EECE 202 NETWORK ANALYSIS I Dr. Charles J. Kim

class note 06: D'arsonval movement and DC measurement

I. D'Arsonval Meter Movement **

Whenever electrons flow through a conductor, a magnetic field proportional to the current is created. This effect is useful for measuring current and is employed in many practical meters. Since most of the meters in use have D'Arsonval movements, which operate because of the magnetic effect, only this type will be discussed in detail.

The basic dc meter movement is known as the D'Arsonval meter movement because it was first employed by the ***French scientist, D'Arsonval***, in making electrical measurement. This type of meter movement is a current measuring device which is used in the ammeter, voltmeter, and ohmmeter. Basically, both the ammeter and the voltmeter are current measuring instruments, the principal difference being the method in which they are connected in a circuit. While an ohmmeter is also basically a current measuring instrument, it differs from the ammeter and voltmeter in that it provides its own source of power and contains other auxiliary circuits.

A. The Structure of Permanent-magnetic moving-coil movement

The compass and conducting wire meter can be considered a fixed-conductor moving-magnet device since the compass is, in reality, a magnet that is allowed to move. The basic principle of this device is the interaction of magnetic fields: the field of the compass (a permanent magnet) and the field around the conductor (a simple electromagnet).

A permanent-magnet moving-coil movement is based upon a fixed permanent magnet and a coil of wire which is able to move, as in figure 1. When the switch is closed, causing current through the coil, the coil will have a magnetic field which will react to the magnetic field of the permanent magnet. The bottom portion of the coil in figure 1-4 will be the north pole of this electromagnet. Since opposite poles attract, the coil will move to the position shown in figure 2.

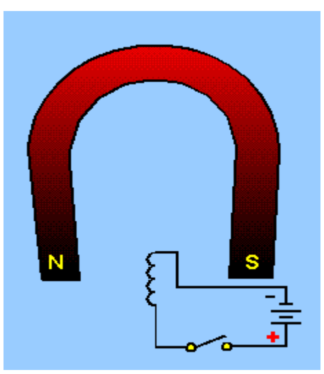


Fig. 1. A movable coil in a magnetic field

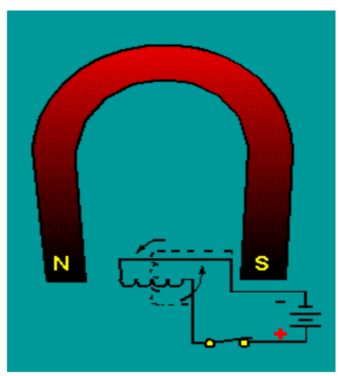


Fig.2. - A movable coil in a magnetic field (no current). (with current).

** Adopted from articles @avstop.com and www.tpub.com

The coil of wire is wound on an aluminum frame, or bobbin, and the bobbin is supported by jeweled bearings which allow it to move freely. This is shown in figure 3. To use this permanent-magnet moving-coil device as a meter, two problems must be solved. First, a way must be found to return the coil to its original position when there is no current through the coil. Second, a method is needed to indicate the amount of coil movement.

The first problem is solved by the use of hairsprings attached to each end of the coil as shown in figure 4. These hairsprings can also be used to make the electrical connections to the coil. With the use of hairsprings, the coil will return to its initial position when there is no current. The springs will also tend to resist the movement of the coil when there is current through the coil. When the attraction between the magnetic fields (from the permanent magnet and the coil) is exactly equal to the force of the hairsprings, the coil will stop moving toward the magnet.

As the current through the coil increases, the magnetic field generated around the coil increases. The stronger the magnetic field around the coil, the farther the coil will move. This is a good basis for a meter.

But, how will you know how far the coil moves? If a pointer is attached to the coil and extended out to a scale, the pointer will move as the coil moves, and the scale can be marked to indicate the amount of current through the coil. This is shown in figure 5.

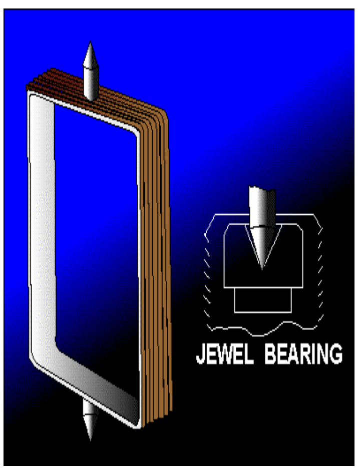


Fig. 3. - A basic coil arrangement.

