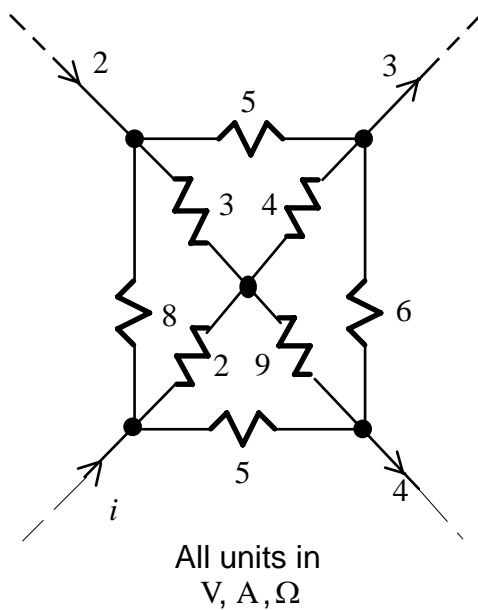


# E

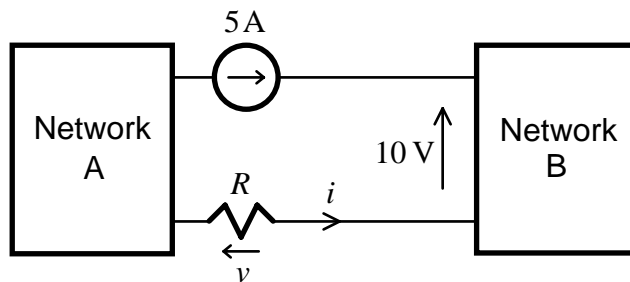
## TUTORIAL PROBLEMS

### E.1 KCL, KVL, Power and Energy

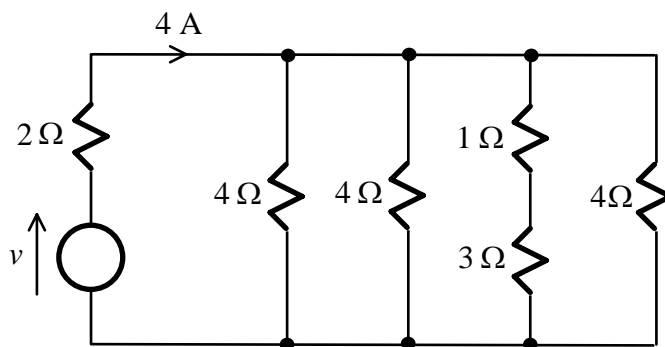
Q.1 Determine the current  $i$  in the following circuit.



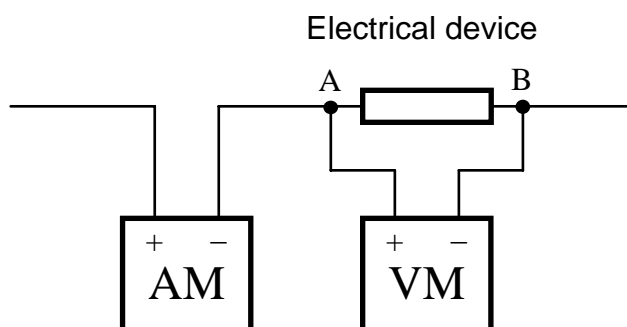
- Q.2 Determine the current  $i$  and the voltage  $v$  in the following circuit for  $R = 2\Omega$  and  $R = 50\text{K}\Omega$ .



- Q.3 Determine the source voltage  $v$  and the voltage across the  $3\Omega$  resistor in the following circuit.



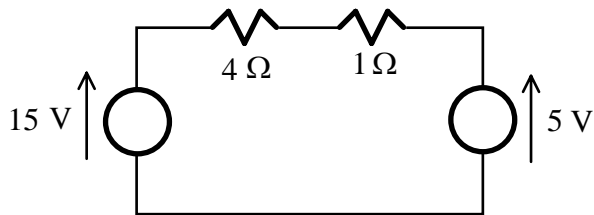
- Q.4 The Ammeter AM and voltmeter VM, connected as shown below, measure current and voltage, respectively. The ammeter will give a positive reading if the current flowing into its "+" terminal is positive.



Determine if the electrical device is consuming or supplying power when

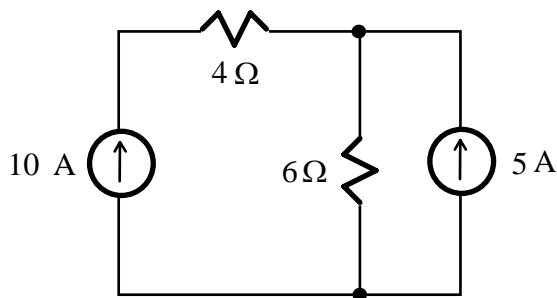
- both meters give positive readings;
- both meters give negative readings; and
- one meter gives a positive reading while the other gives a negative reading.
- one meter or both meters give zero readings.

Q.5 Determine the current in the following circuit.



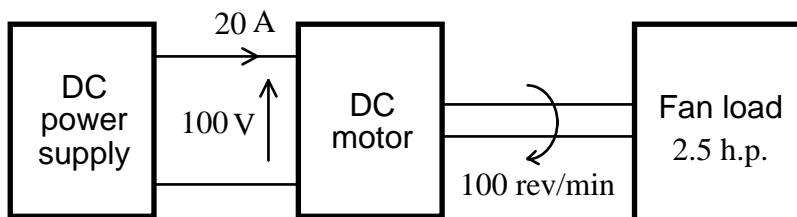
How much power is each component consuming or supplying?

Q.6 Determine the voltages and currents in the following circuit.



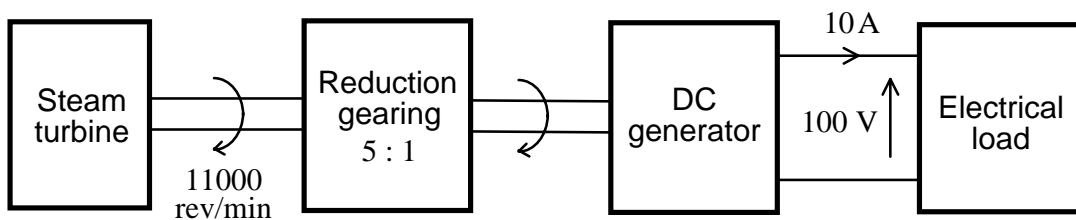
Is the 10 A current source consuming or supplying power?

Q.7 In the following system, determine the efficiency of the motor and the torque on the fan shaft?



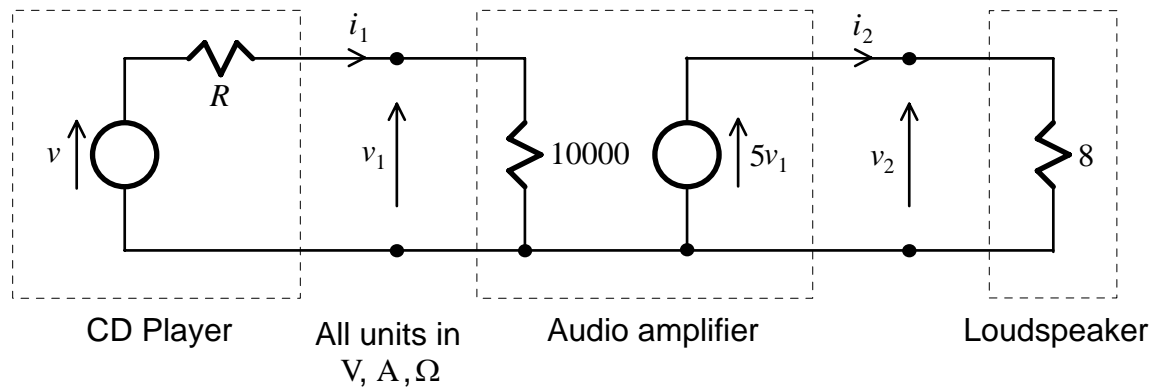
How much energy is lost in the motor per minute? (Note that 1 h.p. = 746 W.)

Q.8 In the following system, the efficiency of the generator is 0.9.



Determine the torque in its shaft.

