SEMESTER 2 EXAMINATIONS 2015-2016

POWER ELECTRONICS AND DRIVES

Duration 120 mins

This paper contains 6 questions

Answer **TWO** questions in **SECTION A** and **TWO** questions in **Section B.**

Section A carries 50% of the total marks for the exam paper

Section B carries 50% of the total marks for the exam paper

All numerical answers should be given to **5 significant figures**.

Only university approved calculators MAY be used.

A foreign language word to word® translation dictionary (paper version) is permitted provided it contains no notes, additions or annotations.

An outline marking scheme is shown in brackets to the right of each question.

SECTION A

Answer *TWO* out of *THREE* questions

Question A1

(a) Describe and discuss the operation and features of the ac to ac power transmission system shown in Figure 1.

[4 marks]

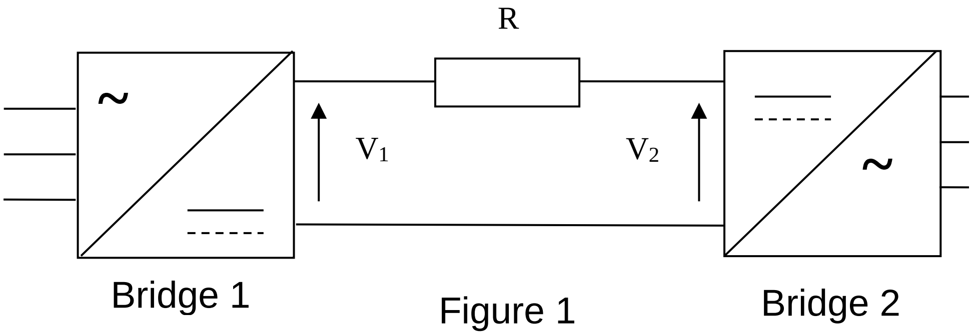

Figure 1

(b) Calculate the voltages V_1 and V_2 for the transmission circuit shown in the figure with the firing advance angle of the inverter and the firing angle of the rectifier. Calculate the system efficiency, ignoring any power loss in the two converters. The system specification is given below.

Question continues on the following page

	Bridge Converter 1	Bridge Converter 2
Type	6-pulse fully controlled	6-pulse fully controlled
Supply voltage	210V	208V
Frequency	60Hz	60Hz
Source inductance per phase	0.022222mH	0.027778mH
Mode	Rectifier	Inverter
Power		750kW
dc current		5000A
The resistance, R is 0.003 Ω.		

The mean output voltage of a p pulse converter, including overlap is given by:

$$V_{mean} = p\frac{V_m}{\pi}\sin\frac{\pi}{p}\cos\alpha - \frac{pXI_L}{2\pi}$$

[10 marks]

(c) A power converter is connected to an electric motor whose inductance, L, varies with rotational speed, ω as follows.

$$L = L_o + L_1\theta$$

where L_o and L_1 are constants. θ is the mechanical rotor angle relative to the stator.
Calculate the current in the inductance after 0.045 ms. The initial current is zero. A ramp in voltage, v, is supplied by the power electronics of the form

$$v = K\,t$$

The parameter values are given below.

TURN OVER

ω	670.12	rpm	K	100	Vs^{-1}
L_o	1	mH			
L_1	1	mH			

[6 marks]

Question A2

(a) (i) Draw and label a circuit diagram of a single phase to single phase cycloconverter. Identify each power electronic device in your circuit by numbering them in order. The supply and output frequencies are 50Hz and 16.667Hz respectively. The delay angles of the converter are all equal at $\pi/6$ rad.

(ii) Draw voltage waveforms for the supply and output for one complete cycle of the output voltage. Also show which devices are conducting using the device numbers shown in your circuit diagram.

(iii) Explain the operation of this cycloconverter with a load consisting of an inductor and resistor in series over an output cycle.

[7 marks]

(b) The supply to a single phase to single phase cycloconverter is 120V and 60Hz. During an output half cycle the delay angles are 140, 110, 46.954, 46.954, 110 and 140 degrees.

(i) Calculate the average voltage over the positive half cycle of the output voltage.

