Student Name: ________________

Student Number: ________________

School: ________________

Year of Entrance: ________________

ShanghaiTech University Midterm Examination Cover Sheet

EE111 Fall 2023/2024 Exam Time 2023/11/18 8:15am-9:55am
6 problems in total (1 A4 crib sheet allowed)
Answer the Questions in English
Two-decimal policy applies for the final answer

Academic Year: 2023 to 2024 Term: Fall

Course-offering School: SIST

Instructor: Dr. Xinbo ZOU

Course Name: Electrical Circuits

Course Number: EE111.01

Exam Instructions for Students:
1. All examination rules must be strictly obeyed throughout the entire test, and any form of cheating is prohibited.
2. Other than allowable materials, students taking closed-book tests must place their books, notes, tablets and any other electronic devices in places designated by the examiners.
3. Students taking open-book tests may use allowable materials authorized by the examiners. They must complete the exam independently without discussion with each other or exchange of materials.

For Marker's Use:

Section	1	2	3	4	5	6	Total
Marks							
Recheck							

Marker's Signature:
Date:

Rechecker's Signature:
Date:

Q1. (15 points) For the following circuit, apply **mesh** analysis method to find current ***I*** and the power absorbed by the ***independent source***.

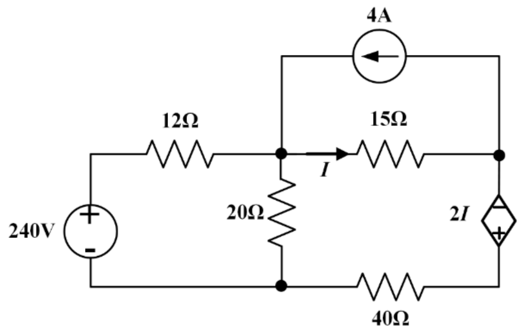
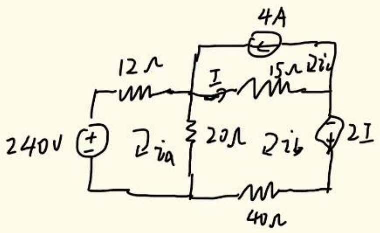


Fig.Q1



$$\begin{cases} -240 + 12 i_a + 20 i_a - 20 i_b = 0 & 2 \\ (20+40+15) i_b - 20 i_a - 15 i_c - 2I = 0 & 2 \\ i_c = -4 & 2 \\ I = i_b - i_c & 2 \end{cases}$$

解得：$i_a = 8.51A$, 1 $i_b = 1.62A$ 1 $i_c = -4A$

$I = i_b - i_c = 5.62A$ 1

$P_V = -240 \times 8.51 = -2042.4W$ 2

$P_A = -4 \times I \times 15 = -337.2W$ 2

Q2. (15 points) Use **nodal analysis method** to calculate the voltage for node ***a, b and c, namely*** v_a, v_b, ***and*** v_c.

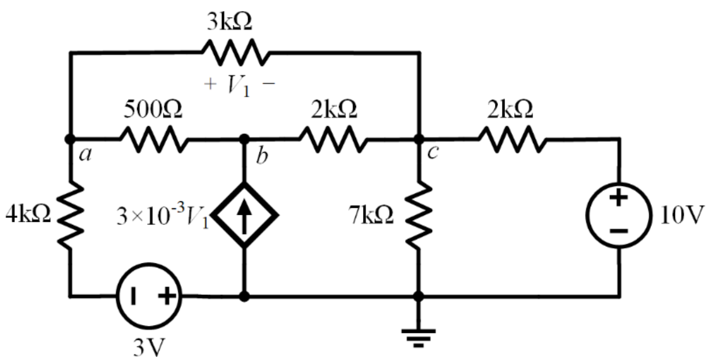


Fig.Q2

$$\begin{cases} \dfrac{V_a+3}{4K} + \dfrac{V_a-V_b}{0.5K} + \dfrac{V_a-V_c}{3K} = 0 & 3 \\ \dfrac{V_b-V_a}{0.5K} + \dfrac{V_b-V_c}{2K} - 3\times10^{-3}V_1 = 0 & 3 \\ \dfrac{V_c}{7K} + \dfrac{V_c-10}{2K} + \dfrac{V_c-V_a}{3K} + \dfrac{V_c-V_b}{2K} = 0 & 3 \\ V_1 = V_a - V_c & 2 \end{cases}$$

