Rebuilt AND gate

\[
\begin{align*}
G &= \frac{10}{3} \times 1 \\
H &= 12 \\
B &= 1 \\
\rho &= 8 + 1
\end{align*}
\]

\[
\begin{align*}
F &= 40 \\
\rho &= 10 \\
F \frac{1}{3} &= 5.42 \\
\hat{D} &= 3 \times 3.42 + 10 = 20.26
\end{align*}
\]

\[
\begin{align*}
F &= 40 \\
\rho &= 11 \\
F \frac{1}{4} &= 2.51 \\
\hat{D} &= 4 \times 2.51 + 11 = 21.06
\end{align*}
\]

Problem 1

A) \[
\begin{align*}
G &= 1 \times 2 \times 1 = 2 \\
H &= \frac{(32 \times 3)}{10} = 9.6 \\
B &= 8 \\
F &= GHB = 2 \times 9.6 \times 8 = 153.6 \\
\hat{f} &= \sqrt[3]{153.6} = 5.36 \\
\hat{D} &= 8 \times 5.36 + (1 + 4 + 1) \\
&= 16.08 + 6 = 22.08
\end{align*}
\]
B) 
\[ C_{w,2} = \frac{2}{\frac{1}{2}} C_{w,1} = 17.91 \]
\[ C_{w,1} = \frac{2}{\frac{1}{2}} (17.91) = 6.68 \]
\[ C_{w,0} = \frac{1}{\frac{1}{2}} (6.68 \times 8) = 9.97 \]

C) 
\[ \log_4(152.6) = \frac{\log_{10}(152.6)}{\log_{10}(4)} = \frac{2.186}{0.602} = 3.6 \]

D) 
8 input inverters
\[ C_g = 8 \times 10 = 80 \text{C} \]
\[ C_d = 8 \times 10 = 80 \text{C} \]
\[ C_{\text{tot}} = 160 \text{C} \]

16 output inverters
\[ C_g = 16 \times 17.9 = 286 \text{C} \]
\[ C_d = 16 \times 17.9 = 286 \text{C} \]
\[ C_{\text{tot}} = 572 \text{C} \]

16 NAND gates
\[ C_g = 4 \times 16 \times 6.68 = 427 \text{C} \]
\[ C_d = 16 \times (4 \times 2.23 + 4.45) = 214 \text{C} \]
\[ C_{\text{tot}} = 640 \text{C} \]

\[ C_{sn} = 160 + 572 + 640 + (16 \times 96) = 2,908 \text{C} \]
**Problem 2**

A) \[ G = 1 \times 1 \times 2 \times 1 \]
\[ H = (32 \times 3)/10 = 9.6 \]
\[ B = 8 \]
\[ T = GB = 153.6 \]
\[ \hat{f} = \sqrt[4]{153.6} = 3.52 \]
\[ \hat{D} = 4 \times 3.52 + (1+1+4+1) \]
\[ = 14.08 + 7 = 21.08 \]
\[ \frac{21.08}{22.08} = 0.954 \text{ or } 4.5\% \text{ faster} \]

B) \[ C_{w,t} = \frac{1}{3.52} (32 \times 3) = 27.2 \]
\[ C_{w,y} = \frac{2}{3.52} (27.2) = 15.5 \]
\[ C_{w,x} = \frac{1}{3.52} (8 \times 15.5) = 35.23 \]
\[ C_{w,u} = \frac{1}{3.52} (35.23) = 10 \]

**Note:** Vary different sizing for gates

And overall \( C_{sw} \) is much higher

Since performance benefit is much and area/energy is so much higher, probably better off using the three-stage design.
Problem 3

Focus on just the fork, optimally sum each path

\[ G = 1 \]
\[ H = \frac{5.6C}{10C} = 0.56 \]
\[ B = 1 \]

\[ d = gh + p \]
\[ d = 1 \cdot \frac{5.6C}{10C} + 1 = 0.56 + 1 = 1.56 \]

\[ F = GMH = 5.3 \]
\[ f = 2\sqrt{5.3} = 2.3 \]
\[ D = 2 \times 2.3 + 2 = 6.6 \]

\[ C_m = \frac{9}{4} C_{out} = \frac{1}{2.3} \]
\[ s = 23C \]

\[ \text{Inverter Branch is a bit slower} \]

Overall delay through 2 inverter branch is

\[ d_u = 1 \cdot \frac{2.3}{10} + 1 = 0.23 + 1 = 1.23 \]
\[ d_v = 1 \cdot \frac{5.3}{2.3} + 1 = 2.3 + 1 = 3.3 \]
\[ d_x = 2 \cdot \frac{17.91}{6.6} + 4 = 5.36 + 4 = 9.36 \]
\[ d_z = 1 \cdot \frac{9.6}{17.91} + 1 = 0.536 + 1 = 1.536 \]

\[ \boxed{22.32} \]

22.32 is pretty close to 22.08