SULIT

UNIVERSITI TEKNOLOGI MALAYSIA
PEPERIKSAAN AKHIR
SEMESTER 1
SESI 2015/2016

KOD MATAPELAJARAN	:	**SKEE 4633**
MATA PELAJARAN	:	**MESIN ELEKTRIK**
PENSYARAH	:	**NIK DIN MUHAMAD (01)** **DR. AWANG JUSOH (02)**
KURSUS	:	**SEE**
SEKSYEN	:	**01 and 02**
MASA	:	**2 JAM 30 MINIT**
TARIKH	:	

ARAHAN KEPADA CALON :

JAWAB EMPAT (4) SOALAN SAHAJA. SEMUA PENGIRAAN HENDAKLAH DITUNJUKKAN DENGAN JELAS.

KERTAS SOALAN INI TERDIRI DARIPADA 9 (SEMBILAN) MUKA SURAT SAHAJA

Question 1

(a) With the help of appropriate equations, explain briefly the production of torque in a singly excited and a doubly excited electromechanical energy system. [5 marks]

(b) In the electromagnetic relay system, the flux linkage λ and current i relationship is given by:

$$i = 7\lambda^2 e^{2x} + 3\lambda(2-x)^{3/2}$$

Evaluate the electromechanical force, f_m when λ = 2 Vs, and x = 1 m. [6 marks]

(c) An elementary two-pole cylindrical rotating machine with a uniform air gap is shown in Figure Q1(c). The mutual inductance between the rotor and the stator is given by

$$L_{12} = 5\cos\theta \quad \text{H}$$

An AC current source $i_1 = 4\cos(8t)\ A$ is applied to the stator and another AC current source $i_2 = 8\sin(10t)\ A$ is applied to the rotor.

(i) Derive the developed torque as a function of θ. State at what mechanical speeds the rotating machine could produce non-zero averaged torque. [5 marks]

(ii) Write the expression for the developed torque when the rotor is locked at θ = 60°. Also, determine the average torque produced by the machine. [4 marks]

(iii) Write the expression for the developed torque when the rotor can freely rotate. Also, determine the average torque developed by the machine. Let θ = 60° at t = 0 and ω_m = 18 rad/s. [5 marks]

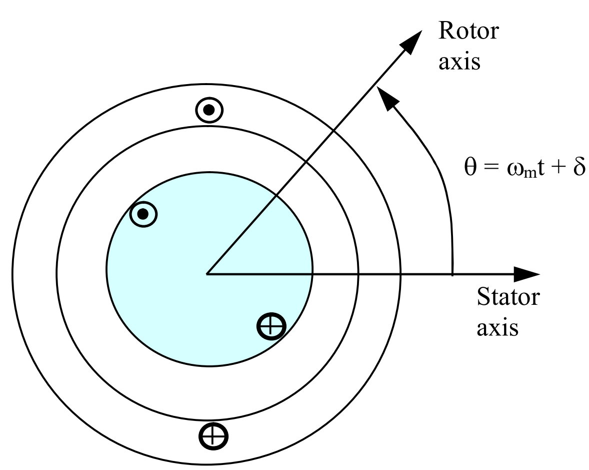

Figure Q1(c)

Question 2

(a) Show typical terminal characteristics ($V_t - I_t$ characteristics) of differentially compounded, cumulatively compounded, shunt, and separately excited DC generators. Explain briefly their characteristics. [6 marks]

(b) A six-pole DC machine has a wave winding of 300 turns. The flux per pole is 0.025 Wb. The DC machine rotates at 1000 rpm.

(i) Determine the generated voltage, E_a.

(ii) Determine the power and torque rating of the machine if the rated current through the turn is 25 A. [5 marks]

(c) A 11.2 kW, 112 V, 1120 rpm, $R_a = 0.1\ \Omega$ DC machine operated as a shunt generator has a magnetization characteristic at 1120 rpm as shown in Figure 2(c) in *Attachment Q2(c)*. The shunt field winding resistance $R_{fw} = 100\ \Omega$ and the number of turns $N_f = 1200$ turns per pole. The rated field current $I_f = 0.95$ A. The machine is provided with a series winding with $R_{sr} = 0.04\ \Omega$ so that it can operate as a compound DC machine as well.

