

task_nyniewamxfshpuwt_with_calculation

Student Group

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resonance, resonant circuit, RMS, exam ee2 SS2021

Exercise E24 Resonant Circuit**(written test, approx. 4 % of a 120-minute written test, SS2021)**

5) Given a resonant RLC circuit that is fed by a sine wave of the voltage $U_{\text{rms}} = 12 \text{ V}$ (see the circuit diagram on the right). The capacitance $C = 20 \text{ nF}$ and the inductance $L = 20 \text{ mH}$ are fixed. The resistance R can be varied.

$$U_{\text{rms}} = 12 \text{ V} \cdot \sin(2\pi \cdot f_0 \cdot t)$$

$$R_i = 200 \text{ m}\Omega$$

$$R = 205.5 \text{ m}\Omega$$

$$C = 30 \text{ nF}$$

For the following calculation, the internal resistance R_i and the resistance R have to be combined:
$$R_{\Sigma} = R_i + R$$

Here, either one knows that the gain factor Q stands for $Q = \frac{U_C}{U_{\text{rms}}}$ and therefore can directly use the following formula:
$$Q = \frac{U_C}{U_{\text{rms}}} = \frac{1}{R_{\Sigma}} \sqrt{\frac{L}{C}}$$

$$R_{\Sigma} = \frac{U_{\text{rms}}}{U_C} \sqrt{\frac{L}{C}}$$

When the gain factor is not known, one has to derive it:

The voltage U at resonance is only given by the total ohmic resistance R_{Σ} and the source voltage U_{rms} :
$$I = \frac{U_{\text{rms}}}{R_{\Sigma}}$$

This current flow also through the impedance of the capacitor
$$U_C = Z_C \cdot I = \frac{1}{\omega C} \cdot I = \frac{U_{\text{rms}}}{\omega C R_{\Sigma}}$$

At resonance, the angular frequency ω is given by $\omega = \frac{1}{\sqrt{LC}}$

$$U_C = \frac{U_{\text{rms}}}{\frac{1}{\sqrt{LC}} R_{\Sigma}} = \frac{U_{\text{rms}} \sqrt{LC}}{R_{\Sigma}}$$

$$R_{\Sigma} = \frac{U_{\text{rms}} \sqrt{LC}}{U_C}$$

6) What is the resonance frequency f_0 ?

Path

In both cases, we end up with the same formula, where we have to insert the physical values:
$$R_{\Sigma} = \frac{U_{\text{rms}}}{U_C} \sqrt{\frac{L}{C}} = \frac{1}{4} \sqrt{\frac{20 \cdot 10^{-3}}{30 \cdot 10^{-6}}}$$

$$f_0 = \frac{1}{2\pi \sqrt{LC}} = \frac{1}{2\pi \sqrt{20 \cdot 10^{-3} \cdot 30 \cdot 10^{-6}}} = 6.25 \text{ kHz}$$

And so, the resistance R is:
$$R = R_{\Sigma} - R_i = 6.25 \text{ kHz} - 200 \text{ m}\Omega$$

$$R = 6.25 \text{ kHz} - 200 \text{ m}\Omega = 6.25 \text{ kHz} - 0.2 \text{ kHz} = 6.05 \text{ kHz} = 6050 \text{ }\Omega$$

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