Lecture 26 (last!!)

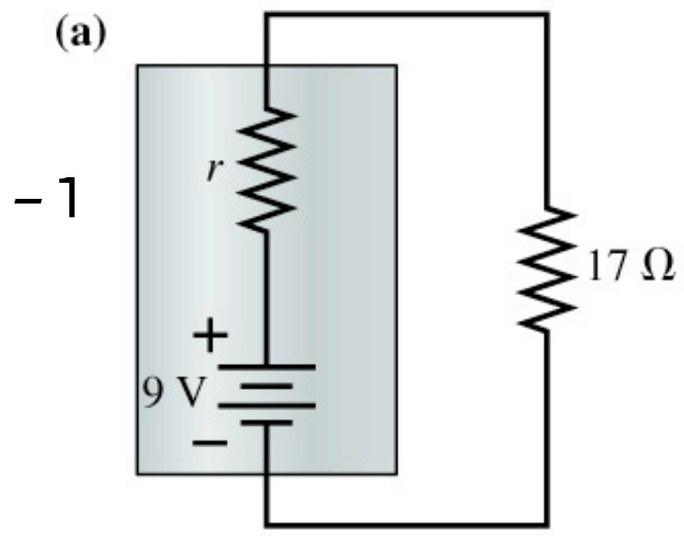
- Example of Resistor Circuits
- Grounding

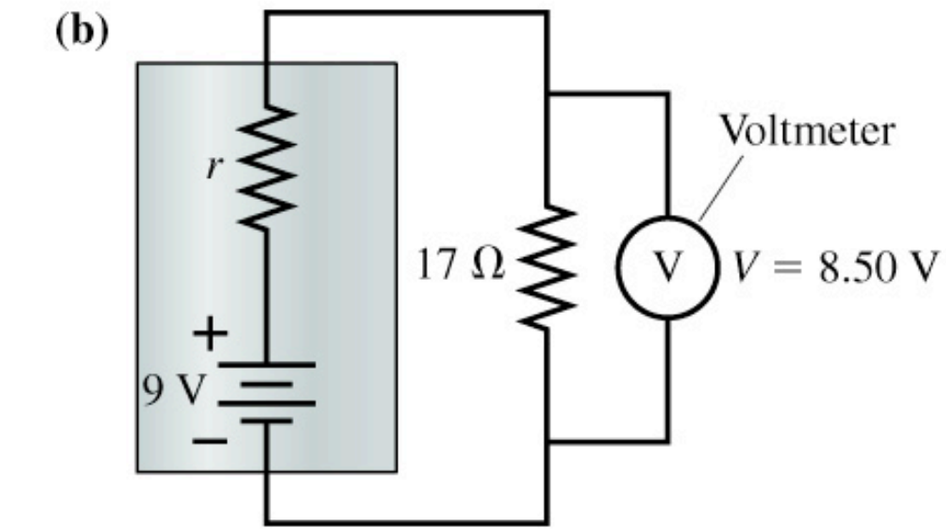
- review of chapters 25-32 for final (see also course webpage and come for review session tomorrow)

Voltmeters

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

  $R_{voltmeter}$ R (ideally, ∞)





