Computer Architecture Assignment

1) Given :- $f = 3GHz$, $V = 1.1V$, total power $(T_p) = 130W$, leakage power $(L_p) = 30W$
$t = 100s$ [Baseline Values], CPU-bound processor

Dynamic Power $(D_p) = T_p - L_p = 130 - 30 = 100W$ $[T_p = D_p + L_p]$

safe voltages :- $0.9V \leq V \leq 1.2V$

$E = T_p \times t = 130 \times 100 = 13000$ Joules [baseline value]

(i) To compute :- smallest t.

Since time is inversely proportional to frequency which is linearly proportional to voltage, to compute smallest t, we need the highest freq and hence highest voltage possible.

Hence lets consider the case when $V \leq 1.2V$.

$\Rightarrow$ increase in voltage from baseline value $= 9.09\%$

$\Rightarrow f_N = 1.09 f$. [since voltage & frequency follow linear relationship]

$\Rightarrow t_N = \frac{1}{1.09} t = 0.917t$ $[f = 1/t]$

Hence, when freq increases by 9%, time decreases by a factor of 0.917

so least time it will take to execute the program now

$= 0.917 \times 100 = 91.7 s$

$\therefore \boxed{t \geq 91.7s}$

(ii) To compute :- highest power. (T_p)

Since the dynamic component of power is dependent on voltage and frequency and the leakage component is dependent on voltage, to compute the highest power, we will consider the highest values of voltage and frequency possible

Hence, lets consider the case when $V \leq 1.2V$

Now $D_p \propto$ activity $\times$ capacitance $\times V^2 \times f$

$\Rightarrow D_p \propto V^2 f$

Since voltage increased by 9.09%

V_N (new voltage) $= 1.09V$

f_N (new freq) $= 1.09f$

New $D_p \leq (1.09V)^2(1.09f)$

$\leq 1.29V^2f$

$\leq 1.29\ D_p$

$\leq 1.29 \times 100$

$\leq 129W$

$L_p \propto$ transistor count $\times$ leakage current $\times V \Rightarrow L_p \propto V$

New $L_p =$ $1.09V$

$\leq 1.09\ L_p$

$\leq 1.09 \times 30$

$\leq 32.7W$

New $T_p =$ New D_p + New L_p

$\leq 129 + 32.7$

$\leq \boxed{161.7W}$

(iii) To compute :- lowest Energy (E)

As per DVFS, we can reduce energy by reducing the voltage and frequency.

Hence we will consider the lowest voltage and frequency.

i.e. $V \geq 0.9V$

This implies a decrease of 18.18% in voltage.

$\Rightarrow V_N = 0.818V$

$f_N = 0.818f$

New $D_p \geq (0.818V)^2(0.818f)$

$\geq$ ~~54.73~~ $0.547\ V^2f$

$\geq 0.547\ D_p$

$\geq 54.7W$

New $L_p \geq (0.818V)$

$\geq 0.818\, L_p$

$\geq 24.54\, W$

New $T_p \geq$ New D_p + New L_p

$\geq 54.7 + 24.54$

$\geq 79.24\, W$

Now $t_N = \frac{1}{0.818} t = 1.22t = 122s$ $[t = 1/f]$

New $E \geq$ New $T_p \times t_N$

$\geq 79.24 \times 122$

$\geq \boxed{9667.28 \text{ Joules}}$

2) Baseline values Given :- $f = 2$ GHz, $V = 1V$, $t = 100s$,
memory bound = $Y\%$, $D_p = 60W$, $L_p = 25W$

$\Rightarrow T_p = D_p + L_p = 60 + 25 = 85W$

Baseline Energy (E) = $T_p \times t$ = 8500 Joules $(E = P \times t)$

Now f ~~has~~ is reduced to 1 GHz

$\Rightarrow$ To compute :- min value of Y, such that program consumes energy less than baseline energy of 8500 Joules.

