Name:	ID:	Date:

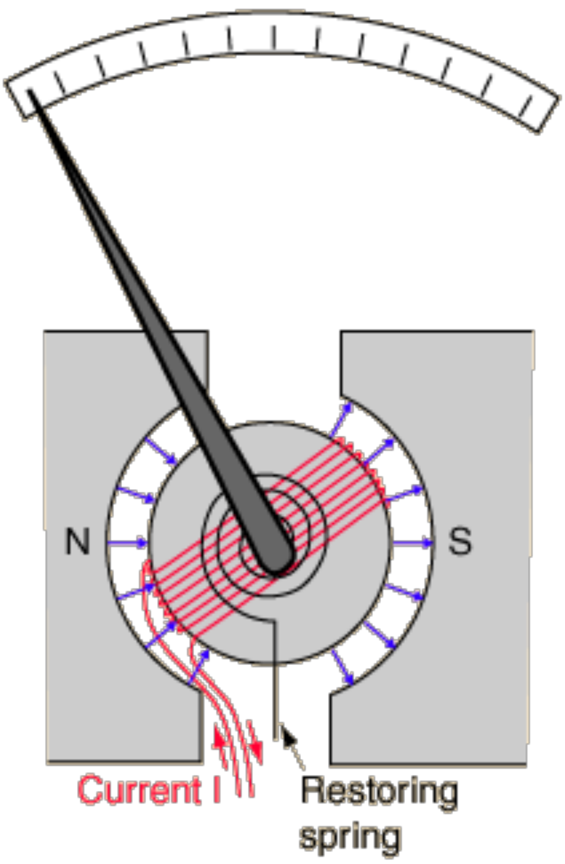
Constructing an Ammeter and a Voltmeter Using a Movement	**EM-3**

PURPOSE

In this experiment you will study and investigate the internal structure of electric meters. You will construct an ammeter and a voltmeter using a movement (moving coil meter, or galvanometer).

GENERAL INFORMATION AND FRACTIONAL DEFLECTION METHOD

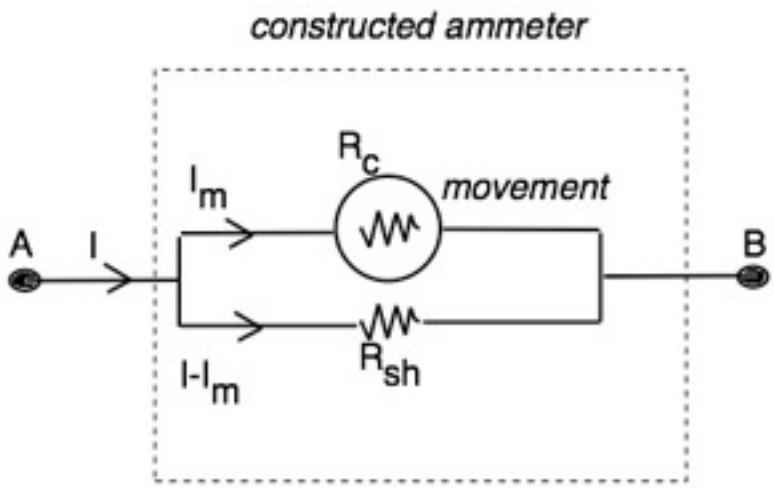
A movementi (also called a moving coil meter or a D'Arsonal galvanometer) is an electric meter that makes use of the torque that a permanent magnetic field exerts on its current carrying wire to measure the current passing through it (see figure below the paragraph). Two large magnets produce a magnetic field that produces a force exerting a torque on the coil that carries the current to be measured. The movement also contains a restoring coil spring that produces a counter torque againts that produced by the magnets. Therefore, the coil rotates until the torque produced by the restoring coil spring balances this torque. Thus, the rotation of the coil is a measure of the current I. The magnitude of rotation is shown by a pointer needle which moves along a calibrated scale that displays the magnitude of the current passing. The movement measures currents up to a maximum value of a few milliamperes and as the value of the current flowing inthe circuit exceeds this value, the pointer needle goes outside the scale and no reading of the current can be obtained.



Name:	ID:	Date:

However, one can make use of a movement for measuring various quantities in an electrical circuit, by also making use of the basic principles of electrical circuits. In this experiment, you will use the movement to 1) measure currents that are orders of magnitude higher than the maximum current that can pass through the coil itself, and 2) to construct a voltmeter. For this purpose, certaing characteristics of a movement and the fractional deflection method should be understood.

There are two parameters that characterize a movement: the maximum deflection current I_c, i.e. the current (thorugh the coil, not the whole circuit) that produces a full-scale deflection, and the internal resistance of the coil R_c. An ammeter is constructed by connecting a **shunt resistance** R_{sh} in parallel to the movement, and the whole set up, that is, the movement and the shunt resistance constitute the **constructed ammeter** (see figure below).



