Test Examination: Mechatronics and Electrical Drives

08.01.2014

First Name:	Student number:
Last Name:	
Course of Study:	

Exercise: (Points)	1 (20)	2 (20)	3 (20)					Total (60)

Duration: 90 Minutes

Permitted:

• a self-created, handwritten sheet of formulas (1 sheet A4, inscribed on one side, no copies or prints)

• a non-programmable calculator without graphic display

• drawing materials (compasses, protractor, ruler, pens ...)

Please bring your student ID card (with photo)!

Please label each exam sheet with your name and student number. Use for each task a new exam sheet. Do not use pencils or red pens.

All solutions must be clearly documented and wherever required explained! The entry of a mere final result without any approach will not be counted.

Good Luck!

Exercise 1: Basic Magnetics **(20 Points)**

For the circuit shown in Figure. 1, calculate the following , when the voltage source V_s has a voltage waveform as shown in figure 2. (Neglect the winding resistance, μ_r of the core is 10,000 and other parameters are given in the figure. neglect the fringing effects and assume that all the flux generated links both the windings)

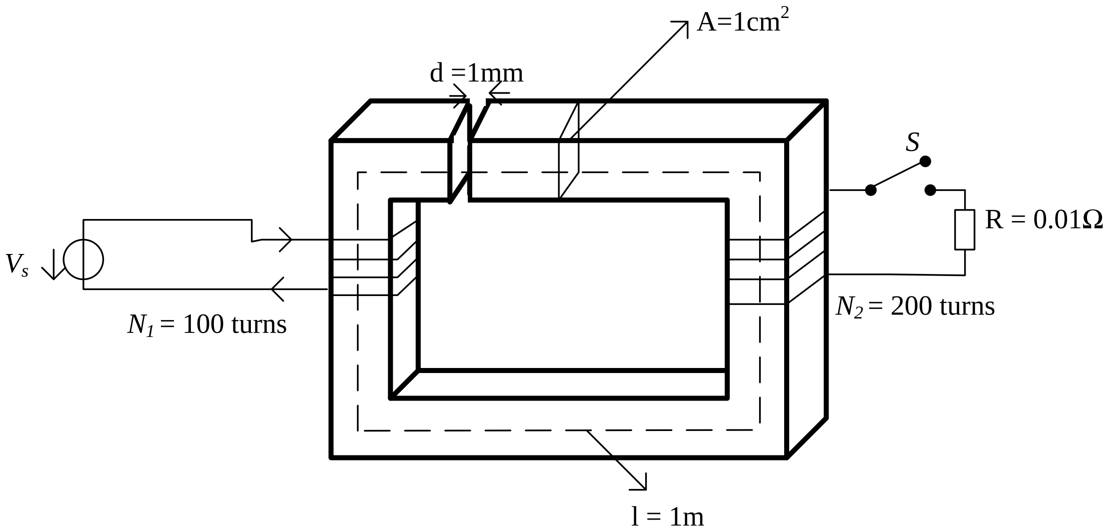


Figure. 1

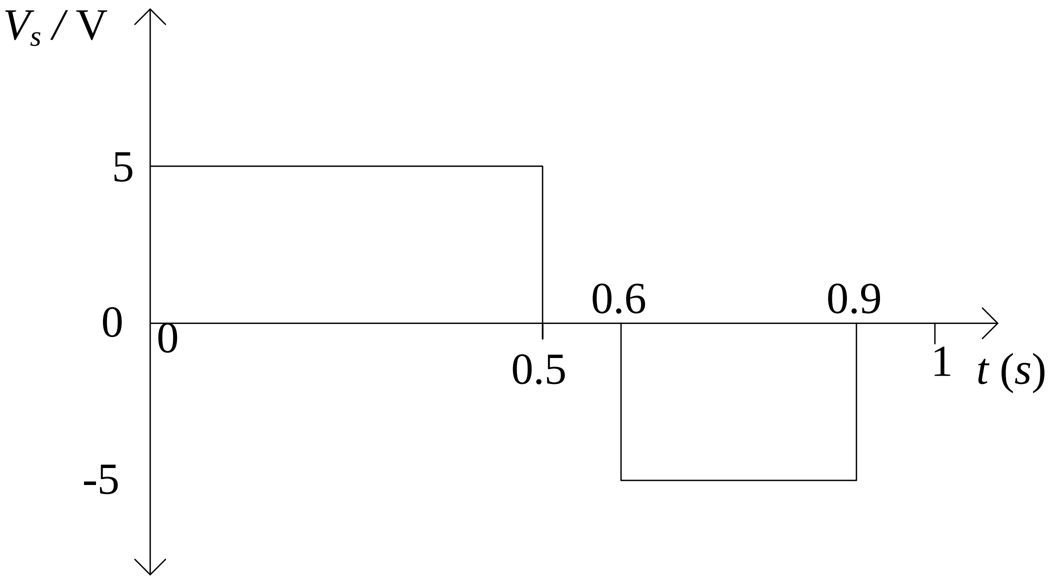


Figure. 2 input voltage waveform

1.1 For the case, with switch *S* open:

a) Calculate the inductance when seen from the primary side (left hand side).

b) Draw the waveform of flux in the core and the primary current waveform, from time t = 0 s to t = 1s. Please use the sheets provided for drawing these waveforms

c) Calculate the value of flux density at the end of 200 ms

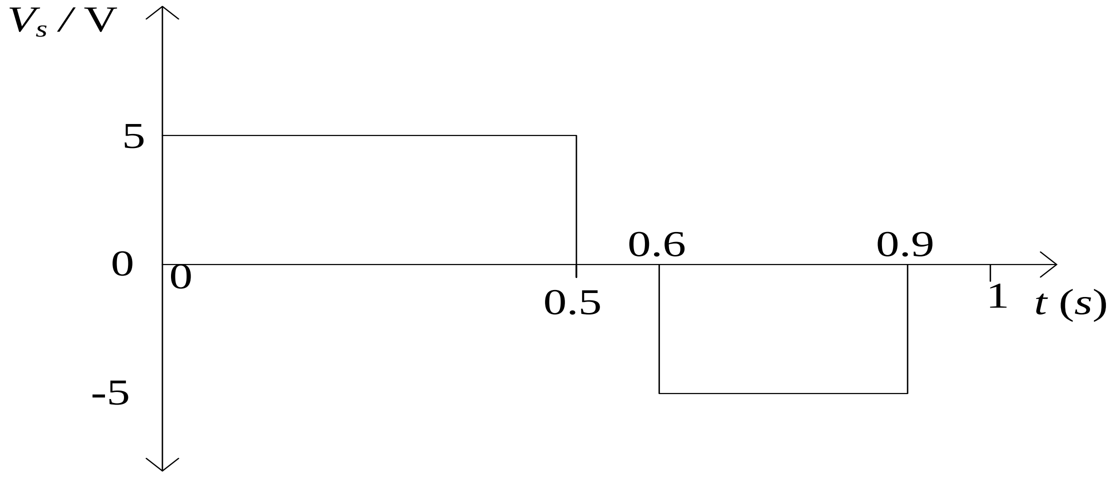
1.2 For the case, with switch S closed:

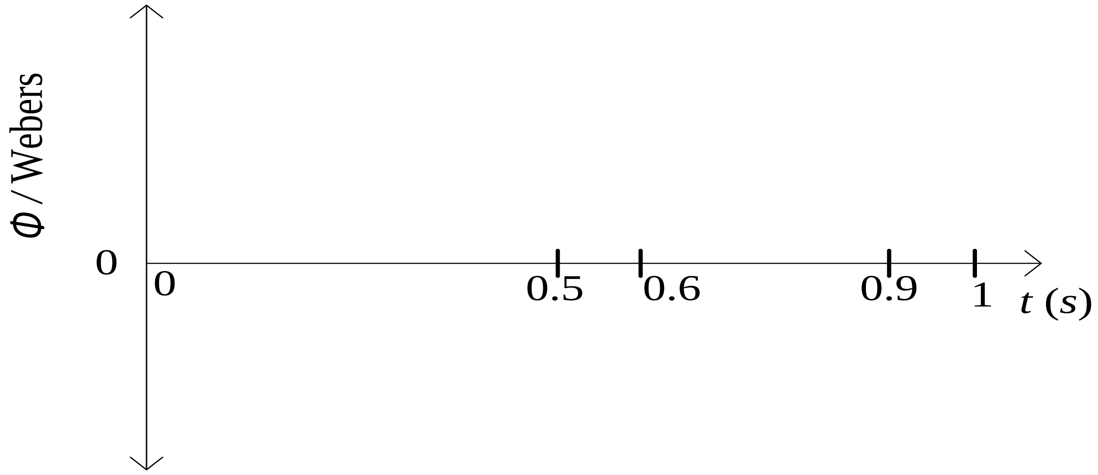
a) Calculate the inductance when seen from the primary side (left hand side).

