Construction of a Voltmeter and an Ammeter from a Galvanometer

Objective

Materials

1. 1-meter stick
2. Ammeter shunt wire
3. Banana-to-banana wires
4. Banana-to-spade wires
5. Decade resistor box (x2)
6. Fisher 1V/30V power supply (set to 30V)
7. Fluke digital multimeter
8. Galvanometer
9. Needle-nose pliers

Introduction

Most analog (not digital) electric meters make use of a galvanometer. A galvanometer is a device constructed such that deflection of a needle is proportional to current through a coil around the base of the needle. The resistance of a galvanometer is usually several ohms. Typically, a current of a fraction of one milliamp will cause full-scale deflection. The various electric meters use resistors in series or in parallel with the galvanometer. In order to choose a resistor for a specific purpose you need to know the resistance of the galvanometer and the current for full-scale deflection.

> **Caution**: *Before you use the decade box in the circuit, turn all the knobs on the decade box to their highest-value position. Always start decreasing the resistance from the highest-value knob, then next highest, and so on ...*

Procedure

Finding the Resistance of the Galvanometer

The circuit of Figure 1 may be used for determining the characteristics of the galvanometer. R_1 is a decade resistance box with a maximum resistance of, say, 10,000 ohms (Ω). With R_2 disconnected from the circuit, starting from very large R_1, decrease the value of R_1 until the

galvanometer reads full-scale; note the value of R_1. Insert R_2, another decade box, into the circuit as shown, and vary its value until the galvanometer reads one-half of the full-scale deflection. Now consider these facts: (a) as stated above, the deflection of the galvanometer needle is proportional to the current through the galvanometer, and (b) the needle is now deflected by half as much as it was without R_2. We can conclude that now half as much current is passing through the galvanomter. Therefore, the "other half" of the current must be passing through R_2. This means that the current passing through the galvanometer must be equal to the current passing through R_2. What does this mean about the resistance of the galvanometer, R_{GM}, compared to the resistance of R_2?
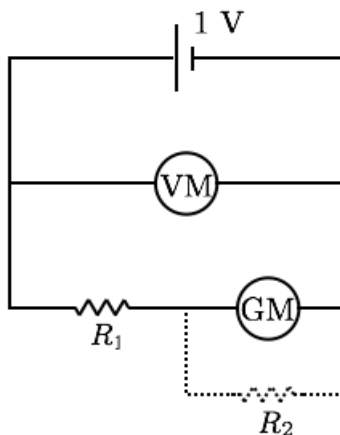

Figure 1

Now back to the circuit without R_2 present. Because the galvanometer is fully deflected, Ohm's law permits you to compute the current for full-scale deflection. Read the potential difference from the voltmeter. The resistance is the sum of R_1 and R_{GM}. Call the current associated with this full-scale deflection I_d, and note that

$$I_d = \frac{V}{R_1 + R_{GM}}$$

Voltmeter

Calculation of series resistance, R_S

A voltmeter consists of a resistor in series with the galvanometer. You will construct a voltmeter to read, say, 5 V full-scale. The problem is to compute the value of R_S needed with the particular galvanometer being used. You know the current for full-scale deflection of the galvanometer is I_d. Now we want the potential difference between points a and b equal to 5 V (see Figure 2). Ohm's law permits the computation of the total resistance between points a and b. From this it is easy to get R_S. From Ohm's law, $V = IR_{total}$, where

$R_{total} = R_S + R_{GM}$. And because R_S and R_{GM} are in series, $I_S = I_d$. Therefore,

$$
\begin{aligned}
I_d &= \frac{V}{R_S + R_{GM}} \\
R_S &= \frac{V}{I_{GM}} - R_{GM}
\end{aligned}
$$

Construction

Set up the circuit as shown in Figure 2. You can change the deflection by using the voltage knob on the power source. Check the potential difference for full deflection of the galvanometer. What value do you get? Is it what you expected? Check the potential difference for one-half of full deflection of the galvanometer. What value do you get? Is it what you expected?
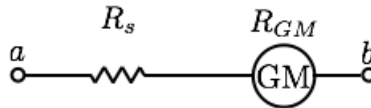

Figure 2

Ammeter

> *You will NOT use the decade boxes for the Ammeter portion of this lab. Please disconnect all wires from them, and place them on the corner of your desk.*

Calculation of parallel resistance R_P

We can make an ammeter using a resistor in parallel with a galvanometer as shown in Figure 3. You will construct an ammeter to read, say, 5 amps full-scale; so it is necessary to compute the value of R_P needed for this particular calibration. Because R_{GM} and R_P are in parallel, their potentials must be equal. The potential V_d for full-scale deflection can be computed from Ohm's law (R_{GM} and I_d are known). Since the desired current through R_P can quickly be determined (5 amps minus I_d), the value of R_P can now be computed from Ohm's law.

$$
\begin{aligned}
V_d &= V_P \\
I_{GM}R_{GM} &= (I - I_{GM})R_P \\
R_P &= \frac{V_d}{I - I_{GM}}
\end{aligned}
$$

What value of R_P do you get? This value of R_P is so small that a decade box is NOT suitable. Instead you will be using wire. The wire you will be using has an empirically determined resistivity of approximately $1.74 \times 10^{-6} \ \Omega \cdot \text{cm}$.
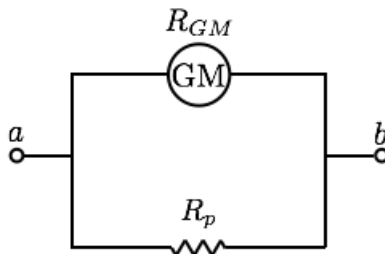
Figure 3

Calculate the required length of wire by using the relation

$$R_P = \frac{\rho \cdot L}{A}$$

where

R_P is the resistance you have calculated
ρ is the resistivity of the material
L is the required length of wire
A is the cross-sectional area of the wire (see Table 1).

B & S Gauge	Cross-sectional Area, A (cm^2)
18	0.0081713
20	0.0051912
22	0.0032472
24	0.0020508
26	0.0012819
28	0.0008042

Table 1

Construction

Now set up the circuit as shown in Figure 3. What is the reading of the current from the power supply for full deflection of the galvanometer? What was your expectation? What is the reading of the current from the power supply for one half of full-scale deflection? What was your expectation?

Hypothetically, if you want your ammeter to read 2.5 A at full deflection, what should be the value of R_P? Check your constructed ammeter against the ammeter in the power supply. Both should read the same value.