In the figure, I is the current that is to be measured, I_m is the current passing through the movement, so the current passing through R_{sh} is $I-I_m$. Since the movement and the shunt resistance are connected in parallel, the potential difference on each of them is the same and is equal to the potential difference between points A and B. That gives:

$$I_m R_c = (I - I_m) R_{sh};$$

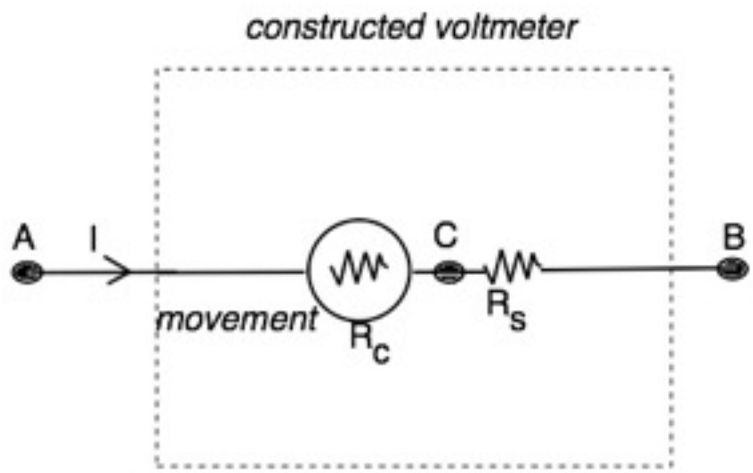
so we observe that $I-I_m$ and I_m are directly proportional. For example, assume that we want to measure I_m in units of I_c. When $I_m=I_c/2$, say, the current I passing between A and B is I_2, and when $I_m=I_c/4$, say, the current I passing between A and B is I_4. Direct proportionality of $I-I_m$ and I_m implies $I_4=I_2/2$. Similarly, then, the maximum current that this constructed ammeter can measure, denoted I_{max}, corresponds to the current passing through the movement be equal to the maximum deflection current, that is, $I_m=I_c$. So, using this fact, when we choose to construct an ammeter that measures up to a desired maximum current, we can calculate the required value for the shunt resistance as follows:

$$I_c R_c = (I_{max} - I_c) R_{sh} \to R_{sh} = \frac{I_c}{I_{max} - I_c} \times R_c.$$

Name:	ID:	Date:

For example, if we want to construct an ammeter that measures up to 2 A, and if we have a movement having I_c=10 mA and R_c=50 Ω, we need to use a shunt resistance of R_{sh}=0.25 Ω by the above equation. Notice that R_{sh} is much smaller than R_c, so most of the current that is to be measured flows through R_{sh} and the set up allows us to measure currents much larger than I_c.

The movement, as stated before, can also be used for constructing a voltmeter. For this purpose, we connect a resistor, denoted by R_s, in series to the movement, as shown:



Here, the same current I passes through both the movement and the additional resistance. However, if R_s is much larger than R_c, than the potential difference between points A and C will be much larger than the potential difference between C and B. Since:

$$V_B - V_A \equiv V_{BA} = I(R_c + R_s)$$

knowing the value of R_s and the value of the current I allows determining V_{BA}, because V_{BA} and I are directly proportional, as seen. As before, we choose some maximum voltage V_{max} which can be measured by the set up, and determine the required value of R_s. That is:

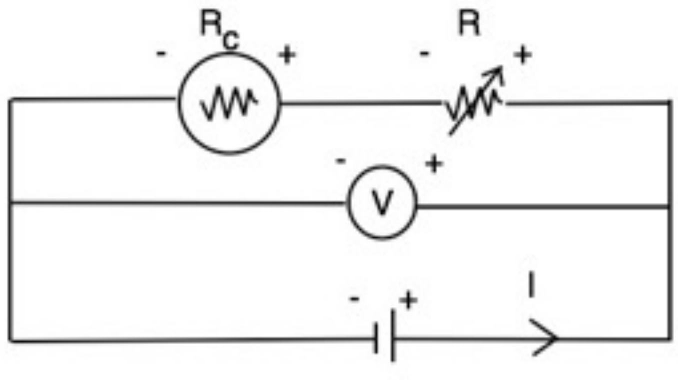
$$V_{max} = I_c(R_c + R_s) \rightarrow R_s = \frac{V_{max}}{I_c} - R_c.$$

For example, if we want to measure voltage values up to 10 V, and if we have a movement having I_c=10 mA and R_c=50 Ω, we need to use an additional resistance R_s=950 Ω by the above equation. So, for instance, when the pointer needle of the galvanometer shows half of the full scale deflection, that is, the current passing through the constructed voltmeter is $I=I_c/2$, we understand that V_{BA}=5 V.

Name:	ID:	Date:

In this experiment, you are going to find the values of R_c and I_c of a movement, then use this movement to construct a 6.0 A ammeter and a 2.5 V voltmeter. For this purpose, you are going to use the fractional deflection method, which is decribed below.