$$\begin{cases} 31V_a - 24V_b - 4V_c = 9 \\ -10V_a + 5V_b + 5V_c = 0 \\ -14V_a - 21V_b + 62V_c = 210 \end{cases} \quad 2 \quad \Rightarrow V_a = 17V,\ V_b = 20V,\ V_c = 14V \quad 2$$

Q3. (15 points) For the following circuit, using **Thevenin equivalent circuit to** determine the ***value of R*** when maximum power could be transferred to it, and calculate the ***maximum power P_R***

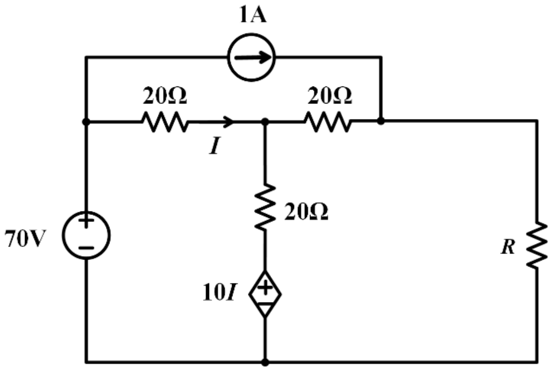
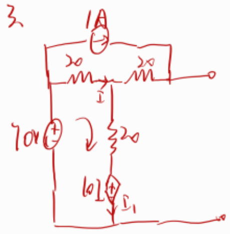


Fig.Q3

3.

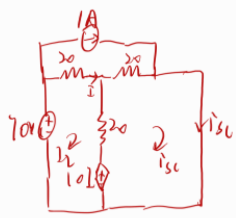


$$70 = 20(I_1-1) + 20I_1 + 10(I_1-1)$$

$$I_1 = 2A. \quad 2'$$

$$V_{oc} = 20\times1 + 20I_1 + 10(I_1-1)$$

$$= 70 \quad 3'$$



$$\begin{cases} 70 - 10I = 40I_1 - 20 - 20i_{sc} \\ 10I = 40i_{sc} - 20I_1 - 20 \\ I = I_1 - 1 \end{cases}$$

$$\begin{cases} I_1 = 3A \\ i_{sc} = 2.5A \end{cases} \quad 4'$$

$$R_{eq} = \frac{V_{oc}}{i_{sc}} = 28\Omega \quad 1'$$

$$R = R_{eq} = 28\Omega \quad 1'$$

$$P_R = \frac{V_{oc}^2}{4R} = 43.75W \quad 4'$$

Q4. (15 points) The following operational amplifier is working in its linear mode.
Find the expression of v_o using v_1, v_2, $\mathbf{R_a}$, $\mathbf{R_b}$, $\mathbf{R_c}$, and $\mathbf{R_d}$.

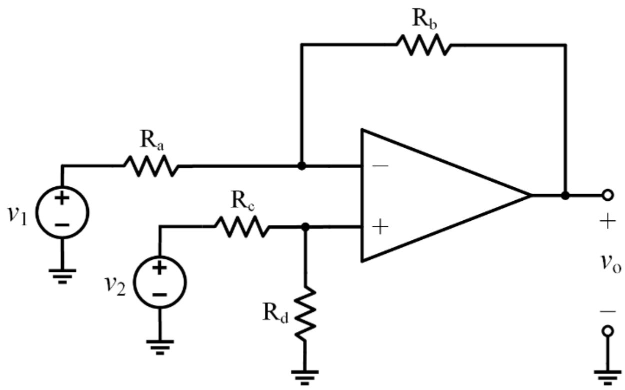


Fig.Q4

$$\left(V_o - \frac{V_2 R_d}{R_c + R_d}\right) \cdot \frac{1}{R_b} = -\left(V_1 - \frac{V_2 R_d}{R_c + R_d}\right) \frac{1}{R_a} \qquad 10$$

$$V_o = \frac{R_d (R_a + R_b)}{R_a (R_c + R_d)} V_2 - \frac{R_b}{R_a} V_1 \qquad 5$$

