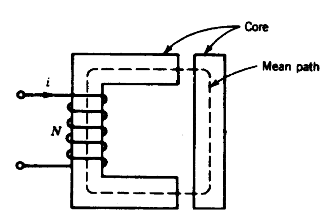
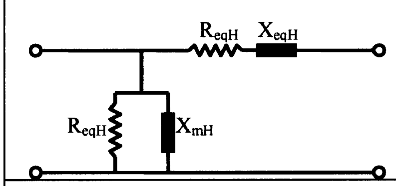
1. Explain the following concepts, use drawings and equations when adequate.
   a) Describe the stator and rotor constructions and the principle of operation of a **cage induction motor**. (Hint: rotating field, induced current, forces on conductors, etc...) (2p.)
   b) List the loss components in an asynchronous motor. Explain why and where they occur and how they are represented in the equivalent circuit of the motor. (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 4 necessary conditions for connecting (synchronizing) a running synchronous generator to the infinite bus? Explain what happens if any of them is not satisfied. (2 p.)
   e) Draw the complete single-phase equivalent circuit of a transformer and explain what each of its component represents (2p.)
   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. The magnetic relay in the figure has a coil of 500 turns curiying a current $I_{dc} = 4{,}19$ A. The mean core path length is $l_c = 360$ mm and each air gap is $l_g = 1{,}5$ mm. The relative permeability of the core is $\mu_r = 1250$ and its cross-section is $A_c = 100\ \text{mm}^2$. Neglect the flux fringing in the air gaps.
   a) Draw the equivalent magnetic circuit of the relay and calculate its parameters (reluctances and mmf) (2 p.)
   b) Calculate the flux density in the air gap by using the magnetic circuit equations (2 p.)
   c) Calculate the total force acting on the moving part of the relay (2 p.)



Simplified magnetic relay

3. Tests are performed on a 1-phase, 10 kVA, 2200/220 V, 60 Hz transformer and the following results are obtained:
   Open-circuit test (high-voltage side open):
   Voltmeter 220 V, Ammeter 2.5 A, Wattmeter 100 W.
   Short-circuit test (low-voltage side shorted):
   Voltmeter 150 V, Ammeter 4.55 A, Wattmeter 215 W.
   a) Derive the parameters for the approximate equivalent circuit shown in the figure, in which the shunt branch is moved to the supply terminal, referred to the high-voltage side (6p.)



Approximate equivalent circuit of a transformer.

4. A three phases, 14 kV, 10 MVA, 60 Hz, two poles, 0,85 PF lagging, star-connected synchronous generator has $X_s = 20\,\Omega$ per phase and $R_s = 2\,\Omega$ per phase. The generator is connected to an infinite bus and is running at rated condition.
   a) Determine the excitation voltage E_f (2 p.)
   b) Determine the load angle δ (2 p.)
   c) Draw the phasor diagram at this rated operation point (2 p.)

ELEC-C8407 Electromechanics, examination 12.12.2017, 12.00-15.00, AS2.

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

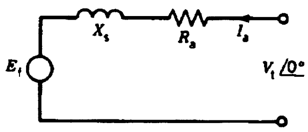
Magnetomotive force: $F = Ni$

Force pressure: $F_{\mathrm{m}} = \frac{B_{\mathrm{g}}^2}{2\mu_0}$

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

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

Equivalent circuit of a synchronous motor:



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