Data Provided: List of useful equations (attached at the end of the paper)

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2013-14 (3.0 hours)

EEE123 Introduction to Electric and Electronic Circuits

Answer **FOUR** questions. **No marks will be awarded for solutions to a fifth or a sixth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1. **a.** Figure 1 shows a network which is to be used as a source for a load which is to be connected between A and B (Load not shown).

(i) Find the value of the current through each of the resistors using Kirchhoff's laws ensuring you indicate the direction of the current in each case. **(5)**

(ii) Derive the Thevenin equivalent circuit for the network. **(3)**

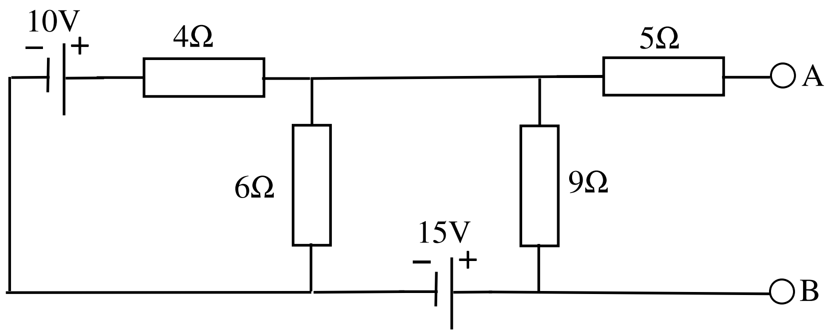

Figure 1

b. A small industrial site is connected to a $6600V_{rms}$, 50Hz supply and consumes 400kW of power at a 0.8 power-factor lagging.

(i) Calculate the kVA rating of the site and the rms current drawn from the supply. **(1)**

(ii) Calculate the reactive power in kVAr. **(1)**

c. The site is enlarged and the following loads are added:

- Process heaters rated at 100kW (operating at unity power-factor)
- A motor load of 360kVA at 0.7 power-factor lagging

(i) Calculate the new kVA rating of the site. **(5)**

(ii) Calculate the new overall power-factor and state whether it is lagging or leading. **(1)**

(iii) It is decided to connect a capacitor in parallel with the other loads to correct the power-factor to unity. (i.e. power-factor = 1) Find kVAr rating of the capacitor, the magnitude of the current drawn by the capacitor, and its value in Farads. **(3)**

(iv) What is the peak voltage and peak current the capacitor must withstand under normal operating conditions? **(1)**

2. **a.** A DC voltage source V_S has an internal resistance R_{INT} and is connected to a load resistance R_L.

(i) Derive an expression for the power dissipated in R_L as a function of V_S, R_{INT} and R_L. **(1)**

(ii) Show that the maximum power transfer in the circuit occurs when $R_{INT} = R_L$. **(3)**

(iii) Derive an expression for the percentage efficiency of the circuit when $R_{INT} = R_L$. **(1)**

b. A battery with an electromotive force of 60V and initially having no internal resistance is connected to a particular load which may be represented by a network of resistors R_1, R_2, R_3 and R_4, as shown in figure 2. Calculate:

(i) the overall resistance of the network. **(1)**

(ii) the current flowing through the series pair R_3 and R_4. **(1)**

(iii) the power dissipated in resistor R_3 and the total power dissipated in the circuit. **(2)**

(iv) the voltage across resistor R_2. **(1)**

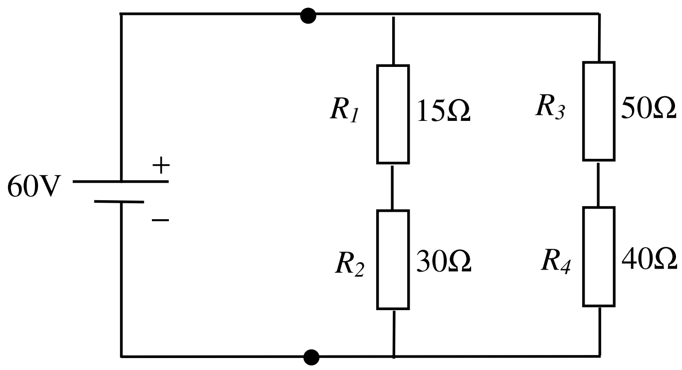

Figure 2

c. The battery now develops an internal resistance of 10Ω. Calculate:

(i) the new voltage across the resistor R_1. **(3)**

(ii) the new value of the power dissipated in resistor R_3 and the power dissipated within the battery itself. **(3)**

