1.) 34 pts. Consider balanced steady-state operation of the induction machine. Recall that for these conditions $\tilde{F}_{ds} = j\tilde{F}_{qs}$, $\tilde{F}_{qs} = \tilde{F}_{as}$, $\tilde{F}'_{dr} = j\tilde{F}'_{qr}$, and that, taking the initial rotor position to be zero $\tilde{F}'_{qr} = \tilde{F}_{ar}$. Starting with the rotor voltage and flux linkage equations expressed in the stationary reference frame, derive the phasor equivalent circuit rotor voltage equation, i.e., $\frac{V'_{ar}}{S} = \frac{r'_r}{S} I'_{ar} + j\omega_e L_M (\tilde{I}_{as} + \tilde{I}'_{ar}) + j\omega_e L'_{lr} \tilde{I}_{as}$.

2.) 33 pts. Consider the operation of a non-salient permanent magnet synchronous machine. Suppose it is desired to achieve a torque T_e^*. Derive an expression for the q- and d- axis currents that will achieve this torque with the minimum possible line-to-neutral, rms stator voltage. You may assume stator resistance is negligible. Your expressions should be in terms of T_e^* and the machine parameters.

3.) 33 pts. Consider a wound rotor synchronous machine with a single damper winding in the q-axis. Prove that if the q-axis stator current is constant then the q-axis damper current will go to zero.