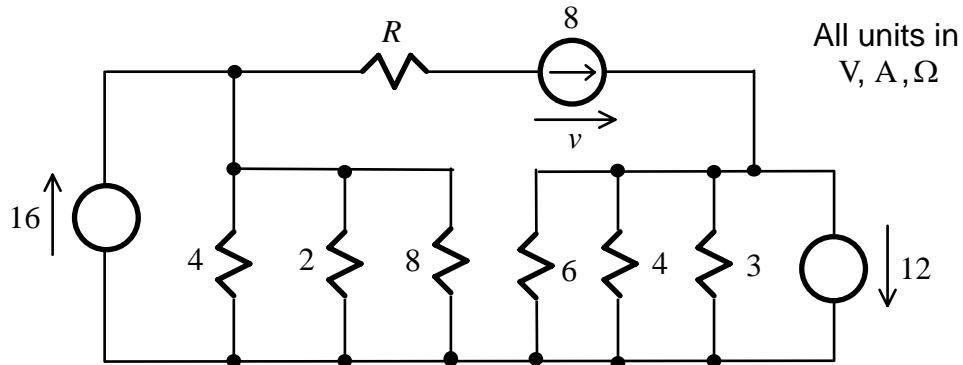
Q.9 The following figure shows the equivalent circuit of an audio amplifier when connected to an input audio source (CD player) and a load (loudspeaker).



Calculate the voltage gain  $|v_2/v_1|$ , current gain  $|i_2/i_1|$  and power gain  $|(v_2 i_2)/(v_1 i_1)|$  of the amplifier in dB. What is the relationship between these gains? Show that these gains will be equal to one another when the load resistance is equal to input resistance of the amplifier. Do you expect this to be the case in practice?

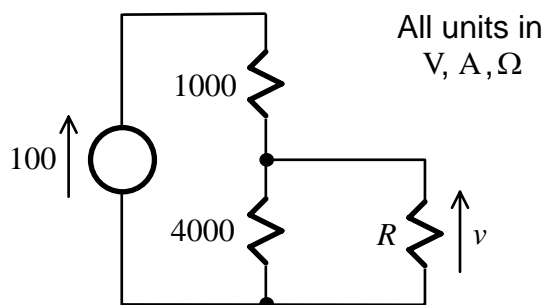
## E.2 KCL, KVL and Grounding

Q.1 Determine the current in each branch of the following circuit by inspection.



If the voltage  $v$  is  $-16\text{V}$ , determine  $R$ .

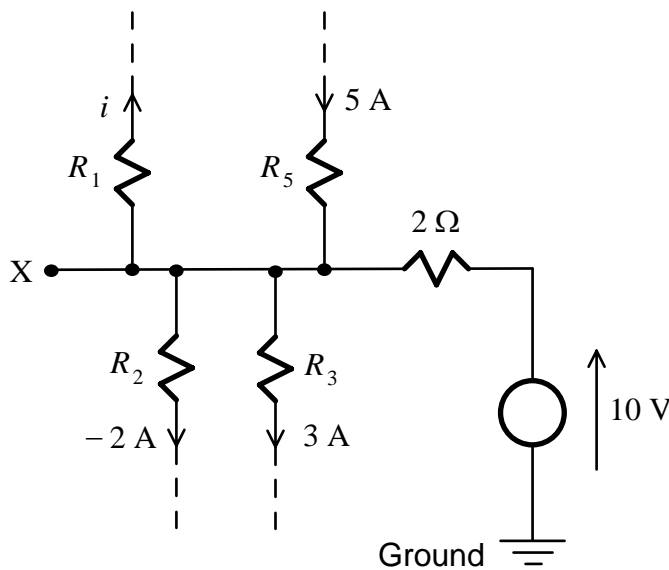
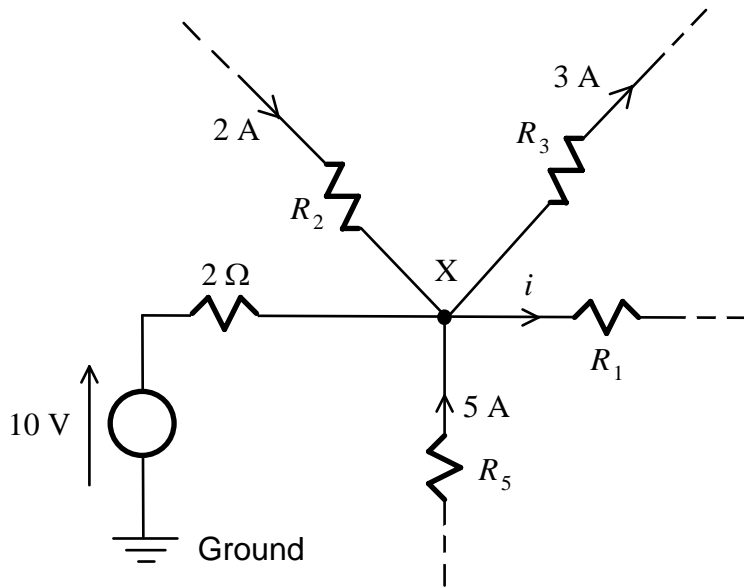
Q.2 The following circuit shows a common voltage divider for obtaining a certain voltage  $v$  across a load resistor  $R$ .



In finding  $v$ , a novice (= 1st year student) may forget (okay, if it's only for this time) to include the loading effects of  $R$ . To understand these effects, determine  $v$  and the current in  $R$  when

- $R = \infty$  (open circuit or no load situation);
- $R = 8000\Omega$ ;
- $R = 200\Omega$ ; and
- $R = 0$  (short circuit situation).

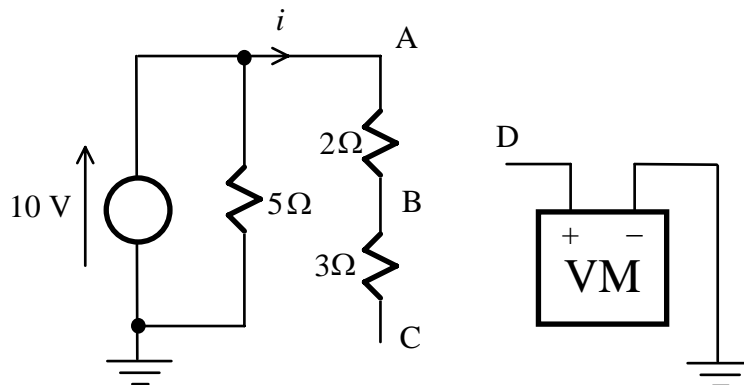
Q.3 Are the two circuits shown below equivalent? Why?



As is done in the above circuits, voltages in electrical systems are often measured with respect to a reference or ground potential. In practice, the ground will be connected to a large number of components and will run through the entire system using thick conductors. It is sometimes connected to the chassis of the system or the earth pin of the 3-pin power plug.

Assuming that there are other components (not shown) connected to ground, determine the current flowing through the voltage source and the potential of node X with respect to ground when  $i = 2\text{ A}$  and  $i = -3\text{ A}$ . Why is the ground node seems to be taking/giving current all the time and still Kirchhoff's current law is not violated?

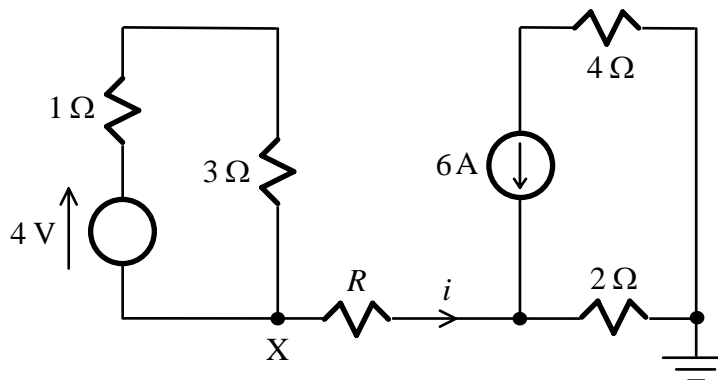
Q.4 In the following circuit, the voltmeter VM is used to measure the voltages of various points with respect to ground.



Assuming that VM does not take any current, determine the current  $i$  and the voltmeter reading when

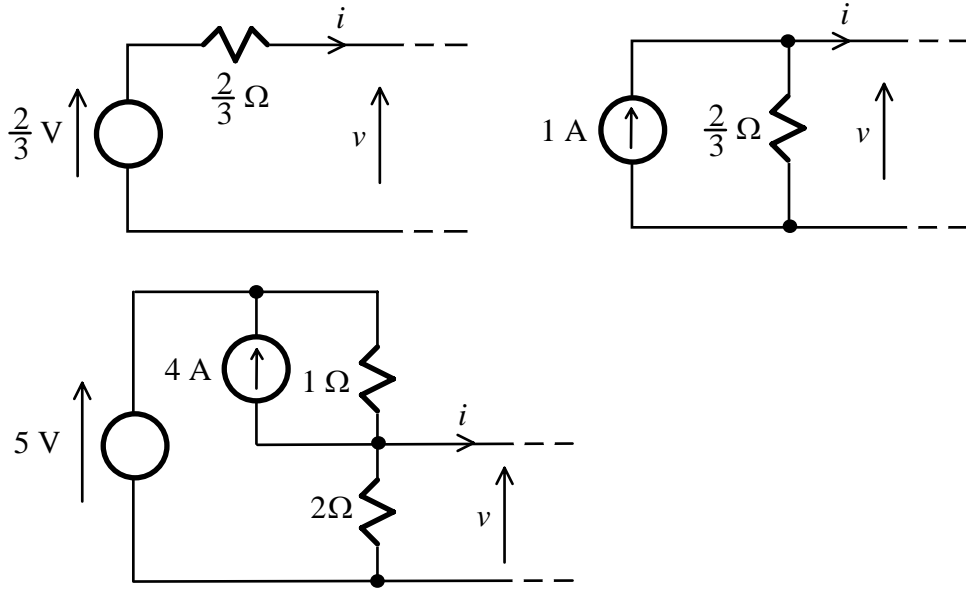
- Point C is grounded and Point B is connected to Point D;
- there is no connection for Point C and Point B is connected to Point D; and
- Point B is grounded and Point C is connected to Point D.

Q.5 Determine the current  $i$  and the potential of node X with respect to ground in the following circuit.



How will these be changed if the circuit is not grounded or if the circuit is grounded at Point X only?

Q.6 Determine the relationships between  $v$  and  $i$  for the following three circuits.

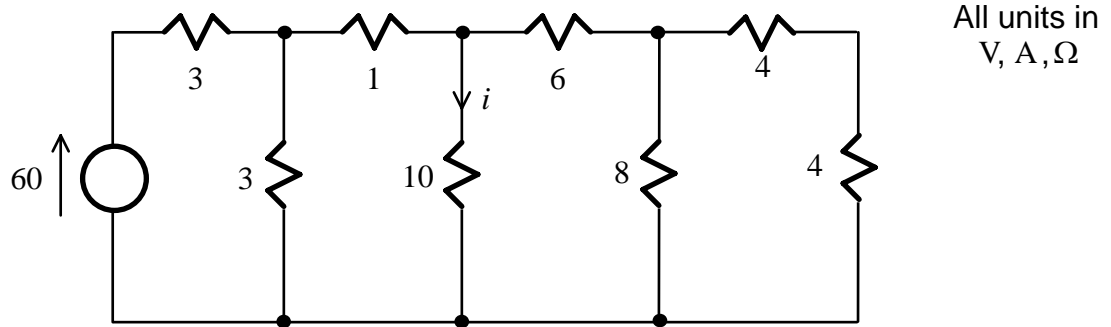


What can you say about these three circuits?



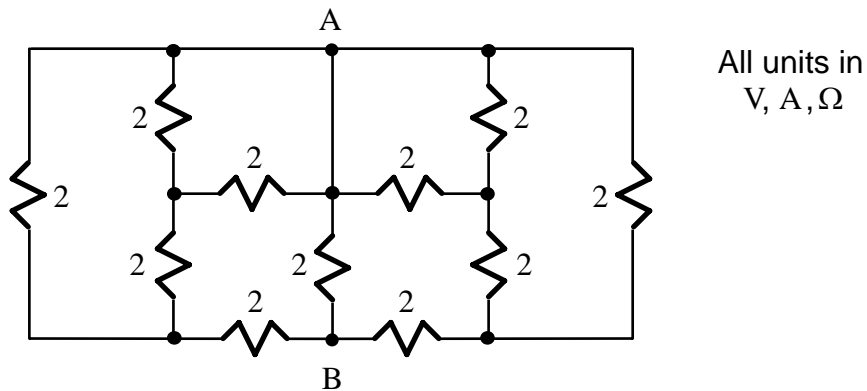
### E.3 DC Circuit Analysis I

- Q.1 Find the source current in the following ladder network by reducing the series and parallel combinations to a single resistor.



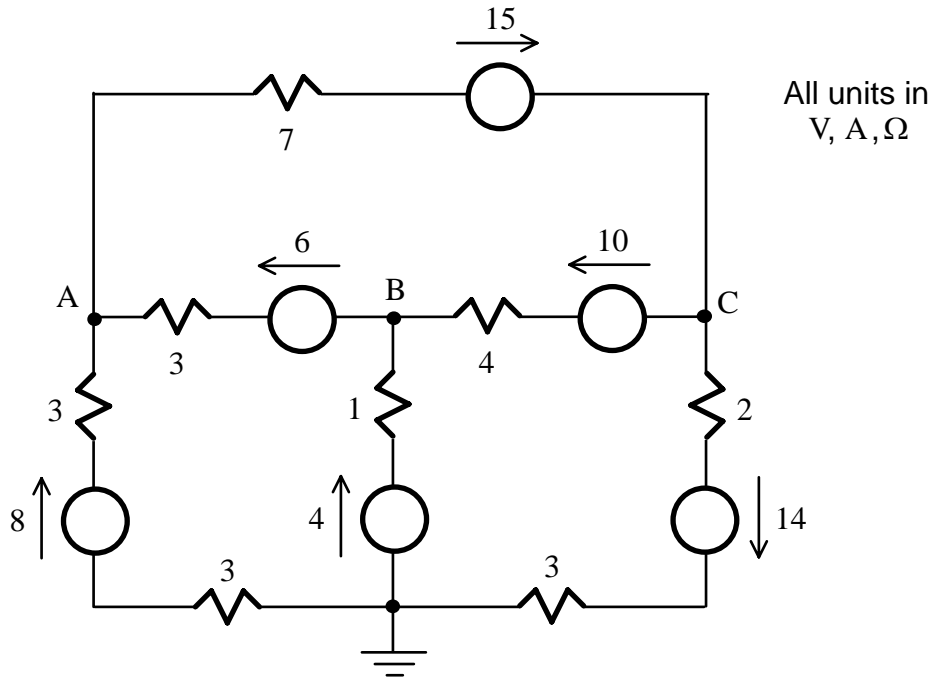
Determine the current  $i$  by using current division.

- Q.2 Determine the equivalent resistance that would be measured between Points A and B of the following circuit.



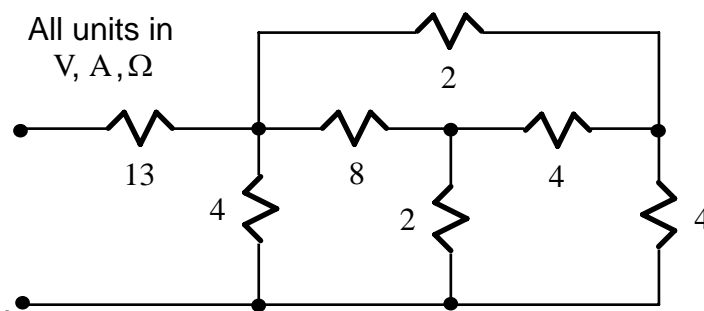
What will the result be if the outer two resistors are short-circuited?

Q.3 Formulate the equations for obtaining the loop currents of the following circuit by using mesh analysis. Determine the voltages of nodes A, B and C with respect to ground in terms of these currents.

