Unit 22 · Semiconductor Devices

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 32

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Spot the error

ANSWER U · 3

That is a **NAND** table (0 only when both inputs are 1). For NOR, $Y = \overline{A + B}$: A + B is 1 whenever either input is 1, so Y is **1, 0, 0, 0** (1 only when both inputs are 0).

MARKING SCHEME

- ✓ The error: her table is the NAND gate's.
- ✓ $Y = \overline{A + B}$.
- ✓ The NOR table 1, 0, 0, 0.

2 Read the data

ANSWER A · 4

(The readings are made up, in the way a silicon diode behaves.)

i. About **0.6–0.7 V**, where the current starts to rise steeply.

ii. $0.6 \div 0.001 = \mathbf{600}\ \Omega$; $0.75 \div 0.030 = \mathbf{25}\ \Omega$.

iii. Its V/I falls steeply as the voltage rises: the graph is a curve, not a straight line, so it doesn't obey Ohm's law.

iv. Far above the knee the current would be very large, and the diode would overheat and be damaged: a resistor must be put in series to limit the current.

MARKING SCHEME

- ✓ Knee about 0.6–0.7 V.
- ✓ 600 Ω and 25 Ω.
- ✓ Its resistance changes with voltage (non-ohmic).
- ✓ 2 V straight across: a huge current, the diode is damaged.

3 Predict, then explain

MARKING SCHEME U · 3

- ✓ Turned round: humps below the axis.
- ✓ With the capacitor: nearly steady with a ripple.
- ✓ Explained: it conducts in the other half cycles; the capacitor charges and discharges.

4 Show that

MARKING SCHEME A · 3

- ✓ Joined NAND: $\overline{A \cdot A} = \overline{A}$, with its table.
- ✓ The last gate's output $\overline{A \cdot B}$.
- ✓ Its table 0, 1, 1, 1 = OR.

5 A real setting

MARKING SCHEME A · 3

- ✓ Transformer steps down; rectifier makes pulsating d.c.
- ✓ Capacitor smooths; regulator holds 5 V steady.
- ✓ Peak ≈ 12.7 V.

6 Which explanation fits?

MARKING SCHEME U · 2

- ✓ Suman.
- ✓ Minority carriers are made at a fixed rate and are all swept across already.

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7 Correct the misconceptions

ANSWER U · 3

1. An n-type semiconductor is **neutral**: each free electron comes from a donor atom that is left as a positive ion.
2. In forward bias the depletion layer becomes **thinner**; it widens in reverse bias.
3. Without a capacitor the output is **pulsating** d.c., rising and falling in humps.

MARKING SCHEME

- ✓ n-type is neutral (donor ions balance the electrons).
- ✓ Forward bias thins the layer.
- ✓ The output is pulsating d.c.

8 Work backwards

MARKING SCHEME A · 3

- ✓ $Y = A \cdot \overline{B}$.
- ✓ NOT on B, then AND with A.
- ✓ The new table 1, 1, 0, 1.

9 Design it

ANSWER A · 4

i. The resistor carries $20 + 10 = 30$ mA with $12 - 6.2 = 5.8$ V across it: $R = 5.8 \div 0.030 \approx$ **190** Ω.

ii. $P = VI = 5.8 \times 0.030 \approx$ **0.17 W**.

iii. At 8.0 V the resistor can pass at most $(8.0 - 6.2) \div 193 =$ **9.3 mA**, less than the 20 mA the load needs: the voltage falls below 6.2 V and the Zener stops conducting, so it no longer regulates.

MARKING SCHEME

- ✓ Current through R = 30 mA.
- ✓ R ≈ 190 Ω.
- ✓ P ≈ 0.17 W.
- ✓ At 8.0 V only 9.3 mA is available, less than the load needs: regulation fails.

10 What if?

ANSWER HA · 2

The reverse current **rises**. It is carried by minority carriers, which are made by heat; a warmer crystal breaks more bonds, making more of them each second to be swept across.

MARKING SCHEME

- ✓ The reverse current rises.
- ✓ More minority carriers are made by heat.

11 Make your own

ANSWER HA · 2

For example: “A 5.1 V Zener is joined across a 510 Ω load, with a 100 Ω resistor in series with a 7.6 V supply. Find the Zener current.” $I_R = (7.6 - 5.1) \div 100 = 25$ mA, $I_L = 5.1 \div 510 = 10$ mA, so $I_Z = 15$ mA. Any numbers giving 15 mA are right.

MARKING SCHEME

- ✓ A sensible regulator problem.
- ✓ Solved correctly to 15 mA ($I_Z = I_R - I_L$).

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See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **Solar House Model** (exhibit): Its solar cells are diodes too: light falling on each p–n junction makes a current, which runs the house and charges its battery.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	11	17	4	**32**

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