

# 5.1 Semiconductors and diode models

Name: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_ Total: 22 marks

**KEY WORDS** ideal model • constant-drop model  
• exponential model • zener diode

## Objective

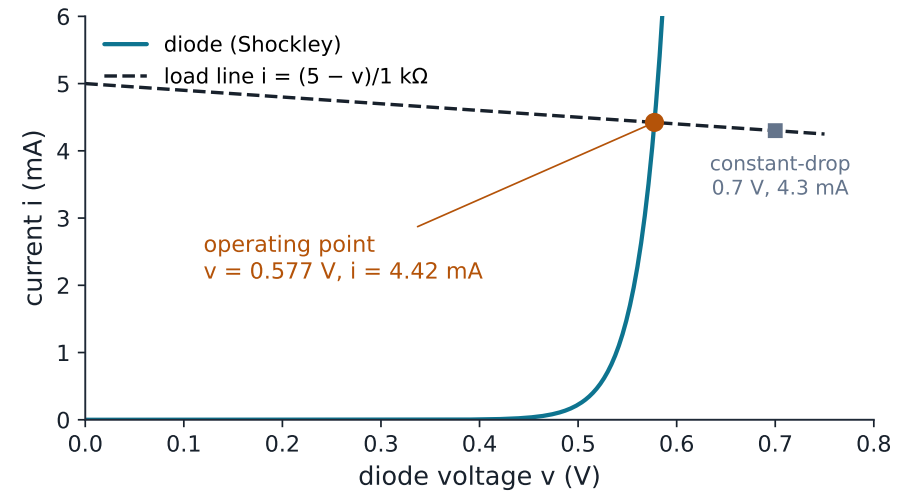
Choose among the diode's model ladder by the question, solve diode circuits each way, and quantify the model error against the exponential law.

## 1 Key knowledge and worked examples

### ■ The model ladder

- **Ideal** : 0 V forward, open reverse – for logic-level reasoning.
- **Constant-drop** : 0.7 V forward – the default for bias arithmetic.
- **Piecewise-linear** : 0.7 V + slope  $r_d = nV_T/I$  – when the load is light and the drop's variation matters.
- **Exponential** Shockley  $i = I_S(e^{v/nV_T} - 1)$ ,  $V_T = 26mV$  – when accuracy is the point.

Rule of thumb: each extra 60 mV multiplies forward current tenfold – the drop barely moves once conducting.



*The load line fixes the current; the steep diode curve barely moves the voltage.*

### ■ Worked example: one circuit, three models, one truth

5 V source, diode, 1 k $\Omega$ . Ideal: 5 mA. Constant-drop: 4.3 mA. Shockley ( $I_S = 10^{-12} \text{ A}$ ): bisection on  $I_S(e^{v/26m} - 1) = (5 - v)/1000$  gives  $v = 0.578 \text{ V}$ ,  $i = 4.42 \text{ mA}$ . The constant-drop error is 2.8% – the resistor dominates the loop, which is precisely when that model earns its keep.

### ■ The on/off discipline

Assume a diode state, solve, CHECK: forward-assumed needs  $i > 0$  and (for the drop models)  $v_{source} > 0.7 \text{ V}$  available; reverse-assumed needs the actual reverse voltage below breakdown. A wrong assumption shows up as an impossible current or voltage – that is the method working, not failing.

## 2 Practice

**2.1** A 9 V source, a diode (constant-drop) and 2 k $\Omega$  in series: give the current. Repeat with the ideal model. [2]

**2.2** Two diodes in series (0.7 V each) with a 3.3 k $\Omega$  resistor across 10 V: current, and the resistor's voltage. [2]

**2.3** A 3 V source with a diode and a 100  $\Omega$  resistor: compute the current by constant-drop AND solve the Shockley equation by bisection ( $I_S = 1pA$ ); state which model is misleading here and why. [4]

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**3 Exam-style questions**

**3.1** A zener regulator:  $V_{in} = 15V$ , series  $R = 470\Omega$ , zener  $V_Z = 9V$ , load  $R_L = 1.8k\Omega$  (zener  $I_Z(min) = 2mA$  for regulation).

Compute the zener current and verify regulation holds. Then find the load resistance at which regulation just ceases, and the zener power at the load removed entirely ( $R_L \rightarrow \infty$ ). State the safe-operating conclusion. [7]

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**3.2** A clipper: two anti-series zeners (each  $V_Z = 5.1V$ , forward drop 0.7 V) across the output of a source with 1 k $\Omega$  series resistance.

State the clipped output levels for a  $\pm 12$  V triangular input (compute the conducting path's total drop). Then sketch/describe the output for one full triangle period, and compute the current through the clipping path at the +12 V peak. Verify the zener pair's power at the peak is within 400 mW each. [7]

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