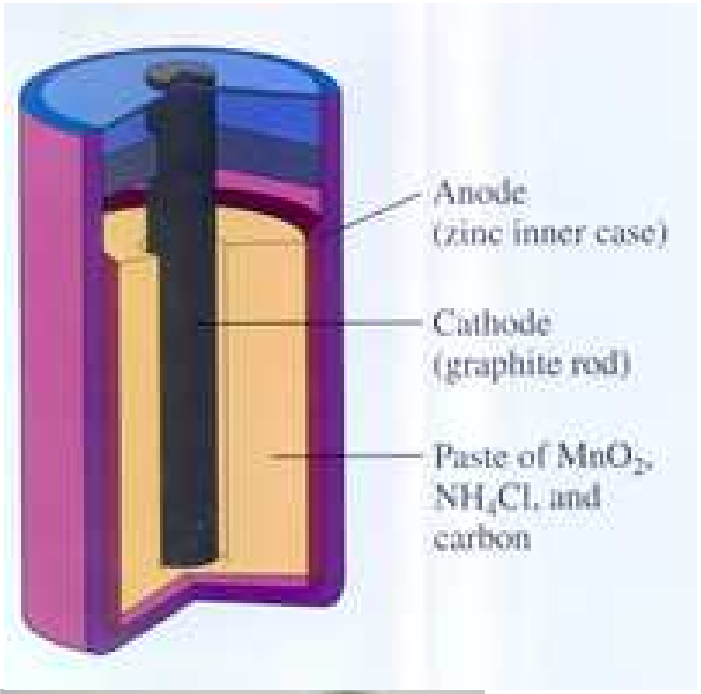
Chemical cell and batteries

An electrochemical cell is a device that generates **electrical energy from a chemical (redox) reaction**. The essential components of an electrochemical cell are an electrolyte and two electrodes of unlike materials, one of which reacts with the electrolyte



There are two types of chemical cells called **primary** (or voltaic) cells and **secondary** (or storage, rechargeable) cells.

Normal/primary cells

Rechargeable/storage cells

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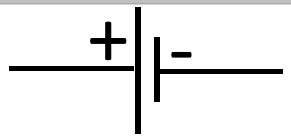
The symbol for a cell is: 

When an external resistance (load) is connected across the terminals, charge flows through the complete circuit **including the cell.** Experimentally, it was discovered that the charge experiences some resistance within the battery i.e. **internal resistance**.

Electromotive force

The electromotive force (EMF) $\mathcal{E}$ of a cell may be defined as the **energy** it will supply **per unit charge** to drive charge round a complete circuit.

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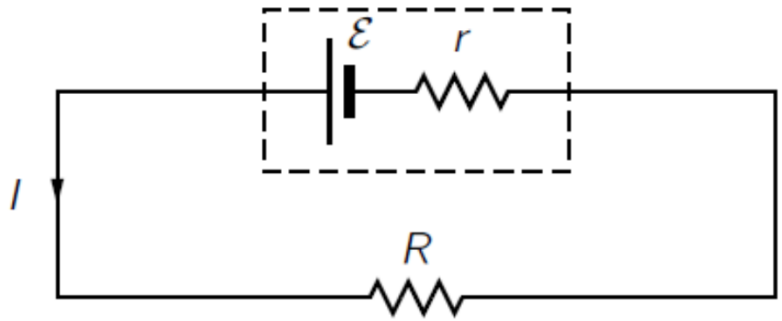
In the circuit depicted in the diagram below, a cell of $\mathcal{E}$ having internal resistance r is connected to a load resistance R. Suppose the cell drives a charge Q around the circuit in time t.



$$W = qV = I^2Rt$$

$$\left(\begin{array}{c}\text{Total energy}\\ \text{supplied}\end{array}\right) = \left(\begin{array}{c}\text{energy to drive}\\ Q \text{ through the}\\ \text{load resistance } R\end{array}\right) + \left(\begin{array}{c}\text{energy to drive}\\ Q \text{ through the}\\ \text{internal resistance } r\end{array}\right)$$

$$\mathcal{E}Q = I^2Rt + I^2rt$$

$$\therefore \quad \mathcal{E}Q = QIR + QIr$$

$$\text{or} \quad \mathcal{E} = V + Ir$$

Hence the potential difference V measured across a cell connected in a circuit is given by

$$V = \mathcal{E} - Ir. \qquad (21)$$

Ir is normally referred to as ‘a lost volt’

