ENGINEERING TRIPOS PART IB

Thursday 6 June 2002 9 to 11

Paper 5

ELECTRICAL ENGINEERING

Answer not more than ***four*** *questions.*

Answer at least ***one*** *question from each section.*

The ***approximate*** *number of marks allocated to each part of a question is indicated in the right margin.*

Answers to questions in each section should be tied together and handed in separately.

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the invigilator

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SECTION A

*Answer at least **one** question from this section.*

1 Fig. 1 shows the circuit of a common emitter amplifier.

(a) Explain why this is called a "common emitter" configuration. [2]

(b) Draw the small-signal equivalent circuit of the amplifier, and hence calculate the voltage gain, v_2/v_1 at mid-band frequencies (i.e. assuming the reactances of the coupling capacitors are negligible). The small-signal parameters of the transistor are : h_{ie} = 2 kΩ, h_{fe} = 70, h_{oe} = 40 μS, h_{re} is negligible. Express the gain both as a number, and in decibels. [8]

(c) At high frequencies, the collector-base capacitance starts to have a detrimental effect on the amplifier performance. Given that the value of this capacitance is 15 pF, estimate the upper 3 dB frequency of the above amplifier circuit. You may neglect the effect of the 200 kΩ resistor. [10]

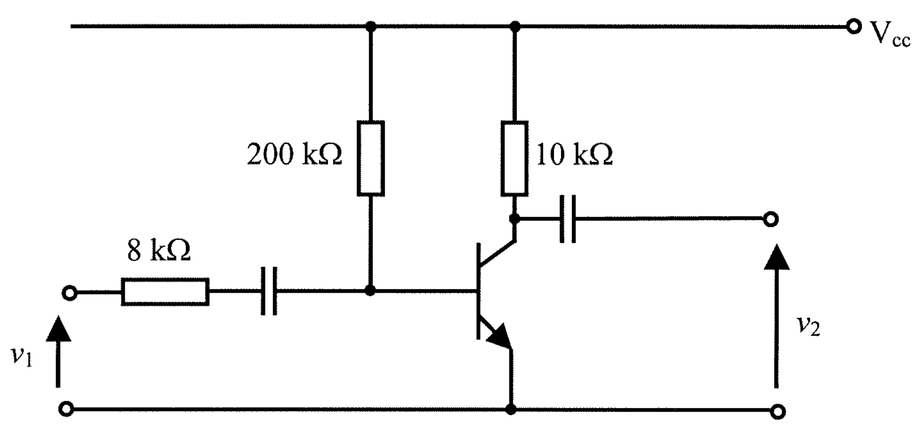

Fig. 1

2 (a) Discuss briefly the advantages and disadvantages of using negative feedback in Op-Amp circuits. [2]

(b) Consider the simple circuit shown in Fig. 2. What is the function of this circuit? Using small-signal analysis, derive expressions for the gain, loop gain, and the input and output impedances. Assume that the open loop gain is finite, as are the internal input and output impedances of the Op-Amp. [8]

(c) Now consider the more complicated inverting amplifier circuit shown in Fig. 3. Derive an expression for the gain v_2/v_1 of this circuit. Assume this time that the Op-Amp is ideal. [8]

(d) For the circuit in part (c) above, what is the gain for $R_1 = R_2 = R_4 = 1\ \mathrm{M\Omega}$ and $R_3 = 10.2\ \mathrm{k\Omega}$? [2]

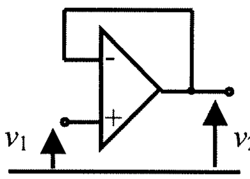

Fig. 2

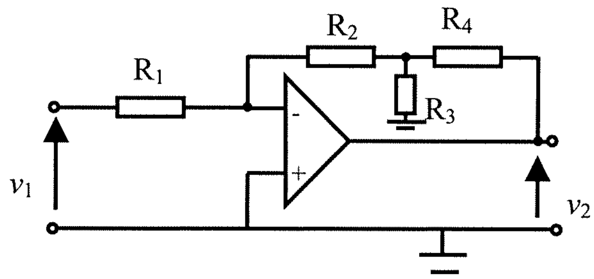

Fig. 3

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SECTION B

*Answer at least **one** question from this section.*

3 (a) Discuss briefly the reasons why three-phase ac is the most common method for the generation and transmission of electric power. What is the phase difference between the phase voltages? [3]

(b) Consider a generator producing balanced three-phase power, where the phases are denoted by V_A, V_B and V_C. The coils of each phase may carry a maximum rated current, I_{max}. Determine the maximum power output of this generator. If the phases are then connected in series in the manner $V_A - V_B + V_C$ to produce a single-phase output, determine the factor by which the maximum power output is reduced. [7]

(c) For the balanced three-phase load shown in Fig. 4, which is connected to a balanced three-phase 11 kV, 50 Hz power supply, find:

(i) the overall power factor; [3]

(ii) the line current; [3]

(iii) the value of the delta-connected capacitors connected in parallel with the load required to correct the power factor to 0.95 lagging. [4]

