The Electromotive Force and Internal Resistance of a Battery

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Abstract/Procedure/Conclusion

In this lab, we measured the electromotive force, $\mathcal{E}$, and internal resistance, r of a battery using resistors in a circuit with the battery and an ammeter. We used a circuit with resistors in series and a circuit with resistors in parallel. When measuring using the series circuit, $\mathcal{E}$ was (1.544 ± 0.023) V and r was (8.54 ± 0.29) Ω. When measuring using the parallel circuit, $\mathcal{E}$ was (0.9238 ± 0.0045) V and r was (1.21 ± 0.020) Ω. The values for $\mathcal{E}$ and r in each circuit were very different, likely because the battery's internal resistance depends on the current flowing through it.

To calculate these values, we use Ohm's law, Kirchhoff's loop law, and Kirchhoff's junction law. Ohm's law is

$$V = IR$$

where V is the voltage drop over a resistor, I is the current through the resistor, and R is the resistance of the resistor. Kirchhoff's loop law says that the voltage drop around any loop in the circuit is zero in total. Kirchhoff's junction law says that the total current entering a junction is equal to the total current exiting the junction.

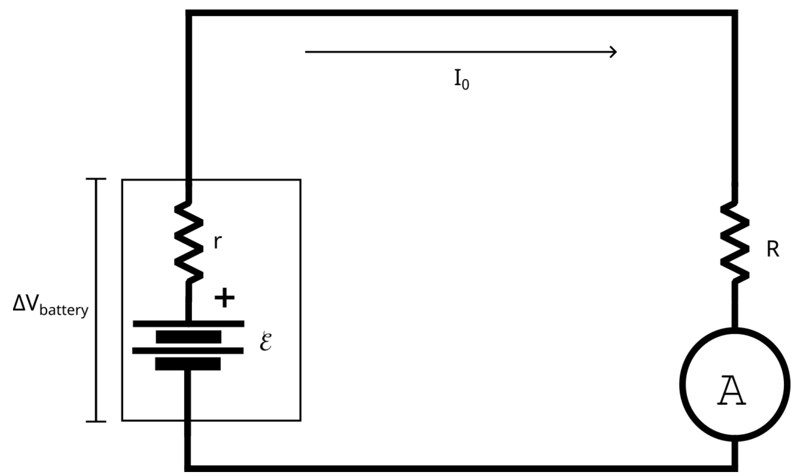

Figure 1: Initial circuit

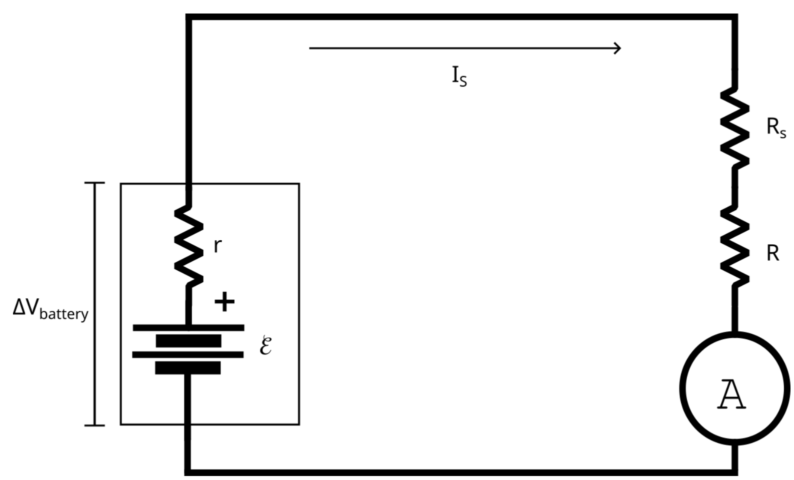

Figure 2: Resistors in series

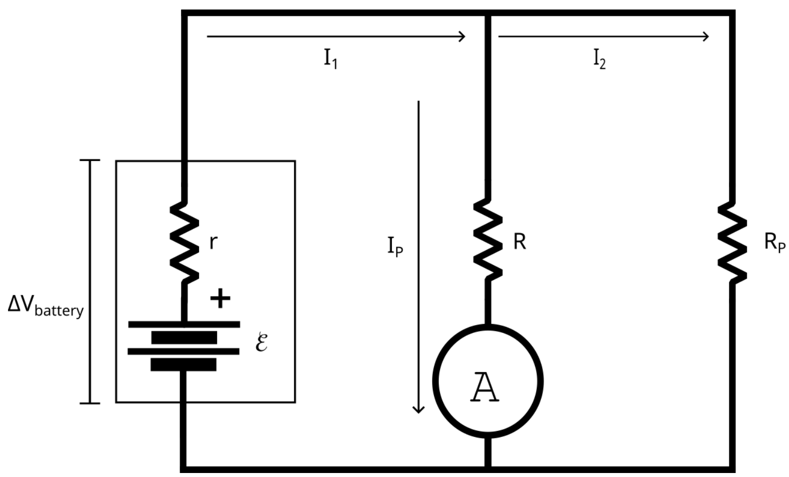

Figure 3: Resistors in parallel

Data

	A	B	C	D	E	F	G	H	I	J	K	L
1	Series											
2	Delta V Batter	I0	R	Rs	Is	EMF1	r1				sigmaI	sigmaR
3	1.493	0.0828	10.1	3.6	0.0694	1.543787	8.544776				0.00005	0.05
4	Parallel											
5	Delta V Batter	I0	R	Rp	Ip	EMF2	r2					
6	1.412	0.0817	10.1	19.9	0.0775	0.923812	1.207372					
7												
8												
9												
10												
11		EMF1_I0	EMF1_Is	EMF1_R	Sigma EMF1							
12		1.538977	1.550686	1.565229	0.02303179							
13					Sigma r1							
14	8.628089888	8.475465	8.803731	8.494776	0.28513693							
15					Sigma EMF2							
16	0.925694999	0.924408	0.927839	0.92409	0.00449369							
17					Sigma r2							
18	1.223486232	1.21913	1.206661	1.210769	0.02024789							
19												

Calculations

$$
\begin{array}{ll}
(1) & \mathcal{E} - I_0 r - I_0 R = 0 \\
(2) & \mathcal{E} - I_s r - I_s R - I_s R_s = 0 \\
(2) - (1) & -I_s r + I_0 r + I_0 R - I_s R - I_s R_s = 0 \\
 & r(I_s + I_0) = I_s(R_s + R) - I_0 R
\end{array}
$$

$$r = \frac{I_s(R_s + R) - I_0 R}{I_s + I_0}$$
$$r = \frac{\mathcal{E} - I_0 R}{I_0}$$
$$\mathcal{E} - I_s \frac{\mathcal{E} - I_0 R}{I_0} - I_s R - I_s R_s = 0$$
$$\mathcal{E}(1 - \frac{I_s}{I_0}) = I_s R_s$$
$$\mathcal{E} = \frac{I_s R_s}{1 - \frac{I_s}{I_0}}$$
$$\mathcal{E} = \frac{I_0 I_s R_s}{I_0 - I_s}$$