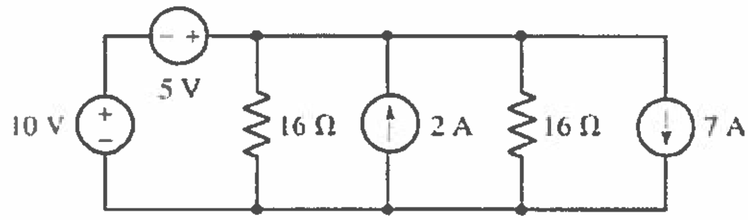
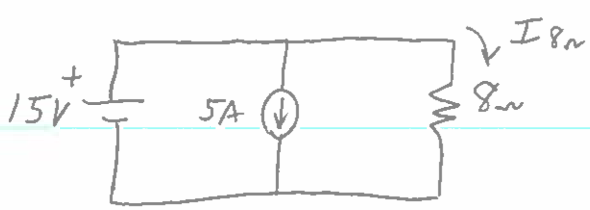
Figure 3.73



18. See Figure 3.73. What is the total power absorbed by the 16-ohm resistors?

REDRAW



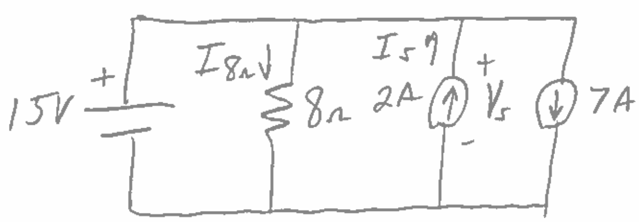
$$I_{8\Omega} = \frac{15V}{8\Omega} = \underline{1.875A}$$

$$P_{8\Omega} = (I_{8\Omega})^2 \cdot (8\Omega)$$

$$= \boxed{28.13W}$$

OR, EACH RESISTOR ABSORBES $\boxed{14.06W}$

P_{SUPPLIED} BY 2A SOURCE?

