

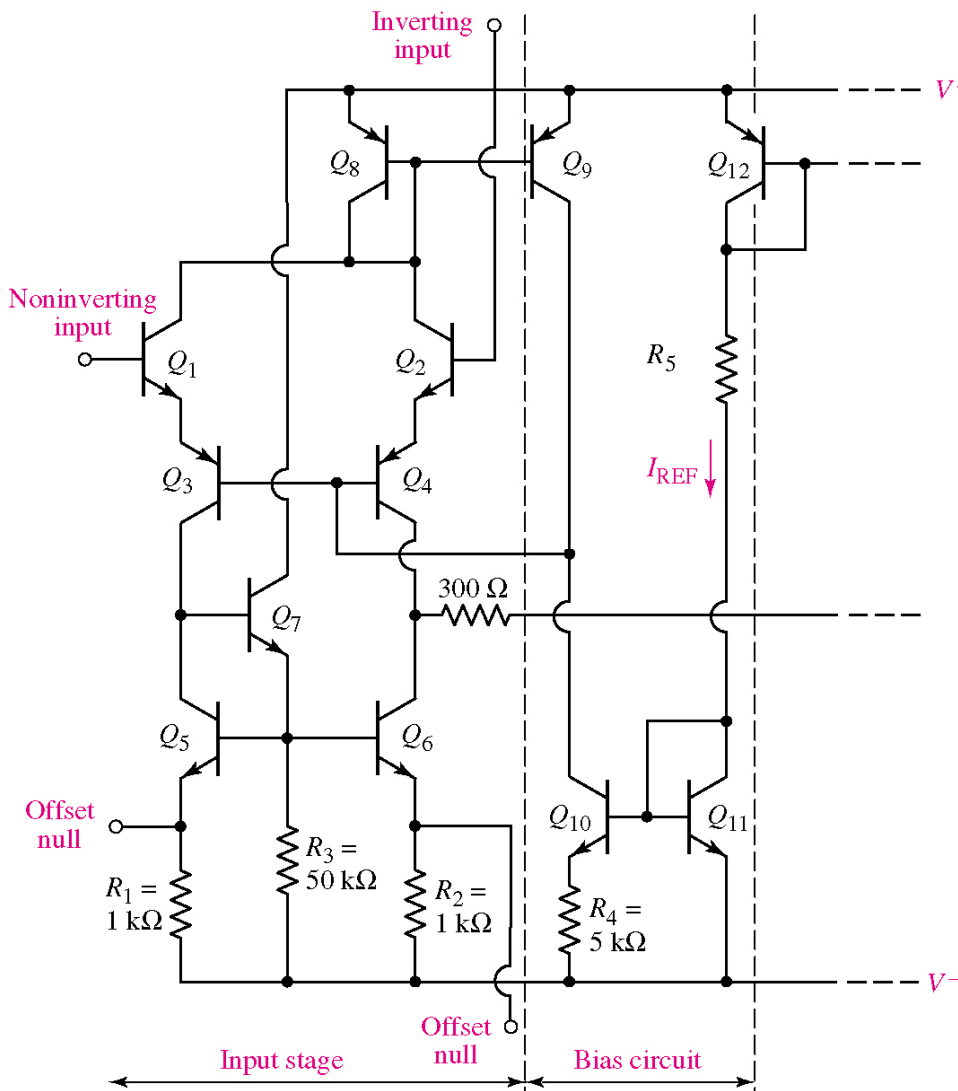
Question:

Study the bias circuit and input stage of **741 operational amplifier** shown in **Figure 1** carefully. Assume V_{BE} for npn = V_{EB} for pnp = **0.7 V**. Neglect dc base currents.

Determine the value of resistor R_5 if bias current for Q_6 is **8 μ A**, and $V^+ = +12$ V and $V^- = -12$ V.

Write your answer using pen, in 4 decimal points, with proper Units for all the parameters.

[10 marks]



$$i_C = I_S e^{v_{BE}/V_T}; \text{ npn}$$

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$$i_C = \alpha i_E = \beta i_B$$

$$i_E = i_B + i_C$$

$$\alpha = \frac{\beta}{\beta + 1}$$

; Small signal

$$\beta = g_m r_\pi$$

$$g_m = \frac{I_{CQ}}{V_T}$$

$$r_\pi = \frac{\beta V_T}{I_{CQ}}$$

$$r_o = \frac{V_A}{I_{CQ}}$$

$$V_T = 26 \text{ mV}$$

Figure 1: Bias circuit and input stage of 741 op-amp.

