

14.1 Circuit power, induction and charged-particle motion

Name: _____ Class: _____ Date: _____

Total: 11 marks**KEY WORDS** root mean square • flux linkage

Objective

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. Original public practice; not an ETS paper.

1 Key knowledge and worked examples

Series resistances add; parallel conductances add. In the 24 V example, 3 Ω parallel 6 Ω gives 2 Ω . Adding series 2 Ω gives total 4 Ω and current 6 A. Branch voltage is 12 V, so currents are 4 A and 2 A. Check both Kirchhoff sums.

Sinusoidal $I_{\text{rms}} = I_{\text{max}}/\sqrt{2}$. Series RLC impedance is $\sqrt{R^2 + (\omega L - 1/(\omega C))^2}$, and average dissipated power is $I_{\text{rms}}^2 R = V_{\text{rms}} I_{\text{rms}} \cos \varphi$. Ideal L and C have zero average dissipation. An ideal single diode gives half-wave pulses, with polarity set by orientation; do not halve rms power again.

Flux is $BA \cos \theta$ for uniform B, with θ from the area normal. Faraday emf is $-N d\Phi/dt$; perpendicular-field average magnitude is $NA|\Delta B|/\Delta t$. Lenz direction opposes the flux change. The centre field of a circular loop is $\mu_0 I/(2R)$, multiplied by N for a compact N-turn coil.

For nonrelativistic perpendicular motion, $r = mv/(|q|B)$ and cyclotron angular frequency $|q|B/m$. Charge sign sets rotation. Deuteron and alpha frequencies are each half the proton value at fixed B. A crossed-field selector requires opposing electric/magnetic forces and $v = E/B$.

■ 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.

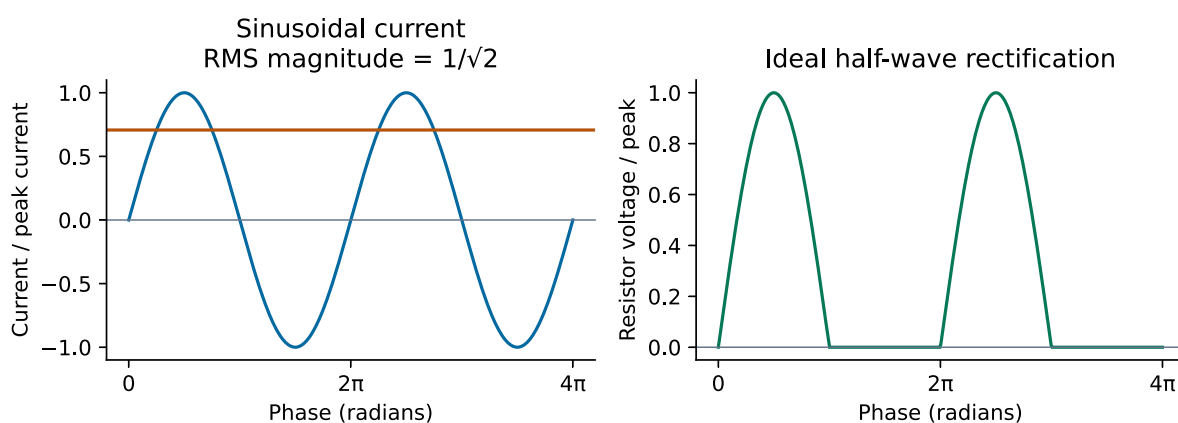
$$R_p = (1/R_1 + 1/R_2)^{-1} = (1/(3\Omega) + 1/(6\Omega))^{-1} = 2\Omega.$$

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

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

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

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



2 Practice

2.1 Choose one answer. In the worked 24 V resistor network, current through the 6 Ω branch is: [1]

- A 12 A
- B 6 A
- C 4 A
- D 2 A
- E 1 A

2.2 Choose one answer. A series RLC circuit has $I_{\text{rms}}=3$ A and $R=4$ Ω . Its average dissipated power is: [1]

- A 18 W
- B 36 W
- C 72 W
- D 12 W
- E 9 W

2.3 At fixed B, an ion with proton charge and three times proton mass has cyclotron frequency _____ times the proton frequency (fraction). Show your relation and units. [2]

Solutions

2.1 D The parallel branches have 12 V, so the 6 Ω branch carries $12/6=2$ A.

Compare the rejected options: 12 A; 6 A; 4 A; 1 A. Use the stated model and conditions.

2.2 B $I_{\text{rms}}^2 R = 9 \cdot 4 = 36$ W; no extra half factor applies to rms current.

Compare the rejected options: 18 W; 72 W; 12 W; 9 W. Use the stated model and conditions.

2.3 $1/3$. Angular frequency is $|q|B/m$.

2.4 True. It conducts in one polarity and blocks in the other.

3.1 Flux linkage changes at rate $NBav$, so $|\mathcal{E}| = NBav$ and $I = NBav/R$. The N edges still in the field give opposing force $F = NIaB = N^2B^2a^2v/R$. $Fv = N^2B^2a^2v^2/R = I^2R$; 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.