Prof. Hanson
EE 302H: Introduction to Electrical Engineering Honors
9/25/2025
100 pts

Mid-Term Exam 1

Name: ____________________ **UT EID:** ____________ **Instructor:** ______________

Please answer ALL questions. 100 points total.

PLEASE ATTEMPT ALL PROBLEMS AND SHOW ALL WORK!

WRITE ALL EXAM SOLUTIONS IN THE SPACES PROVIDED ON THE EXAM SHEETS. YOU MAY USE THE BACK OF EACH PAGE FOR SCRATCH, BUT ONLY THE FRONT SIDES WILL BE SCANNED AND GRADED.

No class notes, books, homework assignments, or other materials are allowed. You may use a calculator for the exam. Any calculator that does not have phone/communication/photo capability is allowed. Your calculator's memory should not contain any disallowed information or programs. You have **120 minutes** from the start of the exam to complete the exam.

NOTES: Unless otherwise stated, you may assume all numerical quantities given in the exam problems are known to 3 significant figures, and calculate your answers accordingly. You must show all of your work to receive credit. If you need to make an assumption to answer a question, state it explicitly.

Instructions for turning in your exam:

1) After completing your exam, you may turn on your phones.
2) Please write your EID on **every page** of the exam.
3) Log in to Gradescope and find **MT1** or **Midterm I**.
4) For each problem:
   (a) If your response is within the space for the answer, choose the option to have Gradescope take a picture of your page. Scan *all* pages of this exam booklet including the first page and any blank pages in the correct order. Gradescope will automatically assign your answers to each question according to the template.
   (b) If your response does not fit in the space for the answer and you used extra sheets, take pictures of each page with your camera app and choose the option to upload the solution. Assign the answer for each question in Gradescope.
5) **DOUBLE CHECK YOUR SUBMISSION.**
6) Turn in your paper exam to the proctor (this will be used as a reference).

Question 1. (25 pts) There are four components in the circuit below (Fig. 1). The 1st one generates 10 kW power, the 2nd and 3rd ones both consume 3 kW power.
(a) (3 pts) Does the 4th component generate or consume power?
(b) (3 pts) How much energy (in Joules) is consumed or generated by the 4th component in 1 ms?
(c) (9 pts) If we observe that 4×10^{17} electrons moving from A side to B side of the 4th component in 2 ms, calculate the voltage difference across the fourth component $V_A - V_B$?
(d) (5 pts) Calculate the current of the 3rd component. Make sure to define the current reference direction.
(e) (5 pts) Calculate the voltage difference across the 1st component, please define the reference direction when you calculate the voltage difference. Please keep two significant digits for this answer.

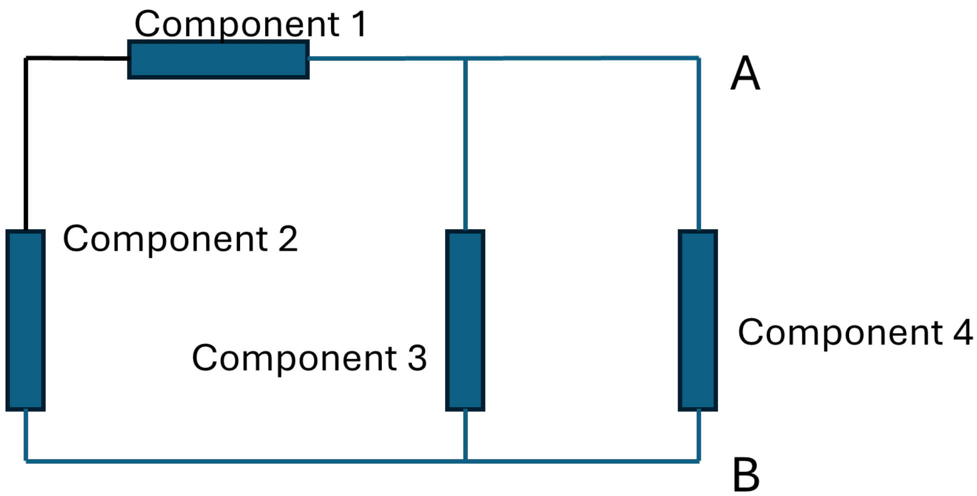

FIGURE 1. Figure 1.

(a)
$P_4 = 4\text{kW} > 0$, so the 4th component consumes power.
(b)
It consumed 4 J energy.
(c)
Current from A to B is $= -32\text{A}$
Voltage difference $V_A - V_B = -125\text{V}$
(d)
If we use the reference direction from top to bottom for Component 3 current $I_3 = \frac{P_3}{(V_A - V_B)} = -24\text{A}$
(e)
For component 1, we define the reference direction as from left to right for both current and voltage difference.
Current through Component 1 $I_1 = I_3 + I_4 = -56\text{A}$.
Voltage difference $V_1 = \frac{P_1}{I_1} = \frac{-10\text{kW}}{-56\text{A}} = 178\text{V}$

Question 2. (25 pts) The circuit below is called a Common-Source Amplifier. The dependent current source represents the behavior of a MOSFET whose known "transconductance" is g_m. The supply voltage v_s provides power to the circuit. The signal input, which we intend to amplify, is v_{in}. Further, this circuit may connect to another external circuit which loads its output; this is represented by i_{load}.

