

5.1 Semiconductors and diode models

Name: _____ Class: _____ Date: _____

Total: 22 marks

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

Objective

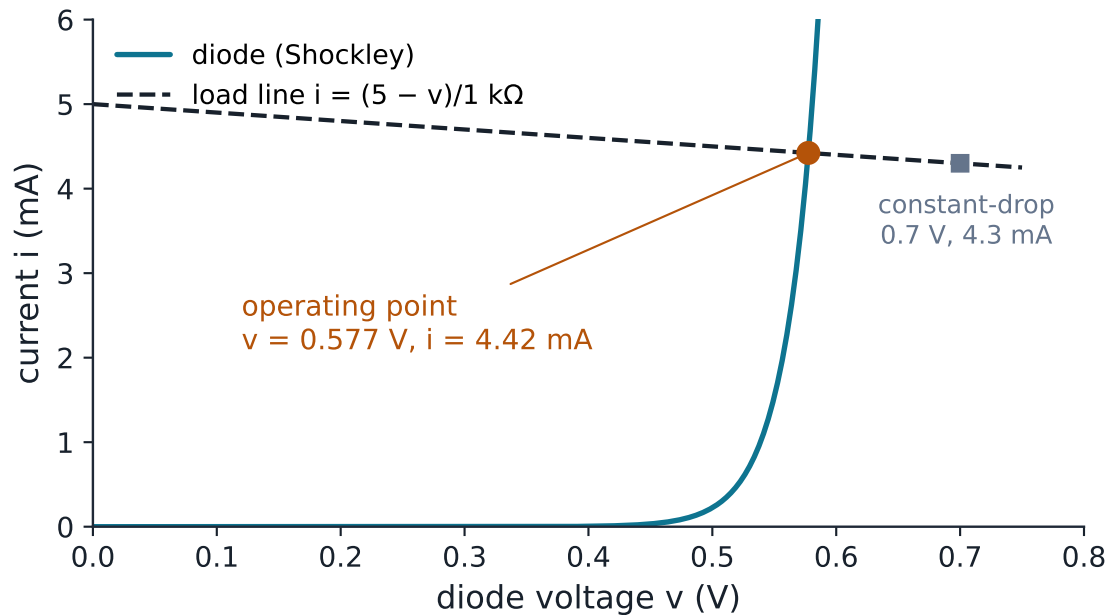
Choose among the diode's model ladder by the question, solve diode circuits each way, and quantify the model error against the exponential law.

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 Ω . 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) $v_{\text{source}} > 0.7 \text{ V}$ 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 Ω 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 Ω 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 ($I_S = 1\text{pA}$); state which model is misleading here and why. [4]

3 Exam-style questions

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

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]
