Family Name ....

Given Name ....

Student No. ....

Signature ....

THE UNIVERSITY OF NEW SOUTH WALES

School of Electrical Engineering & Telecommunications

MID-TERM EXAMINATION

Term 1, 2019

ELEC1111
Electrical and Telecommunications Engineering

TIME ALLOWED:	**75 min**
TOTAL MARKS:	**100**
TOTAL NUMBER OF QUESTIONS:	**5**

THIS EXAM CONTRIBUTES 25% TO THE TOTAL COURSE ASSESSMENT

Reading Time: 5 minutes.

This paper contains 4 pages.

Candidates must **ATTEMPT ALL** questions.

Answer each question in a **separate answer booklet**.

Marks for each question are indicated beside the question.

This paper **MAY NOT** be retained by the candidate.

Print your name, student ID and question number on the front page of each answer book.

Authorised examination materials:

Candidates should use their own UNSW-approved electronic calculators.

This is a closed book examination.

Assumptions made in answering the questions should be stated explicitly.

All answers must be written in ink. Except where they are expressly required, pencils **may only be used** for drawing, sketching or graphical work.

QUESTION 1 [20 marks]

a. **(10 marks)** For the circuit shown in Figure 1,

i. **(6 marks)** Apply mesh analysis and write down the mesh equations using the labels provided. Note: Simplify the equations, but DO NOT solve them.

ii. **(4 marks)** Given the values of mesh currents as $i_1 = 5.95\ A$, $i_2 = 4.65\ A$ and $i_3 = 0.95\ A$, find the power dissipated in the 5A current source.

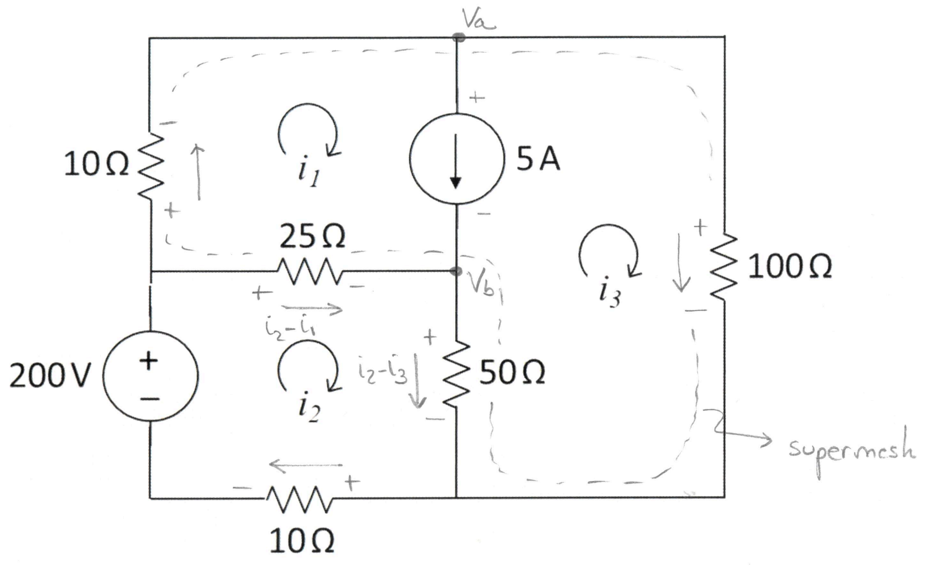


Figure 1

i)

$10 i_1 + 100 i_3 - 50(i_2 - i_3) - 25(i_2 - i_1) = 0 \quad \Rightarrow \quad 35 i_1 - 75 i_2 + 150 i_3 = 0$ ①

$-200 + 25(i_2 - i_1) + 50(i_2 - i_3) + 10 i_2 = 0 \quad \Rightarrow \quad -25 i_1 + 85 i_2 - 50 i_3 = 200$ ②

