Solutions

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

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

2.1

one instruction: $5 \times 200 = \mathbf{1000}$ ps

100 instructions: $(5 + 99) \times 200 = \mathbf{20\,800}$ ps

2.2

a load-use data hazard on `x1`

1 stall

2.3

structural: two instructions need the same unit in one cycle, e.g. one memory for fetch and data

control: the pipeline does not yet know which instruction to fetch after a branch

2.4

no prediction: $1 + 0.2 \times 2 = \mathbf{1.4}$

with the predictor: $1 + 0.2 \times 0.1 \times 2 = \mathbf{1.04}$

3.1

(a) 1000×1000 ps $= \mathbf{1\ \mu s}$

(b) cycle $200 + 20 = 220$ ps; $(5 + 999) \times 220 = \mathbf{220\,880}$ ps

(c) $10^6 / 220\,880 \approx \mathbf{4.53}$

(d) the latch delay makes each cycle longer; the pipeline takes 4 extra cycles to fill

(e) $1000 / 220 \approx \mathbf{4.55}$

3.2

(a) **2**: each `add` uses the register loaded by the `lw` just before it

(b) `lw x1`; `lw x4`; `add x2`; `add x5`: each `add` is now at least one instruction after its load, and the meaning does not change

(c) 2×10^6 cycles $\times 1$ ns $= \mathbf{2\ ms}$

3.3

(a) A: $1 + 0.2 \times 0.05 \times 2 = \mathbf{1.02}$; B: $1 + 0.2 \times 0.05 \times 6 = \mathbf{1.06}$

(b) A: 1.02 ns; B: $1.06 / 1.8 \approx \mathbf{0.59}$ ns

(c) A: $1 + 0.2 \times 0.2 \times 2 = 1.08$, so 1.08 ns; B: $1 + 0.2 \times 0.2 \times 6 = 1.24$, so $1.24 / 1.8 \approx 0.69$ ns: B is still faster, but by less

(d) maybe not: a 1.8 GHz deep pipeline uses much more power, and a phone is limited by battery and heat, so A may give more work per joule; B suits a plugged-in machine where speed matters most

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