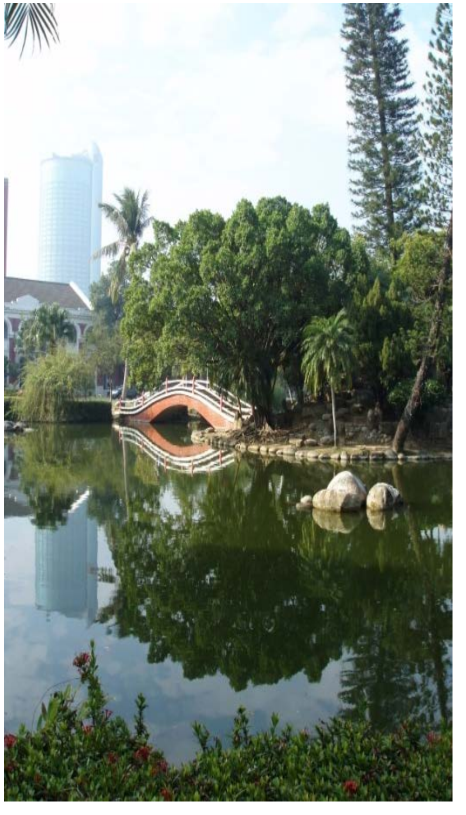
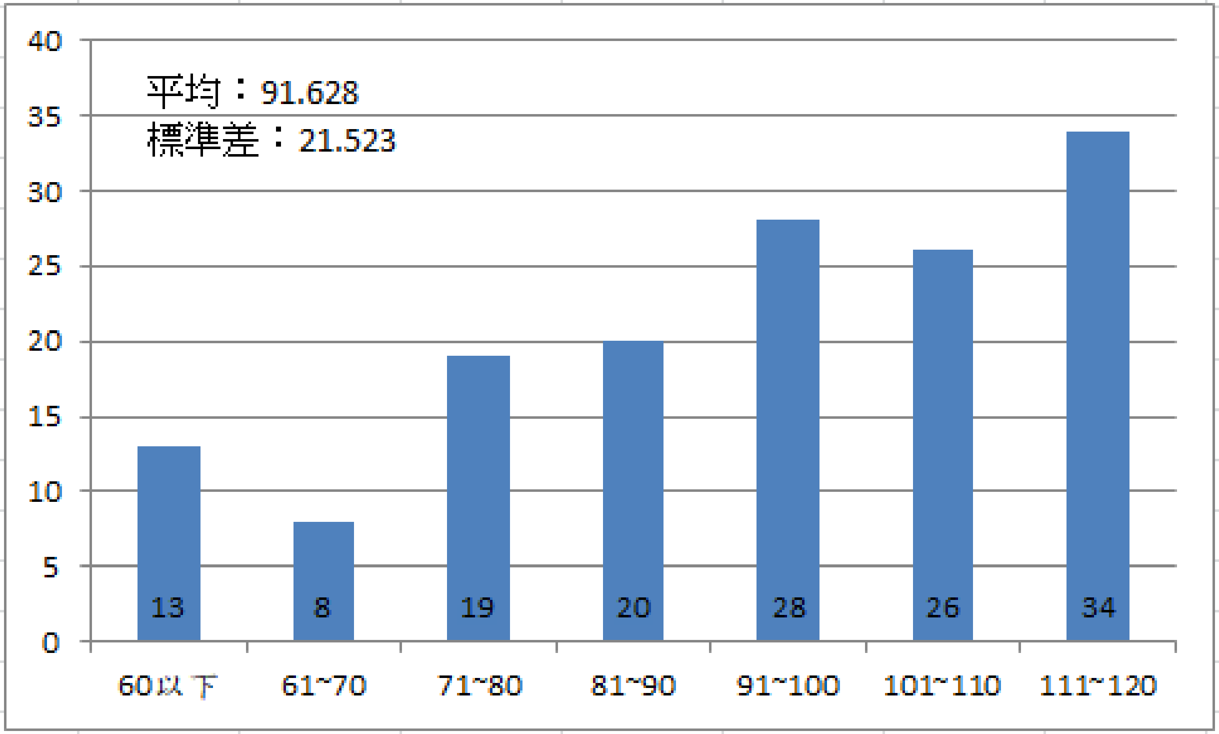
電子電工學
Lecture 6



Midterm I Results

60以下	60	13
61~70	70	8
71~80	80	19
81~90	90	20
91~100	100	28
101~110	110	26
111~120	120	34

平均	91.62838
標準差	21.52274



Chapter 5

CONTROLLED SOURCES AND NONLINEAR COMPONENTS

Voltage-controlled current source (dependent source)

INDEPENDENT SOURCE

⇒ DEPENDENT SRC

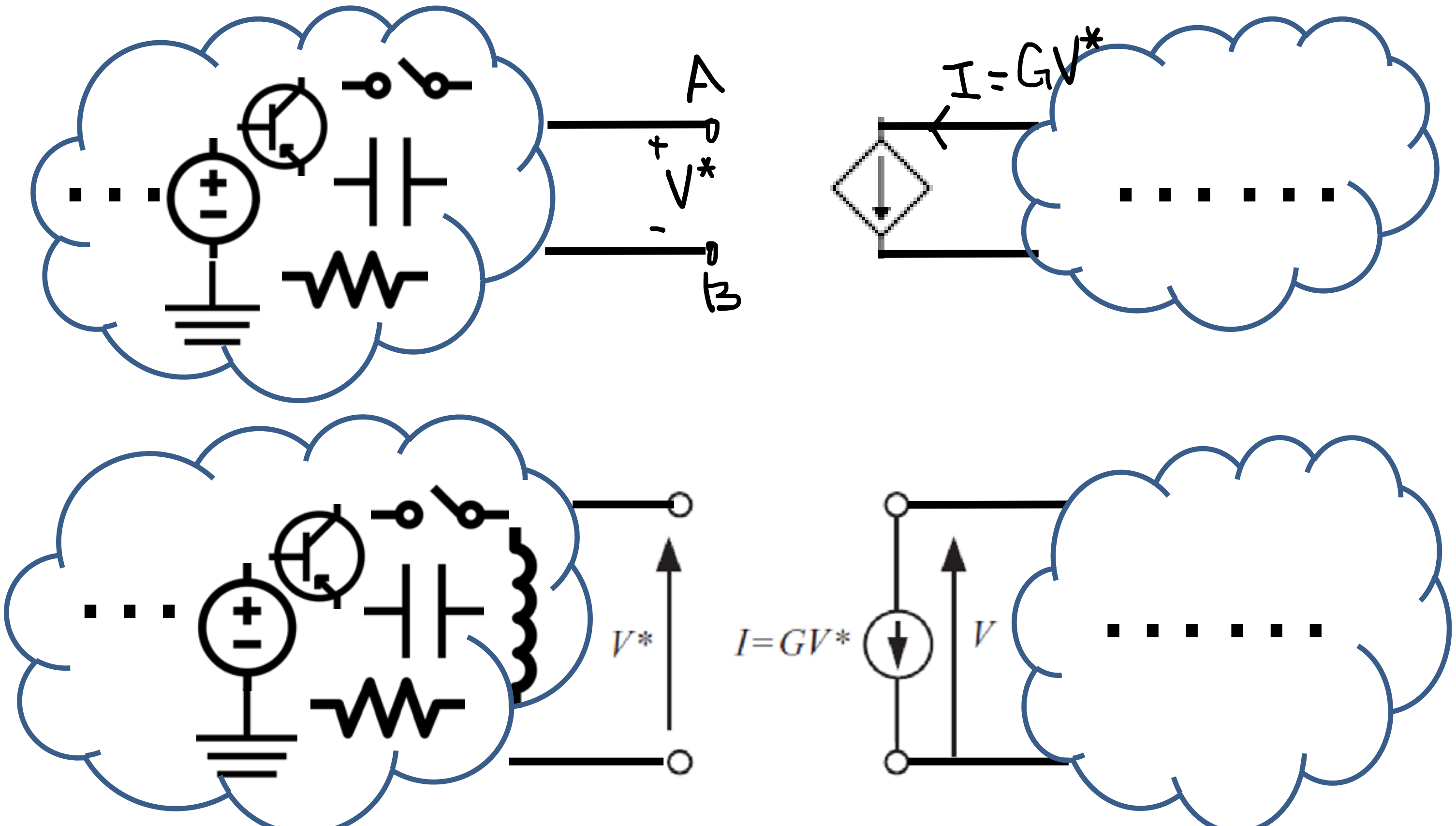


Figure 5.1 Representation of a voltage-controlled current source

Voltage-controlled current source

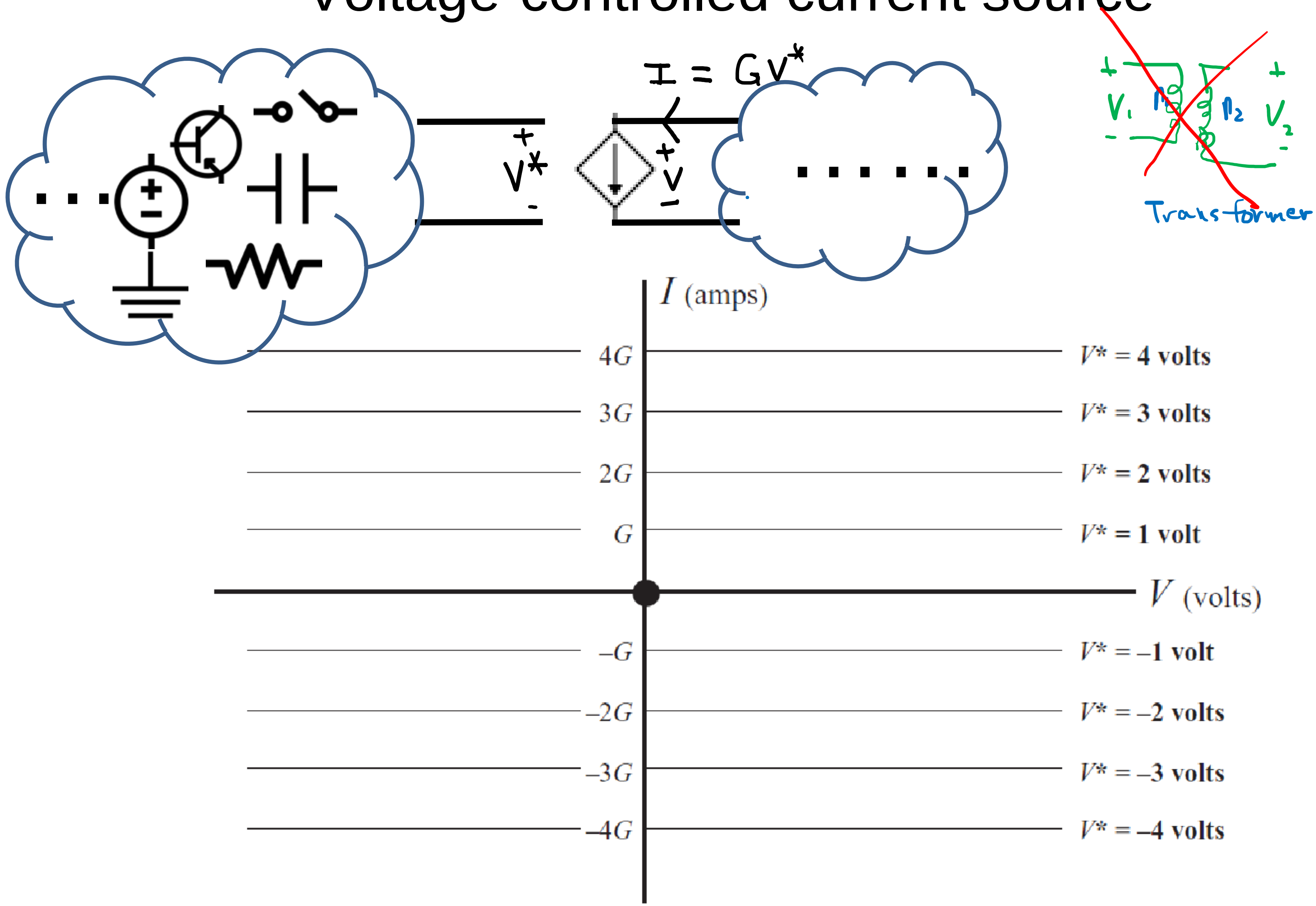


Figure 5.2 The voltage–current characteristics of a voltage-controlled current source

