SEMESTER 2 EXAMINATIONS 2017/18

POWER ELECTRONICS AND DRIVES

Duration 120 mins (2 hours)

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 dictionary is permitted ONLY IF it is a paper version of a direct 'Word to Word' translation dictionary AND it contains no notes, additions or annotations.

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

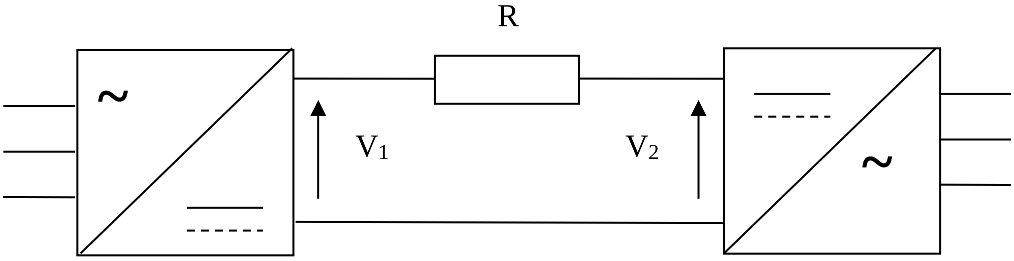
11 page examination paper (+ data sheets)

SECTION A

Answer *TWO* out of *THREE* questions

Question A1

(a) Write a list of bullet points to illustrate the operation and features of the ac to ac power transmission system shown in Figure 1.



Bridge 1 Figure 1 Bridge 2

[4 marks]

(b) Calculate the voltages V1 and V2 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.

	Bridge Converter 1	Bridge Converter 2
Type	6-pulse fully controlled	6-pulse fully controlled
Supply voltage	415 V	380 V
Frequency	50 Hz	60 Hz
Source inductance per phase	0.0092593 mH	0.015556 mH
Mode	Rectifier	Inverter
Power		1.0875 MW
dc current		7.5 kA
The resistance R is 0.00400000 Ω.		

Question continues on the following page

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) In another ac to ac power transmission system the power loss in the system is 100.8 kW and the combined resistance of the cables is 0.002 Ω.
Calculate the average and RMS currents in one thyristor if during conduction the anode to cathode voltage is 1.2V. State any assumptions made in your calculations.

[6 marks]

TURN OVER

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 60 Hz and 20 Hz respectively. The delay angles of the converter are all equal at $\pi/4$ 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. Put tick marks on the horizontal axis at the peak and zero crossings of the supply waveform.

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

[7 marks]

(b) The supply to a single phase to single phase cycloconverter is 380 V and 60 Hz. During an output half cycle the delay angles are 150, 100, 42, 15.939, 15.939, 42, 100 and 150 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 0.22050 Ω.

[7 marks]

Question continues on following page

(c) In a different converter, the power, p(t), in a load, over the time interval $-2 \le t \le 2$, is given by

$$\mathrm{p(t)} = 3\,\mathrm{t} + 6 \qquad -2 \le t \le -1$$

$$\mathrm{p(t)} = 3 \qquad -1 \le t \le 0$$

$$\mathrm{p(t)} = 3\,\mathrm{t} \qquad 0 \le t \le 1$$

$$\mathrm{p(t)} = 3 \qquad 1 \le t \le 2$$

$$\mathrm{p(t)} = \mathrm{p(t+2)}$$

Sketch the power over the interval

$$-4 \le t \le 4$$

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

[6 marks]

TURN OVER

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 600 V, the output power is 1000 W and the duty cycle is 0.083333.

(ii) Calculate the output current at the boundary of continuous and discontinuous current for a switching frequency of 50kHz. 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) The current, i(t), in the drain of a power MOSFET is given by

$$\mathrm{i}\,(\mathrm{t}) = 1000\,(1 - \mathrm{t}^2)^{\frac{1}{2}} \qquad 0 \le \mathrm{t} \le 1$$

Determine an expression for the charge over the time interval, t.
Sketch the current and charge waveforms and label the axes.

[6 marks]

SECTION B

Answer *TWO* out of *THREE* questions

Question B1

A heavy-duty linear positioning system incorporating a ballscrew with a lead l (as indicated in figure 2) of 1 cm and the screw shaft diameter D of 3 cm is driven by a fractional horsepower inverter-fed three-phase 200 V 50 Hz 4 poles AC squirrel cage induction motor. The load of this linear positioning system is a linearly movable carriage.