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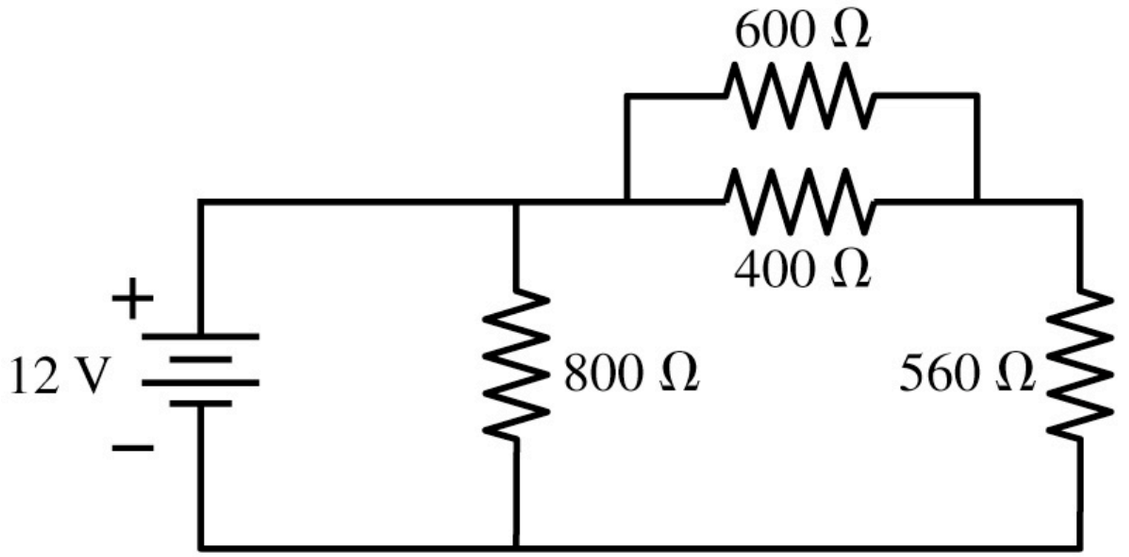
Strategy for Resistor Circuits

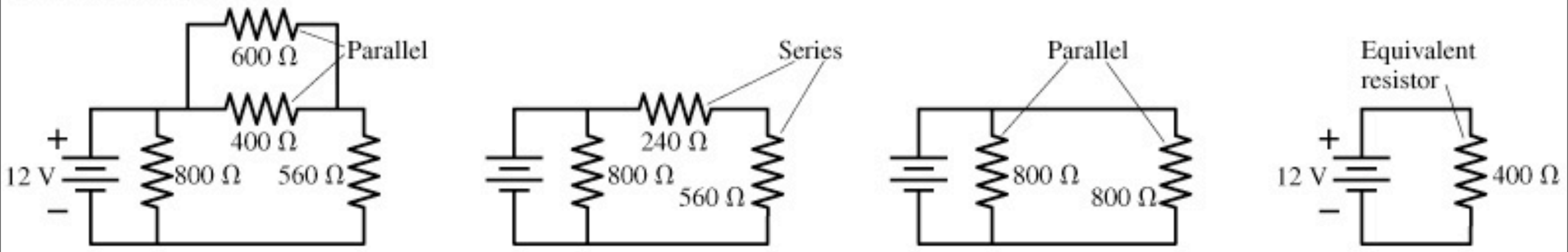
- assume ideal wires, batteries
- use Kirchhoff's laws and rules for series and parallel resistors
- reduce to equivalent resistor (basic circuit)
- rebuild using current same for series and potential difference same for parallel

