1) [10 pts] A 3φ 60-Hz 400-MVA 13.8-kV 4-pole turbine-generator unit has an H constant of 5.0 s.

   a) Calculate the energy stored in the rotating mass at synchronous speed.
   b) If the unit is operating at synchronous speed and suddenly experiences an accelerating power of 400 MW, calculate the mechanical angular acceleration in rad/sec and the speed in RPM after 0.5 seconds.
   c) Convert H to its equivalent J values in both Kg-m² and lbm-ft².

2) [10 pts] A power system is represented by two non-coherent synchronous generators which are connected by a short 13.8-kV line whose impedance is j0.40 p.u. on a 100 MVA base. The specifications for the generators, on the respective bases of the two generators, are given as:

   Generator 1: 13.6 kV
   80 MVA
   \[X_d' = j0.15 \text{ p.u.}\]
   \[H = 4.0 \text{ s}\]

   Generator 2: 13.8 kV
   50 MVA
   \[X_d' = j0.15 \text{ p.u.}\]
   \[H = 5.0 \text{ s}\]

   a) Calculate the equivalent H value and the transfer impedance if this 2-machine equivalent is converted to a single machine connected to an infinite bus.
   b) Draw the per-phase equivalent circuit. State all values on the 100-MVA system base.

3) [20 pts] For a given fault, \(P_{MAX,E}\) before, during, and after a fault is 3.125, 0.625 and 2.0 p.u. respectively. \(P_M\) is 1.0 p.u. and can be considered constant.

   a) Sketch out \(P_E\) and \(P_M\) for the three cases given above.
   b) Calculate the pre-fault torque angle, the critical clearing angle, and the post-fault torque angle.
   c) Is stability possible? Can you say at this point if transient stability will be achieved?
4) [20 pts] The per phase equivalent of a 3φ system is shown below. A fault occurs midway along the indicated line.

\[ 1.05 \frac{\text{p.u.}}{\text{MVA}} \]

\[ j0.3 \text{ p.u.} \]
\[ j2.0 \text{ p.u.} \]
\[ j2.0 \text{ p.u.} \]

\[ \infty \frac{\text{p.u.}}{\text{MVA}} \]

a) Calculate the transfer impedance, Thevenin voltage of the infinite bus, and \( P_{\text{MAX,E}} \) for prefault conditions.

b) Calculate the transfer impedance, Thevenin voltage of the infinite bus, and \( P_{\text{MAX,E}} \) for fault conditions.

c) Calculate the transfer impedance, Thevenin voltage of the infinite bus, and \( P_{\text{MAX,E}} \) after the line section has been cleared.
5) Study questions (these won't be graded)
   a) [5 pts] What is the main assumption made that allows us, for the purpose of transient stability studies, to approximate a salient rotor machine as a Thevenin equivalent of voltage $E_q$ and impedance $X_d$?

   b) [5 pts] Consider the equal-area criterion as applied to a synchronous generator. What significance do the area above and the area below the $P_m$ line have in terms of the speed of the synchronous machine?

   c) [5 pts] Explain what reclosing is and whether or not reclosing can improve the stability of a system.

   d) [5 pts] Why is solution of the swing equation complicated if the reference speed of the system is not chosen to be synchronous speed?

   e) [5 pts] For a given machine, what steady-state torque angle would result in the highest natural frequency oscillations for load fluctuations? Answer in terms of the synchronizing power coefficient or with reference to the terms in the natural frequency equation.