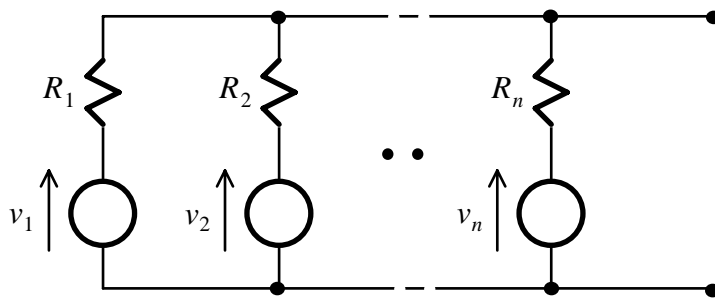


Using nodal analysis, derive the equations for obtaining the voltages of the three nodes.

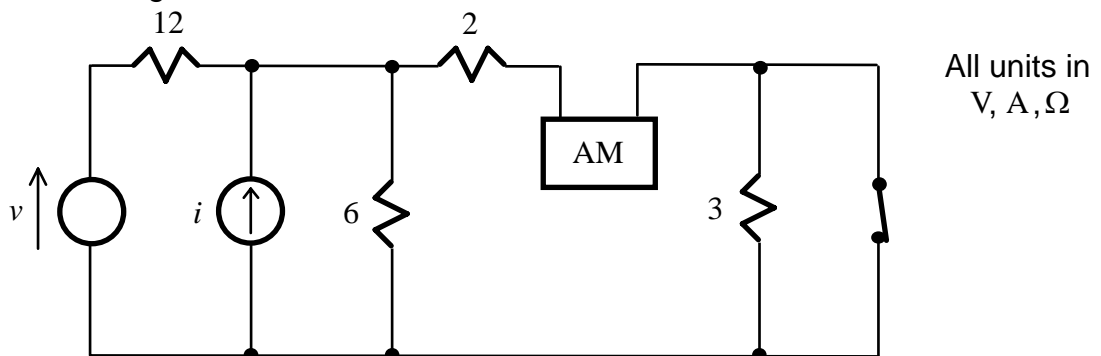
Q.4 Using nodal analysis, calculate the equivalent resistance of the following 2-terminal network.



- Q.5 Determine Norton's and Thevenin's equivalent circuits for the following 2-terminal network.

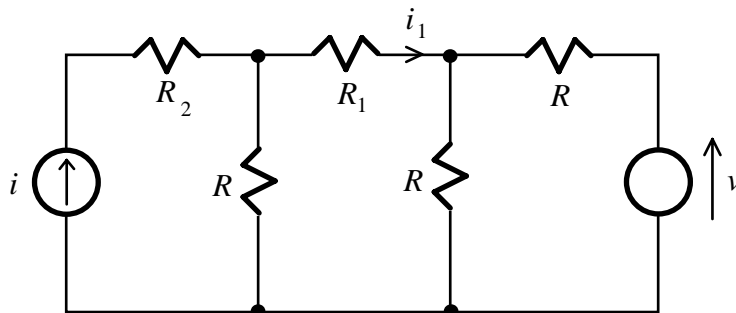


- Q.6 In the following circuit, the ammeter AM reads 1A when the switch is closed.



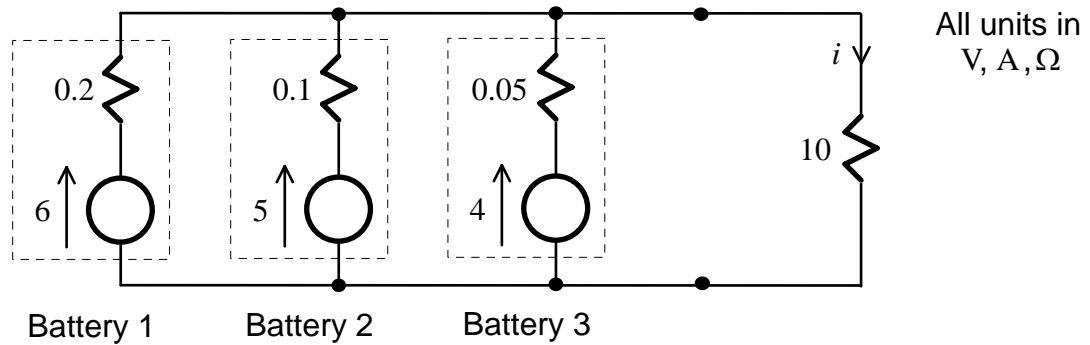
Using Norton's equivalent circuit, determine the reading when the switch is open.

- Q.7 Using Thevenin's equivalent circuit, determine the current  $i_1$  in the following circuit.



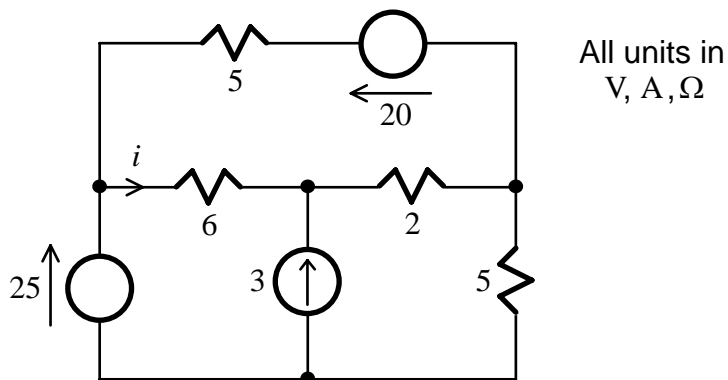
## E.4 DC Circuit Analysis II

- Q.1 The following circuit shows three batteries connected in parallel and supplying power to a  $10\Omega$  load.

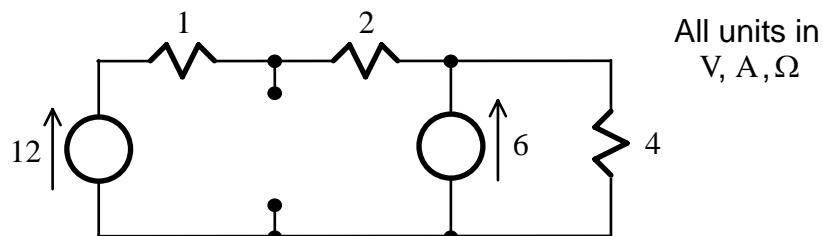


Using superposition, determine the component of the load current  $i$  due to each battery. Hence, calculate the load current.

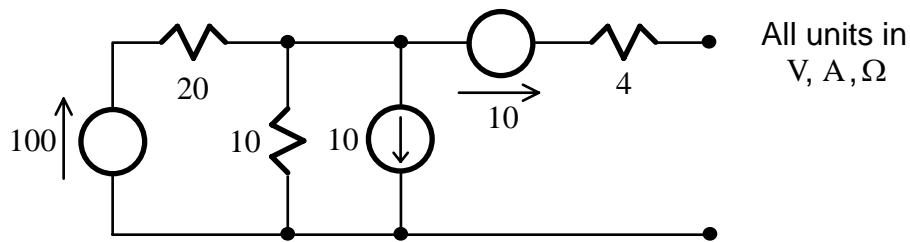
- Q.2 Determine the current  $i$  in the following circuit by using superposition.



- Q.3 Determine the maximum power that can be obtained from the two terminals of the following circuit.

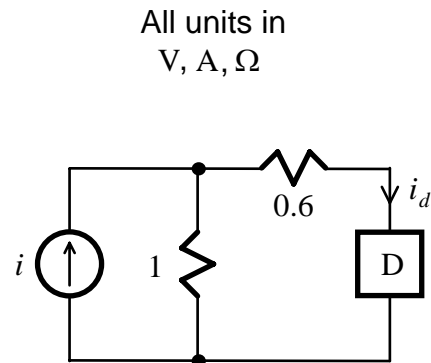
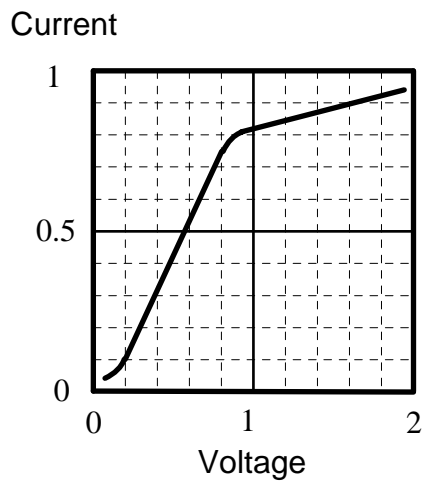


- Q.4 Determine the resistor that will draw a current of 2 A when connected across the two terminals of the following network.