Transistor characteristics

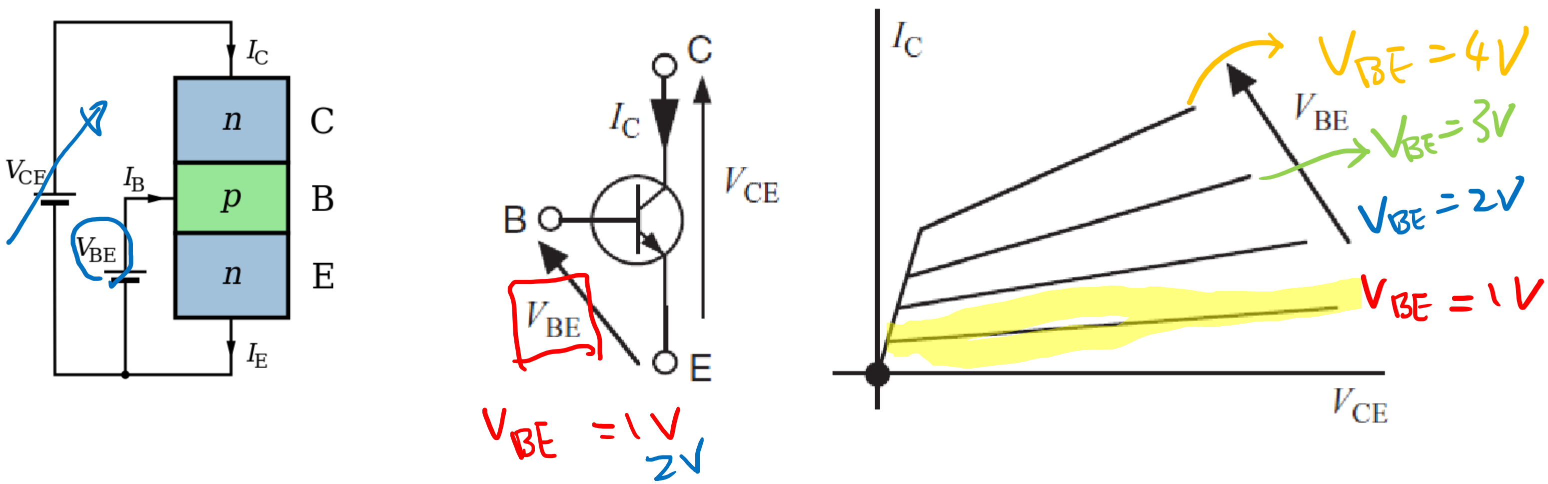
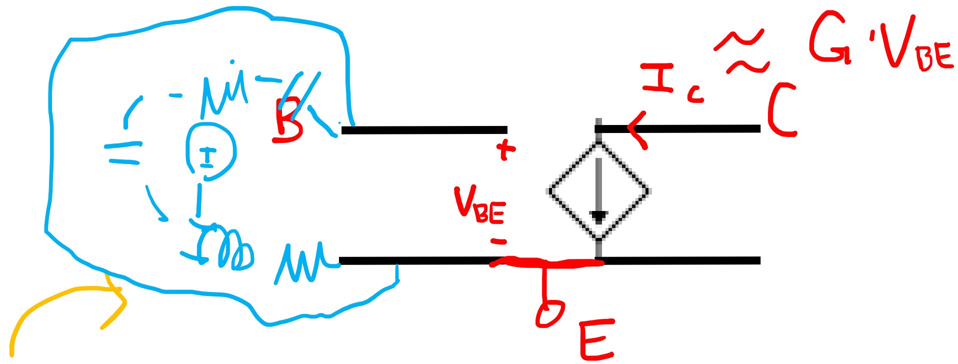


Figure 5.3 The symbol for a transistor, with terminals E (emitter), B (base) and C (collector) and the (sketched) measured characteristics showing the control of the current I_C by the voltage V_{BE}

Transistor characteristics



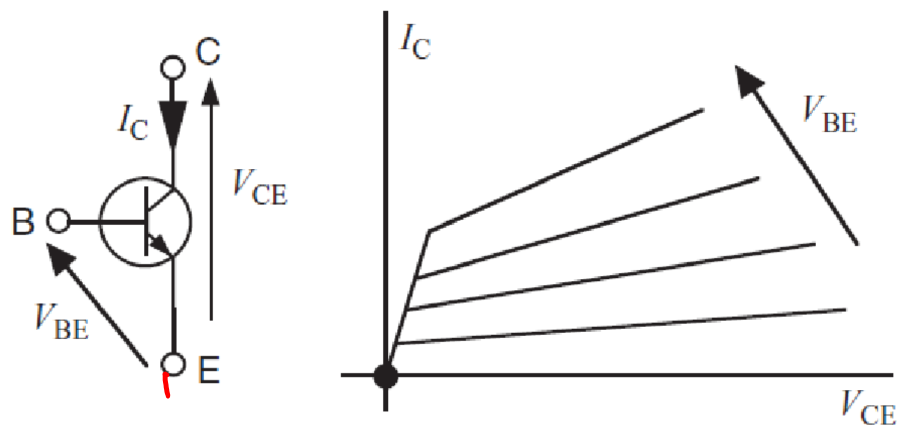
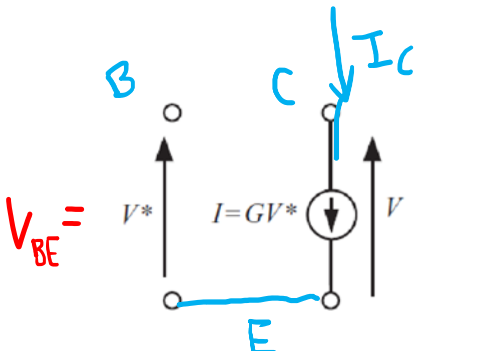


Figure 5.3 The symbol for a transistor, with terminals E (emitter), B (base) and C (collector) and the (sketched) measured characteristics showing the control of the current I_C by the voltage V_{BE}

Transistor characteristics



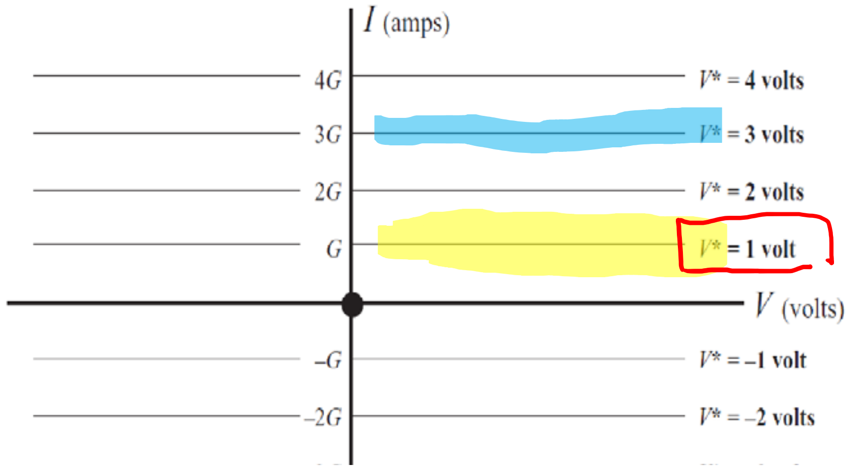


Figure 5.1 Representation of a voltage-controlled

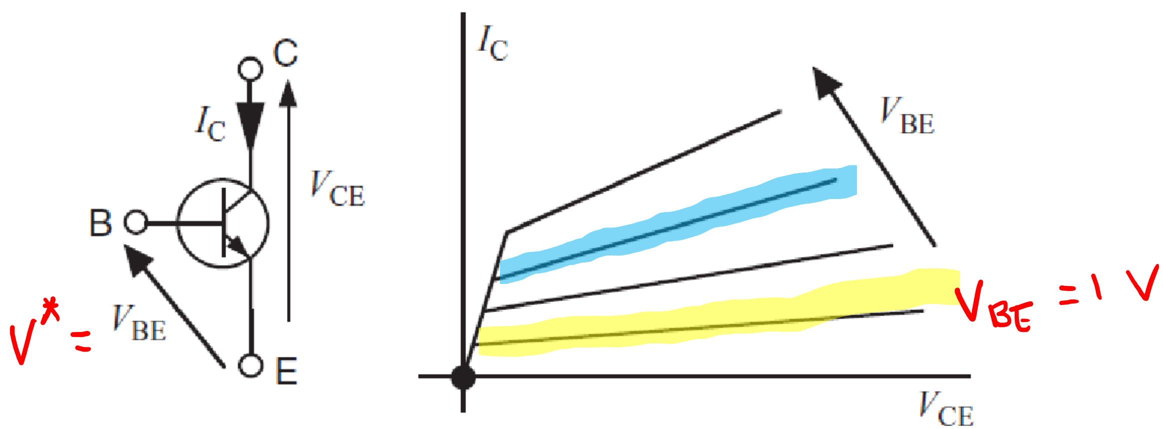


Figure 5.3 The symbol for a transistor, with terminals E (emitter), B (base) and C (collector) and the (sketched) measured characteristics showing the control of the current I_C by the voltage V_{BE}

Active component

Power $= V \times I > 0$ dissipate

$V \times I < 0$ provide

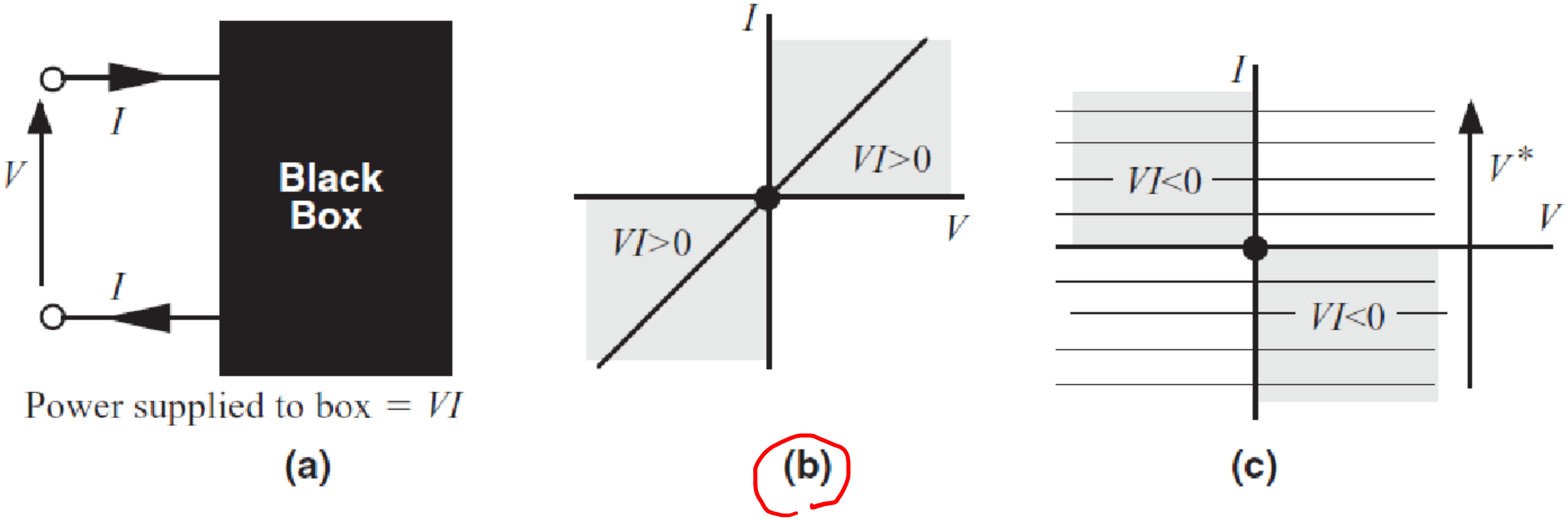


Figure 5.4 (a) The condition for a component to be passive; (b) a resistor is passive: it cannot supply energy; (c) a VCCS is said to be active because it can supply energy if it is operating in the appropriate shaded region

