Unit 19 · Alternating Current

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 32

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Spot the error

ANSWER U · 3

He used the inductor's form. A capacitor's reactance falls as f and C grow:

$X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi \times 50 \times 20 \times 10^{-6}} = \mathbf{159}\ \Omega$. A check: a few milliohms would let a capacitor pass mains current almost as a wire, which it doesn't.

MARKING SCHEME

- ✓ The error: $X_C = 1/(2\pi fC)$, not $2\pi fC$.
- ✓ Correct substitution.
- ✓ $X_C = 159\ \Omega$.

2 Read the data

ANSWER HA · 4

(The readings are made up, for C = 1.6 μF and R = 50 Ω.)

i. About **400 Hz**, where the current is greatest.

ii. $C = \dfrac{1}{4\pi^2 f_0^{\,2} L} = \dfrac{1}{4\pi^2 \times 400^2 \times 0.10} = \mathbf{1.6\ \mu F}$.

iii. At resonance Z = R: R = 5.0 ÷ 0.100 = **50** Ω.

iv. Below f_0, X_C ($\propto$ 1/f) grows fast as f falls; above it, X_L ($\propto$ f) grows only in proportion. So on a frequency scale the current falls off more steeply on the low side.

MARKING SCHEME

- ✓ f_0 about 400 Hz.
- ✓ C = 1.6 μF.
- ✓ R = 50 Ω.
- ✓ The two reactances change differently with f (1/f against f).

3 Predict, then explain

MARKING SCHEME U · 3

- ✓ On a.c. the lamp dims.
- ✓ The iron raises L, so X_L and Z rise.
- ✓ On d.c. no lasting change: no reactance for a steady current.

4 Show that

MARKING SCHEME A · 3

- ✓ rms = $\sqrt{}$(mean of I^2).
- ✓ Mean of $I^2 = I_0^{\,2}/2$.
- ✓ $I_{\text{rms}} = I_0/\sqrt{2}$.

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5 A real setting

ANSWER A · 3

i. $P = V_{rms} I_{rms} \cos\varphi = 230 \times 10 \times 0.80 =$ **1840 W**.

ii. $I = 1840 \div 230 =$ **8.0 A**.

iii. A low power factor needs a larger current for the same useful power, and the lines heat by I^2R, so more power is lost in the wires and transformers for nothing.

MARKING SCHEME

✓ P = 1840 W.

✓ 8.0 A at a power factor of 1.

✓ More current for the same power, so more I^2R loss.

6 Which explanation fits?

MARKING SCHEME U · 2

✓ Gita.

✓ No charge crosses the gap: more cycles a second move more charge on and off the plates.

7 Correct the misconceptions

ANSWER U · 3

1. 230 V is the **rms** value; the peak is $\sqrt{2} \times 230 \approx 325$ V.
2. At resonance V_L and V_C are equal and opposite and cancel, but each can be **large**, many times the supply voltage (Q times it).
3. The power is $V_{rms} I_{rms} \cos\varphi$; it equals $V_{rms} I_{rms}$ only when the current and voltage are in phase.

MARKING SCHEME

✓ 230 V is the rms value (peak about 325 V).

✓ At resonance V_C is not zero; it cancels V_L.

✓ $P = V_{rms} I_{rms} \cos\varphi$.

8 Work backwards

ANSWER A · 3

$C = \dfrac{1}{4\pi^2 f_0^2 L} = \dfrac{1}{4\pi^2 \times (10^8)^2 \times 0.25 \times 10^{-6}} =$ **1.0×10^{-11} F** (10 pF). Since $f_0 \propto 1/\sqrt{C}$, a higher frequency needs a **smaller** capacitance.

MARKING SCHEME

✓ $C = 1/(4\pi^2 f_0^2 L)$.

✓ C = 10 pF.

✓ Smaller, since $f_0 \propto 1/\sqrt{C}$.

9 Design it

ANSWER A · 4

i. A **capacitor with the tweeter**: its reactance is large at low frequencies and small at high ones, so it blocks the low notes. A **coil with the woofer**: its reactance grows with frequency, so it blocks the high notes.

ii. $C = \dfrac{1}{2\pi f X_C} = \dfrac{1}{2\pi \times 3000 \times 8} =$ **6.6 µF**; $L = \dfrac{X_L}{2\pi f} = \dfrac{8}{2\pi \times 3000} =$ **0.42 mH**.

MARKING SCHEME

✓ Capacitor with the tweeter (blocks low frequencies).

✓ Coil with the woofer (blocks high frequencies).

✓ C = 6.6 µF.

✓ L = 0.42 mH.

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10 What if?

ANSWER HA · 2

$f_0 = 1/2\pi\sqrt{LC}$ has no R, so it **stays the same**. At resonance Z = R, so the current **halves**.

$Q = \frac{1}{R}\sqrt{L/C}$ halves too, so the resonance curve becomes **broader** (less sharp).

MARKING SCHEME

✓ f_0 unchanged; the current halves.

✓ Q halves: a broader, less sharp resonance.

11 Make your own

ANSWER HA · 2

For example: "A 0.10 H coil is in series with a 1.0 μF capacitor. Find the resonant frequency."

$f_0 = \frac{1}{2\pi\sqrt{0.10 \times 1.0 \times 10^{-6}}} = 503$ Hz, about 500 Hz. Any L and C with LC = 1.0×10^{-7} s^2 is right.

MARKING SCHEME

✓ A sensible problem.

✓ Solved correctly with $f_0 = 1/(2\pi\sqrt{LC})$.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	11	13	8	**32**

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