(iii) the efficiency of the system. **(1)**

(iv) If the resistors R_1 and R_2 are now replaced by a single 40mH inductor, calculate the power dissipated in resistor R_3 and the energy stored in the inductor after steady-state has been reached. **(3)**

3. **a.** An ideal transformer has N_1 turns on the primary winding and N_2 turns on the secondary. If the secondary winding has an impedance, Z_2, connected across it, derive an expression for the impedance seen reflected into primary coil. **(2)**

b. An ideal transformer has a turns ratio of 12:1 (primary:secondary) and an input voltage of $600V_{rms}$ at 50Hz.

(i) Calculate the secondary voltage, the current in **both** the primary and secondary windings and the power dissipated if a resistive load of 20Ω is connected across the secondary. **(3)**

(ii) Calculate the secondary voltage, the current in **both** the primary and secondary windings and the power dissipated if the load across the secondary now comprises a resistance of 15Ω in series with a capacitance of 150μF. **(4)**

(iii) For the case described in part **(ii)** above, what would be the input power factor and the required VA rating of the transformer? **(2)**

(iv) If the maximum core flux of the transformer is 5mWb calculate the actual number of turns on each winding. **(1)**

(v) If the transformer were to be operated in a country where the supply frequency is 60Hz, what is the maximum permissible supply voltage without the maximum core flux of 5mWb being exceeded? **(1)**

c. An ideal transformer with 800 turns on its primary and 15 turns on its secondary has its primary winding connected to a $400V_{rms}$, 50Hz supply. Connected across the secondary is a steel rod, 0.6m long and having a diameter of 8mm. You may assume the following information:

Resistivity of steel at 0 °C = $\rho = 8.33 \times 10^{-8}$ Ωm

Temperature coefficient of resistance of steel = $\alpha_0 = 6 \times 10^{-3}$ /°C

$R_T = R_0\,(1 + \alpha_0 T)$

R_T = Resistance at temperature T °C

R_0 = Resistance at temperature 0 °C

(i) Find the power dissipated in the rod at 40°C and when it is at a temperature of 650°C. **(5)**

(ii) Calculate the transformer primary current for both cases in **c (i)**. **(1)**

(iii) If the transformer was now assumed to have an efficiency of 96% calculate the input power required if the rod is at 40°C. **(1)**

4. **a.** The circuit of figure 4a consists initially of V_i, R, D_1 and V_{B1}, that is V_{B2} and D_2 are not initially included in the circuit. V_i is a triangular wave-shape with positive going and negative going slopes of equal magnitude and a peak value of 10 V.

On the same set of axes sketch V_i and the resulting V_O and I_D that you would expect to observe if V_{B1} = 4.3 V. Label peak values and clipping levels.

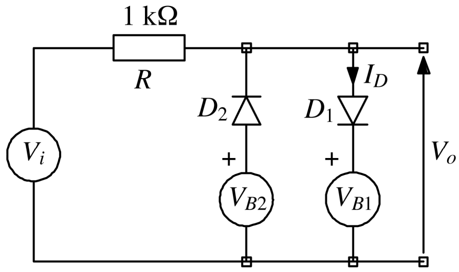

Figure 4a

V_{B2} and D_2 are now added to the circuit as shown in figure 4a. What value of V_{B2} should be chosen in order to prevent V_O becoming more negative than – 1 V?

Assume that D_1 and D_2 conduct perfectly when the forward voltage across them, V_D, reaches 0.7 V and insulate perfectly for all $V_D < 0.7$ V. **(7)**

b. The circuit of figure 4b is to be used to supply smoothed dc to a load that draws a constant current, I_L. The circuit is to be used in an airborne application where the supply frequency may vary over the range 380 Hz to 800 Hz depending on engine speed.

