Circuits — Full Practice

Physics Standard 7.1 · Ohm's Law and Circuits

Part 1 builds the foundation: one resistor, then pure series, then pure parallel. Part 2 combines them, ending at the exact Level 4 target of complex mixed circuits with multiple parallel branches.

Every circuit here collapses using series and parallel rules alone. No junction rule. No loop rule. Two components are in **parallel** only if both ends touch the same pair of nodes. Two are in **series** only if they share a node with nothing else attached. Points joined by bare wire are one node.

Show every step and carry units throughout.

Part 1 · Foundations

Level 1 and 2. One resistor, then series, then parallel. No tricks, no hidden structure.

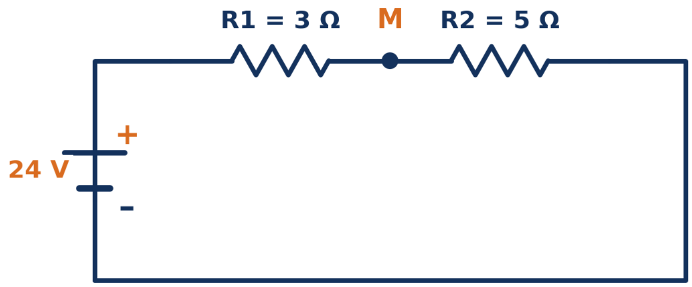
1. A single resistor is connected across a battery.
(a) Find the current in the circuit.
(b) State the voltage across the resistor and explain in one line why it equals the battery voltage.
(c) How much charge passes through the resistor in 5.0 seconds?

2. Two resistors in series.

(a) Find the equivalent resistance.

(b) Find the current in the circuit.

(c) Find the voltage across each resistor and check that they add to 24 V.

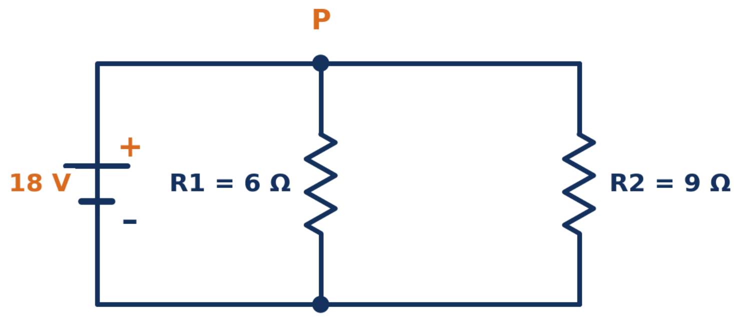


3. Two resistors in parallel.

(a) Find the equivalent resistance.

(b) State the voltage across each resistor.

(c) Find the current through each resistor and the total current from the battery.

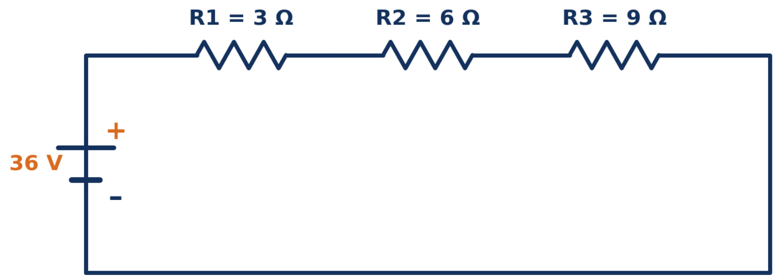


4. Three resistors in series.

(a) Find the equivalent resistance and the current.

(b) Find the voltage across each resistor.

(c) Which resistor takes the largest share of the voltage, and why?

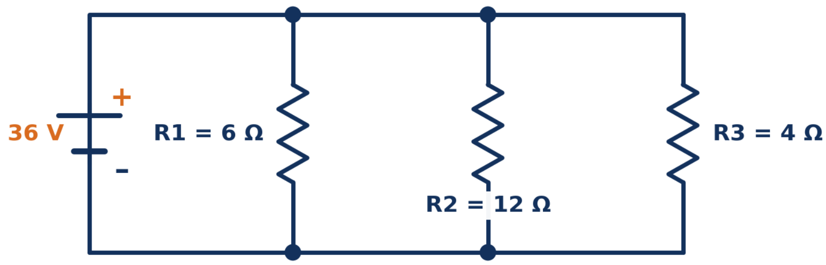


5. Three resistors in parallel.

(a) Find the equivalent resistance.

(b) Find the current through each resistor and the total.

(c) Which resistor carries the largest current, and why?

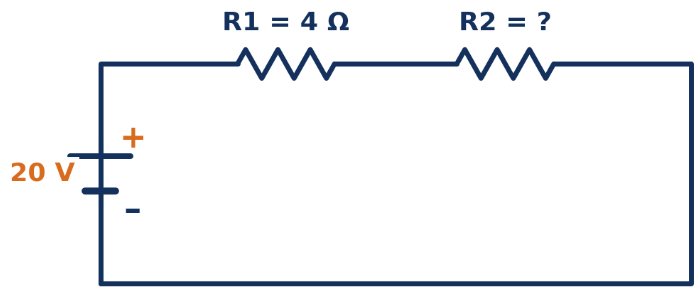


6. Two resistors in series. An ammeter placed anywhere in the loop reads 2.0 A.

(a) Find the equivalent resistance of the circuit.

