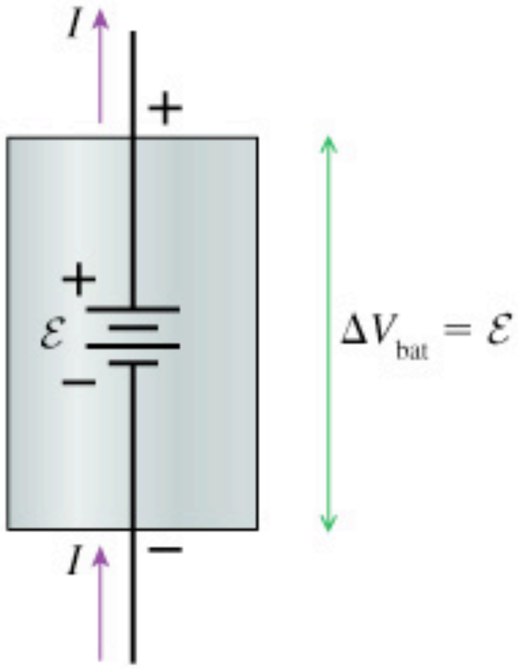
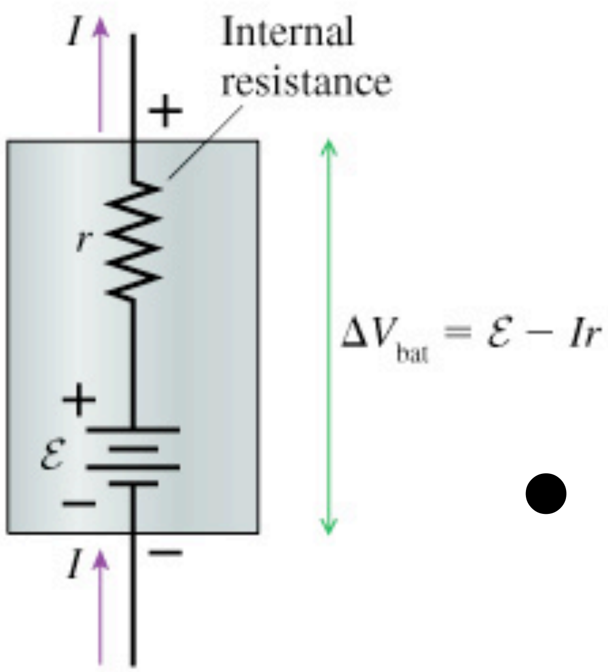
Lecture 38

- Real batteries
- Resistors in Parallel
- Example of Resistor Circuits
- Grounding