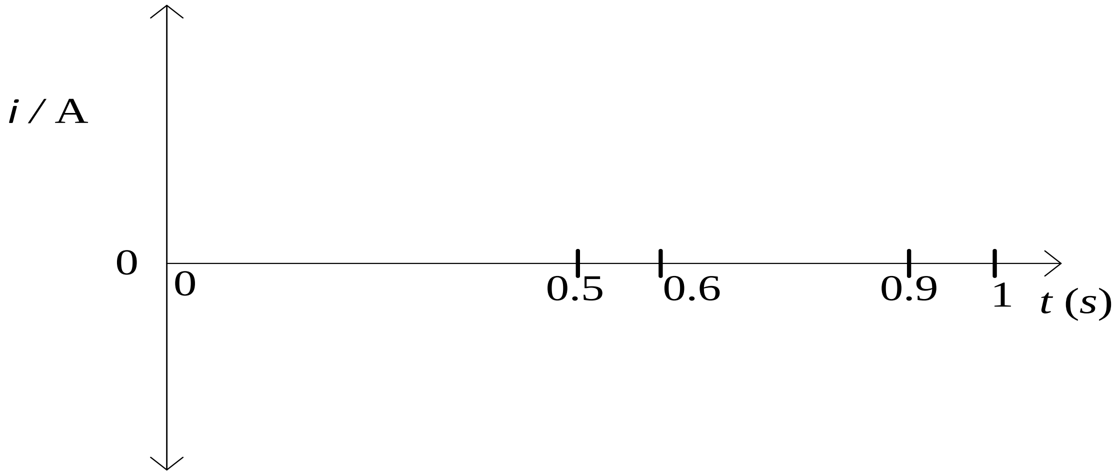
b) Draw the waveform of flux in the core and the primary current waveform, from time t = 0 s to t = 1 s. Please use the sheets provided for drawing these waveforms.

c) Calculate the value of flux density in the core at the end of 200 ms.

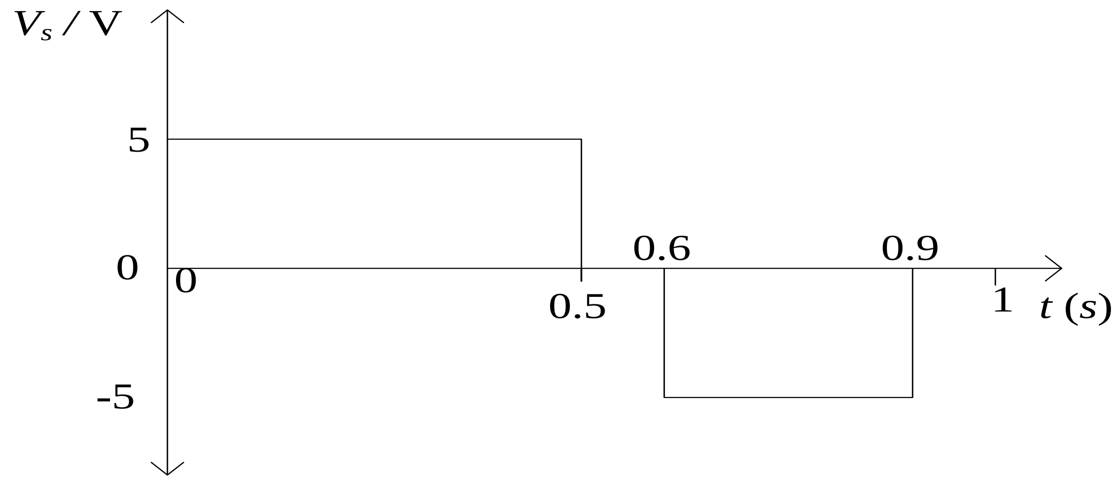
Answer 1.1: For the case, with switch S open