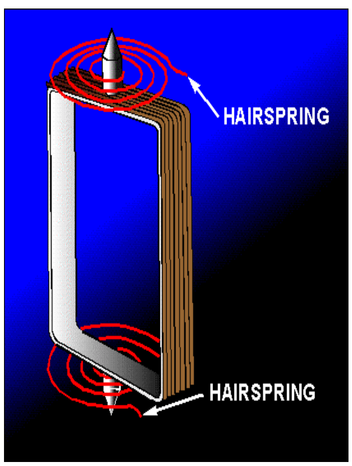


Fig. 4. - Coil and hairsprings.

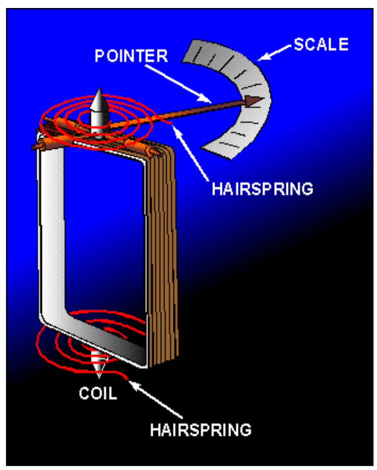


Fig. 5. - A complete coil.

Two other features are used to increase the accuracy and efficiency of this meter movement. First, an iron core is placed inside the coil to concentrate the magnetic fields. Second, curved pole pieces are attached to the magnet to ensure that the turning force on the coil increases steadily as the current increases.

The meter movement as it appears when fully assembled is shown in figure 6. This permanent-magnet moving-coil meter movement is the basic movement in most measuring instruments. It is commonly called the d'Arsonval movement because it was first employed by the Frenchman d'Arsonval in making electrical measurements. Figure 7 is a view of the d'Arsonval meter movement used in a meter.

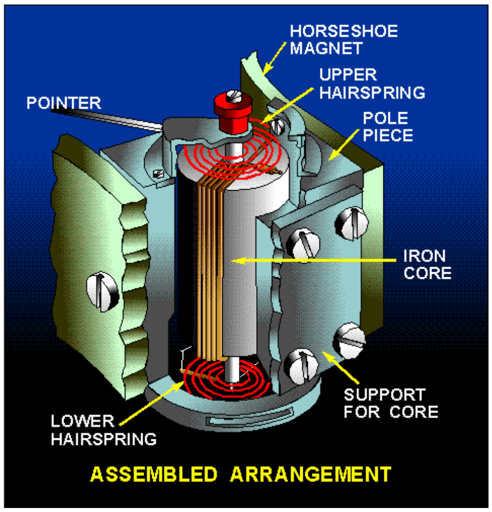


Fig. 6. - Assembled meter movement.

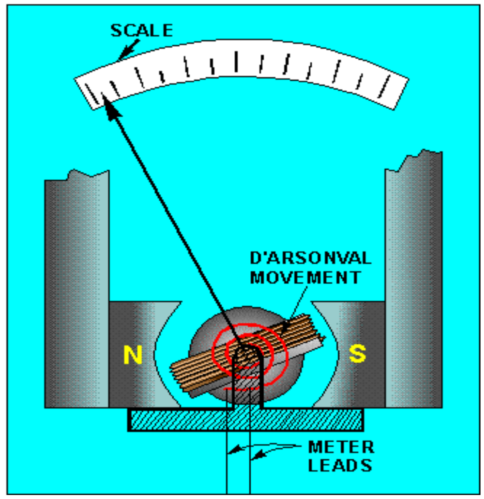


Fig. 7. - A meter using d'Arsonval movement.

B. Meter Sensitivity and Scale Change

The *sensitivity of a meter movement* is usually expressed as the ***amount of current required to give full scale deflection***. In addition, the sensitivity may be expressed as ***the number of millivolts across the meter when full scale current flows through it***. This voltage drop is obtained by multiplying the full scale current by the resistance of the meter movement. A meter movement, whose resistance is 50 ohms and which requires 1 milliampere (mA) for full scale reading, may be described as a 50 mV 0 - 1 mA.

