

Circuit power, induction and charged-particle motion

GRE undergraduate preparation · local supported objectives

Choose the physical question

Reasoning

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

Reasoning

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 $2\ \Omega$ series resistor and parallel $3\ \Omega$ and $6\ \Omega$ branches, the parallel equivalent is $2\ \Omega$. 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

Reasoning

For sinusoidal current $I = I_{\max} \sin(\omega t - \phi)$, $I_{\text{rms}} = I_{\max} / \sqrt{2}$. A series RLC circuit has impedance magnitude $\sqrt{R^2 + (\omega L - 1/(\omega C))^2}$ and average dissipated power $I_{\text{rms}}^2 R = V_{\text{rms}} I_{\text{rms}} \cos \phi$. 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

Reasoning

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

Reasoning

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 reasoning 1

Reasoning

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

Worked relation 2

Reasoning

Apply this relation only under the conditions just stated.

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

Worked relation 4

Reasoning

Apply this relation only under the conditions just stated.

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

Worked relation 6

Reasoning

Apply this relation only under the conditions just stated.

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

Worked relation 8

Reasoning

Apply this relation only under the conditions just stated.

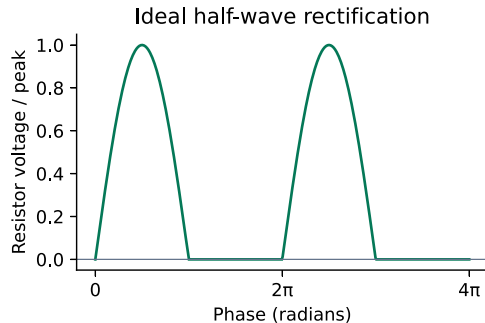
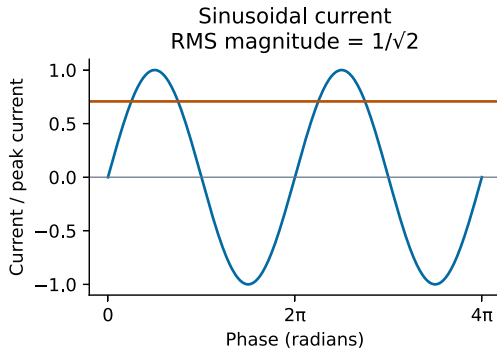
$$I_2 = V_p/R_2 = (12\text{ V})/(6\,\Omega) = 2\text{ A}.$$

Worked reasoning 9

Reasoning

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

Read the original diagram



- Original GRE teaching diagram: Circuit power, induction and charged-particle motion
- Identify the axes, units, directions and the stated model.

Independent transfer · attempt

Reasoning

A square N -turn loop of side a moves at speed v out of a uniform field B normal to its plane. Its total resistance is R . While one edge is crossing the straight field boundary, find the emf magnitude, current and required pulling force at constant speed. Verify mechanical input power equals resistor power. Neglect inductance. **[5]**

Independent transfer · reasoning

Reasoning

Flux linkage changes at rate $NBav$, so $|\mathcal{E}| = NBav$ and $I = NBav/R$. The N edges still in the field give opposing force $F = NlaB = N^2 B^2 a^2 v/R$. $Fv = N^2 B^2 a^2 v^2/R = I^2 R$; external work supplies the resistor heat. Lenz's law sets the force opposite motion. Award flux rate, emf/current, force, power check and direction. These results hold only during boundary crossing.

Check assumptions and limits

Reasoning

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.

Keep the technical distinctions

Reasoning

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.

Check yourself

- Define root mean square and give its condition of use.
- Define flux linkage and give its condition of use.
- Redo the original transfer with a changed parameter; check a limiting case.