Consider the first circuit:

(a) (7 pts) Use superposition to solve the circuit below for v_{out} as a function of the inputs. Express each source's contribution as a constant times the source's value.

(b) (1 pts) One characteristic of an amplifier is its *gain*, defined as v_{out}/v_{in} with other inputs zero. What is the gain of this particular amplifier?

(c) (1 pts) Another characteristic of an amplifier is its *power supply rejection ratio*, defined as $(v_{out}/v_s)^{-1}$ with other inputs zero. A high value indicates that the output is largely immune to changes in the input (it "rejects" noise from the power supply). What is the PSRR of this particular amplifier?

(d) (3 pts) Another characteristic of an amplifier is its *(Thevenin) output resistance*, which informs how much load current it can support without the output voltage varying too much. What is the output resistance of this particular amplifier? (i_{load} is not part of the amplifier itself)

Now consider the second circuit, in which a "source degeneration" resistor R_s has been added between the MOSFETsource and GND.

(e) (10 pts) Solve for v_{out} as a function of the inputs using any method.

(f) (3 pts) Are the gain, PSRR, and output resistance improved or degraded by the presence of R_s?

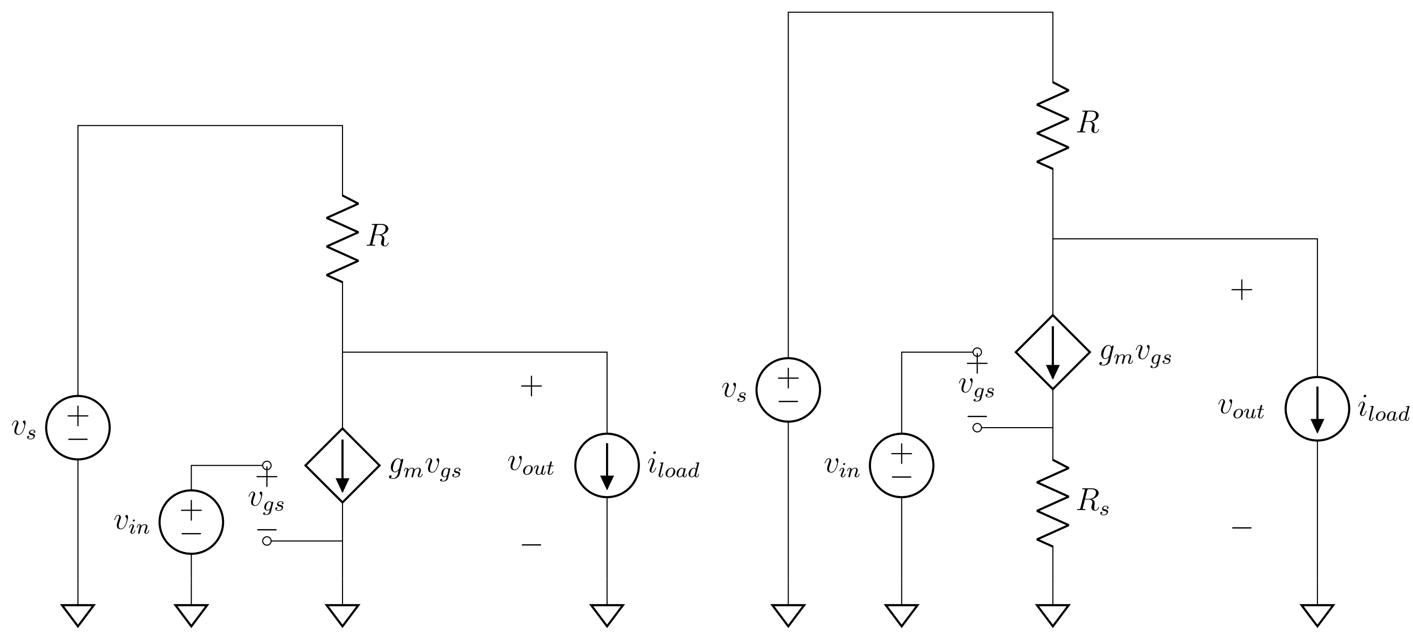

FIGURE 2. Question 2.

Q2(a)
$v_{out} = (-g_m R)v_{gs} + (1)v_s + (-R)i_{load}$
Q2(b)
$-g_m R$
Q2(c)
1
Q2(d)
$+R$
Q2(e)
$g_m(v_{in} - v_{source}) = v_{source}/R_s$
$v_{source} = g_m R_s/(g_m R_s + 1) \times v_{in}$
$\frac{v_s - v_o}{R} - g_m\left(v_i n - \frac{g_m R_s}{g_m R_s + 1} v_{in}\right) - i_{load} = 0$
$v_o = -g_m R\left(1 - \frac{g_m R_s}{g_m R_s + 1}\right) v_{in} + 1v_s - Ri_{load} = -\frac{g_m R}{g_m R_s + 1} v_{in} + 1v_s - Ri_{load}$
Q2(f)
The gain is degraded, while the PSRR and output resistance are unchanged.