$i_1 - i_3 = 5A$ (constraint equation) ③

* Note: outer mesh can also be used: $10 i_1 + 100 i_3 + 10 i_2 - 200 = 0$

ii)

First, calculate voltage across 5A source using KVL in mesh 1:

$10 i_1 + V_{5A} - 25(i_2 - i_1) = 0 \quad \Rightarrow \quad V_{5A} = -35 i_1 + 25 i_2 = -35 \times 5.95 + 25 \times 4.65 = -92V$

$\boxed{P_{5A} = V_{5A} \times 5A = -92 \times 5 = -460\ W}$

* Note: Power across 5A current source can also be calculated using other methods, E.g.

- Calculating voltage using nodal analysis, where $V_{5A} = V_a - V_b$ and $V_a = 140.5V$ and $V_b = 235.5V$.
- Calculating power from power balance equation for all the circuit (not for the different meshes).
- Calculating voltage using KVL in mesh 3.

All options were appropriately considered when marking

b. **(10 marks)** Bipolar transistors can serve as amplifiers, producing both current gain and voltage gain. Such amplifiers can be used to furnish a considerable amount of power to devices that convert energy from one form to another, such as loudspeakers or control motors. For the simplified transistor circuit shown in Figure 2,

i. **(6 marks)** Use nodal analysis to find the nodal voltage v_1.

ii. **(4 marks)** Use your result from part (i) to calculate the output current i_0 and output voltage v_0.

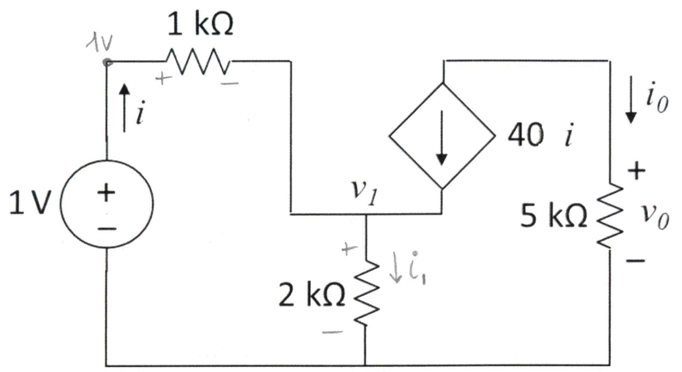


Figure 2

i) KCL @ node V_1: $i + 40i = i_1$

$41i = i_1$

$41\,\frac{1-V_1}{1k} = \frac{V_1}{2k}$

$41 - 41V_1 = 0.5V_1 \Rightarrow 41 = 41.5V_1 \Rightarrow \boxed{V_1 = \frac{41}{41.5} = 0.988V}$

ii) $\boxed{i_0} = -40i = -40\,\frac{1-V_1}{1k} = -40\,\frac{1-0.988}{1k} = \boxed{-0.48\,mA}$

$\boxed{V_0} = 5k \times i_0 = -0.48\,mA \times 5k = \boxed{-2.4\,V}$

QUESTION 2 [15 marks]

For the circuit shown in Figure 3,

a. **(6 marks)** Calculate the equivalent resistance R_{eq} as seen from terminals *a*-*b*.

b. **(3 marks)** Find current i_g using the result of part (a).

c. **(6 marks)** Find the power dissipated in the 8 Ω resistor.

