Triple Modular Redundancy (TMR)

N modular redundancy: C1, C2, ... C-N

2 or more out of the 3
Reliability of each component is R.
What is the reliability of the overall system? (TMR)

Reliability = Pr(Component/System operating correctly)

Ans:
Reliability of system = Pr(3 components working correctly) + Pr(2 components working correctly)
= \( R^3 + C(3, 2) \times R^2 \times (1 - R) \)
= \( R^3 + 3R^2(1 - R) \)
= \( R^3 + 3R^2 - 3R^3 \)
= \( 3R^2 - 2R^3 \)
Dynamic Redundancy

1. Hot spares
2. Warm spares
3. Cold spares

C1, C2, C3: 0.99 * 0.95 * 0.90  Time: 10
C1, C2, !C3: 0.99 * 0.95 * 0.10  Time: 10
!C1, C2, C3:  Time: 15
C1, !C2, C3:  Time: 15
...

Static redundancy
or Error masking

\[ C_1 \quad | \quad C_2 \quad | \quad \ldots \quad | \quad C_n \]

Voter

System output

Dynamic redundancy

\[ C_i \]

Error det

System output

Port of Standby resource
Static
\[ P(\text{success}) \quad \text{Time to completion} \]
\begin{align*}
G & \quad 0.99 & \quad 5 \quad \text{Voter's config = 2 of 3.} \\
C_2 & \quad 0.95 & \quad 10 \\
C_3 & \quad 0.90 & \quad 15
\end{align*}

[1] Reliability of system = ?

[2] If system succeeds, what is the expected time to get a result from the system?

\[ P(\text{success}) = P(\text{atleast 2 out of 3 are correct}) \]
\[ = P(C_1, C_2 \text{ work } C_3 \text{ doesn't}) + P(C_1, C_3 \checkmark C_2 \checkmark) + P(C_2, C_3 \checkmark C_1 \checkmark) + P(C_1, C_2, C_3 \checkmark) \]
\[ = 0.9936 \]

[2]

Time to get result for each case:
\[ = 0.69405 \times 10 + 0.04455 \times 15 + 0.00855 \times 15 + 0.08465 \times 10 \]
\[ = 0.9405 + 0.66825 + 0.12825 + 0.84645 \]
\[ \geq 10.267 \quad \text{\[ \text{Sum} \]} \]
For the dynamic redundancy, answer (1) and (2) come up with the best ordering of $c_1, c_2, c_3$. 