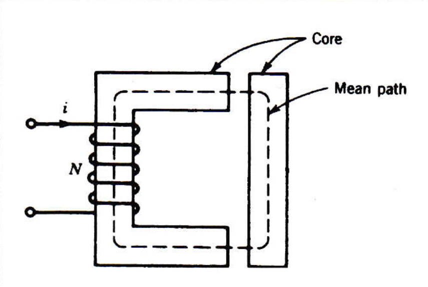
1. Explain the following concepts, use drawings and equations when adequate.
   a) Describe the stator and rotor constructions and the principle of operation of an induction motor. (Hint: rotating field, induced current, forces on conductors, etc…) (2p.)
   b) List the loss components in an asynchronous motor. Explain why and where they occur. (2 p.)
   c) Explain how the power factor of a synchronous generator can be controlled, while the machine is delivering a constant active power. Draw the phasor diagram of the generator at unity power factor and lagging power factor (hint: use the terminal voltage as reference, 0 deg) (2p.).
   d) Explain the static stability limits of a synchronous machine. What are these limits? Why they are important? What happens if any of them exceeds? (hint: use drawing in the PQ plan) (2p.)
   e) Draw the complete single-phase equivalent circuit of a transformer and explain what each of its component represents (2p.)
   f) The location, connection and role of the compensating winding in a DC machine (2 p.)

2. The magnetic relay in the Figure has a coil of 500 turns curying a current $I_{dc} = 4{,}19$ A. The mean core path length is $l_c = 360$ mm and the air gap is $l_g = 1{,}5$ mm. The relative permeability of the core is $\mu_c = 1250$ and its cross-section is $A_c = 100\ \text{mm}^2$. Neglect flux fringing in the air gaps.
   a) Draw the equivalent magnetic circuit of the relay and calculate its parameters (2 p.)
   b) Calculate the flux and flux density in the air gap (2 p.)
   c) Calculate the total force acting on the moving part of the relay (2 p.).



Simplified relay.

3. A three-phase, 5 kVA, 1000 V, four-pole, 50 Hz, star-connected synchronous machine has negligible stator winding resistance and a synchronous reactance of 170 Ω **per phase**. The machine is operated as a generator in parallel with a three-phase, 1000 V, 50 Hz power supply. The machine is delivering rated kVA at power factor 0,8 lagging.
   a) Determine the active and reactive power, the excitation voltage and the load angle. (2 p.)
   b) Draw the phasor diagram for this condition ($\underline{V}_t$, $\underline{E}_f$, $\underline{I}_a$, δ and ϕ) (2 p.)
   c) With the field current as in a) the prime mover power is slowly increased. What is the maximum power limit? What are the corresponding values of the stator current, power factor, and reactive power at this maximum power transfer condition? (2 p.)

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

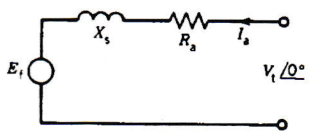
Magnetomotive force: $F = Ni$

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

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

3-phase AC active power: $P = \sqrt{3}VI\cos\phi$

Permeability of vacuum: $\mu_0 = 4\pi 10^{-7}$

Equivalent circuit of a DC-motor: