ELEC-C8407 Electromechanics, examination 12.3.2018, 16.30-19.30, AS2.

1. Explain the following concepts, use drawings and equations when adequate.
   a) Describe the construction and operation principles of a synchronous generator. (Stator, rotor, windings, frequencies, etc…) (2 p.)
   b) Draw the complete single-phase equivalent circuit of a transformer and explain what each of its component represents (2p.)
   c) List the starting methods for a 3-phase synchronous motor. (Why they are needed?) (2 p.)
   d) Explain the Eddy-current and Hysteresis phenomena in electrical steel (what are they? what do they affect?) (2 p.)
   e) A 3-phase, 2-pole induction machine is fed from a 50 Hz supply. What is the rotational speed of the stator flux, rotor flux, and air gap flux in the stator reference frame (2 p.)
   f) Explain how the power factor of a synchronous machine can be controlled, while the machine is delivering a constant active power. Draw the phasor diagram of the machine at unity power factor and lagging power factor (hint: use the terminal voltage as reference, 0 deg) (2p.).

2. In the magnetic circuit of Fig. 1, the relative permeability of the core is μ_r=1200. All dimensions are in centimeters, and the magnetic material has a square cross section area. Neglect fringing and magnetic leakage. Use the dashed line as the average magnetic flux path.
   a) Draw the magnetic equivalent circuit and calculate its parameters (2 p.)
   b) Calculated the air gap flux and flux density (2 p.)
   c) Calculate the force acting on one of the air gap ferromagnetic surfaces. (2 p.)

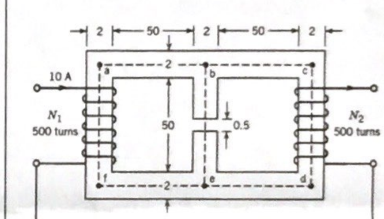

Fig. 1: *Simplified inductor.*

3. Explain by answering the questions bellow the tests needed to determine the parameters of the equivalent circuit of an induction machine (Fig. 2).
   a) List and explain the connections for the tests. (2 p.)
   b) Draw the equivalent circuits under the tests conditions. (2 p.)
   c) What are the voltages, currents and frequencies for each test, with respect to the nominal values? (2 p.)

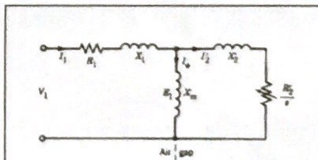

Fig. 2: Equivalent circuit of an induction machine.

4. A 2-pole DC-motor connected to 345 V supply draws 39 A current and produces 11 kW mechanical power at 1500 rpm.
   a) Calculate the mechanical torque, and resistive losses in armature winding (R_a=0,8706 Ω) (2p.)
   b) Calculate the input power of the motor and its efficiency (neglect all other losses) (2 p.)
   c) Calculate the back electromotive force E_a when the flux factor at nominal field current is k_ϕ=1,895 Vs/rad (2 p.)

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Evaluation:

Grade	Lower limit	Upper limit
0	0	13
1	14	16
2	17	19
3	20	22
4	23	26
5	27	30

Some useful formulas and drawings:

Magnetic reluctance: $\Re = \frac{l}{\mu A}$

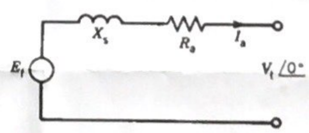
Magnetomotive force: $F = Ni$

Force pressure: $F_m = \frac{B_g^2}{2\mu_0}$

Speed of AC-machine: $n = \frac{120 f}{p}$ (p is the number of poles!)

Slip of induction machine: $s = \frac{n_s - n}{n_s}$

Equivalent circuit of a synchronous generator:



Real power of a synchronous machine: $P_{3\phi} = \frac{3|V_t||E_f|}{|X_s|} \sin\delta = P_{max} \sin\delta$

Imaginary/Reactive power of a synchronous machine: $Q_{3\phi} = \frac{3|V_t||E_f|}{|X_s|} \cos\delta - \frac{3|V_t|^2}{|X_s|}$

Convention: lagging reactive power positive -- > phase angle of current negative

AC active power: $P = 3V_{ph} I_{ph} \cos\phi = \sqrt{3} VI \cos\phi$

Magnetic permeability: $\mu = \mu_r \mu_0$; $\mu_0 = 4\pi 10^{-7}\ Hm^{-1}$

For an asynchronous machine, we can write the rotor resistance part as: $\frac{R_2'}{s} = R_2' + \frac{(1-s)R_2'}{s}$

Back emf and torque of a DC machine: $E_a = k_\phi \omega_m$; $T = k_\phi I_a$