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 2015-16 (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. Three $200V_{rms}$, 100W bulbs, which may be assumed to be pure resistances, are connected in parallel and are to be used with a $300V_{rms}$, 50Hz supply. A series inductor is included in the circuit to reduce the voltage across the bulbs from $300V_{rms}$ to the $200V_{rms}$ required as shown in Figure 1.1.

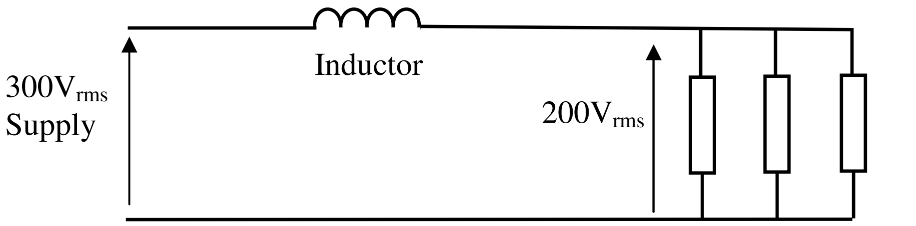


Figure 1.1

(i) Sketch and label a phasor diagram showing the relationship between the supply voltage, the voltage across the bulbs, the voltage across the inductor and the current flowing in the circuit. **(2)**

(ii) What total current will flow from the supply to operate the bulbs at their rated voltage ($200V_{rms}$) and power? **(1)**

(iii) What will be the voltage across the series inductor? **(1)**

(iv) What is the value of the inductor required? **(2)**

(v) A capacitor is to be used to correct the overall power-factor of the circuit to unity. By means of a diagram explain where you would connect this capacitor and calculate its value. **(3)**

(vi) What is the peak voltage that the capacitor must withstand under normal operating conditions? **(1)**

b. A car assembly line receives is electrical power from a 4kV, 50Hz sinusoidal supply. The electrical equipment on the assembly line may be represented as an effective impedance of $(15+j20)\Omega$.

(i) Calculate the magnitude and phase angle of the current drawn from the supply. Calculate the power factor and state whether this is leading or lagging. (*Take the supply voltage as reference*). **(2)**

(ii) What is the kVA rating of the equipment on the assembly line? **(1)**

(iii) Calculate the reactive power drawn from the supply in kVAr **(1)**

c. The site is extended to include an engine manufacturing facility and the following additional loads are added:

- Lighting load rated at 80kW (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)**

2.

a. A coil of 900 turns is wound on a toroidal iron core having of mean diameter 25cm and cross-sectional area 8cm^2 as shown in Figure 2.1. The core has a relative permeability, $\mu_r = 1000$. (***Assume the permeability of free space, $\mu_0 = 4 \times \pi \times 10^{-7}$ H/m.***)

(i) Calculate the reluctance of the magnetic circuit. **(2)**

(ii) What is the coil current required to establish a flux density of 1.5T in the core? **(2)**

(iii) Calculate the self inductance of the coil. **(1)**

b. If a 5mm wide slot is now cut in the iron toroid to form an airgap as shown in Figure 2.2, find:

(i) The new level of current required to maintain the previous flux density of 1.5T. **(3)**

(ii) The new value of the self inductance of the coil. **(1)**

c. The coil wound on the toroidal iron core from part **(a)** is connected to a 10V d.c. supply through a switch which is initially closed. The switch is then opened within 1ms. If the wire forming the coil has a resistance of 5Ω, calculate the magnitude of the peak voltage which appears across the coil after the switch is opened. **(2)**

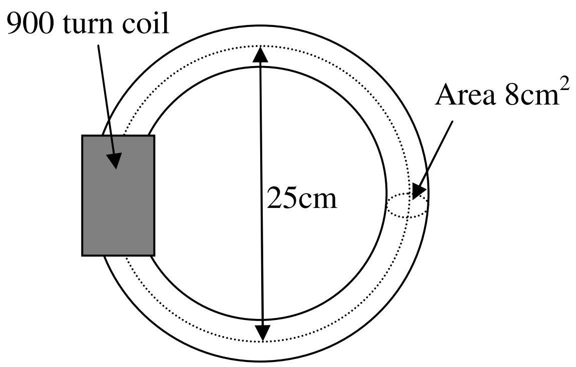


Figure 2.1

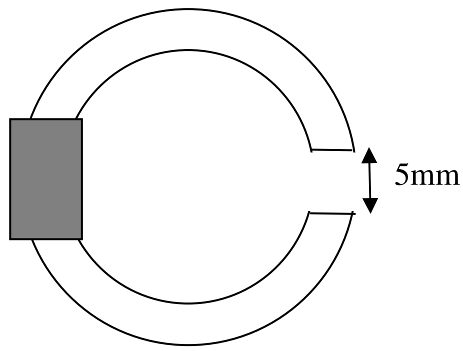


Figure 2.2

d. An ideal transformer has a turns ratio of 1:4 (primary:secondary) and an input voltage of 150V$_{rms}$ at 50Hz.

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

(ii) Calculate the current in the primary winding and the power dissipated if the load across the secondary now comprises a resistance of 18Ω in series with an inductance of 75mH. **(3)**

(iii) For the case described in part **(ii)** above, what would be the input power factor and the required VA rating of the transformer? **(1)**

(iv) If the maximum core flux of the transformer is 4mWb calculate the actual number of turns on the primary 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 4mWb being exceeded? **(1)**

3.

a. For the network shown in Figure 3.1, find the value of the current through the 4Ω resistance using the method of superposition. Indicate the direction of the current. **(6)**

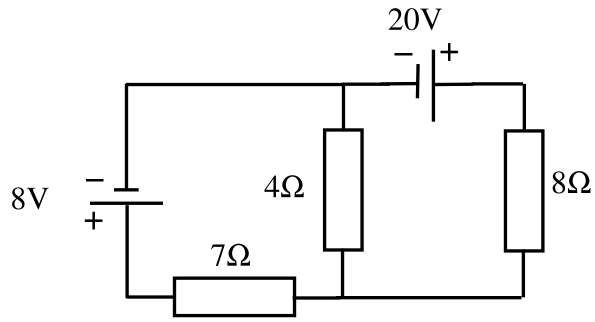


Figure 3.1

b. A constant current source of 6A is added to the network in parallel with the 8Ω resistor, as shown in Figure 3.2. Calculate the new current through the 4Ω resistor. **(4)**

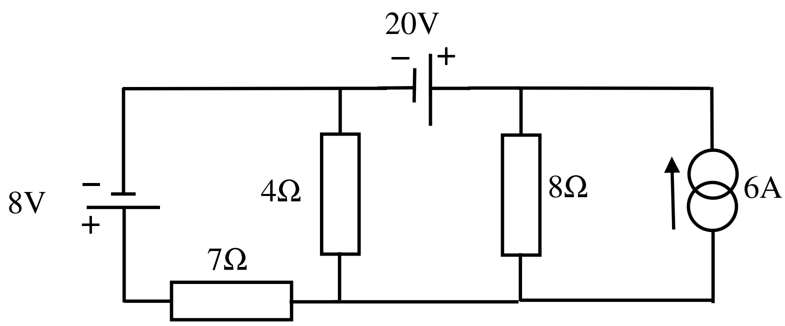


Figure 3.2

c. The network of Figure 3.1 is to be used as a source for a load resistor of 6Ω, which is connected between **A** and **B**, as shown in Figure 3.3. Derive the Thevenin equivalent circuit for the source and hence calculate the power dissipated in the load resistor. **(6)**

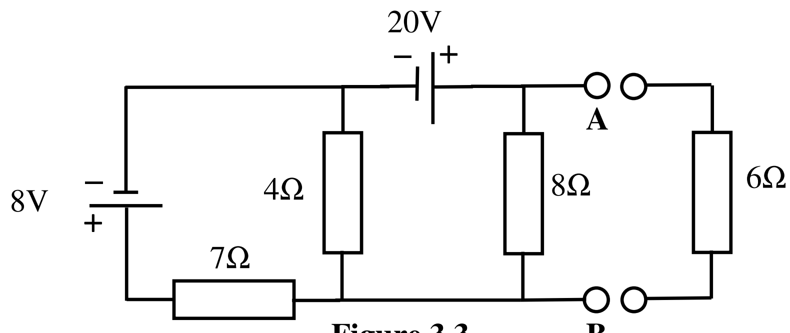


Figure 3.3

d. A rechargeable battery of nominal voltage of 18V is now connected between **A** and **B** (positive terminal connected to **A**) of Figure 3.3 in place of the 6Ω load resistor. Determine whether this battery will receive or deliver power and find the magnitude of the current passing through it when it is fully charged (18V). Assume that the battery has a negligible internal resistance. **(2)**

e. Calculate the Norton equivalent circuit for the source network shown in Figure 3.3 (i.e. not including the load resistor). **(2)**

4.

