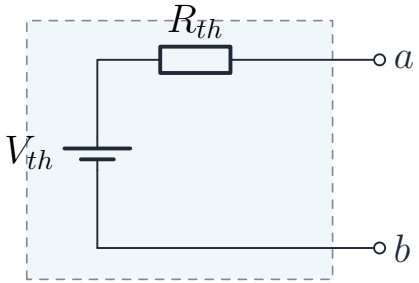
Exercise walk-through

1.2
Ohm's law and Kirchhoff's laws

University Electrical Engineering

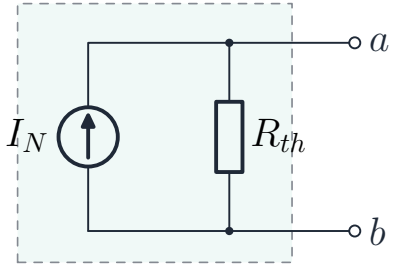
Every linear one-port is one source and one resistance

Thévenin: series form



same port ⟷

Norton: parallel form



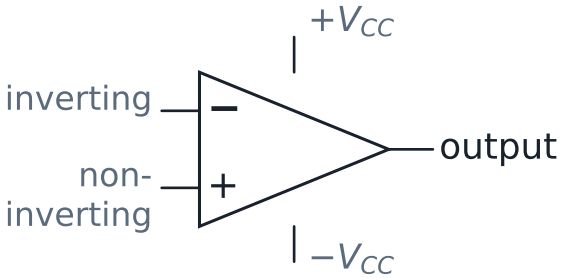
V_{th}: open-circuit voltage at a–b
R_{th}: resistance at a–b, sources set to zero

$I_N = V_{th}/R_{th}$,
the short-circuit current at a–b

> Measure the **open-circuit voltage** and the zeroed-source resistance; the whole network folds into Vth in **series** with Rth, or IN in **parallel**.

