EE2-3B Power Engineering 2010/11

Sample Paper in New Format

There are 3 questions. Answer all questions.

[The basic structure of the paper is of questions becoming increasingly more challenging but with the first question weighted to allow a basic pass.]

[Question 1 is taken from the 2009/10 paper. It is considered to be a straightforward question that most candidates should be able to complete in its entirety. The questions rely on recall of basic facts or application of simple formulae.]

1. This question covers several topics and all parts should be attempted.

a) A three-phase source with a line voltage of 11 kV is connected to three impedances, each with a resistance of 200 Ω and inductive reactance of 50 Ω, in star configuration. Calculate the line current, real power and reactive power drawn by the load and the power factor. [6]

b) i) Explain the operation of a boost switch-mode power supply during the **on** and **off** states of the transistor. [4]

ii) A boost SMPS operating in continuous mode has an output voltage of 15 V. The switching frequency is 150 kHz and the diode is known to conduct for 4 μs. Calculate the duty-cycle and input voltage. [6]

c) i) Describe the principle of operation of an induction machine. [5]

ii) A four pole-pair induction machine is connected to a 50 Hz supply and runs at a slip of 0.04. Calculate the rotor speed in rpm. [5]

d) Describe the causes of power loss in a real transformer. [6]

e) i) Describe the difference between the functions of generation, transmission, distribution and supply in an electricity supply system. [5]

ii) Explain the advantages of using very high voltages for transmission and why lower voltages are used for distribution and end use. [3]

[Question 2 is taken from the 2007/08 paper but shortened slightly to make it easier to complete in the time available. It requires a greater depth of knowledge than question 1 but is still based on recall and the application of equations that were shown in the lectures and further explored in the problem sheets. The question is structured into clear steps.]

2. A boost switch-mode power supply, SMPS, as shown in figure Q2, has the following design properties.

Input voltage	$V_I = 6.0$ V
Output voltage	$V_O = 18.0$ V
Maximum output current	$I_O^{max} = 0.5$ A
Switching frequency	$f = 10$ kHz
Inductor	$L = 500$ μH
Capacitor	$C = 1{,}000$ μF
MOSFET on resistance	$R_{DS(on)} = 0.25$ Ω
MOSFET turn-on loss	$E_{on} = 13$ μJ when switched on at 1.5 A
MOSFET turn-off loss	$E_{off} = 7$ μJ when switched off at 1.5 A

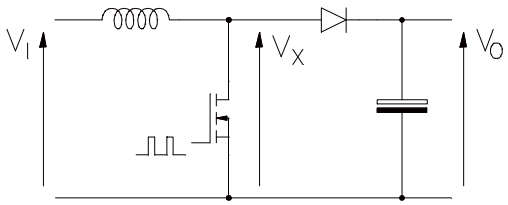

Figure Q2

(i) Calculate the duty-cycle at which the circuit should be operated assuming the circuit is in continuous conduction mode. [4]

(ii) Calculate the average value of the current through the diode and the average current through the inductor when the load draws the maximum output current. [5]

(iii) Sketch the waveforms of the currents through the diode, capacitor and inductor for the conditions when the circuit operates at maximum output current. [5]

(iv) Calculate the voltage ripple across the capacitor. There is no need to consider the series resistance of the capacitor. [5]

(v) Calculate the ripple component of the inductor current. [3]

(vi) Calculate the value of inductor current at which the SMPS enters discontinuous conduction mode and the value of output current to which this corresponds. [4]

(vii) Calculate the power losses in the MOSFET. [4]

[Question 3 is modified version of a question in the 2007/8 paper and is intended to be more challenging that the first two. Not all candidates are expected to complete this in full. Part (a) requires some interpretation of the information given in the lecture notes. Part (b) is a common form of calculation, examples of which were given in the problem sheet, but here it is less structured and requires the candidates to think about which calculation steps to take. Part (c) tests deeper understanding of how the equivalent circuit equations are able to predict the system performance.

3. A 2-pole-pair, 3-phase induction machine is connected in star to a 480 V (line), 50 Hz supply. The equivalent circuit parameters, referred to the stator, are:

Stator resistance	0.06 Ω
Referred rotor resistance	0.08 Ω
Stator leakage reactance	0.30 Ω
Referred rotor leakage reactance	0.30 Ω
Magnetising reactance	20.0 Ω
Magnetising resistance	200 Ω

(a) State the physical property of the induction motor that gives rise to each of the components in the equivalent circuit. [5]

(b) For operation at 1,450 r.p.m. calculate the following calculate the

(i) the stator current; [10]

(ii) the mechanical power and the power losses; [10]

(c) Without performing detailed calculations, comment on how the power losses, mechanical power and efficiency would change if the speed changed to 1,475 r.p.m., that is, if the slip is halved. [5]