(b) Find R_2.

(c) Find the voltage across each resistor.



ammeter in the loop reads 2.0 A

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7. No diagram.

(a) Two resistors in parallel combine to 4.0 Ω. One of them is 12 Ω. Find the other.

(b) Three identical 30 Ω resistors are placed in parallel. Find the equivalent resistance.

(c) State in one sentence which quantity every component shares in a series circuit, and which quantity every component shares in a parallel circuit.

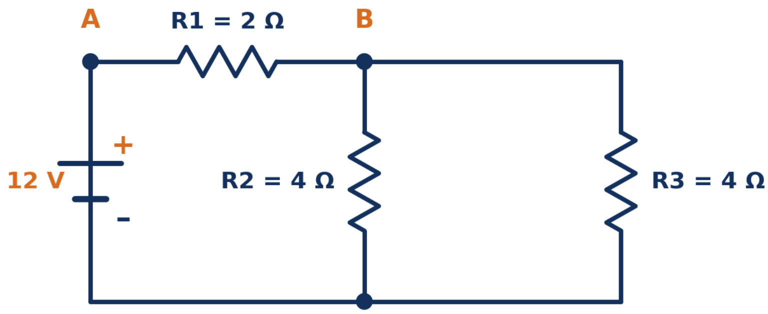
(d) Explain in one sentence why a parallel combination is always smaller than its smallest branch.

8. One series resistor feeding a parallel pair. This is the simplest mixed circuit there is.

(a) Find the equivalent resistance and the total current.

(b) Find the voltage across R_1 and the voltage across the parallel pair.

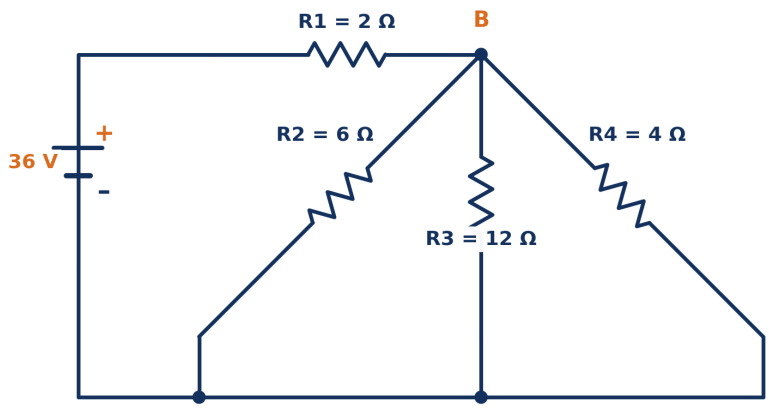
(c) Find the current through R_2 and through R_3, and check them against the total.



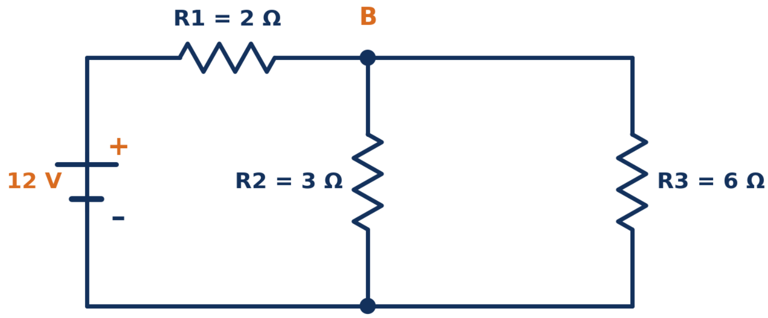
Part 2 · Mixed Circuits

Level 3 and 4. Series and parallel nested inside each other, sometimes drawn in an unfamiliar layout, and once with a bare wire across a resistor. Find the node pairs, collapse the innermost group, expand back out.

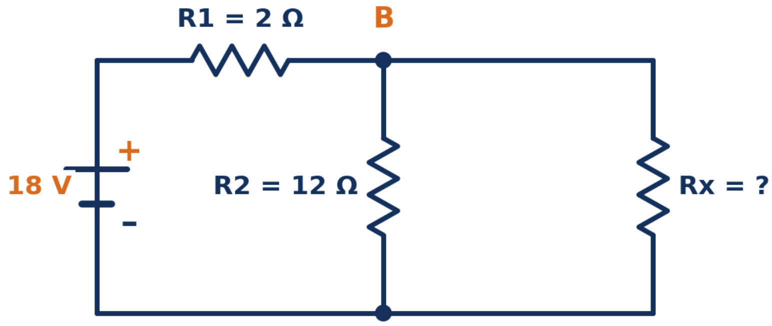
9. Find the equivalent resistance and complete an IRV chart for all four resistors. Verify your branch currents add to the total.



10. For the circuit below, calculate the power dissipated by every resistor and rank them largest to smallest. State which quantity, current or voltage, each resistor shares with its neighbour.