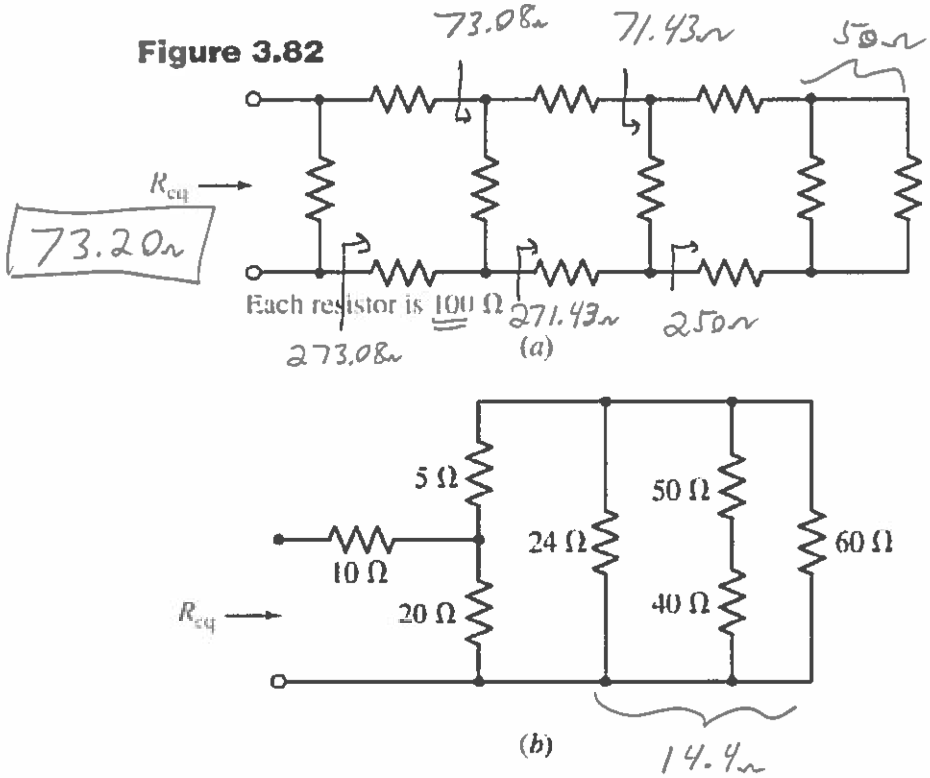


$$P_{2A\ supplied} = (V_s) \cdot (I_s)$$

$$= (15V)(2A)$$

$$= \boxed{30W}$$

Figure 3.82



19. See Figure 3.82(a). Find R_{eq}

20. See Figure 3.82(b). Find R_{eq}

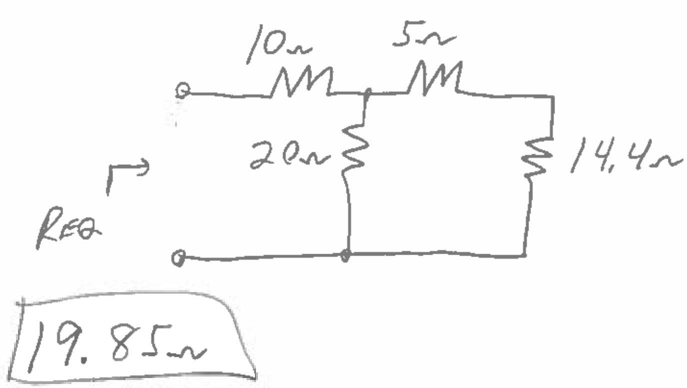
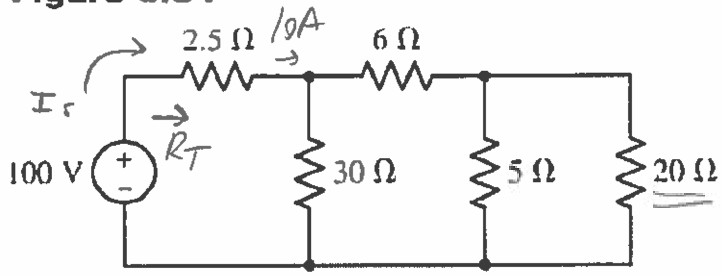


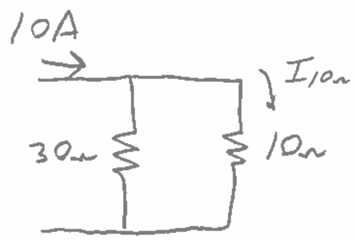
Figure 3.84



$R_T = 10\Omega$

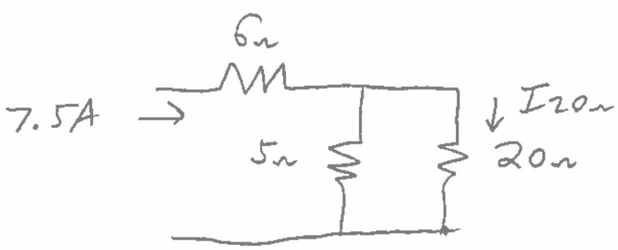
$I_S = \dfrac{100V}{10\Omega} = 10A$

21. See Figure 3.84. Find the power absorbed by the 20-ohm resistor



$$I_{10\Omega} = I_T\left(\frac{R_T}{R_X}\right)$$

$$= 10A\left(\frac{30\Omega \parallel 10\Omega}{10\Omega}\right) = \underline{7.5A}$$



$$I_{20\Omega} = I_T\left(\frac{R_T}{R_x}\right)$$

$$= 7.5A\left(\frac{4\Omega}{20\Omega}\right)$$

$$I_{20\Omega} = \underline{1.5A}$$

$$\therefore P_{20\Omega} = I^2 \cdot R$$

$$= (1.5A)^2 \cdot (20\Omega)$$

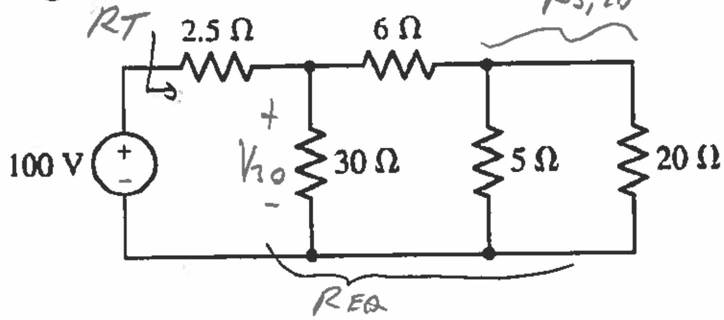
$$P_{20\Omega} = \boxed{45W}$$

ALTERNATE W/ VOLTAGE DIVIDER

$R_{EQ} = 7.5\,\Omega$

$\therefore\ \underline{R_T = 10\,\Omega}$

Figure 3.84

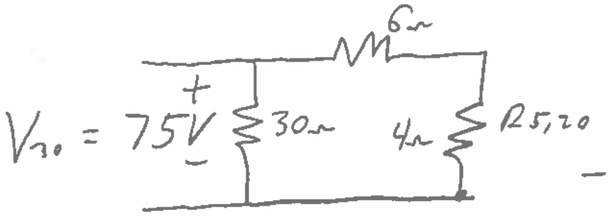


21. See Figure 3.84. Find the power absorbed by the 20-ohm resistor

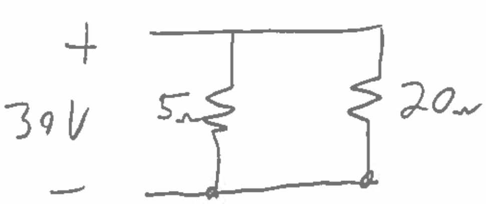
USING VOLTAGE DIVIDER:

$$V_{30} = 100\text{V}\left(\frac{R_{EQ}}{R_T}\right)$$

$$= 100\text{V}\left(\frac{7.5\,\Omega}{10\,\Omega}\right) = \underline{\underline{75\text{V}}}$$



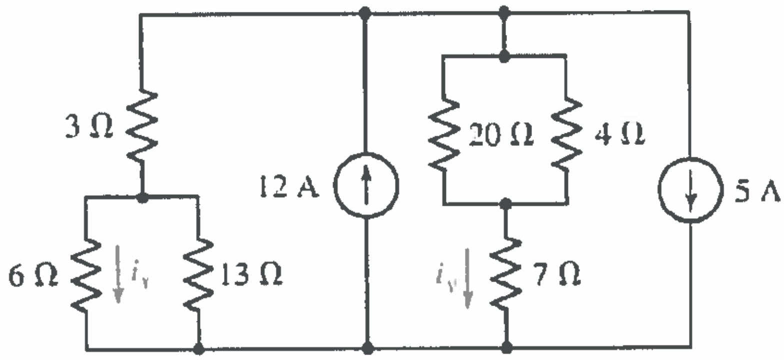
$$V_{5,20} = 75\text{V}\left(\frac{4\,\Omega}{10\,\Omega}\right) = \underline{\underline{30\text{V}}}$$



$$P_{20\,\Omega} = \frac{(V_{20\,\Omega})^2}{20\,\Omega}$$

$$= \frac{(30\text{V})^2}{20\,\Omega} = \boxed{45\text{W}}$$

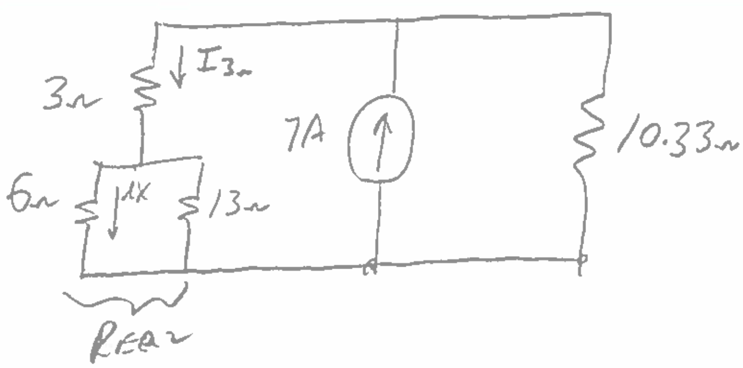
Figure 3.92



22. See Figure 3.92. Find i_x

REQ1

REDRAW



$$I_{3\Omega} = I_T\left(\frac{R_T}{R_X}\right) \qquad REQ1//REQ2$$

$$= 7A\left(\frac{4.21\Omega}{7.105\Omega}\right) \qquad REQ2$$

$$I_{3\Omega} = \underline{4.148}A$$

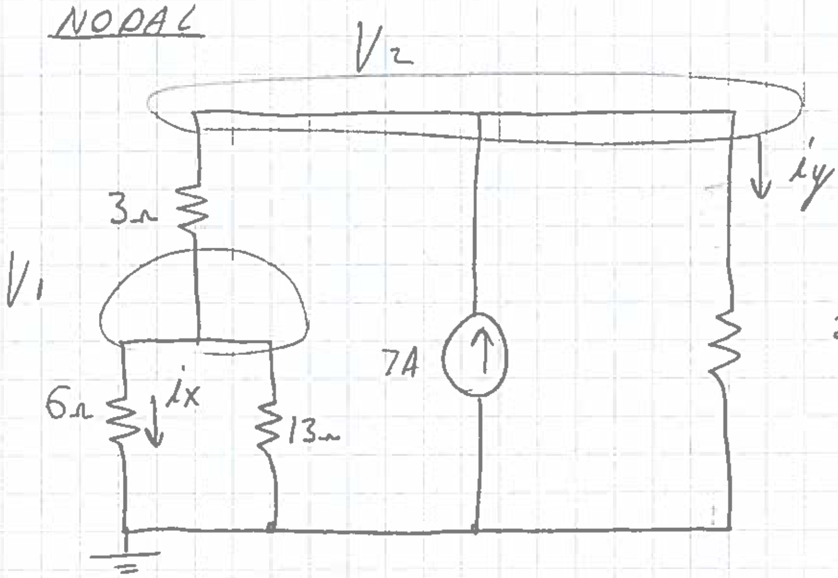
$$i_x = I_T\left(\frac{R_T}{R_X}\right)$$