(i) Draw an equivalent circuit of the compound DC machine. Label all key quantities. [3 marks]

(ii) The machine is operated as a shunt generator at 1120 rpm and the no load terminal voltage is adjusted to 112 V. Determine the full load terminal voltage for with and without armature reaction effect. Assume the effect of armature reaction at full-load is $I_{f(AR)} = 0.05$ A. [4 marks]

(iii) The machine is operated as a compound DC machine at 1120 rpm so that the terminal voltage of 112 V can be achieved at no load as well as at full load (i.e., zero voltage regulation). How many series turns per pole, N_{sr} are required to obtain the zero voltage regulation. Assume the effect of armature reaction at full-load is $I_{f(AR)} = 0.05$ A. [7 marks]

You must submit *Attachment Q2(c)* with your answer booklet

Question 3

(a) Describe briefly the following:

(i) Why is a starting resistor used in DC motor circuits?

(ii) Explain how the direction of rotation of a separately excited DC motor is reversed?

[6 marks]

(b) Explain briefly the characteristics and advantages of the terminal voltage control for controlling the speed of a separately excited DC motor. [4 marks]

(c) An 11.2 kW, 112 V, 1120 rpm, R_a = 0.1 Ω DC machine has a magnetization characteristic at 1120 rpm as shown in Figure 3(c) in *Attachment Q3(c)*. The shunt field winding resistance R_{fw} = 100 Ω and the number of turns N_f = 1200 turns per pole. The machine is provided with a series winding with the number of turns N_{sr} = 2 and negligible R_{sr} so that it can operate as a compound DC motor as well. The machine is connected to a 112 V DC supply and is operated as a shunt DC motor. At no load condition, the motor runs at 1120 rpm and the armature takes 5 A.

(i) Find the back emf E_a, field current I_f, and field resistance, R_f at no load condition.

[3 marks]

(ii) Find the speed of the motor when the rated current flows in the armature. Neglect the armature reaction effect. [4 marks]

(iii) Find the speed of the motor when the rated current flows into the armature. Consider that the effect of armature reaction at full load in equivalent field current is, $I_{f(AR)}$ = 0.15 A. [4 marks]

(iv) If the machine is operated as a differentially compound DC motor, determine the speed of the motor at the full load. Assume the armature reaction effect at full load is $I_{f(AR)}$ = 0.15 A. [4 marks]

You must submit *Attachment Q3(c)* with your answer booklet

Question 4

a) Briefly explain the fundamental operation of an induction motor.

[4 marks]

b) Draw the per-phase approximate equivalent circuit of an induction motor. Based on this circuit, derive the equation for mechanical torque developed as a function of the circuit parameters

[7 marks]

c) The following test results are obtained from a three-phase, 100 hp, 415 V, eight-pole, star connected squirrel-cage induction machine

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No load test:	415V, 50 Hz, 40 A, 4.2 kW
Blocked-rotor test:	100 V, 12.5 Hz, 140 A, 8 kW

The dc resistance is 0.076 Ω per stator phase.

(i) Calculate the machine parameters (R_1, R_2, X_1, X_2, X_m) and draw the IEEE recommended equivalent circuit. [6 marks]

(ii) The motor is connected to a three-phase, star connected, 415 V, 50 Hz supply and runs at 715 rpm. By using the approximate equivalent circuit, determine:
(1) the slip, (2) input current, input power, air gap power, rotor copper loss, mechanical power developed, output power, and efficiency of the motor.

[8 marks]

Question 5

a) Explain briefly the conditions for a synchronous generator to be connected to a grid system.

[4 marks]

b) Explain, with the help of a phasor diagram, what will happen to the power factor of a synchronous motor as its shaft power is held constant and the field excitation is excited with over excitation.

