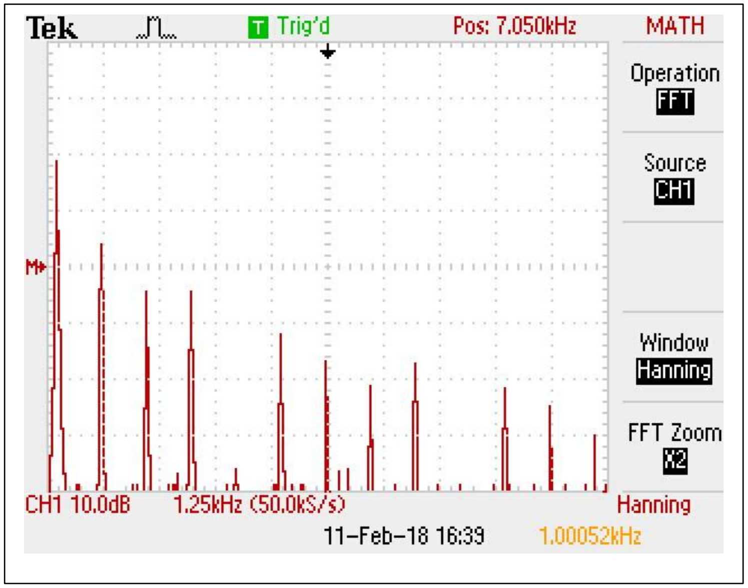
   With the digital 'scope you simply push a button and the image on the screen is sent to a flash drive that plugs into a socket on the front of the scope. (*Caveat, for whatever reason, Tek designed their system to use flash drives of no more than 2Gig capacity. No, you can't partition a larger drive, no you can't do any tricks that I know of. An ancient 2Gig drive is all that will work).*

6. And guess what. Here is the image of that screen from my flash drive. Let's see what sorts of information it gives me.



   a. That I'm set to 2 volts per division
   b. That my frequency is 1.00063 kHz. (ok, so I can't read it that close on an analog scope.
   c. That it was taken at 4:06 in the afternoon of the 11^{th} of February 2018
   d. That the horizontal trace was moving 250 microseconds per division.
   e. That I was using a no-gain probe.
   f. That I wasn't using a noise filter
   g. That I was DC coupled to the input.



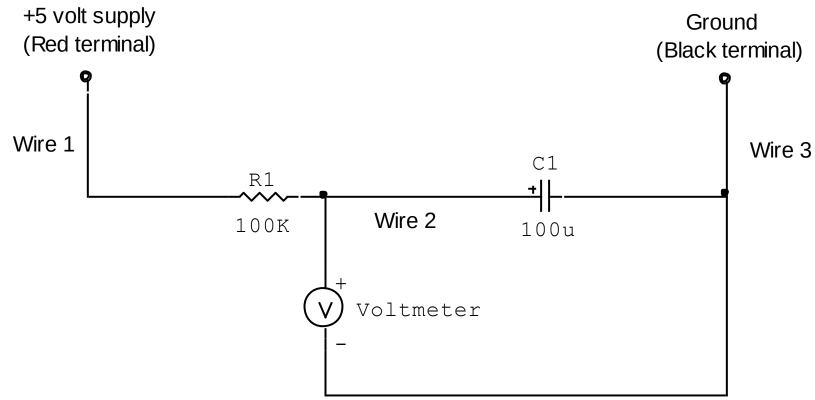


7. This is invaluable to me, and perhaps to you some day. We don't know yet (but we are about to find out in a couple of weeks) that all signals and waveforms may be made up from a bunch of sine waves of differing frequencies that are "harmonics" (integer multiples of some fundamental sine wave frequency. Indeed, it is true that all music, for example, is nothing more than sine waves and their multiples to make up the sounds of individual instruments. Here, for example, is what we call a "triangle wave". We would like to know what sine wave components make up this waveform.