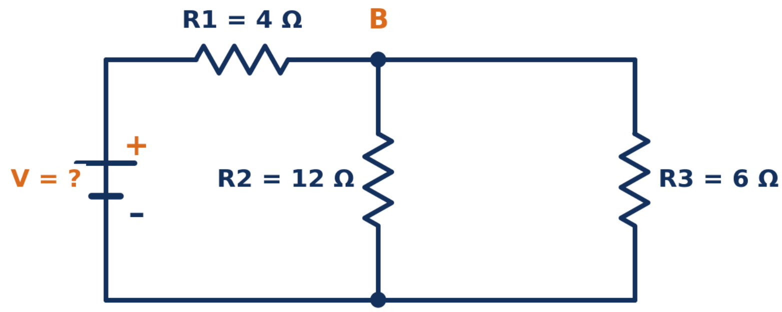


11. An ammeter placed at the battery reads 3.0 A. Find R_x, then find the current through R_2 and through R_x separately.



ammeter at the battery reads 3.0 A

12. An ammeter placed in the R_3 branch reads 1.0 A. Find the source voltage V, the total current, and the voltage across R_1.



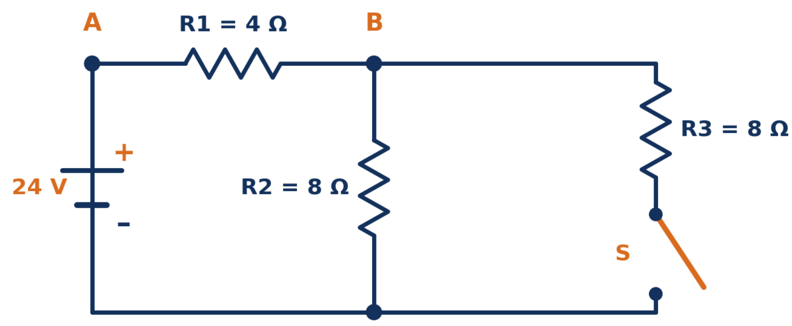
ammeter in the R3 branch reads 1.0 A

13. Switch S is initially open.

(a) Find the total current and the voltage at node B.

(b) Close S. Find the new total current and the new voltage at node B.

(c) Explain why closing a switch that adds a resistor *increases* the current the battery delivers.



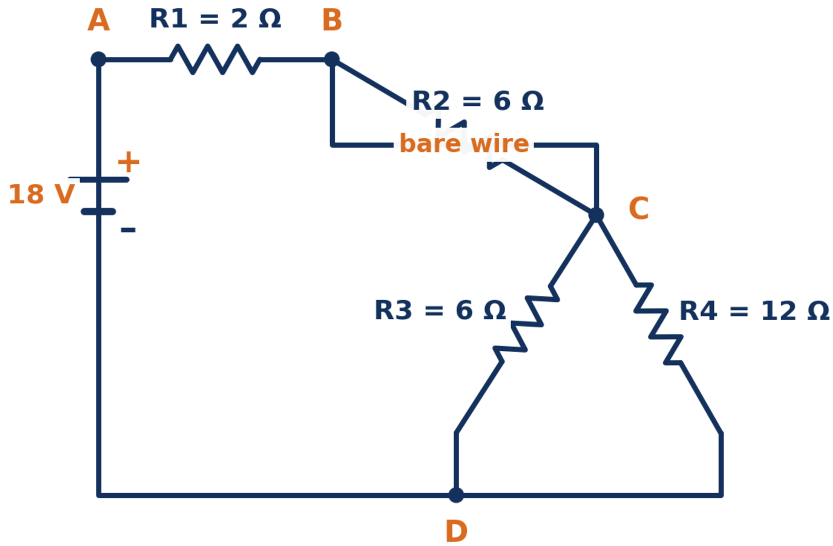
14. A bare wire runs from node B to node C, bypassing R_2 entirely.

(a) Find the current through R_2 and justify it in one sentence.

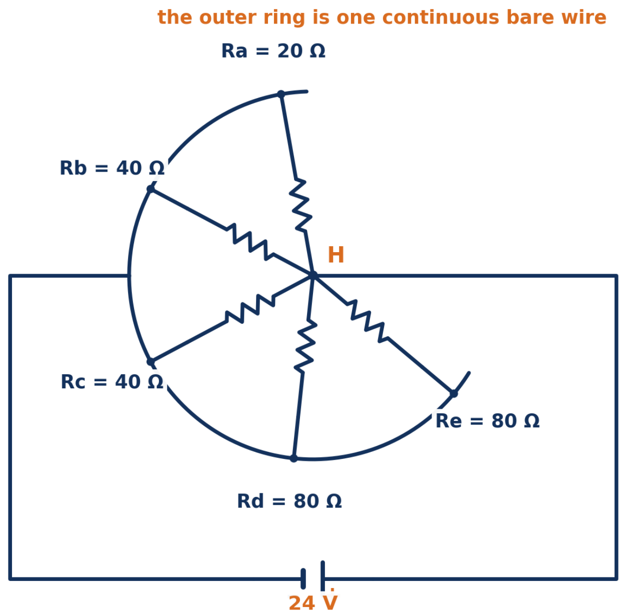
(b) Find the equivalent resistance and the total current.