Real Batteries



Ideal battery



Real battery

- terminal (user) voltage

$$\Delta V_{bat} = E - I r$$

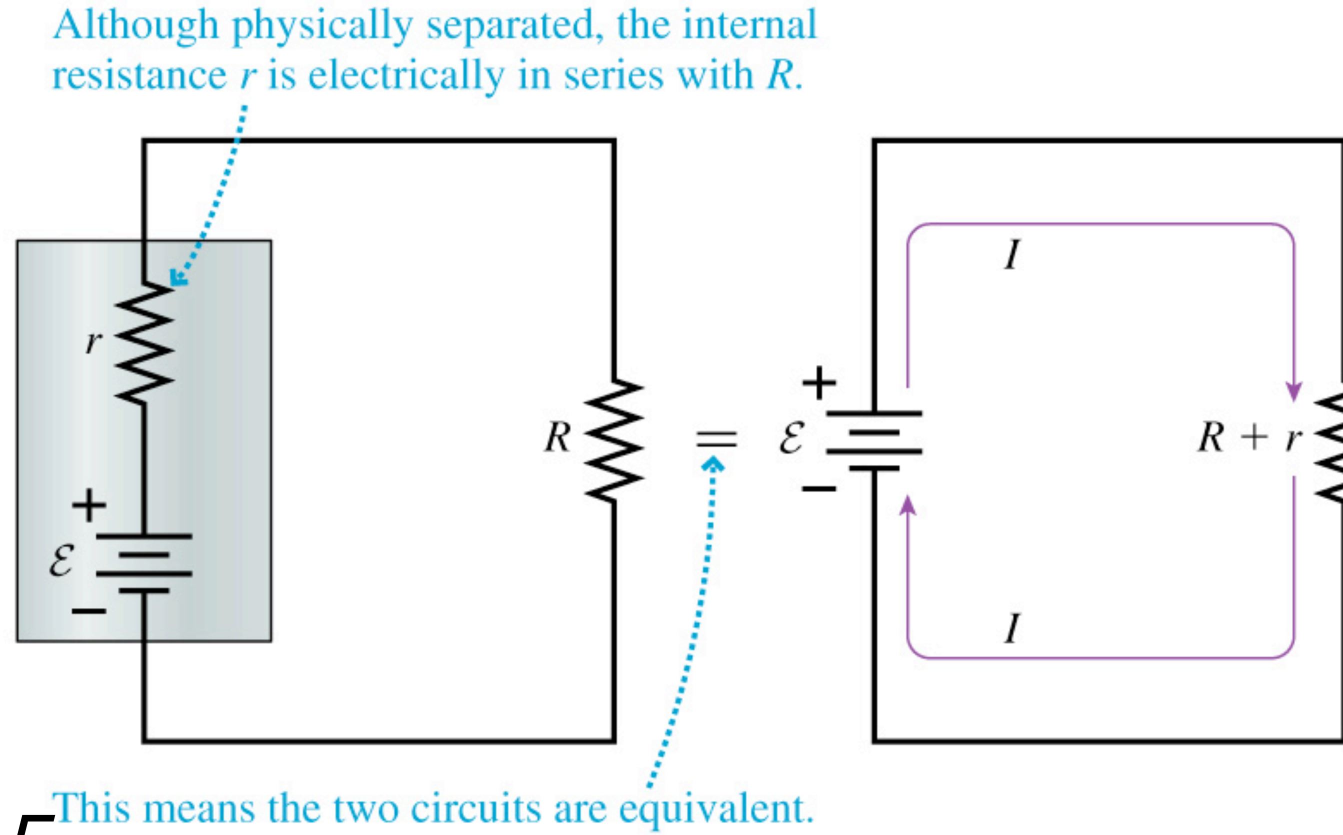
- for resistor connected:

$$I = \frac{E}{R_{eq}} = \frac{E}{R + r}$$

$$\Delta V_R = I R = \frac{R}{R + r} E$$

$$\Delta V_{bat} = E - I r;$$

$$\Delta V_R = \Delta V_{bat} == E$$



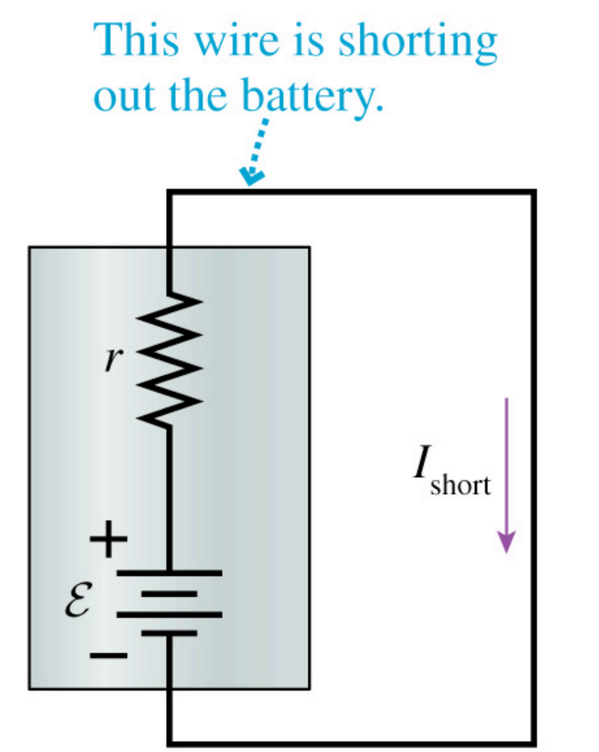
Short Circuit

- replace high by zero resistance →

$$I_{short} = \frac{E}{r}$$

$(\infty$ for ideal, $r = 0)$

- maximum possible current battery can produce



Parallel Resistors

- potential differences same:

$$\Delta V_1 = \Delta V_2 == V_{cd}$$

- Kirchhoff's junction law: $I = I_1 + I_2$
- Ohm's law:

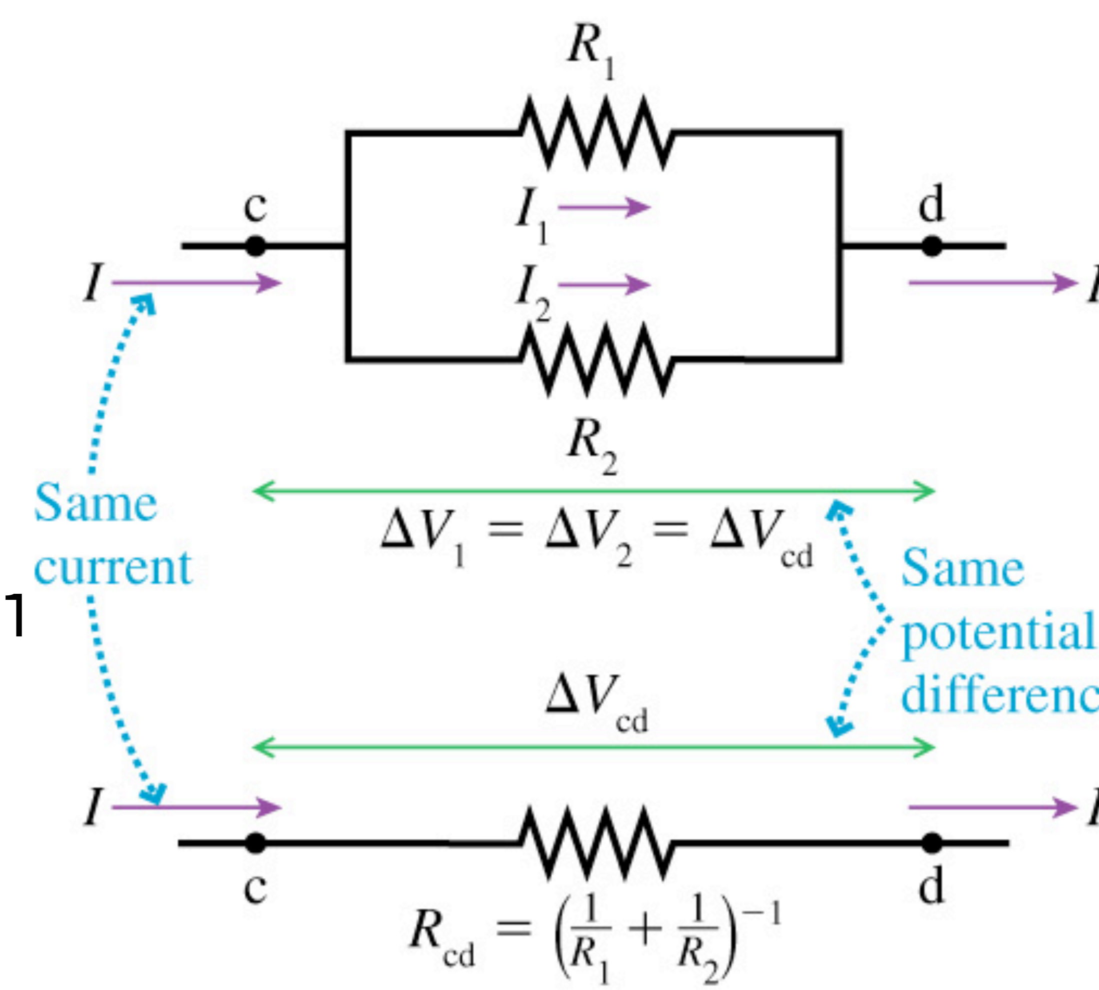
$$I = \frac{\Delta V_1}{R_1} + \frac{\Delta V_2}{R_2} = \Delta V_{cd} \; \frac{1}{R_1} + \frac{1}{R_2}^{\;-1}$$