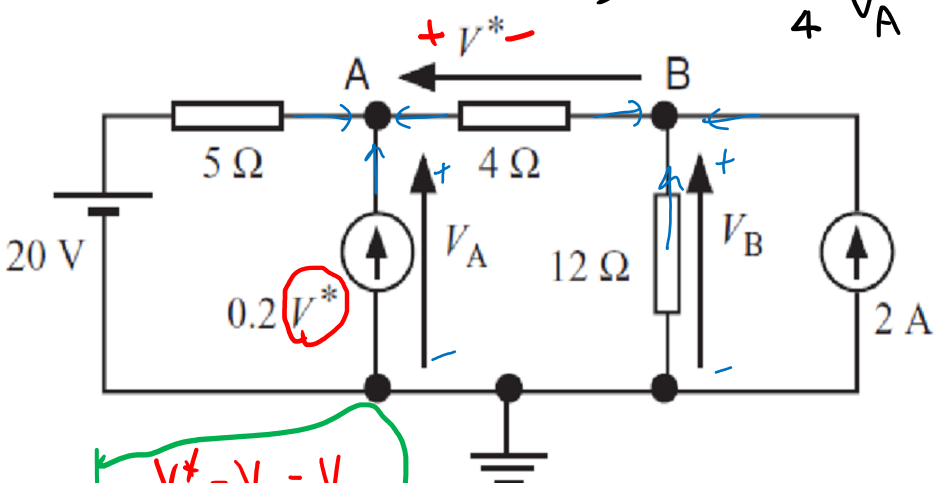
Example 5.1 (Nodal analysis) ← {Ohm's, KCL, KVL}

$V_A=?\quad V_B=?$

KCL @ A (INWARD +)

$$\frac{20-V_A}{5} + 0.2\,V^* + \frac{V_B-V_A}{4} = 0 \qquad (V_A - V_B)$$

$$\rightarrow \quad -\frac{1}{4}V_A + \frac{1}{20}V_B = -4 \quad \text{------ (1)}$$



$V^* = V_A - V_B$

KCL

@A

$$\frac{20-V_A}{5} + 0.2V^* + \frac{V_B-V_A}{4} = 0$$

@B

$$\frac{V_A-V_B}{4} + \frac{0-V_B}{12} + 2 = 0$$

Figure 5.5 The circuit analysed in Example 5.1. It contains one voltage-controlled current source whose mutual conductance is 0.2 A/V (i.e., 0.2 S)

Example 5.1

KCL @ B (INWARD +)

$$\frac{V_A - V_B}{4} + \frac{0 - V_B}{12} + 2 = 0$$

$$\Rightarrow \frac{V_A}{4} - \frac{V_B}{3} = -2 \quad \cdots\cdots (2)$$

$$(1)(2) \Rightarrow \begin{cases} V_A = 344/17 \\ V_B = 360/17 \end{cases}$$

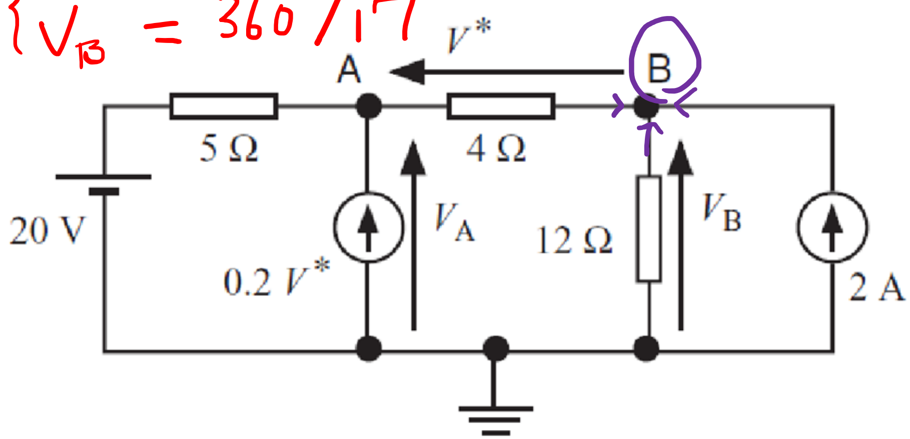


Figure 5.5 The circuit analysed in Example 5.1. It contains one voltage-controlled current source whose mutual conductance is 0.2 A/V (i.e., 0.2 S)

Example 5.2 (Superposition)

$V_A = ?$

$V_A = V_A|_{S1} + V_A|_{S2}$ (ONLY INDEPENDENT SOURCE)

INDEPENDENT Sources : Activate one-by-one
Disable others

DEPENDENT Sources : "LEFT ALONE"

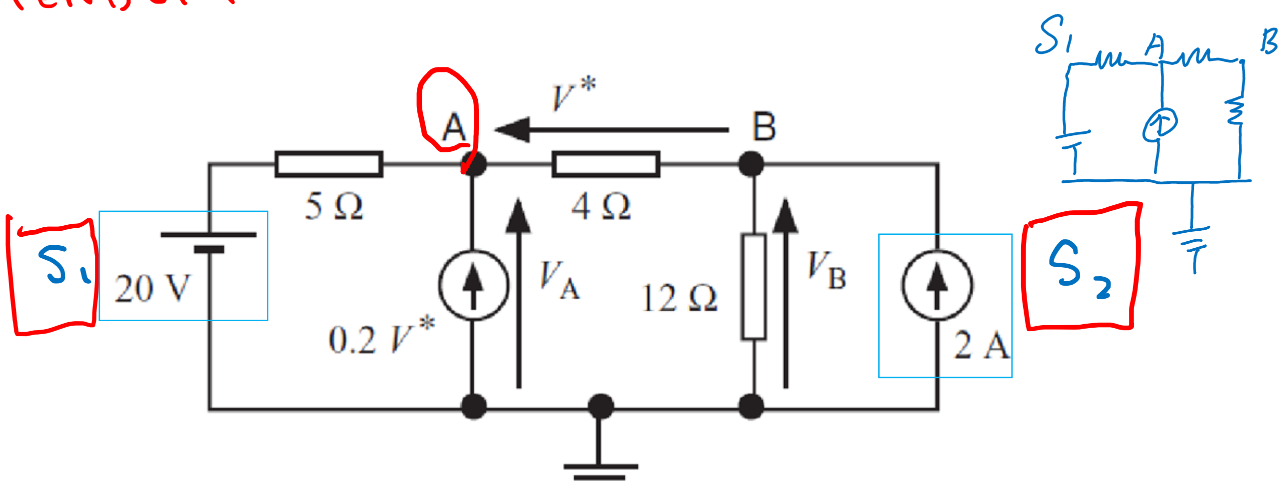


Figure 5.5 The circuit analysed in Example 5.1. It contains one voltage-controlled current source whose mutual conductance is 0.2 A/V (i.e., 0.2 S)

Example 5.2

Source 1 only

S_1 : 20V

KCL @ A :

$$\frac{20-V_A}{5} + 0.2V^* + \frac{V_B - V_A}{4} = 0$$

$\frac{V_A}{4}$

$-V^* = -\frac{V_A}{4}$

$V_A = V_A|_{S_1} + V_A|_{S_2}$

$$\frac{V_A - V_B}{4} + \frac{0 - V_B}{12} = 0$$

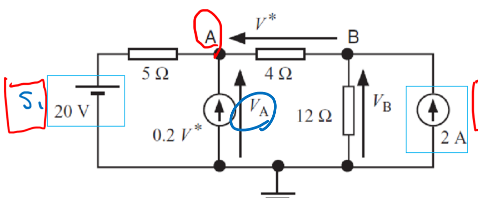
$$\frac{3V_A - 3V_B - V_B}{12} = 0$$

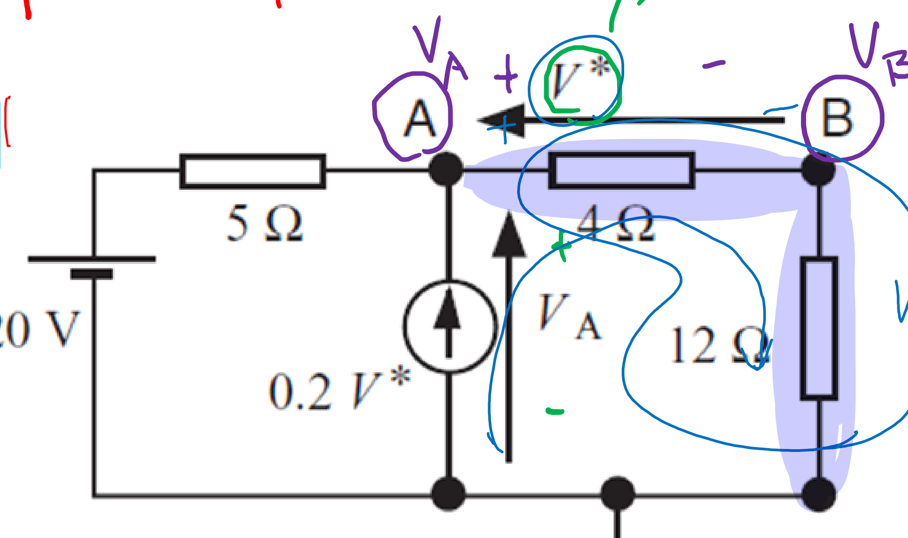
$3V_A = 4V_B$

$V_B = \frac{3}{4}V_A$

$$\Rightarrow V_A|_{S_1} = \frac{320}{17} \text{ (V)}$$

$$V^* = V_A \times \frac{4}{4+12} = \frac{V_A}{4}$$





(a)

(Voltage Divider)

$V^* = V_A - V_B$

$= \frac{1}{4}V_A$

Example 5.2

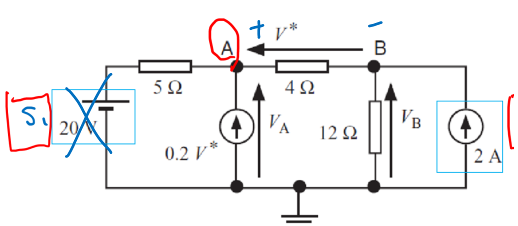
Source 2 only

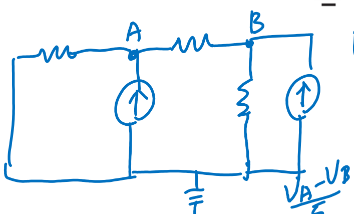
S_2 : 2A (By Nodal Anaysis)

KCL@A : $\frac{0-V_A}{5} + 0.2(V_A - V_B) + \frac{V_B - V_A}{4} = 0 \rightarrow -\frac{1}{4}V_A + \frac{1}{20}V_B = 0$