(ii) Also calculate the average power dissipated in a resistive load of 0.3Ω.

[7 marks]

Question continues on the following page

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(c) In a different converter, the current, i(t), in a load, over the time 0 < t < 2, is given by

$$\mathrm{i(t)} = \begin{Bmatrix} 1\,, & 0 < t < \frac{1}{2}\,, \\ 0\,, & \frac{1}{2} < t < 1\frac{1}{2}, \\ -1\,, & 1\frac{1}{2}\,, < t < 2, \end{Bmatrix}$$

$$\mathrm{i(t) = i(t + 2r)} \qquad \mathrm{r} = 1, 2, 3, \ldots$$

Sketch the current over the interval

$$0 < t < 2$$

Determine the Fourier series expansion for this current.
Express the series in terms of the n^{th} harmonic.
Write in your answer book the first four terms of the series.

[6 marks]

Question A3

(a) (i) Draw and label a circuit diagram for a dc-dc switch-mode and step-down converter using a power MOSFET as the main semiconductor switching device. Describe the operation of this circuit, when continuous current flows in the inductor. Include in your answer, voltage and current waveforms for the inductor and circuit diagrams.

[7 marks]

(b) (i) Calculate the average output (load) current if the supply voltage is 400V, the output power is 800W and the duty cycle is 0.5.

(ii) Calculate the output current at the boundary of continuous and discontinuous current for a switching frequency of 100kHz. The inductor has a value of 200 µH. Also calculate the peak current.

(iii) Calculate the peak inductor current and the time during the off-period when the inductor current is zero for a duty cycle of 0.05.

[7 marks]

(c) Determine an expression for the Energy Loss, EL, in a power semiconductor device where the voltage, v, across the device and the current, i, through it are given by the following two equations.

$$v = D\left(t + E\,exp\left(-\frac{t}{\tau}\right)\right)$$

$$i = A - Bt$$

where A, B, D, E and τ are constants.

[6 marks]

TURN OVER

SECTION B

Answer *TWO* out of *THREE* questions

Question B1

A linear positioning system incorporates a high performance ballscrew with a lead (as defined in figure 2) of 0.025m, and is required to position the load to a resolution of 10^{-4}m.

a) Determine the minimum pulses per revolution (PPR) of the incremental rotary position transducer that is used in this system, assuming the encoder is directly coupled to the ballscrew.

[4 marks]

b) Discuss the operation of the optical rotary encoder suitable for this application, and highlight its advantages and disadvantages when used in this type of application.

[6 marks]

c) If the maximum linear speed of the load is 10m sec^{-1}, determine the encoder's maximum speed and maximum output pulse frequency.

[4 marks]

d) Describe absolute optical encoder, semi absolute encoders and incremental encoders.

[6 marks]

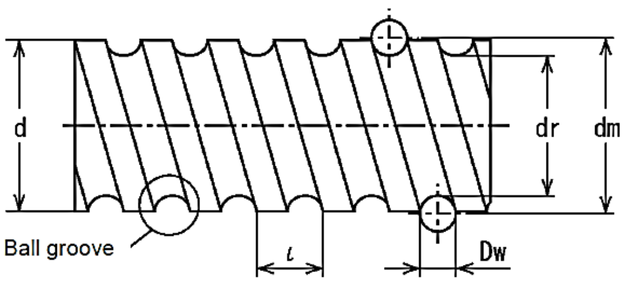

Figure 2: Ball screw schematic

Question B2

To test the component shown in Figure 3, it is spun at 2000 Rev.min^{-1} around the Z-Z axis using a directly coupled permanent magnet brushed d.c. motor. Assuming that the component has a uniform density of 4000 kg.m^{-3}, determine:

a) The inertia of the component, around the axis of rotation, and hence the torque required to accelerate the component to 2000 rev min^{-1} in 20 seconds.

[6 marks]

b) The stored energy in the rotating system at 2000 rev min^{-1}

[2 marks]

c) Based on the results from part (a), estimate the constant braking torque required to stop the motor from 2000 rev.min^{-1} to 0 rev.min^{-1} in 10s. Then, determine the associated regenerative current and the energy returned to the supply, assuming a constant regenerative current throughout.