$f_N = 1$ GHz

$\Rightarrow$ frequency decreased by 50%

$\Rightarrow f_N = 0.5f$

$\Rightarrow$ New $D_p = 0.5\, D_p$ [since $D_p \propto f$]

$= 0.5 \times 60$

$= 30W$

$\Rightarrow$ New T_p = New D_p + L_p = $30 + 25 = 55W$

Since its memory-bound CPU and Ys ~~is~~ time is spent on accessing memory, the baseline time for processing in the CPU is $(100-y)$s.

Now that $f_N = 0.5f$

~~$t_N = 2t$~~ ~~[t being the execution time to finish the program]~~

only the CPU-processing time will be double $\left[\begin{aligned} t &= 1/f \\ &= \frac{1}{0.5}t \\ &= 2t \end{aligned}\right]$

$\Rightarrow$ new total time $t_N = 2(100-y) + y$

$\uparrow$ memory accessing time is unaffected by frequency scaling.

$= 200 - y$

Now, $E_N < 8500$

$\Rightarrow 55(200-y) < 8500$

$\Rightarrow 11000 - 55y < 8500$

$\Rightarrow 55y > 2500$

$\Rightarrow \boxed{y > 45.456}$

3) Given:-

	Prog P	Q	R	S	S.E.T.	SWET	GM
ref → Sys A	120	60	200	500	880	4	$\sqrt[4]{72 \times 10^7} = 2.91 \times 10^{7/4}$
Sys B	150	90	180	400	820	4.45	$\sqrt[4]{97.2 \times 10^7} = 3.14 \times 10^{7/4}$
Sys C	100	50	250	600	1000	4.11	$\sqrt[4]{75 \times 10^7} = 2.94 \times 10^{7/4}$

To compute :- speedup of C over B

In terms of sum of Execution times [S.E.T.]

[Perf = 1/exec. time]

$$\text{speedup of C over B} = \frac{\text{Performance}_C}{\text{Performance}_B}$$

$$= \frac{\text{Execution time}_B}{\text{Execution time}_C}$$

$$\Rightarrow \text{Speedup} = \frac{B_{S.E.T.}}{C_{S.E.T}} = \frac{820}{1000} = \boxed{0.82}$$

3. In terms of sum of weighted execution times [S.W.E.T.]

$$\text{Speedup of C over B} = \frac{B_{SWET}}{C_{SWET}} = \frac{4.45}{4.11}$$

$$\boxed{\cancel{=}1.08}$$

In terms of geometric mean [G.M]

$$\text{speedup} = \frac{B_{GM}}{C_{GM}} = \frac{3.14 \times 10^{7/4}}{2.94 \times 10^{7/4}}$$

$$= \boxed{1.06}$$

4) Given:- clockspeed of new laptop = 15% higher than old

$\Rightarrow$ ~~Ocs~~ old clock speed $O_{CS} = 1$

new clock speed $N_{CS} = 1.15$

new clock speed is same.

# of cycles for each instruction is same.

Hence to calculate the performance improvement of new laptop. we can find the AM of IPCs.

Program	P	Q	R	S	T	CS	AM
IPC old	0.3	0.9	0.9	1.3	1.5	1	0.98
IPC new	0.4	0.8	1.0	1.2	1.4	1.15	0.96

$$\text{speedup of New laptop over old} = \frac{\text{Performance New}}{\text{Performance old}}$$

$$\left[\text{perf} = \frac{\text{clock speed} \times \text{IPC}}{\text{\# of instruction}}\right]$$

$$= \frac{N_{CS}}{O_{CS}} \times \frac{N_{IPC}}{O_{IPC}}$$

$$= \frac{1.15}{1} \times \frac{0.96}{0.98} = 1.126$$

$$\simeq 1.13$$

Now performance improvement = speedup - 1

$= 1.13 - 1 \Rightarrow \boxed{0.13}$

--- x ------- x ------- x ----