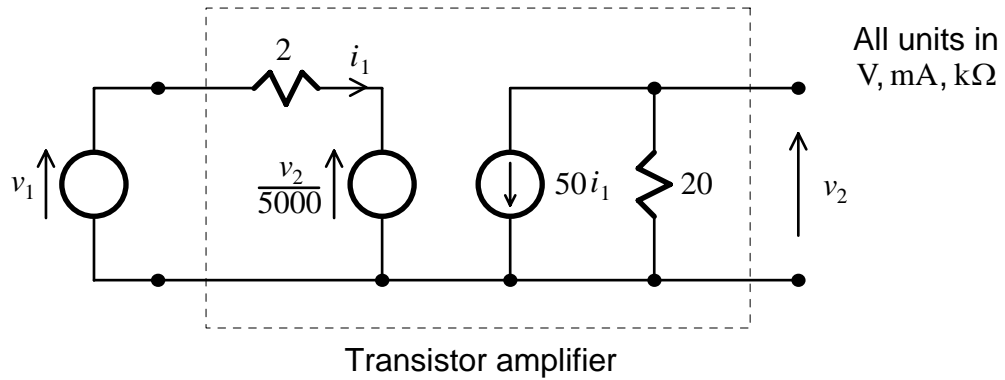
What resistor will absorb the maximum power? Calculate this power.

- Q.5 The following figure shows the voltage-current curve of an electrical device D and a circuit in which the device is employed.



Determine the device current  $i_d$  if  $i = 1.6\text{ A}$ . At what value of  $i$  will the power dissipated in D be 0.6W?

- Q.6 The following figure shows the equivalent circuit of a transistor amplifier connected to amplify the magnitude of the voltage  $v_1$  from an input voltage source. The main activities of the transistor are represented by the two dependent sources, while the substrate and other contact resistances are represented by the two resistors.



Determine the output voltage  $v_2$  of the amplifier in terms of  $v_1$ . What is the gain of the amplifier in terms of voltage magnitudes? Give your answer in dB. Determine the Thevenin's equivalent circuit of the system as seen from the output terminals.

## E.5 AC Circuit Analysis I

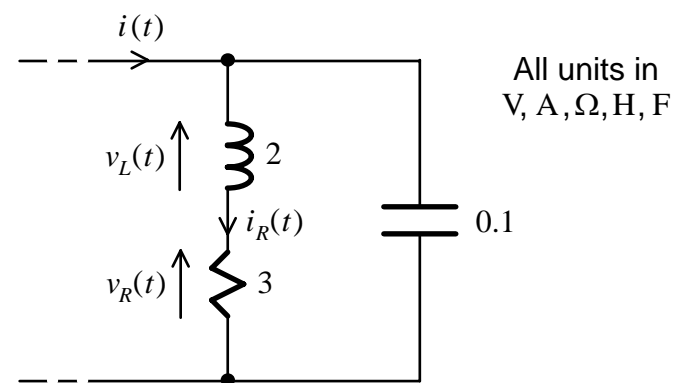
Q.1 Write down the peak and rms values, frequency, phase, complex and phasor representations of the following ac quantities.

- (a)  $5\sqrt{2} \sin(\omega t)$
- (b)  $5\sqrt{2} \cos(\omega t)$
- (c)  $10\sqrt{2} \sin(20t + 30^\circ)$
- (d)  $120\sqrt{2} \cos(314t - 45^\circ)$
- (e)  $-50 \sin\left(4t - \frac{\pi}{3}\right)$
- (f)  $0.25 \cos(2t + 100^\circ)$

Q.2 Taking the frequency to be 50Hz, write down the sinusoidal voltages and currents corresponding to the following phasors.

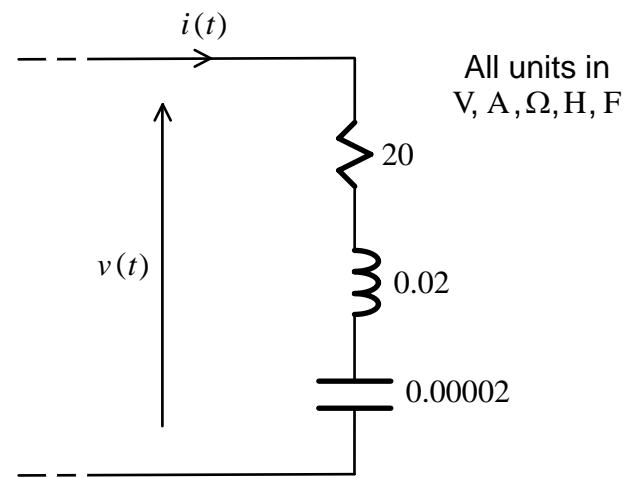
- (a)  $\frac{100}{\sqrt{2}} e^{j30^\circ} \text{ V}$
- (b)  $115 e^{j\pi/3} \text{ V}$
- (c)  $-0.12 e^{-j\pi/4} \text{ A}$
- (d)  $-0.69 \angle 60^\circ \text{ A}$

Q.3 In the following ac circuit,  $v_R(t) = 12\sqrt{2} \cos(2t) \text{ V}$ .



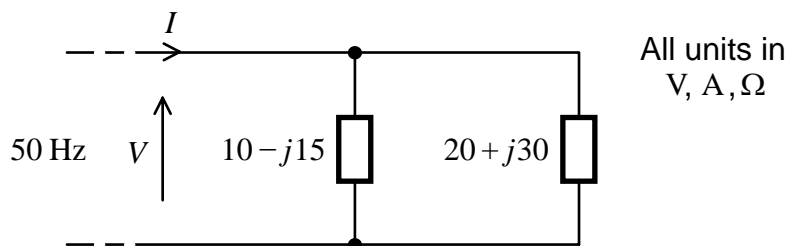
Determine  $i_R(t)$ ,  $v_L(t)$  and  $i(t)$  by using phasor analysis.

- Q.4 In the following series RLC circuit,  $v(t) = 50\sqrt{2} \cos(1250t + 30^\circ) \text{ V}$ . Determine the phasors of the voltages across the three components and that of the current  $i(t)$ .



Draw a phasor diagram showing all these phasors in the complex plane.

- Q.5 The following figure shows an ac circuit with two parallel branches. Each branch consists of two series components:  $RL$  (resistor and inductor) or  $RC$  (resistor and capacitor) or  $LC$  (inductor and capacitor). From the impedances given, find the components and their values in the circuit.

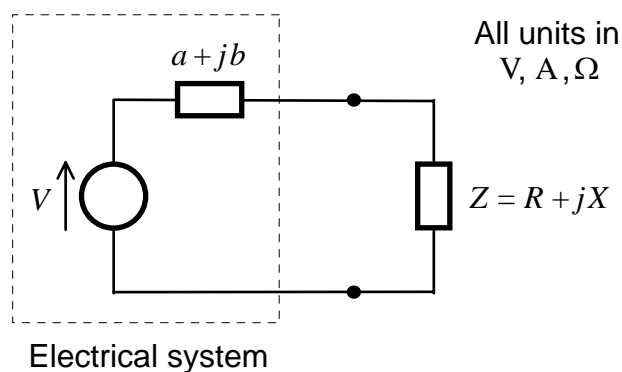


Calculate the admittance (reciprocal of impedance) of the entire circuit and the phase angle between  $I$  and  $V$ . What is the power factor of the circuit?



## E.6 AC Circuit Analysis II

- Q.1 A  $4\ \Omega$  resistor is connected in series with a coil across a  $20\ \text{V}$   $50\ \text{Hz}$  supply. The voltage across the resistor is  $9\ \text{V}$  and that across the coil is  $14\ \text{V}$ . If the coil can be represented as an ideal inductor  $L$  in series with a resistor  $R$  (accounting for the winding resistance and other losses), calculate the values of  $L$  and  $R$ , the power absorbed by the coil, and the power factor of the whole circuit.
- Q.2 A load connected across a  $2000\ \text{V}$   $50\ \text{Hz}$  line draws  $10\ \text{kW}$  at a lagging power factor of  $0.5$ . Determine the current taken by the load. To improve the power factor, a capacitor  $C$  is now connected in parallel with the load. Determine the value of  $C$  so that the overall power factor is  $0.9$  lagging, unity and  $0.8$  leading.
- Q.3 The following diagram shows the Thevenin's equivalent circuit of an ac system when connected to a load with impedance  $Z = R + jX$ .