$$= I_{3\Omega}\left(\frac{6\Omega//13\Omega}{6\Omega}\right)$$

$$= \boxed{2.84A}$$

NODAL

ALTERNATE



$20 \| 4 + 7 = 10.33\Omega$

NODE ①

$$\frac{V_1 - V_2}{3} + \frac{V_1}{6} + \frac{V_1}{13} = 0$$

$$V_1\left(\frac{1}{3} + \frac{1}{6} + \frac{1}{13}\right) - V_2\left(\frac{1}{3}\right) = 0$$

$$0.577\,V_1 - 0.333\,V_2 = 0 \qquad (1)$$

NODE ②

$$\frac{V_2 - V_1}{3} + \frac{V_2}{10.33} = 7$$

$$-\frac{1}{3}V_1 + \left(\frac{1}{3} + \frac{1}{10.33}\right)V_2 = 7$$

$$-0.333\,V_1 + 0.430\,V_2 = 7 \qquad (2)$$

SOLVE (1) & (2) $\quad \underline{V_1 = 17.03V}$

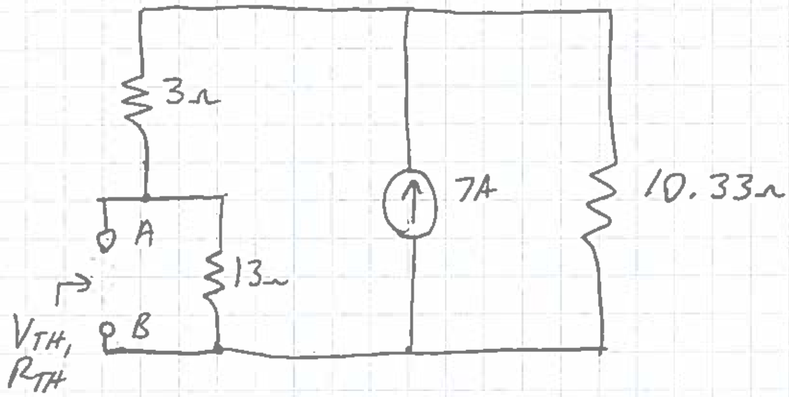
$\underline{V_2 = 29.48V}$

$$i_x = \frac{V_1}{6\Omega} = \frac{17.03V}{6\Omega} = \boxed{2.84A}$$

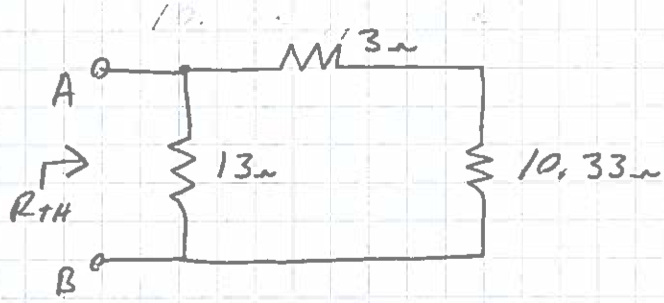
$$i_y = \frac{V_2}{10.33\Omega} = \frac{29.48V}{10.33\Omega} = \boxed{2.85A}$$

$$P_{13\Omega} = \frac{V_1^2}{13\Omega} = \frac{(17.03V)^2}{13\Omega} = \boxed{22.3W}$$