Q5. (20 points) In the circuit below, the switch has been open for a long time and reaches steady state before t=0. At t = 0, the switch is turned to node a and remains there for **15ms**. Then it is turned to node b. Given no initial charge stored in the capacitor, please find:

(a) $v_c(t)$ for $t > 0$. (15 points)

(b) Sketch the plot of $v_c(t)$ versus time t. (5 points)

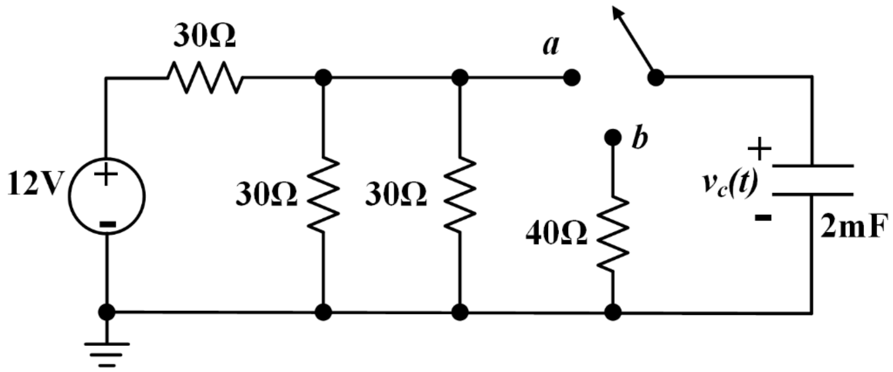


Fig.Q5

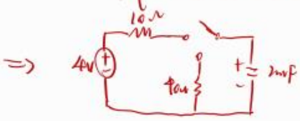
Natural response:

Using Thevenin:

$V_{oc} = 12 \times \frac{30 \| 30}{30\|30+30} = 12 \times \frac{1}{3} = 4V$ 2'

$R_{eq} = 30 \| 30 \| 30 = 10\Omega$ 2'

$\Rightarrow$



1'

when $t<0$ $\quad v_c(0^-) = 0V$

$t=0^+$ $\quad v_c(0^+) = v_c(0^-) = 0V$ 1'

$t>0$ $\quad v_c(\infty) = 4V$

$\tau = R_{eq} \cdot C = 10\Omega \times 2\times 10^{-3} F = 0.02 s$ 2'

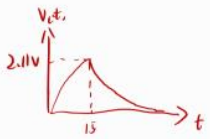
$V_c(t) = 4 - 4e^{-50t} \quad (t \geq 0)$ 2'

when $t = 15ms$ $\quad V_c(15) = 4 - 4e^{-50 \times 0.015} = 2.11 V$ 1'

$\tau' = 40 \times 2 \times 10^{-3} F = 0.08 s$ 1'

$V_c(t) = 2.11 e^{-\frac{(t-0.015)}{0.08}} = 2.11 \cdot e^{-12.5t} \cdot e^{\frac{3}{16}}$

$= 2.545 e^{-12.5t}$ 3'



5'

Q6. (20 points) For the following circuit, the switch has been at node ***a*** for a long time before ***t***=0. At ***t*** = 0, the switch is turned to node ***b***. Please find

(a) the current on the inductance $\boldsymbol{i_L(t)}$ for $\boldsymbol{t} \geq 0$. (10 points)

(b) the voltage on the inductance $\boldsymbol{v_L(t)}$ for $\boldsymbol{t} \geq 0$ (5 points)

(c) the voltage on the 2Ω-resistor $\boldsymbol{v(t)}$ for $\boldsymbol{t} \geq 0$ (5 points)