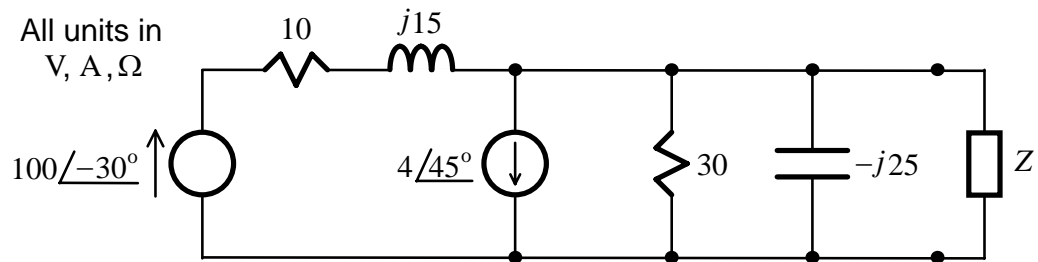


Show that  $R$  and  $X$  should be given by

$$Z = R + jX = (a + jb)^* = a - jb$$

in order for the load to absorb the maximum power. Determine this maximum power.

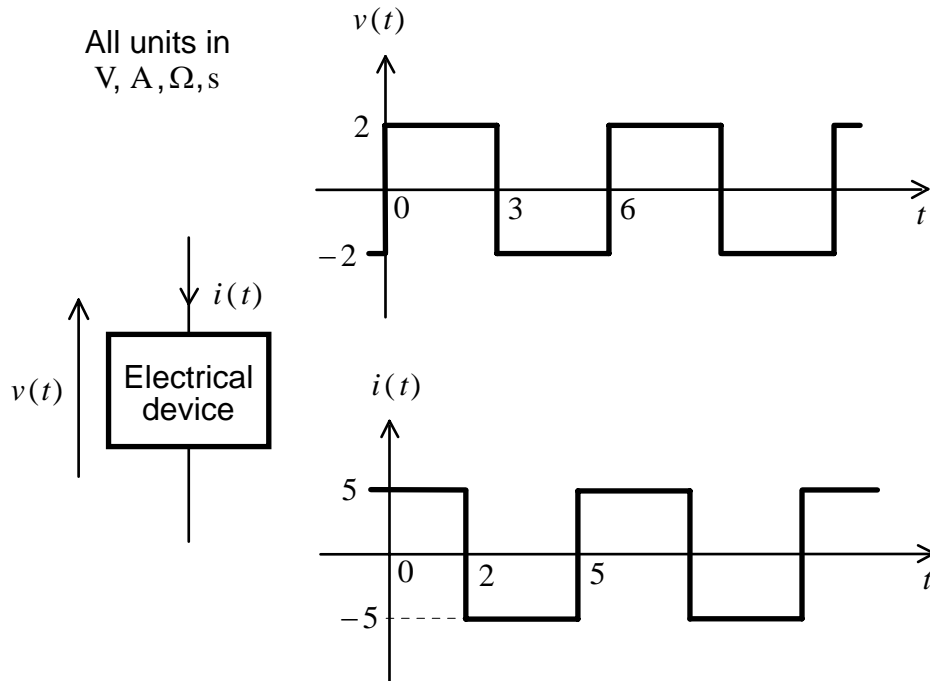
- Q.4 Using Norton's equivalent circuit, determine the maximum power that can be absorbed by the load with impedance  $Z$  in the following ac system.



- Q.5 A certain tune circuit consists of a  $100 \mu\text{H}$  coil with a resistance of  $10 \Omega$  (representing losses due to thermal resistance and other effects) connected in series with a  $100 \text{ pF}$  capacitor. Determine the resonant frequency,  $Q$  factor, bandwidth and 3dB cutoff frequencies of the circuit.
- Q.6 A variable tuning capacitor in a radio receiver has a maximum capacitance of  $500 \text{ pF}$  and a minimum capacitance of  $20 \text{ pF}$ . What inductance is required so that the lowest frequency to which the circuit can be tuned is  $666 \text{ kHz}$ ? What is the highest frequency to which this circuit can be tuned?

## E.7 Periodic Signals

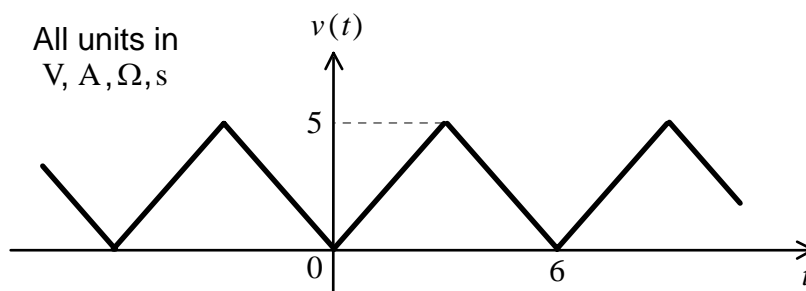
Q.1 The voltage  $v(t)$  applied to and the current  $i(t)$  resulted from an electrical device are periodic and are given below.



Determine

- the period of the voltage and current waveforms;
- the average or mean value of  $v(t)$  and  $i(t)$ ;
- the time when the device is consuming power and when it is supplying power;
- the period of the instantaneous power curve; and
- the average power consumed by the device.

Q.2 The following figure shows a symmetrical and periodic sawtooth voltage waveform  $v(t)$  from a signal generator.



- Determine the period and mean value of  $v(t)$ .
- Sketch the variation of  $v^2(t)$  as a function of time  $t$ . Hence, determine the period and mean value of  $v^2(t)$ . Calculate  $v_{rms}$ , the square root of this mean value.  $v_{rms}$  is the rms (root mean square) value of the periodic signal  $v(t)$ .
- If  $v(t)$  is applied to a resistor  $R$ , show that the average power being consumed is given by  $v_{rms}^2/R$ . (From this, it is easy to see why the rms value is sometimes called the effective value.)

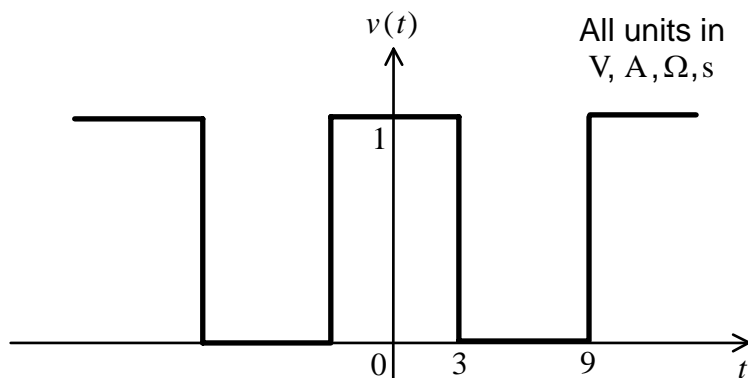
Q.3 Write down the phasor representations of  $v_1(t)$  and  $v_2(t)$  and determine their phase difference for the following two situations.

(a)  $v_1(t) = 10\sqrt{2} \cos(2\pi t + 2^0)$  and  $v_2(t) = 20\sqrt{2} \cos(2\pi t + 23^0)$

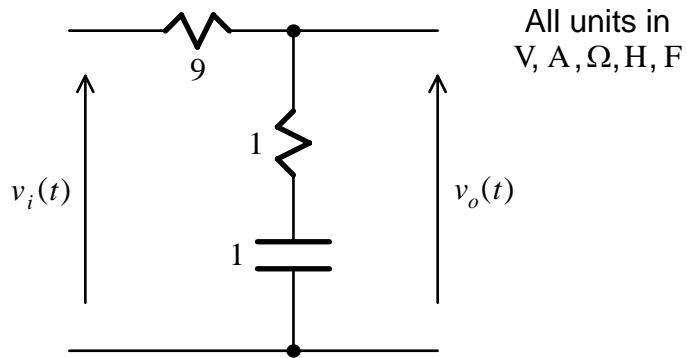
(b)  $v_1(t) = 10\sqrt{2} \cos(2\pi t + 2^0)$  and  $v_2(t) = 20\sqrt{2} \cos(\sqrt{2}\pi t + 23^0)$

What happens when  $v_1(t)$  and  $v_2(t)$  are observed by an observer with a time origin of  $t = 0.5$  so that  $v_1(t+0.5)$  and  $v_2(t+0.5)$  are seen instead?