- Replace by equivalent resistance:

$$R_{cd} = \frac{\Delta V_{cd}}{I} = \; \frac{1}{R_1} + \frac{1}{R_2}^{\;-1}$$

$$R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N}\right)^{-1} \qquad \text{(parallel resistors)}$$

(a) Two resistors in parallel



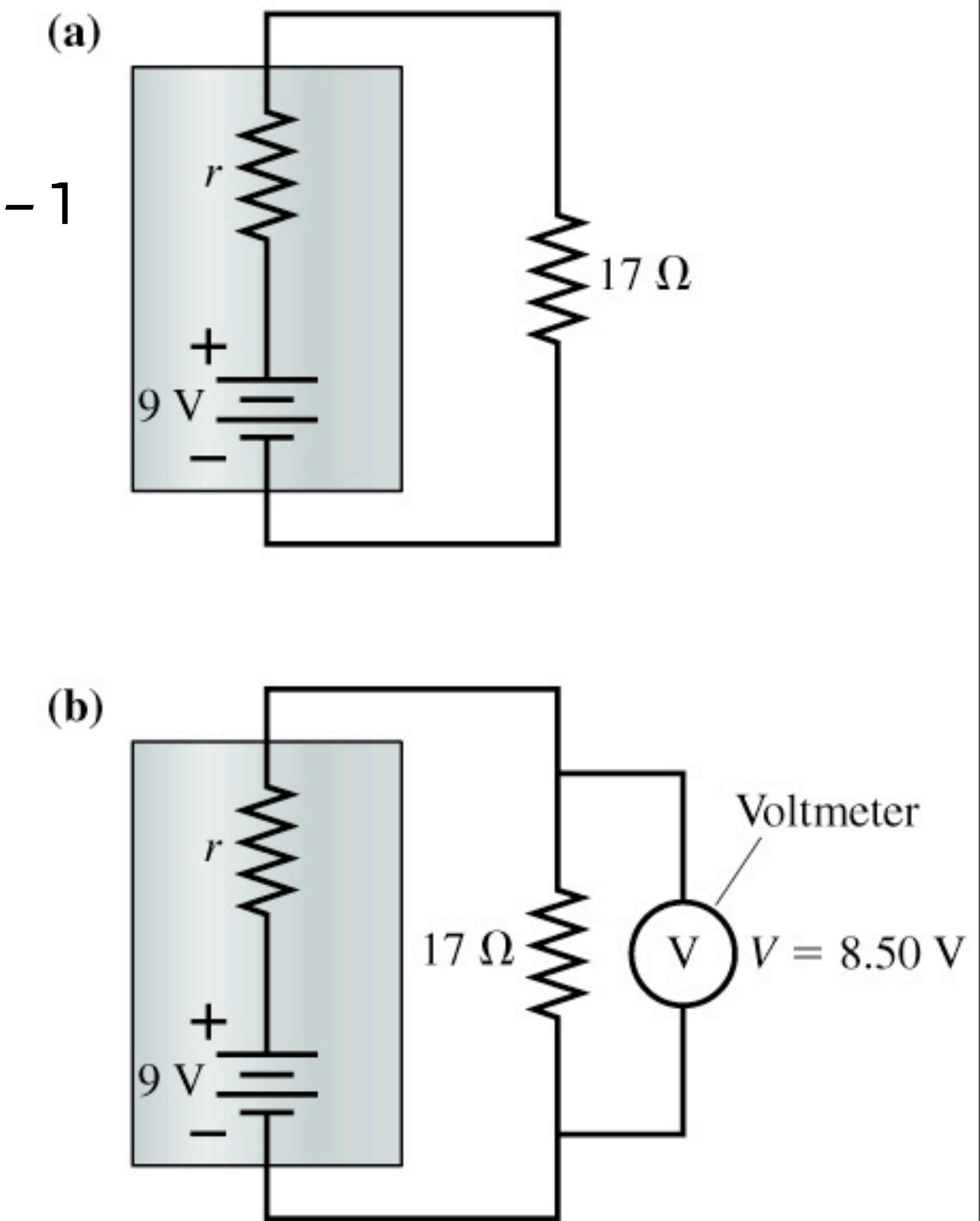
(b) An equivalent resistor

- Identical resistors($R_1 = R_2$): $R_{series\ eq} = 2R$; $R_{parallel\ eq} = \frac{R}{2}$
- In general, $R_{eq} < R_1$ or R_2...in parallel

