McGill

April 2015
Final Examination

Electric Circuits 1

ECSE-200 Section: 1

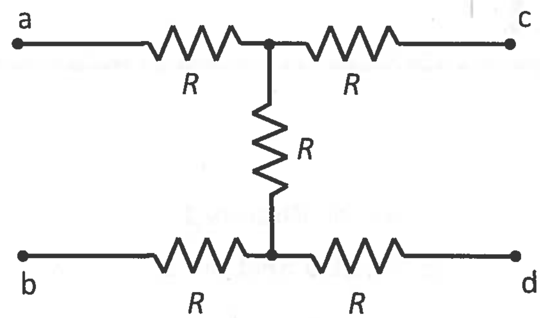
16 April 2015, 2:00PM

Examiner: Thomas Szkopek   Assoc Examiner: Michael Rabbat

INSTRUCTIONS:

- This is a **CLOSED BOOK** examination.
- **NO CRIB SHEETS** are permitted.
- Provide your answers in an **EXAM BOOKLET**.
- **STANDARD CALCULATOR** permitted ONLY.
- This examination consists of 4 questions, with a total of 6 pages, including the cover page.
- This examination is **PRINTED ON BOTH SIDES** of the paper

1. Consider the circuit below. Answer the questions. [12 pts]



a) What is the definition of a passive element? [1pt]

b) What is the definition of a linear element? [1pt]

c) What is the physical law at the origin of Kirchoff's current law? [1pt]

d) What is the physical law at the origin of Kirchoff's voltage law? [1pt]

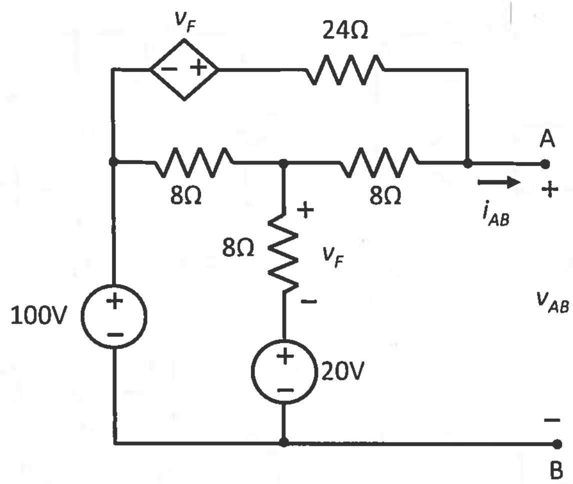
e) What is the equivalent resistance between terminals a and b, if there is an open circuit between the terminals c and d ? [2pts]

f) What is the equivalent resistance between terminals a and b, if there is a short circuit attached between the terminals c and d ? [2pts]

g) What is the equivalent resistance between terminals a and b, if a resistance *R* is attached between the terminals c and d ? [2pts]

h) What is the equivalent resistance between terminals a and b, if terminal a is connected to terminal d and terminal b is connected to terminal c ? [2pts]

2. Consider the circuit below. Answer the questions. [12 pts]



a) What is Thévenin's theorem? [1pt]

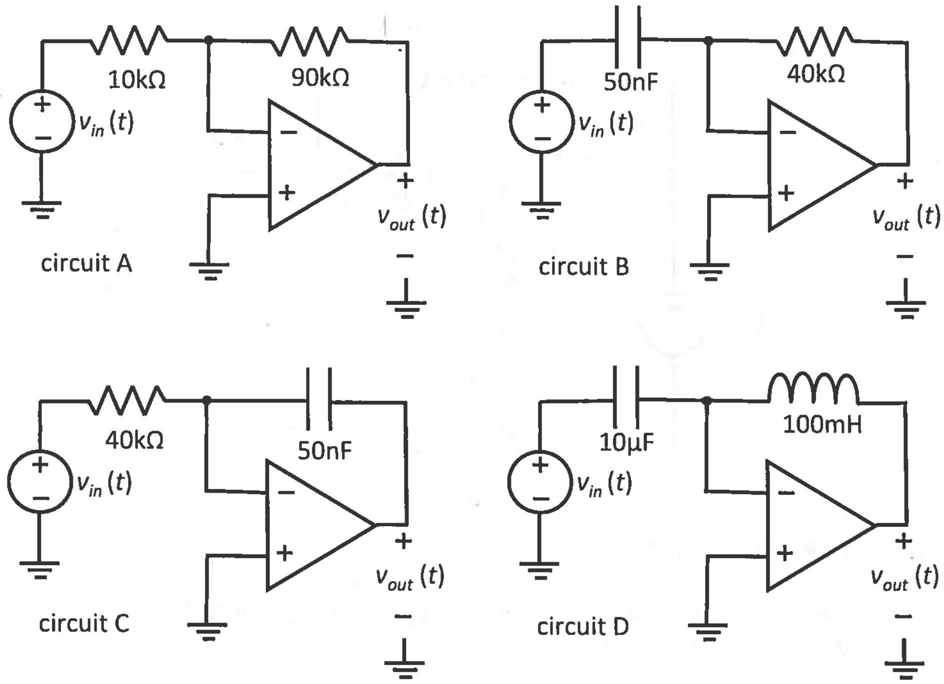
b) Draw the Thévenin equivalent circuit with respect to terminals A and B. Be sure to label the terminals A and B in your diagram. [5pts]