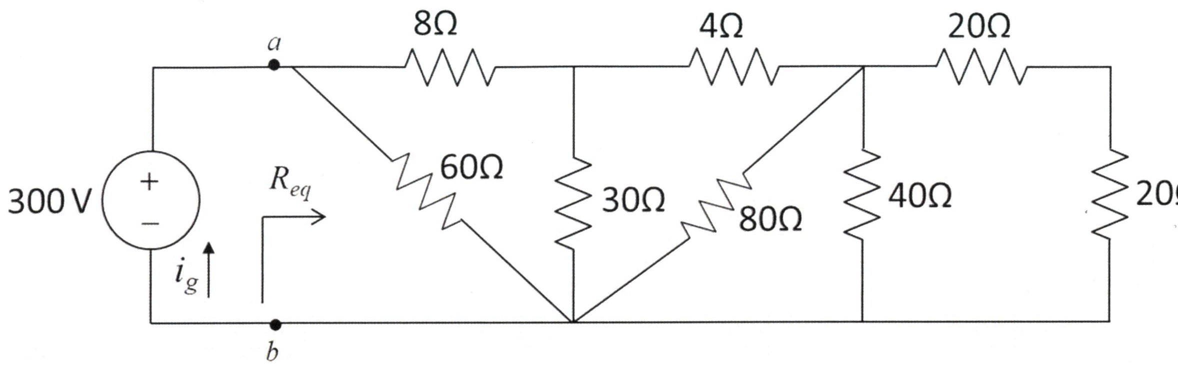
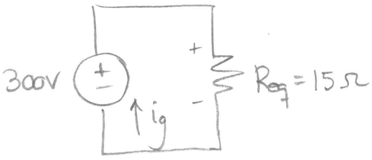


Figure 3

a)

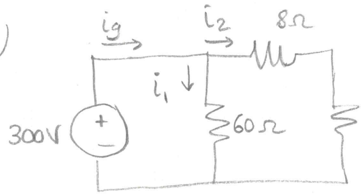
$$\boxed{R_{eq}} = \Bigg[\bigg[\Big[\underbrace{\underbrace{\underbrace{(20+20)\,||\,40}_{40\,||\,40\,=\,20}\,||\,80}_{20\,||\,80\,=\,16}\Big]+4}_{16+4\,=\,20}\bigg]\,||\,30\Bigg]+8\Bigg]\,||\,60 = (\underbrace{\underbrace{20\,||\,30}_{20||30\,=\,12} + 8}_{12+8\,=\,20})\,||\,60 = 20\,||\,60 = \boxed{15\,\Omega}$$

b)



$$\boxed{i_g} = \frac{300}{15} = \boxed{20\text{ A}}$$

c)



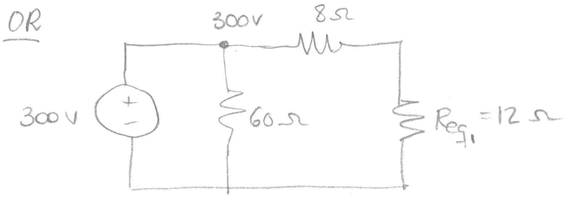
$R_{eq_1} = (((20+20)\,||\,40\,||\,80)+4)\,||\,30 = 20\,||\,30 = 12\,\Omega$

$$i_2 = i_g \frac{60\,||\,20}{20} = 20\,\frac{15}{20} = 15\text{ A}$$

current division

$$\boxed{P_{8\Omega} = i_2^2 \times 8 = 15^2 \times 8 = 1800\text{ W}}$$

OR



$$V_{8\Omega} = 300\,\frac{8}{8+12} = 120\text{ V}$$

voltage division

$$\boxed{P_{8\Omega} = V_{8\Omega}^2/8 = 120^2/8 = 1800\text{ W}}$$

QUESTION 3 [15 marks]

For the circuit shown in Figure 4, use a succession of source transformations (only source transformations) to find an equivalent circuit consisting of a single voltage source and a single resistor.