(c) Find the current through R_3 and R_4.

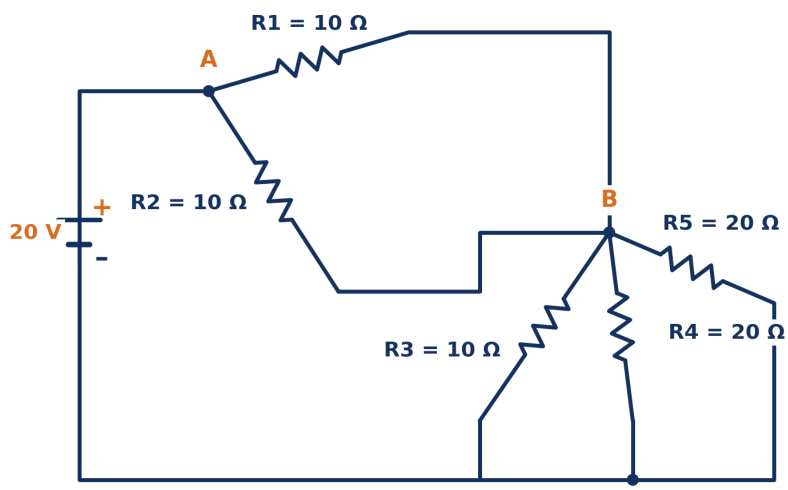
(d) The bare wire is now cut. Find the new equivalent resistance.



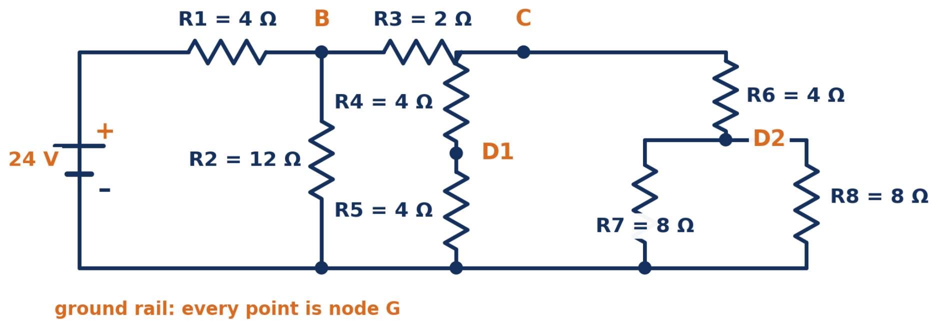
15. Five resistors radiate from hub H to a continuous bare outer ring. Redraw this in a standard rectangular form, then find the equivalent resistance, the total current, and the current in each of the five resistors.



16. The resistors below are drawn scattered across the page. Label every node, list each resistor as "node X to node Y", then find the equivalent resistance and the current through every resistor.



17. Eight resistors. Every point on the bottom rail is the same node G. Collapse the network starting from the far right and work back to the battery. Find the equivalent resistance, the total current, and the current through R_7.