Q.4 Determine the Fourier series representation of the following symmetrical periodic square waveform.



- Q.5 In the following circuit,  $v_i(t)$  is the excitation and  $v_o(t)$  is the response. Derive the frequency response of the circuit. Sketch the magnitude response and show that the circuit is lowpass in nature. Deduce this from the low and high frequency characteristics of the capacitor as well.



Determine  $v_o(t)$  if  $v_i(t)$  is given by the non-periodic signal

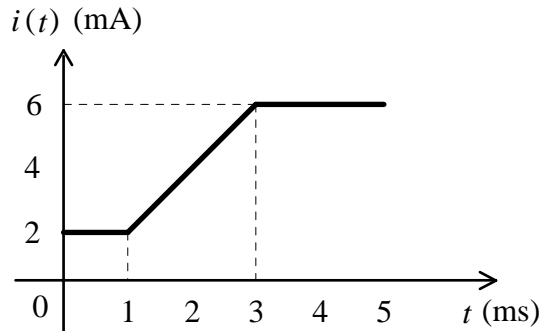
$$v_i(t) = \cos(2\pi t) + \sin(\sqrt{2}\pi t)$$

and also when it is a periodic square waveform with Fourier series

$$v_i(t) = \sin(2\pi t) + \frac{\sin(6\pi t)}{3} + \frac{\sin(10\pi t)}{5} + \dots$$

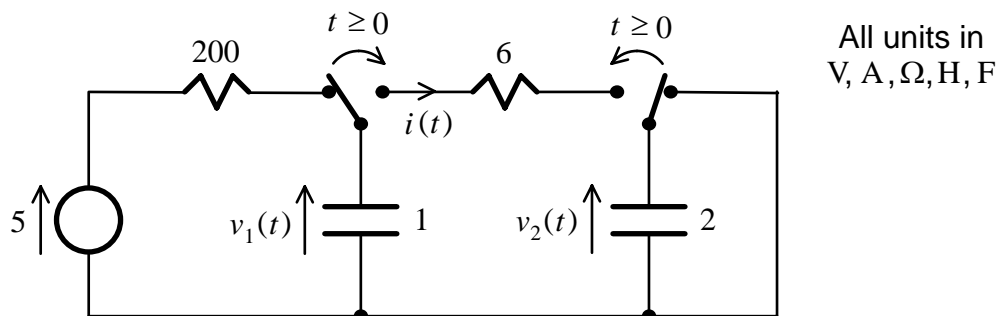
## E.8 Transients I

- Q.1 The current  $i(t)$  in the following figure flows through a 5 H inductor and an initially uncharged  $5 \mu\text{F}$  capacitor.



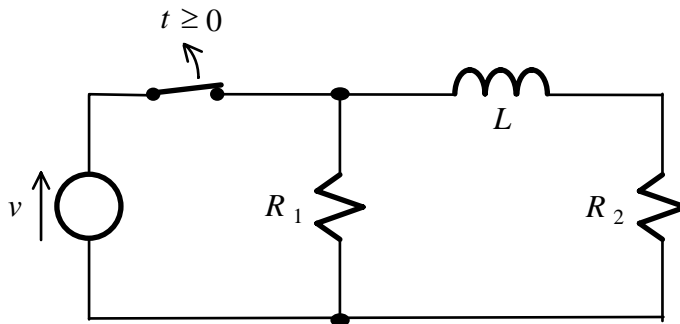
Plot the voltages across the inductor and capacitor as functions of time  $t$ .

- Q.2 In the following circuit, the two switches have been in the positions shown for  $t < 0$  and are thrown to the other positions for  $t \geq 0$ .

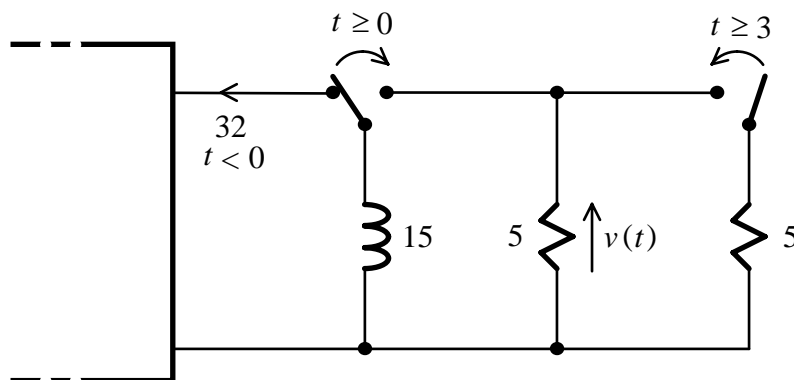


- Assuming that the switches have been in their original positions for a long time so that the voltages and currents in the circuit have settled down to constant values, determine the values of  $v_1(t)$ ,  $v_2(t)$  and  $i(t)$  for  $t < 0$ .
- Determine  $v_1(t)$ ,  $v_2(t)$  and  $i(t)$  just after the switches were thrown to the other positions at  $t = 0$ .
- Derive and solve the governing differential equation for  $i(t)$  for  $t \geq 0$ . Hence, obtain expressions for  $v_1(t)$  and  $v_2(t)$  for  $t \geq 0$ .
- Sketch  $v_1(t)$ ,  $v_2(t)$  and  $i(t)$  as functions of  $t$ .

- Q.3 In the following circuit, the switch has been closed for a long time. At time  $t = 0$ , the switch is opened.



- (a) Determine the voltages and currents in the circuit for  $t < 0$ . What is the energy stored in the inductor?
- (b) Determine the current in the inductor  $i(t)$  just after the switch is opened at  $t = 0$ .
- (c) Derive an expression for  $i(t)$  for  $t \geq 0$ .
- (d) By integrating  $(R_1 + R_2)i^2(t)$ , determine the energy consumed by the resistors after the switch is opened. Derive the same result by using conservation of energy.
- Q.4 In the following diagram, the inductor is carrying a current of 32 A when the switch on the left is turned from the position shown to the other position at time  $t = 0$ . At the end of 3 s, the other switch is closed.

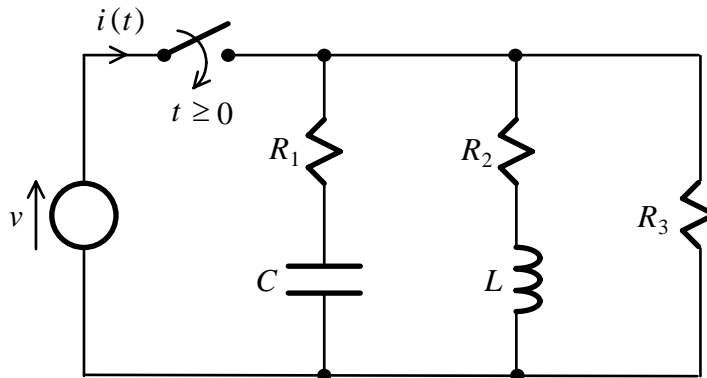


All units in  
V, A,  $\Omega$ , H, F

Derive an expression for  $v(t)$  and sketch it.

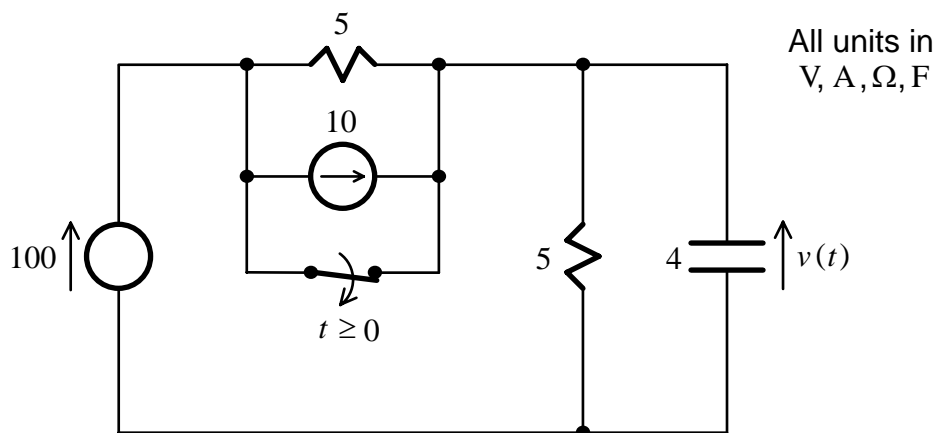
## E.9 Transients II

- Q.1 In the following circuit, the switch has been opened for a long time. At time  $t = 0$ , the switch is closed.