THEVENIN — TO FIND i_x

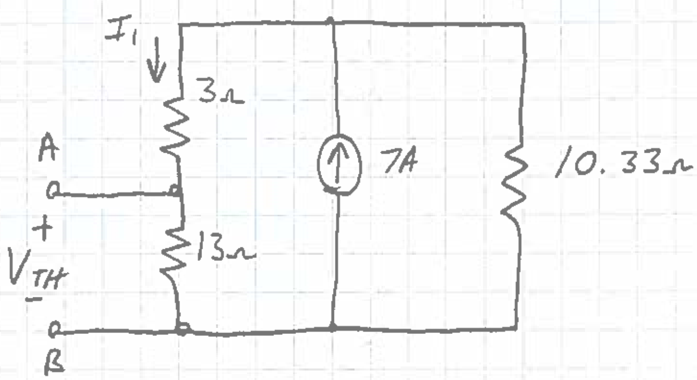


R_{TH} — O/C THE 7A SOURCE
— FIND R_{AB}



$$R_{TH} = 13\Omega \,//\, 13.33\Omega = \underline{\underline{6.58\Omega}}$$

V_{TH} — FIND V_{AB} O-C

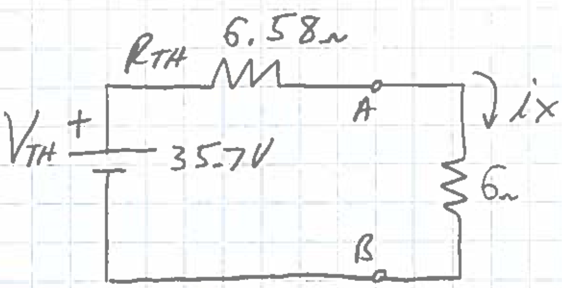


$$I_1 = I_T \frac{R_T}{R_X}$$

$I_T = 7A$
$R_T = 16\Omega \,//\, 10.33\Omega = 6.28\Omega$
$R_X = 16\Omega$

$$I_1 = 7A\left(\frac{6.28\Omega}{16\Omega}\right) = \underline{2.75A}$$

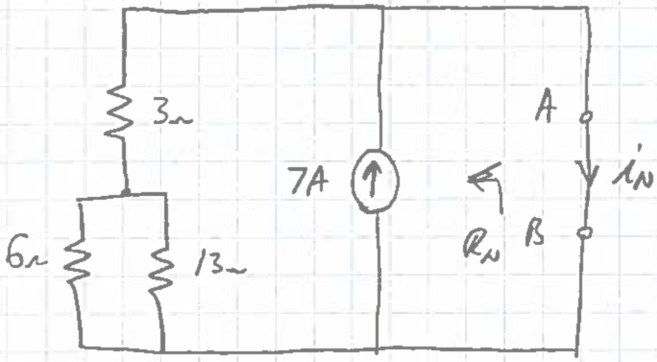
EQ CKT $\therefore$ $V_{TH} = (13\Omega)(2.75A) = \underline{\underline{35.7V}}$



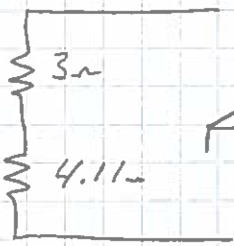
$$i_x = \frac{V_{TH}}{R_T} = \frac{35.7V}{12.58\Omega}$$

