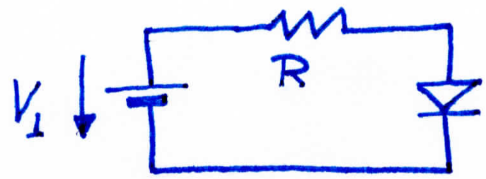
ITE – Homework 04 – Solution

Problem 01

DC voltage source 2.0V

$R = 1\,k\Omega$ Si-diode

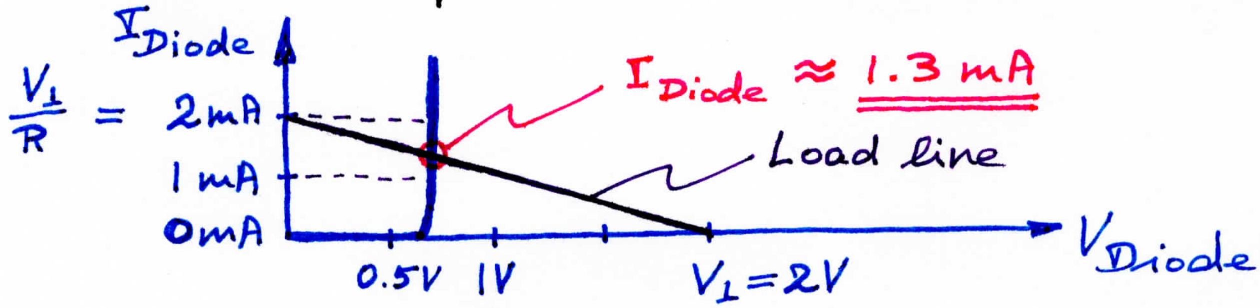
(a)



$$V_{Diode} = V_1 - RI$$

$$\Rightarrow I = \underbrace{\frac{V_1 - V_{Diode}}{R}}_{\text{Load line}}$$

Quantitative plot



(b) Diode is forward biased $\Rightarrow V_{Diode} = 0.7V$

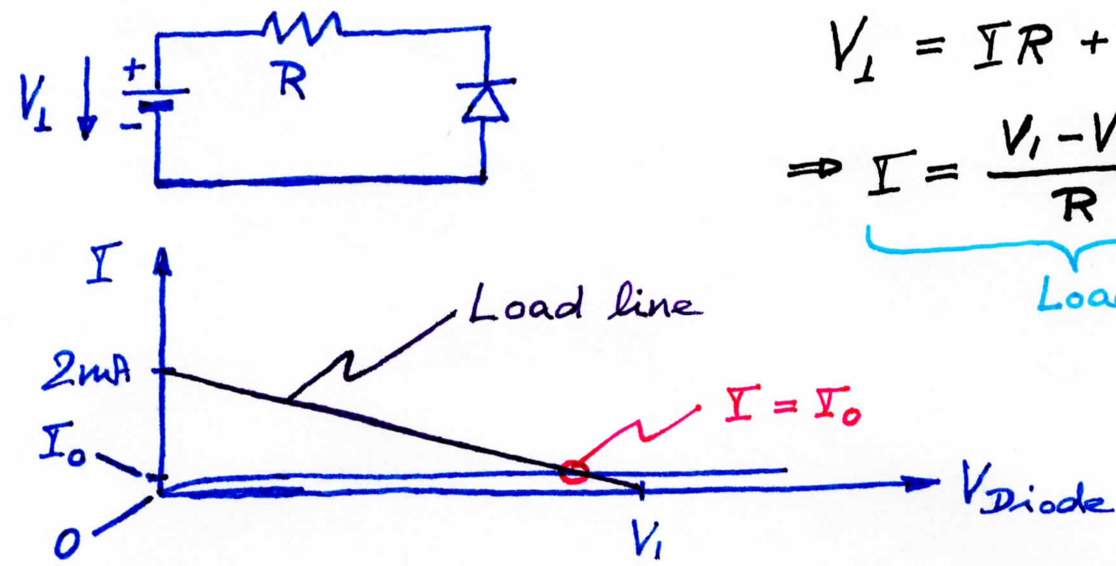
$$\Rightarrow \underbrace{V_1}_{2V} = IR + 0.7V$$

$$\Rightarrow IR = 2.0V - 0.7V = 1.3V \Rightarrow I = \frac{1.3V}{R} = \frac{1.3V}{1k\Omega}$$

$$= 1.3\,mA$$

Graphical solution ($\sim 1.3\,mA$) and analytic solution are in good agreement.

(c) Reverse polarity of diode



$$V_1 = IR + V_{Diode}$$

$$\Rightarrow I = \underbrace{\frac{V_1 - V_{Diode}}{R}}_{\text{Load line}}$$

$\Rightarrow$ Diode current is $I_0 = 1.0\,nA$

(d) Diode current is reverse saturation current $\Rightarrow$ 1 nA. Voltage drop across resistor: $V_R = IR = 1nA \times 1k\Omega = 1\,\mu V$

$\Rightarrow V_R$ can be neglected.

