

Experiment 2

Meter Circuits

Even in these days of digital circuitry, the d'Arsonval meter movement still finds application as a simple passive indicator of electric current. In this instrument, an electric current produces a proportional magnetic field that interacts with a permanent magnetic field to stress a spring. The strain of the spring is read as a deflection of a scale. Most d'Arsonval meter movements are linear; that is, the displacement is directly proportional to the current passing through the meter.

In this experiment, the basic d'Arsonval meter movement and simple passive circuitry will be used to construct a voltmeter, an ammeter, and an ohmmeter. In order to design a meter circuit, the full-scale deflection current and the internal resistance of the meter movement must be known. Generally the full-scale deflection will be obvious. For example, if the meter is marked "DC MICROAMPERES" and has a full-scale reading of 100, it is, of course, a 100-microampere meter movement. The internal resistance of the meter is not so obvious, and needs to be measured. This measurement is the first part of this experiment.

Part 1- Meter Internal Resistance Measurement

Measurement of the internal resistance of the meter is accomplished by connecting the meter to a current source. A current source may be approximated by a voltage source connected in series to a high resistance. The current source is adjusted to produce a full-scale reading on the meter being measured. Then, a resistance decade box is connected in parallel with the meter, and the resistance is adjusted to produce exactly a half-scale reading on the meter. Now, only half of the original current flows through the meter; the other half of flows through the resistance decade box. Since the decade box and the meter are connected in parallel, the same voltage appears across each. Therefore, since the current flowing through each is also the same, the resistance of the meter movement must be equal to the resistance setting of the decade box.

1. Connect the circuit shown in Figure 1, but leave the power supply turned off.
2. Make sure that the meter indicator mechanical zero is set properly so that the indicator reads precisely zero with no current passing through the meter.
3. After the lab instructor inspects your circuit, turn on the power supply and adjust the output voltage to produce exactly full-scale deflection on the meter being measured.

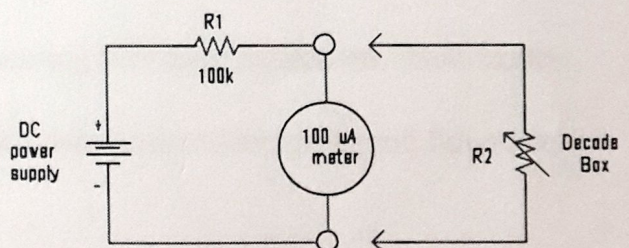


Figure 1

4. Connect the resistance decade box in parallel with the meter.
5. Set all of the decade box switches to the OFF position.
6. Add resistance on the decade box to produce exactly a half-scale deflection on the meter.
7. The decade box resistance is the sum of all the switch settings that are in the ON position. This value is also internal resistance of the meter. Record this resistance.
8. Turn off the voltage source.

1100 k -

1.121 k Ω

- Disconnect the decade box and check its resistance reading with the digital ohmmeter. Record this value. If this reading is significantly different from the value found in step 7, the decade box is probably defective. Inform the lab instructor about this, and use the ohmmeter reading of the decade box resistance for all your calculations.

Part 2 – Ammeter Circuit

An ammeter is an instrument that is used to measure the current flowing through a circuit path. Since the ammeter is connected in series, its internal resistance should be as small as possible (ideally zero), in order for the measurement to be accurate. Consequently, the amount of current that produces full-scale deflection of the meter movement is also small, necessitating a means of extending the current measuring capability.

In this part of the experiment, an ammeter circuit is constructed using a 100-microampere meter movement. The ammeter is designed to measure 100-milliamperes full-scale. This is accomplished by connecting a shunt in parallel with the 100-microampere meter movement. The shunt allows the excess circuit current to bypass the meter movement.

To construct and test the ammeter:

- Connect the circuit shown in Figure 2, but leave the power supply turned off.
- Set the decade box to a resistance value of 1498 minus the meter internal resistance that was found in part. $= 377 \Omega$
- After the lab instructor inspects your circuit, turn on the power supply.
- Increase the power supply output voltage while observing the meter deflections. Both meters should move upscale.
- Adjust the power supply voltage to produce full-scale deflection on one meter and full-scale or less deflection on the other.
- Record the current for both meters in Table 1.

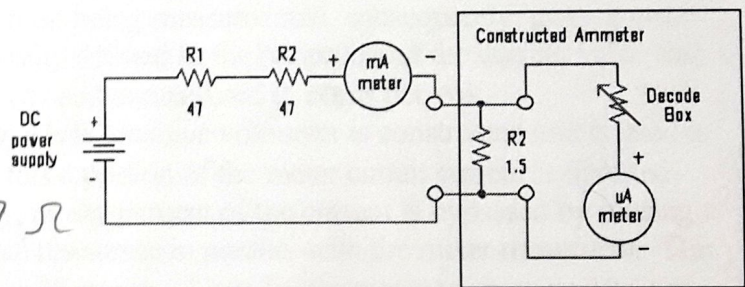


Figure 2

Table 1 Ammeter Circuit			
Scale deflection	Milliamperes	Microamperes	Percent error
Full	99	100	
$\frac{3}{4}$	74	75	
$\frac{1}{2}$	49.5	50	
$\frac{1}{4}$	25.5	25	

7. Adjust the power supply to produce $\frac{3}{4}$, $\frac{1}{2}$ and $\frac{1}{4}$ scale deflections and record the current for both meters at each of these values in Table 1.
8. Calculate the percentage error at each of the four currents.