$$\boxed{i_x = 2.84A}$$

NORTON - TO FIND i_y

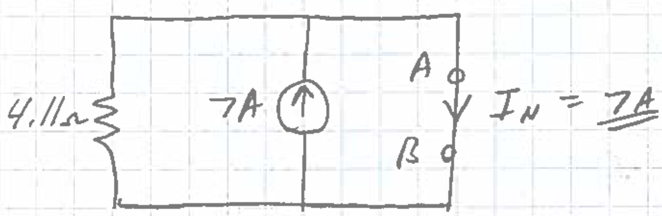


R_N - O/C THE 7A SOURCE

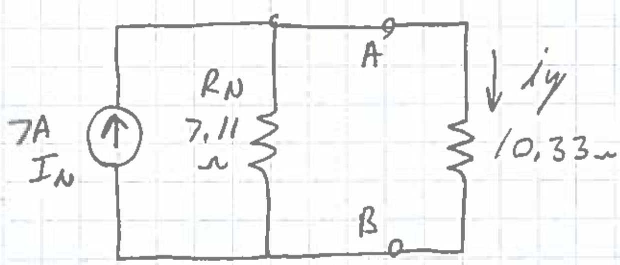


$\leftarrow R_N = \underline{\underline{7.11\Omega}}$

I_N - FIND I_{AB} S-C



EQ. CKT



$$i_y = I_N \left(\frac{R_T}{R_x} \right)$$

$R_T = 7.11\Omega \,//\, 10.33\Omega$

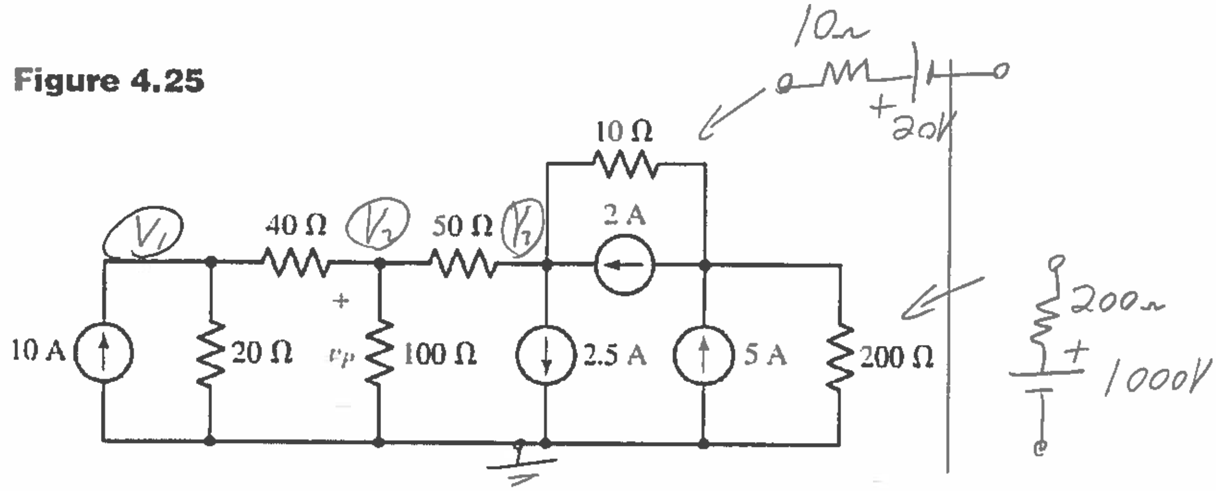
$\underline{R_T = 4.21\Omega}$

$\underline{R_x = 10.33\Omega}$

$$\therefore\ i_y = 7A \left(\frac{4.21\Omega}{10.33\Omega} \right)$$

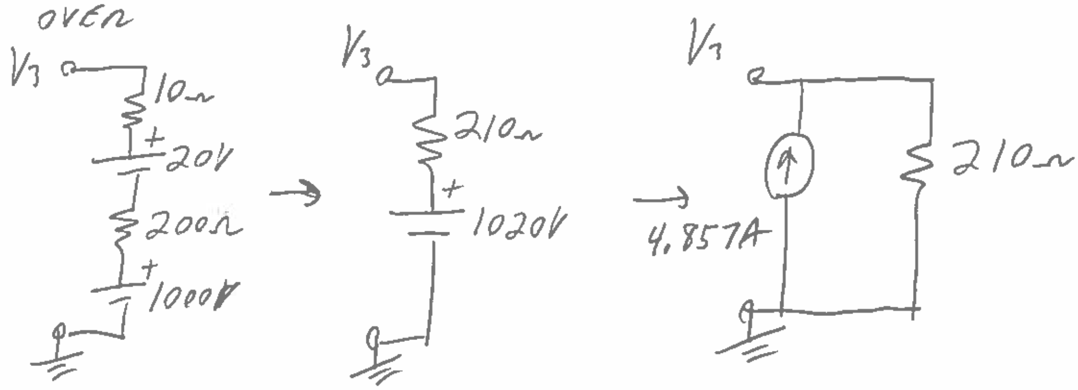
$$\boxed{i_y = 2.85A}$$

Figure 4.25



25. See Figure 4.25. Find v_p + $I_{50\Omega}$

4-NODE PROBLEM, REDRAW AS 3-NODE PROBLEM FROM V_3 OVER



$$V_1:\ 10 = \frac{V_1}{20} + \frac{V_1 - V_2}{40} \rightarrow 0.075V_1 - 0.025V_2 + 0V_3 = 10 \quad (1)$$

$$V_2:\ 0 = \frac{V_2 - V_1}{40} + \frac{V_2}{100} + \frac{V_2 - V_3}{50} \rightarrow -0.025V_1 + 0.055V_2 - 0.020V_3 = 0 \quad (2)$$

$$V_3:\ 4.857 = 2.5 + \frac{V_3 - V_2}{50} + \frac{V_3}{210} \rightarrow 0V_1 - 0.020V_2 + 0.02476V_3 = 2.357 \quad (3)$$