KCL@B : $\frac{V_A - V_B}{4} + \frac{0 - V_B}{12} + 2 = 0 \rightarrow \frac{1}{4}V_A - \frac{1}{3}V_B = -2$

$$\Rightarrow V_A\Big|_{S2} = \frac{24}{17}\ (V)$$





$V^* = V_A - V_B$

$\frac{V_A - V_B}{5}$

KCL @ A

$\frac{0-V_A}{5} + 0.2V^* + \frac{V_B - V_A}{4} = 0$

0V

$\frac{-\cancel{4V_A} + \cancel{4V_B} - 4V_B + 5V_A - 5V_B}{20} = 0$

$5V_A - 9V_B = 0$ $5V_A = 9V_B$ $V_B = \frac{5}{9}V_A$

KCL @ B

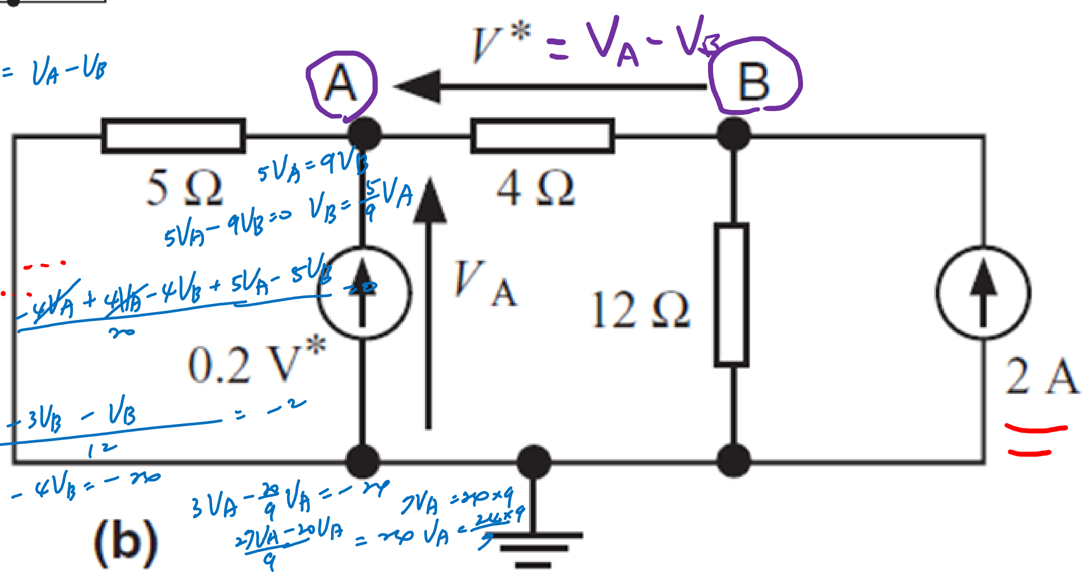
$\frac{V_A - V_B}{4} + \frac{0 - V_B}{12} + 2A = 0$

$\frac{3V_A - 3V_B - V_B}{12} = -2$

$3V_A - 4V_B = -20$

$3V_A - \frac{20}{9}V_A = -24$

$\frac{27V_A - 20V_A}{9} = -20$ $7V_A = 24 \times 9$ $V_A = \frac{24 \times 9}{7}$



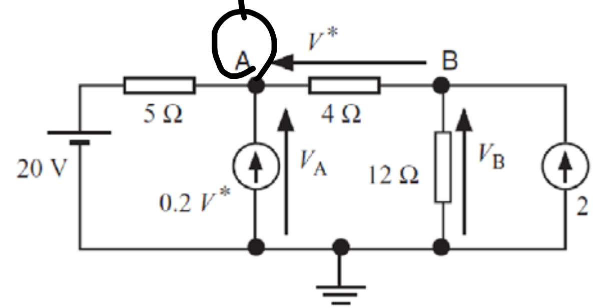
Example 5.2

$$V_A = V_A\big|_{S1} + V_A\big|_{S2}$$

$$= \frac{320}{17} + \frac{24}{17}$$

$$= \frac{344}{17}\ (V)$$

$$\boxed{\frac{344}{17}\ V}$$



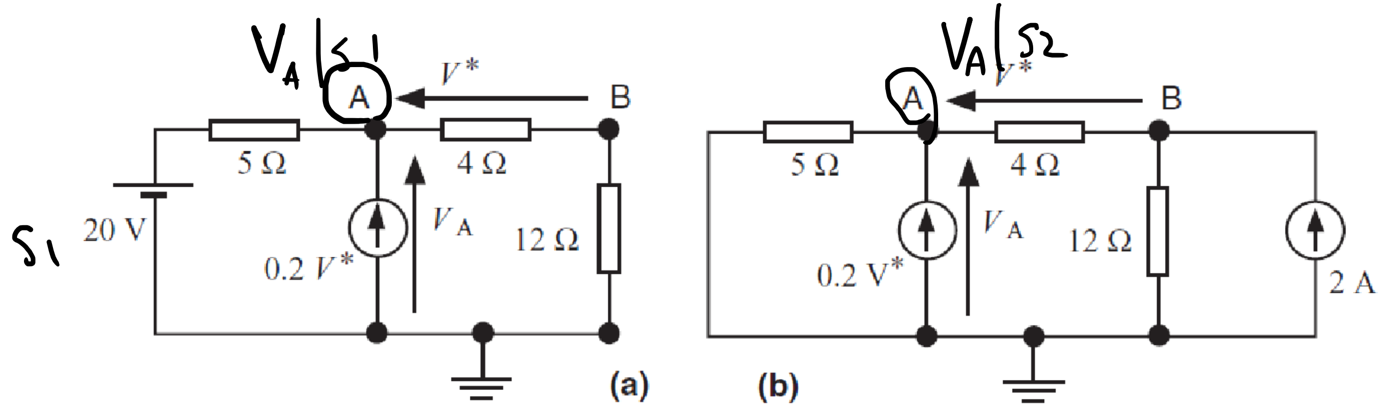
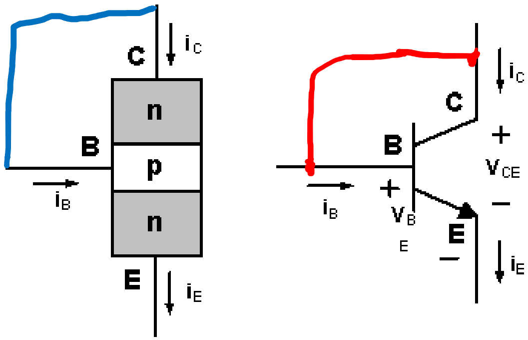
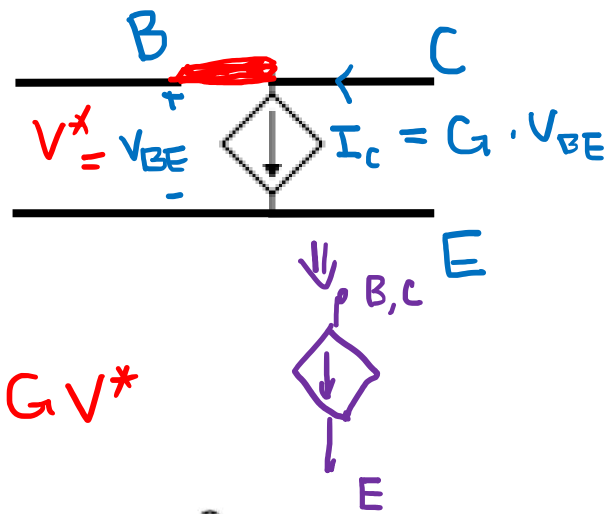


Figure 5.6 Circuits prepared for application of the superposition principle to the analysis of the circuit of Figure 5.5. From (a) it is found that the component of V_A due to the independent 20 V source is 320/17 volts. From (b) it is found that the component of V_A due to the independent 2 A source is 24/17 V. Superposition allows us to state that the actual value of V_A in the circuit of Figure 5.5 is $320/17 + 24/17 = 344/17$ V

Equivalent resistor

$V_{BE} = V_{CE} = V^*$





$I = GV^*$

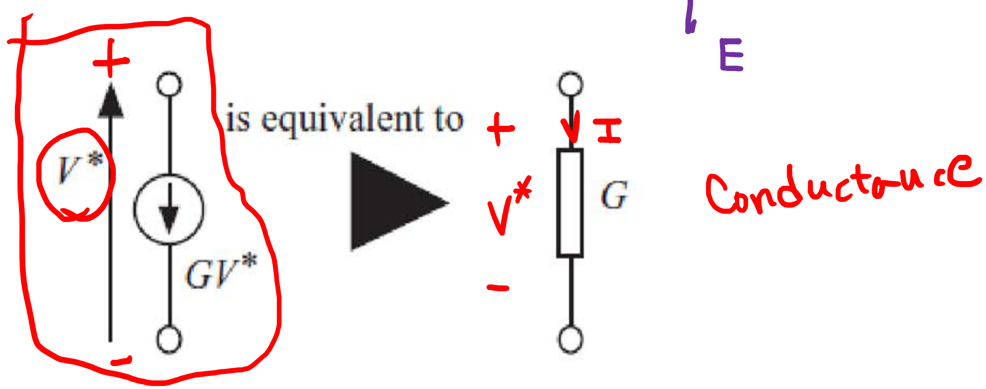
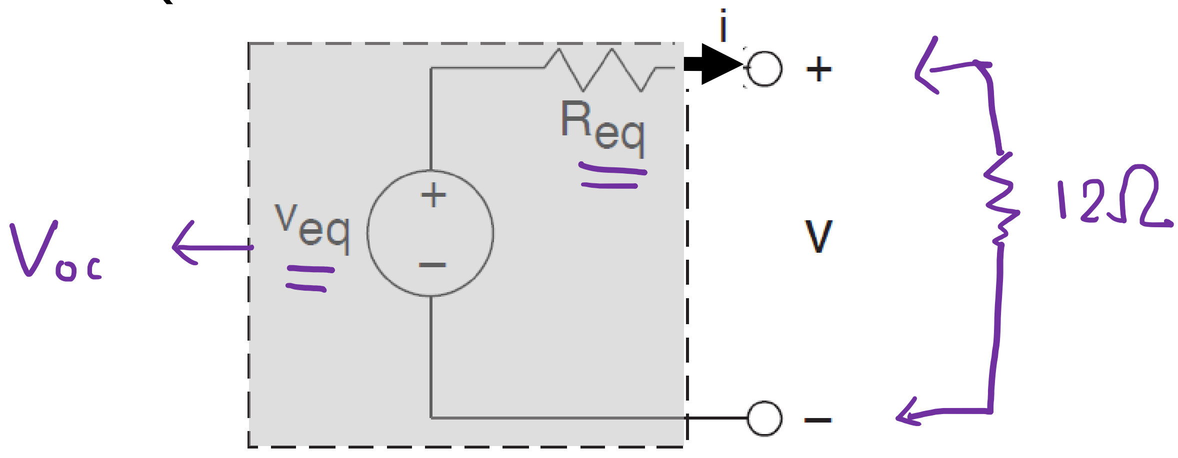


Figure 5.10 A VCCS whose controlling voltage appears directly across the controlled current source is equivalent to a resistor of appropriate value

Example 5.3 (Thevenin model)



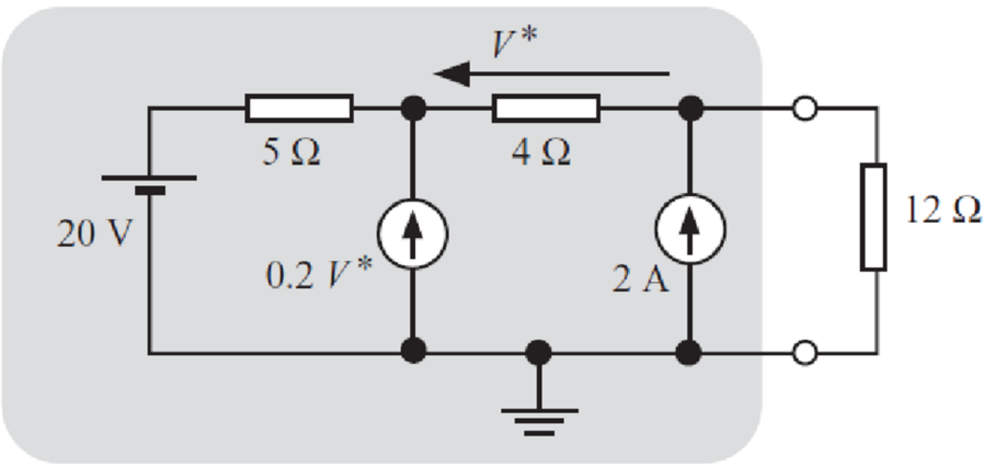


Figure 5.7 The circuit of Figure 5.5 rearranged to show that part for which a Thevenin model is to be found

Example 5.3 (2)

