A toroidal transformer core is made of ferrite whose magnetization curve is represented in figure 1. In the transformer is built an airgap whose length $l_g$ is a thousandth of the core length $l_m$

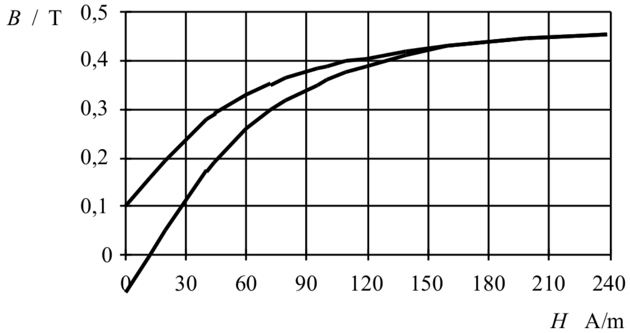


Figure 1: Ferrite magnetization curve.

Draw the B-H curve of the airgaped magnetic circuit and calculate the value of the remanence $B_r$. The airgap's surface area $A_g$ can be considered as large as the core surface area $A_{core}$
The remanence is the value of $B$ when $H \to 0$
The vacuum permeability is $\mu_0 = 4\pi \times 10^{-7}$H/m (or Vs.(Am)$^{-1}$)
The flux is

$$\Phi = B_2 A_{core} = B_g A_g \tag{1}$$

Where $B_2$ is the magnetic flux density of the ferrite core with the airgap.
The flux density is given by

$$B = \mu_m H \tag{2}$$

The magnetic permeability is

$$\mu_m = \mu_r \mu_0 \tag{3}$$

and the magnetomotive force is

$$F_m = H_1 l_m = H_2 l_m + H_g l_g \tag{4}$$

where $H_1$ is the magnetic field density of the ferrite core without airgap and $H_2$ with airgap, and $H_g$ the magnetic field density in the airgap.

# Exercise 2

A flyback converter works in the demagnetizing area, i.e. the magnetization of the transformer goes to zero before the next cycle. This region corresponds to discontinuous conduction mode (DCM) where the instantaneous output current goes to zero during the switching period.

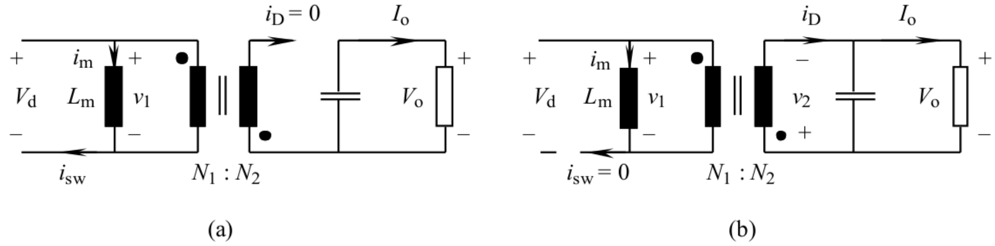


Figure 2: Flyback converter when (a) the switch conducts and (b) the switch does not.

Prove that in DCM the voltage ratio $V_o/V_d$ can be written as

$$\frac{V_o}{V_d} = D\sqrt{\frac{R}{2L_m f_s}} \tag{5}$$

and in Continuous conduction mode (CCM)

$$\frac{V_o}{V_d} = \frac{N_2 D}{N_1 \Delta_1} = \frac{N_2}{N_1}\frac{D}{1-D} \tag{6}$$

where $R$ is the load resistance, $f_s$ the switching frequency, $L_m$ the transformer inductance and $D$ the duty cycle.

## Exercise 3

Using the previous exercise, calculate the maximal value of the magnetizing inductance $L_m$ that keeps the converter working in the demagnetizing area. The numerical values are: $N_1 : N_2 = 1$, $f_s = 200$kHz, $V_o = 12$V, $12 \leq V_d \leq 24$V, the output power $6 \leq P_o \leq 60$W