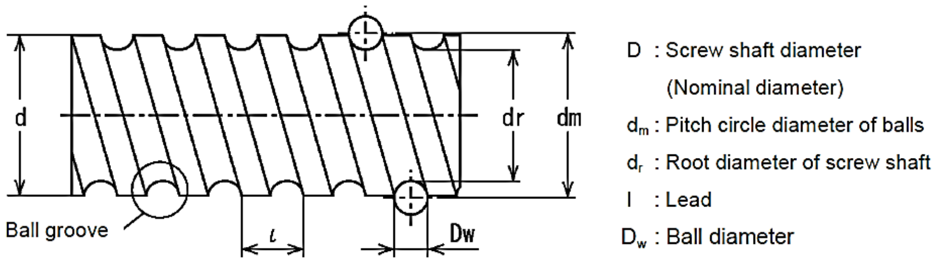


Figure 2: Ball screw schematic

a) The linear positioning system is required to position the carriage to a resolution of 0.1 cm and the required maximum linear speed of the carriage is 0.2 m/sec. Determine the maximum rotational speed in rpm and the minimum pulses per revolution (PPR) of the incremental rotary encoder that is required in this system, assuming the encoder is directly coupled to the ballscrew.

[4 marks]

b) The carriage requires a maximum force of 200N for acceleration/deceleration of its load and an additional maximum of 40 N to overcome friction and other opposing force components acting on the carriage. What is the total maximum torque required to be produced by the AC induction motor? Note that the surface friction between the ballscrew and the nut fixed on the carriage is 0.6.

[4 marks]

TURN OVER

c) The induction motor's electrical parameters have been determined as follows: R_s = 2.0 Ω, R_r = 1.6 Ω, X_{ls} = 5.0 Ω, X_{lr} = 4.5 Ω, and X_m = 120 Ω. Standard constant *V/f* control (a.k.a scalar control) is used to control the motor speed for the required linear positioning purpose. Determine the stator supply rms voltage, the motor mechanical speed, and the supply phase rms current when the motor operates at constant speed at 40 Hz supply while being subjected to a load torque of 2 Nm.

[12 marks]

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 10 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 10 s. 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 N.m .amp^{-1}. The motor's rotor resistance is 0.4 ohm and its inertia is 0.20 kg.m^2
.