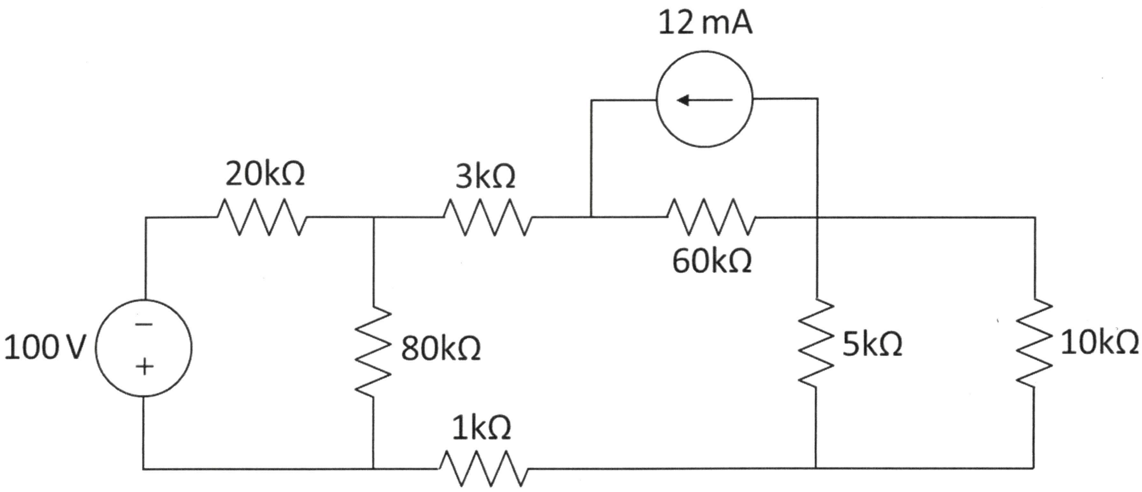
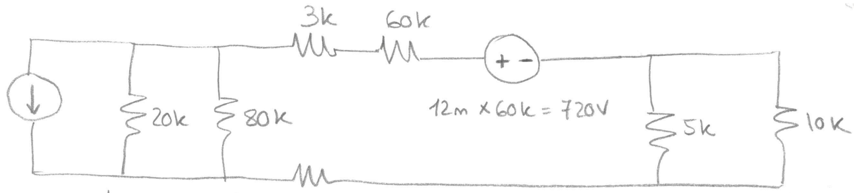


Figure 4

$\frac{100}{20k} = 5\,mA$

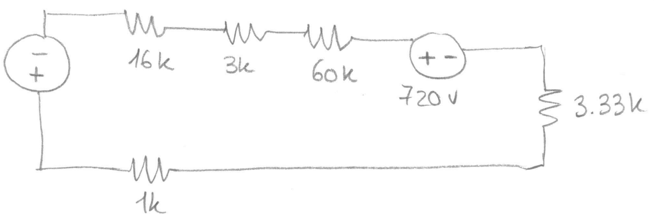


$12m \times 60k = 720V$

$20k \| 80k = 16k$

$5k \| 10k = 3.33k$

$80V = 5mA \times 16k$



$R_{tot} = 16k + 3k + 60k + 3.33k + 1k = 83.33k$

$800V = 80 + 720$

* Note: Since no terminals or specific currents/voltages to keep track of have been specified, doing source transformation following a different order might result in other (also correct) voltage and resistor values. All potential options have been appropriately considered when marking.

QUESTION 4 [20 marks]

The circuit shown in Figure 5 is being used to illuminate a mine. Generator 1 is at the entrance of the mine, with 50 metres of cabling connecting the generator to the lighting system as shown. Generator 2 is at a campsite 75 metres away and is connected to Generator 1 to boost the power that can be supplied to the lighting system. The cables have resistance of 0.01Ω per metre. The lighting system is made of light bulbs in parallel and can be modelled as a single resistor.

a. **(10 marks)** Use the superposition principle to find the Thevenin voltage at the lighting system terminals (terminals *a-b*).

b. **(5 marks)** Calculate the lighting system resistance that will ensure the maximum transfer of power from the circuit to the lighting system.

c. **(5 marks)** Find the maximum power that can be delivered to the lighting system.