Extending the Range of an Ammeter: A 0 - 1 mA movement may be used to measure currents greater than 1 ma. by connecting a resistor in parallel with the movement. The parallel resistor is called a shunt because it bypasses a portion of the current around the movement, extending the range of the ammeter. A schematic drawing of a meter movement with a shunt connected across it to extend its range is shown in figure 8.

Determining the Value of a Shunt*:* The value of a shunt resistor can be computed by applying the basic rules for parallel circuits. If a 50 mV 0 - 1 mA is to be used to measure values of current up to 10 ma., the following procedure can be used: The first step involves drawing a schematic of the meter shunted by a resistor labeled R_s (shunt resistor), as shown in figure 9.

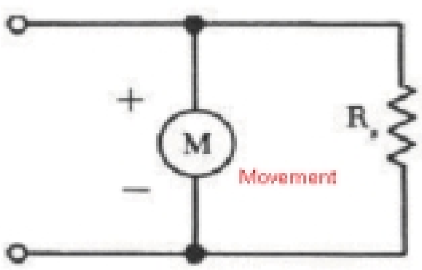


Fig. 8

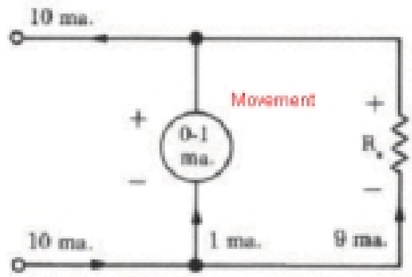


Fig. 9

Since the sensitivity of the meter is known, the meter resistance can be computed. The circuit is then redrawn as shown in figure 10, and the branch currents can be computed, since a maximum of 1 ma. can flow through the meter.

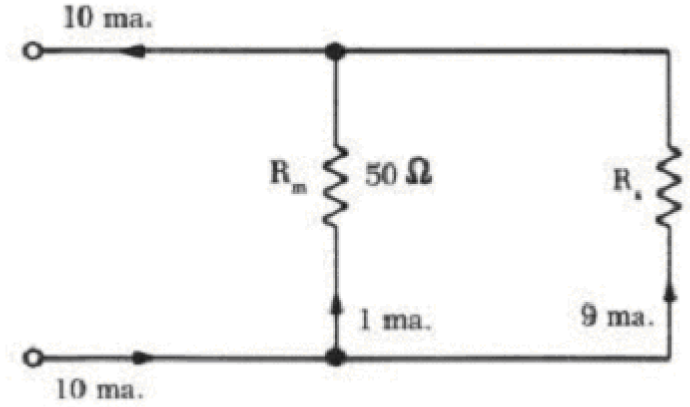


Fig. 10

The voltage drop across R_s is the same as that across the meter internal resistance, R_m:

$E = IR = 0.001*50 = 0.05\,[V]$

R_s can be found by applying Ohm's law: $R_s = \frac{R_{rs}}{I_{rs}} = \frac{0.05}{0.009} = 5.55\,[\Omega]$

Multi-Range Meters: Ammeters having a number of internal shunts are called multirange ammeters. Some multimeters avoid internal switching through the use of external shunts. Changing ammeter ranges involves the selection and installation on the meter case of the proper size shunt. See Fig. 10 below.

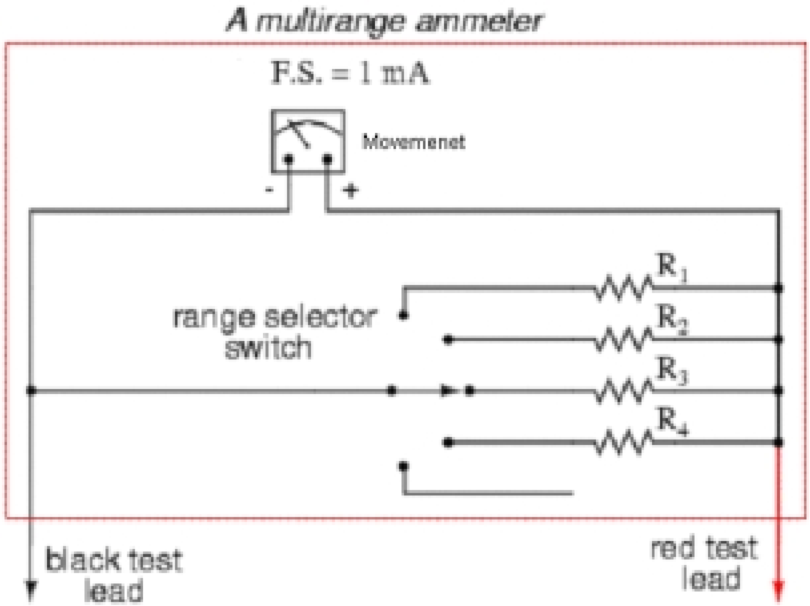
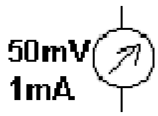


