This is a comprehensive formula sheet and collection of shortcut methods for Network Theory (Circuit Analysis), tailored for the GATE exam. It focuses on high-yield formulas and "inspection" techniques to save time.

1. Basics & Circuit Simplification

Concept	Formula / Condition	**Shortcut / Trick**
KCL	$\sum I_{in} = \sum I_{out}$	**Nodal Analysis** is often faster than Mesh. Total equations = $N - 1$.
KVL	$\sum V_{rise} = \sum V_{drop}$	**Mesh Analysis** total equations = $B - (N - 1)$.
Star → Delta	$R_a = \frac{R_1R_2+R_2R_3+R_3R_1}{R_1}$ (Opposite Resistor)	If all R are equal: $R_\Delta = 3R_Y$
Delta → Star	$R_1 = \frac{R_aR_b}{R_a+R_b+R_c}$ (Adjacent Product / Sum)	If all R are equal: $R_Y = R_\Delta/3$
Source Transformation	$V_s = I_sR_s$ (Series R) ↔ $I_s = V_s/R_s$ (Parallel R)	Use this to reduce multiple sources into one single loop or node pair.

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2. Network Theorems (The "Power" Tools)

Thevenin's & Norton's Theorem

- V_{th} **(Thevenin Voltage):** Open Circuit Voltage (V_{OC}) at terminals.
- I_N **(Norton Current):** Short Circuit Current (I_{SC}) at terminals.
- R_{th} **(Equivalent Resistance):** Deactivate independent sources (Voltage → Short, Current → Open).
- **Relationship:** $V_{th} = I_N \times R_{th}$

> **GATE Shortcut:** If the circuit has **Dependent Sources**:
>
> 1. Find V_{OC} (which is V_{th}).

2. Find I_{SC} (short the terminals).
3. Calculate $R_{th} = \frac{V_{OC}}{I_{SC}}$. *Do not try to find R_{th} by deactivating sources if dependent sources are present unless you use the "Test Source" method (V_{test}/I_{test}).*

Maximum Power Transfer Theorem

Condition for P_{max} depends on the Load (Z_L):

Source Impedance (Z_s)	Load Type (Z_L)	**Condition for Max Power**
Pure Resistive (R_s)	Variable R_L	$R_L = R_s$
Complex ($R_s + jX_s$)	Variable $R_L + jX_L$	$Z_L = Z_s^*$ (Conjugate)
Complex ($R_s + jX_s$)	Variable R_L (only)	$R_L =
Max Power Value:	**DC:** $P_{max} = \frac{V_{th}^2}{4R_{th}}$	**AC:** $P_{max} = \frac{

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3. Transient Analysis (First Order RC / RL)

Standard Formula (The "Golden" Equation):

$$x(t) = x(\infty) + [x(0^+) - x(\infty)]e^{-t/\tau}$$

Where $x(t)$ is either voltage $v_C(t)$ or current $i_L(t)$.

Shortcut for Initial/Final Conditions:

- **At $t = 0$ (Just closed):**
  - **Inductor (L):** Acts as **Open Circuit** (Current cannot change instantly: $i_L(0^-) = i_L(0^+)$).
  - **Capacitor (C):** Acts as **Short Circuit** (Voltage cannot change instantly: $v_C(0^-) = v_C(0^+)$).
- **At $t = \infty$ (Steady State):**
  - **Inductor (L):** Acts as **Short Circuit** (wire).
  - **Capacitor (C):** Acts as **Open Circuit**.

Time Constant (τ):

- **RC Circuit:** $\tau = R_{eq}C$
- **RL Circuit:** $\tau = \frac{L}{R_{eq}}$
- **Shortcut:** To find R_{eq}, "Look" from the capacitor/inductor terminals and **kill** all independent sources (Voltage $\rightarrow$ Short, Current $\rightarrow$ Open).

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4. AC Analysis & Resonance

Resonance Formulas (Series RLC)

- **Resonant Freq:** $\omega_0 = \frac{1}{\sqrt{LC}}$ rad/s
- **Quality Factor (Q):** Voltage Magnification.

$$Q = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 RC} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

- **Bandwidth (BW):** $BW = \frac{R}{L} = \frac{\omega_0}{Q}$
- **Half Power Frequencies:** $\omega_{1,2} = \omega_0 \pm \frac{BW}{2}$ (Approx valid if $Q > 10$).
- **Impedance at Resonance:** $Z_{min} = R$ (Purely Resistive, Unity PF).

Resonance Formulas (Parallel RLC)

- **Resonant Freq:** $\omega_0 = \frac{1}{\sqrt{LC}}$
- **Quality Factor (Q):** Current Magnification.

$$Q = \frac{R}{\omega_0 L} = \omega_0 RC = R\sqrt{\frac{C}{L}}$$

- **Impedance at Resonance:** $Z_{max} = R$ (Be careful: parallel resonance has Max Impedance).

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5. Two-Port Networks (Parameters & Conditions)

Parameter	Equations	Condition for Reciprocity	Condition for Symmetry
Z (Impedance)	$V_1 = z_{11}I_1 + z_{12}I_2$ $V_2 = z_{21}I_1 + z_{22}I_2$	$z_{12} = z_{21}$	$z_{11} = z_{22}$
Y (Admittance)	$I_1 = y_{11}V_1 + y_{12}V_2$ $I_2 = y_{21}V_1 + y_{22}V_2$	$y_{12} = y_{21}$	$y_{11} = y_{22}$
h (Hybrid)	$V_1 = h_{11}I_1 + h_{12}V_2$ $I_2 = h_{21}I_1 + h_{22}V_2$	$h_{12} = -h_{21}$	$\Delta h = 1$
T (ABCD)	$V_1 = AV_2 - BI_2$ $I_1 = CV_2 - DI_2$	$AD - BC = 1$	$A = D$

Shortcuts for Two-Port Interconnections:

- **Series Connection:** Add **Z** matrices ($[Z] = [Z_A] + [Z_B]$).
- **Parallel Connection:** Add **Y** matrices ($[Y] = [Y_A] + [Y_B]$).
- **Cascade Connection:** Multiply **T** matrices ($[T] = [T_A] \times [T_B]$).
- **Lattice Network (Symmetric):**
  - $Z_{11} = \frac{Z_b+Z_a}{2}$, $Z_{12} = \frac{Z_b-Z_a}{2}$ (where Z_a is series arm, Z_b is cross arm).

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6. Important Tricks & Special Cases

- **Symmetry Trick:** If a network is symmetric (looks same from left and right):
    - **Horizontal Axis of Symmetry:** Potential at symmetric points is equal. You can disconnect or connect these points without changing the circuit.
    - **Vertical Axis of Symmetry:** Current distribution is symmetric.
- **Wheatstone Bridge:** If balanced ($R_1R_4 = R_2R_3$), no current flows through the diagonal galvanometer/resistor. Treat it as open circuit.
- **Equivalent Inductance (Coupled):**
    - Series Aiding: $L_{eq} = L_1 + L_2 + 2M$
    - Series Opposing: $L_{eq} = L_1 + L_2 - 2M$
    - *Dot Convention:* Current entering dot → Positive Mutual Inductance voltage at other dot.
- **Graph Theory:**
    - Number of Trees = N^{N-2} (for complete graph).
    - Number of Fundamental Loops = $B - N + 1$.
    - Number of Fundamental Cut-sets = $N - 1$.