HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 26

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

n = 1 is the **ground state**; the first excited state is **n = 2**, at $-13.6/2^2 = -3.40$ eV. So **3.40 eV** frees it.

MARKING SCHEME

- ✓ The error: n = 1 is the ground state.
- ✓ The first excited state is n = 2, −3.40 eV.
- ✓ 3.40 eV is needed.

2 Work backwards

ANSWER A · 3

$E = hc/\lambda = 6.63 \times 10^{-34} \times 3.0 \times 10^{8} \div 700 \times 10^{-9} = 2.84 \times 10^{-19}$ J = **1.78 eV**. Yes: 520 nm is shorter, so its photons have more energy (2.4 eV) than the gap.

MARKING SCHEME

- ✓ $E = hc/\lambda$.
- ✓ 1.78 eV.
- ✓ Yes, shorter wavelengths carry more energy than the gap.

3 Check the readings

ANSWER HA · 3

$E_n = -13.6/n^2$: for n = 4, $-13.6/16$ = **−0.85 eV**, not −0.95 (the others fit). Falling to level 2 gives a photon of 3.40 − 0.85 = **2.55 eV**.

MARKING SCHEME

- ✓ Each checked against $-13.6/n^2$.
- ✓ n = 4 should be −0.85 eV.
- ✓ Photon 2.55 eV.

4 Least and most

ANSWER HA · 3

i. $3 \rightarrow 2$: 1.51 → 3.40, **1.89 eV**; $2 \rightarrow 1$: **10.2 eV**; $3 \rightarrow 1$: **12.09 eV**. Three lines in all.

ii. The smallest energy, **1.89 eV** ($3 \rightarrow 2$): $\lambda = hc/E = 6.63 \times 10^{-34} \times 3.0 \times 10^{8} \div (1.89 \times 1.6 \times 10^{-19}) =$ **6.6×10^{-7} m**, red light.

MARKING SCHEME

- ✓ The three energies 1.89, 10.2 and 12.09 eV.
- ✓ The longest wavelength is the smallest energy.
- ✓ 660 nm (red).

5 Estimate it

ANSWER A · 2

1 $cm^3 = 10^{-6}$ m^3, so about $10^{16} \times 10^{-6} =$ **10^{10}** free electrons, each from a broken bond. The fraction is $10^{16} \div 10^{29} =$ **10^{-13}**: one bond in ten million million.

MARKING SCHEME

- ✓ About 10^{10} broken bonds in 1 cm^3.
- ✓ A fraction of about 10^{-13}.

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6 Predict, then explain

ANSWER HA · 3

Turned round: the lamp goes **out**. The diode is then reverse biased, its depletion layer widens, and only a tiny current of minority carriers flows. With a 0.5 V cell the lamp also stays **out**: 0.5 V is less than silicon's barrier potential of about 0.7 V, so even forward biased the diode doesn't conduct properly.

MARKING SCHEME

- ✓ Battery turned round: lamp out, the diode reverse biased (depletion layer widens).
- ✓ 0.5 V: lamp out.
- ✓ Below the 0.7 V barrier potential, almost no current flows.

7 Which explanation?

ANSWER HA · 2

Binita. Warm atoms vibrate **more**, which on its own would raise the resistance, as it does in a metal. But warming gives far more electrons enough energy to cross the gap, each also making a hole; the rise in carriers far outweighs the extra scattering.

MARKING SCHEME

- ✓ Binita: more electrons cross the gap (and leave holes).
- ✓ The atoms vibrate more, not less; the extra carriers outweigh the scattering.

8 Correct the misconceptions

ANSWER U · 3

1. p-type silicon is **neutral**: each hole comes from an acceptor atom, left as a negative ion. “p” names the majority carriers.
2. An insulator's gap is wide, **5 to 10 eV**; about 1 eV is a **semiconductor's**.
3. The levels are **discrete**: the electron can be at −13.6 or −3.40 eV, but at nothing in between.

MARKING SCHEME

- ✓ p-type is neutral overall.
- ✓ Insulators' gaps are 5–10 eV; 1 eV is a semiconductor.
- ✓ Hydrogen's energies are discrete.

9 Think

ANSWER HA · 2

A photon frees an electron only if its energy is at least the gap. Red light's photons (about 1.8 eV) have more than silicon's 1.12 eV but less than cadmium sulphide's 2.4 eV, so they lift silicon's electrons across but not cadmium sulphide's. Silicon's gap is crossed by every visible photon, down to about 1100 nm in the infrared.

MARKING SCHEME

- ✓ A photon must have at least the band gap's energy.
- ✓ Red photons (about 1.8 eV) exceed 1.12 eV but not 2.4 eV.

10 Make your own

ANSWER HA · 2

For example indium, one atom in 10^9: trivalent, so **p-type**; $5 \times 10^{28} \div 10^9 = \mathbf{5 \times 10^{19}}$ **holes per m^3**. Any choice with the right type (pentavalent n-type, trivalent p-type) and $5 \times 10^{28} \div$ N carriers is right.

MARKING SCHEME

- ✓ The type named rightly from the impurity's valence.
- ✓ Majority carriers = $5 \times 10^{28} \div$ N per m^3.

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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.

- **Plasma Ball** (exhibit): The gas glows because atoms excited by the discharge drop back between energy levels, giving out light of definite energies; another gas would glow another color.
- **Solar House Model** (exhibit): Each solar cell is a p–n junction: light frees electrons and holes, and the field across the depletion layer drives them apart, making the house's current.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	6	5	15	**26**

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