Example of Resistor Circuit

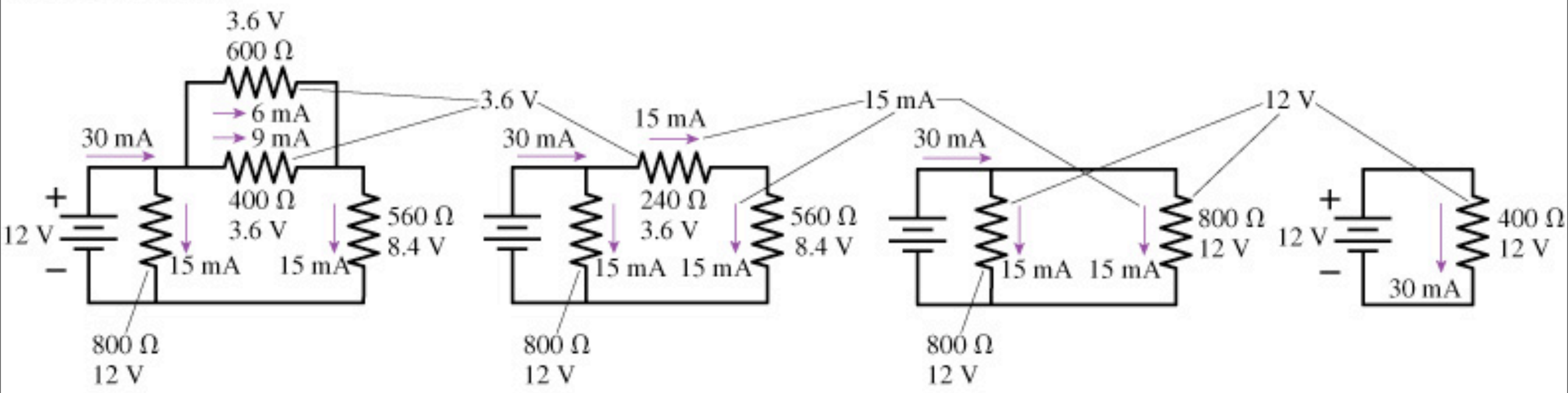
- Find I and ΔV for each resistor



(a) Break down the circuit

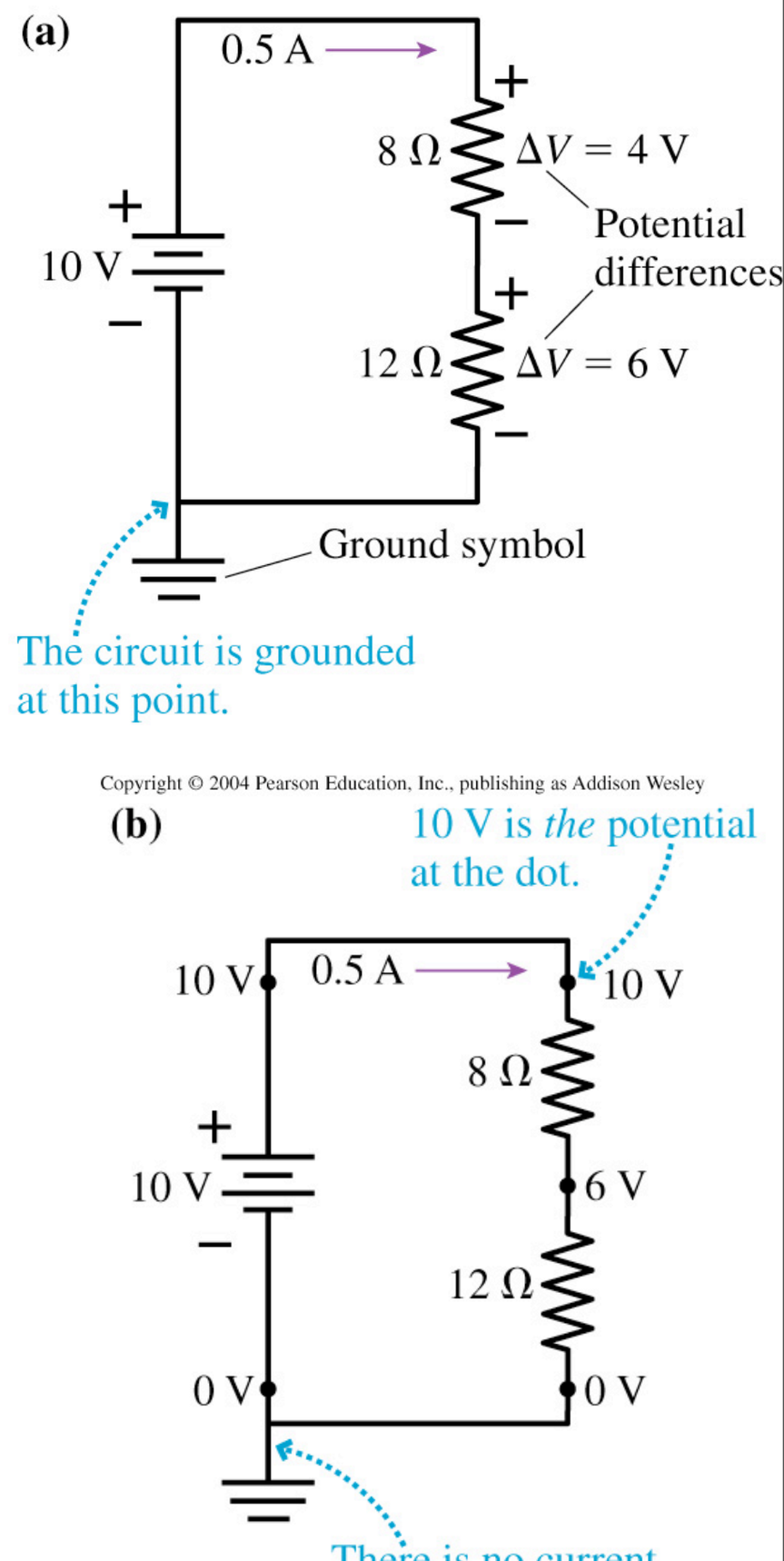


(b) Rebuild the circuit



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...)



Review of chapters 26-32

Electrostatics

- Coulomb's law (forces between 2 point charges): $F_{1\,\text{on}\,2} = F_{2\,\text{on}\,1} = \frac{K|q_1||q_2|}{r^2}$
- Electric Field: source charge alters space (creates "field"); test/probe charge responds to it ($\vec{E}(x, y, z) = \frac{\vec{F}_{\text{on}\,q}\ \text{at}\ (x, y, z)}{q}$)
- Electric Field due to point charge: $\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r}$
- superposition (dipole, rod, ring, disk, plane/capacitor): $E_{net} = \sum_i E_i$
- motion of charge in electric field: $a = \frac{F}{m} = \frac{qE}{m}$
- Gauss's law (useful for symmetric charge distribution): $\Phi_e = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{in}}}{\epsilon_0}$

Currents

- causes electrons to drift (on top of random motion): $v_d = \frac{e}{m}E$, giving current: $i = \frac{ne\tau A}{m}E$; $J = \sigma E$

Review of chapters 26-32 (continued)

- Electric Potential (Energy): $\Delta U_{elec} = -W_{elec}(i \quad f)$; $U_{q+\text{sources}} = qV$
- Electric Potential due to point charge: $V = \frac{U_{q'+q}}{q'} = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$
- Superposition (V due to ring, disk...): $V = \quad _i V_i$