[4 marks]

c) A 50 Hz 3-phase star connected synchronous generator has negligible stator winding resistance and a synchronous reactance of 10 Ω/phase. In one situation, the generator delivers a power of 2 MW to an infinite bus bar with a power factor of 0.85 lagging. The bus bar voltage is equal to 11 kV (line-to-line). If the steam applied to the machine prime mover is fixed (constant power),

(i) Draw the per phase generator equivalent circuit. [2 marks]

(ii) Determine the excitation voltage (E_f) generated by the synchronous generator.

[5 marks]

(iii) Calculate the voltage regulation of this generator. [3 marks]

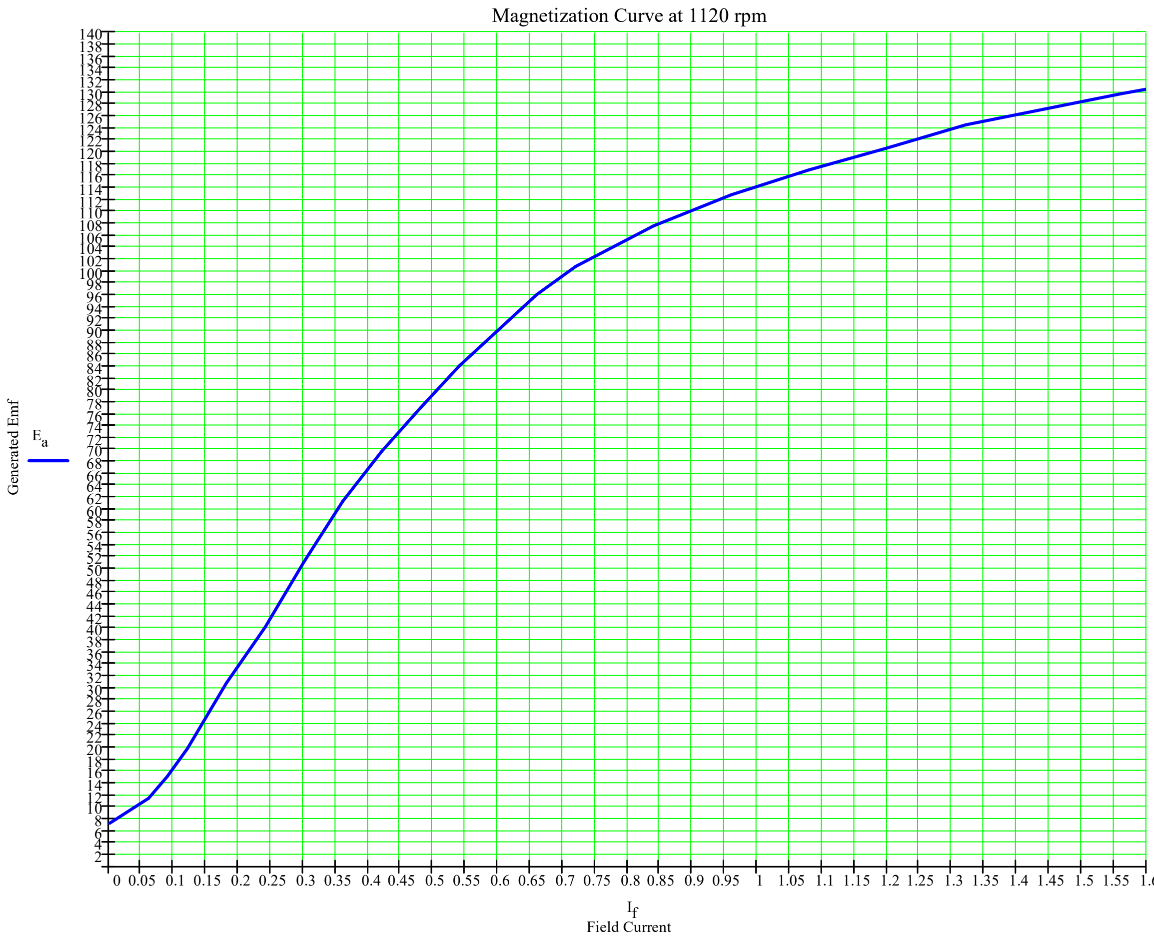
(iv) Draw a phasor diagram to show the voltage and current relationship of this generator

