Problem 1: 33 points

1a:

Delta-Y transformation	+1 point
Delta-Y transform + KCL/KVL or only KCL/KVL	+2 points
Correct answer	+5 points

$$I_X = -7\ A$$

1a) -7 A
1b) doesn't matter ; 0

1b:

1st part:

Wrote down power expression	+1 point
Correct answer	+2 points

$$R_C = doesn't\ matter$$

2nd part:

Correct answer	+2 points

$$R_B = 0\ \Omega$$

1c:

Didn't know how to find V_3	**- 4 points**
Knew how to find V_3, but didn't know current $i_x = \frac{V_{in}}{R_1}$.	**- 2 points**
Knew how to find V_3 and i_x, but had wrong signs in the answer	**- 1 point**

$$V_3 = V_y + i_x = V_y + \frac{V_{in}}{R_1}$$

1d:

Supplying/absorbing wrong	**- 3 points**
Calculated power instead of energy	**- 2 points**
Calculated energy, but reported unit of power	**- 1 point**
Calculated energy, reported correct units, but had math error	**- 1 point**

Absorbing power; $Energy = 1\ V * \int_{q_o}^{q^1} dq = q(t=1) - q(t=0) = 3 * (e^4 - 1)\ J$

1e:

Didn't get the correct answer	**- 3 points**

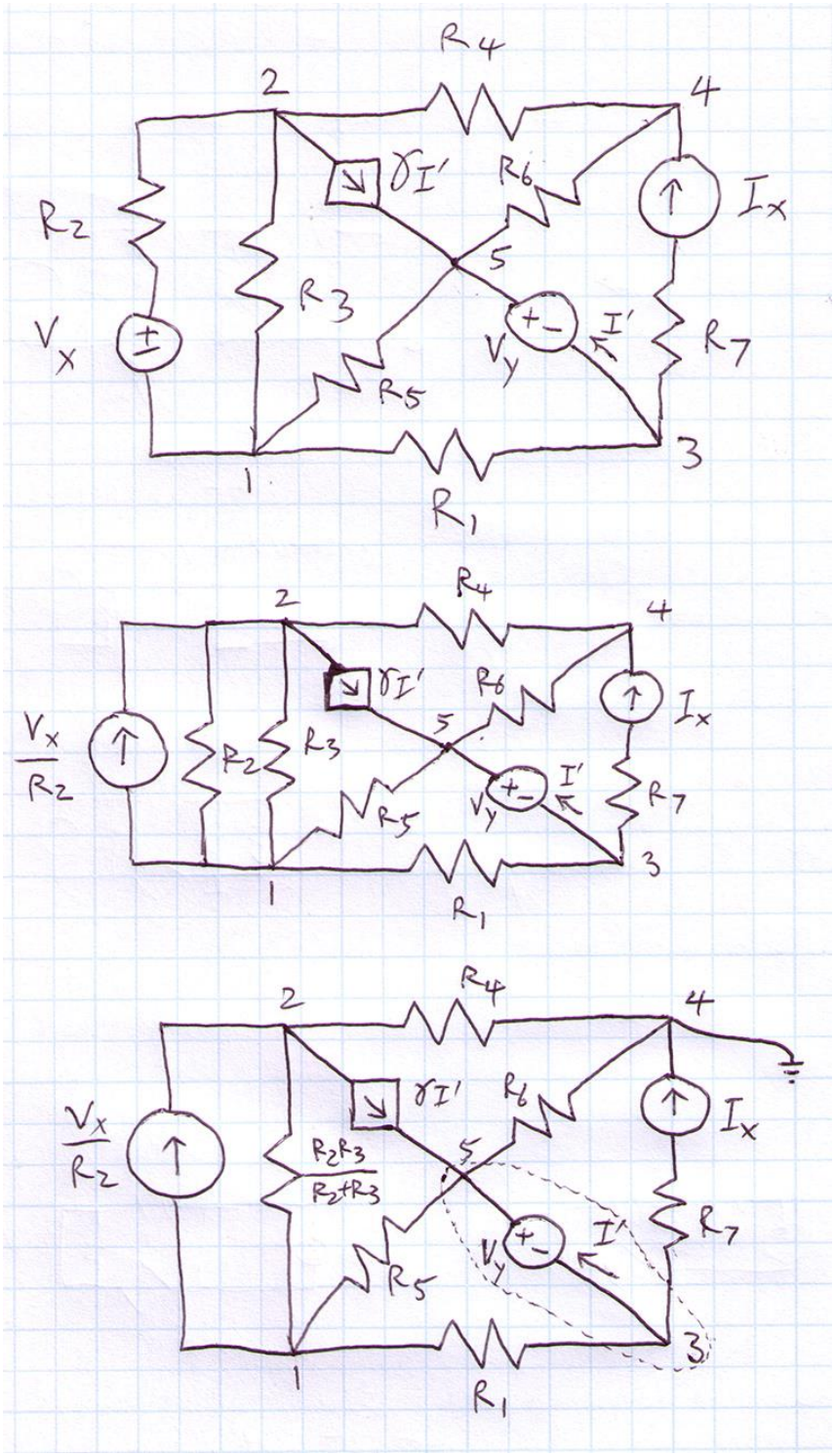
$$V_{ab} = 0\ V$$

1f:

$V_{th} = V_1$ **(+3points)** else **0 point**
$I_n = \infty$ **(+3points)** else
Knowing $R_{th} = 0$ **(+1point)**
Knowing $I_n = V_{th}/R_{th}$ **(+1point)**

1g:
Write down: $I_{R1} = 1.5A$ **(+1piont)**
Get two KCL equations right: $I_o = 2I_x$ and $I_o = -(I_{R1} + I_x)$ **(+3points)**. I give some points for people doing mesh analysis and get the equation right.
Get: $I_0 = -1A$ **(+1point)**

Problem 2: 25 points



Method 1: Nodal Analysis with Super Node

Step 1: Set Up Equations
Node 1: (V1-V2)*(R2+R3)/(R2*R3) + Vx/R2 + (V1-V5)/R5 + (V1-V3)/R1 = 0
Node 2: (V2-V1)*(R2+R3)/(R2*R3) - Vx/R2 + γI' + V2/R4 = 0
Supernode (3&5): V5/R6 + (V5-V1)/R5 + (V3-V1)/R1 - γI' + Ix = 0
Supernode Aux: V5 = V3 + Vy

Step 2: Simplify
Node 1: V1*[(R2+R3)/(R2*R3) + 1/R5 + 1/R1] + V2*[-(R2+R3)/(R2*R3)] + V3*[-1/R1] + V5*[-1/R5] = -Vx/R2
Node 2: V1*[-(R2+R3)/(R2*R3)] + V2*[(R2+R3)/(R2*R3) + 1/R4] + V3*0 + V5*0 = Vx/R2 - γI'
Supernode (3&5): V1*[-1/R5 + -1/R1] + V2*0 + V3*[1/R1] + V5*[1/R6 + 1/R5] = γI' + Ix
Supernode Aux: V1*0 + V2*0 + V3*[-1] + V5*1 = Vy

Node 5: V5/R6 + (V5-V1)/R5 = γI' + I'
I'*(γ+1) = V5(1/R6 + 1/R5) - V1/R5

Step 3: I' substitution
Node 2: V1*[-(R2+R3)/(R2*R3)] + V2*[(R2+R3)/(R2*R3) + 1/R4] + V3*0 + V5*0 = Vx/R2 - γ*[V5(1/R6 + 1/R5) - V1/R5]/(γ+1)
V1*[-(R2+R3)/(R2*R3) - γ/[(γ+1)*R5]] + V2*[(R2+R3)/(R2*R3) + 1/R4] + V3*0 + V5*[γ/(γ+1)]*[1/R6 + 1/R5] = Vx/R2
Supernode (3&5): V1*[-1/R5 + -1/R1] + V2*0 + V3*[1/R1] + V5*[1/R6 + 1/R5] = γ*[V5(1/R6 + 1/R5) - V1/R5]/(γ+1) + Ix
V1*[-1/R5 + -1/R1 + γ/[(γ+1)*R5]] + V2*0 + V3*[1/R1] + V5*[1/R6 + 1/R5]/(γ+1) = Ix

Step 4: Numeric substitution and simplify
4V1 - 2V2 - V3 - V5 = -2
5V1 - 6V2 - 2V5 = -4
15V1 - 10V3 - 10V5 = 1
V3 - V5 = -1

Method 2: Pure KCL/KVL

Step 1: Set-up equalities and put variables on RHS
Currents:
Node 1: 40*V1 - 20*V2 – 10*V3 - 10*V5 = -20
Node 2: -20*V1+ 30*V2 + 0*V3 + 0*V5 = 20 - I'
Node 3: -10*V1 + 0*V2 + 10*V3 + 0*V5 = -1 - I'
Node 5: -10*V1 + 0*V2 + 0*V3 + 20*V5 = 2*I'

Voltages:
V5=V3+Vy: 0*V1 + 0*V2 – V3 + V5 = 1

Step 2:
Keep 1 and 5
Eliminate I' from 2,3,4 and reduce it to 2 nodal equivalents
$40V_1 - 20V_2 - 10V_3 - 10V_5 = -20$
$-10V_1 + 30V_2 - 10V_3 = 21$
$10V_2 + 10V_5 = -1$
$-V_3 + V_5 = 1$

Note:
Any combination of this equation and others below is okay. For example, $30V_1 + 20V_2 - 20V_3 = 0$ is acceptable, since this equation is a linear combination of three equations above.

Rubric:
+5 points: Work showing at least one correct KCL/KVL equation or correct supernode analysis.
+5 points (x4): Each linearly independent equation equivalent to a linear combination of the listed equations. All the equations that satisfy (V_1, V_2, V_3, V_5) = (-0.8, 0.05, -1.15, -0.15) will be accepted.
+2.5 points (up to x4): Partial credit was awarded in the cases where students made small math or sign errors: an incorrect sign, a factor of 10, in one box of an otherwise correct equation.