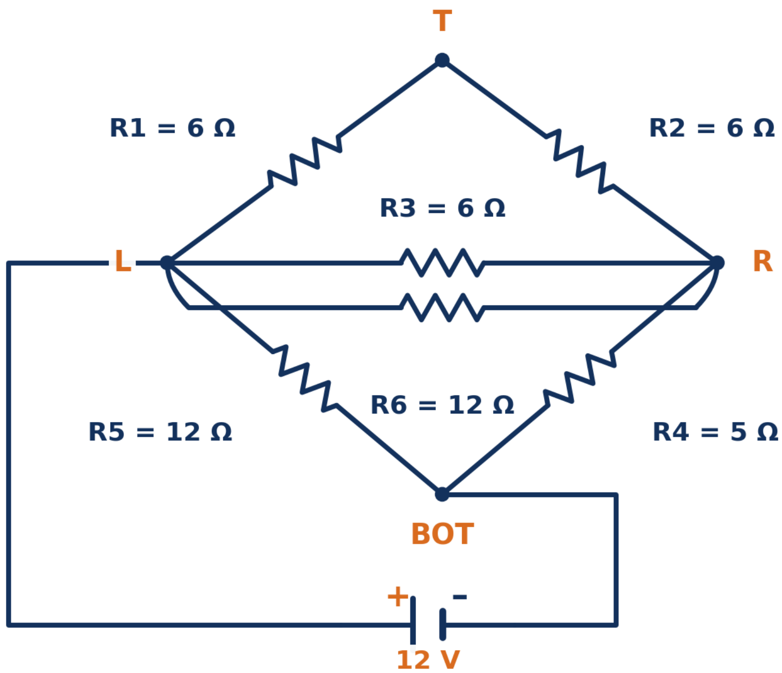


18. The double diamond. R_3 and R_6 are two separate chords, both running from node L to node R.

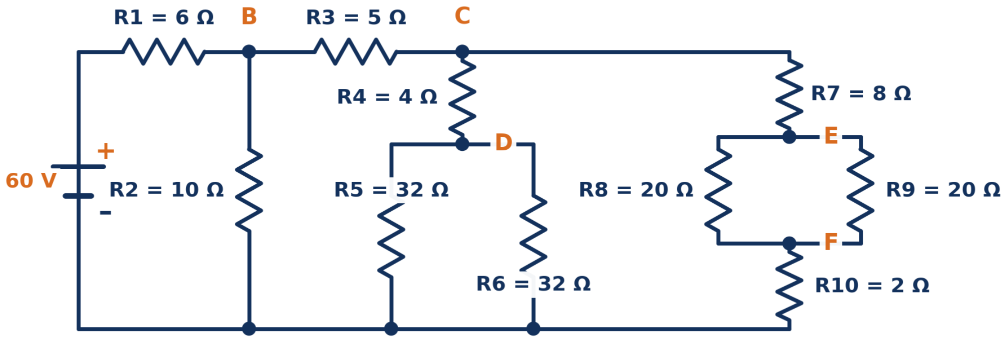
(a) Find the equivalent resistance and the total battery current.

(b) Find the current and voltage for all six resistors.

(c) R_5 burns out and opens. State whether the current through R_4 changes, and justify using nodes.



19. Ten resistors, multiple parallel branches at three different depths. Find the equivalent resistance, the total current, and the current through R_5, R_8, and R_{10}.



20. No diagram. Reasoning only.

(a) In a series pair, which resistor dissipates more power, the larger or the smaller? In a parallel pair, which one? Justify both with a formula.

(b) Explain why adding a resistor in series raises the total resistance, but adding one in parallel lowers it.

(c) Two resistors sit in parallel across a battery. One of them is removed. State what happens to the current in the remaining resistor and what happens to the total current from the battery, with a reason for each.

Answer Key

Standard 7.1 · full worked solutions

1. One resistor, one loop.

(a) $I = V/R = 12/4 = 3.0$ A

(b) 12 V. The only other elements are ideal wires, which drop no voltage, so the entire battery voltage must appear across the resistor.

(c) $q = It = (3.0)(5.0) = 15$ C

(a) 3.0 A (b) 12 V (c) 15 C

Common error: Thinking some voltage is “lost in the wires”. Ideal wire has zero resistance and therefore zero drop.

2. Series: resistances add and the current is shared.

(a) $R_{eq} = 3 + 5 = 8.0\ \Omega$

(b) $I = 24/8 = 3.0$ A, the same through both

(c) $V_1 = (3.0)(3) = 9.0$ V; $V_2 = (3.0)(5) = 15.0$ V

Check: $9 + 15 = 24$ V

$R_{eq} = 8.0\ \Omega$ $I = 3.0$ A $V_1 = 9.0$ V $V_2 = 15.0$ V

Common error: Splitting the current between the two resistors. In series the current never divides.

3. Parallel: voltage is shared and currents add.

(a) $R_{eq} = (6)(9)/(6+9) = 54/15 = 3.6\ \Omega$

(b) Both ends of each resistor touch the battery terminals, so each has the full 18 V.

(c) $I_1 = 18/6 = 3.0$ A; $I_2 = 18/9 = 2.0$ A

$I_{total} = 3.0 + 2.0 = 5.0$ A. Check: $18/3.6 = 5.0$ A

$R_{eq} = 3.6\ \Omega$ $V = 18$ V on each $I_1 = 3.0$ A $I_2 = 2.0$ A $I_{total} = 5.0$ A

Common error: Adding 6 + 9 to get 15 Ω. A parallel result must come out below 6 Ω, so anything larger than the smallest branch is instantly wrong.

4. Three in series.

(a) $R_{eq} = 3 + 6 + 9 = 18.0\ \Omega$, $I = 36/18 = 2.0$ A

(b) $V_1 = (2)(3) = 6.0$ V; $V_2 = (2)(6) = 12.0$ V; $V_3 = (2)(9) = 18.0$ V. Check: $6 + 12 + 18 = 36$ V

(c) R_3, the largest. All three carry the same current, and $V = IR$, so the largest resistance needs the largest push to drive that shared current through it.

$R_{eq} = 18.0\ \Omega$ $I = 2.0$ A $V = 6.0 / 12.0 / 18.0$ V

Common error: Assuming the three resistors split the voltage equally. They split it in proportion to their resistances.

5. Three in parallel.

(a) $1/R = 1/6 + 1/12 + 1/4 = 2/12 + 1/12 + 3/12 = 6/12$, so $R_{eq} = 2.0\ \Omega$

(b) Each has the full 36 V:

$I_1 = 36/6 = 6.0$ A; $I_2 = 36/12 = 3.0$ A; $I_3 = 36/4 = 9.0$ A
$I_{total} = 6 + 3 + 9 = 18.0$ A. Check: $36/2 = 18$ A
(c) R_3, the smallest. All three have the same voltage across them, and $I = V/R$, so the least opposition carries the most current.