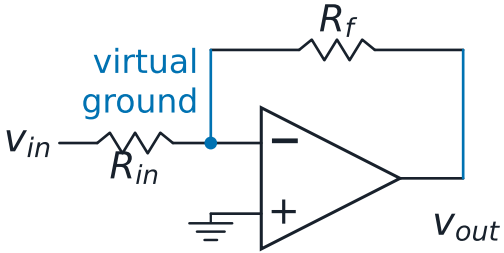
Five terminals and one taming trick

Five terminals



ideal: infinite gain,
infinite input resistance

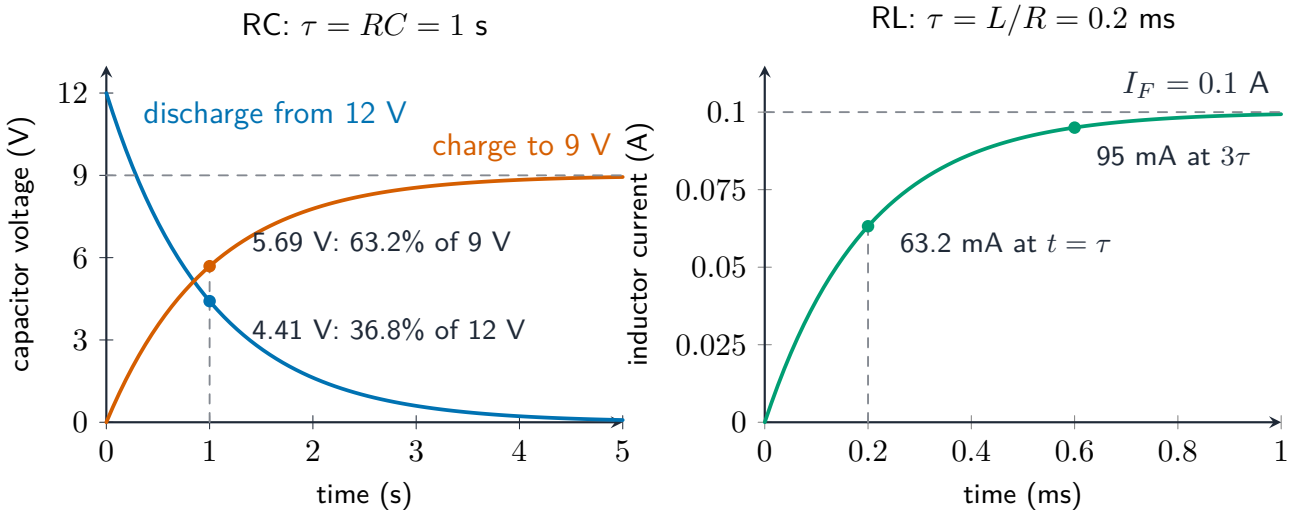
Inverting amplifier



the − node sits at 0 V, so
all of v_{in}/R_{in} flows through R_f

The triangle has two inputs, one output and two supply rails; **negative feedback** pins the minus node to the plus node - the **virtual ground** that makes gain exact.

The same shape, capacitor or inductor



Charge and discharge share one curve family; τ marks the 63.2% point.

Exercise 2.1

2.1 A 24 V supply is connected across a 330 Ω resistor with a power rating of $\frac{1}{2}$ W. Find the current and the power, using two different power formulas. Is the resistor safe? [4]



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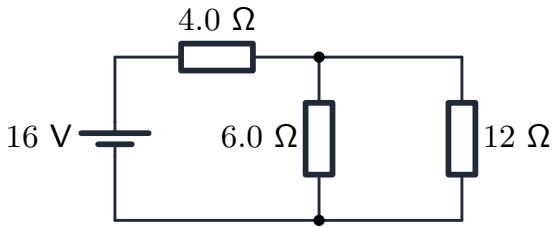
2.1

$i = \dfrac{24}{330} = \mathbf{72.7\ mA}$; $p = vi = 24 \times 0.0727 = \mathbf{1.75\ W}$; check $\dfrac{v^2}{R} = \dfrac{576}{330} = 1.75$ W

not safe: 1.75 W is 3.5 times the 0.5 W rating; use a 2 W (better 3 W) resistor

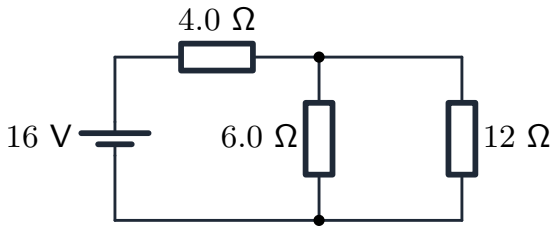
Exercise 2.2

2.2 A 16 V source feeds a 4.0 Ω resistor in series with 6.0 Ω and 12 Ω in parallel. Find the source current and the current in the 12 Ω resistor. [3]



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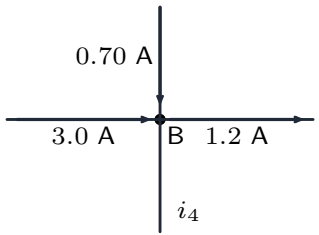


2.2

$6 \parallel 12 = \dfrac{72}{18} = 4.0\ \Omega$, total $8.0\ \Omega$; source current $\dfrac{16}{8.0} = \mathbf{2.0\ A}$; $i_{12} = 2.0 \times \dfrac{6}{6+12} = \mathbf{0.67\ A}$

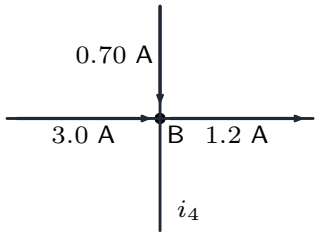
Exercise 2.3

2.3 Four wires meet at node B. A current of 3.0 A flows in on one wire and 0.70 A flows in on another; 1.2 A flows out on the third. Find the current i_4 in the fourth wire and say whether it flows in or out. [2]



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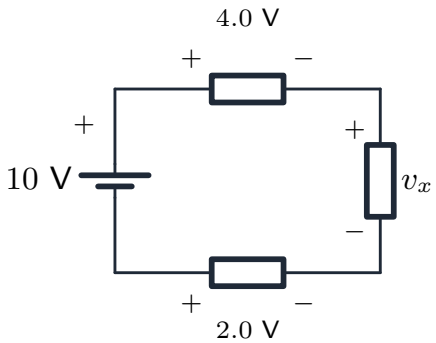


