

task_ludzwiuhjxitz85b_with_calculation

Student Group

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induction, flux, induced voltage, exam ee2 SS2021

Exercise E1 effect of induction

(written test, approx. 5 % of a 120-minute written test, SS2021)

A single conductor loop is penetrated by a changing magnetic flux.

The following figure shows the variation of the flux $\Phi(t)$ over time.

Calculate the variation of the induced voltage $U_{\text{ind}}(t)$ over time and draw it in a separate diagram.

\$\$u_{\text{ind}}(t) = - \frac{d\Phi(t)}{dt} = - \frac{d}{dt} \left(\frac{1}{2} t^2 \right) = - t

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Path

Based on Faraday's Law of Induction the induced voltage is given by:
$$U_{\text{ind}} = - \frac{d\Phi(t)}{dt} = - \frac{d}{dt} \left(\frac{1}{2} t^2 \right) = - t$$

For a linear function, the derivative can be substituted by Δ ($\frac{d}{dt} \rightarrow \frac{\Delta}{\Delta t}$):

$$U_{\text{ind}} = - \frac{\Delta \Phi(t)}{\Delta t} = - \frac{\Phi(t_{n+1}) - \Phi(t_n)}{t_{n+1} - t_n} = - \frac{\frac{1}{2} t_{n+1}^2 - \frac{1}{2} t_n^2}{t_{n+1} - t_n} = - \frac{1}{2} (t_{n+1} + t_n)$$

For a piece-wise linear function, the induced voltage can be calculated for each interval.

Here, there are 5 different intervals - in the following called I to V from left to right:

$\dots$

- For the intervals I , III , and V , the flux $\Phi(t)$ is constant. Therefore, $\Delta \Phi(t) = 0$ and $U_{\text{ind}}(t) = 0$ for V .

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- For the interval Δt :
 - The change in the flux is: $\Delta \Phi(t) = 1.5 \cdot 10^{-4} \text{ Vs} - 4.5 \cdot 10^{-4} \text{ Vs} = -3.0 \cdot 10^{-4} \text{ Vs}$
 - The time span is: 0.2 s
 - Conclusively, the induced voltage is: $U_{\text{ind}}(t) = + \frac{3.0 \cdot 10^{-4} \text{ Vs}}{0.2 \text{ s}} = 1.5 \text{ mV}$

- For the interval Δt :
 - The change in the flux is: $\Delta \Phi(t) = 0 \cdot 10^{-4} \text{ Vs} - 1.5 \cdot 10^{-4} \text{ Vs} = -1.5 \cdot 10^{-4} \text{ Vs}$
 - The time span is: 0.2 s
 - Conclusively, the induced voltage is: $U_{\text{ind}}(t) = + \frac{1.5 \cdot 10^{-4} \text{ Vs}}{0.2 \text{ s}} = 0.75 \text{ mV}$

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