c) Draw the i_{AB} versus v_{AB} diagram for the circuit. [2pts]

d) What is the voltage v_{AB} measured by a voltmeter with a 1kΩ total internal resistance that is attached to the terminals A and B? [2pts]

e) What is the maximum power that the circuit can deliver to an optimally chosen load resistor attached to the terminals A and B? [2pts]

3. Consider the circuits below. Assume ideal op-amp behaviour. Answer the questions. [12 pts]



a) Give one reason why negative feedback is used in op-amp circuits. [2pts]

b) How is v_{out} related to v_{in} for circuit A ? [2pts]

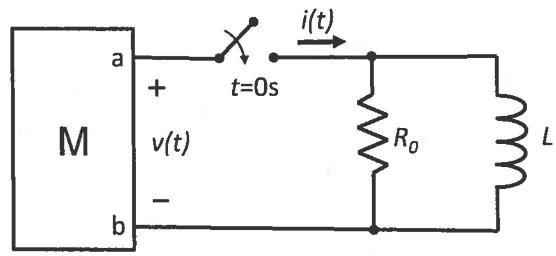
c) How is v_{out} related to v_{in} for circuit B ? [2pts]

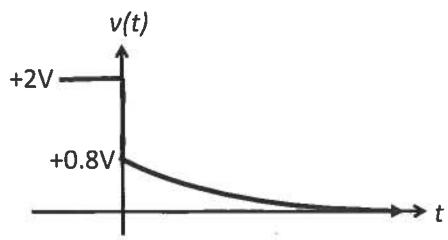
d) How is v_{out} related to v_{in} for circuit C ? [2pts]

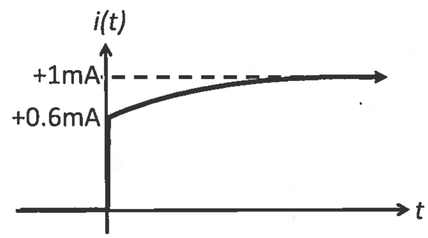
e) How is v_{out} related to v_{in} for circuit D ? [2pts]

f) Assume an input voltage $v_{in}(t)$ = 1V sin(2π×1000Hz×t), where Hz = s^{-1}. Which of the circuits above produces an output voltage $v_{out}(t)$ of largest amplitude?

4. Consider the circuit below. The circuit M is a Thévenin equivalent circuit. The circuit is in dc steady state for t < 0 with the switch open. The switch closes instantaneously at t = 0s. The circuit reaches a new dc steady state as $t \to \infty$. The voltage $v(t)$ and the current $i(t)$ are plotted versus t. Answer the questions. [12 pts]







a) Give one physical reason why inductor current is continuous. [2pts]

b) What is the open circuit voltage of M? [2pts]

c) What is the short circuit current of M? [2pts]

d) What is the Thévenin resistance of M? [2pts]

e) What is the value of R_0? [2pts]

f) The time constant for t > 0 is found to be 5μs. What is the inductance L? [2pts]