Derive an expression for  $i(t)$  as a function of time. For what values of  $R_1$ ,  $R_2$  and  $R_3$  will this current be independent of time?

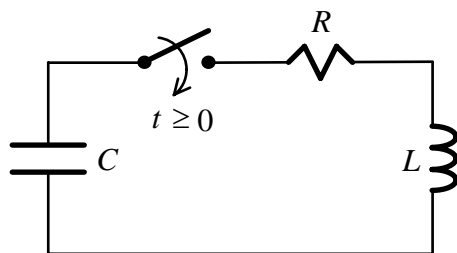
- Q.2 In the following circuit, the switch is opened at  $t = 0$  after steady state conditions have prevailed.



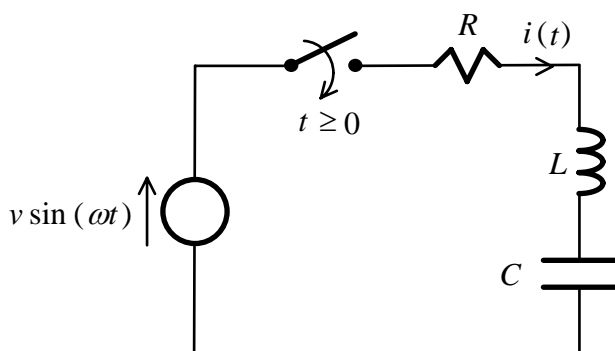
Derive an expression for  $v(t)$  for  $t \geq 0$ .



- Q.3 In the following circuit, the capacitor is initially charged to 10 V before the switch is closed.



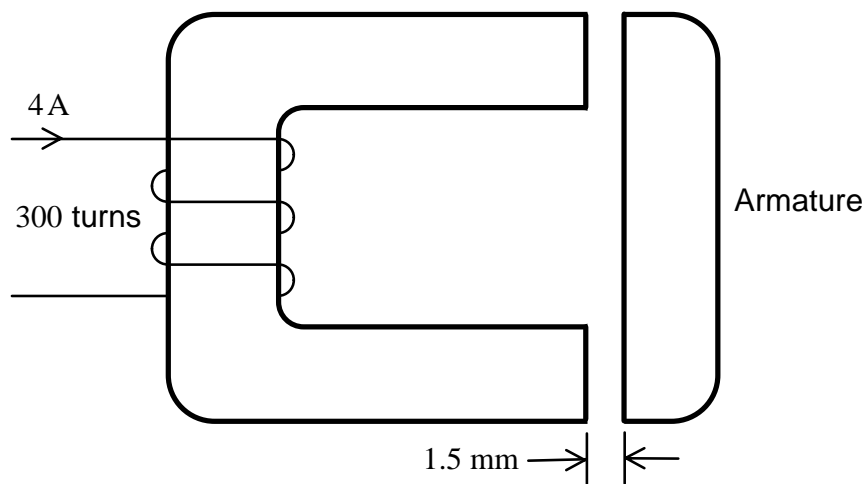
- Determine the voltages and current in the circuit before the switch is closed.
  - Determine the voltages and current just after the switch is closed at  $t = 0$ .
  - Derive the governing differential equation for the current for  $t \geq 0$ . Express all the constants involved in terms of the resonant frequency and  $Q$  factor of the circuit. What are the initial conditions that have to be satisfied?
  - Determine and sketch the current for  $t \geq 0$  under the overdamped situation of  $Q < \frac{1}{2}$ .
  - Determine and sketch the current for  $t \geq 0$  under the underdamped situation of  $Q > \frac{1}{2}$ .
  - Determine and sketch the current for  $t \geq 0$  under the undamped situation when  $R = 0$ .
- Q.4 In the following circuit, the capacitor is initially uncharged and there is no current through the inductor when the switch is closed at time  $t = 0$ .



Derive the governing differential equation and initial conditions for finding the circuit current  $i(t)$  for  $t \geq 0$ . Determine the steady state current.

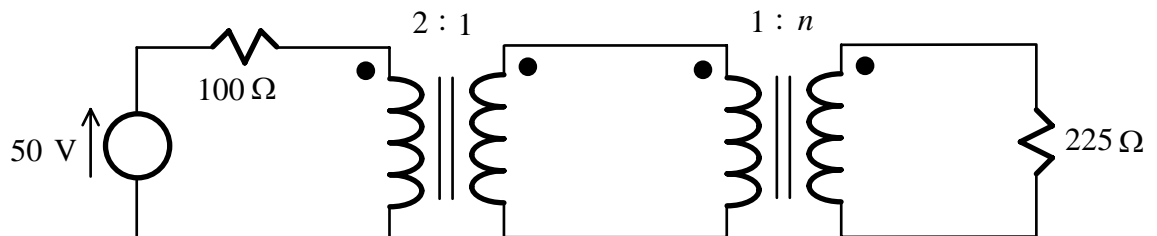
## E.10 Magnetic Circuits

- Q.1 A magnetic circuit comprises an iron core with a short air gap. The core cross-section is  $1000\text{ mm}^2$ , its length is  $500\text{ mm}$  and the relative permeability of the iron is  $600$ . The gap length is  $2.5\text{ mm}$ . Estimate the mmf required to produce a flux of  $1.8\text{ mWb}$  in the gap. Neglect fringing effects.
- Q.2 Assuming that the effective area of each air gap is  $0.05\text{ m}^2$ , the iron path requires  $\frac{1}{3}$  of the total mmf and the total flux is kept constant, calculate the force of attraction on the armature of the electromagnet shown in the following figure.



What will the force be if the current is doubled? Will the force be less than this in a practical device? Why?

- Q.3 In the following circuit, an  $225\Omega$  load is connected to a  $50\text{ V}$   $100\Omega$  source through two ideal transformers.



Given that maximum power is being drawn from the source, determine the turn ratio  $n$  and all the voltages and currents in the circuit.

- Q.4 A transformer has a rating of 6600/230 V (6600 V primary, 230 V secondary) and 100 kVA (maximum value which can be delivered under normal operating conditions). If it is supplying  $\frac{1}{2}$  rated current at 0.8 lagging power factor, calculate the value of the actual load impedance. What is the value of the load impedance referred to the primary?
- Q.5 The flux density in the core of a 440/220 V 50 Hz single-phase transformer has a maximum value of 0.6 T. If the primary winding has 1320 turns, determine the number of turns in the secondary winding. Using Faraday's law of induction, derive the relationship between the maximum flux in the core and the rms value of the voltage across the primary. Hence, calculate the cross sectional area of the core.
- Q.6 There are two main types of power losses in a practical transformer. Copper loss is caused by the resistances of the copper wire in the windings and is proportional to the square of the currents. Iron loss is caused by the induction of eddy currents and the repeated changes in magnetisation in the magnetic core of the transformer. This loss increases as the frequency increases, but is usually independent of the load and supply currents.

A 50 kVA 2200/220 V 60 Hz transformer has an iron loss of 350 W and a copper loss of 630 W at full load or rated current. Determine the efficiency at full load and unity power factor; at  $\frac{3}{4}$  full load and unity power factor; at full load and 0.8 power factor; and at  $\frac{3}{4}$  full load and 0.8 power factor. Determine the all-day efficiency if the operating schedule is as follows.

0000 – 0600 hr	no load
0600 – 1200 hr	full load, unity pf
1200 – 1400 hr	$\frac{3}{4}$ full load, unity pf
1400 – 1800 hr	full load, 0.8 pf
1800 – 2200 hr	$\frac{3}{4}$ full load, 0.8 pf
2200 – 2400 hr	no load