2018 Ph H2 Q11

Section: Electricity

Topic: Sources, internal resistance, band theory of LEDs

(a) State what is meant by the electromotive force (e.m.f.).
(b) Using the V–I graph, determine the internal resistance of the potato battery.
(c) Explain, using band theory, why the battery operates the red LED but not the blue LED.

Worked solution

(a)
The e.m.f. of a source is the energy supplied by the source to each coulomb of charge passing through it.

Answer: Energy per unit charge supplied by the source

(b)
From the graph of V against I: the slope = –r.
Slope = $\Delta V / \Delta I$.
From graph: (700 – 100) mV / (20 – 0) mA.
= (0.700 – 0.100) V / (0.020 A).
= 0.600 / 0.020 = 30 Ω.

Depending on precise points taken, answer around 30 Ω is acceptable.

Answer: $r \approx 30\ \Omega$

(c)
Red LED has a smaller band gap (lower photon energy). Battery provides enough voltage to overcome this gap, so electrons can cross and recombine, emitting red light.
Blue LED has a larger band gap (higher photon energy). The potato battery voltage is too small to provide the required energy. Therefore, electrons cannot be excited across the gap, and no blue light is emitted.

Answer: Band gap of blue LED too large for the battery voltage

Final answers

(a) Energy per unit charge supplied by the source

(b) Internal resistance ≈ 30 Ω

(c) Blue LED not lit: band gap too large for battery voltage

Revision tips

- e.m.f. = energy per coulomb of charge.
- From V–I graph: slope = –r, intercept = emf.
- Internal resistance causes terminal voltage to drop with current.

- LEDs emit photons when electrons fall across band gap.
- Photon energy (and colour) depends on size of band gap.