SOLVING YIELDS: $V_1 = 190.6V$
$V_2 = 171.7V$
$V_3 = 233.8V$

$$V_p = V_2 = \boxed{171.7V}$$

$$I_{50\Omega} = \frac{V_3 - V_2}{50\Omega} = \boxed{1.24A}$$

Summary of Equations to Accompany

INTRODUCTORY CIRCUIT ANALYSIS, Thirteenth Edition, by Robert L. Boylestad

dc

Introduction

Conversions 1 meter = 100 cm = 39.37 in., 1 in. = 2.54 cm, 1 yd = 0.914 m = 3 ft, 1 mile = 5280 ft, °F = 9/5°C + 32, °C = 5/9(°F − 32), K = 273.15 + °C **Scientific notation** 10^{12} = tera = T, 10^9 = giga = G, 10^6 = mega = M, 10^3 = kilo = k, 10^{-3} = milli = m, 10^{-6} = micro = μ, 10^{-9} = nano = n, 10^{-12} = pico = p **Powers of ten** $1/10^n = 10^{-n}$, $1/10^{-n} = 10^n$, $(10^n)(10^m) = 10^{n+m}$, $10^n/10^m = 10^{n-m}$, $(10^n)^m = 10^{nm}$

Voltage and Current

Coulomb's law $F = kQ_1Q_2/r^2$, $k = 9 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2$, Q = coulombs (C), r = meters (m) **Current** $I = Q/t$ (amperes), t = seconds (s), $Q_e = 1.6 \times 10^{-19}$ C **Voltage** $V = W/Q$ (volts), W = joules (J)

Resistance

Circular wire $R = \rho l/A$ (ohms), ρ = resistivity, l = feet, $A_{CM} = (d_{mils})^2$, ρ(Cu) = 10.37 **Metric units** l = cm, A = cm^2, ρ(Cu) = 1.724×10^{-6} ohm-cm **Temperature** $(|T_i| + T_1)/R_1 = (|T_i| + T_2)/R_2$, $R_1 = R_{20}[1 + \alpha_{20}(T_1 - 20°\text{C})]$, α_{20}(Cu) = 0.00393 **Color code** Bands 1–3: 0 = black, 1 = brown, 2 = red, 3 = orange, 4 = yellow, 5 = green, 6 = blue, 7 = violet, 8 = gray, 9 = white, Band 3: 0.1 = gold, 0.01 = silver, Band 4: 5% = gold, 10% = silver, 20% = no band, Band 5: 1% = brown, 0.1% = red, 0.01% = orange, 0.001% = yellow **Conductance** $G = 1/R$ siemens (S)

Ohm's Law, Power, and Energy

Ohm's law $I = E/R$, $E = IR$, $R = E/I$ **Power** $P = W/t = VI = I^2R = V^2/R$ (watts), 1 hp = 746 W
Efficiency $\eta\% = (P_o/P_i) \times 100\%$, $\eta_T = \eta_1 \cdot \eta_2 \cdot \eta_3 \cdots \eta_n$
Energy $W = Pt$, W (kWh) = $[P(\text{W}) \cdot t(\text{h})]/1000$

Series Circuits

$R_T = R_1 + R_2 + R_3 + \cdots + R_N$, $R_T = NR$, $I = E/R_T$, $V = IR$
Kirchhoff's voltage law $\Sigma_{\circlearrowright} V = 0$, $\Sigma_{\circlearrowright} V_{\text{rises}} = \Sigma_{\circlearrowright} V_{\text{drops}}$
Voltage divider rule $V_x = R_xE/R_T$

Parallel dc Circuits

$R_T = 1/(1/R_1 + 1/R_2 + 1/R_3 + \cdots + 1/R_N)$, $R_T = R/N$, $R_T = R_1R_2/(R_1 + R_2)$, $I = EG_T = E/R_T$
Kirchhoff's current law $\Sigma I_{\text{entering}} = \Sigma I_{\text{leaving}}$
Current divider rule $I_x = (R_T/R_x)I$, (Two parallel elements): $I_1 = R_2I/(R_1 + R_2)$, $I_2 = R_1I/(R_1 + R_2)$

Series-Parallel Circuits

Potentiometer loading $R_L >> R_T$
Ammeter $R_{\text{shunt}} = R_mI_{CS}/(I_{\max} - I_{CS})$
Voltmeter $R_{\text{series}} = (V_{\max} - V_{VS})/I_{CS}$
Ohmmeter $R_s = (E/I_{CS}) - R_m$ − zero-adjust/2

Methods of Analysis and Selected Topics (dc)

Source conversions $E = IR_p$, $R_s = R_p$, $I = E/R_s$

Determinants $D = \begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix} = a_1b_2 - a_2b_1$