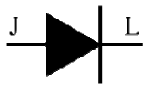
A diode symbol is shown in figure 4.1 

Figure 4.1

a. The diode's two terminals are labelled **J** and **L**. Which of these two terminals is connected to the diode's **Cathode** and which to the **Anode**? **(1)**

b. For a diode to conduct in the forward direction a voltage difference must be exist across the diode such that one of the terminals labelled in figure 4.1 is more positive than the other. Which terminal must be more positive than the other? **(1)**

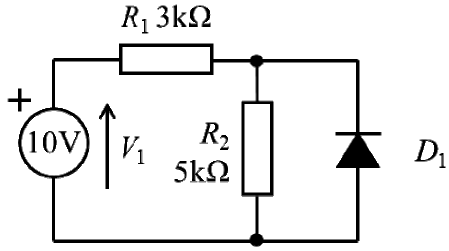


Figure 4.2

Assume diode D_1 has a forward volt drop of 0.7V when it is conducting.

c. Identify the conduction state of diode D_1 in circuit shown in figure 4.2 above, is it **conducting** or **not conducting**? **(2)**

d. The voltage source V_1 shown in figure 4.2 is to be changed to any value you choose. What **voltage** should that source V_1 be changed to in order to bring diode D_1 to the exact point where its state of conduction is changing from one state to the other? State any assumptions that you have made. **(5)**

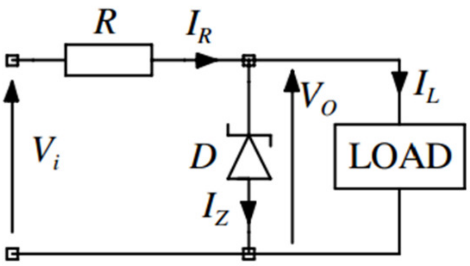


Figure 4.3

The circuit shown in figure 4.3 is designed to produce a regulated output V_O of 15V DC across the load. The input voltage, V_i is DC and has an average value of 20V and a ripple voltage varying by + or – 1V either side of 20V. The load is purely resistive and demands a load current I_L of between 50mA and 100mA. The Zener diode manufacturer tells us the diode must have a minimum current $I_{Z\,MIN}$ of at least 5mA to work properly. You may assume the Zener slope resistance is zero.

e. What Zener breakdown voltage is required for a V_O of 15V? **(1)**

f. Given the input voltage V_i range stated above, what maximum value of resistance must resistor R have in order to meet the load current demands stated above whilst also maintaining the required output voltage? **(6)**

g. Using the value of resistor R you obtained in part **f.**, if the load is disconnected (left open-circuit). What value of current would flow in the Zener diode (I_Z)? **(2)**

h. Using the answer you obtained in part **g.** above, what minimum power dissipation capability must the Zener diode have to survive? **(2)**

5.

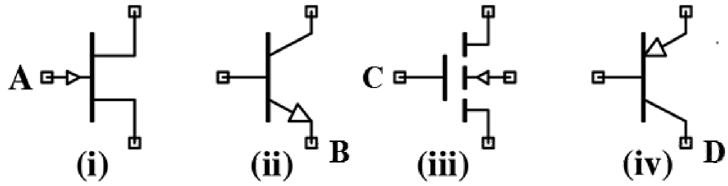


Figure 5.1

a. Figure 5.1 shows the symbols for four types of transistor: n-p-n BJT, p-n-p BJT, MOSFET, JFET. Four of the terminals of these symbols have been labelled with letters A, B, C & D. Identify each of (i), (ii), (iii) and (iv) with the appropriate transistor name and write down the names of terminals for A, B, C & D. **(8)**

b.

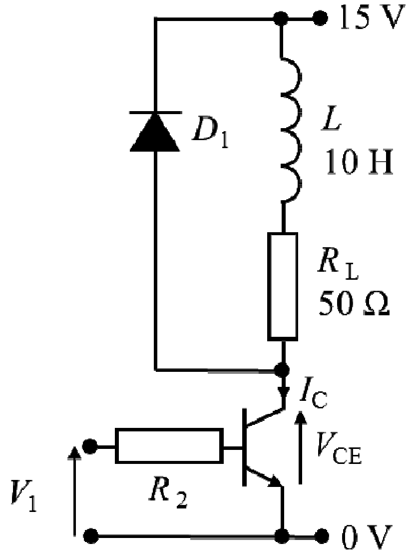


Figure 5.2

The circuit shown on the left (figure 5.2) uses a transistor as a switch that controls a door lock mechanism that consists of inductor L and series resistance R_L.

When V_1 = 3.3 V, the lock is active (transistor in its on-state). Alternatively the lock is inactive when V_1 = 0 V (transistor in its off-state).

