THE UNIVERSITY *of* EDINBURGH

SCHOOL OF ENGINEERING

POWER ENGINEERING 2

SCEE08008

Exam Date: **07/05/2018** From and To: **14:30 to 16:00** Exam Diet: **May 2018**

Please read full instructions before commencing writing

Exam paper information

- This paper consists of TWO sections.
- Candidates should attempt THREE questions, chosen as follows:
- **SECTION A:** ONE question. Attempt the whole section.
- **SECTION B:** Attempt TWO out of the THREE questions.

Special instructions

- Students should assume reasonable values for any data not given in a question nor available on a datasheet, and should make any such assumptions clear on their script.
- Students in any doubt as to the interpretation of the wording of a question, should make their own decision, and should state it clearly on their script.
- Please write your name in the space indicated at the right hand side on the front cover of the answer book. Also enter your examination number in the appropriate space on the front cover.
- Write **ONLY** your examination number on any extra sheets or worksheets used and firmly attach these to the answer book(s).
- This examination will be marked anonymously.

Special items

- Data sheet (1 page)

Convenor of Board of Examiners: **Professor R Cheung**
External Examiner: **Dr Zahid Durrani & Professor John Morrow**

SECTION A

Question A1

a) In a standard UK three pin plug connected to a kettle:

(i) What is the purpose of the earth pin?

(ii) What is the earth pin connected to in the kettle?

(iii) What will happen to the kettle operation if the wire to the earth pin becomes disconnected? **(3)**

b) In the lighting circuit of a house wiring system, should the switches for the lights be placed in the live, the neutral, or both wires? Give full reasons for your answer. **(4)**

c) In a separately excited DC motor, explain why the field current should never be switched off while the motor is running. **(3)**

d) Draw the torque-speed curve of a typical induction machine, and indicate the areas of stable motor operation and stable generator operation. **(4)**

e) Explain why no torque is produced by an induction machine when it is rotating at exactly synchronous speed. **(3)**

f) If the total output of all the power stations in the UK is greater than total demand plus losses, the system frequency will rise. Explain why the frequency rises. **(3)**

SECTION B

Question B1

a) Explain why three phase ac systems are generally used to generate and transmit electrical power, rather than single phase ac systems. **(5)**

b) Figure B1 shows a balanced three-phase, 400 V (line) supply feeding a star connected load. If $Z_a = Z_b = Z_c = 10+j6\ \Omega$, calculate:

(i) the magnitude of the line currents I_a, I_b, and I_c; **(3)**

(ii) the magnitude of the neutral current I_n; **(1)**

(iii) the total active power dissipated in the load; **(3)**

(iv) the total reactive power drawn from the supply. **(3)**

c) The same loads in part b) are reconnected so that they are now in a delta connection instead of in a star connection. Calculate:

(i) the new total active power dissipated in the load; **(2)**

(ii) the new magnitude of the line currents I_a, I_b, and I_c. **(3)**

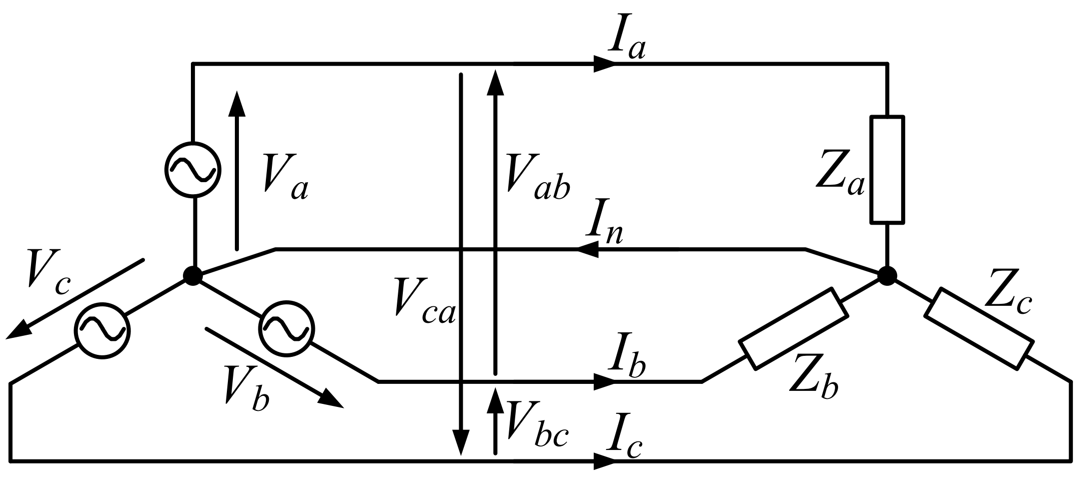

Figure B1

Question B2

a) Figure B2a shows the full equivalent circuit for a single phase transformer. Explain what each component in the circuit represents. **(7)**

b) Figure B2b shows the equivalent circuit of a single phase, 3,300:230 V, 5 kVA transformer with the secondary referred to the primary. The following tests were carried out on the transformer:

Open Circuit test:
V_1 = 3,300 V
I_1 = 0.1 A
Active power = 200 W

Short Circuit test:
V_1 = 300 V
I_1 = 1 A
Active power = 150 W

(i) From the results above, calculate the transformer parameter values (where possible) as in Figure B2b. **(9)**

(ii) Discuss any approximations that you may have made in part b)(i). **(2)**

(iii) Explain why all the equivalent circuit parameters cannot be completely determined from these tests. **(2)**

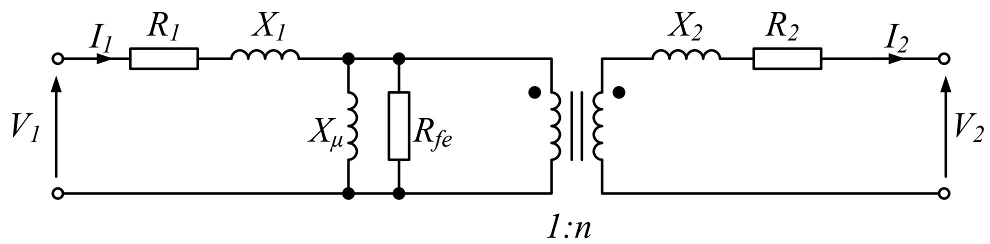

Figure B2a

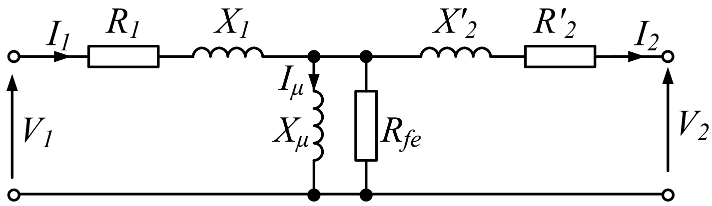

Figure B2b

Question B3

A three-phase, star connected synchronous generator driven by a hydro turbine supplies power into the 132 kV (line), 50 Hz network via a 20 kV to 132 kV step-up transformer. The generator has a synchronous reactance of 2 Ω/phase.

a) If the hydro turbine full load maximum efficiency occurs at a speed of 310 rpm, how many pole-pairs should the generator have? **(2)**

b) Calculate the required generator open-circuit voltage, E, and load angle, δ, if it is required to supply 100 MW at a power factor of 0.9 (lagging) into the electricity network. **(10)**

c) The operator opens the valve to increase the water flowing through the turbine. Discuss (giving reasons) how the following would be affected:

(i) the turbine rotational speed;

(ii) the generator output (active) power;

(iii) the generator load angle, δ;

(iv) the power factor. **(4)**

d) The operator then increases the generator field current, I_f. Discuss (giving reasons) how the following parameters would be affected:

(i) the turbine rotational speed;

(ii) the generator output (active) power;

(iii) the generator load angle, δ;

(iv) the power factor. **(4)**

END OF PAPER

Power Engineering 2: Formula Sheet

Three-phase systems

	Star	Delta
Voltage	$V_L = \sqrt{3}V_{ph}$	$V_L = V_{ph}$
Current	$I_L = I_{ph}$	$I_L = \sqrt{3}I_{ph}$
Power	$3V_{ph}I_{ph}\cos\varphi = \sqrt{3}V_L I_L \cos\varphi$	

$$\Delta V \approx \frac{RP + XQ}{V_r} \quad \text{per phase}$$

Transformer

$$\frac{V_2}{V_1} = \frac{I_1}{I_2} = \frac{N_2}{N_1} = n$$

$$Z_2 = n^2 Z_1$$

$$V = 4.44 f \Phi_m N$$

Synchronous Motor

$$P = \frac{3.V.E.\sin\delta}{X_s}$$

Induction Motor

$$T \cong \frac{3V_s^2 R_r'}{s\omega_o[(R_s + R_r'/s)^2 + (X_s + X_r')^2]}$$

$$s = \frac{\omega_o - \omega_r}{\omega_o}$$

DC Motor

$$E = k\,\phi_f\,\omega \approx K I_f \omega$$

$$T \approx K\,I_f\,I_a$$

Constants:

$$\mu_0 = 4\pi \times 10^{-7} \ \text{H m}^{-1}$$