Answer:

$$\begin{aligned} I_{C6} &= 8 \mu\text{A} && [1] \\ &= I_{C8} / 2 = I_{C9} / 2 && = I_{C10} / 2 && [1] \\ I_{C10} &= 2 \times I_{C6} && = 16 \mu\text{A} && [1] \\ \\ I_{C10} R_4 &= V_T \ln(I_{REF} / I_{C10}) && [1] \\ I_{REF} &= I_{C10} \exp[I_{C10} R_4 / V_T] && [1] \\ &= (16\mu) \exp[(16\mu \times 5\text{k}) / (26\text{m})] && [1] \\ &= 0.347 \text{ mA} && [1] \\ \\ I_{REF} &= (V^+ - V - V_{EB12} - V_{BE11}) / R_5 \\ R_5 &= (V^+ - V - V_{EB12} - V_{BE11}) / I_{REF} && [1] \\ &= (12 - (-12) - 0.7 - 0.7) / (0.347\text{m}) && [1] \\ &= 65.129 \text{ k}\Omega && [1] \end{aligned}$$

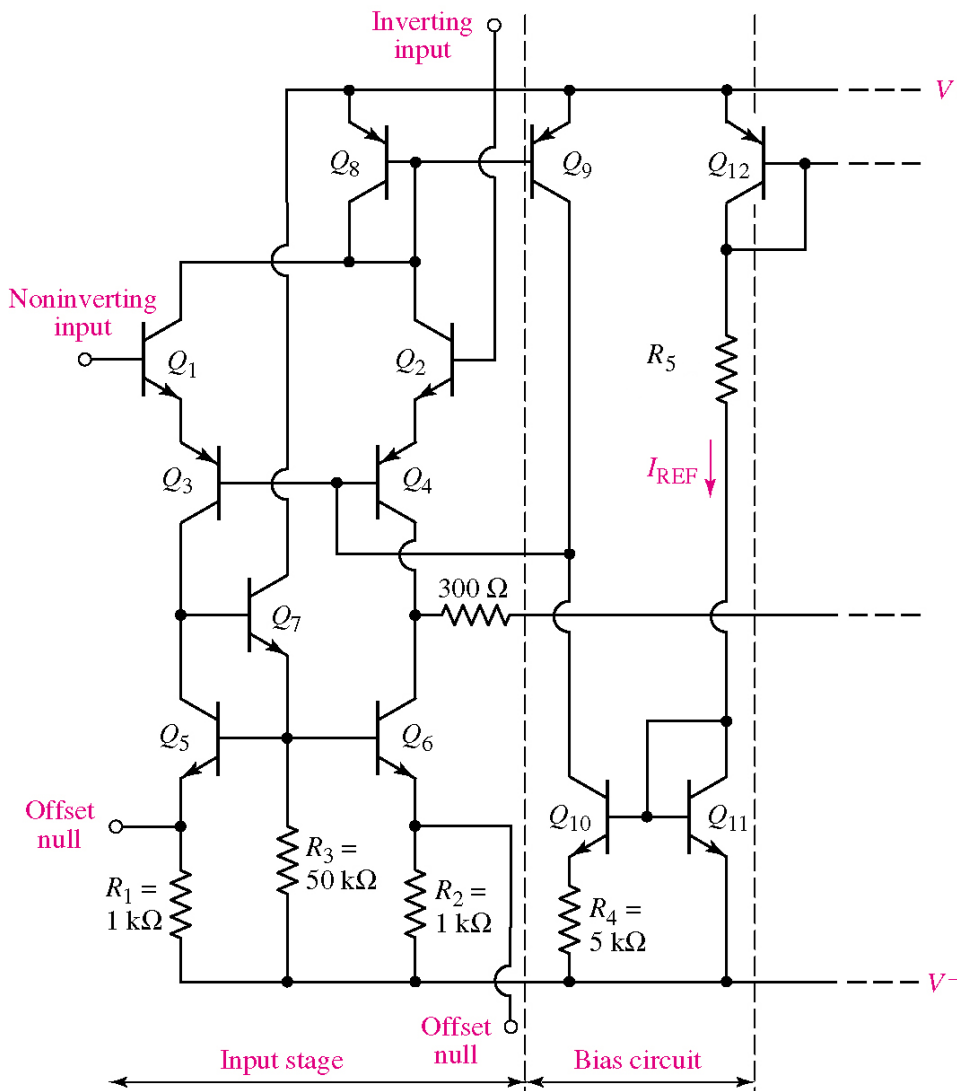
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I_{C6}	$= 8.5 \mu\text{A}$		[1]
	$= I_{C8} / 2 = I_{C9} / 2$	$= I_{C10} / 2$	[1]
I_{C10}	$= 2 \times I_{C6}$	$= 17 \mu\text{A}$	[1]
$I_{C10} R_4$	$= V_T \ln(I_{REF} / I_{C10})$		[1]
I_{REF}	$= I_{C10} \exp[I_{C10} R_4 / V_T]$		[1]
	$= (17\mu) \exp[(17\mu \times 5\text{k}) / (26\text{m})]$		[1]
	$= 0.4469 \text{ mA}$		[1]
I_{REF}	$= (V^+ - V^- - V_{EB12} - V_{BE11}) / R_5$		
R_5	$= (V^+ - V^- - V_{EB12} - V_{BE11}) / I_{REF}$		[1]
	$= (12 - (-12) - 0.7 - 0.7) / (0.4469\text{m})$		[1]
	$= 50.570 \text{ k}\Omega$		[1]