2.3

KCL: in = out: $3.0 + 0.70 = 1.2 + i_4$; $i_4 = \mathbf{2.5\ A}$, flowing **out** of B

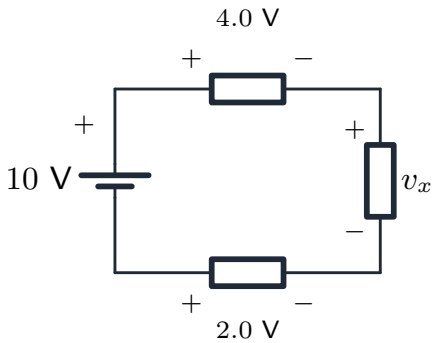
Exercise 2.4

2.4 In the loop shown, the source gives 10 V. The top resistor has 4.0 V across it, and the bottom element has 2.0 V across it with the polarity marked. Use KVL to find v_x. [3]



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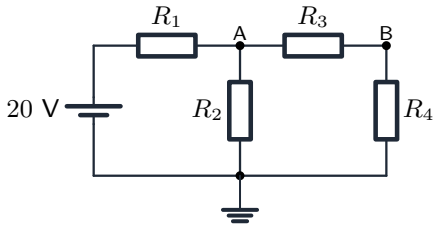
2.4

clockwise, drops positive: $-10 + 4.0 + v_x - 2.0 = 0$; the bottom element is a rise of 2.0 V going clockwise; $v_x = \mathbf{8.0\ V}$

Exercise 3.1

3.1 A ladder network is fed from 20 V: $R_1 = 2.0\ \Omega$ in series to node A; $R_2 = 6.0\ \Omega$ from A to ground; $R_3 = 1.0\ \Omega$ from A to node B; $R_4 = 2.0\ \Omega$ from B to ground.

Find the source current, the current in every resistor and the voltage at B. Check your answers with a power balance. [6]

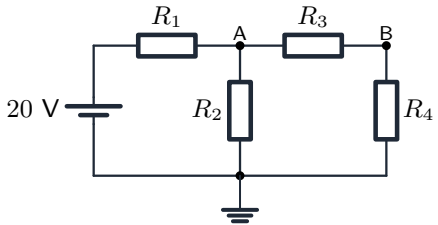


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$R_1 = 2.0,\ R_2 = 6.0$
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3.1

$R_3 + R_4 = 3.0\ \Omega$, $3.0 \parallel 6.0 = 2.0\ \Omega$, total $4.0\ \Omega$; source current **5.0 A**

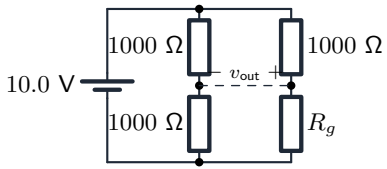
$v_A = 20 - 5.0 \times 2.0 = 10$ V, so $i_{R2} =$ **1.67 A** and $i_{R3} = i_{R4} =$ **3.33 A**; $v_B = 3.33 \times 2.0 =$ **6.67 V**

power balance: source $20 \times 5.0 = 100$ W; resistors $50 + 16.7 + 11.1 + 22.2 = 100$ W, so it checks

Exercise 3.2

3.2 A **Wheatstone bridge** measures strain. It is fed from 10.0 V. The left side has two 1000 Ω resistors; the right side has a fixed 1000 Ω resistor on top and a strain gauge of $R_g = 1002\ \Omega$ below. The output v_{out} is taken between the two middle nodes.