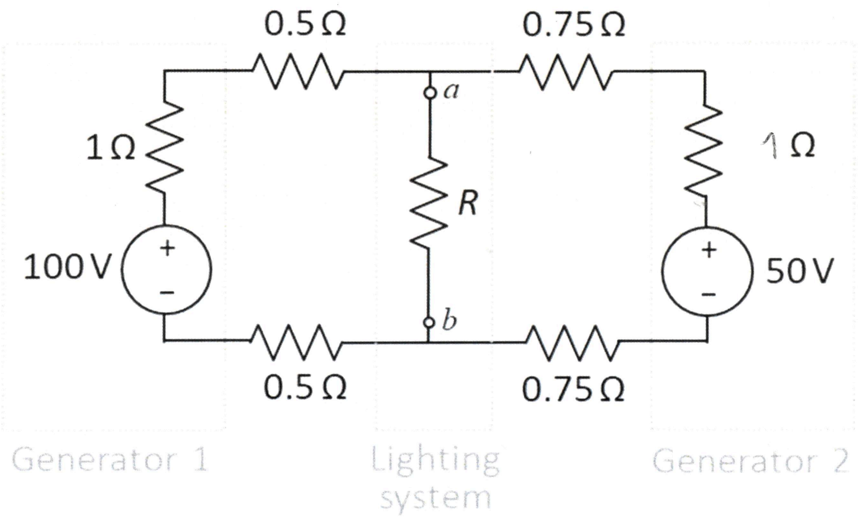
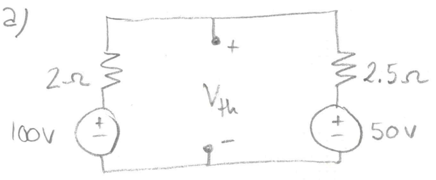
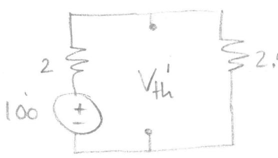


Figure 5

a)



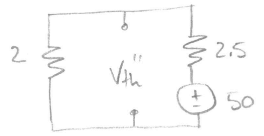
1. Turn off 50-V voltage source



$V'_{th} = 100 \times \frac{2.5}{2+2.5} = 55.555$ V

voltage divider

2. Turn off 100-V voltage source



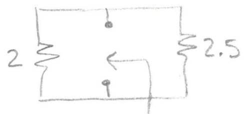
$V''_{th} = 50 \times \frac{2}{2+2.5} = 22.222$ V

voltage divider

3. Calculate total voltage : $\boxed{V_{th} = V'_{th} + V''_{th} = 77.778 \text{ V}}$

b) R = R_{th} for max. power transfer

Turn off independent sources



$\boxed{R_{th} = 2 \| 2.5 = 1.111\Omega = R}$

c) $\boxed{P_{max} = \frac{V_{th}^2}{4R_{th}}} = \frac{77.778^2}{4 \times 1.111} = \boxed{1361.1 \text{ W}}$

QUESTION 5 [30 marks]

a. **(15 marks)** Find the voltage across the capacitors in the circuit of Figure 6 under DC steady state conditions.

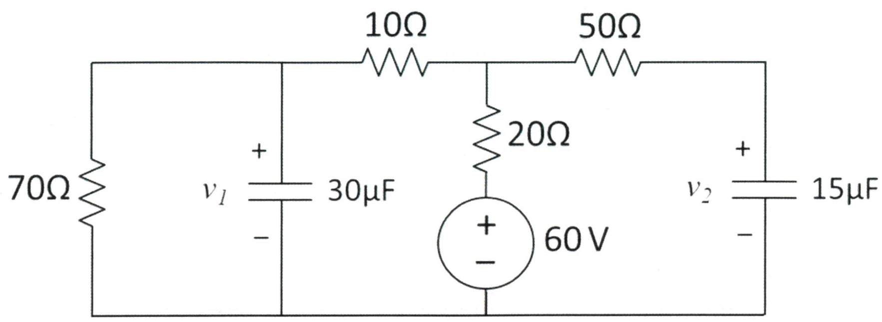
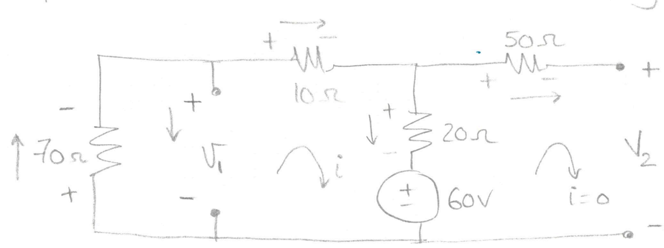