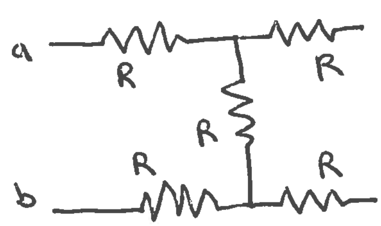
end

1 a) an element that cannot deliver more energy than it has absorbed [+1]

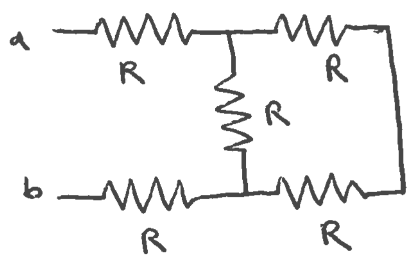
b) an element with terminal current and voltage related by a linear function or linear operator [+1]

c) conservation of charge [+1]

d) conservation of energy [+1]

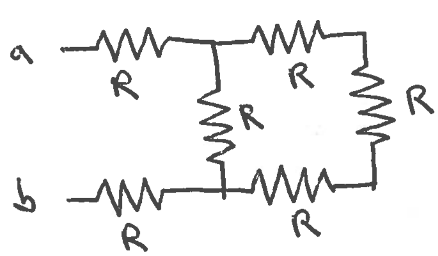
e) 

$R_{ab} = 3R$ [+2]

f) 

$R_{ab} = 2R + R // 2R$ [+1]

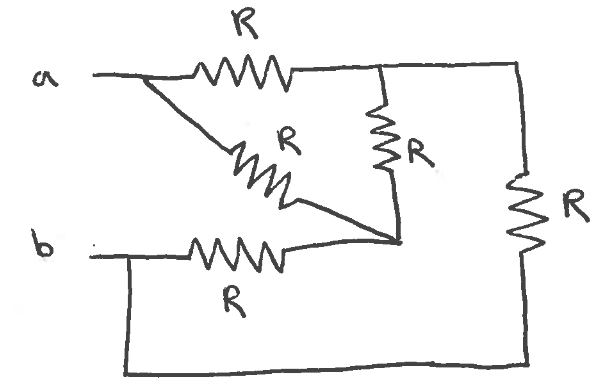
$= \frac{8}{3} R$ [+1]

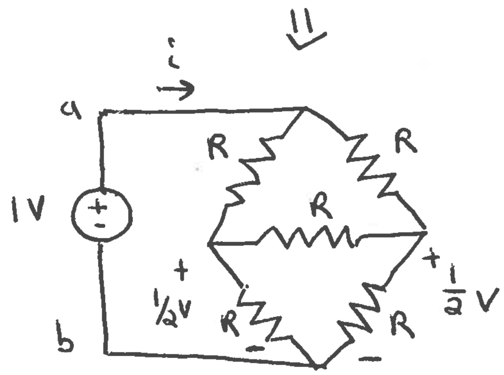
g) 

$R_{ab} = 2R + R // 3R$ [+1]

$= \frac{11}{4} R$ [+1]

h)





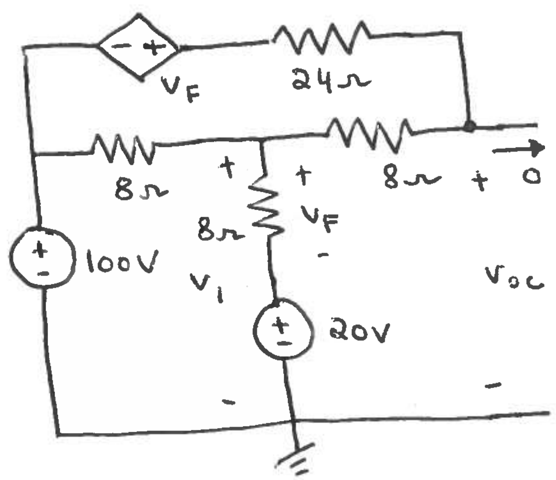
$$i = \frac{\tfrac{1}{2}V}{R} + \frac{\tfrac{1}{2}V}{R} = \frac{1V}{R}$$

$$R_{ab} = \frac{1V}{i} \quad [+1]$$

$$= R \quad [+1]$$

2 a) a circuit composed of independent sources, dependent sources and resistors is equivalent to a Thévenin circuit [+1]