$R_{eq} = 2.0\ \Omega$ $I = 6.0 / 3.0 / 9.0$ A $I_{total} = 18.0$ A

Common error: Computing $1/R = 6/12$ and stopping there. That is $1/R_{eq}$, not R_{eq}. Invert at the end.

6. Work backwards from the measured current.

(a) $R_{eq} = V/I = 20/2.0 = 10.0\ \Omega$

(b) $R_2 = 10 - 4 = 6.0\ \Omega$

(c) $V_1 = (2.0)(4) = 8.0$ V; $V_2 = (2.0)(6) = 12.0$ V. Check: $8 + 12 = 20$ V

$R_{eq} = 10.0\ \Omega$ $R_2 = 6.0\ \Omega$ $V_1 = 8.0$ V $V_2 = 12.0$ V

Common error: Dividing the source voltage by R_1 to get a current. Only the equivalent resistance goes with the source voltage.

7. Reasoning and inversions.

(a) $1/4 = 1/12 + 1/x \rightarrow 1/x = 3/12 - 1/12 = 2/12 \rightarrow x = 6.0\ \Omega$

(b) $1/R = 3/30 = 1/10$, so $R = 10.0\ \Omega$. Identical resistors in parallel: divide by how many there are.

(c) Series components all share the same CURRENT. Parallel components all share the same VOLTAGE.

(d) Adding a branch gives charge a second route, so more total current flows for the same voltage, and more current at the same voltage is exactly what less resistance means.

(a) 6.0 Ω (b) 10.0 Ω (c) series shares current, parallel shares voltage

Common error: Reversing (c). Getting this backwards makes every later calculation wrong, so check it against the picture: one path means one current.

8. The simplest mixed circuit: collapse the pair, then treat it as series.

(a) $R_2 \parallel R_3 = (4)(4)/8 = 2.0\ \Omega$
$R_{eq} = 2 + 2 = 4.0\ \Omega$, $I_{total} = 12/4 = 3.0$ A
(b) V across $R_1 = (3.0)(2) = 6.0$ V
V across the pair $= 12 - 6 = 6.0$ V
(c) $I_{R2} = 6/4 = 1.5$ A; $I_{R3} = 6/4 = 1.5$ A. Check: $1.5 + 1.5 = 3.0$ A

$R_{eq} = 4.0\ \Omega$ $I_{total} = 3.0$ A $V_{R1} = 6.0$ V $V_{pair} = 6.0$ V $I_{R2} = I_{R3} = 1.5$ A

Common error: Using the full 12 V to find the branch currents. Only 6 V sits across the pair.

9. R_2, R_3 and R_4 all span node B to ground. Three in parallel.

$1/R = 1/6 + 1/12 + 1/4 = 2/12 + 1/12 + 3/12 = 6/12$, so $R = 2.0\ \Omega$

$R_{eq} = 2 + 2 = 4.0\ \Omega$, $I_{total} = 36/4 = 9.0$ A

V across $R_1 = (9)(2) = 18.0$ V, so V across the bank = 18.0 V

$I_{R2} = 18/6 = 3.0$ A; $I_{R3} = 18/12 = 1.5$ A; $I_{R4} = 18/4 = 4.5$ A

Check: $3.0 + 1.5 + 4.5 = 9.0$ A

$R_{eq} = 4.0\ \Omega$ $I_{total} = 9.0$ A I = 3.0 / 1.5 / 4.5 A V = 18.0 V on each

Common error: Reading the three angled resistors as a series chain because they are drawn fanning out. All three touch node B and the rail, so they are parallel.

10. Series R_1 feeding a parallel pair.

$R_2 \parallel R_3 = (3)(6)/9 = 2.0\ \Omega$, $R_{eq} = 2 + 2 = 4.0\ \Omega$

$I_{total} = 12/4 = 3.0$ A

$P_{R1} = I^2R = (3)^2(2) = 18.0$ W

V across the pair $= 12 - (3)(2) = 6.0$ V

$P_{R2} = V^2/R = 36/3 = 12.0$ W; $P_{R3} = 36/6 = 6.0$ W

Check: $18 + 12 + 6 = 36$ W $= (3.0)(12)$

$P_{R1} = 18.0$ W > $P_{R2} = 12.0$ W > $P_{R3} = 6.0$ W. R_1 shares current with the pair; R_2 and R_3 share voltage.

Common error: Assuming the largest resistor always dissipates the most. In parallel the smaller resistor wins, because it draws more current at the same voltage.

11. Work backwards from the measured total current.

$R_{eq} = 18/3.0 = 6.0\ \Omega$; parallel section $= 6 - 2 = 4.0\ \Omega$

$4 = (12)(R_x)/(12 + R_x) \rightarrow 48 + 4R_x = 12R_x$

$8R_x = 48 \rightarrow R_x = 6.0\ \Omega$

V across $R_1 = (3.0)(2) = 6.0$ V, so 12.0 V sits across the pair

$I_{R2} = 12/12 = 1.0$ A; $I_{Rx} = 12/6 = 2.0$ A

$R_x = 6.0\ \Omega$ $I_{R2} = 1.0$ A $I_{Rx} = 2.0$ A

Common error: Setting R_x equal to the whole 6 Ω equivalent without subtracting R_1 first.