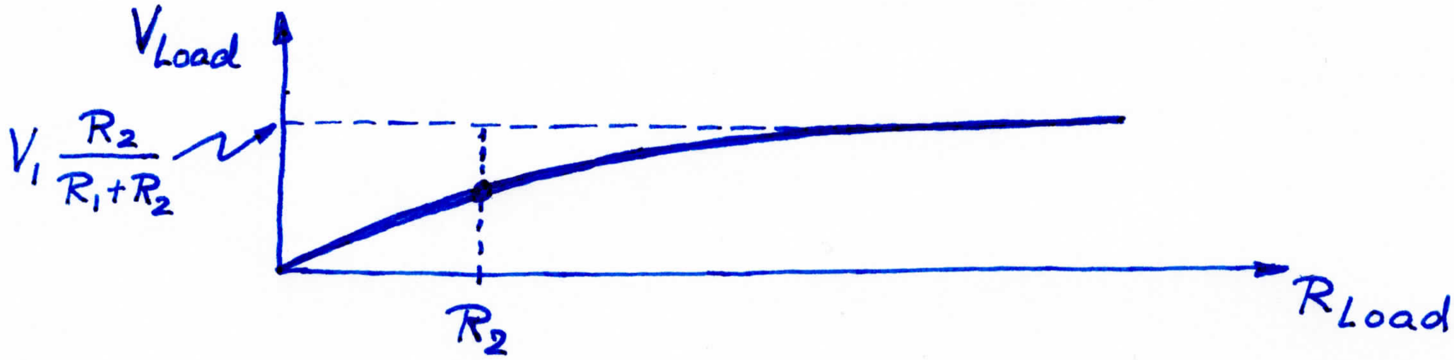
A reversely biased diode carries the reverse saturation current $\Rightarrow I_0 = 1nA$

$\Rightarrow$ Good agreement between graphical and analytic solution.

Problem 2 : Voltage divider circuit

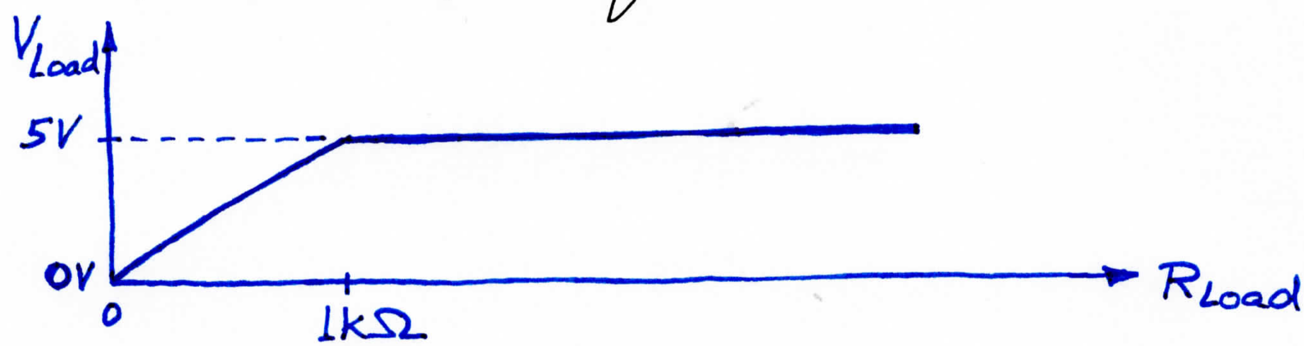
(a) Completion of diagram

$$V_{Load} = V_1 \frac{R_2 \parallel R_{Load}}{R_1 + (R_2 \parallel R_{Load})}$$



(b) We learn that the condition $R_{Load} \gg R_2$ must be satisfied for the voltage divider to work as intended

(c) Completion of diagram



⇒ Zener diode provides better voltage sabilization than voltage divider. R_{Load} must not be too small. Here R_{Load} must be $> 1k\Omega$.

(e) A Zener diode generally provides better voltage stabilization than a voltage divider.

Problem 3 Power supply

(a) The Zener diode stabilizes the output voltage to V_{zener}. Any excess voltage is cut off.

(b) Major disadvantage: Lots of power will be dissipated by the Zener diode, if the voltage from the rectifier bridge exceeds the Zener voltage.

Problem 4 Diode circuit

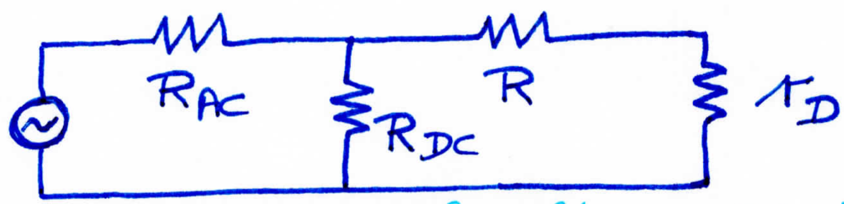
(a) Si-diode voltage $= 0.7\,V$

Si-diode current

$$V_{DC} = IR_{DC} + IR + \underbrace{V_{Diode}}_{\to\,0.7V} \qquad \text{(KVL)}$$

$$\Rightarrow I = \frac{V_{DC} - V_{Diode}}{R_{DC} + R} = \frac{5V - 0.7V}{100\Omega + 1k\Omega} = \underline{\underline{3.91\,mA}}$$