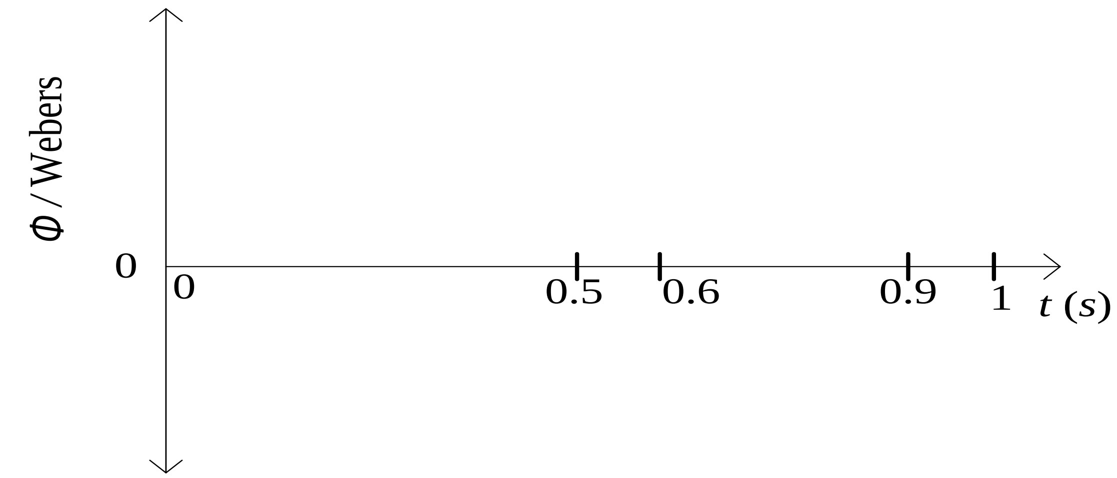


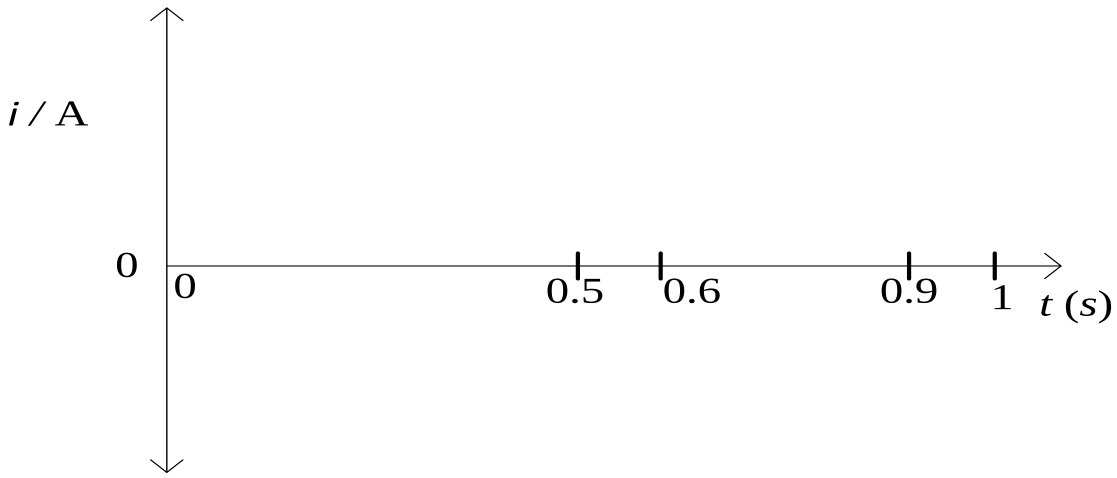




Answer 1.2: For the case, with switch S closed,

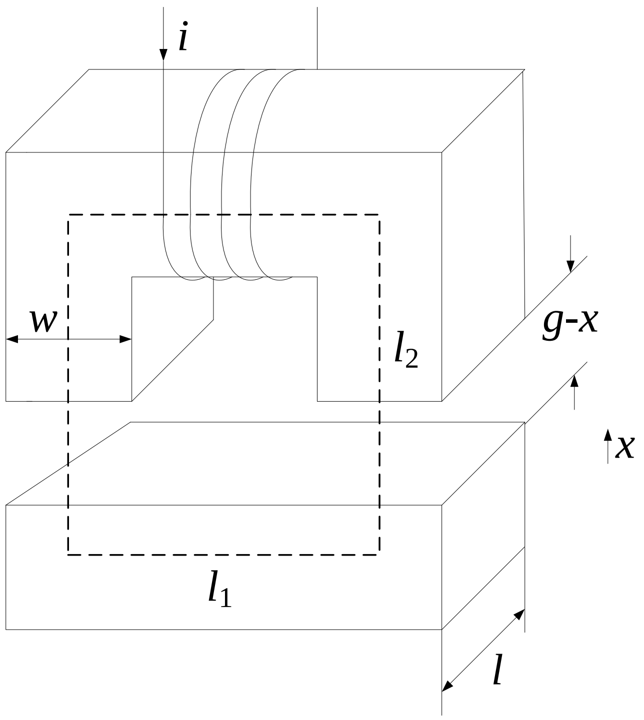






Exercise 2: Magnetic Bearing **(20 Points)**

Figure below depicts an electromagnet used to suspend an I-shaped core with a magnetic force. The C-core has a width *w* and a length *l*. The main flux path is indicated by a dotted line. The length of the flux paths in the C and I -cores are represented by l_1 and l_2. The winding has *N* turns with the current value as *i*. The airgap length is *g* at the nominal position. At a displacement *x*<<*g*, as shown in the figure, obtain the following:



2.1 Assume the core permeability to be μ_r. Evaluate the various reluctances and obtain the equivalent magnetic circuit.

2.2 Now consider the cores to be ideal ($\mu_r = \infty$). Evaluate the various reluctances with this assumption and obtain the following:

Hint: Use $\frac{1}{g-x} = \frac{1}{g}\left(1 + \frac{x}{g}\right) for\ x \ll g$, wherever required

a) The flux linkage in the coil

b) Inductance of the coil

c) Flux density in the air-gap

d) Energy and Co-energy

e) Force experienced by the I-core. Indicate the direction of force. How can the direction of the force be reversed?

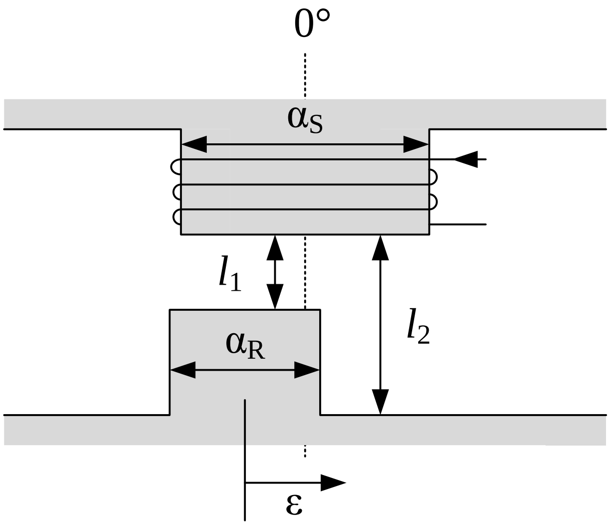
f) Is the system inherently stable? Explain. If not, how can the system be stabilized? Explain.

Exercise 3: Reluctance Motor **(20 Points)**

The figure below depicts a segment of a reluctance motor. The lower rotor pole is moving at a constant speed under an energized stator pole. The dimensions of the air gap are l_1 = 1 mm and l_2 = 2.5 mm. The dimensions of the motor are listed as:

$\alpha_S = 50°$, $\alpha_R = 25°$, $A_S = 800\ \text{mm}^2$, $A_R = 400\text{mm}^2$, $i = 35$ A, $N = 10$

Note: Assume that the magnetic field is oriented in the vertical direction. The reluctance the stator and rotor iron can be neglected.