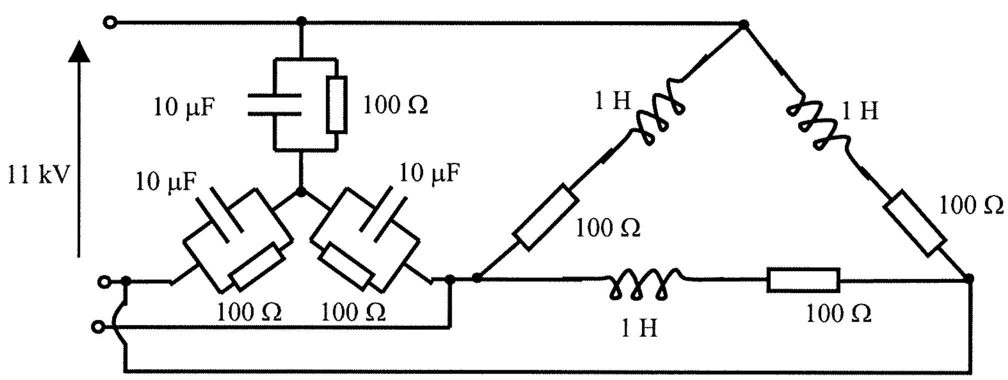

Fig. 4

4 (a) ac generators which are connected to an infinite bus only generate power when rotating at the synchronous speed. Explain this with reference to the two conditions required for steady torque production. [4]

(b) A star-connected synchronous ac generator has a synchronous reactance of 1.5 Ω per phase, and negligible stator resistance. It delivers 300 MW at power factor 0.95 lagging to a 22 kV infinite bus. Calculate the stator current, load angle and the line-to-line excitation emf. [6]

(c) The mechanical power input is increased until the machine delivers 400 MW of power. Calculate the new stator current, power factor and load angle, assuming that the excitation remains constant. [4]

(d) The generator is rated at 500 MVA, and prime-mover input power to 400 MW. At rated field current, the excitation emf E is 33kV (line). Draw an operating chart for the generator and label the various operating limits. [6]

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5 (a) For dc machines, derive the databook equations:

(i) $e_a = k\phi\omega$ [2]

(ii) $T = k\phi i_a$ [2]

stating any assumptions made.

(b) A 500 V separately-excited dc motor with armature resistance 0.8 Ω is tested on open circuit at a speed of 800 rpm, giving the characteristics shown in Table 1. The motor is required to deliver 30 kW at 1000 rpm to a load. The rotational losses are 1.5 kW. Calculate the gross torque, and the possible values of field current, stating which one you would choose, and why. [8]

(c) The field current is now set to 1.75 A while the load torque remains the same. Determine the new rotational speed. [4]

i_f (A) =	0.0	1.0	2.0	3.0	4.0	5.0	6.0
V_{oc} (V) =	0	110	220	330	410	470	510

Table 1.

(d) Explain why controlling the armature voltage is preferable to controlling the field current for varying the speed of a dc motor. Under what circumstances is it necessary to use field current control? [4]

SECTION C

*Answer at least **one** question from this section.*

6 (a) Fig. 5 shows a lossless transmission line of characteristic impedance Z_1 and length ℓ which has a load of impedance Z_2 placed on the end. Discuss qualitatively what happens when a signal is sent down the transmission line for the cases (i) $Z_1 = Z_2$ and (ii) $Z_1 \neq Z_2$. [4]

(b) Calculate the reflected voltage in terms of the forward voltage, V_+ for the case where $Z_1 = 70\ \Omega$ and $Z_2 = j\ 150\ \Omega$. [4]

(c) Calculate the input impedance to the transmission line in (b) for the case $\ell = 0.25\ \lambda$ where λ is the characteristic wavelength. [6]

(d) Calculate the input impedance to the transmission line in (b) for the cases (i) $\ell = 0.5\ \lambda$ and (ii) $\ell = 1.25\ \lambda$. Comment briefly on the results.

[6]

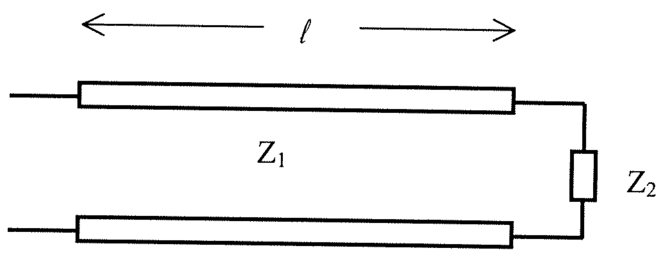

Fig. 5

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7 (a) Show that the expression $E_y = E_0 e^{j(\omega t - \beta z)}$

is a solution to the wave-equation $\nabla^2 E - \varepsilon_0 \mu_0 \frac{\partial^2}{\partial t^2} E = 0$ for the electric field vector in the case of a plane-polarised electromagnetic wave propagating in the positive z-direction. [6]

(b) Write down an expression for another independent solution, which also corresponds to propagation in the positive z direction. [4]

(c) Consider a signal which is broadcast isotropically from a fixed station. The carrier frequency is 800 MHz and the total radiated power is 5 kW. The receiver is a simple loop antenna with effective area 0.02 m^2, and it requires a minimum signal power of 2 x 10^{-9} W for good reception. Estimate the maximum distance between the transmitter and the receiver, stating any assumptions made. [6]

(d) In part (c), the receiver is placed at 90% of the maximum distance from the transmitter. Calculate by how many degrees the loop antenna can be mis-oriented from the maximum and still receive adequate reception of the signal. [4]

END OF PAPER