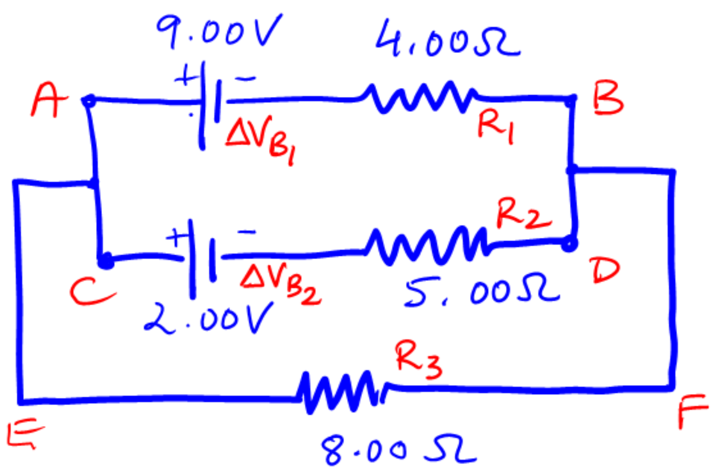
PhysicsTutor

Crazy circuit

Giambattista 18.68

Problem:

- At what rate is electric energy converted into heat in the 4.00 Ω and 5.00 Ω resistors in the diagram?



Relevant ideas:

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- Power = Energy/Time. Rate of energy conversion = power dissipated.

heat = energy transfer

mechanical power : how much work has a force done per unit time.

electric motor : converts electric energy into mechanical at some rate → power.

resistor : converts electrical energy into heat at some rate → power dissipated.

Relevant ideas:

- Power = Energy/Time. Rate of energy conversion = power dissipated.
- Power = Voltage times Current. (1 W = 1 V A)

$$P_i = \Delta V_i \, I_i = \frac{\Delta V_i^2}{R_i} = R_i \, I_i^2$$

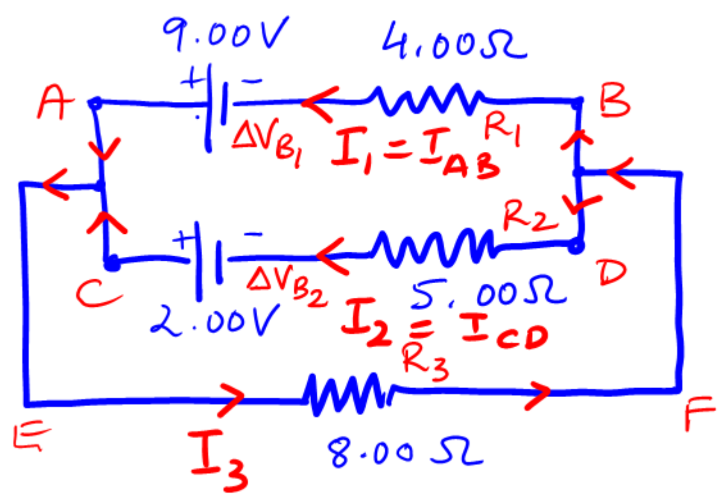
↑ we need the currents "only"

Relevant ideas:

- Power = Energy/Time. Rate of energy conversion = power dissipated.
- Power = Voltage times Current. (1 W = 1 V A)
- We need the AB and CD currents (which are the battery currents), also need the relevant resistor voltage drops.

needed: $P_1 = R_1 I_1^2$, $P_2 = R_2 I_2^2$

$I_1 + I_2 = I_3$ junction

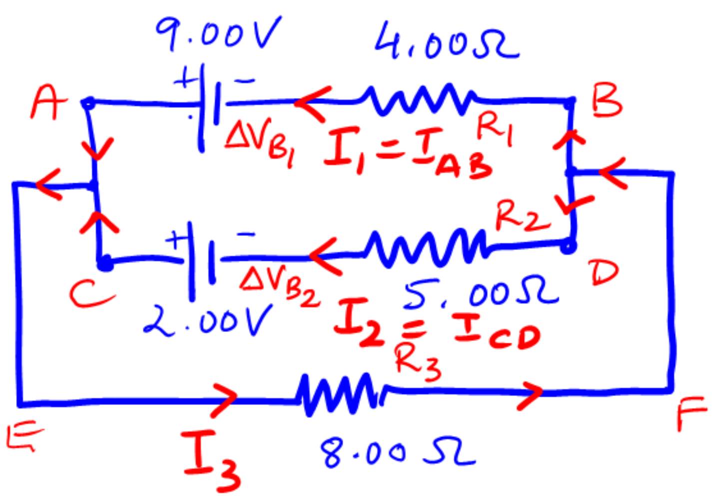


Relevant ideas:

- Power = Energy/Time. Rate of energy conversion = power dissipated.
- Power = Voltage times Current. (1 W = 1 V A)
- We need the AB and CD currents (which are the battery currents), also need the relevant resistor voltage drops.
- Kirchhoff's rules are needed to sort out what's going on (multiple loops, also junctions).