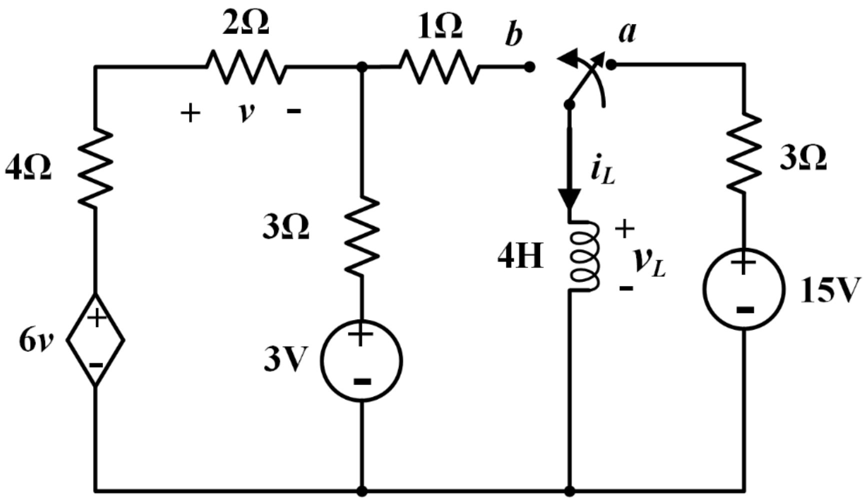
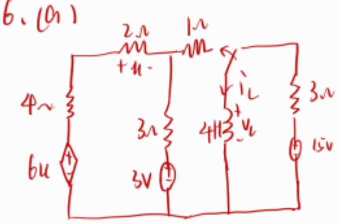


Fig.Q6

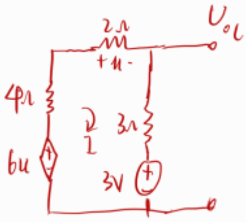
6. (a)



t<0: $i_L(0^-) = \frac{15}{3} = 5A$

t=0⁺: $i_L(0^+) = i_L(0^-) = 5A$ 2'

t≥0



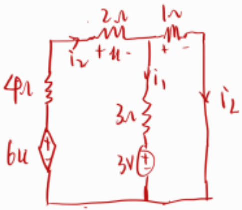
$4I + 2I + 3I + 3 - 6(2I) = 0$

$I = 1A$

$U_{oc} = 3 + 3I = 6V$

3'

$i_L(\infty)$:



$$\begin{cases} i_L = 3i_1 + 3 \\ 6i_2 + i_L = 6\cdot 2i_2 \\ 6i_2 + 3i_1 + 3 = 6\cdot 2i_2 \end{cases}$$

$i_2 = i_1 + i_L$ $\quad i_2 = 6i_2 + 2i_2 - 1$

$i_2 = \frac{1}{7}A$ 3'

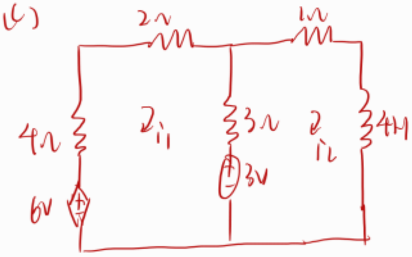
$\Rightarrow i_L(\infty) = \frac{6}{7}A$

$Req = \frac{U_{oc}}{I_{sc}} = 7\Omega$ $\quad \tau = \frac{L}{R} = \frac{4}{7}s$ $\quad i_L = \frac{6}{7} + (5 - \frac{6}{7})e^{-\frac{7t}{4}}A$

$= \frac{6}{7} + \frac{29}{7}e^{-\frac{7t}{4}}A$ 2'

(b) $U_L(t) = L\cdot\frac{di(t)}{dt} = -29e^{-\frac{7}{4}t}$ 5'

(c)



$-6\times 2i_1 + 4i_1 + 2i_1 + 3(i_1 - i_L) + 3 = 0$ 2'

$i_1 = 1 - i_L$

$i_1 = \frac{1}{7} - \frac{29}{7}e^{-\frac{7}{4}t}$ 1'

$V(t) = i_1 R = \frac{2}{7} - \frac{58}{7}e^{-\frac{7}{4}t}$ V $(t \geq 0)$ 2'