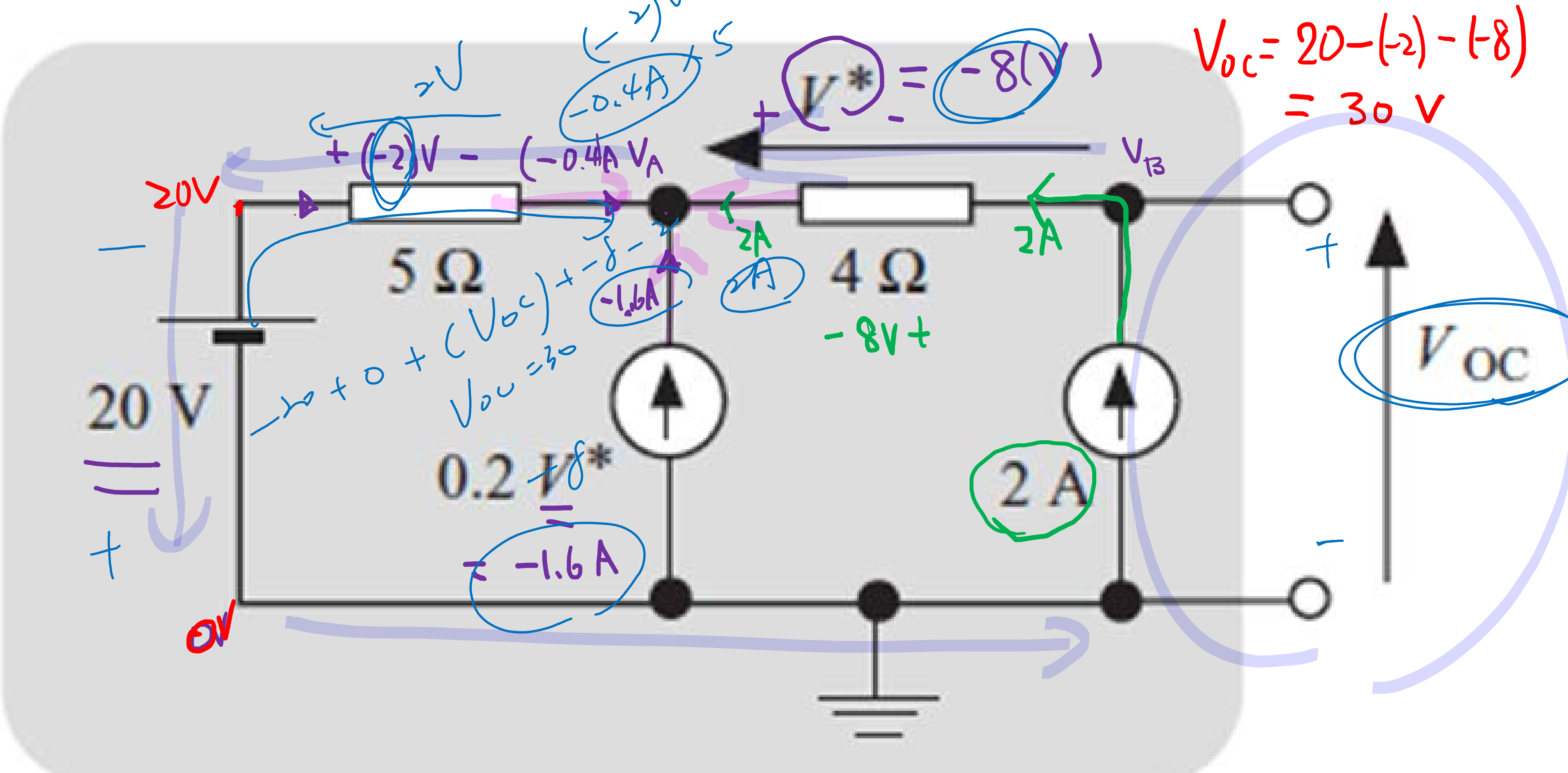
① NODAL ANALYSIS ⇒ 2 eqns ⇒ $V_B = V_{OC} = 30\ V$ (Textbook)

② Superposition

③ Direct ANALYSIS

$V^* = -2 \times 4 = -8$

$V_{OC} = 20 - (-2) - (-8) = 30\ V$



Example 5.3 (3)

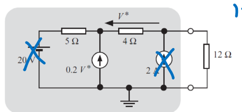
To find R_o, Apply 1A current source

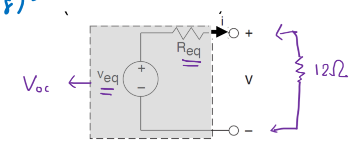
measure $V_{AB} = 5V$

$\Rightarrow R_o = V_{AB}/1A = 5\ \Omega$

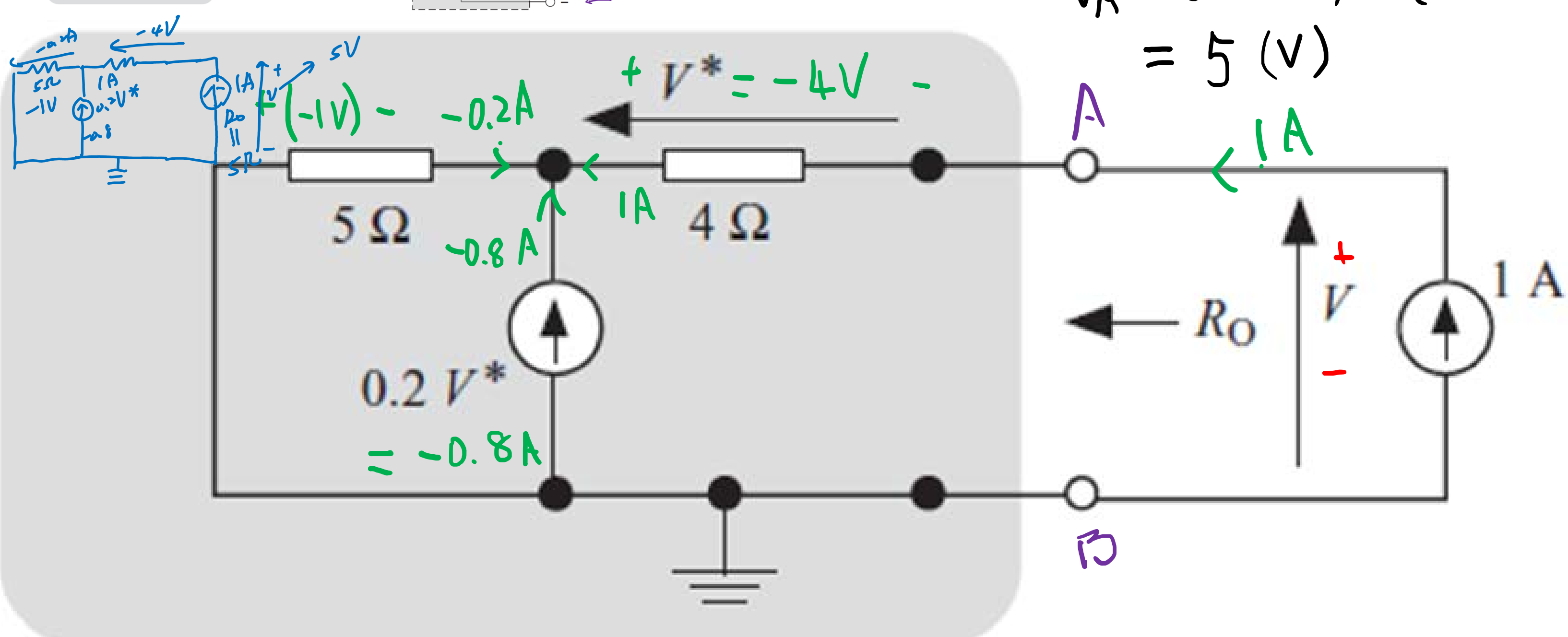
Set [Independent Source → 0
Dependent Source (Left alone!)]

$1 + (-0.8) = 0.2$

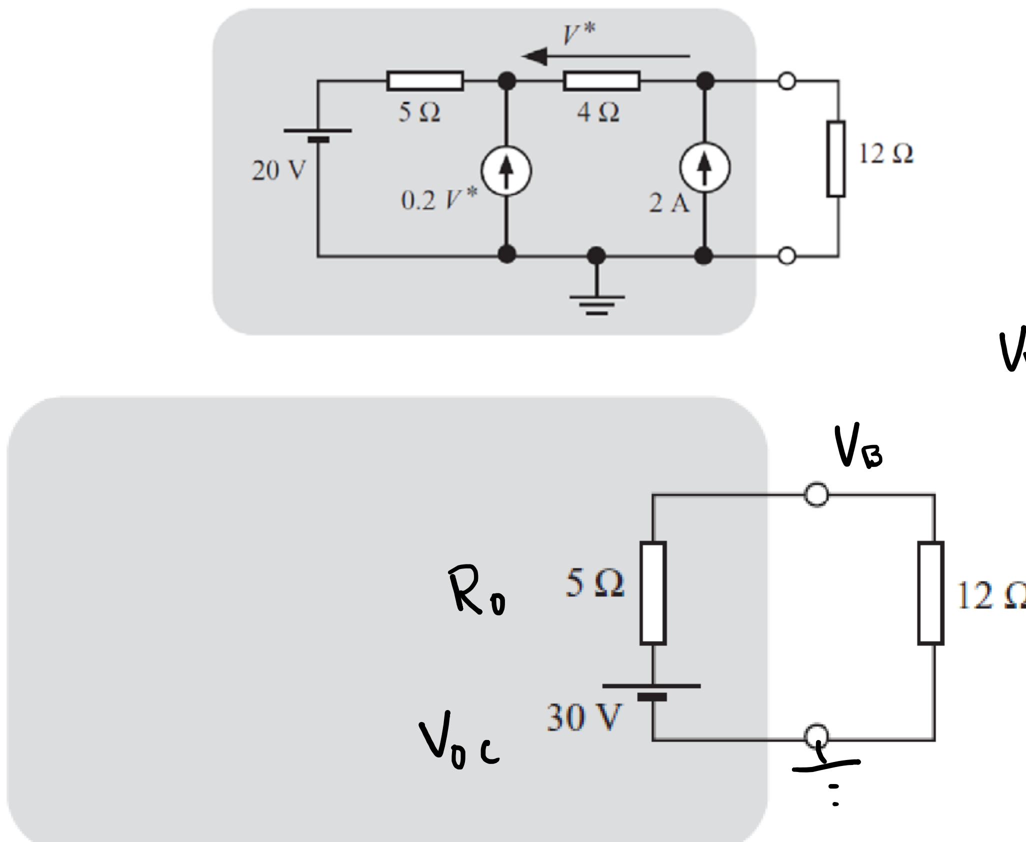




$V_A = 0 - (-1) - (-4)$
$= 5\ (V)$



Example 5.3 (4)



$$V_B = 30 \times \frac{12}{5+12}$$

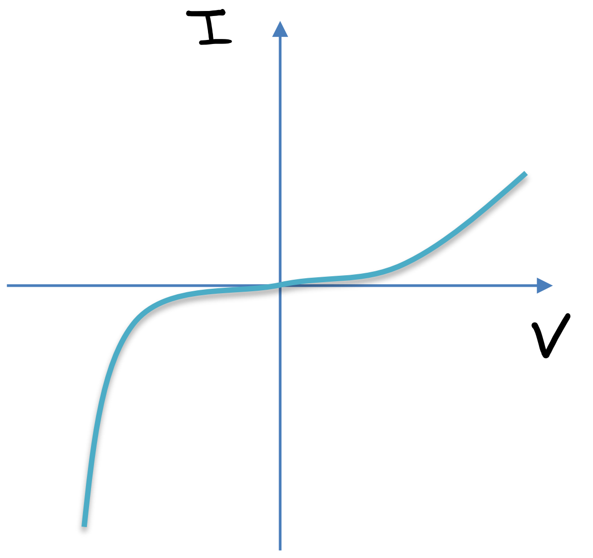
$$= \frac{360}{17}\ (V)$$

Figure 5.9 Use of the Thevenin model of the circuit of Figure 5.7 to calculate the voltage across the 12 Ω resistor. If the 12 Ω resistor is replaced by another resistor having a different value only a very simple calculation is involved, invoking Ohm's law

