Question 1:

Q1) 5 stage pipeline with each stage taking one cycle.

we have to assume 5 different stages, hence we assume:

→ IF 200ps, ID 100ps, EX 200ps, MEM 400ps, WB 100ps

IF	ID	EX	MEM	WB
200ps	100ps	200ps	400ps	100ps

source: Assignment 3

→ Baseline is Single cycle interaction.

* Basic calculation:

$$T_{net,single\ cycle} = IF + ID + EX + EM + WB$$
$$= 200 + 100 + 200 + 400 + 100$$
$$= \underline{\underline{1000ps}}$$

For N interactions =>

$$\boxed{T_{net} = 1000N}$$

* Time taken for pipeline:

a) → 30% Raw & 20% branch dependency:

$$T_{clock\ cycle,net} = max\{Time\ by\ stages\} = 400ps$$

For dependencies:

$$CPI = \Sigma CPI_{per\ inst.} \times fraction$$
$$= (1-0.2-0.3) \times 1 + 0.3 \times 4 + 0.2 \times 3$$
$$= 0.5 \times 1 + 0.3 \times 4 + 0.2 \times 3$$
$$= 0.5 + 1.2 + 0.6$$
$$= \underline{\underline{2.3}}$$

$$T_{exec} = IC \times CPI \times \text{Clock Cycle}$$
$$= N \times 2.3 \times 400$$
$$T_{exec} = \underline{\underline{920\,N}} \text{ ps}$$

$$\therefore \text{Speedup} = \frac{T_{baseline}}{T_{pipeline}} = \frac{1000}{920} = \underline{\underline{1.087}}.$$

b) → 40% branch dependency:

$$CPI = (1-0.4)\times 1 + 0.4\,(1 + stall_{branch})$$
$$= 0.6 \times 1 + 0.4 \times (1+2)$$
$$CPI = 0.6 + 1.2 = 1.8$$

$$\therefore T_{exec} = IC \times CPI \times \text{ClockCycleTime}$$
$$= N \times 1.8 \times 400\text{ps}$$
$$= 720\,N \text{ ps}.$$

$$\therefore \text{Speedup} = \frac{1000N}{720N} = \underline{\underline{1.3889}}$$

⇒ Branch predictor with 80% accuracy.

a) 30% RAW, 20% branch

On calculation,

4% branch, 30% RAW, 66% Normal.

$$CPI = 0.66 \times 1 + 0.3\,(1 + stall_{RAW}) + 0.04\,(1 + stall_{branch})$$
$$= 0.66 \times 1 + 0.3\,(1+3) + 0.04\,(1+2)$$
$$= 0.66 + 1.2 + 0.12$$
$$= 1.98$$

$T_{exec} = N \times 1.98 \times 400 = 792N$ ps.

$\therefore$ Speedup $= \frac{1000}{792} = \underline{\underline{1.2626}}$

$\Rightarrow$ Speedup increased from the previous value (without branch predictor).

$\Rightarrow$ 40% branch dependency:

$\Rightarrow$ 8% branch, 92% Normal.

$\therefore$ $CPI = 0.92 \times 1 + 0.08 \times (1 + stall_{branch})$

$= 0.92 + 0.08(1+2)$

$= 0.92 + 0.24 = \underline{\underline{1.16}}$

$\therefore$ $T_{exec} = N \times 1.16 \times 400 = 464N$ ps

$\therefore$ Speedup $= \frac{1000}{464} = \underline{\underline{2.156}}$

$\Downarrow$

increased from previous value, where there isn't branch predictor.

Question 2:

20% branch instruction.

Delayed branching with one delay slot.

Base CPI = 1.5 ... (No delay slots)

$$CPI_{base} = CPI_{nonbranch} \times f_{nonbranch} + CPI_{branch} \times f_{branch}$$

Thus,

$$1.5 = CPI_{nonbranch} \times 0.8 + CPI_{branch} \times 0.2 \quad \text{— (1)}$$

★ 85% delayed slots are filled:

∴ Fraction of branch instruction where delayed slot is filled ⇒ $0.2 \times 0.85 = 0.17$.

∴ fraction of branch instruction (with delay slot = empty) $= 0.2 \times 0.15 = \underline{\underline{0.03}}$

$$CPI_{new} = 0.8 \times CPI_{non\text{-}branch} + 0.2 \times CPI_{branch} - 0.17 \quad \text{— (2)}$$

from (1) & (2), we get

$$CPI_{new} = 1.5 - 0.17 = \underline{\underline{1.33}}$$