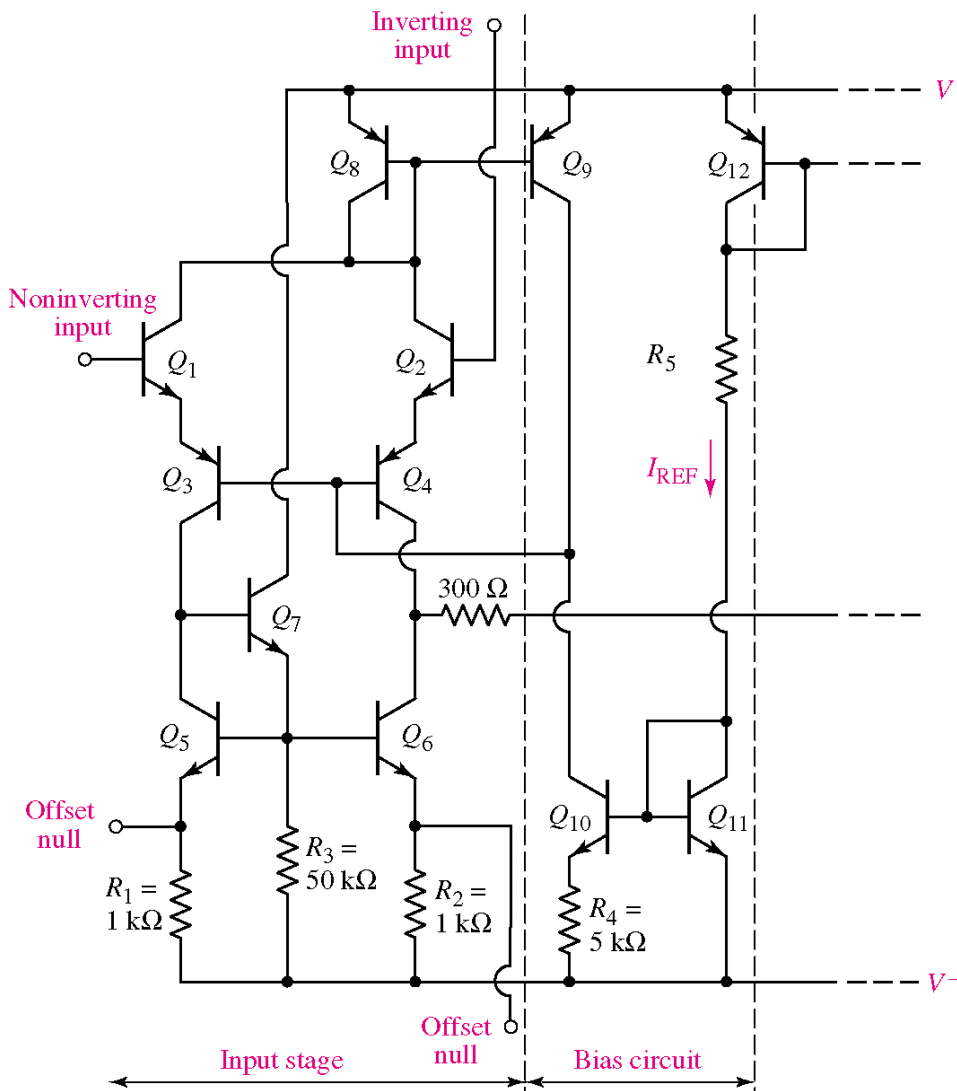
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