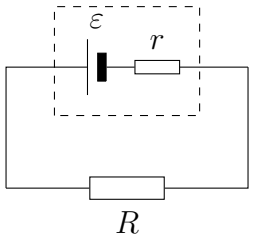
# On internal resistance

A.C. Norman
ACN.Norman@radley.org.uk

## Warm-up problems

1. Explain how the formula
$$\varepsilon = IR + Ir$$
is arrived at, including what the various terms mean. It can sometimes be written as $V = \varepsilon - Ir$. What does the $V$ represent, and what is the combination $Ir$?

2. Explain the following diagram. What does the dashed box represent, and where might you place a voltmeter to measure the *terminal p.d.*?




3. Each of the cells shown below has e.m.f. 1.5 V and internal resistance 0.3 Ω. What is the e.m.f. and internal resistance of the battery combination in each case?


## Regular problems

4. (a) Does the internal resistance of a battery increase or decrease its terminal voltage when it supplies current? Justify your answer.
   (b) What non-physical (silly) results might a too-simplistic model of a battery, which does not account for the effects of internal resistance, lead to?

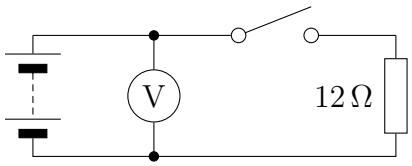
5. A high resistance voltmeter reads 3 V when connected across the terminals of a battery on an open circuit (no other components are connected) and 2.6 V when the battery sends a current of 0.2 A through a lamp. What is
   (a) the e.m.f. of the battery,
   (b) the terminal p.d. of the battery when supplying 0.2 A,

(c) the 'lost volts',

(d) the internal resistance of the battery,

(e) the resistance of the lamp?

6. In the following circuit, the voltmeter has a very high resistance. It reads 6 V when the switch is open and 4.8 V when it is closed. What is the e.m.f. and internal resistance of the battery?




7. (WJEC PH1 June 2013 Q3) A student carries out an experiment to determine the emf and internal resistance of a cell. The pd across the cell is measured when it is supplying various currents. The following readings are obtained.

| current / A | 0.20 | 0.42 | 0.66 | 0.96 | 1.20 |
|---|---|---|---|---|---|
| p.d. / V | 1.31 | 1.13 | 0.93 | 0.68 | 0.48 |

(a) Plot these results on the grid (p.d. on the $y$-axis and current on the $x$-axis) and draw a line through your points.

(b) Use your graph to determine

i. the e.m.f. of the cell,

ii. the internal resistance of the cell.

(c) The cell is then connected to a torch bulb of resistance 6.0 Ω for 20 minutes. Calculate the charge that flows through the bulb in this time. Assume the emf remains constant.

8. (WJEC PH1 June 2014 Q3) A torch battery converts 6480 J of chemical energy into electrical energy while supplying a current of 0.15 A for 2 hours. In this time only 5932 J of this energy is supplied to the bulb. Calculate

(a) the charge that flows,

(b) the e.m.f. of the battery,

(c) the potential difference across the bulb,

(d) the battery's internal resistance.

# Extension problems

9. Prove the *maximum power theorem*, that the maximum power drawn from a battery of e.m.f. $\varepsilon$ and internal resistance $r$ occurs when the circuit resistance $R = r$. What fraction of the energy supplied by the chemical energy of the battery is transferred to the circuit in this case?