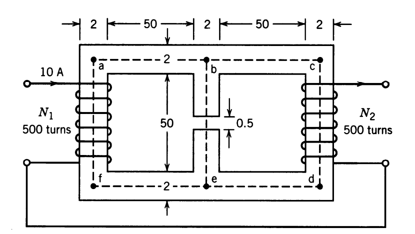
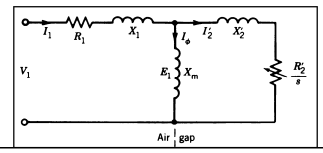
1. Explain the following concepts, use drawings and equations when adequate.
   a) Construction and operation principles of a synchronous generator. (Stator, rotor, windings, frequencies, armature current, etc…) (2 p.)
   b) List the loss components in an asynchronous motor. Explain why and where they occur. (2 p.)
   c) Explain the three running modes of operation of an induction machine by drawing the Torque-Speed/Slip curve and give the range of the slip for each mode of operation (2 p.)
   d) What are the necessary conditions for connecting (synchronizing) a running synchronous generator to the infinite bus? What happens if any of them is not satisfied and why? (2 p.)
   e) Explain how the voltage builds-up in a self-excited (shunt) DC-generator and list the three conditions necessary for this voltage to build-up (hint: magnetization curve, remanence) (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 simplified inductor of the figure, the relative permeability of the core is 1200. All dimensions are in centimeters, and the magnetic material has a square cross section area (2x2 cm). Neglect fringing and magnetic leakage. Use the dashed line as the average magnetic flux path.
   a) Draw the magnetic equivalent circuit of the inductor 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.)



Simplified inductor.

3. A three phases, 250 kW, 460 V, 60 Hz, eight poles, star-connected induction machine is connected to a 460 V infinite bus and is running as a generator at a slip $s = -2,5\,\%$. The equivalent circuit of the machine (Fig. 3) has the following parameters
   $R_1 = 0{,}015 W;\quad R_2^{'} = 0{,}035 W;$
   $X_1 = 0{,}145 W;\quad X_2^{'} = 0{,}145 W;\quad X_m = 6{,}5 W$
   a) Determine the speed of the rotor (2 p.)
   b) Determine the power delivered to the infinite bus and the power factor (2 p.)
   c) Determine the efficiency of the generator. The rotational and core losses are 3 kW (2 p.)



IEEE-recommended equivalent circuit of an induction machine.

4. A 1 MVA, 3 phases, 2300 V, 60 Hz, 10 poles, star-connected cylindrical-rotor synchronous motor is connected to an infinite bus. The synchronous reactance is 4,23 W. The synchronous motor delivers 746 kW and operates at 0,85 power factor **leading**. All losses may be neglected.
   a) Determine the armature current I_a (2p)
   b) Determine the excitation voltage E_f and the load angle d. (2 p.)
   c) Determine the maximum power the motor can deliver for the excitation of part (b). (2 p.)

ELEC-C8407 Electromechanics, examination 13.12.2016, 12.00-15.00, S3.

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: $\mathcal{R} = \frac{l}{\mu A}$

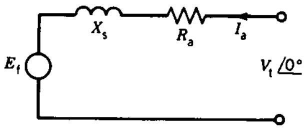
Magnetomotive force: $F = Ni$

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 motor:



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

AC active power: $P = 3VI\cos\phi$