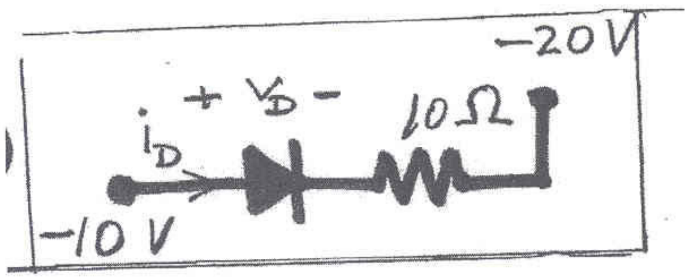
20/20

PROBLEM 1 (20 points)

Determine whether the **IDEAL DIODE** in the following two circuits is "ON" or "OFF". You **MUST** show $i_D > 0$ if diode is "ON", and $v_D < 0$ if diode is "OFF".

(a)



ASSUME ON

$i_D = \frac{-10-(-20)\,V}{10\,\Omega} = \frac{10\,V}{10\,\Omega} = 1A$

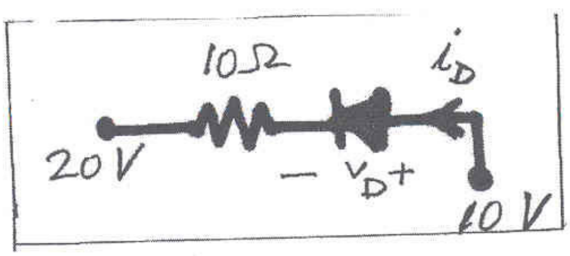
$i_D > 0$ SO ASSUMPTION IS CORRECT

i_D = 1A

v_D = 0V

Diode state (ON or OFF): ON

(b)



ASSUME OFF

$10V - 20V = V_D = -10V$

$V_D < 0$ ✓

ASSUMPTION IS CORRECT SINCE $V_D < 0$

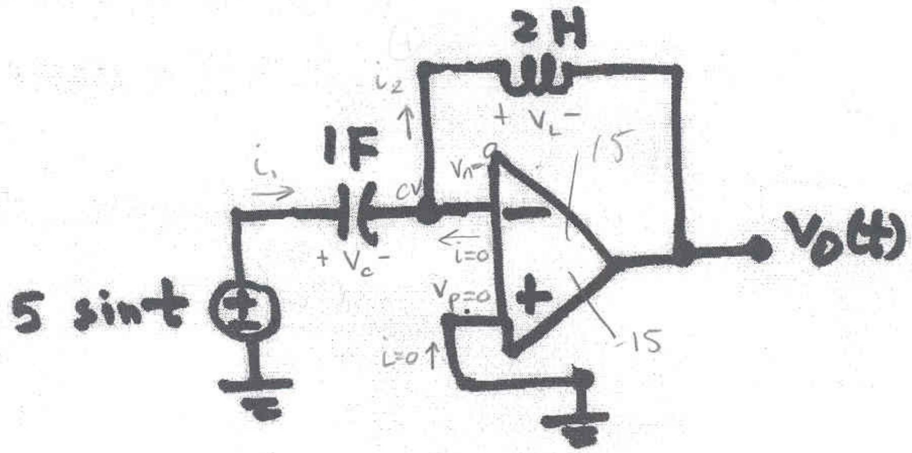
i_D = 0

v_D = -10V

Diode state (ON or OFF): OFF

PROBLEM 2 (10 points)

Find the output voltage $v_o(t)$ of the following OP AMP circuit. Assume ideal op-amp model with saturation voltage $E_{sat} = \pm 15$ V.



$\frac{di}{dt}$

$\frac{dv}{dt}$

$V_c = 5\sin(t) - 0$

$V_c = 5\sin(t)$

$\frac{dV_c}{dt} = 5\cos(t)$

$i_1 = 1 \cdot 5\cos(t)$

$i_2 = 5\cos(t)$ $\quad \frac{di_2}{dt} = -5\sin(t)$

$V_L = L(-5\sin(t))$

$V_L = -2(5\sin(t))$

$= -10\sin(t)$

$0 - (V_L) = V_o(t)$

$-(-10\sin(t)) = V_o(t)$

$10\sin(t) = V_o(t)$

↓

KCL ⇒ $i_1 + 0 = i_2$

$i_1 = i_2$

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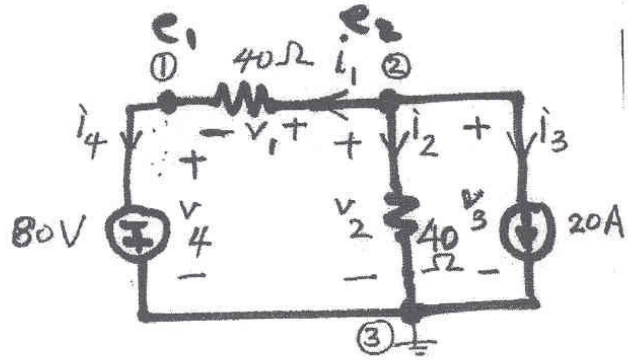
$v_o(t) =$ $10\sin(t)$

$-15 < 10\sin(t) < 15$

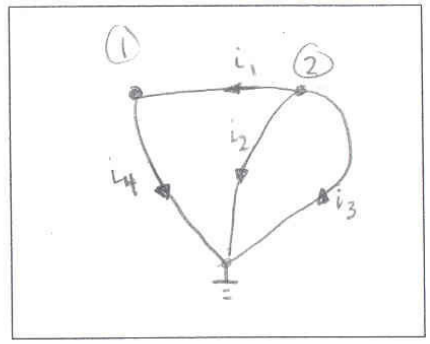
SO IT DOESN'T RAIL SINCE $V_o(t)_{max}$ IS 10 AND $V_o(t)_{min} = -10$

PROBLEM 3 (20 points)

(a) Draw the digraph of the following circuit and write down the associated reduced incidence matrix.



DIGRAPH



$$A = \begin{array}{c} \\ ① \\ ② \end{array}\begin{bmatrix} 1 & 2 & 3 & 4 \\ -1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \\ i_4 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

REDUCED INCIDENCE MATRIX: A =

(b) Write 2 KCL equations and 4 KVL equations directly from the reduced incidence matrix found from part (a).

KCL ⇒ $i_4 - i_1 = 0$

$i_1 + i_2 + i_3 = 0$

$$\begin{bmatrix} -1 & 1 \\ 0 & 1 \\ 0 & 1 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} e_1 \\ e_2 \end{bmatrix} = \begin{bmatrix} v_1 \\ v_2 \\ v_3 \\ v_4 \end{bmatrix}$$

$e_2 - e_1 = v_1$

$e_2 = v_2$

$e_2 = v_3$

$e_1 = v_4$

KCL EQUATIONS: $i_4 - i_1 = 0$

$i_1 + i_2 + i_3 = 0$

KVL EQUATIONS: $e_2 - e_1 = v_1$

$e_2 = v_2$

$e_2 = v_3$

$e_1 = v_4$

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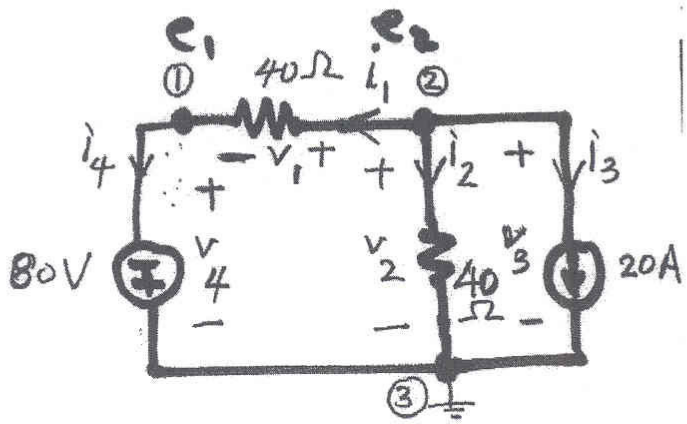
PROBLEM 4 (20 points)

(a) Find the voltage v_2 of the circuit from problem 3 (reproduced below) by applying the **SUPERPOSITION** theorem.



