

Circuit power, induction and charged-particle motion

GRE · GRE Subject Test · GRE Physics

A resistor in a parallel branch sees the branch voltage, which can differ from the battery voltage because another resistor is in series.

Prerequisites: 2, 30.

- Solve resistor networks and distinguish rms from peak AC quantities
- Apply flux linkage, Lenz direction and the current-loop field
- Use charge-to-mass ratios and balance crossed-field forces

Choose the system and model

For steady ideal resistor circuits, series resistances add and parallel conductances add. Reduce a network while preserving which nodes share the same voltage. With a 24 V source, a 2 Ω series resistor and parallel 3 Ω and 6 Ω branches, the parallel equivalent is 2 Ω. Total current is 6 A, branch voltage is 12 V and branch currents are 4 A and 2 A. The current through every component is not necessarily the total current; verify Kirchhoff current and voltage sums after reduction.

Use the governing relation

For sinusoidal current $I = I_{\text{max}} \sin(\omega t - \varphi)$, $I_{\text{rms}} = I_{\text{max}}/\sqrt{2}$. A series RLC circuit has impedance magnitude $\sqrt{R^2 + (\omega L - 1/(\omega C))^2}$ and average dissipated power $I_{\text{rms}}^2 R = V_{\text{rms}} I_{\text{rms}} \cos \varphi$. Ideal inductors/capacitors exchange stored energy with zero average dissipation. If rms current is already given, do not insert another factor 1/2. An ideal rectifying diode conducts in its forward direction and blocks in reverse: a suitably oriented series diode clips the negative half of a sinusoidal resistor voltage; it does not create a full-wave rectifier by itself.

Apply the conditions

Magnetic flux is $\int \mathbf{B} \cdot d\mathbf{A}$, or $BA \cos \theta$ for a uniform field with θ measured from the area normal. Faraday emf is $-N d\Phi/dt$. For changing perpendicular field and fixed loop geometry, its average magnitude is $NA|\Delta B|/\Delta t$. Determine the sign or current direction using opposition to the flux change, not opposition to the field itself. The magnetic field at the centre of one circular loop is $\mu_0 I/(2R)$, obtained from Biot–Savart: every element contributes in the same axial direction. An N-turn compact coil multiplies this result by N.

Check the conclusion

For a nonrelativistic charge with velocity perpendicular to uniform B, magnetic force $|q|vB$ provides centripetal force mv^2/r . Thus $r = mv/(|q|B)$ and cyclotron angular frequency is $|q|B/m$, independent of speed in this approximation. Charge sign sets rotation direction. A deuteron has approximately twice proton mass and the same charge, while an alpha particle has four times its mass and twice its charge; their frequencies are each half the proton value. In crossed E and B fields, undeflected motion requires electric and magnetic forces opposite and $v = E/B$. Check vector directions before using this magnitude.

Worked method

A 24 V ideal source drives 2 ohms in series with parallel 3 and 6 ohm branches. Identify nodes before reducing the network.

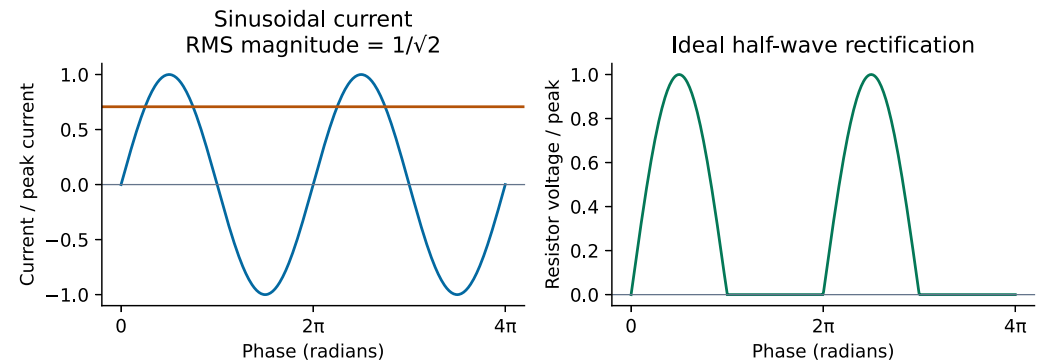
$$R_p = (1/R_1 + 1/R_2)^{-1} = (1/(3\Omega) + 1/(6\Omega))^{-1} = 2\Omega.$$

$$I = V/(R_s + R_p) = (24\text{ V})/(4\Omega) = 6\text{ A}.$$

$$V_p = IR_p = (6\text{ A})(2\Omega) = 12\text{ V}.$$

$$I_2 = V_p/R_2 = (12\text{ V})/(6\Omega) = 2\text{ A}.$$

The other branch carries 4 A; the branch currents sum to the source current.



Circuit power, induction and charged-particle motion: original GRE teaching diagram.

Check conditions and vocabulary

Do not apply battery voltage to every branch or halve an rms-current power again. Flux angle uses the area normal; a selector also needs opposing force directions.

root mean square: Square root of the mean squared value, used for effective AC current or voltage.

flux linkage: Sum of magnetic flux through a coil's turns.