Figure 6

Capacitors behave as open circuits in steady state DC.



Calculate i in mesh 1 using KVL (current in right mesh is zero):

$70i + 10i + 20i + 60 = 0$; $10\cancel{0}\, i = -6\cancel{0}$ $\Rightarrow$ $i = -0.6$ A

$\boxed{V_1 = -V_{70\Omega} = -70 \times i = -70 \times (-0.6) = 42\text{ V}}$

Calculate V_2 using KVL in mesh 2:

$-60 - 20i + \cancel{50 \times 0} + V_2 = 0$; $\boxed{V_2 = 60 + 20i = 60 + 20 \times (-0.6) = 48\text{ V}}$

b. (15 marks) The circuit shown in Figure 7 is used to estimate the speed of a horse running a 4 km racetrack. The switch closes when the horse begins and opens when the horse crosses the finish line at $t = t_1$ s.

- **i. (8 marks)** Calculate the voltage $v_c(t)$ in the capacitor for $t < t_1$ s. Assume that the capacitor was initially discharged.
- **ii. (5 marks)** If the capacitor is charged to 85.6 V when the horse crosses the finish line, calculate the time instant t_1.
- **iii. (2 marks)** Calculate the speed of the horse in m/s.

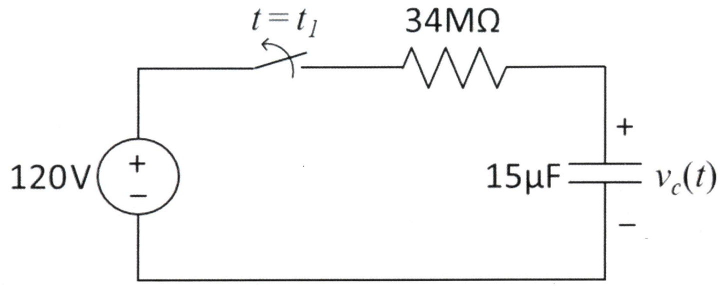
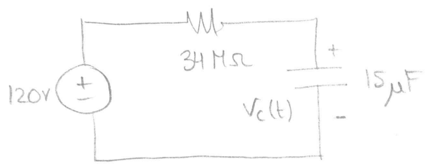


Figure 7

END OF PAPER

i) $t < t_1$ (switch is closed)



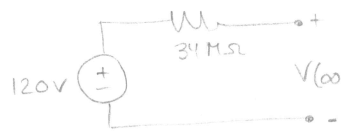
Step response

$V_c(t) = V(\infty) + (V(0) - V(\infty))\, e^{-t/\tau}$

$V(0) = 0$ V

$\tau = RC = 34\,M\Omega \times 15\,\mu F = 510$ s

* Calculate $V(\infty)$:



$V(\infty) = 120V$

* Calculate the response: $V_c(t) = 120 - 120\, e^{-t/510}$ V, $t < t_1$

ii)

$V_c(t_1) = 85.6$ V

$120\left(1 - e^{-t_1/510}\right) = 85.6$

$e^{-t_1/510} = -\left(\frac{85.6}{120} - 1\right)$; $e^{-t_1/510} = 0.2867$

$-t_1/510 = \ln(0.2867)$

$\boxed{t_1 = -510 \times (-1.2494) = 637.21\text{ s}}$

iii)

$\boxed{v = 4000\,m / 637.21\,s = 6.277\ m/s}$