Equations associated with ideas:

$P_1 = R_1 I_1^2$ $\qquad P_2 = R_2 I_2^2$ $\qquad I_3 = I_1 + I_2$ ①



Ohm carefully $\quad \Delta V = -RI$ (drop)

Loop AEFB, start at battery: (used ①)

$$9 - 8(I_1 + I_2) - 4 I_1 = 0$$

Loop CEFD, start at battery: (used ①)

$$2 - 8(I_1 + I_2) - 5 I_2 = 0$$

2 eq's 2 unknowns → problem solved

3rd loop (consistency check) ACDB:

$$9 - 2 + 5 I_2 - 4 I_1 = 0$$

Strategy

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- Define currents in the three branches and relate them using the junction rule.

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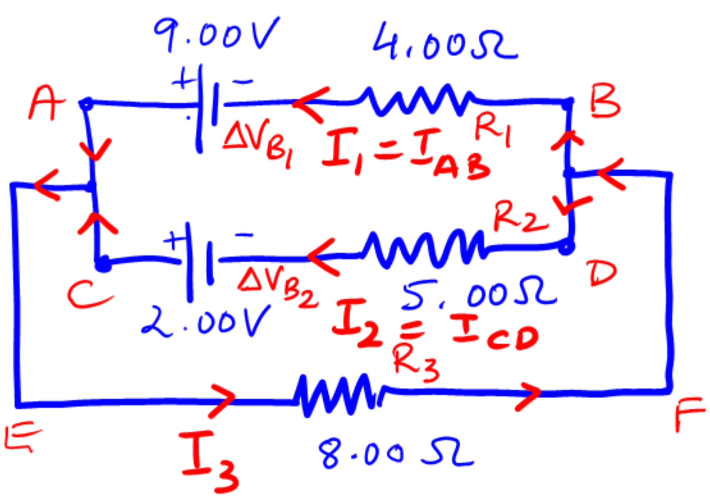

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Strategy

- Define currents in the three branches and relate them using the junction rule.
- Formulate several loop rule relations, but watch out for redundancies.
- Two unknown currents and two unknown voltages are to be determined; we need four conditions. → using Ohm's law twice we reduced the problem to finding I_1 and I_2. Then we used $I_3 = I_1 + I_2$ and two of the three obvious loops.

Solution

Solution

- $9 - 8(I_1 + I_2) - 4I_1 = 0$; $2 - 8(I_1 + I_2) - 5I_2 = 0$ → $12I_1 = 9 - 8I_2 \quad | :3$; $8I_1 = 2 - 13I_2 \quad | :2$

Solution

- $9 - 8(I_1 + I_2) - 4I_1 = 0$; $2 - 8(I_1 + I_2) - 5I_2 = 0$ $\Big\}$ $12I_1 = 9 - 8I_2 \quad | :3$; $8I_1 = 2 - 13I_2 \quad | :2$
- $\frac{9 - 8I_2}{3} = \frac{2 - 13I_2}{2}$ $\therefore$ $I_2 = -\frac{12}{23}A = -0.522A$

Solution

- $$9 - 8(I_1 + I_2) - 4I_1 = 0$$ $$2 - 8(I_1 + I_2) - 5I_2 = 0$$ $$12 I_1 = 9 - 8 I_2 \quad | :3$$ $$8 I_1 = 2 - 13 I_2 \quad | :2$$
- $$\frac{9 - 8I_2}{3} = \frac{2 - 13 I_2}{2} \quad \therefore \quad I_2 = -\frac{12}{23} A = -0.522 A$$
- $$I_1 = \frac{2 - 13 I_2}{8} \quad \therefore \quad I_1 = \frac{101}{92} A = 1.10 A$$

Solution

- $9 - 8(I_1 + I_2) - 4I_1 = 0$
  $2 - 8(I_1 + I_2) - 5I_2 = 0$
  $\Rightarrow$ $12 I_1 = 9 - 8 I_2 \quad |:3$
  $8 I_1 = 2 - 13 I_2 \quad |:2$
- $\frac{9 - 8I_2}{3} = \frac{2 - 13 I_2}{2} \quad \therefore \quad I_2 = -\frac{12}{23} A = -0.522 A^*$
- $I_1 = \frac{2 - 13 I_2}{8} \quad \therefore \quad I_1 = \frac{101}{92} A = 1.10 A$
- $P_1 = R_1 I_1^2 = 4.82 W \qquad P_2 = R_2 I_2^2 = 1.36 W$

The not-so-good news → battery 2 experiences a reverse current → very undesirable operation → "crazy" circuit