12. Start at the branch where the current is known.

V across $R_3 = (1.0)(6) = 6.0$ V

R_2 and R_3 are parallel, so V across $R_2 = 6.0$ V as well

$I_{R2} = 6/12 = 0.5$ A; $I_{total} = 1.0 + 0.5 = 1.5$ A

V across $R_1 = (1.5)(4) = 6.0$ V

$V = 6.0 + 6.0 = 12.0$ V

V = 12.0 V $I_{total} = 1.5$ A $V_{R1} = 6.0$ V

Common error: Treating the measured 1.0 A as the total current. It is one branch of a parallel pair.

13. Opening a switch removes an entire parallel branch.

(a) S open: the R_3 branch is broken, carries no current and offers no path.

$R_{eq} = 4 + 8 = 12.0\ \Omega$, $I = 24/12 = 2.0$ A, $V_B = (2.0)(8) = 16.0$ V

(b) S closed: $R_2 \parallel R_3 = (8)(8)/16 = 4.0\ \Omega$

$R_{eq} = 4 + 4 = 8.0\ \Omega$, $I = 24/8 = 3.0$ A, $V_B = (3.0)(4) = 12.0$ V

(c) Adding a resistor in PARALLEL opens a second route for charge. Two routes carry more total current than one, so the equivalent resistance falls and the battery current rises.

Open: 12.0 Ω, 2.0 A, V_B = 16.0 V. Closed: 8.0 Ω, 3.0 A, V_B = 12.0 V.

Common error: Adding R_3 into the series total when S closes. It is parallel with R_2, not in series with anything.

14. A bare wire in parallel with a resistor kills that resistor.

(a) The wire makes B and C the same node. One node has no potential difference with itself, so V across $R_2 = 0$ and $I_{R2} = 0/6 = 0$ A.

(b) $R_3 \parallel R_4 = (6)(12)/18 = 4.0\ \Omega$

$R_{eq} = 2 + 0 + 4 = 6.0\ \Omega$, $I_{total} = 18/6 = 3.0$ A

(c) V across $R_1 = 6.0$ V, so 12.0 V across the pair

$I_{R3} = 12/6 = 2.0$ A; $I_{R4} = 12/12 = 1.0$ A. Check: 2 + 1 = 3 A

(d) Wire cut: R_2 rejoins in series. $R_{eq} = 2 + 6 + 4 = 12.0\ \Omega$

I_{R2} = 0 A R_{eq} = 6.0 Ω I_{total} = 3.0 A I_{R3} = 2.0 A I_{R4} = 1.0 A Cut: 12.0 Ω

Common error: Treating the shorting wire as a very small resistance and carrying it forward. An ideal wire is exactly 0 Ω, so the parallel result is exactly 0.

15. Every spoke runs hub to ring, and the ring is one node.

The ring is bare wire, so all five outer ends are the SAME node. All five resistors span H to that node: five in parallel.

$1/R = 1/20 + 1/40 + 1/40 + 1/80 + 1/80 = 4/80 + 2/80 + 2/80 + 1/80 + 1/80 = 10/80 = 1/8$

$R_{eq} = 8.0\ \Omega$, $I_{total} = 24/8 = 3.0$ A

Each resistor sees the full 24 V:

$I_a = 24/20 = 1.2$ A; $I_b = I_c = 24/40 = 0.6$ A; $I_d = I_e = 24/80 = 0.3$ A

Check: 1.2 + 0.6 + 0.6 + 0.3 + 0.3 = 3.0 A

R_{eq} = 8.0 Ω I_{total} = 3.0 A I = 1.2 / 0.6 / 0.6 / 0.3 / 0.3 A

Common error: Reading the radial layout as a series chain because the spokes are drawn end to end around a circle. They all touch the same two nodes.

16. Node labelling turns a scattered drawing into two parallel banks.

Node list: R_1: A–B. R_2: A–B. R_3: B–G. R_4: B–G. R_5: B–G.

$R_1 \parallel R_2 = (10)(10)/20 = 5.0\ \Omega$

$1/R = 1/10 + 1/20 + 1/20 = 2/20 + 1/20 + 1/20 = 4/20$, so $R = 5.0\ \Omega$

$R_{eq} = 5 + 5 = 10.0\ \Omega$, $I_{total} = 20/10 = 2.0$ A

V across each bank = (2.0)(5) = 10.0 V

$I_{R1} = I_{R2} = 1.0$ A; $I_{R3} = 1.0$ A; $I_{R4} = I_{R5} = 0.5$ A

$R_{eq} = 10.0\ \Omega$ $I_{total} = 2.0$ A $I_{R1} = I_{R2} = I_{R3} = 1.0$ A $I_{R4} = I_{R5} = 0.5$ A

Common error: Solving straight from the drawing. Write the node list first; the arithmetic becomes trivial once the list exists.