[12 marks]

The motor's constants are K_e=0.6 Volt sec Rad^{-1} and K_t=0.6 Nm Amp^{-1}. The motor's rotor resistance is 0.2 Ohm and its inertia is 0.15 kg.m^2

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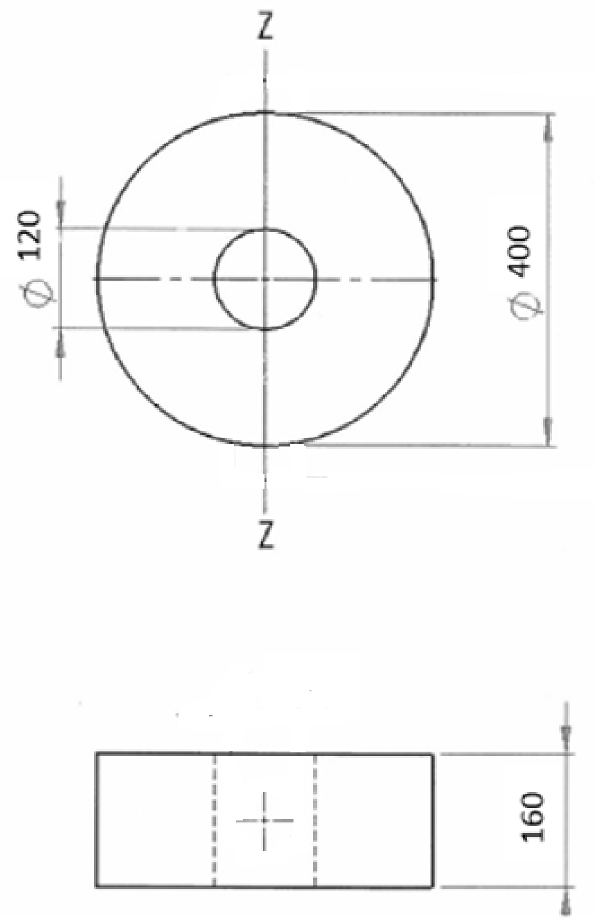


Figure 3: Components to be tested, all dimensions are in millimetres

Question B3

Considering a controller for automated systems:

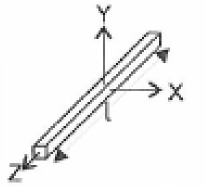
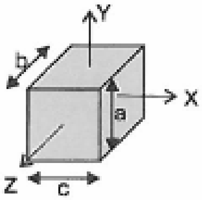
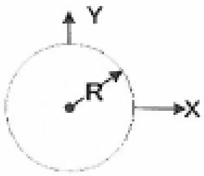
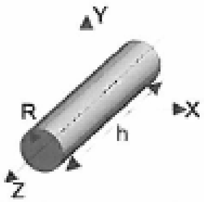
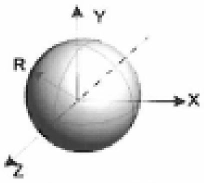
a) Draw the diagram of a generalised representation of a feedback control system and discuss some of the issues related to servo control.

[12 marks]

b) Discuss the advantages and draw the block diagram of a digital controller.

[8 marks]

Hand-out for power electronics and drives

Body		I_{xx}	I_{yy}	I_{zz}
Slender bar		$\frac{ml^2}{12}$	$\frac{ml^2}{12}$	–
Cuboid		$\frac{m}{12}(a^2 + b^2)$	$\frac{m}{12}(b^2 + c^2)$	$\frac{m}{12}(a^2 + c^2)$
Thin disc*		$\frac{mR^2}{4}$	$\frac{mR^2}{4}$	$\frac{mR^2}{2}$
Cylinder		$\frac{m}{12}(3R^2 + h^2)$	$\frac{m}{12}(3R^2 + h^2)$	$\frac{mR^2}{2}$
Sphere		$\frac{2}{5}mR^2$	$\frac{2}{5}mR^2$	$\frac{2}{5}mR^2$

* A thin disc is considered a special case of a cylinder where h = 0.

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