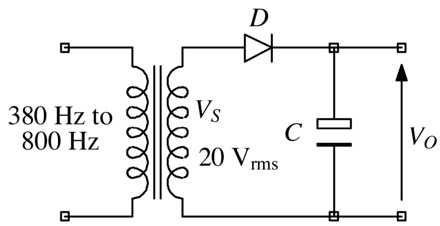

Figure 4b

(i) Which of the three terms, "bridge rectifier", "half wave rectifier" and "full wave rectifier" correctly describes the circuit of figure 4b? **(1)**

(ii) Sketch the form of V_O as a function of time that you would expect to observe. Ensure that your sketch covers at least one complete charging cycle and label all the key features of your sketch. **(4)**

(iii) If I_L = 0.15 A, what value of C is necessary to ensure that the ripple component of V_O does not exceed 2 V over the whole operating frequency range. State any assumptions or approximations used in arriving at your answer. **(6)**

(iv) Why is this type of rectifier and smoothing circuit a poor choice from the point of view of the main a.c power source? **(2)**

5. **a.** On the same set of axes, sketch three transconductance characteristics typical of an n-channel JFET, an n-channel MOSFET and an n-p-n BJT and label each characteristic with the device it represents. **(6)**

b. The BJT of figure 5 is used to switch a 12V car headlamp. The cold resistance of the lamp filament is 0.6 Ω and the operating lamp power is 50 W.

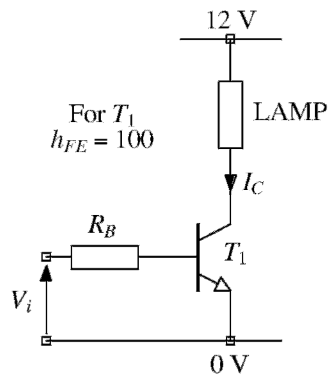

Figure 5

(i) What is the initial switch on current of the lamp assuming that the transistor is a perfect switch? **(2)**

(ii) What is the lamp resistance at its normal operating temperature and what is the corresponding lamp current? **(3)**

(iii) If the on-state drive, V_i in figure 5, is 5 V, what value of R_B must be used for the switch to work properly under both the initial and normal load resistance conditions. Assume that $V_{BE(ON)}$ can be taken as 0.7 V. **(4)**

c. Explain briefly why inductive loads can cause problems for switches. Draw a circuit including a switch, an inductive load and some extra circuitry that will protect the switch against these problems. Explain briefly how your extra circuitry achieves its protective role. **(5)**

6. a. Which five of the following terms and phrases could be used to describe a typical operational amplifier or its properties,

analogue,	low input resistance,	low output resistance,
inverting,	high output impedance;	well controlled voltage gain,
discrete,	very high voltage gain,	virtual earth,
digital,	high input impedance,	differential input,
non-inverting.		

(only the first five answers you put down will be marked) **(5)**

b. (i) Which of the two main op-amp based amplifier circuit configurations, inverting and non-inverting, correctly describes the circuit of figure 6a? **(1)**

(ii) Identify a virtual earth node in the circuit of figure 6a and specify the ratio R_2/R_1 required for the circuit to give $|v_o/v_i| = 24$? What is the phase of v_o with respect to v_i in this circuit? **(3)**

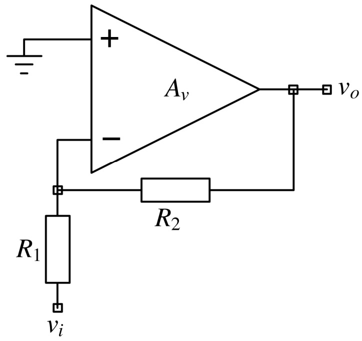

Figure 6a

(iii) With the help of the op-amp equation show that for finite A_v, the gain v_o/v_i is

given by $$\frac{v_o}{v_i} = -\frac{\dfrac{R_2}{R_1+R_2}}{\dfrac{1}{A_v}+\dfrac{R_1}{R_1+R_2}}.$$ **(5)**

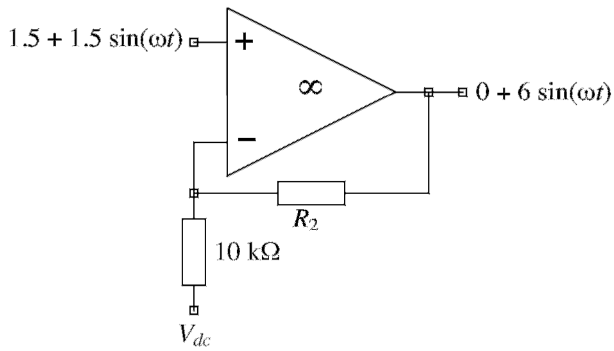

Figure 6b

c. The output voltage, v_o, of the circuit of figure 6b is required to be $v_o = 0 + 6\sin(\omega t)$ as shown when the input voltage is $1.5 + 1.5\sin(\omega t)$ as shown. Find the values of R_2 and V_{dc} necessary to satisfy this requirement. **(6)**

KM/RCT/MH