To find R_c and I_c of the movement given to you, firstly the following circuit is going to be constructed (circuit A):



The resistor drawn with an arrow on it is called a rheostat, and has a variable resistance R, so the current I flowing in the circuit can be adjusted as desired. Assume that we adjust the output voltage of the power supply to some value V_1 and adjust the value of R so that the movement exhibits maximum deflection, meaning that $I=I_c$. We call the corresponding value of the resistance R_1. We record the values V_1 and R_1. Then we adjust the output voltage of the power supply to another value and denote this as V_2. We then adjust the resistance so that the movement exhibits half maximum deflection, meaning that $I=I_c/2$, and denote the corresponding value of the resistance as R_2. Kirchoff's laws give the following equations for I_c, R_c, R_1, R_2, V_1 and V_2:

$$R_c = \frac{2V_2R_1 - V_1R_2}{V_1 - 2V_2}; \; I_c = \frac{V_1 - 2V_2}{R_1 - R_2}.$$

Following the procedure given below in Part A and using the above equations you will calculate I_c and R_c.

EQUIPMENT

A DC power supply, a meter movement, a rheostat, a commercial ammeter, a commercial voltmeter, a Ni-Cr resistance wire, a ruler.

PROCEDURE

PART A: DETERMINATION OF I_c AND R_c

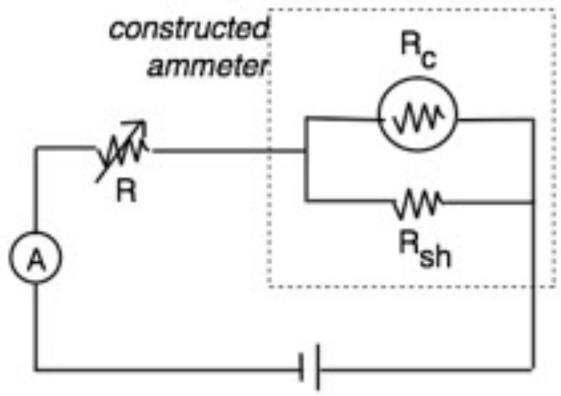
Using the fractional deflection method, determine I_c and R_c of the movement. First, construct circuit A described in the above pages. Record your data and results in Table 1 below in the "Data and Results" section. Choose your voltage values between 1 - 5 V.

Name:	ID:	Date:

PART B: CONSTRUCTING AN AMMETER

In this part, you are going to construct an ammeter which measures currents up to 6.0 A. You are going to use the movement whose values of I_c and R_c have been calculated in Part A. The Ni-Cr wire to be used as shunt resistance has a known resistance per unit length, and this will be provided to you during the experiment. Using this value, calculate the required value of the shunt resistance, and record this in the space provided. Using this value, calculate the required length of the Ni-Cr wire to be used. **Do not** cut the wire; you will be provided crocodile cables so that you can adjust the required length.

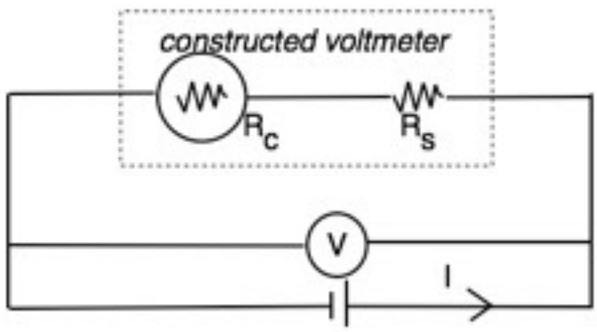
Now construct the following circuit (circuit B):



To check your constructed ammeter, you are going to measure the same current using two ammeters, the constructed ammeter and the commercial ammeter. Adjust the rheostat so that you measure some current (up to your choice) lower than the maximum current that can ben measured with the constructed ammeter, that is, lower than 6.0 A. Record your readings from the constructed and commercial ammeters in Table 2 given below in the "Data and Results" section.

PART C: CONSTRUCTING A VOLTMETER

In this part, you are going to contruct a voltmeter which can measure voltages up to 2.5 V. For this purpose, calculate the required value of R_s and record this value in the space given. You will use the rheostat as the additional resistor here, and adjust the relevant value of R_s on the rheostat. You will use the following circuit (circuit C):



Name:	ID:	Date:

Set the power supply to a voltage lower than 2.5 V, and connect the commercial voltmeter and the constructed voltmeter parallel to it. This way you can construct circuit C. Measure the output voltage both by the commercial and the constructed voltmeters, and record your readings in Table 3 given below in the “Data and Results” section.

Report all of your results with the correct number of significant figures.

DATA AND RESULTS:

PART A: DETERMINATION OF I_c AND R_c

Table 1

	V_1 (V)	R_1 (Ω)	V_2 (V)	R_2 (Ω)
DATA				
RESULTS	I_c=	A	R_c=	Ω

Show your calculations here.

………
………

PART B: CONSTRUCTING AN AMMETER

Required value of shunt resistance: R_{sh}=……………………… Ω
Length of Ni-Cr wire=……………………… cm
Show your calculations here.

………
………

Current readings: Table 2

	Constructed Ammeter	Standard Ammeter
I (A)		

PART C: CONSTRUCTING A VOLTMETER

Required resistance of the additional resistor: R_s=……………………… Ω
Show your calculations here.

………
………

Voltage readings: Table 3

	Constructed Voltmeter	Standard Voltmeter
V (V)		