Part 3- Voltmeter Circuit

A voltmeter is an instrument that is used to measure the voltage that appears across two points in a circuit. Since the voltmeter is connected in parallel, its internal resistance should be as large as possible (ideally infinite), in order for the measurement to be accurate.

In this part of the experiment, a voltmeter is constructed using a 100-microammeter meter movement. The meter is designed to read full-scale when it is measuring 10 volts. Since the internal resistance of the movement is approximately 1k ohm, a current of 100 microamperes flows through it when a voltage of 0.1 volts is applied across the meter terminals. However, a meter that measures 10 volts full-scale is desired. To accomplish this a series resistance is added to the meter so that 100 microamperes flows through the circuit when 10 volts is applied across the series combination. The total circuit resistance must therefore be $R=V/I$ or 100k ohms. Thus the additional series resistance needed is 99k ohms. The closest standard resistance value to this is 100k ohms. Since the meter movement is accurate to only about three percent, the error caused by not subtracting the meter internal resistance is negligible.

An important consideration in selecting a voltmeter is its sensitivity rating. A more sensitive voltmeter has less loading effect on the circuit being measured and, consequently, gives a more accurate reading. Sensitivity is conventionally defined as the reciprocal of the current value that produces a full-scale deflection of the meter, and is measured in ohms per volt.

To investigate the effect of sensitivity, a less sensitive voltmeter is constructed and is used to measure the same circuit voltage. To do this a portion of the meter circuit current is diverted around the meter movement. Specifically, ninety percent of the current is bypassed by placing a resistance equal to $1/9$ of the meter internal resistance in parallel with the meter movement. This increases the full-scale meter current to 1 milliampere. Thus for the meter to measure 10 volts full-scale, the total series resistance becomes $R=V/I$ or 10k ohms.

To construct and test the voltmeters:

1. Measure the values of the components to be used in the circuit. Try to find a 100k ohm resistor that is within two percent of 100k ohms.
2. Connect the circuit shown in Figure 3, but leave the power supply turned off.