Voltmeters

- measure potential difference across circuit element (place in parallel; don't need to break connections, unlike for ammeter)
- total resistance: $R_{eq} = \left(\frac{1}{R} + \frac{1}{R_{voltmeter}} \right)^{-1}$
- in order not to change voltage:

  $R_{voltmeter} \quad R$ (ideally, ∞)

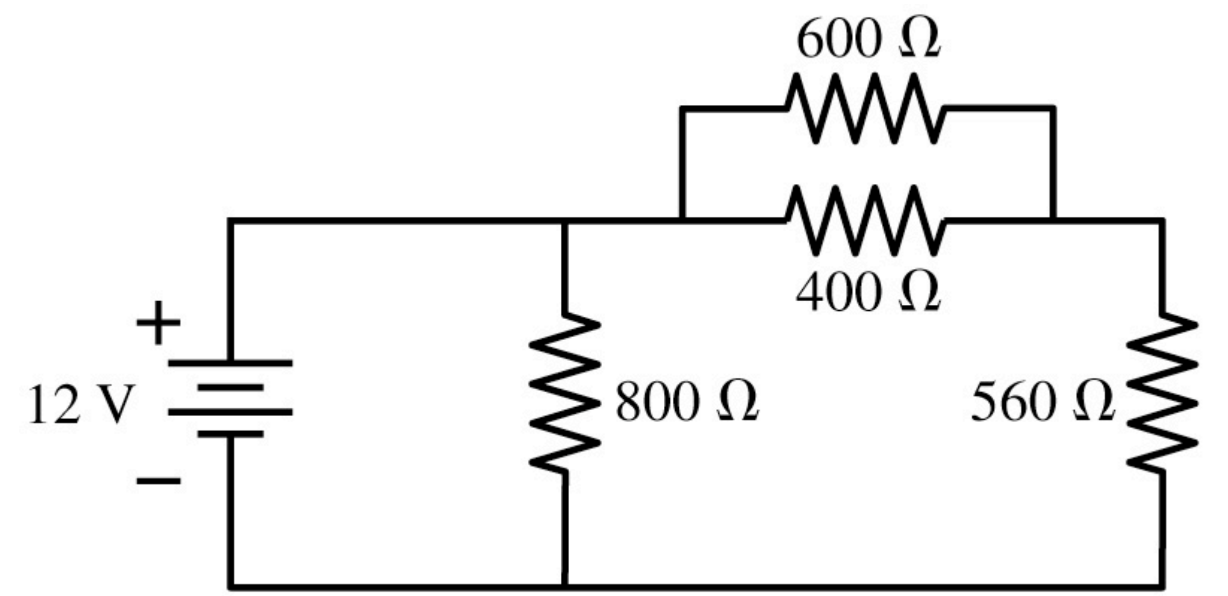


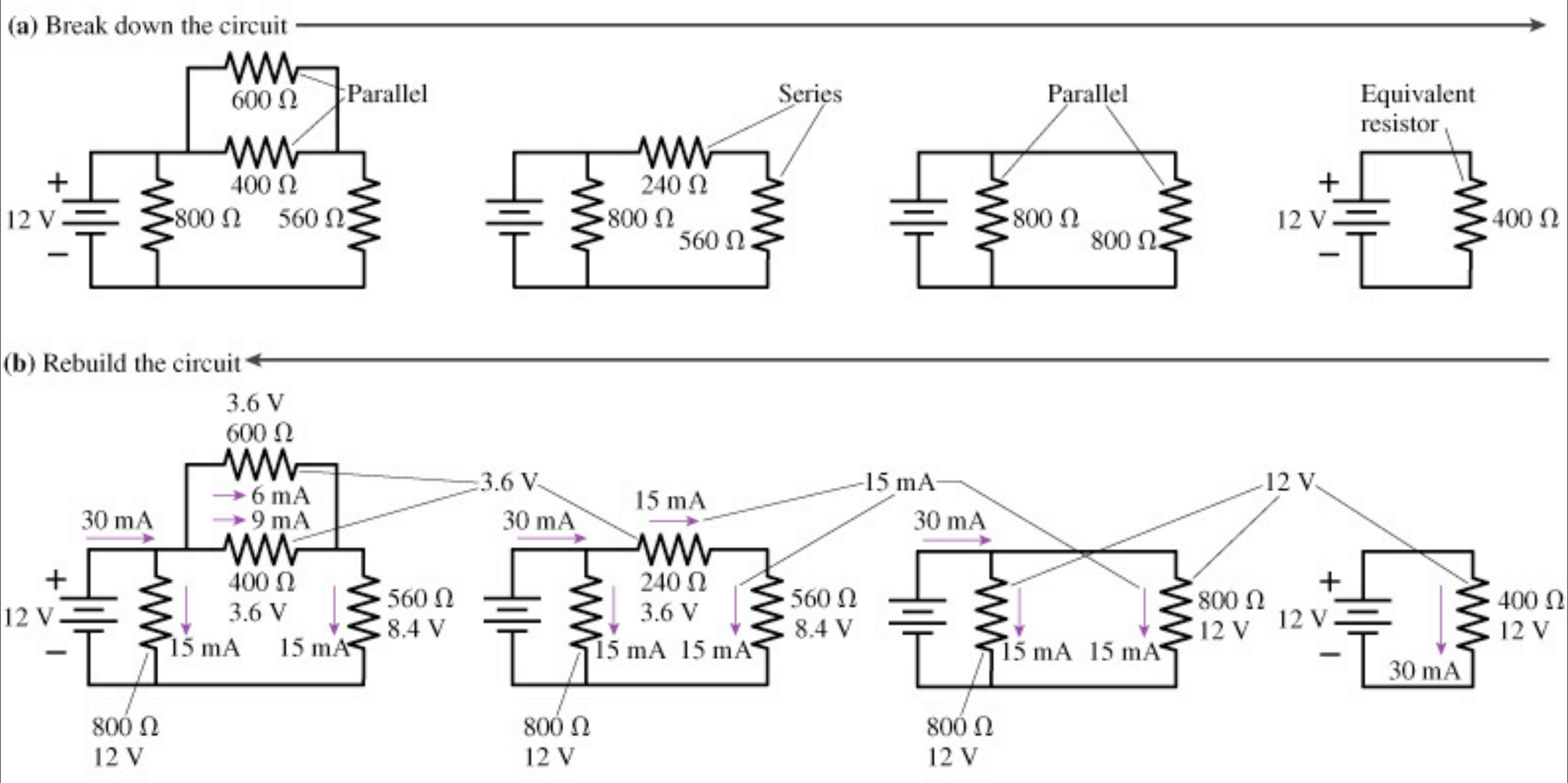
Strategy for Resistor Circuits

- assume ideal wires, batteries
- use Kirchhoff's laws and rules for series and parallel resistors
- reduce to equivalent resistor (basic circuit)
- rebuild using current same for series and potential difference same for parallel

Example of Resistor Circuit

- Find I and ΔV for each resistor





Grounding

- so far, potential difference, ΔV (physically meaningful), enters Ohm's law (no need to establish zero point)
- need common reference point for connecting 2 circuits
- grounding: connect 1 point in circuit to earth ($V_{earth} = 0$) by ideal wire: no return wire (no current); wire is equipotential → point in circuit has earth's potential → specific value of potential at each point
- does not change how circuit functions... unless malfunction/breaking of circuit (enclose circuit in grounded case insulated from circuit): case comes in contact with circuit (→ touching would have caused electrocution) → current thru' wire (fuse blows...)