(b) AC equivalent circuit



Thermal voltage $= 26\,mV$

$$r_D = \frac{V_t}{I_{Diode}} = \frac{26\,mV}{3.91\,mA} = \underline{\underline{6.65\,\Omega}}$$

(c) Total resistance of circuit

$$R_{total} = \underbrace{R_{AC}}_{100\Omega} + \big(\underbrace{R_{DC}}_{100\Omega} \;||\; \underbrace{(R + r_D)}_{1006.65\Omega}\big)$$

$$= 100\Omega + 90.96\Omega = 191\,\Omega$$

AC current

$$I_{RAC} = \frac{V_{AC}}{R_{total}} = \frac{10\,mV}{191\,\Omega} = 52.4\,\mu A$$

Voltage at LHS of R:

$$V = V_{AC} - I R_{AC} = 10\,mV - 100\,\Omega \times 52.4\,\mu A$$

$$= 10\,mV - 5.24\,mV = 4.76\,mV$$

AC current through R

$$I = \frac{V}{R + r_D} = \frac{4.76\,mV}{1006.65\,\Omega} = 4.73\,\mu A$$

AC current through diode

$$I_{Diode} = \underline{\underline{4.73\,\mu A}}$$

AC voltage across diode

$$V_{Diode} = r_D \underbrace{I_{Diode}}_{\to AC} = 6.65\,\Omega \times 4.73\,\mu A$$

$$= \underline{\underline{31.4\,\mu V}}$$

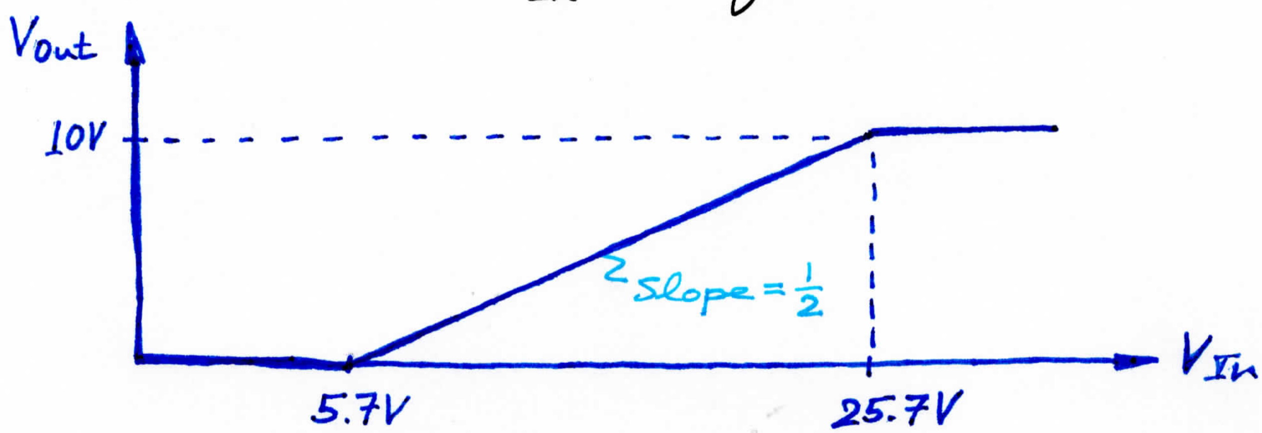
⇒ Voltage is small, since diode is biased in forward direction.

Problem 5 Zener diode circuit

(a) **Threshold voltage** is voltage at which diode becomes conductive when biased in forward direction $\Rightarrow V_{th} = 0.7V$.

Zener voltage is voltage at which a Zener diode becomes conductive when biased in reverse direction. Example: $V_{zener} = 5V$.

(b) V_{out} - versus - V_{In} diagram



(c) For $V_{In} < 5.7V \Rightarrow$ No current $\Rightarrow V_{out} = 0$

For $5.7V < V_{In} < 25.7V \Rightarrow V_{out} = \frac{1}{2}(V_{In} - 5.7V)$ due to voltage divider circuit

For $V_{In} > 25.7V \Rightarrow V_{out} = 10V$ due to the two Zener diodes

(d) $V_{In} = 10V$

$\Rightarrow$ Voltage across resistors $= 10V - 5V - 0.7V$

$= 4.3V \Rightarrow \underline{\underline{V_{Out}}} = \frac{1}{2} 4.3V = \underline{\underline{2.15V}}$

Current through R_1

$I_{R1} = \frac{V}{R} = \frac{4.3V}{2k\Omega} = \underline{\underline{2.15\,mA}}$

(e) $V_{In} = 30V$

$\Rightarrow \underline{\underline{V_{Out} = 10V}}$ due to Zener diodes

Voltage drop across $R_1 = 30V - 5V - 0.7V - 10V$

$= \underline{\underline{14.3V}}$

$\Rightarrow I_{R1} = \frac{14.3V}{1k\Omega} = \underline{\underline{14.3\,mA}}$