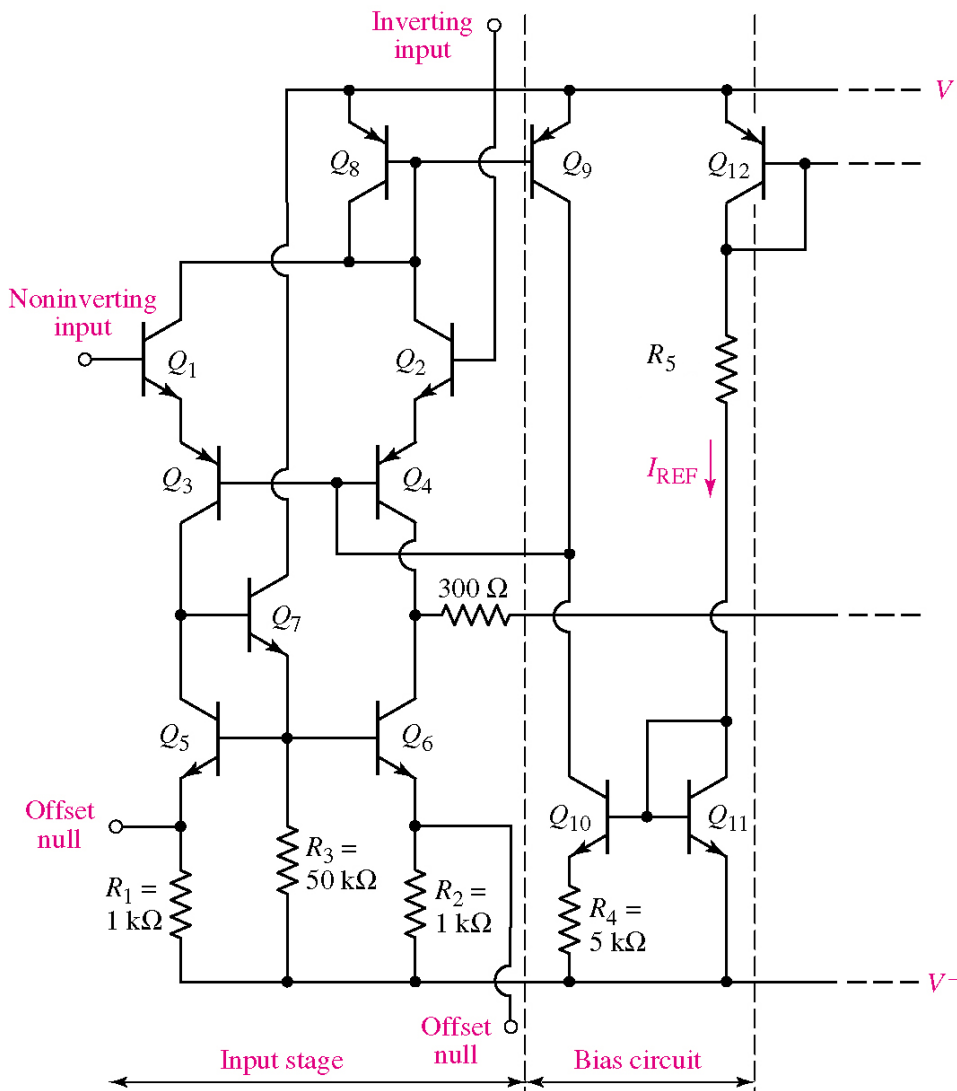
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