[3 marks]

(v) At the same bus bar voltage, determine the excitation voltage generated by the machine if the generator is supplying the bus bar at 0.85 leading power factor with the same amount of current. Draw the phasor diagram and give comment with respect to (iv). [4 marks]

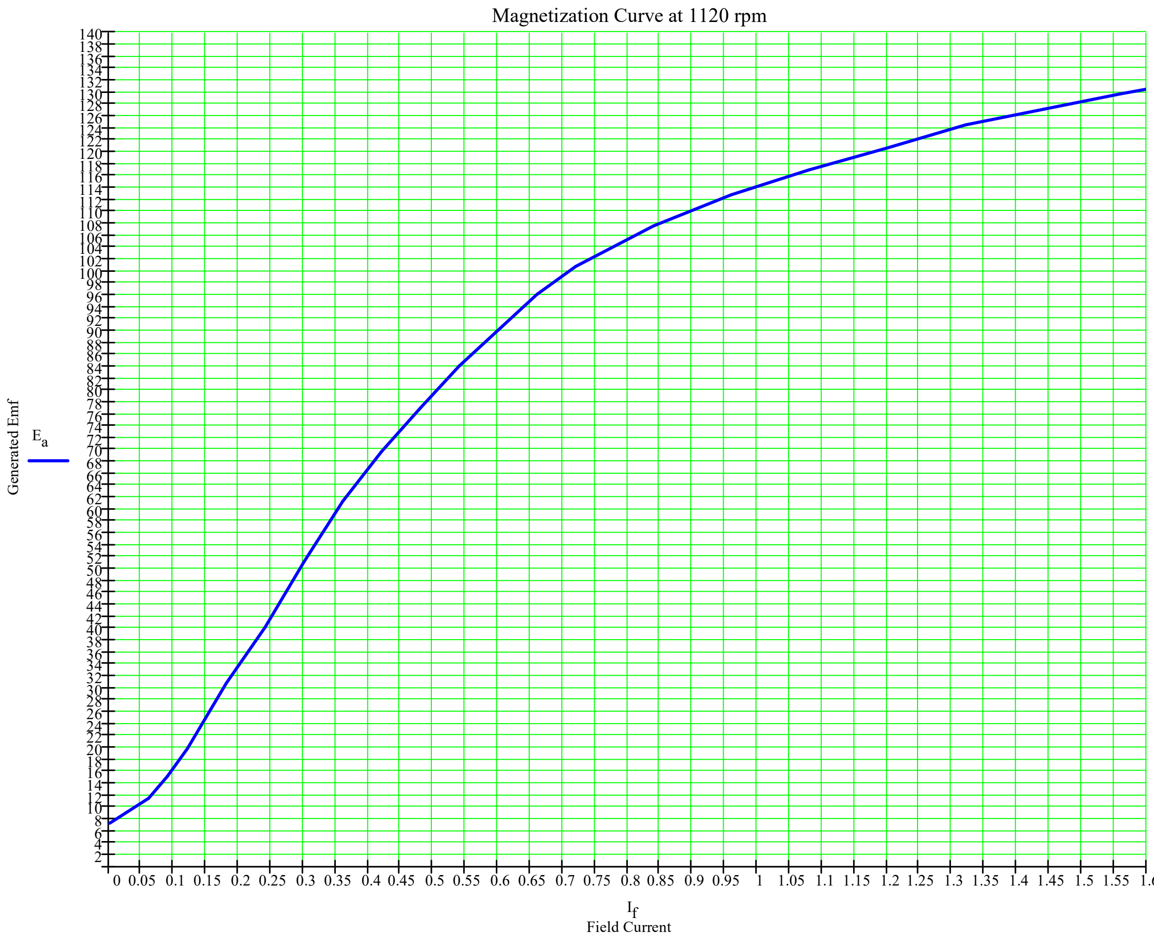
Attachment Q2(c)

