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Theory and Problems of ELECTRIC CIRCUITS

Fourth Edition

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$$\begin{aligned}
 v &= iR_1 + iR_2 + iR_3 \\
 &= i(R_1 + R_2 + R_3) \\
 &= iR_{\text{eq}}
 \end{aligned}$$

where a single equivalent resistance R_{eq} replaces the three series resistors. The same relationship between i and v will pertain.

For any number of resistors in series, we have $R_{\text{eq}} = R_1 + R_2 + \cdots$.

If the three passive elements are inductances,

$$\begin{aligned}
 v &= L_1 \frac{di}{dt} + L_2 \frac{di}{dt} + L_3 \frac{di}{dt} \\
 &= (L_1 + L_2 + L_3) \frac{di}{dt} \\
 &= L_{\text{eq}} \frac{di}{dt}
 \end{aligned}$$

Extending this to any number of inductances in series, we have $L_{\text{eq}} = L_1 + L_2 + \cdots$.

If the three circuit elements are capacitances, assuming zero initial charges so that the constants of integration are zero,

$$\begin{aligned}
 v &= \frac{1}{C_1} \int i dt + \frac{1}{C_2} \int i dt + \frac{1}{C_3} \int i dt \\
 &= \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \right) \int i dt \\
 &= \frac{1}{C_{\text{eq}}} \int i dt
 \end{aligned}$$

The equivalent capacitance of several capacitances in series is $1/C_{\text{eq}} = 1/C_1 + 1/C_2 + \cdots$.

EXAMPLE 3.3. The equivalent resistance of three resistors in series is 750.0Ω . Two of the resistors are 40.0Ω and 410.0Ω . What must be the ohmic resistance of the third resistor?

$$\begin{aligned}
 R_{\text{eq}} &= R_1 + R_2 + R_3 \\
 750.0 &= 40.0 + 410.0 + R_3 \quad \text{and} \quad R_3 = 300.0 \Omega
 \end{aligned}$$

EXAMPLE 3.4. Two capacitors, $C_1 = 2.0 \mu\text{F}$ and $C_2 = 10.0 \mu\text{F}$, are connected in series. Find the equivalent capacitance. Repeat if C_2 is 10.0 pF .

$$C_{\text{eq}} = \frac{C_1 C_2}{C_1 + C_2} = \frac{(2.0 \times 10^{-6})(10.0 \times 10^{-6})}{2.0 \times 10^{-6} + 10.0 \times 10^{-6}} = 1.67 \mu\text{F}$$

If $C_2 = 10.0 \text{ pF}$,

$$C_{\text{eq}} = \frac{(2.0 \times 10^{-6})(10.0 \times 10^{-12})}{2.0 \times 10^{-6} + 10.0 \times 10^{-12}} = \frac{20.0 \times 10^{-18}}{2.0 \times 10^{-6}} = 10.0 \text{ pF}$$

where the contribution of 10.0×10^{-12} to the sum $C_1 + C_2$ in the denominator is negligible and therefore it can be omitted.

Note: When two capacitors in series differ by a large amount, the equivalent capacitance is essentially equal to the value of the smaller of the two.

3.5 CIRCUIT ELEMENTS IN PARALLEL

For three circuit elements connected in parallel as shown in Fig. 3-4, KCL states that the current i entering the principal node is the sum of the three currents leaving the node through the branches.

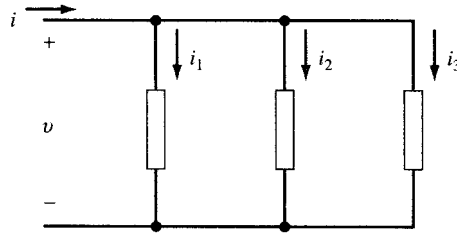


Fig. 3-4

$$i = i_1 + i_2 + i_3$$

If the three passive circuit elements are resistances,

$$i = \frac{v}{R_1} + \frac{v}{R_2} + \frac{v}{R_3} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \right) v = \frac{1}{R_{\text{eq}}} v$$

For several resistors in parallel,

$$\frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$$

The case of two resistors in parallel occurs frequently and deserves special mention. The equivalent resistance of two resistors in parallel is given by the *product over the sum*.

$$R_{\text{eq}} = \frac{R_1 R_2}{R_1 + R_2}$$

EXAMPLE 3.5. Obtain the equivalent resistance of (a) two $60.0\text{-}\Omega$ resistors in parallel and (b) three $60.0\text{-}\Omega$ resistors in parallel.

$$(a) \quad R_{\text{eq}} = \frac{(60.0)^2}{120.0} = 30.0 \, \Omega$$

$$(b) \quad \frac{1}{R_{\text{eq}}} = \frac{1}{60.0} + \frac{1}{60.0} + \frac{1}{60.0} \quad R_{\text{eq}} = 20.0 \, \Omega$$

Note: For n identical resistors in parallel the equivalent resistance is given by R/n .

Combinations of inductances in parallel have similar expressions to those of resistors in parallel:

$$\frac{1}{L_{\text{eq}}} = \frac{1}{L_1} + \frac{1}{L_2} + \cdots \quad \text{and, for two inductances,} \quad L_{\text{eq}} = \frac{L_1 L_2}{L_1 + L_2}$$

EXAMPLE 3.6. Two inductances $L_1 = 3.0 \text{ mH}$ and $L_2 = 6.0 \text{ mH}$ are connected in parallel. Find L_{eq} .

$$\frac{1}{L_{\text{eq}}} = \frac{1}{3.0 \text{ mH}} + \frac{1}{6.0 \text{ mH}} \quad \text{and} \quad L_{\text{eq}} = 2.0 \text{ mH}$$

With three capacitances in parallel,

$$i = C_1 \frac{dv}{dt} + C_2 \frac{dv}{dt} + C_3 \frac{dv}{dt} = (C_1 + C_2 + C_3) \frac{dv}{dt} = C_{\text{eq}} \frac{dv}{dt}$$

For several parallel capacitors, $C_{\text{eq}} = C_1 + C_2 + \cdots$, which is of the same form as resistors in series.