University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

Spring, 22/23 TRIMESTER EXAMINATIONS

EEEN20090

Electrical Energy Systems

Module Coordinator: Professor Federico Milano

Student Number

Seat Number

Time Allowed: 120 minutes

Material Permitted in the Exam Venue:
Non-programmable calculators are permitted.

Material to be Supplied to Students:
12 page answer booklets

Instructions to Students:
Answer any three of five questions. All question papers **must** be handed up with the answer booklets at the end of the exam. The distribution of marks in the right margin gives an approximate indication of the relative importance of each part of the questions.

Question A

For the three-phase circuit in Figure 1, assume a balanced three-phase voltage source, with $v_1(t) = 170\sin(120\pi t)$.

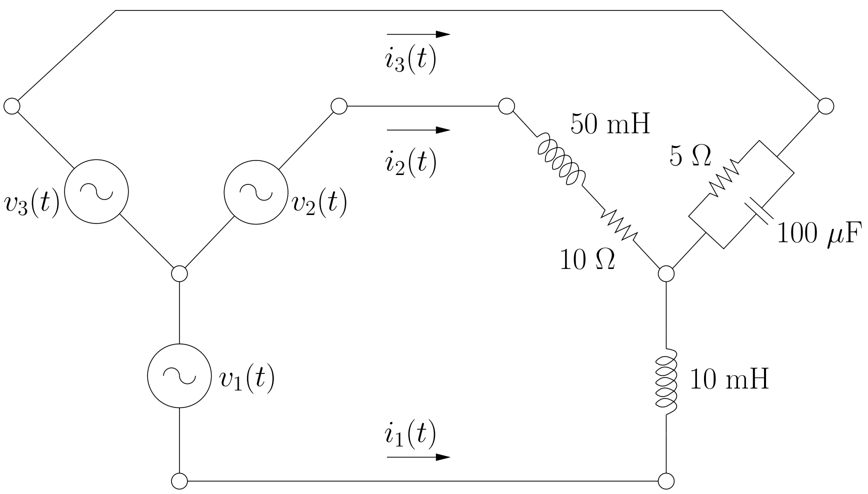

Figure 1

Determine:

1. The currents $i_1(t)$, $i_2(t)$, and $i_3(t)$. 75%
2. The total active (P) and reactive (Q) powers delivered to the load. 25%

Question B

Consider the magnetic solenoid actuator of Figure 2. A bar of magnetic material can slide into a gap in a magnetic circuit, excited by a coil of N turns. Both elements have uniform depth d into the paper.

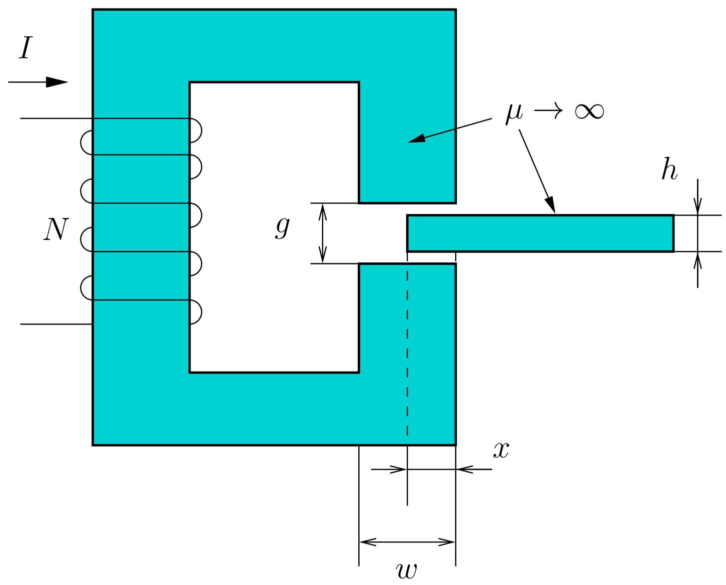

Figure 2

Determine:

3. The inductance $L(x)$. 50%

4. The co-energy $W'_f(I, x)$ and the energy $W_f(\lambda, x)$. 25%

5. The force $f(I, x)$ acting on the bar. Show that the same expression of the force can be obtained from the expression either of the co-energy and of the energy obtained in the previous point. 25%

Question C

A three-phase delta-connected induction motor has the following nominal quantitites: 400 V, 4 kW, 50 Hz and 4 poles. The parameters of the equivalent circuit of the motor are (all expressed in Ω per-phase):

$$R_1 = 1.47 \qquad R_2' = 1.393$$
$$X_1 = 1.834 \qquad X_2' = 1.834 \qquad X_\mu = 54.1$$

Determine:

6. The magnitude of the rotor current I_2', the torque T and the total mechanical power P_2 if the slip factor is $\sigma = 0.05$. — 50%
7. The maximum torque $T_{\max}$ that the motor can develop at nominal voltage. — 25%
8. The start-up torque T_{su} and the magnitude of the start-up current $I_{1,\mathrm{su}}$ in the stator at nominal voltage. — 25%

Question D

Considering the Blondel's two-reaction theory, the expressions of the stator currents of a synchronous machines are given by:

$$I_d = \frac{E_f - V_q}{X_d}, \qquad I_q = \frac{V_d}{X_q}.$$

Assuming a complex frame of reference where the stator voltage and current are $\bar{V} = V_d + jV_q = V \sin\delta + jV\cos\delta$ and $\bar{I} = I_d + jI_q$, respectively, determine:

9. The expressions of the active and reactive powers, namely $P(V,\delta)$ and $Q(V,\delta)$, assuming that the generator is a salient-pole machine. — 70%
10. The expressions of the active and reactive powers, namely $P(V,\delta)$ and $Q(V,\delta)$, assuming that the generator is a round-rotor machine. — 30%

Question E

A single-line scheme of a three-phase system is shown in Figure 3. The voltage sources at each end have the same voltage magnitude of 138 kV, line-line. Assume that the sending end has a phase advance over the receiving end of angle $\delta = \theta_1 - \theta_2$.

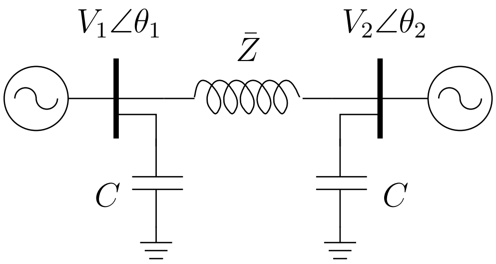

Figure 3

11. If $\bar{Z} = 4 + j40\ \Omega$, calculate the active power flow P_2 into the receiving end of the line for $\delta = 10°$. 40%

12. Assuming $\bar{Z} = j40\ \Omega$, what angle δ results in a real power flow of 100 MW from the sending to the receiving end? 20%

13. Assume $\bar{Z} = j40\ \Omega$ and $C = 6.6\ \mu$F and a system frequency of 60 Hz. With $\delta = 15°$, how much reactive power is produced at each end of the line (Q_1 and Q_2)? 40%

Result Sheet

Student Number

Question A	**1**	$i_1(t) =$ $i_2(t) =$ $i_3(t) =$
	2	$P =$ $Q =$
Question B	**3**	$L(x) =$
	4	$W'_f(I, x) =$ $W_f(\lambda, x) =$
	5	$f(I, x) =$
Question C	**6**	$I'_2 =$ $T =$ $P_2 =$
	7	$T_{\max} =$
	8	$T_{\text{su}} =$ $I_{1,\text{su}} =$
Question D	**9**	$P(V, \delta) =$ $Q(V, \delta) =$
	10	$P(V, \delta) =$ $Q(V, \delta) =$
Question E	**11**	$P_2 =$
	12	$\delta =$
	13	$Q_1 =$ $Q_2 =$

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