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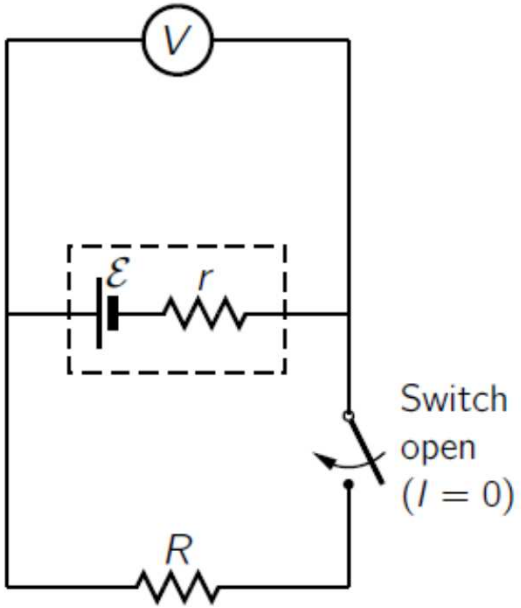
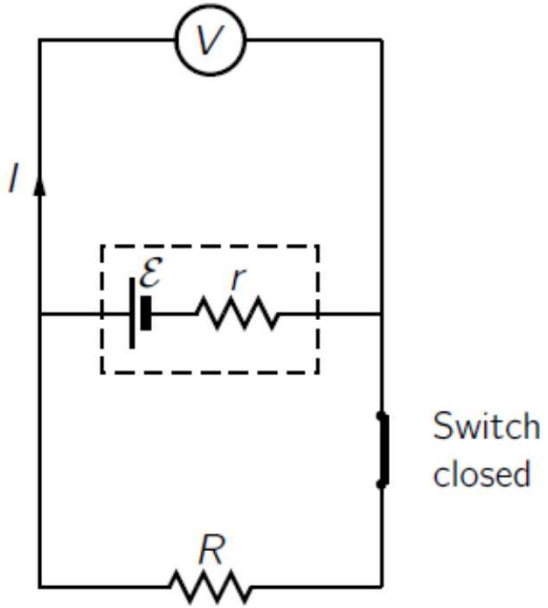
The potential difference Ir is commonly referred to as the "lost volts". Note that:

(a) If $I = 0$ then $V = \mathcal{E}$
(b) If $I > 0$ then $V < \mathcal{E}$

} See the diagrams below.



Voltmeter reads $\mathcal{E}$



Voltmeter reads less than $\mathcal{E}$

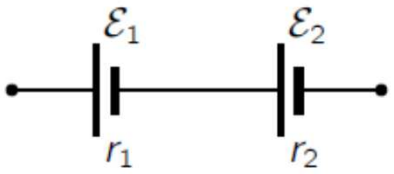
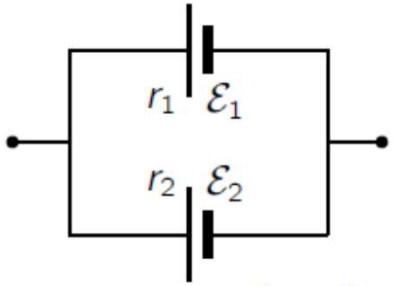
Chemical cell and batteries

Example 2.5: Terminal voltage of a battery under load

A battery has an emf of 12.0 V and an internal resistance of 0.15 Ω. What is the terminal voltage when the battery is connected to a 1.50 Ω resistor?

Batteries

Groups of cells can be connected together in different ways to form a battery. A car battery, for instance, consists of several cells connected in series. The table below summarizes two common ways in which cells can be combined. In these diagrams, r represents the internal resistance of the cell.

Cells in series	Cells in parallel
	
effective $r = r_1 + r_2$ effective $\mathcal{E} = \mathcal{E}_1 + \mathcal{E}_2$	effective r given by $\frac{1}{r} = \frac{1}{r_1} + \frac{1}{r_2}$ effective $\mathcal{E}$: (a) when $\mathcal{E}_1 = \mathcal{E}_2$ then $\mathcal{E} = \mathcal{E}_1$ (b) when $\mathcal{E}_1 \neq \mathcal{E}_2$ we don't consider in this course.
Increase voltage, current	Increase lifetime, Ampere-hour rating.

Ampere-hour rating

Ampere-hour rating indicates the amount of current a battery would supply while maintaining the same voltage indicated on it. For example, a 12 V car battery rated at 40 ampere-hour (40 A h) means that this battery can deliver 40 A for 1 hour whilst maintaining a potential difference of 12 V across its terminals.

ampere-hour rating = number of amps delivered × time in hours.

Example 2.6: Amp-hour rating of a battery

A 40 A h car battery supplies 800mA at 12 V.

a) What is the total energy available.

b) How long will it last?