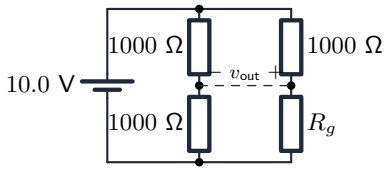
Find v_{out} in mV. A common shortcut is $v_{\text{out}} \approx \dfrac{V\delta}{4}$, where $R_g = R(1+\delta)$. Find the shortcut value and say whether it is good enough here. [5]



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3.2

left middle node: $10.0 \times \dfrac{1000}{2000} = 5.000$ V; right middle node: $10.0 \times \dfrac{1002}{2002} = 5.004995$ V

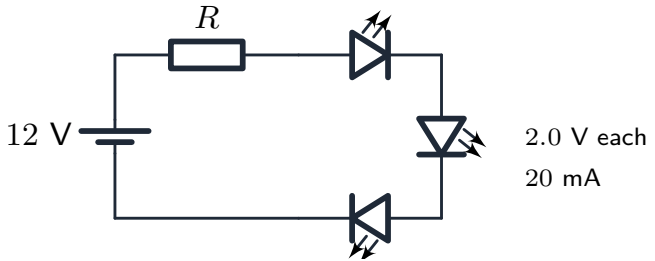
$v_{\text{out}} = \mathbf{4.995\ mV}$; $\delta = 0.002$, so $\dfrac{V\delta}{4} = \mathbf{5.000\ mV}$

the difference is 0.1%, far below normal measurement error, so the shortcut is good for small δ

Exercise 3.3 (a)

3.3 A designer drives LEDs from a car's 12 V supply. Each LED needs 20 mA and has 2.0 V across it when lit. The LEDs are in series with one resistor R.

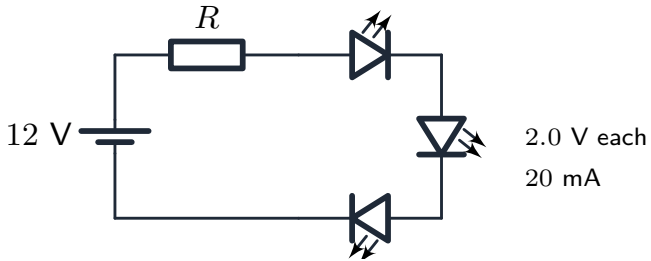
(a) For three LEDs in series, find R, the power in R, and the fraction of the supply power that reaches the LEDs. [3]



Exercise 3.3 (a)

3.3 A designer drives LEDs from a car's 12 V supply. Each LED needs 20 mA and has 2.0 V across it when lit. The LEDs are in series with one resistor R.

(a) For three LEDs in series, find R, the power in R, and the fraction of the supply power that reaches the LEDs. [3]



(a) $R = \dfrac{12 - 3 \times 2.0}{0.020} = \mathbf{300}\ \Omega$; $p_R = 6.0 \times 0.020 = \mathbf{0.12}\ \mathbf{W}$; LEDs get $\dfrac{6.0}{12} = \mathbf{50}\%$

Exercise 3.3 (b)

3.3 A designer drives LEDs from a car's 12 V supply. Each LED needs 20 mA and has 2.0 V across it when lit. The LEDs are in series with one resistor R.

(b) A car's supply really varies from 11.0 V to 14.4 V. Find the LED current at each end. The LEDs' absolute maximum current is 30 mA. Is the design safe? [2]

Exercise 3.3 (b)

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(b) $\dfrac{11.0 - 6.0}{300} = \mathbf{16.7\ mA}$ and $\dfrac{14.4 - 6.0}{300} = \mathbf{28\ mA}$; below 30 mA, so safe, but with little margin

Exercise 3.3 (c)

3.3 A designer drives LEDs from a car's 12 V supply. Each LED needs 20 mA and has 2.0 V across it when lit. The LEDs are in series with one resistor R.

(c) A colleague suggests five LEDs in series, with a new R, to waste less power. Find the new R, the efficiency, and the current at 14.4 V. Which design do you choose, and why? [3]

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(c) $R = \dfrac{12-10}{0.020} = \mathbf{100}\ \Omega$, efficiency $\dfrac{10}{12} = \mathbf{83}\%$; at 14.4 V: $\dfrac{4.4}{100} = \mathbf{44\ mA}$, over the maximum; choose three LEDs (or a constant-current driver): when R drops only a small voltage, a small change in supply gives a large change in current