17. Collapse the ladder from the far end inward, one layer at a time.

$R_7 \parallel R_8 = (8)(8)/16 = 4.0\ \Omega$

Right branch C→G = $R_6 + 4 = 8.0\ \Omega$

Left branch C→G = $R_4 + R_5 = 8.0\ \Omega$

C→G total = (8)(8)/16 = 4.0 Ω

B→G through $R_3 = 2 + 4 = 6.0\ \Omega$

B→G total = (12)(6)/18 = 4.0 Ω

$R_{eq} = 4 + 4 = 8.0\ \Omega$, $I_{total} = 24/8 = 3.0$ A

V across $R_1 = 12.0$ V, so $V_B = 12.0$ V

$I_{R2} = 1.0$ A; $I_{R3} = 2.0$ A; V across $R_3 = 4.0$ V

$V_C = 8.0$ V, so each 8 Ω branch carries 1.0 A

$V_{D2} = 8 - (1.0)(4) = 4.0$ V, $I_{R7} = 4/8 = 0.5$ A

$R_{eq} = 8.0\ \Omega$ $I_{total} = 3.0$ A $I_{R7} = 0.5$ A

Common error: Starting the collapse at the battery. A ladder can only be reduced from the end furthest from the source.

18. Three separate paths span L to R; R_5 sits straight across the battery.

(a) $R_1 + R_2 = 12\ \Omega$ from L to R (they share node T alone).

That 12 Ω, $R_3 = 6\ \Omega$ and $R_6 = 12\ \Omega$ all span L to R:

$1/R = 1/12 + 1/6 + 1/12 = 4/12$, so $R = 3.0\ \Omega$

Chain L→BOT = 3 + 5 = 8.0 Ω; $R_5 = 12\ \Omega$ also spans L to BOT

$R_{eq} = (12)(8)/20 = 4.8\ \Omega$, $I_{total} = 12/4.8 = 2.5$ A

(b) R_5: 12.0 V, 1.0 A. Chain: 12/8 = 1.5 A

R_4: V = 7.5 V, I = 1.5 A; V across the L–R block = 4.5 V

R_3: 4.5 V, 0.75 A. R_6: 4.5 V, 0.375 A. R_1, R_2: 0.375 A each at 2.25 V each

Check: 0.75 + 0.375 + 0.375 = 1.5 A

(c) No change. R_5 connects L to BOT, which are the battery terminals themselves, so its branch is independent. The chain still sees 12 V and still carries 1.5 A. Only the battery total falls, from 2.5 A to 1.5 A.

R_{eq} = 4.8 Ω I_{total} = 2.5 A R_1, R_2: 0.375 A / 2.25 V R_3: 0.75 A / 4.5 V R_4: 1.5 A / 7.5 V R_5: 1.0 A / 12.0 V R_6: 0.375 A / 4.5 V

Common error: Calling R_1 and R_2 parallel because they sit on opposite sides of the diamond. They meet at node T with nothing else attached, which makes them series.

19. Collapse each sub-branch fully before combining anything higher up.

$R_5 \parallel R_6 = (32)(32)/64 = 16.0\ \Omega$, so left branch C→G = 4 + 16 = 20.0 Ω

$R_8 \parallel R_9 = (20)(20)/40 = 10.0\ \Omega$, so right branch C→G = 8 + 10 + 2 = 20.0 Ω

C→G total = (20)(20)/40 = 10.0 Ω

B→G through R_3 = 5 + 10 = 15.0 Ω

B→G total = (10)(15)/25 = 6.0 Ω

$R_{eq} = 6 + 6 = 12.0\ \Omega$, $I_{total} = 60/12 = 5.0$ A

V across R_1 = 30.0 V, so V_B = 30.0 V

$I_{R2} = 3.0$ A; $I_{R3} = 2.0$ A; V across R_3 = 10.0 V

V_C = 20.0 V, so each 20 Ω branch carries 1.0 A

$V_D = 20 - 4 = 16.0$ V, so $I_{R5} = 16/32 = 0.5$ A

V_E = 12.0 V and V_F = 2.0 V, so V across R_8 = 10.0 V and I_{R8} = 0.5 A

R_{10} carries the whole right branch: 1.0 A

R_{eq} = 12.0 Ω I_{total} = 5.0 A I_{R5} = 0.5 A I_{R8} = 0.5 A I_{R10} = 1.0 A

Common error: Combining R_4 with R_7 because both hang off node C. They belong to different branches and never share a second node.

20. Reasoning only.

(a) Series: both carry the same current and $P = I^2R$, so the LARGER resistance dissipates more. Parallel: both have the same voltage and $P = V^2/R$, so the SMALLER resistance dissipates more.

(b) In series the charge must pass through both resistors one after the other, so the oppositions add and the total can only grow. In parallel the second resistor is an extra route rather than an extra obstacle, so more total current flows for the same voltage, and more current at the same voltage is exactly what less resistance means.

(c) The remaining resistor is unchanged: it still has the full battery voltage across it, so its current stays exactly the same. The total current from the battery falls, because the current that used to flow in the removed branch is simply gone.

(a) series: larger; parallel: smaller (b) series adds obstacles, parallel adds routes (c) the remaining branch is unchanged; the battery total falls

Common error: Answering (a) with one rule for both cases. Which formula applies depends on which quantity is shared, and series and parallel share opposite things.