b) Find V_{oc}. [+1]



$$0 = \frac{V_1 - 100V}{8\Omega} + \frac{V_1 - 20V}{8\Omega} + \frac{V_1 - (100V + V_F)}{32\Omega}$$

$$V_F = V_1 - 20V$$

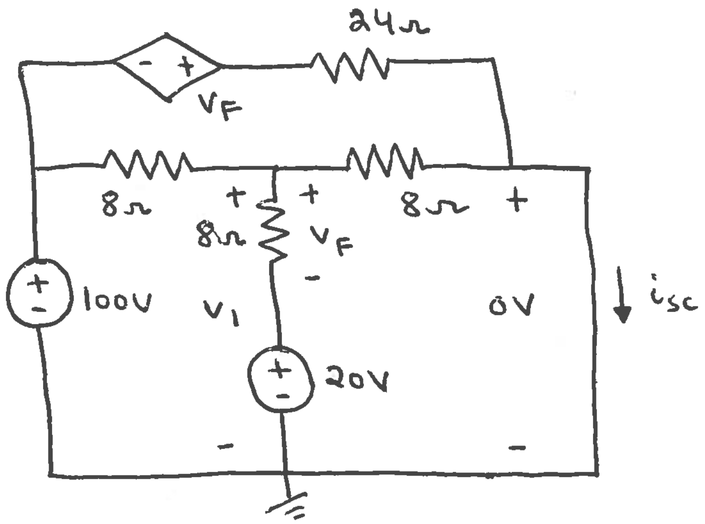
$$\therefore \quad 0 = V_1\left(\frac{1}{8} + \frac{1}{8} + \frac{1}{32} - \frac{1}{32}\right) + \left(\frac{-100}{8} - \frac{20}{8} - \frac{100}{32} + \frac{20}{32}\right)$$

$$V_1 = 70V \qquad V_F = 50V$$

$$V_{oc} = V_1 - 8\Omega \cdot \left(\frac{V_1 - (100V + V_F)}{32\Omega}\right)$$

$$= 90V$$

Find i_{sc}. [+1]



$$0 = \frac{V_1 - 100V}{8\Omega} + \frac{V_1 - 20V}{8\Omega} + \frac{V_1}{8\Omega}$$

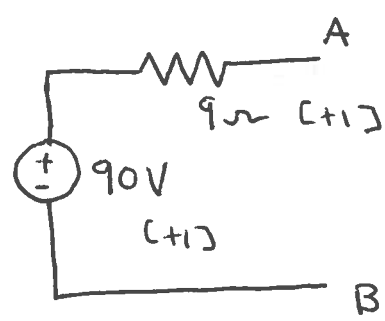
$$0 = V_1\left(\frac{1}{8} + \frac{1}{8} + \frac{1}{8}\right) + \left(-\frac{100}{8} - \frac{20}{8}\right)$$

$V_1 = 40V$ $\quad\quad$ $V_F = V_1 - 20V = 20V$

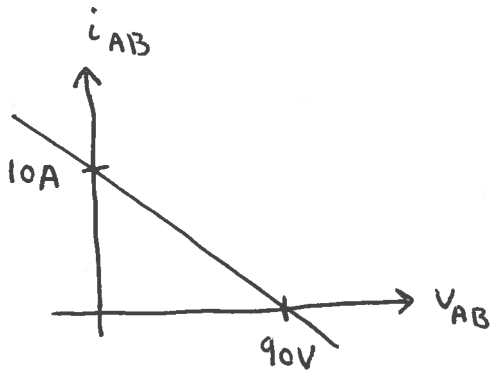
$$i_{sc} = \frac{V_1}{8\Omega} + \frac{100V + V_F}{24\Omega} = 10\,A$$

$$R_T = \frac{v_{oc}}{i_{sc}} \quad [+1]$$

$$= 9\Omega$$



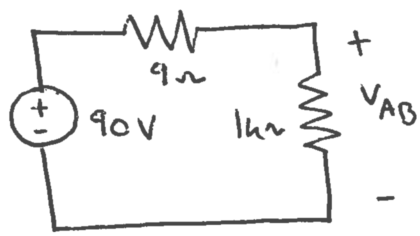
c)



