Unit 22 · Semiconductor Devices

ANSWER KEY · FOR TEACHERS

Full marks 33

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

1 Key words

1. depletion layer → **f.** the region at a p–n junction with no free carriers, only fixed ions — K · 3
2. barrier potential → **e.** the p.d. across the depletion layer, about 0.7 V for silicon
3. forward bias → **g.** the p side joined to the positive terminal, so the layer thins
4. Zener diode → **b.** a heavily doped diode made to work in reverse breakdown
5. rectifier → **a.** a circuit that turns a.c. into d.c.
6. universal gate → **c.** a gate from which every other gate can be built

Each carries 0.5 mark.

2 Label the graph

1. breakdown VB= 25 V — K · 2
2. reverse
3. forward
4. knee

Each carries 0.5 mark.

3 Multiple choice

i. **c.** 100 — U · 1

A full-wave rectifier gives a hump in every half cycle: $2 \times 50 = 100$ a second.

ii. **b.** 4.3 mA — A · 1

0.7 V is across the diode, so $5.0 - 0.7 = 4.3$ V is across the resistor: $I = 4.3\ V \div 1.0\ k\Omega = 4.3$ mA.

iii. **c.** both inputs are 0 — K · 1

$Y = \overline{A + B}$: A + B is 0 only when both are 0, so Y is 1 only then.

iv. **a.** becomes wider and the barrier higher — U · 1

The battery pulls the holes and electrons away from the junction, uncovering more fixed ions: the layer widens and the barrier rises.

v. **b.** an AND gate — U · 1

NOT undoes the NAND's bar: $\overline{A \cdot B} = A \cdot B$, an AND gate.

4 Short answers

a. MARKING SCHEME — U · 2

- ✓ The barrier potential (about 0.7 V) opposes the majority carriers.
- ✓ Only above the knee voltage is it overcome, so the current rises.

b. MARKING SCHEME — U · 2

- ✓ The output is pulsating d.c.
- ✓ The capacitor charges at each peak and discharges between them, smoothing it.

c. MARKING SCHEME — U · 2

- ✓ In reverse breakdown its voltage stays at V_Z whatever the current.
- ✓ Changes in input go to the resistor and Zener current, so the load stays at V_Z.

5 Long answer

ANSWER

The transformer's secondary feeds two opposite corners of a bridge of four diodes; the load joins the other two corners. In one half cycle, one end of the secondary is positive: two of the diodes, on

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opposite sides of the bridge, are forward biased and conduct, and the current goes through the load from one corner to the other. In the next half cycle the other end is positive: the other two diodes conduct, and the current goes through the load in the same direction as before. So the load gets a hump in every half cycle, all in one direction: full-wave pulsating d.c. The sketch: a sine wave in; the same humps, all on one side, out. U · 4

MARKING SCHEME

- ✓ A diagram: four diodes in a bridge, a.c. on one diagonal, the load on the other.
- ✓ In one half cycle two opposite diodes conduct.
- ✓ In the other half the other two conduct, sending current the same way through the load.
- ✓ Sketch: sine in, all humps one way out (full wave).

6 Numerical problems

a. **ANSWER** A · 4

i. The resistor has $12 - 5.1 = 6.9$ V across it: $I_R = 6.9 \div 230 =$ **30 mA**.
ii. $I_L = 5.1 \div 1000 =$ **5.1 mA**.
iii. $I_Z = 30 - 5.1 =$ **24.9 mA**.
iv. $I_R = (15 - 5.1) \div 230 = 43$ mA, so $I_Z = 43 - 5.1 \approx$ **38 mA**; the load still has 5.1 V and 5.1 mA.

MARKING SCHEME

- ✓ $I_R = 30$ mA.
- ✓ $I_L = 5.1$ mA.
- ✓ $I_Z = 24.9$ mA.
- ✓ About 38 mA at 15 V (the load's current unchanged).

b. **ANSWER** A · 3

The resistor has $6.0 - 0.7 = 5.3$ V: $I = 5.3 \div 470 =$ **11 mA**. $P = I^2R = 0.0113^2 \times 470 =$ **0.060 W**.
Turned round, the diode is reverse biased: only a tiny reverse current of a few μA flows, **almost none**.

MARKING SCHEME

- ✓ I = 11 mA.
- ✓ P = 0.060 W.
- ✓ Reversed: almost no current (reverse biased).

c. **ANSWER** A · 3

rms: $230 \div 20 =$ **11.5 V**; peak: $\sqrt{2} \times 11.5 =$ **16.3 V**. Full wave: $2 \times 50 =$ **100 humps a second**.

MARKING SCHEME

- ✓ 11.5 V rms.
- ✓ 16.3 V peak.
- ✓ 100 a second.

7 Think

ANSWER HA · 3

Y = (A + B) · C: an OR gate for A and B, its output and C into an AND gate. Y = 1 for (A, B, C) = (1, 0, 1), (0, 1, 1) and (1, 1, 1); every other row gives 0.

MARKING SCHEME

- ✓ Y = (A + B) · C.
- ✓ An OR gate feeding an AND gate with C.
- ✓ The three rows 101, 011, 111.

8 Activity: A diode's forward characteristic

(not marked)

WHAT STUDENTS SHOULD FIND

Almost no current until about 0.5–0.6 V, then a steep rise: the knee is near 0.7 V. The graph curves, so the diode does not obey Ohm's law: its resistance (V/I) is large below the knee and small above it. (The resistor in series protects the diode from too large a current.)

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- **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	6	13	11	3	**33**

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