Nonlinear components

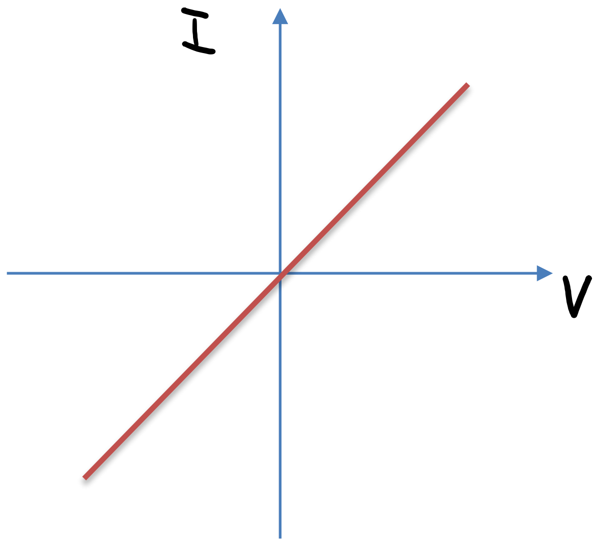
Transistor
Diode

Vs

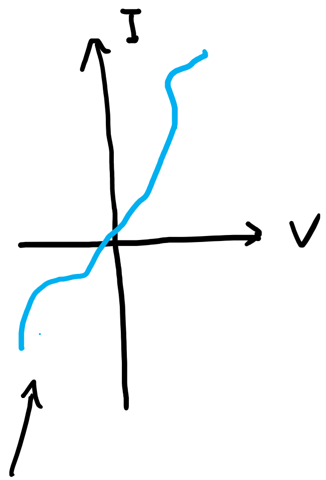


Linear components

R, L, C, Sources



Nonlinear components in circuits



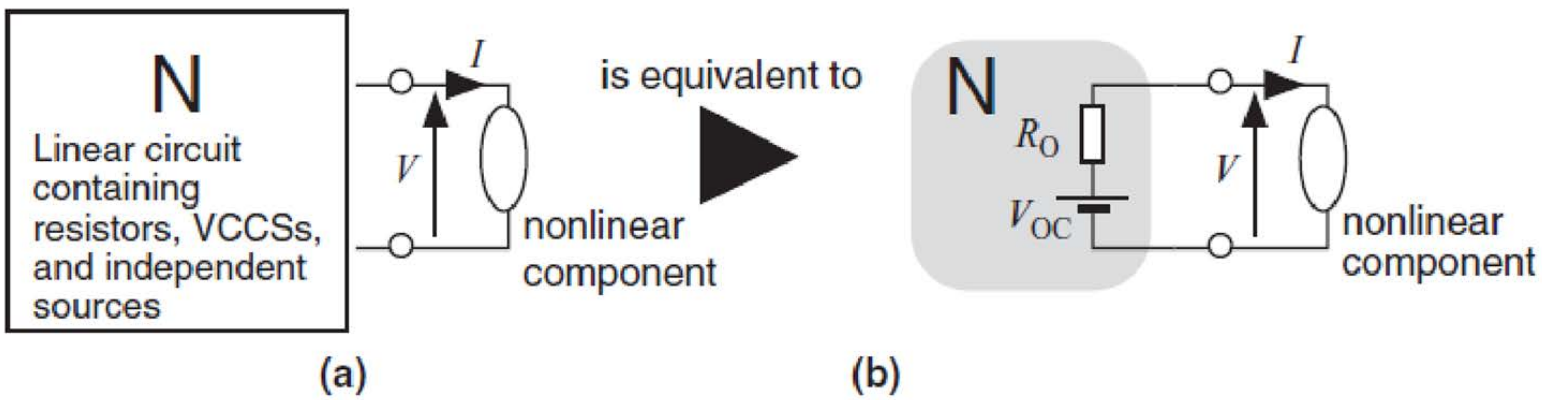
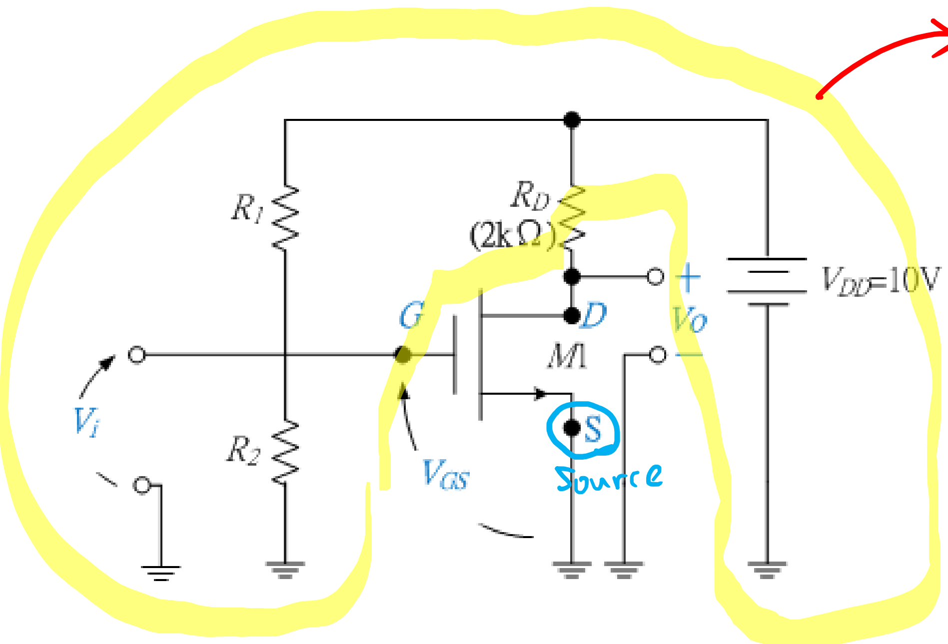
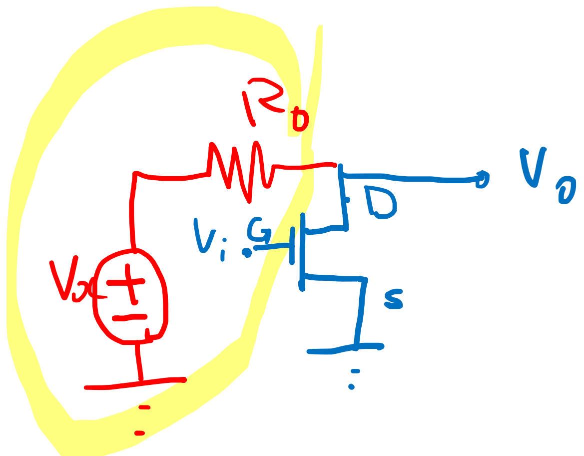


Figure 5.11 (a) A circuit containing one nonlinear component whose voltage and current are of interest; (b) a representation of the linear part of the circuit by a Thevenin model

Example: transistor

Common Source Amplifier





MOSFET

Load-line construction

$$I = -\frac{V}{R_0} + \frac{V_{oc}}{R_0} \quad \text{— (1)}$$

$$I = f(V) \quad \text{— (2)}$$

(1) (2) Eq'n System

$$-\frac{V}{R_0} + \frac{V_{oc}}{R_0} = f(V)$$

↓ Solve

V^*, I^*

Linear

Thevenin eq. ckt

$IR_0 - V_{oc} + V = 0$

$V + IR_0 - V_{oc} = 0$

$IR_0 = V_{oc} - V$

$$I = \frac{-V + V_{oc}}{R_0}$$

(V^*, I^*)

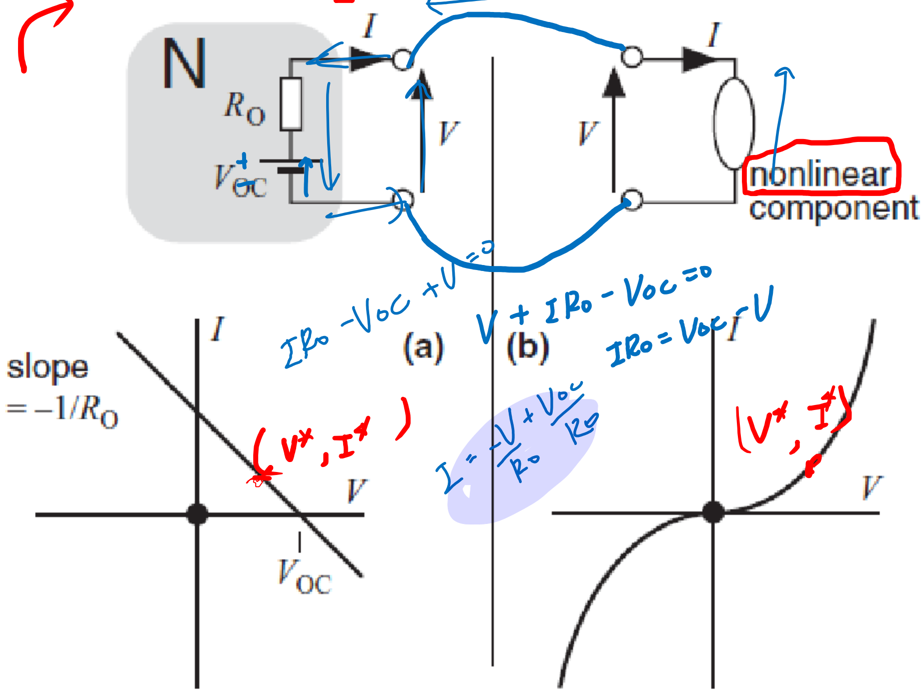


Figure 5.12 Separation of the linear and nonlinear parts of the circuit in Figure 5.11, and their characterization by current~voltage plots

$\boxed{\text{Load-line}}$ construction

Solve $\quad -\dfrac{V}{R_o} + \dfrac{V_{oc}}{R_o} = f(V)$

$\Rightarrow V^*, \ I^*$

Load-Line

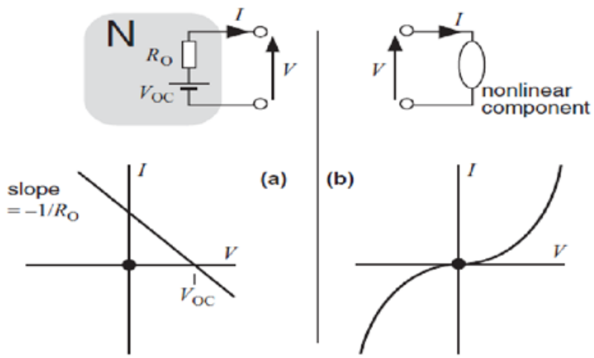
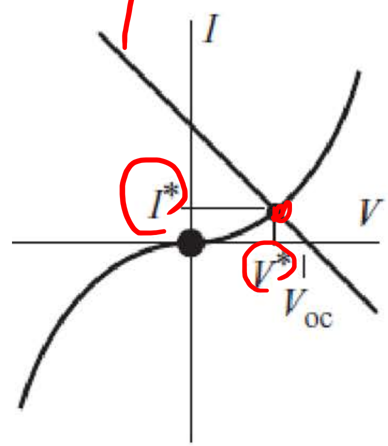


Figure 5.12 Separation of the linear and nonlinear parts of the circuit in Figure 5.11, and their characterization by current~voltage plots



$\rightarrow \quad I = -\dfrac{V}{R_o} + \dfrac{V_{oc}}{R_o}$

Figure 5.13 The point I, V must lie on both characteristics, and hence at their intersection (I^*,V^*)

Problem 5.9

Maximum Power rating = 300 mW

Find ① minimum R s.t. $VI \leq 300$ mW

② Power dissip. in R = ?