The manufacturer of the transistor provides the following specifications:

$V_{CE\,SAT}$ = 250 mV, on-state V_{BE} = 0.7 V,

$h_{FE\,MAX}$ = 120 and $h_{FE\,MIN}$ = 80.

Forward volt drop of D_1 is 0.7 V.

In the answers that follow write down clearly any assumptions that you have made and show all calculations used.

(i) What is the on-state current, I_C, when the transistor has been in its on-state (input V_1 = 3.3V) for a long time (for example, for more than 10 Seconds)? **(3)**

(ii) What is the maximum possible value for R_2 that will ensure the transistor is able to provide the desired I_C that you calculated as your answer in question (**i**) above? **(3)**

(iii) Why might a designer choose a lower value of R_2? **(1)**

(iv) Assume the transistor has been in its on-state for a long time. The transistor then changes to the off-state instantly, what current will be flowing in the inductor immediately after the transistor enters the off-state? (You may assume that no current flows through the transistor when it is in the off-state.) **(1)**

(v) In the same circumstances as described in part (**iv**) above, what value will the voltage V_{CE} be immediately after the transistor enters the off-state? **(2)**

(vi) What will the maximum instantaneous power dissipated by diode D_1 be in this circuit when used as discussed in part (**iv**) above? **(2)**

6.

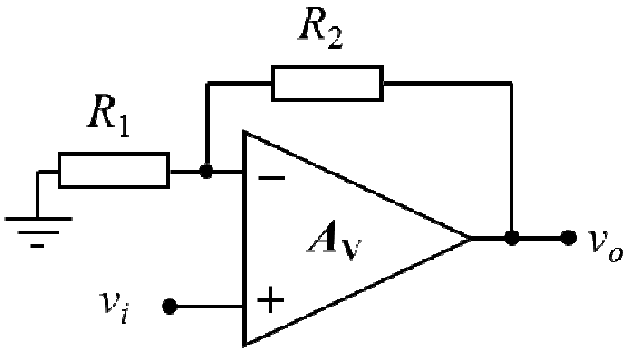


Figure 6.1

a. Is the amplifier configuration shown in figure 6.1 an inverting amplifier or a non-inverting amplifier? **(1)**

b. Assuming $A_V \rightarrow \infty$ for the operational amplifier used in figure 6.1 and using the assumption that $v^+ = v^-$, derive an expression for the voltage gain v_o/v_i of this circuit in terms of the circuit components only. **(3)**

c. In figure 6.1, let us now assume that the operational amplifier gain is actually A_v, where A_v is a very large number but **not** an infinitely large number. Show, by deriving an expression, starting from the voltages at the two operational amplifier inputs, that the gain v_o/v_i of such a circuit can be expressed as:

$$\frac{v_o}{v_i} = \frac{1}{\frac{1}{A_v} + \frac{R_1}{R_1 + R_2}}$$

Hint: you might find the expression $v_o = A_v(v^+ - v^-)$ useful. **(6)**

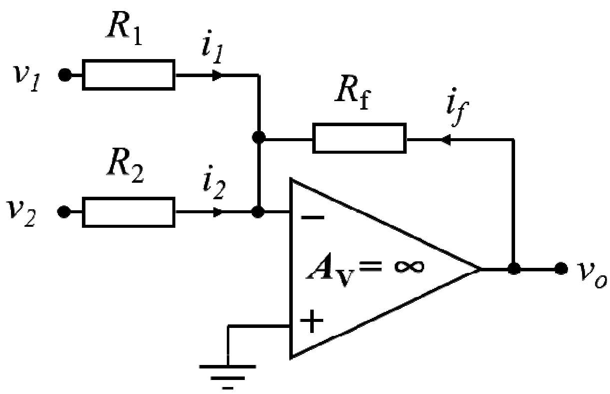


Figure 6.2

d. For the circuit shown in figure 6.2 write an expression for v_o in terms of the input voltages (v_1 and v_2) and the resistances (R_1, R_2 and R_f) only. You may assume $A_V \rightarrow \infty$ and $v^- \rightarrow$ a "virtual earth" and therefore 0. (Hint: it might be useful to use Kirchoff's current law in relation to the node connected to the operational amplifier's negative input). **(6)**

e. In the circuit shown in figure 6.2 resistor R_2 is 20kΩ and input voltages are

$v_1 = \sin(\omega t)\ Volts$ and $v_2 = 2\ Volts$.

An output voltage of $v_o = -8 - 6\sin(\omega t)\ Volts$ is required.

Choose suitable values for R_1 and R_f. **(4)**

KM/PLJ/MH