- Electric Potential and Field: $\Delta V = V(s_f) - V(s_i) = -\int_{s_i}^{s_f} E_s ds$; $E_s = -\frac{dV}{ds}$
- Connecting Potential and Current: battery (source of potential difference) creates $\Delta V_{bat} = \Delta V_{wire} \longrightarrow E_{\text{wire}} = \frac{\Delta V_{\text{wire}}}{L} \longrightarrow I = \frac{\Delta V_{\text{wire}}}{R}$
- Ohm's law: $I = \frac{\Delta V}{R}$
- Capacitance: $Q = C\,\Delta V_C$ (charge on a capacitor)
- Combinations of Capacitors:

$C_{eq} = \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots\right)^{-1}$ (series capacitors) $C_{eq} = C_1 + C_2 + C_3 + \cdots$ (parallel capacitors)

- Energy stored in capacitor: $U_C = \frac{Q^2}{2C} = \frac{1}{2}C(\Delta V_c)^2$; in electric field: $u_E = \frac{0}{2}E^2$

Review of chapters 26-32 (continued)

Electric Circuits

- Circuit analysis using Kirchhoff's junction law: $\sum I_{\text{in}} = \sum I_{\text{out}}$ and Kirchhoff's loop law: $\Delta V_{\text{loop}} = \sum_i (\Delta V)_i = 0$
- Power delivered by emf: $P_{\text{bat}} = I\mathcal{E}$; dissipated by resistor: $P_{\text{R}} = I\Delta V_{\text{R}} = I^2R = \dfrac{(\Delta V_{\text{R}})^2}{R}$
- Combinations of resistors:

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

- don't confuse formulae for capacitors with resistors!

Example on electric power

- A standard 100 W (120 V) lightbulb contains a 9.00 cm-long tungsten filament. The high-temperature resistivity of tungsten is 9.0×10^{-7} ohm-meter. What is the diameter of the filament?

Good luck!