Problem 3: 15 points

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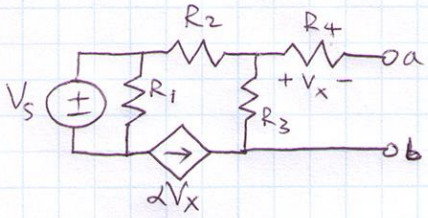
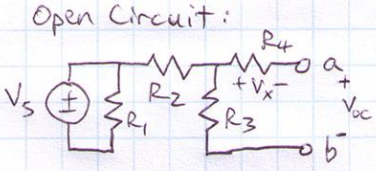
$R_1 = R_2 = 1\,k\Omega$ $R_3 = R_4 = 100\,\Omega$ $V_s = 100\,mV$ $\alpha = 0.01$



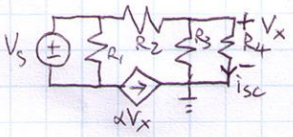
Find R_{th} across terminals a and b as a numerical answer with units

Open Circuit:



No current through R_4: $V_x = 0$
$\alpha V_x = 0$: current source → open circuit
No current through R_3: $V_a = V_b$
$V_{oc} = 0$

Short Circuit:



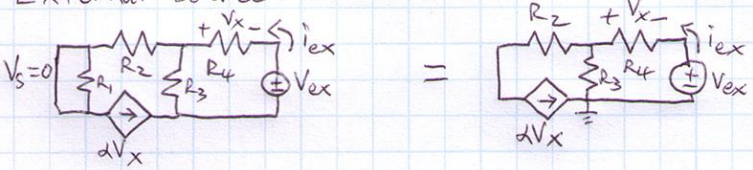
Assign ground: $i_{sc} = V_x / R_4$
Ground node: $\alpha V_x + \frac{V_x}{R_3} + \frac{V_x}{R_4} = 0$

$V_x \left(\alpha + \frac{1}{R_3} + \frac{1}{R_4}\right) = 0$: $V_x = 0$

$i_{sc} = V_x / R_4 = 0$

Both V_{oc} and i_{sc} are 0 so R_{th} would be undefined.
Another solution method is necessary: external source.

External Source:



R_1 shorted out by zero'd independent source

Ohm's Law: $V_x = -i_{ex} R_4$

Nodal: $i_{ex} = \alpha V_x + (V_{ex} + V_x)/R_3$

$V_{ex} = i_{ex}(R_3 + R_4 + \alpha R_3 R_4)$

$R_{th} = 300\,\Omega$

Assign ground.

$= -\alpha i_{ex} R_4 + V_{ex}/R_3 - i_{ex} R_4/R_3$

$V_{ex}/i_{ex} = R_{th} = R_3 + R_4 + \alpha R_3 R_4$

Rubric:
Concept - 5 points
Execution - 5 points
Correctness - 5 points

Concept:
This problem could not be done using the open circuit and short circuit method of equivalent circuits. If the student wrote that they explicitly realized this after attempting this method, that the answer was undefined and something was wrong, proceeded to do the external source method, or began with the external source method and attempted to execute it, they received the points. If the student arrived at a numerical answer that was 0, infinity, or anything other than undefined using this method, they received no points.

Execution:
If the student did the analysis either symbolically or numerically using either an external voltage or external current source, and showed using any combination of KCL, KVL, and Ohm's Law that they solved for the equivalent resistance without any errors concerning passive sign convention or execution of KCL and KVL, they received the points. If the student made minor errors such as copying the wrong values for the given variables, inverting the Ohm's Law relationship for equivalent resistance (reciprocal answer), not zero'ing the independent sources (still correct answer), or sign errors that did not directly relate to passive sign convention or KCL and KVL book-keeping, they received the points.

Correctness:
If the student gave the correct numerical answer with units, they received the points.

If you feel that your grading of this problem did not follow the above rubric, please submit a regrade request.

Problem 4: 27 points

Note: We have been generous in this grading. Each correct concept or expression got points however trivial with minimum (-1) penalty for wrong units or no units. The rubric is enclosed for your information and full points were given for correct work irrespective of the methodology used. Re-grade requests on this problem has a higher probability of returning lower grades.

4a: (maximum 6 points)

No : 3 points

Resistor can't deliver power or equivalent reasoning : 6 points

4b: (maximum 21 points)

Yes: 3 points (only if there is no other work and 4a answer is "No" or "bank")

Solution : 21 points

Nodal 1: (Vs –Vx) / Rs + (V1 – Vx) / Rb1 + (V2 – Vx) / Rb2 = 0 :	3 pts
Substitution: 0.01 (1-Vx) = 0.002 * (Vx -0.5)	1 pt
Vx = 11/12 V ; Ib1 = Ib2 = 5/12 mA	6 pts
Nodal 2: b2 * Ib2 + b1* Ib1 – I_L = 0	3 pts
Substitution: IL = 5/12 (0.1 + b1) mA	1 pt
Power = $I_L^2 * R_L$	2 pts
Substitution: $(5/12 (0.1 + b1) 0.001)^2 * 144\ 10^6$ = 1 W	2 pts
Solve b1 = 0.1	3 pts