$e_2 - e_1 = V_1 = -440 - (-80) = -360V$

$e_2 = V_2$ $\quad e_2 = V_2 = V_3 = -440V$

$e_2 = V_3$

$e_1 = V_4 = -80V$

$i_4 = i_1$

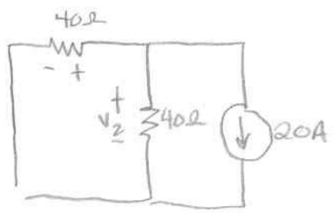
$i_1 + i_2 + i_3 = 0$

$i_3 = 20A$

$i_2 = \frac{-440V}{40\Omega} = -11A$

$i_1 = -(i_2 + i_3) = -(-11 + 20) = -9A$

FROM CURRENT SOURCE

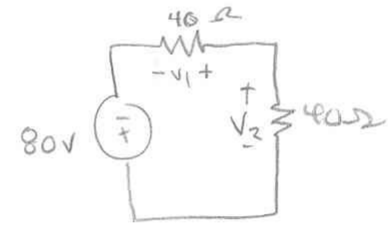


$20\left(\frac{40}{40+40}\right) = 10A$

$V_{2_1} = -(10)(40)$ ~~= 400V~~

$V_2 = -400V$

FROM VOLTAGE SOURCE



$-80\left(\frac{40}{40+40}\right) = -40V$

$V_{2_2} = -40V$

$80 - V_1 + V_2 = 0$

$80 = V_1 - V_2$

$40 - (-40) = 80$ ✓

$V_2 = -400 - 40 = -440V$

v_2 = $-440V$ ✓

(b) Use your answer from (a) to enumerate the following by inspection:

$v_1 = -360V$,	$v_2 = -440V$,	$v_3 = -440V$,	$v_4 = -80V$
$i_1 = -9A$,	$i_2 = -11A$,	$i_3 = 20A$,	$i_4 = -9A$

✓

(c) Validate your solution via Tellegen's Theorem:

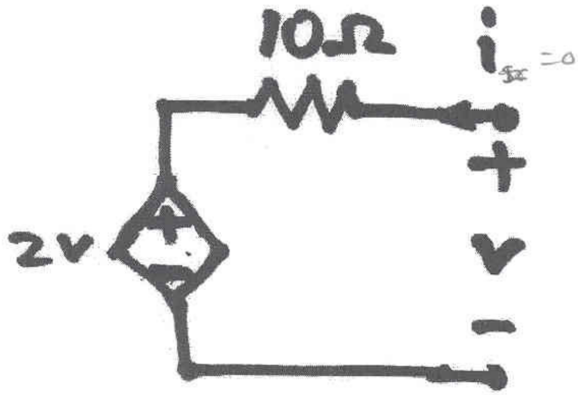
$\sum_{0}^{j} V_j i_j = (-360V)(-9A) + (-440V)(-11A) + (-440V)(20A) + (-80V)(-9A) = 0$

$3240 + 4840 - 8800 + 720 = 0$ ✓

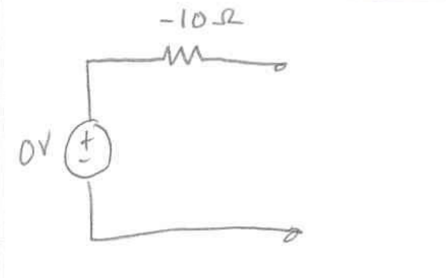
$0 = 0$ ✓

PROBLEM 5 (10 points)

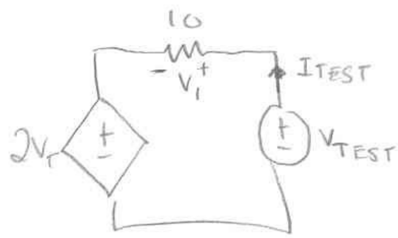
(a) Find the Thevenin equivalent of the following circuit.



