Q1. A or B, both are right. Give 2 marks to anybody who has given answer as A, B or A&B both.

Q2: E. ALL 4 circuits have a time constant = 1 sec.

Q3: C. -20 dB/decade - A low pass STC has a pole and a pole has -20 dB/decade slope or downward slope as frequency increases.

Q4: B. High Pass STC; the phase shifts from +90° to 0° at corner frequency. The phase shift is +45°.

Q5: B. Zero at s=0, pole at s=-10²=-100
and pole at s = -10⁵ = -100000

\[ A: 6 \]

\[ I_c = 0.5 \text{mA} \]

\[ \beta = 100 \]

\[ V_A = 50 \text{V} \]

\[ R_0 = \frac{V_A}{I_c} = \frac{50 \text{V}}{0.5 \text{mA}} = 100 \text{K}\Omega \]

\[ g_m = \frac{I_c}{V_T} = \frac{0.5 \text{mA}}{25 \text{mV}} = 20 \text{mV} \]

\[ \beta_0 = \frac{100}{20 \times 10^{-3}} = 5 \text{K}\Omega \]

\[ C_p = \frac{C_{p0}}{(1 + V_{CB}/V_{AC})^{0.5}} = \frac{30 \text{fF}}{[1 + 2/0.75]^{0.5}} = 15.666699 \text{fF} \]
\[ C_{je} = 2 \times C_{je0} = 2 \times 20 = 40 \text{ fF} \]
\[ C_{de} = C_F \cdot g_m = 30 \text{ ps} \times 20 \text{ mV} = 600 \text{ fF} \]
\[ C_{\pi} = C_{je} + C_{de} = 40 + 600 = 640 \text{ fF} \]
\[ f_T = \frac{g_m}{2\pi (C_{\pi} + C_F)} = \frac{20 \text{ mV}}{2\pi (0.640 + 0.015666699)} \]
\[ = 4.85 \text{ GHz} \]
\[ = 4854.746 \text{ MHz} \]

A.7. Small Signal Model at Mid Band is:

\[ R_{\pi} = \frac{\beta_0}{g_m} \]

\[ I_E \approx I_C \approx 0.3 \text{ mA} \]
\[ \beta_0 = 120 \]
\[ r_0 = 300 \text{ k}\Omega \]
\[ r_\pi = \frac{50}{2} \]
\[ f_T = 700 \text{ MHz} \]
\[ C_F = 1 \text{ pF} \]
\[ R_C = 4.7 \text{ k}\Omega \]
\[ R_L = 3.6 \text{ k}\Omega \]
\[ V_{cc} = 5 \text{ V} \]
\[ g_m = 0.3 \text{ mA/25 mV} = 12 \text{ mV} \]
\[ R_{\pi} = \frac{\beta_0}{g_m} = \frac{120}{12 \text{ mV}} = 10 \text{ k}\Omega \]

\[ R_{in} = R_1 \parallel R_2 \parallel (r_x + r_{\pi}) = 33 \text{ k}\Omega \parallel 22 \text{ k}\Omega \parallel 10.05 \text{ k}\Omega \]
\[ = 5.70 \text{ k}\Omega \]
Midband Gain

$$A_m = \left( \frac{-R_{in}}{R_{in} + R_{sig}} \right) \cdot \left( \frac{\beta_\pi}{\beta_\pi + \alpha} \right) \cdot g_m \left( R_C || R_L || R_0 \right)$$

Collector Load

Small loading due to $\alpha x$ taken into account.

$$= -\left[ \frac{5.7K}{5.7K + 5K} \right] \left[ \frac{10K}{10.05K} \right] \cdot 12 \times 10^{-3} \left[ 4.7K || 3.6K || 300K \right]$$

$$= -12.87 \text{ Volts/Volts}$$

To calculate $f_h$, we have to calculate $R_{sig}$

$$R_{sig} = \beta_\pi \left[ \alpha x + R_i || R_L || R_{sig} \right]$$

$$= 10K \left[ 0.05K + 33K || 22K || 5K \right]$$

$$= 10K \left[ 0.05K + 3.6263K \right]$$

$$= 10K || 3.6763K = 2.688K$$

$$R_L' = \frac{R_0 || R_C || R_L}{300K || 4.7K || 3.6K} = 2.024795K$$
\[
C_{\mu} + C_{\mu} = \frac{Jm}{2\pi f_T} = \frac{12 \text{ mV}}{2\pi \times 700 \text{ MHz}} = 2.73 \text{ pF}
\]

\[
C_{\mu} = 2.73 \text{ pF} - 1 \text{ pF} = 1.73 \text{ pF}
\]

\[
C_{\text{in}} = C_{\mu} + C_{\mu} \left( 1 + \frac{gm R_L}{R} \right)
\]

\[
= 1.73 \text{ pF} + 1 \text{ pF} \left( 1 + 12 \times 2.024k \right)
\]

\[
= 1.73 \text{ pF} + 25.29 \text{ pF} = 27.02 \text{ pF}
\]

\[
f_H = \frac{1}{2\pi C_{\text{in}} R_{\text{sig}}} = \frac{1}{2\pi \times 27.02 \text{ pF} \times 2.688k}
\]

\[
= 2.192 \text{ MHz}
\]

\[\times\]

A. 8. We have been given 3 capacitance values and we have to calculate lower cutoff frequencies pertaining to each one of them separately.