Question 3. (25 pts)
(a) (15 pts) Solve the following circuit for V_1, V_4, and I_1 using the node-voltage method. See Fig. 3.

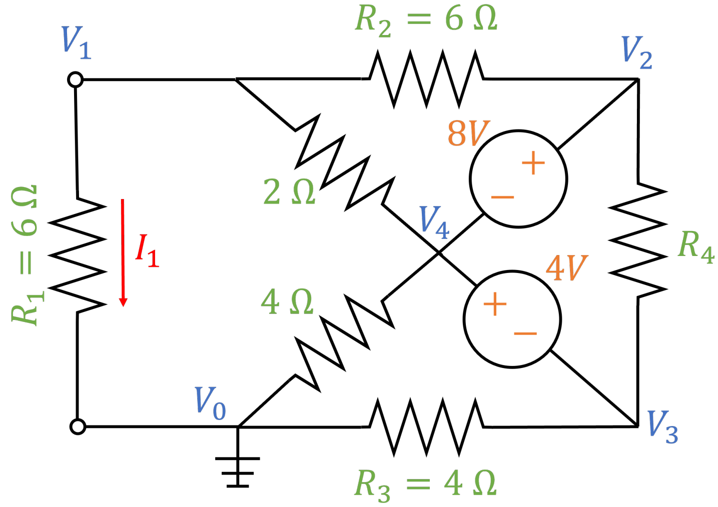

FIGURE 3. Q3(a)

V1 = 2.53V V4 = 1.16V I1 = 0.42A

(b) 10 pts The resistor R_3 is replaced by a variable resistor of resistance R and resistor R_2 is shorted (see figure 4). Write the expression for the voltage V_1 as a function of resistance R. Write your answer in the form: $V_1(R) = \frac{aR+b}{cR+d}$

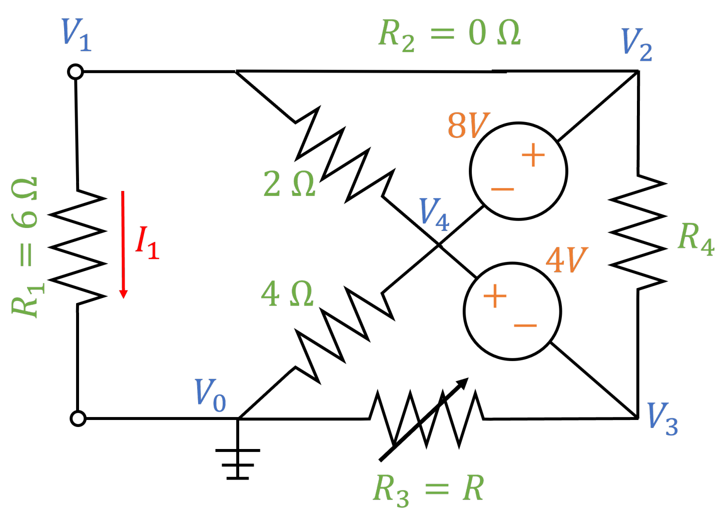

FIGURE 4. Q3(b)

$$V_1 = \frac{24R + 144}{5R + 12}$$

Question 4. (25 pts)
(a) (13 pts) Two independent voltage sources V_1 and V_2 are connected to a linear network that contains no independent sources inside the solid box. When $V_1 = V_2 = 1\,\text{V}$, the measured current is $I_2 = 2\,\text{A}$. When $V_1 = 2\,\text{V}$ and $V_2 = 1\,\text{V}$, the measured current is $I_2 = 3\,\text{A}$. Find R_{TH} for the circuit in the dashed box.
(b) (12 pts) A network consisting only of ideal independent voltage sources is connected in parallel with a $1\,\Omega$ resistor, as shown in Fig.5b. Find R_{TH} for the circuit in the dashed box.

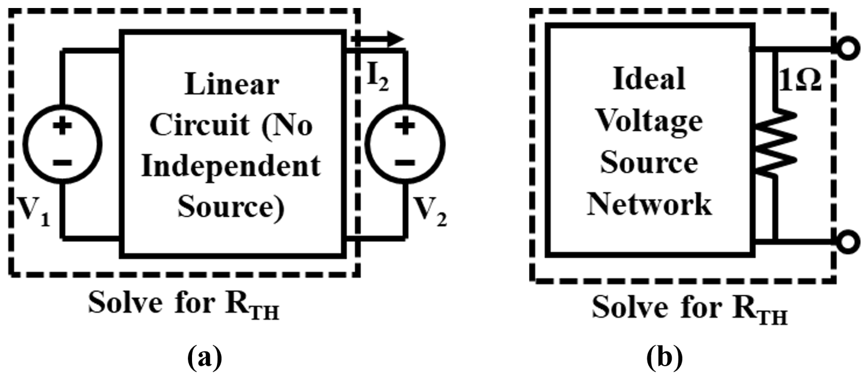

Figure 5. Question 4

(a) - 1 Ohm
(b) 0 ohm