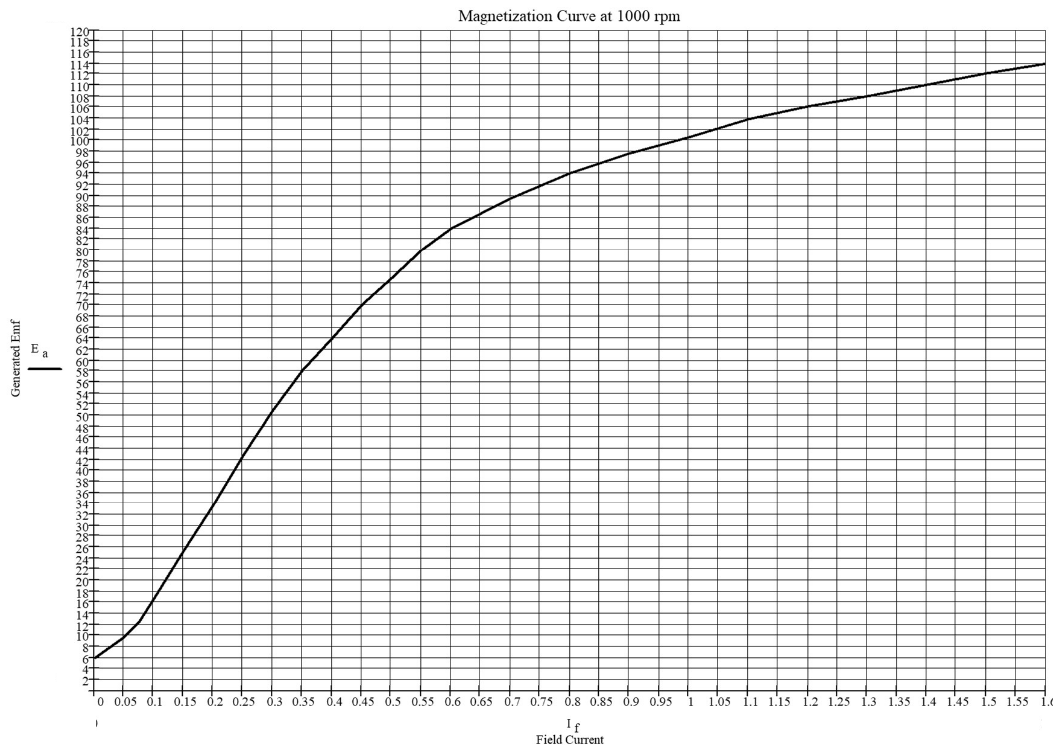
Name: ………………………………………………………………

TEST #2 **SKEE4633/SEE3433** **1 hour 20 minutes**

Q1. The dc machine (10 kW, 100 V, 1000 rpm, $R_a = 0.1\ \Omega$, $R_{fw} = 80\ \Omega$, Nf = 800 turns) is connected to a 100 V dc supply and is operated as a dc shunt motor. At no-load condition, the motor runs at $\omega_m = 1000$ rpm and $E_a = 99$ V.



(a) Find the value of the shunt field resistance, R_f, and the rotational losses at 1000 rpm. (3 marks)

(b) Find the speed in rpm when the rated current flows in the armature. Consider that the air gap flux is reduced by 6.5 % when rated current flows in the armature because of armature reaction. (3 marks)

(c) How many series field turns per pole should be added to make this machine into differentially compound motor whose speed will be 1100 rpm at full-load? Consider that the armature reaction effect in equivalent field current, $I_{f(AR)} = 0.15$ A. (3 marks)

Q2. A 360 V, 10 kW series motor is mechanically coupled to a fan and draws 28 A, and runs at $\omega_1 = 500$ rpm when connected to a 330 V supply with no external resistance connected to the armature circuit (i.e. $R_{ae1} = 0$). The torque required by the fan is given by $T_L = k\omega^{2.1}$, where k is a constant of proportionality. $R_a = 0.6\ \Omega$ and $R_{sr} = 0.4\ \Omega$. Neglect armature reaction and the rotational losses.

(a) Determine the back emf, E_{a1}, the power delivered to the fan, P_1, and the torque developed by the motor, T_1. (3 marks)

(b) The speed is to be reduced to $\omega_2 = 400$ rpm by inserting a resistance, R_{ae2} in the armature circuit. Determine the value of this resistance and the torque developed by the motor, T_2. (3 marks)

(c) Sketch speed-torque characteristics (ω versus T) of the series DC motor for two different values of R_{ae} together with the given load profile, $T = k\omega^{2.1}$. Label clearly R_{ae1}, R_{ae2}, T_L, ω_1, ω_2, T_1, and T_2 on the sketch. (2 marks)

Q3. A 3-phase, **Δ**-connected, 400 V, 47.5 kW, 50 Hz, 580 rpm, 10-pole induction motor is operating at rated conditions has an efficiency of 90 percent. The rotational loss is 1 kW and it draws a line current of 96 A. Assume that the core losses are embedded in rotational losses. Find

i. Mechanical power (1 mark)
ii. Air gap power (1 mark)
iii. Rotor copper loss (1 mark)
iv Input power (1 mark)
v. Stator copper loss (1 mark)

Draw power flow diagram starting from the input power to the output power. Label all the power components and state their names and values. (2 marks)

Q4. A 3-phase, 400 V (line to line), 50 Hz, 720 rpm, 8-pole, **Δ**-connected, induction motor has the following equivalent circuit constants in ohms per phase.

$R_1 = 1.5\ \Omega$, $R_2' = 0.65\ \Omega$, $X_1 = 2\ \Omega$, $X_2' = 1.2\ \Omega$ and $X_m = 50\ \Omega$.

The rotational losses of the motor may be assumed to be constant at 325 W, independent of load.

(a) Calculate the starting torque and the corresponding power factor. (3 marks)
(b) Calculate the slip at the maximum torque and the corresponding torque. (3 marks)
(c) Calculate the efficiency for the full-load slip. (3 marks)

Use the approximate equivalent circuit.

Potentially useful formula

$$E_a = K_a\phi\omega \qquad E_a = V_t - I_aR_a \qquad \frac{E_{aFL}}{E_{aNL}} = \frac{K_a\emptyset\omega_{FL}}{K_a\emptyset\omega_{NL}}$$

$$P = E_aI_a \qquad E_a = V_t - I_a(R_a + R_{sr} + R_{ae}) \qquad E_a = K_{sr}I_a\omega_m$$

$$P = T\omega \qquad I_{f(\text{eff})} = I_f - I_{f(\text{AR})} - \frac{N_{sr}}{N_f}I_t \qquad T = K_{sr}I_a^2$$

$$I_{f(\text{eff})} = I_f - I_{f(\text{AR})} \qquad N_s = \frac{120f}{p} \qquad s = \frac{N_s - N_r}{N_s}$$

$$P_{rotor} = sP_{ag} \qquad P_m = (1-s)P_{ag} \qquad P_{ag} = I_2'^2\frac{R_2'}{s}$$

$$P_{ag} = T\omega_s \qquad S_{Tmax} = \frac{R_2'}{\sqrt{[(R_1^2 + (X_1 + X_2)^2]}} \qquad I_2' = \frac{V_1}{R_1 + \frac{R_2'}{s} + j(X_1 + X_2')}$$