$V = IR$

R↓ |I|↑ $P = |IV|$ ↑

R↑ |I|↓ $P = |IV|$ ↓

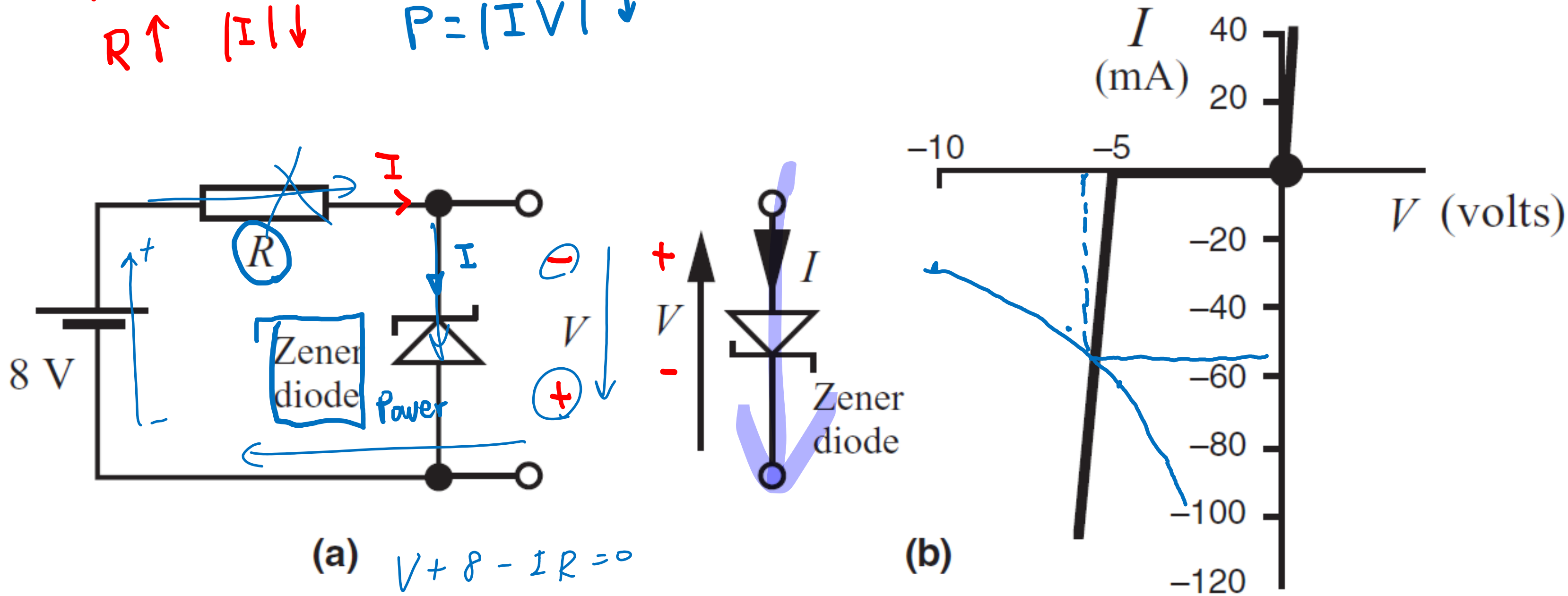


Figure P5.9

Problem 5.9

$P = VI \leq 300\ mW$

$V^* \cong -5.5V$

$I^* \cong -50mA$

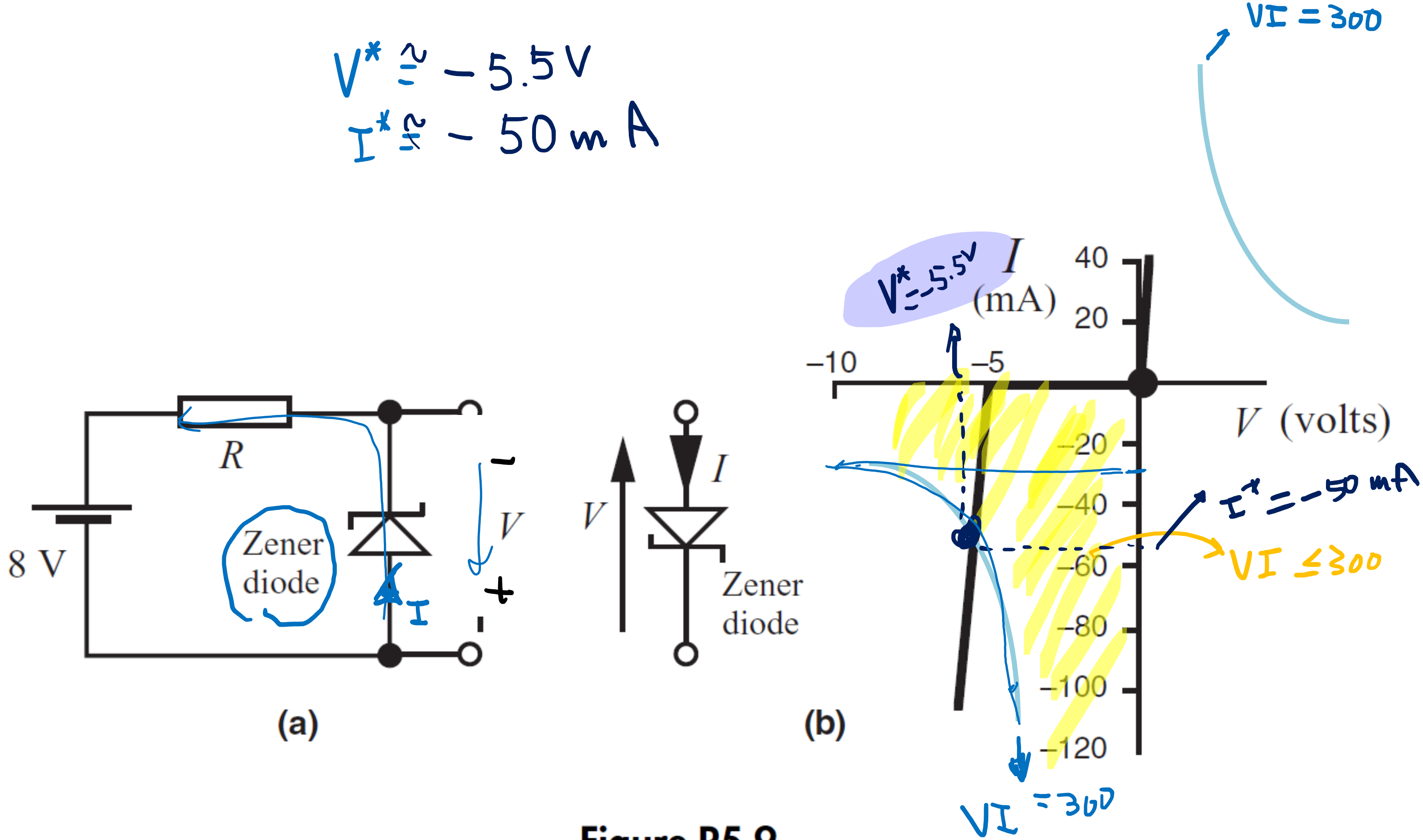


Figure P5.9

Problem 5.9

$V^* = -5.5\,V$

$I^* = -500\,mA \Rightarrow R = ?$

KVL : $8 + IR + V = 0 \Rightarrow I = -\frac{V}{R} - \frac{8}{R}$

$I^*, V^* \Rightarrow R_{min} = 50\,\Omega$

$8 + (-50)R - 5.5V = 0$

$2.5 = 50\times10^{-3}R$

$R = \frac{2.5}{0.05} = 50\,\Omega$

$V + 8 + IR = 0$

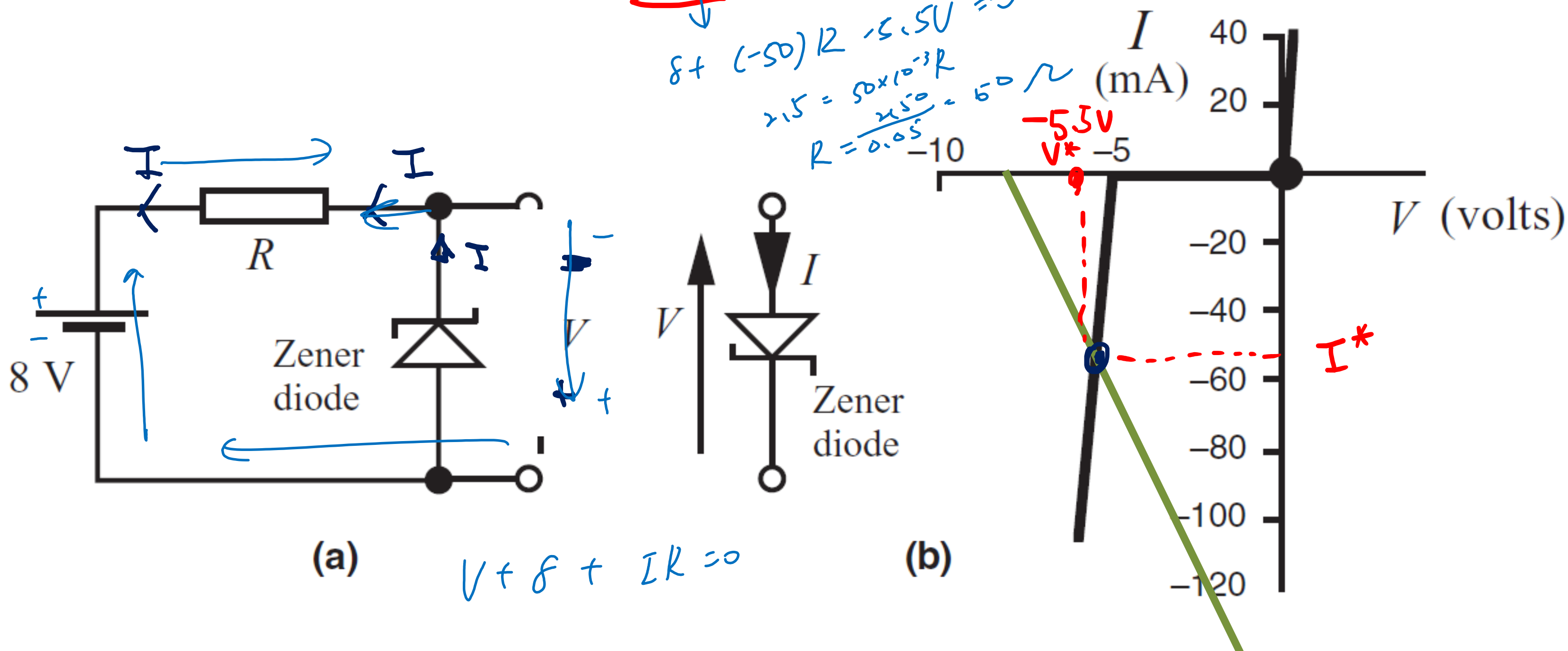


Figure P5.9

Problem 5.9

Power dissipated on $R = 50\,\Omega$

$I^* \hat{=} -50\,\text{mA}$

$P_R = I^{*2} R$

$= (-50)^2 \cdot 50$

$= 125\ \text{mW}$

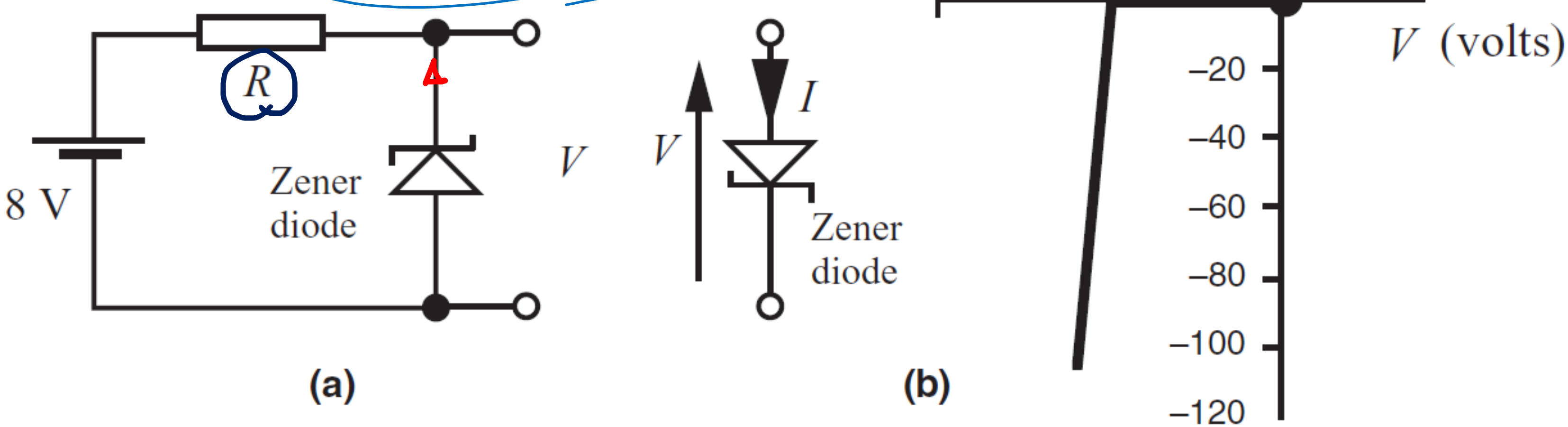


Figure P5.9

Example: transistor

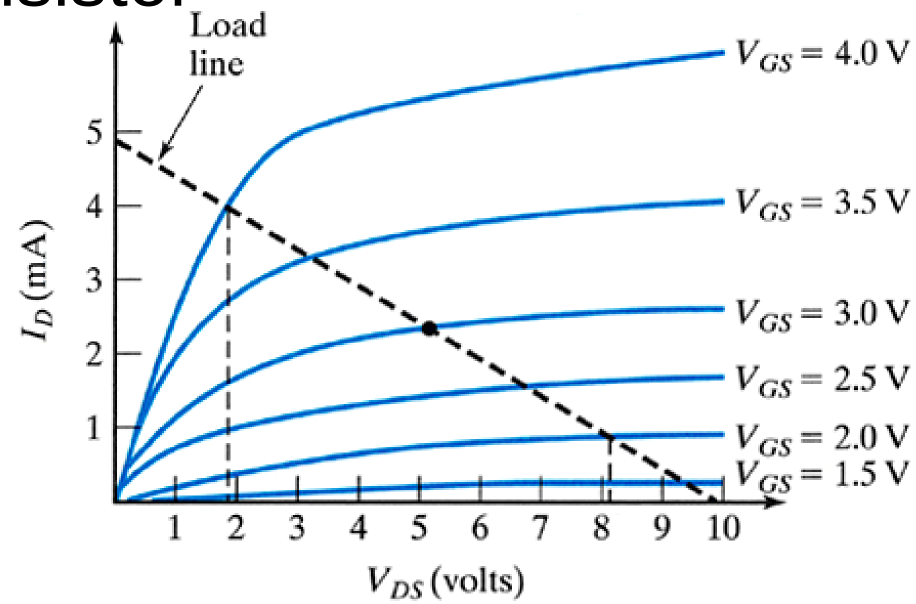
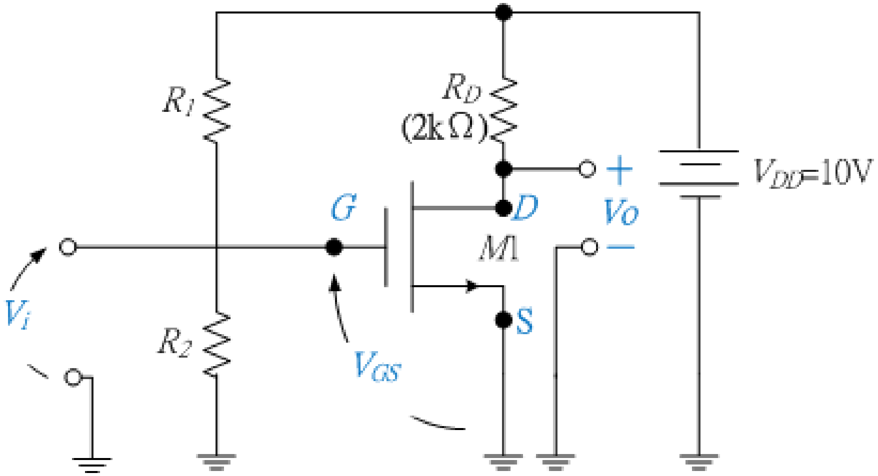


FIGURE 11.22 Enhancement-mode MOSFET transistor output characteristics.



Quiz 4

The circuit of Fig. 1 contains a Zener diode (as in Fig. 2). A good approximation to its *I-V* relation is shown in Fig.3. The maximum power that can be absorbed by the diode and dissipated as heat is 250 mW.