Calculations of Break Frequency \(f_{\text{BP}}\) due to \(C_1\) :

Case 1: Consider input with \(C_1\). Assume \(C_2\) & \(C_3\) perfect short circuit.

See the input circuit:

\[
V_{\text{sig}} + \frac{1 \text{ pF}}{5k} = \frac{1 \text{ pF}}{33k} \quad C_1 \quad \frac{1 \text{ pF}}{22k} \quad R_2 = 10k
\]
Total Equivalent Resistance across $C_c$ terminals: $R_{eq1} = R_{C1}$

$R_{C1} = R_{sig} + \left( \frac{33K \parallel 22K}{10.05K} \right)$

$= 10.7K$

$$f_{p1} = \frac{1}{2\pi R_{C1} C_{C1}} = \frac{1}{2\times3.14\times10.7K \times 1\mu F} = \boxed{14.88\text{ Hz}}$$

Case 3: Consider Output with $C_c$ 2. Assume $C_c$ and $C_E$ to be $5\mu F$

The output small signal model is

\[ R_L = 3.6K \]

Total equivalent resistance $R_{eq2}$ or $R_{C2}$ seen by $C_2$ will be

$R_{C2} = R_L + R_C \parallel \tau_0 = \frac{3.6K + 4.7K}{300K}$

$= \frac{4.6275K + 3.6K}{8.227 K}$

$$f_{p3} = \frac{1}{2\pi R_{C2} C_{C2}} = \frac{1}{2\pi \times 8.227K \times 1\mu F} = \boxed{19.35\text{ Hz}}$$
Case 2: Consider input with $C_E$ & $R_E$ with $C_c_1$ and $C_c_2$ as perfect shortckt.

See the circuit as seen by $V_{\text{sig}}$:

Now we can either reflect $R_E$, $C_E$ towards Base or bring rest of 5 resistors towards emitter.

Let us do the second case.

The equivalent circuit resistance seen by $C_E$ will be $R_E$ in parallel with 4 other resistors all brought from base to emitter by dividing them by $(1+\beta)$.

\[
R'_E = \text{Eqv. resist. in E & G} = R_E \parallel \left[ \frac{r_T + r_X + (r_2 || r_1 || R_{\text{Sig}})}{1+\beta} \right]
\]

\[
= 3.9 \, \Omega \parallel \left[ \frac{10.05 \, \Omega + 3.62 \, \Omega}{121} \right] = \frac{1}{0.130 \, \Omega} = 109.8 \, \Omega
\]

\[
\therefore C_E = 10 \, \mu F \implies f_p = \frac{1}{2\pi C_E R'_E} = \frac{1}{2\pi \times 10 \, \mu F \times 109.8 \, \Omega}
\]

\[
f_L = f_p + f_{p_2} + f_{p_3} = 14.88 + 145.02 + 19.35 = 145.02 \, \text{Hz}
\]

\[
\frac{f_L}{f_L} = 179.25 \, \text{Hz}
\]
We have to choose $C_1$, $C_2$ and $C_E$ such that the total contribution of 3 of them leads to $f_L = 100 \text{ Hz}$.

$$f_L = 100 \text{ Hz} = f_{p_1} + f_{p_2} + f_{p_3}$$

We have been given guideline that contribution due to $C_1$ and $C_2$ i.e. $f_{p_1}$ and $f_{p_3}$ must be 5% each. Rest 90% contribution must come from $f_{p_2}$.

$$f_{p_2} = 0.9 \times 100 \text{ Hz} = 90 \text{ Hz} = \frac{1}{2\pi C_E R_E}$$

$$\therefore C_E = \frac{1}{2\pi \times 109.8 \Omega \times 90 \text{ Hz}} = 16.11 \mu F$$

We can choose next higher commercial value available such as 22 $\mu F$.

$$f_{p_1} = f_{p_3} = 0.05 \times 100 \text{ Hz} = 5 \text{ Hz}$$

$$\therefore C_{C_1} = \frac{1}{2\pi \times R_{C_1} \times 5 \text{ Hz}} = \frac{1}{2\pi \times 10.7 \times 5 \text{ kHz}} = 2.976 \mu F$$

So choose $C_{C_1} = 3.3 \mu F$ which is next higher value.

Calculate $C_{C_2}$ similarly

$$C_{C_2} = \frac{1}{2\pi \times R_{C_2} \times 5 \text{ Hz}} = \frac{1}{2\pi \times 8.227 \times 5 \text{ kHz}} = 3.87 \mu F$$

So choose $C_{C_2} = 4.7 \mu F$ which is next higher value.

--- End of Solution ---