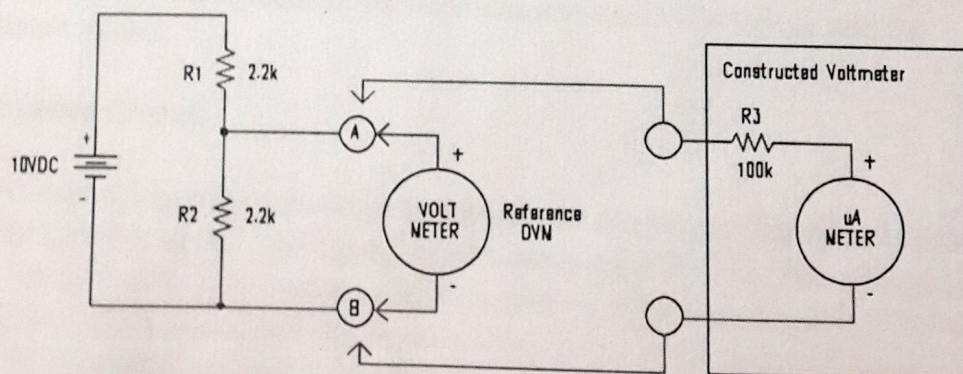


Figure 3

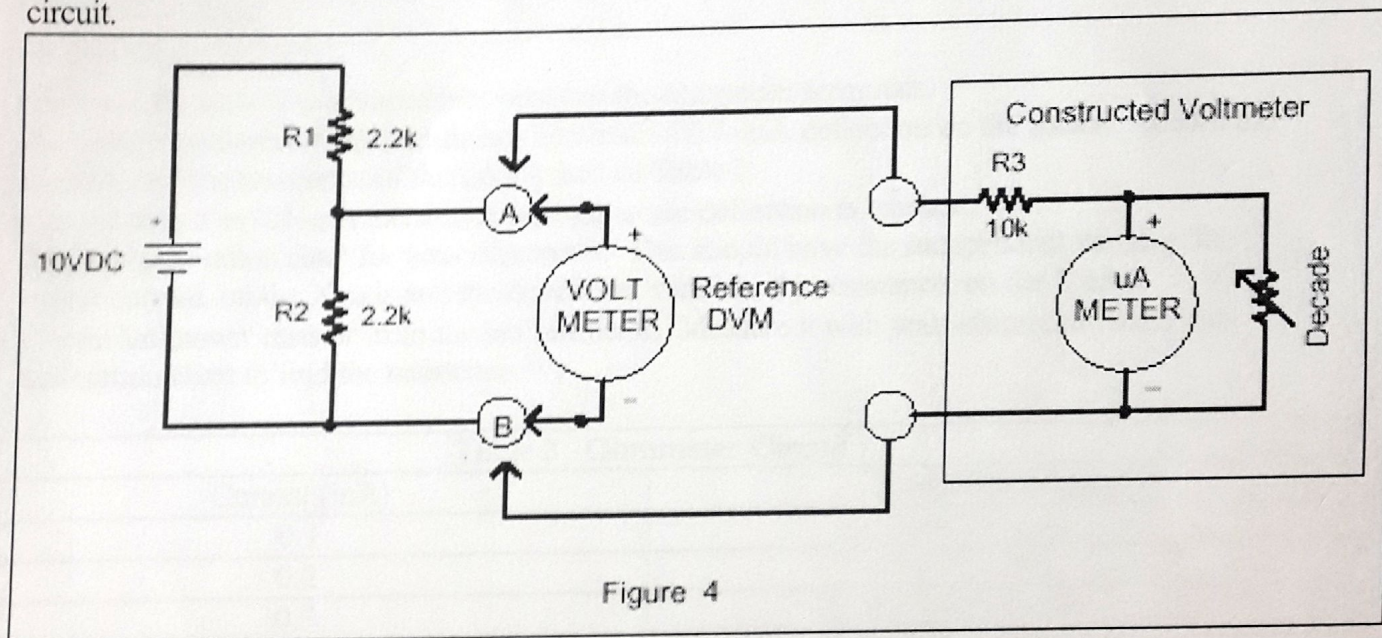
- After the lab instructor inspects your circuit, turn on the power supply.
- Observe the readings on the digital voltmeter (DVM) and the constructed voltmeter and record these values in Table 2.

Table 2 Voltmeter Circuits					
Figure 3			Figure 4		
DVM	Constructed	Unloaded	DVM	Constructed	Unloaded
5 v	50	5.05	4.55 v	46.5	5.05 v

1121/9

- Disconnect one lead from the 100k ohm resistor.
- Observe the reading on the DMV and record this value in Table 2. This is the actual (unloaded) circuit voltage.
- Modify the constructed voltmeter circuit as shown in Figure 4. Set the decade box at 1/9 of the microammeter internal resistance. Try to find a 10k ohm resistor that is within two percent of 10k ohms. This is the less sensitive voltmeter circuit.

124.5



- Repeat step 4.
- Disconnect one lead from the 10k ohm resistor.
- Repeat step 6.

In your report calculate the expected voltage between nodes A and B using the power supply voltage value. Comment on the agreement between this and the DVM values and the constructed voltmeter values.

Part 4- Ohmmeter Circuit

If the source voltage in a single loop circuit is known and is constant, the circuit resistance can be related to the circuit current. The Ohm's law relationship is $R=V/I$. Most simple ohmmeters utilize this principle. The meter scale is marked with resistance values of zero resistance at full-scale deflection and infinite resistance (open circuit) at zero deflection. This type of ohmmeter has a variable resistance connected in series with the voltage source, meter and external resistance. This variable resistance is adjusted, with the external resistance leads

shorted, to position the meter indicator at full-scale (zero resistance). Any added external resistance will produce something less than full-scale deflection.

To construct and test the ohmmeter:

1. Connect the circuit shown in Figure 5, but leave the power supply turned off.
2. After the lab instructor inspects your circuit, turn on the power supply.
3. Short-circuit the ohmmeter terminals (X and Y) and adjust the variable resistance to obtain a full-scale deflection on the meter.

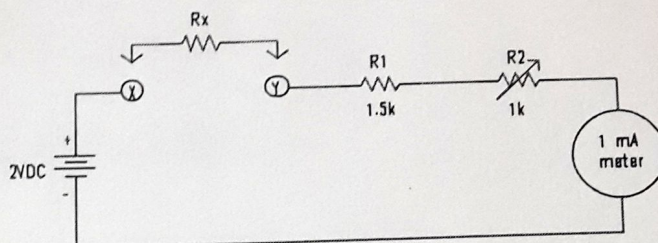


Figure 5

4. Connect the decade resistance box between the ohmmeter terminals.
5. Vary the resistance of the decade box to obtain a 0.1-mA deflection on the meter. Record the current and the resistance of the decade box in Table 3.
6. Repeat step 5 in 0.1-mA increments until full-scale deflection is reached.
7. Make a calibration chart for your ohmmeter. This should have the independent variable, the meter current, on the X axis and the dependent variable, the resistance, on the Y axis.
8. Get an 'unknown' resistor from the lab instructor. Measure it with your ohmmeter, using the calibration chart to find the resistance.

Table 3 Ohmmeter Circuit

Current (mA)	Resistance (ohms)
0.1	16440 Ω
0.2	8440 Ω
0.3	5440 Ω
0.4	3900 Ω
0.5	2940 Ω
0.6	2310 Ω
0.7	1850 Ω
0.8	1500 Ω
0.9	1230 Ω
1.0	1k Ω

Your report should include the following:

1. A discussion of the technique for measuring the meter internal resistance.
1. A discussion of the principles of operation of each of the circuits constructed.
2. A discussion of the equation for the decade box resistance setting in part 2 of step 2.
3. An explanation for the difference in the readings obtained with the two constructed voltmeters.