Question continues on following page

TURN OVER

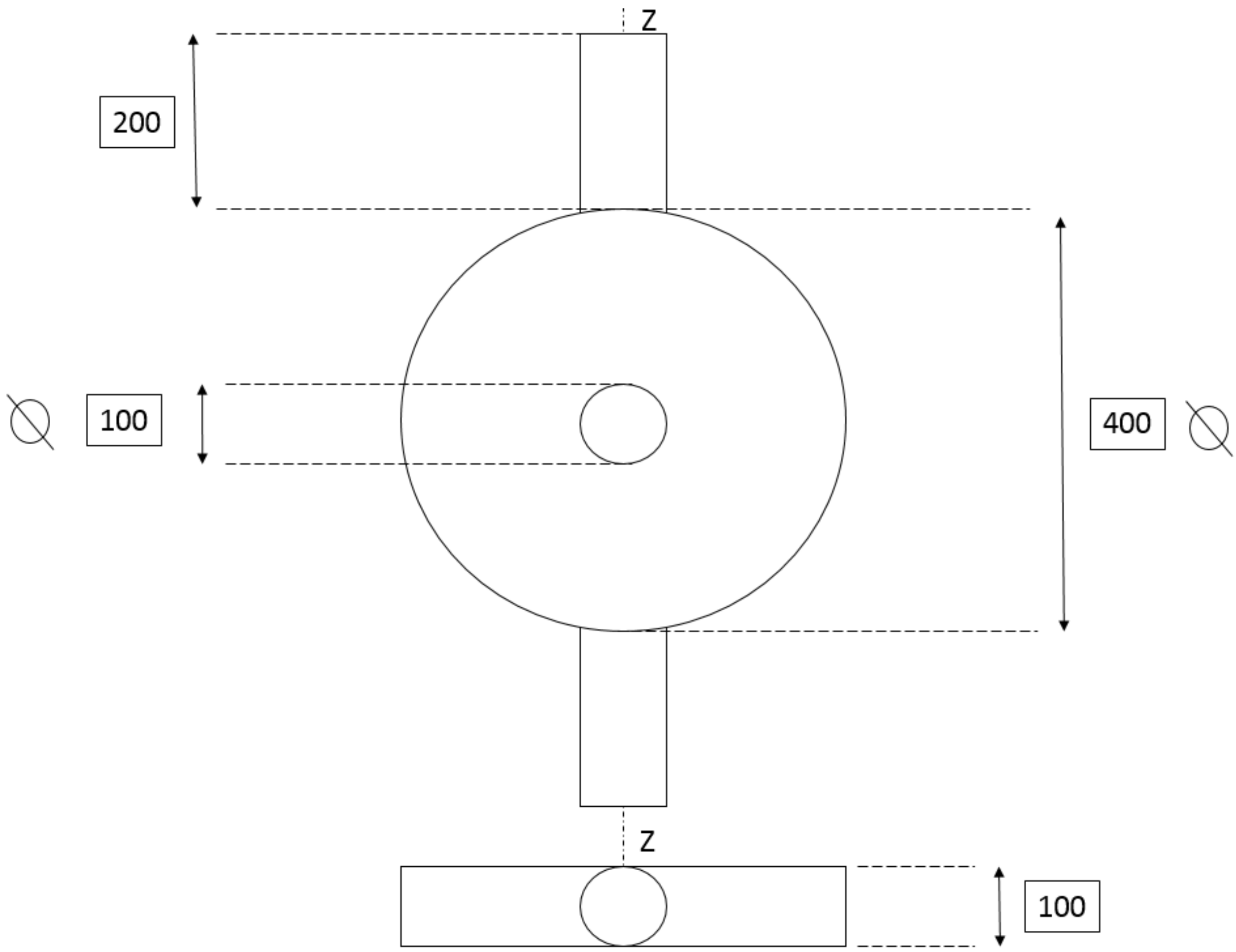


Figure 3: Components to be tested, all dimensions are in millimetres

Question B3

The speed of a 15 hp 300 V 1500 rpm separately excited DC motor is controlled by a three-phase full converter drive. The field current is controlled by a single-phase full converter supplied by one pair of lines from the three-phase, star-connected, line-to-line 220 V 50 Hz supply. The armature and field resistances are 0.2 Ω and 120 Ω respectively, and the motor voltage constant is 1.0 V/(A-rad/s). The field converter's delay angle has been set to be 20^{o}. The armature and field currents can be assumed to be continuous and ripple-free. The viscous/windage friction is negligible.

(a) Determine the field current.

[3 marks]

(b) Determine the delay angle of the armature converter α_a if the three-phase converter supplies a rated current to the motor operating at rated speed.

[9 marks]

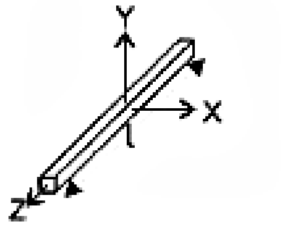
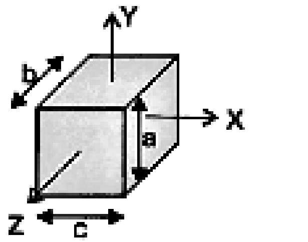
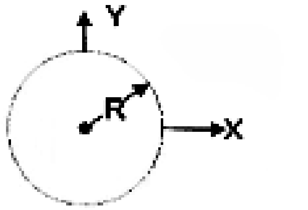
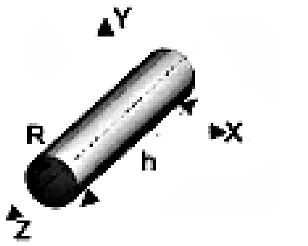
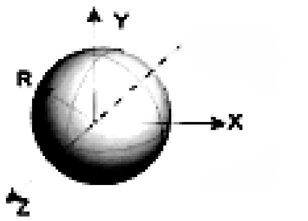
(c) Determine the no-load speed if the delay angle is the same as in part (b) and the armature current is 15% of the rated value.

[5 marks]

(d) The speed regulation at the no-load condition as in part (c).

[3 marks]

END OF PAPER

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

END OF PAPER