1. Calculate the minimum value of *R* that will keep the Zener diode in operation.
2. Calculate the power dissipated by the resister *R*.

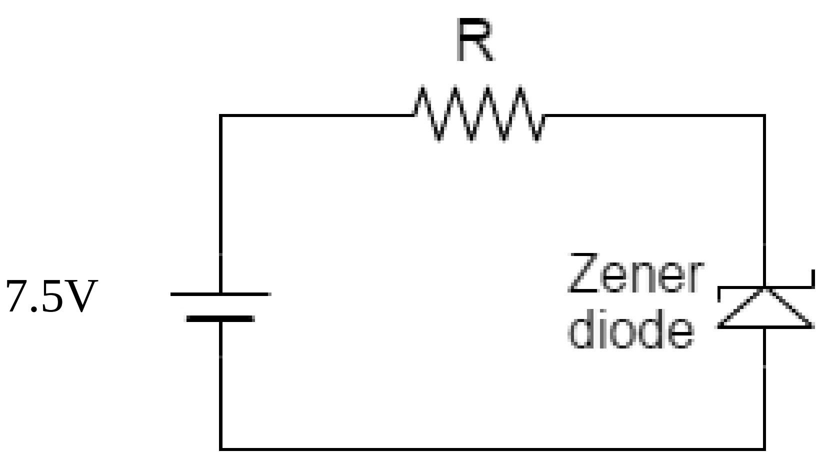


Fig. 1

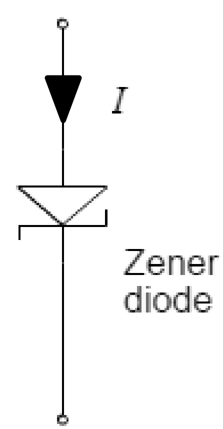


Fig. 2

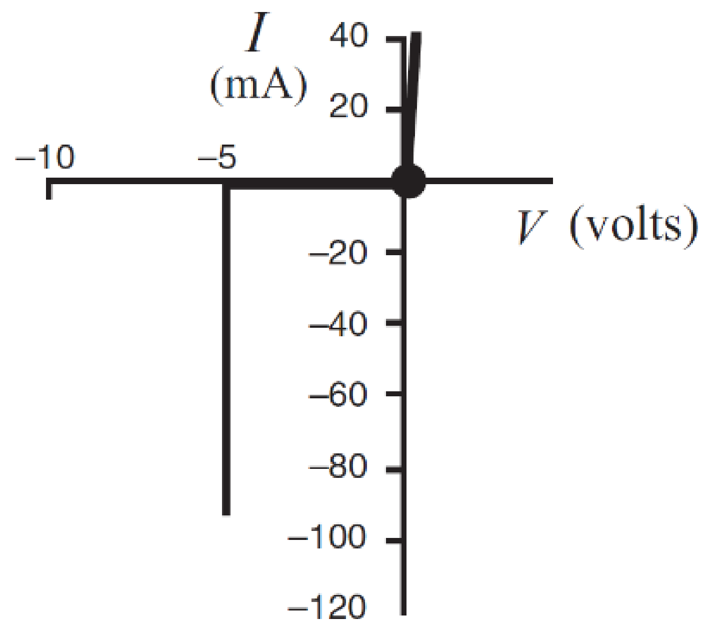


Fig. 3

Quiz Review

$P_{max} = 250\ mW$

$VI \leq 250$

$V^* = -5V$

$I^* = -50\ mA$

KVL

$7.5 + I^* R + V^* = 0$

$\Rightarrow R = 50\ \Omega$

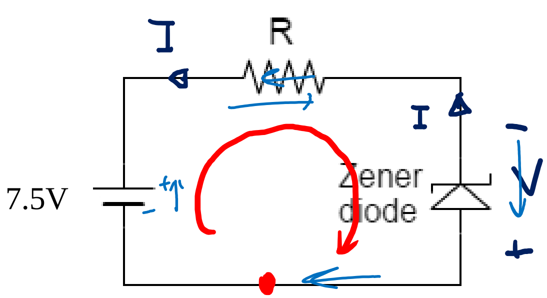


Fig. 1

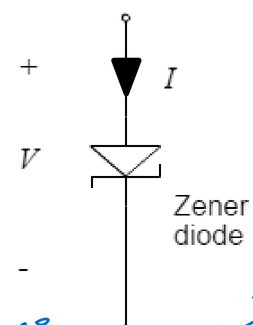


Fig. 2

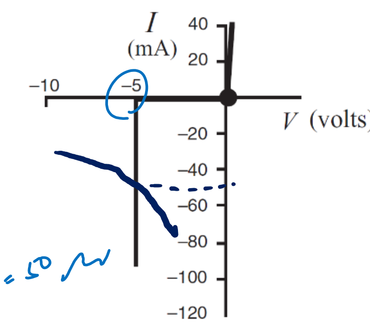


Fig. 3

$7.5 + IR + V = 0$

-5

-50

$IR = -2.5$

$R = \frac{2.5}{0.05} = 50\ \Omega$

Quiz Review

Power on R

$$P_R = I^2 R$$

$$= (-50\ mA)^2 \times 50$$

$$= 125\ mW$$

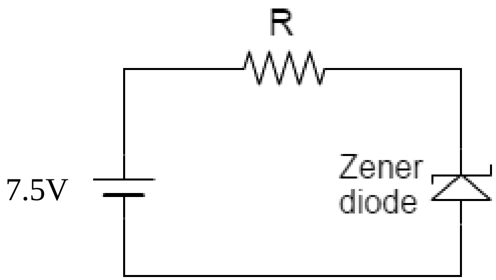


Fig. 1

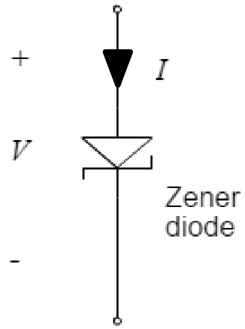


Fig. 2

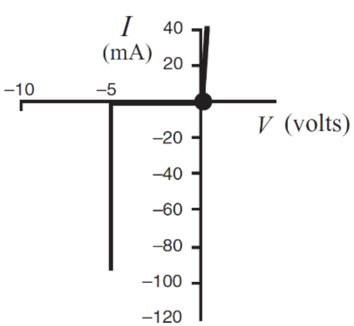


Fig. 3

Example: transistor

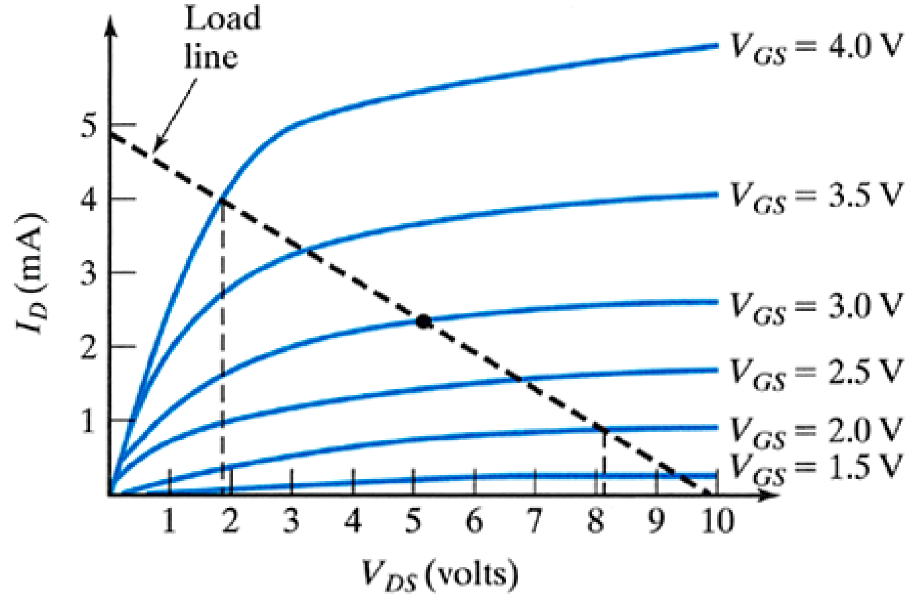


FIGURE 11.22 Enhancement-mode MOSFET transistor output characteristics.