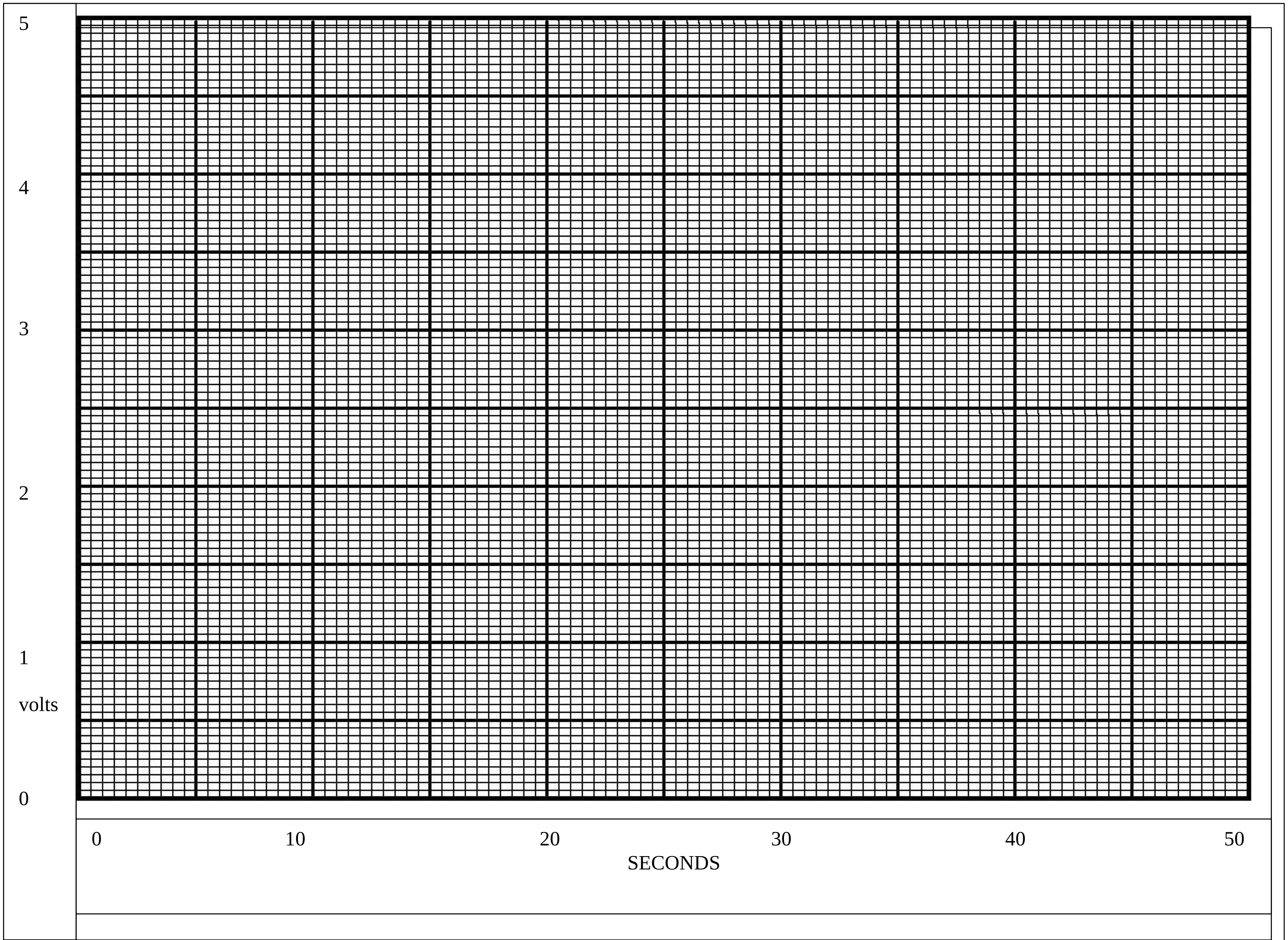
   The mathematician Fourier told us how to go about calculating these frequencies, but this oscilloscope does it for us. To the left is the triangle wave. To the right are the frequencies and amplitudes of the sine waves that make up this wave