Bridge networks $R_1/R_3 = R_2/R_4$ **Δ-Y conversions** $R' = R_A + R_B + R_C$, $R_3 = R_AR_B/R'$, $R_2 = R_AR_C/R'$, $R_1 = R_BR_C/R'$, $R_Y = R_\Delta/3$
Y-Δ conversions $R'' = R_1R_2 + R_1R_3 + R_2R_3$, $R_C = R''/R_3$, $R_B = R''/R_2$, $R_A = R''/R_1$, $R_\Delta = 3R_Y$

Network Theorems

Superposition Voltage sources (short-circuit equivalent), current sources (open-circuit equivalent)
Thévenin's Theorem R_{Th}: (all sources to zero), E_{Th}: (open-circuit terminal voltage)
Maximum power transfer theorem $R_L = R_{Th} = R_N$, $P_{\max} = E^2_{Th}/4R_{Th} = I^2_NR_N/4$

Capacitors

Capacitance $C = Q/V = \epsilon A/d = 8.85 \times 10^{-12}\epsilon_r A/d$ farads (F), $C = \epsilon_r C_o$ **Electric field strength** $\mathscr{E} = V/d = Q/\epsilon A$ (volts/meter) **Transients** (charging) $i_C = (E/R)e^{-t/\tau}$, $\tau = RC$, $v_C = E(1 - e^{-t/\tau})$, (discharge) $v_C = Ee^{-t/\tau}$, $i_C = (E/R)e^{-t/RC}$ i_C $i_{C_{av}} = C(\Delta v_C/\Delta t)$
Series $Q_T = Q_1 = Q_2 = Q_3$, $1/C_T = (1/C_1) + (1/C_2) + (1/C_3) + \cdots + (1/C_N)$, $C_T = C_1C_2/(C_1 + C_2)$ **Parallel** $Q_T = Q_1 + Q_2 + Q_3$, $C_T = C_1 + C_2 + C_3$ **Energy** $W_C = (1/2)CV^2$

Inductors

Self-inductance $L = N^2\mu A/l$ (henries), $L = \mu_r L_o$
Induced voltage $e_{L_{av}} = L(\Delta i/\Delta t)$ **Transients** (storage) $i_L = I_m(1 - e^{-t/\tau})$, $I_m = E/R$, $\tau = L/R$, $v_L = Ee^{-t/\tau}$ (decay), $v_L = [1 + (R_2/R_1)]Ee^{-t/\tau'}$, $\tau' = L/(R_1 + R_2)$, $i_L = I_me^{-t/\tau'}$, $I_m = E/R_1$
Series $L_T = L_1 + L_2 + L_3 + \cdots + L_N$ **Parallel** $1/L_T = (1/L_1) + (1/L_2) + (1/L_3) + \cdots + (1/L_N)$, $L_T = L_1L_2/(L_1 + L_2)$
Energy $W_L = 1/2(LI^2)$

Magnetic Circuits

Flux density $B = \Phi/A$ (webers/m^2) **Permeability** $\mu = \mu_r\mu_o$ (Wb/A · m)
Reluctance $\mathscr{R} = l/\mu A$ (rels) **Ohm's law** $\Phi = \mathscr{F}/\mathscr{R}$ (webers)
Magnetomotive force $\mathscr{F} = NI$ (ampere-turns) **Magnetizing force** $H = \mathscr{F}/l = NI/l$ **Ampère's circuital law** $\Sigma_{\circlearrowright} \mathscr{F} = 0$
Flux $\Sigma \Phi_{\text{entering}} = \Sigma \Phi_{\text{leaving}}$ **Air gap** $H_g = 7.96 \times 10^5 B_g$

Greek Alphabet

Letter	Capital	Lowercase	Letter	Capital	Lowercase
Alpha	A	α	Nu	N	ν
Beta	B	β	Xi	Ξ	ξ
Gamma	Γ	γ	Omicron	O	o
Delta	Δ	δ	Pi	Π	π
Epsilon	E	ϵ	Rho	P	ρ
Zeta	Z	ζ	Sigma	Σ	σ
Eta	H	η	Tau	T	τ
Theta	Θ	θ	Upsilon	Υ	υ
Iota	I	ι	Phi	Φ	ϕ
Kappa	K	κ	Chi	X	χ
Lambda	Λ	λ	Psi	Ψ	ψ
Mu	M	μ	Omega	Ω	ω

Prefixes

Multiplication Factors	SI Prefix	SI Symbol
1 000 000 000 000 000 000 = 10^{18}	exa	E
1 000 000 000 000 000 = 10^{15}	peta	P
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^9	giga	G
1 000 000 = 10^6	mega	M
1 000 = 10^3	kilo	k
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a