THEVENIN EQUIVALENT



$V_{oc} = 0$
$I_{sc} = 0$
SINCE THERE ARE NO INDEPENDENT VOLTAGE OR CURRENT SOURCES



$R_{eq} = \frac{V_{TEST}}{I_{TEST}}$

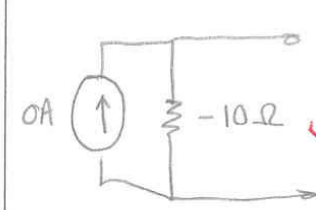
$R_{eq} = \frac{-10 I_{TEST}}{I_{TEST}} = -10\Omega = R_{eq}$

$-V_{TEST} + 10 I_{TEST} + 2V_{TEST} = 0$

$V_{TEST} = -10 I_{TEST}$

(b) Find the Norton equivalent of the circuit above.

NORTON EQUIVALENT

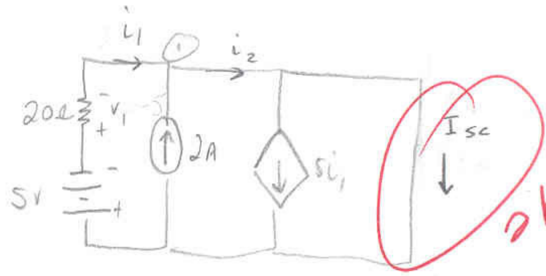


PROBLEM 6 (20 points)

For the following circuit:

(a) Find the open-circuit voltage v_{oc} by assuming i = 0.
(b) Find the short-circuit current i_{sc} by assuming v = 0.
(c) Find the Thevenin equivalent circuit from (a) and (b).

For I_{sc}



$KVL \Rightarrow -v_1 - 5V = 0$

$v_1 = -5V$

$i_1 = \frac{-5V}{20\Omega} = -1/4\ A$

$i_1 + 2A = i_2$

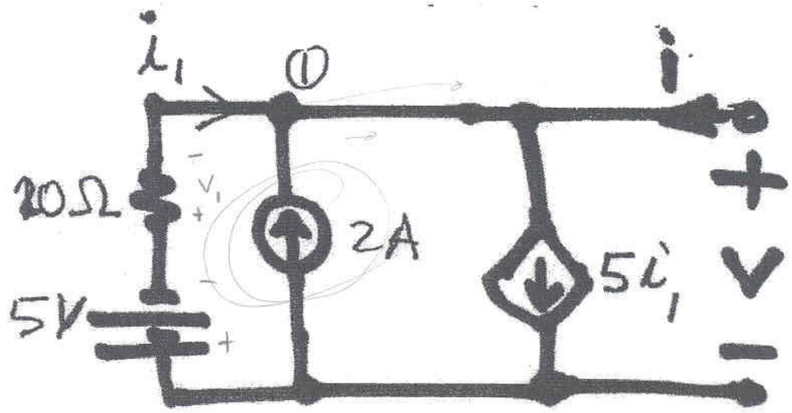
$-1/4 + 2 = 1.75A = i_2$

$-I_{sc} + i_2 = 5(-1/4)$

$-I_{sc} = -\frac{5}{4} - 1.75 = -3A$

$I_{sc} = 3A$

ok.



For Voc

KCL @ ①

$i_1 + 2 = 5i_1$

$2 = 4i_1$

$i_1 = 1/2\ A$

KVL $-V_{oc} - V_1 - 5 = 0$

$V_{oc} = -(1/2)(20) - 5 = -15\ V = V_{oc}$

$R_{eq} = \frac{V_{oc}}{I_{sc}} = \frac{-15V}{3A} = -5\Omega$

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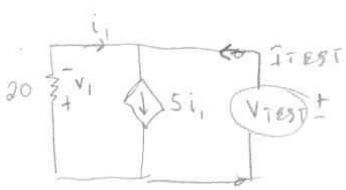

$R_{eq} = \frac{V_{TEST}}{I_{TEST}}$

$i_1 + I_T = 5i_1$

$I_T = 4i$

$-V_{TEST} = 20i$

$V_T = -20i$

$R_{eq} = \frac{-20i}{4i} = -5\Omega = R_{eq}$

(a) v_{oc} = -15V

(b) i_{sc} = 3A

THEVENIN EQUIVALENT CIRCUIT