Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

$W + R = 3$, not more than $N = 3$

yes: the read may go to the one replica the write missed

2.2

P1: $a = 1$, send $m = 2$, $c = 3$

P2: $b = 1$, $d = 2$

receive m: $\max(2, 2) + 1 = \mathbf{3}$

2.3

all down: $0.01^3 = 10^{-6}$

$1 - 10^{-6} = \mathbf{99.9999}\%$

2.4

the first request may have succeeded, only the reply was lost

so the retry could charge twice

the client sends the same unique key with both; the server stores done keys and returns the first result for a repeat

3.1

(a) **2**

(b) the 3 side has a majority, so it can elect a leader and commit writes; the 2 side cannot commit anything

(c) 4 nodes need a majority of 3, so they survive only 1 failure, the same as 3 nodes, with more machines to fail

(d) the leader plus 2 followers make 3 of 5: it waits for the second-fastest, **20** ms

3.2

(a) bank balance: consistency, refusing some requests, because two sides could both allow spending the same money; shopping cart: availability, merging the two versions later, since a lost sale costs more than a duplicate item

(b) replicas may disagree for a while, but when updates stop and messages get through, they all reach the same value

3.3

(a) at least one round trip: **200 ms**; in practice more, with retries and the TLS set-up

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(b) one edit silently disappears; keep both versions and ask the user, or use data types that merge (CRDTs)

(c) laws such as China's PIPL and the EU's GDPR limit moving personal data abroad, so each region's users' data may need to stay in that region, with permission or a legal basis for any transfer

(d) each user's data has a home region and is written there: writes are fast for local users, laws are respected, and cross-region sharing reads public copies; conflicts are rare because one region owns each album