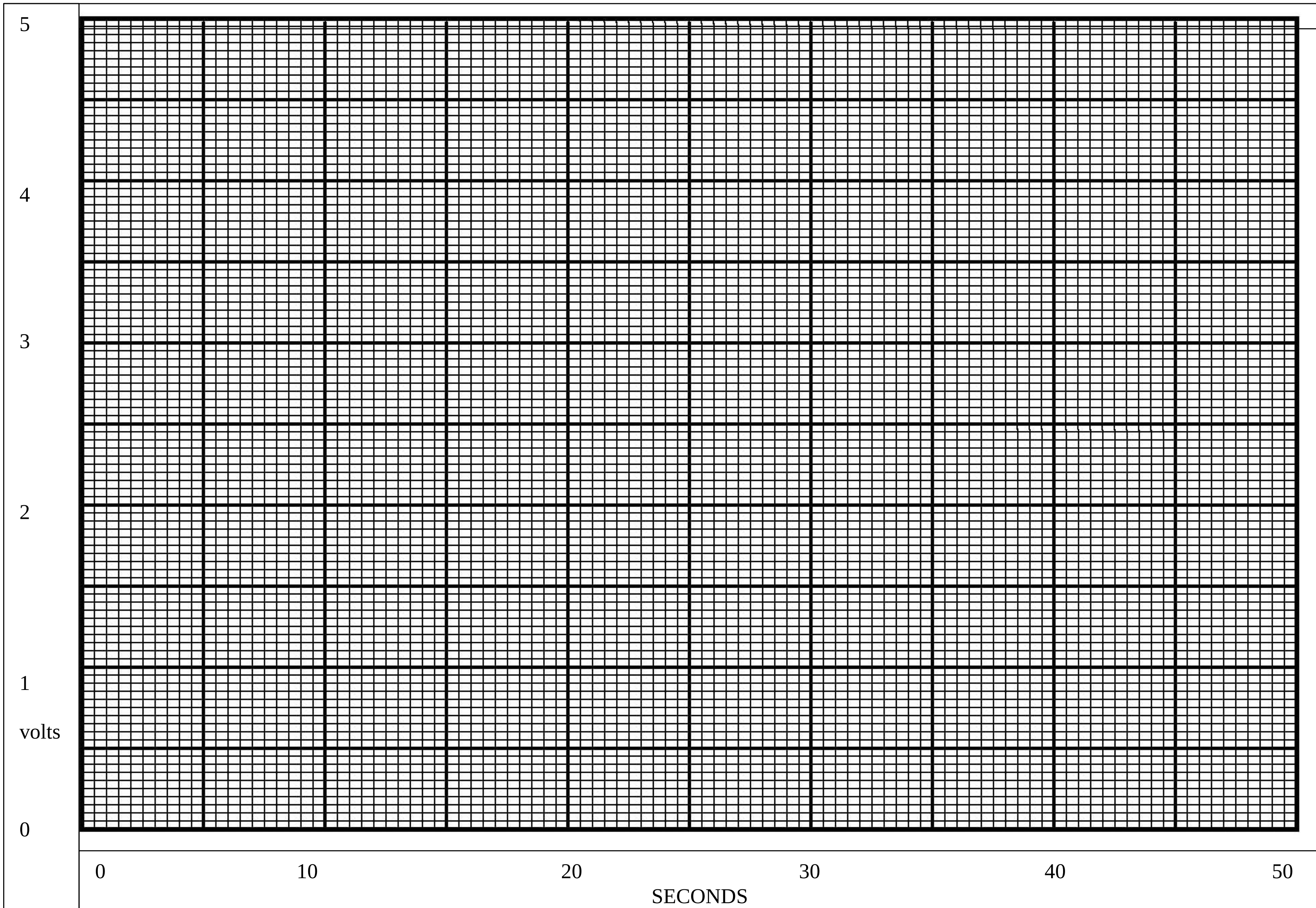
8. Let's do a little experiment on capacitor time constant. The basic idea is going to be to use the trainer and the constant 5 volt supply of the trainer, a single resistor, a single capacitor, and a voltmeter to measure time constant. The time constant is going to be somewhat long so that we can use a regular clock with a sweep second hand to do the timing.