[+1] for shape

[+1] for values

d)



$$V_{AB} = V_{oc} \cdot \frac{1k\Omega}{1k\Omega + R_T} \quad [+1]$$

$$= 89.20 \text{ V} \quad [+1]$$

e)

$$P_{max} = \frac{V_{oc}}{2} \cdot \frac{i_{sc}}{2} \quad [+1]$$

$$= 225 \text{ W} \quad [+1]$$

3 a) stability

programmability

b)
$$0 = \frac{-v_{in}}{10k\Omega} + \frac{-v_{out}}{90k\Omega} \quad [+1]$$

$$v_{out} = -9\, v_{in} \quad [+1]$$

c)
$$0 = -50nF \cdot \frac{dv_{in}}{dt} + \frac{-v_{out}}{40k\Omega} \quad [+1]$$

$$v_{out} = -2ms \frac{dv_{in}}{dt} \quad [+1]$$

d)
$$0 = \frac{-v_{in}}{40k\Omega} - 50nF \frac{dv_{out}}{dt} \quad [+1]$$

$$v_{out}(t) = v_{out}(t_0) - \frac{1}{2ms} \int_{t_0}^{t} v_{in}(t')\, dt' \quad [+1]$$

e)
$$0 = -10\mu F \frac{dv_{in}}{dt} - \frac{1}{100mH} \int v_{out}(t)\, dt \quad [+1]$$

$$v_{out} = -10^{-6} s^2 \frac{d^2 v_{in}}{dt^2} \quad [+1]$$

f) compare amplitudes:

A: 9

B: $1V \cdot 2ms \cdot 2\pi \cdot 1000\ s^{-1}$

$= 12.57\ V$

C: $1V \cdot \frac{1}{2ms} \cdot \frac{1}{2\pi \cdot 1000 s^{-1}}$

$= 79.6\ mV$

D: $1V \cdot 10^{-6} s^2 \cdot (2\pi \cdot 1000 s^{-1})^2$

$= 39.48\ V$

circuit D produces the largest amplitude output [+2]

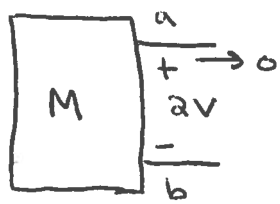
4

a) finite voltage

finite power

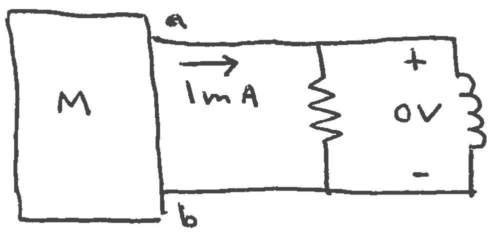
conservation of energy [+2]

b) $t < 0$



$V_{oc} = 2V$ [+2]

c) $t \to \infty$

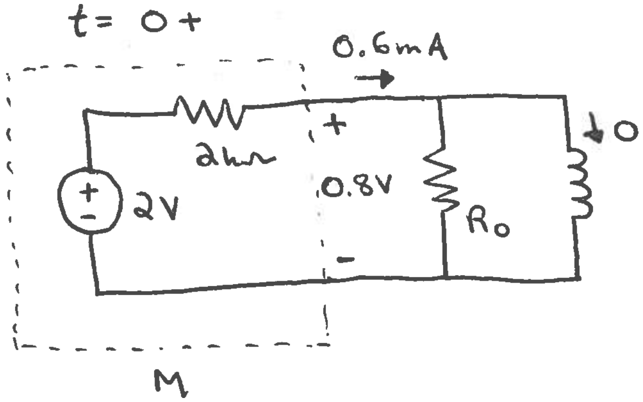


$i_{sc} = 1mA$ [+2]

d) $R_T = \dfrac{V_{oc}}{i_{sc}}$ [+1]

$= 2k\Omega$ [+1]

e) $t = 0+$



$R_o = \dfrac{0.8V}{0.6mA}$ [+1]

$= 1.333\ k\Omega$ [+1]

f) $\tau = \dfrac{L}{R_{T,ab}} = \dfrac{L}{R_o // R_T}$ [+1]

$L = 5\mu s \cdot 2k\Omega // 1.333 k\Omega$

$= 4\,mH$ [+1]