S-17.3020 Transient Phenomena in Electrical Machines
Examination 10/01/2006 at 9 – 12 o'clock, Room I 256.

1. Explain briefly:
   a) What is a state-space presentation of a differential equation?
   b) How do the space-vector model and two-axis model of a cage induction motor differ from each other?
   c) What does the circle diagram of an induction motor represent?
   d) The space vector of a three-phase current is presented in stator and rotor frames of reference. What is the transformation equation between these two presentations?
   e) Arrange the time constants T'_{d0}, T'_d ja T''_d of a salient pole synchronous machine according to their magnitude, starting from the smallest to the largest one.

2. a) A one-phase transformer is connected to a sinusoidal voltage source $u = \hat{u}\cos\omega t$. Derive the differential equations of the primary and secondary currents. Solve the equations assuming that the load of the transformer is zero. The resistance and inductance of the primary winding are R_1 and L_1, and those of the secondary winding R_2 and L_2. The mutual inductance of the windings is L_m.

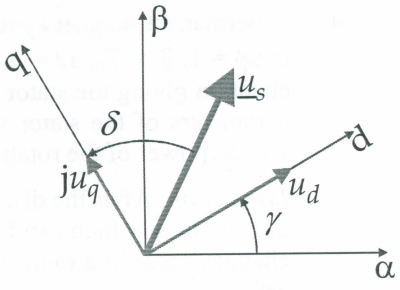
   b) From the previous disconnection, there is a remanence flux in the iron core of the transformer. It is associated with the ferromagnetic hysteresis of the core material. How should the remanence flux be taken into account in the model, and how does it affect the transient when connecting the transformer to the voltage source?

3. The instantaneous power fed to a three-phase winding is given by equation $P = u_a i_a + u_b i_b + u_c i_c$, where u_x and i_x are the phase voltages and currents. Derive the equation for this power using space vectors.

4. The figure on the right is related to the definition of the power angle δ. The equation of motion when using the position angle γ is

$$\frac{3}{2}p\left(\psi_d i_q - \psi_q i_d\right) = \frac{J}{p}\frac{\mathrm{d}^2\gamma}{\mathrm{d}t^2} + T_m$$

   Derive the equation of motion if the power angle δ is used to represent the rotor position.



5. A salient pole synchronous motor is started by connecting its stator winding to a three-phase grid. How and from which components is the starting torque produced, and how can we affect the starting torque? Sketch the average torque versus speed curve of a synchronous motor during a slow starting.