This experiment is intended for TWO lab partners. One is the connector/observer and one is the recorder. The circuit we are going to use is as follows:



a. Connect the circuit as shown EXCEPT for wire 2. Note that C1 is POLARIZED and must be installed with the (-) lead connected to ground.
b. See that the voltmeter reads very near 5 volts.
c. Remove the connection between wire 1 and the 5 volt supply and install wire 2. See that the voltmeter reads zero volts.
d. The instructor will count down from 5 to zero. At zero the lab connector partner will reconnect the red wire to 5 volts.
e. The instructor will then count down every ten seconds from 3 to zero. At zero, the observer will read the voltmeter to the recorder. The recorder will write down the voltmeter reading.
f. There will be a countdown every ten seconds for a full minute.
g. At the end of that minute, the recorder will read back the voltmeter readings and the connector will fill in the graph of voltage versus time and determine the "time constant" (in seconds) of this circuit at the 67% of full voltage point. (Graph paper next page.)
h. The instructor will then count down again from 5 to zero at which time the connector will immediately remove the connection of wire 1 from the 5 volt supply and connect it to ground.
i. Repeat steps e through g on the second graph paper.


5
4
3
2
1
volts
0
0
10
20
30
40
50
SECONDS



5
4
3
2
1
volts
0
0
10
20
30
40
50
SECONDS

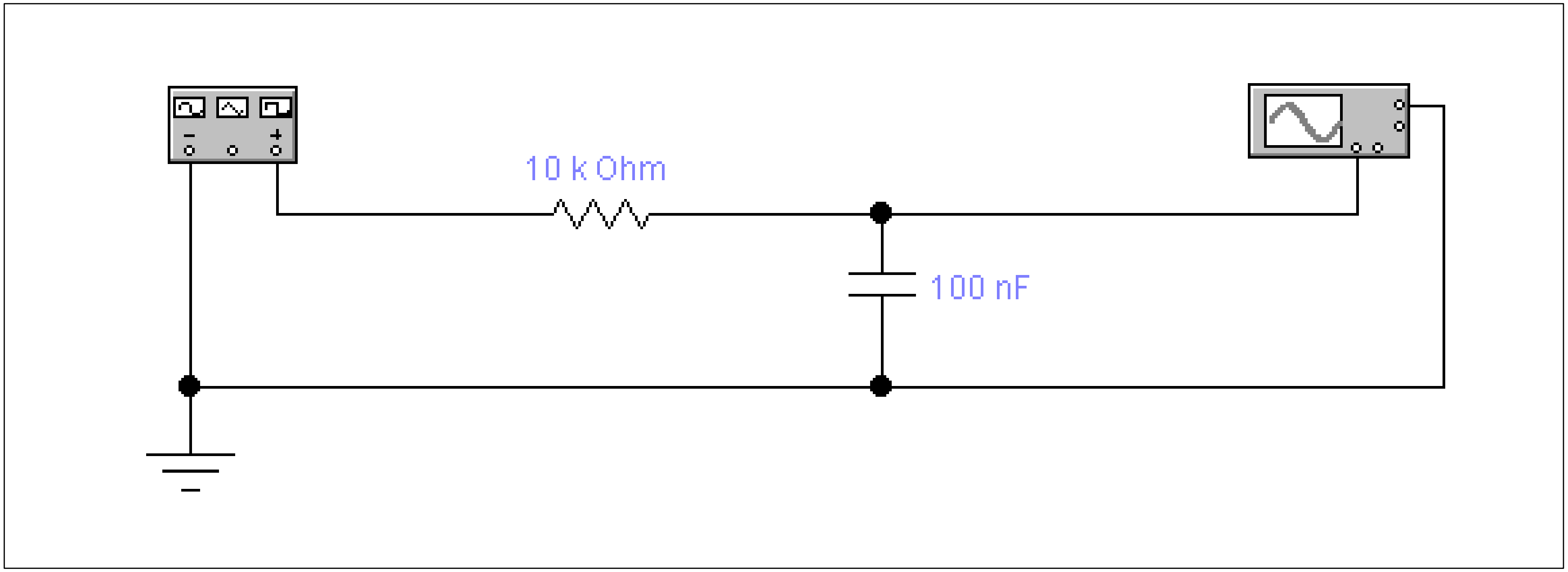
9. We said in the lecture that a capacitor and a resistor have a "TIME CONSTANT". That is, if you attempt to charge up a capacitor through a resistor, the resistor "resists" letting electrons through so it takes some time for those electrons to charge up that capacitor. How much time?

We said that it takes one "TIME CONSTANT" (the product of the resistor value times the capacitor value) in seconds for the voltage across the capacitor to reach 63% of the applied voltage.

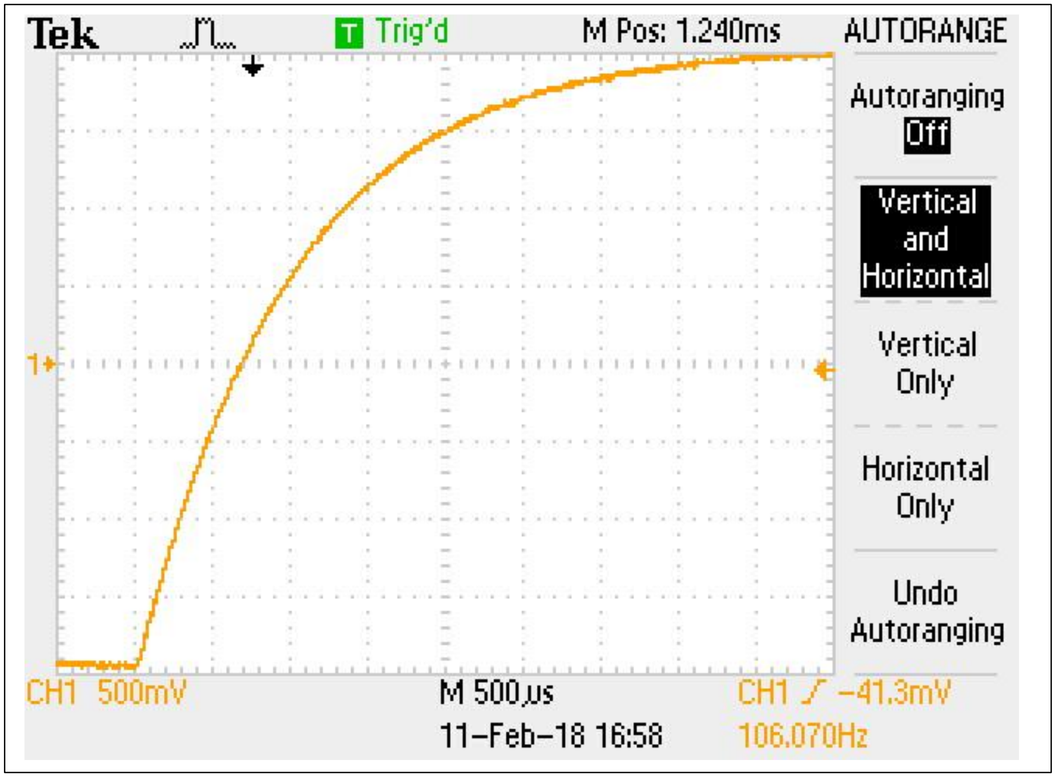
In particular, if we use a 100 nanofarad (100 x 10^{-9} farads) capacitor and a 10 kΩ (10 x 10^{3} ohms) resistor, that time constant ought to be pretty close to 1 x 10^{-3} seconds, or one milli-second.

Now that we have a really neat way of measuring time with the oscilloscope, let's see if we can figure out how to do this. Using the square wave on the trainer ought to let us apply a voltage that is periodic (happens over and over again) so that our oscilloscope can measure this time easily.

Here is the pictorial on how I am going to set this experiment up using 100 Hz. on the trainer for a frequency and letting the oscilloscope set my picture so that I can read it properly. Let the oscilloscope set the picture automatically for the square wave out of the trainer and set the square wave frequency to about 100 Hz.:



And here is what I hope to see on the oscilloscope:



10. Complete the following table and call it a day.

Capacitor Value (nanofarads)	Resistor Value (Ohms)	Calculated Time Constant	Measured Time Constant
100	10k	1 millisecond	.93 milliseconds
100	1k		
100	3.3k		
100	4.7k		
100	47k		
100	100k		