3.1 Set up the equations for the air-gap reluctance as a function of the angle ε :

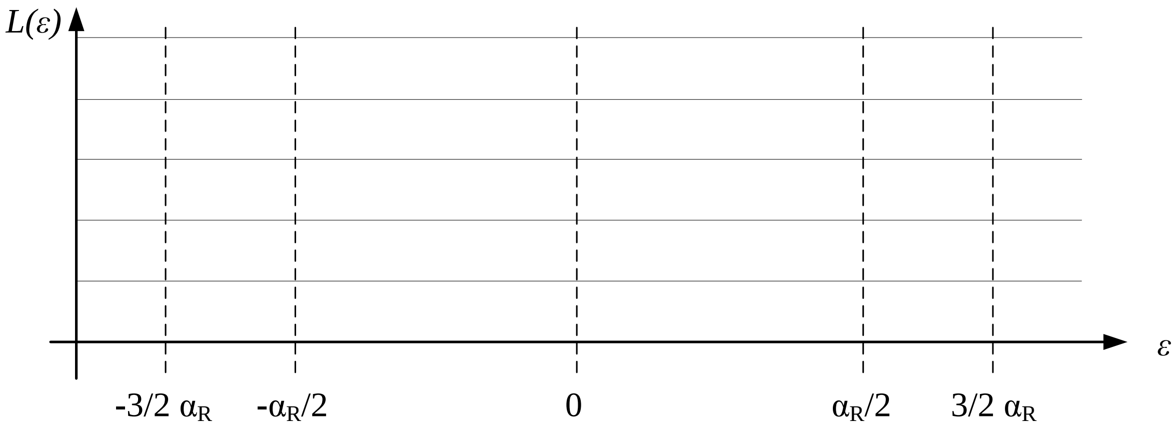
a) in the non-aligned position ($\varepsilon = \alpha$)

b) in the fully aligned position ($\varepsilon = 0°$)

c) during transition ($-3/2\ \alpha_R < \varepsilon < -\alpha_R/2$)

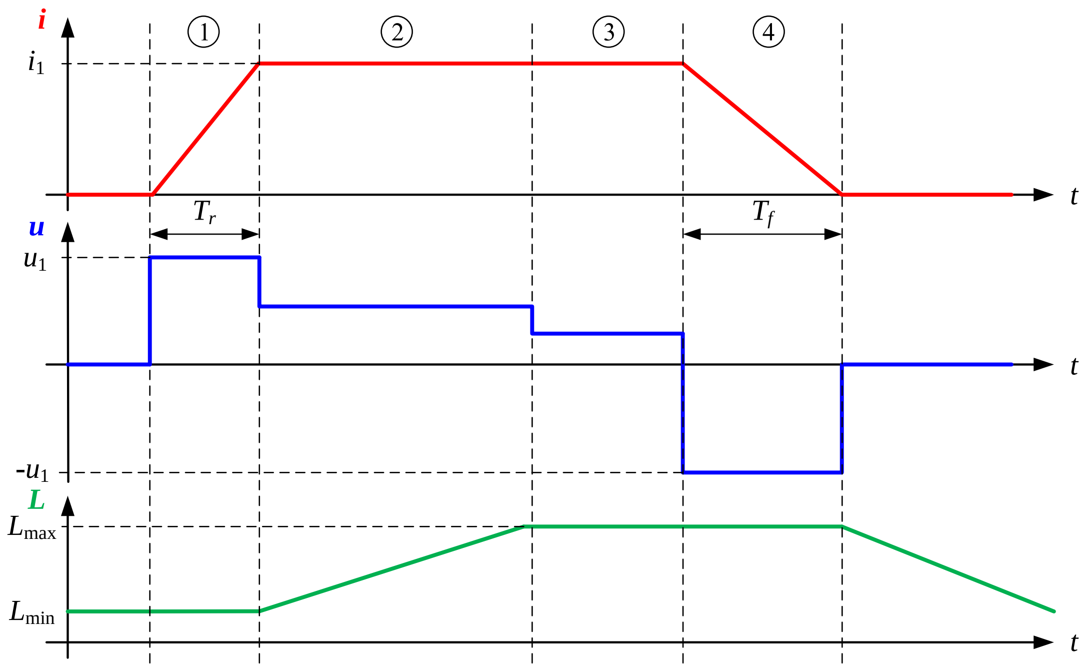
d) Sketch the variation of the air gap reluctance for a complete electrical cycle.

3.2 Calculate the torque and sketch the variation of inductance as a function of the angle ε in the graph on the next page.



The following questions are independent of the machine configuration and can be answered without results from the previous task!

3.3 a) Explain the following characteristic curves of a reluctance motor for the different sub-intervals 1, 2, 3 and 4.



b) Calculate the magnetization and demagnetization times T_r und T_f, with the following values: u_1 = 250 V, i_1 = 35 A, L_{min} = 1 mH, L_{max} = 2,75 mH

Note: The ohmic resistance can be neglected.

3.4 Is material with a non-linear magnetization behavior in a reluctance motor advantageous? Give reasons for your answer!

3.5 Why does an asymmetric half-bridge converter instead of a four quadrant converter enough for supplying a reluctance motor? Explain.