Name: ____



Attachment Q3(c)

Name: ____



Potentially Useful Formulae

$$\mu_o = 4\pi \times 10^{-7} \text{ H/m}$$

$$B = \frac{\phi}{A} = \mu H$$

$$R = \frac{l}{\mu A}$$

$$Hl = Ni$$

$$L \equiv \frac{\lambda}{i} = \frac{N\phi}{i} = \frac{N^2}{R}$$

$$\lambda \equiv N\phi = Li$$

$$e = \frac{d\lambda}{dt}$$

$$W_f = \int_0^{\lambda} i d\lambda$$

$$W_f' = \int_0^{i} \lambda di$$

$$w_f = \int_0^{B} H dB$$

$$w_f' = \int_0^{H} B dH$$

$$W_f = \frac{1}{2} i^2 L(x)$$

$$f_m = -\frac{\partial W_f(\lambda, x)}{\partial x}\bigg|_{\lambda = \text{constant}}$$

$$f_m = \frac{\partial W_f'(i, x)}{\partial x}\bigg|_{i = \text{constant}}$$

$$f_m = \frac{i^2}{2}\frac{d}{dx}L(x)$$

$$f_m = \frac{\lambda^2}{2L(x)^2}\frac{d}{dx}L(x)$$

$$R_f = R_{fw} + R_{fc}$$

$$I_a = I_f + I_t$$

$$I_{f(eff)} = I_f - I_{f(AR)}$$

$$I_{f(eff)} = I_f \pm \frac{N_{sr}}{N_f} I_t - I_{f(AR)}$$

$$\omega_m = -\frac{R_a}{(K_a\phi)^2} + \frac{V_t}{K_a\phi}$$

$$E_a = K_{sr} I_a \omega_m$$

$$E_f = V_t \angle 0 \pm I_a j X_s$$

$$E_a = K_a \phi \omega_m$$

$$V_t = E_a \pm I_a R_a$$

$$K_a = \frac{Np}{\pi a}$$

$$V_t = R_f I_f$$

$$\omega_m = \frac{V_t - I_a R_a}{K_a \phi}$$

$$P = E_a I_a = T\omega_m$$

$$T = K_a \phi I_a$$

$$T = \frac{1}{\omega_{syn}} P_{ag}$$

$$s_{T\max} = \frac{R_2}{\left[R_1^2 + (X_1 + X_2)^2\right]^{\frac{1}{2}}}$$

$$N_s = \frac{120 f}{p}$$

$$s = \frac{N_s - N_r}{N_s}$$

$$N_r = (1 - s) N_s$$

$$P = \frac{3 E_f V_t}{X_s} \sin\delta$$

$$P = \sqrt{3} V I \cos\theta$$

$$P_{mech} = I_2^2 \frac{R_2}{s}(1 - s) = P_{ag}(1 - s)$$

$$P_{ag} = I_2^2 \frac{R_2}{s}$$

$$\sin(x)\cos(y) = \frac{\sin(x+y)}{2} + \frac{\sin(x-y)}{2}$$

$$\sin(x)\sin(y) = \frac{\cos(x-y)}{2} - \frac{\cos(x+y)}{2}$$

$$\cos(x)\cos(y) = \frac{\cos(x+y)}{2} + \frac{\cos(x-y)}{2}$$

$$V_{Th} = \frac{X_m}{\left[R_1^2 + (X_1 + X_m)^2\right]^{\frac{1}{2}}} V_1$$

$$Z_{Th} = \frac{jX_m (R_1 + jX_1)}{R_1 + j(X_1 + X_m)}$$

$$T = \frac{1}{2} i_1^2 \frac{dL_{11}}{d\theta} + \frac{1}{2} i_2^2 \frac{dL_{22}}{d\theta} + i_1 i_2 \frac{dL_{12}}{d\theta}$$

$$T = \frac{1}{\omega_{syn}} \frac{V_1^2}{(R_1 + R_2/s)^2 + (X_1 + X_2)^2} \frac{R_2}{s}$$