Fig. 10

II. Meter Scale Change Problems

1. d'Arsonval Movement Fundamental



1.1. Movement has rated current (through) I_m, and rated voltage (across), V_m

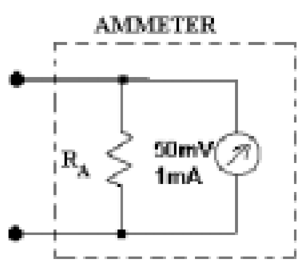
1.2. Hence, the movement has an internal resistance, R_m: $R_m = \frac{V_m}{I_m}$

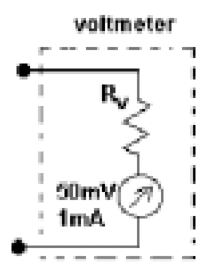
1.3. When current through the movement is the same as the rated current, then the needle indicates the maximum scale.

1.4. Remember that: in any circumstance, the current through the movement must be below the rated current, and the voltage across the meter must be below the rated voltage.

2. Scale Change Fundamental

2.1. The full scale of a meter (using the meter movement) can be changed by inserting a shunt resistor R_A for an Ammeter and a series resistor R_V for a Voltmeter.





2.2. The main idea behind:

2.2.1 Divert excessive current to R_A by current-division principle (Ammeter)

2.2.2 Divert excessive voltage to R_V by voltage-division principle (Voltmeter)

2.2.3. So that the voltage and the current of the movement keep the rated values.

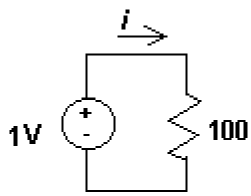
3. The effect of the meter resistance in DC measurement Fundamental

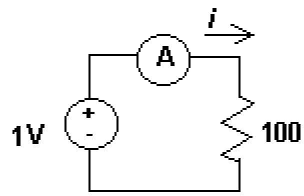
3.1. A meter has internal resistance introduced by the d'Arsonval movement resistor (R_m) and the shunt (R_A) or series (R_V) resistor brought by scale change.

3.2. When the meter is inserted to a circuit for current or voltage measurement, the meter resistance is also inserted to the circuit, and it changes the circuit configuration or behavior.

4. Examples of meter effect

4.1. Ammeter Example: An Ammeter with 50mV@1mA movement, with full scale of 10 mA is used to measure the circuit below. (a) What is the current I without the Ammeter insertion, and (b) with the Ammeter insertion (i.e., the Ammeter reading)?



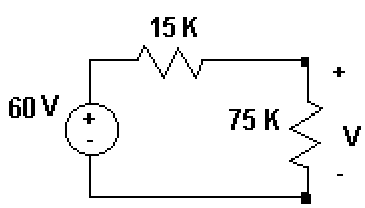


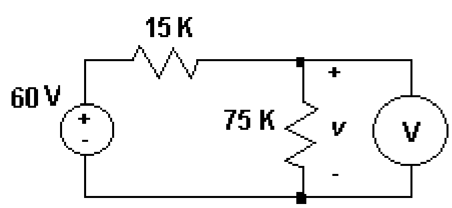
SOLUTION:

(a) i=1/100=0.01[A]=10[mA]

(b) Since the rated current and the full scale current are different, we know that there is a shunt resistor to divert the excessive current (i.e., 10 – 1 = 9 [mA]). Since the voltage across the movement must be 50mV (no matter what), then the total internal resistance of the meter (R_m + R_A)=50[mV]/10[mA]=5[Ω]. Therefore, the actual current (or the Ammeter reading) is $\frac{1}{100+5} = \frac{1}{105} = 9.52\,[\text{mA}]$

4.2. Voltmeter Example: A voltmeter with 50mV@1mA movement, with full scale of 150V is used to measure the circuit below. (a) What is the voltage V without the Voltmeter insertion, and (b) with the Voltmeter insertion (i.e., the Voltmeter reading)?





