InkPhysics

ANSWER BOOK

Rectification and smoothing

Magnetic fields · Year 13

CIE 21.2.1, 21.2.2, 21.2.3, 21.2.4

19 questions · 50 marks

NAVY EDITION

SECTION A · Warm-up

A1 A diode conducts in one direction only (1). Only the half-cycles that drive current in the conducting direction pass, so the load receives humps of one polarity with gaps where the reversed half-cycles are blocked (1). [2]

A2 Half-wave: positive humps separated by flat intervals at zero, one hump per input cycle (1). Full-wave: the negative half-cycles are inverted rather than removed, giving two humps per input cycle with no flat gaps (1). [2]

A3 Disadvantage: half the input power is discarded (or the output has longer gaps, making it harder to smooth) (1). Advantage: only one diode is needed instead of four (1). [2]

A4 100 per second: full-wave rectification gives one peak every half-cycle (1). [1]

A5 Peaks arrive once per 20 ms cycle, so 20 ms apart (1); the output is zero for the blocked half-cycle, 10 ms in each cycle (1). [2]

A6 Ripple is the small periodic variation that remains in the smoothed output voltage (1); it is caused by the capacitor discharging through the load between the peaks that recharge it (1). [2]

SECTION B · Standard

B1 The diodes conduct in opposite pairs (1). In one half-cycle one pair is forward biased and steers the current through the load in a particular direction; in the other half-cycle the supply reverses and the other pair conducts (1). The current through the load is in the same direction in both half-cycles, so the output has two humps per input cycle (1). [3]

B2 Near each peak the rectified voltage charges the capacitor (1). As the rectified voltage falls, the capacitor discharges through the load, holding the output voltage up until the next peak recharges it (1). The output is therefore a nearly steady voltage with a small ripple, instead of falling to zero between humps (1). [3]

B3 $\tau = RC = 500 \times 2200 \times 10^{-6}$ (1) [2]

$\tau = 1.1$ s (1)

B4 The ripple decreases (1); a larger capacitance gives a longer time constant RC, so the capacitor voltage falls less in the fixed time between successive peaks (1). [2]

B5 The smaller resistance makes the time constant RC ten times shorter (a larger current is drawn) (1); the capacitor discharges much further between peaks, so the sag in voltage between top-ups, the ripple, is larger (1). [2]

B6 The supply period is 1/50 = 20 ms, so humps every 10 ms means one per half-cycle (1); that requires the negative half-cycles to be folded up rather than blocked, so the rectification is full-wave (half-wave would give humps 20 ms apart) (1). [2]

B7 Charge lost by the capacitor: $Q = I\Delta t = 0.060 \times 0.010 = 0.60 \times 10^{-3}$ C (1) [3]
$\Delta V = Q/C$ (1)
$\Delta V = (6.0 \times 10^{-4})/(1000 \times 10^{-6}) = 0.6$ V (1)

B8 With half-wave rectification the capacitor must supply the load for 20 ms between peaks, but only 10 ms with full-wave (1); with the same time constant RC, the voltage falls further during the longer discharge (1); so the half-wave output has the larger ripple (1). [3]

SECTION C · Stretch

C1 Full-wave rectification gives a peak every half-cycle, so every 10 ms (1) [4]
$\tau = RC = 1000 \times 470 \times 10^{-6} = 0.47$ s (1)
τ is 47 times the interval between peaks (1)
The capacitor loses only a small fraction of its charge before each top-up, so the ripple is small and the smoothing is effective (1).

C2 $V_0 = \sqrt{2} \times 12 = 17$ V (1). The smoothed trace touches each hump near its peak, then falls only slightly before the next peak recharges the capacitor (1); it stays close to 17 V, always at or above the unsmoothed curve at the same instant (1). [3]

C3 $RC = 2000 \times 100 \times 10^{-6} = 0.20$ s (1) [4]
$V/V_0 = e^{-t/RC} = e^{-0.010/0.20}$ (1)
$V/V_0 = 0.951$, so about 5% of the peak voltage is lost between top-ups (1)
The ripple is only a few per cent of the peak, so the smoothing is acceptable for most purposes (1).

C4 Full-wave rectification: the capacitor discharges for up to 10 ms between peaks (1) [5]
Time constants: RC = 0.050 s, 0.11 s and 0.235 s (1)
Fractions remaining after 10 ms: $e^{-t/RC}$ = 0.82, 0.91 and 0.96 (1)
Only the 470 μF capacitor stays above 0.95 of the peak (1)
So the 470 μF capacitor is the smallest that meets the requirement (1)

C5 In one half-cycle the conducting path through the bridge is broken, so no current reaches the load; in the other half-cycle the remaining pair still conducts (1). The output becomes half-wave rectified, with peaks 20 ms apart instead of 10 ms (1). The capacitor must supply the load for twice as long between top-ups, so the ripple of the smoothed output increases (1). [3]