SOLUTION:

(a) By voltage division: $v = 60\frac{75}{75+15} = 50\,[\text{V}]$

(b) Since the rated voltage and the full scale voltage are different, we know that there is a series resistor to divert the excessive voltage (i.e., 150 – 0.05 = 149.95 [V]). Since the current through the movement must be 1mA (no matter what), then the total internal resistance of the meter is (R_m //R_V) or $\frac{150}{1\times10^{-3}} = 150\,[\text{k}\Omega]$ (guess where this comes from?).

Therefore, the effect of the voltmeter insertion is adding 150kΩ to the 75K resistor in parallel.

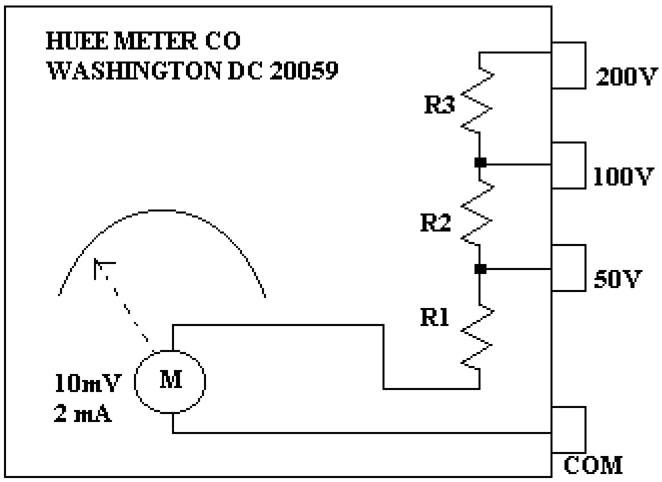
Then, the new resistance value is: $75//150 = \frac{(75)(150)}{75+150} = 50\,[\text{k}\Omega]$

Finally, the voltage by voltage-division is: $v = 60\frac{50}{15+50} = 46.15\,[\text{V}]$

III. Multi-Range Voltmeter Example

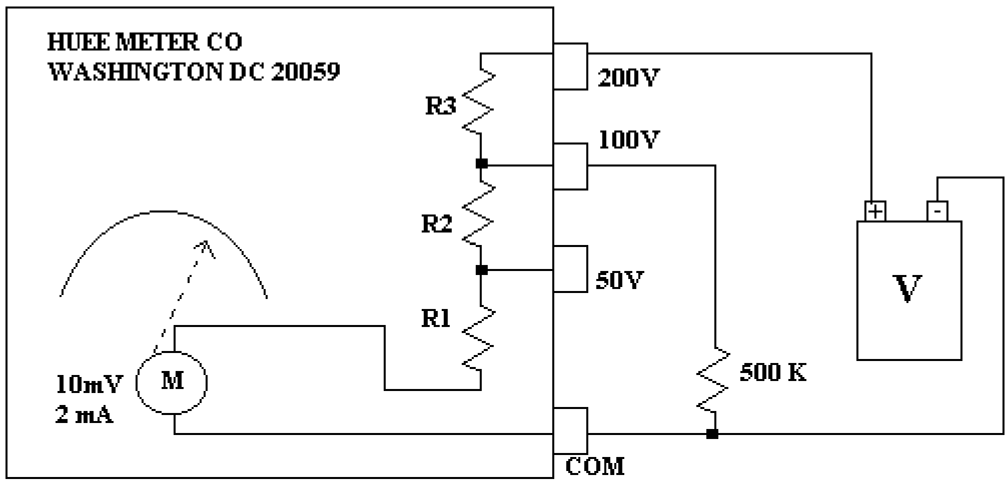
Problem Setting:

1. We are going to design a multi-range voltmeter (full scales of 200, 100, and 50 V) using a d'Arsonval-movement with rating 10mV@2 mA. **Find R_1, R_2, and R_3**



SOLUTION:

2. After finishing the design, a 500KΩ resistor is connected between the COM and the 100V terminals. Then, an unknown voltage source is connected to the COM and +200V terminals. **If the voltmeter reading is 188[V], what is the <u>exact voltage level</u> of the unknown voltage source?**



SOLUTION: