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Important Questions *for* GATE 2022

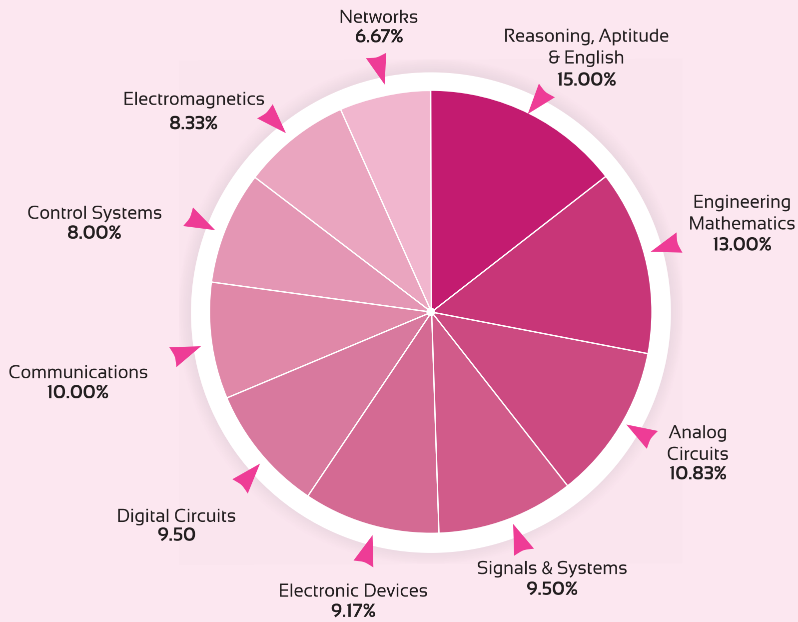
ELECTRONICS ENGINEERING

Day 3 of 8

Q.51 - Q.75 (Out of 200 Questions)

Control Systems and Analog Circuits

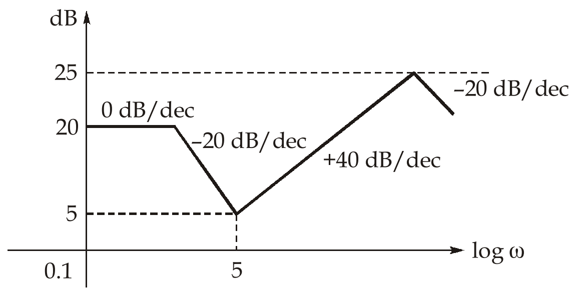
SUBJECT-WISE WEIGHTAGE ANALYSIS OF GATE SYLLABUS



Subject	Average % (last 5 yrs)*
Reasoning, Aptitude & English	15.00%
Engineering Mathematics	13.00%
Analog Circuits	10.83%
Signals & Systems	9.50%
Electronic Devices	9.17%
Digital Circuits	9.50%
Communications	10.00%
Control Systems	8.00%
Electromagnetics	8.33%
Networks	6.67%
Total	**100%**

Control Systems and Analog Circuits

Q.51 Consider the Bode plot shown in the figure below,



the transfer function is,

(a) $\dfrac{35(s+5)^2}{(s+0.89)(s+22.32)^3}$ (b) $\dfrac{281.37(s+5)^3}{(s+0.89)(s+15.81)^3}$

(c) $\dfrac{281.37(s+5)^3}{(s+1)(s+15)^3}$ (d) $\dfrac{35(s+5)^3}{(s+1)(s+22.32)^3}$

Q.52 The open loop transfer function of a unity feedback control system is given by

$$G(s) = \frac{K}{s(0.1s+1)}$$

The value of K such that the resonance peak becomes 1.25 is ________.

Q.53 The open loop transfer function of a control system is given by

$$G(s) = \frac{K}{s(1+s)(1+0.1s)}$$

The value of gain K for which the gain margin of the system is 20 dB is

(a) 1.10 (b) 10

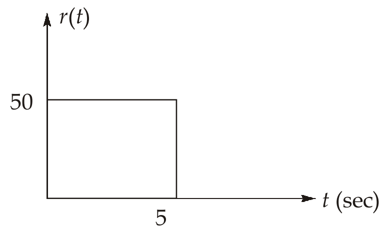
(c) 11 (d) 12.1

Q.54 The open loop transfer function of a unity feedback control system is given as

$$G(s) = \frac{K}{s^2}$$

The value of system gain K for which point $+j2$ lie on the root locus is ________.

Q.55 The steady state error of a unity feedback linear control system for a unit step input is 0.5. The steady state error of the same system, for a pulse input as shown in the figure below is



(a) zero (b) 12

(c) 25 (d) infinite

Q.56 An uncompensated open loop transfer function of a system is given by

$$G(s)H(s) = \frac{100}{s(s+1)}$$

In order for the velocity error constant of compensated system to be 10, the required compensator is given by

$$G_c(s) = \frac{(s+10)}{(s+a)}$$

then the value of 'a' is ________.

Q.57 The transfer function of a control system is given as

$$G(s) = \frac{10}{s(s+2)}$$

A first order compensator is designed in a unity feedback configuration so that the poles of the compensated system are located at –1, –3 and –5. The transfer function of the compensator is,

(a) $\frac{0.9(s+4)}{(s+7)}$ (b) $\frac{10(s+3)}{(s+5)}$

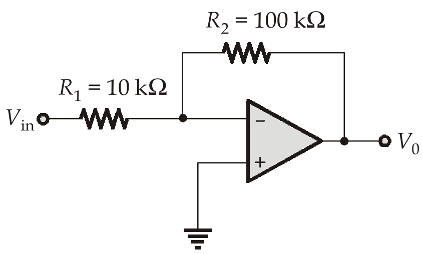
(c) $\frac{0.9(s+1.67)}{(s+7)}$ (d) $\frac{10(s+1.67)}{(s+5)}$

Q.58 A unity negative feedback system has an open loop transfer function

$$G(s)H(s) = \frac{K(s+2)}{s(s-1)}$$

The value of system gain K for which the stable closed loop system has critically damped response is __________.

Q.59 Consider an ideal inverting op-amp circuit as seen in the figure below:

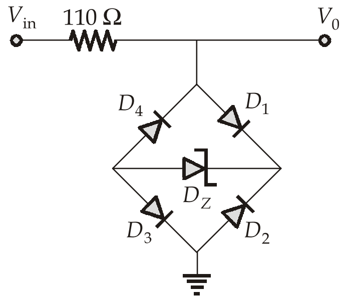


Both the resistances R_1 and R_2 are constructed with a tolerance of 5%, then the range in which the gain of the amplifier can approximately vary is

(a) $-9 < G_v < -10$ (b) $-8 < G_v < -11$

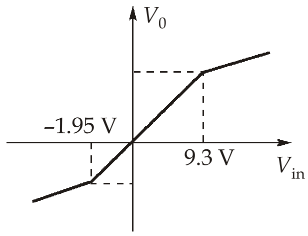
(c) $-9 < G_v < -11$ (d) $-8 < G_v < -10$

Q.60 Consider the circuit shown in the figure below.

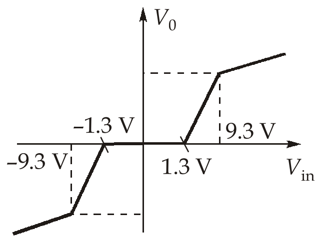


The diodes shown in the figure are identical and could be modeled as a constant voltage source of V_D = 0.65 V along with a forward resistance r_D = 20 Ω. The Zener diode can also be modeled with a voltage drop V_z = 8.2 V along with a resistance of r_Z = 20 Ω when reverse biased, then the transfer characteristic curve can be represented as

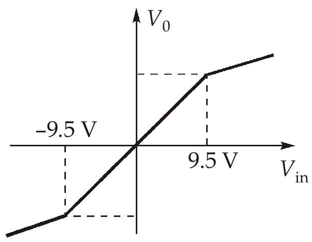
(a)



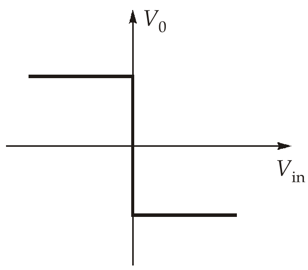
(b)



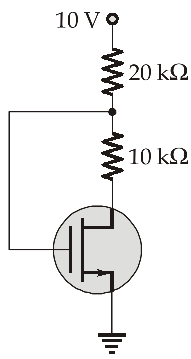
(c)



(d)



Q.61 Consider the transistor circuit shown in the figure below.



The transistor has parameter $\frac{\mu_n C_{ox} W}{2L} = 12.5\,\text{mA/V}^2$ and V_T = 1 V, then the value of V_{DS} is equal to ___________ V.

Q.62 Consider the clamper circuit shown below.

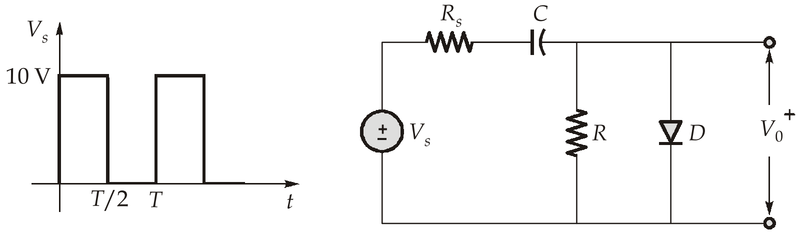


Figure 1

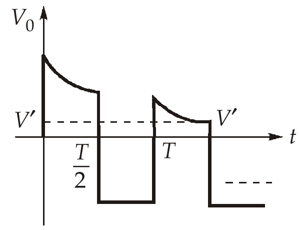
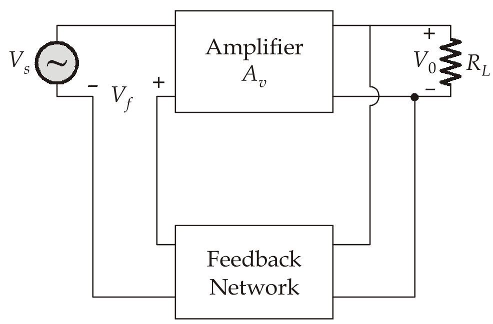


Figure 2

The diode D has a small signal forward resistance $R_f = 100\ \Omega$. The value of $R_s = 100\ \Omega$, $R = 100\ \text{k}\Omega$ and $C = 1\ \mu\text{F}$. The input to the circuit is a square wave $V_s(t)$ with amplitude of 10 V and frequency of 5 kHz. The output of the circuit is drawn in figure 2 which is created by neglecting the forward drop across the diode and the current flowing through resistance R, then the value of V' is equal to ________ V.

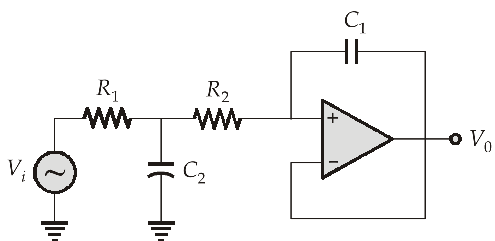
Q.63 Consider the block diagram of a feedback network shown in the figure below.



The circuit is operated by having an input voltage V_s = 100 mV, V_f = 95 mV and giving an output voltage V_0 = 10 V. Then the value of voltage gain A_v and feedback factor β is equal to

(a) $A_v = 200$ and $\beta = 0.837$
(b) $A_v = 2 \times 10^3$ and $\beta = 0.0095$
(c) $A_v = 100$ and $\beta = 0.095$
(d) $A_v = 3 \times 10^3$ and $\beta = 0.0635$

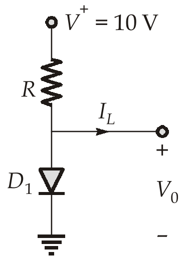
Q.64 Consider the active filter circuit shown in the figure below.



Then the transfer function of the filter can be given as
(Assume the op-amp to be ideal)

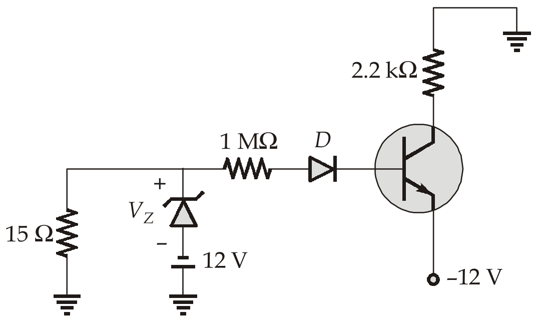
(a) $\dfrac{1}{(1+sR_1C_2)(1+\Delta R_2C_1)}$
(b) $\dfrac{1-sR_1C_2}{1+sR_2C_1}$
(c) $\dfrac{(1+sR_2C_1)}{(1+sR_1C_2)}$
(d) $\dfrac{1}{1+sR_1C_2}$

Q.65 Consider the circuit shown in the figure below.



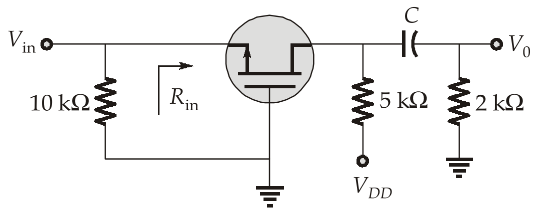
The value of I_L is sufficiently small so that the corresponding change in regulator output voltage ΔV_0 is small enough to justify using small signal model. The value of R is selected such that at no load the voltage across the diode is 0.7 V. Then the magnitude of I_D that results in a load regulation $\left(\frac{\Delta V_0}{I_L}\right) = 5$ mV/mA is equal to ________ mA. [Assume $\eta = 1$ and $V_T = 0.025$ V]

Q.66 Consider the transistor circuit shown in the figure below.



The forward drop of BJT and the diode is equal to 0.7 V and the Zener breakdown voltage $V_z = 5$ V. If $\beta = 30$ and $V_{CE\,(sat)} = 0.2$ V, then the current through collector is equal to ________ mA.

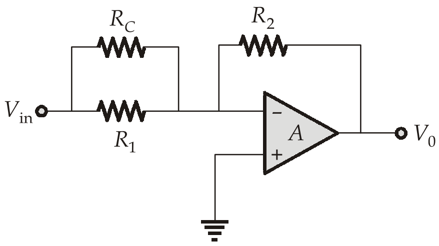
Q.67 Consider the transistor circuit shown in the figure below.



Assume the transistor is biased in saturation region with $g_m = 5$ mA/V. Then the value of input resistance R_{in} is equal to

(a) 500 Ω
(b) 250 Ω
(c) 200 Ω
(d) 728 Ω

Q.68 Consider the op-amp circuit shown in the figure below.

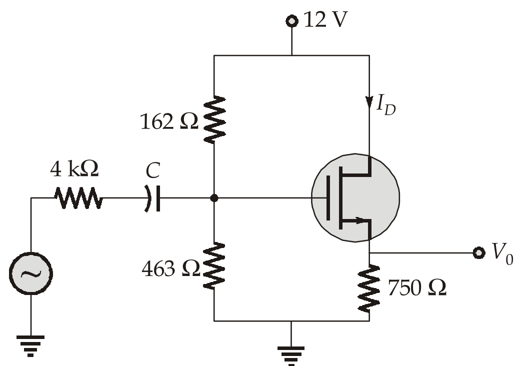


The op-amp is ideal except for having a finite open-loop gain and is used to realize the inverter circuit as can be seen from the figure above. The inverter has normal magnitude of gain $G = \frac{R_2}{R_1}$.

To compensate for the gain reduction due to finite gain A, a resistor R_C is shunted across R_1, then the value of R_c for a perfect compensation is equal to

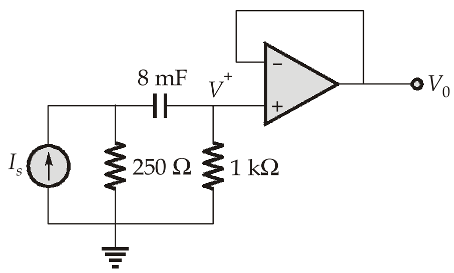
(a) $\frac{A-G}{1+G}R_1$
(b) $\frac{A+G}{A-G}\cdot R_1$
(c) $\frac{A-G}{1+G}\cdot R_1$
(d) $\frac{G}{A-G}\times R_1$

Q.69 Consider the circuit shown in the figure below. Transistors parameters are V_T = 1.5 V, $\frac{\mu_n C_{ox} W}{2L} = 4\text{ mA/V}^2$.



The small-signal transconductance of the amplifier is equal to ___________ mA/V.

Q.70 Consider the circuit shown in the figure below.



The source I_s = $5u(t)$ mA is connected to an RC circuit which in turn is connected to an ideal op-amp circuit. The value of output voltage V_0 at t = 5 sec will be __________ V.

Q.71 Consider the op-amp circuit shown in the figure below.

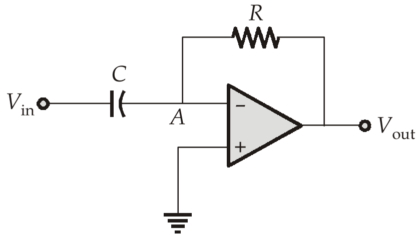


Figure (1)

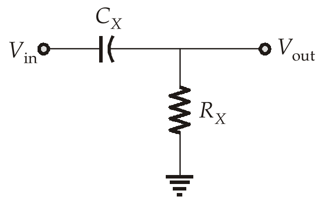
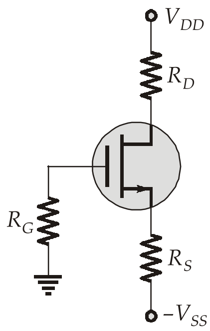


Figure (2)

The op-amp is an ideal op-amp except having a finite open loop gain of A_0. The above circuit can be modeled as a high pass filter as shown in figure 2. Then the condition for which the poles of figure 1 and figure 2 will concide can be given as

(a) $C_X = A_0C_1$ and $R_X = R_1/A_0$
(b) $C_X = (1 + A_0)C_1$ and $R_X = R_1(1 + A_0)$
(c) $C_X = (1 + A_0)$ and $R_X = R_1$
(d) $C_X = C_1/(1 + A_0)$ and $R_X = R_1$

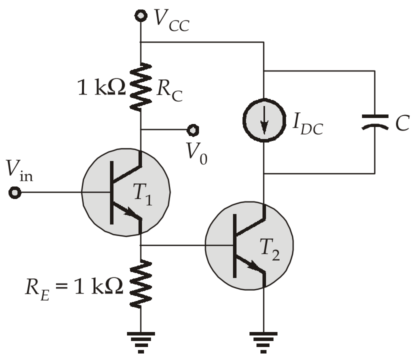
Q.72 A MOS transistor is biased at a drain current of I_D, with $K = \frac{1}{2}\mu_n C_{ox}\frac{W}{L} = 100\ \mu A/V$ and $V_T = 1$ V as shown in the figure below.



The value of k varies ±10% of the actual value, then the value of R_s that would result in $I_D = 100\ \mu A$ with a variablity of ±1% is equal to

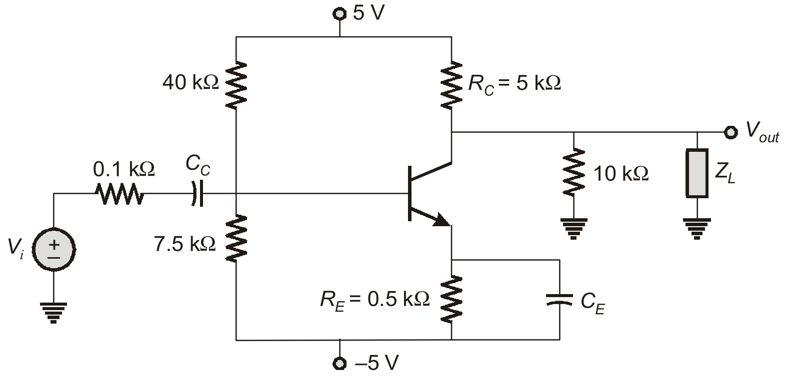
(a) 35 kΩ
(b) 45 kΩ
(c) 55 kΩ
(d) 65 kΩ

Q.73 Consider the circuit shown in the figure below.



The transistors T_1 and T_2 are identical with β = 100. They are biased in such a way that $g_{m1} = 5$ mA/V and $g_{m2} = 100$ mA/V. The magnitude of small signal voltage gain of the amplifier $A_v = \left|\frac{V_0}{V_{in}}\right|$ is equal to ________ V/V.

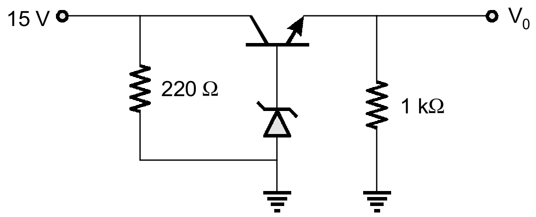
Q.74 Consider the common emitter circuit as shown in the figure below:



A load is connected to the transistor with $Z_L = \dfrac{-j\times10^{12}}{30\pi f}\,\Omega$. Due to this load a cut-off frequency of the circuit is f_H, where $f_H = \dfrac{1}{2\pi\tau_L}$. Then the value of τ_L is _______ nsec.

Multiple Select Questions (MSQ)

Q.75 In the regulator circuit shown below, V_z = 12 V, β = 50, V_{BE} = 0.7 V.



Then which of the following is/are correct?

(a) Current through zener diode is 13.41 mA.

(b) Output voltage (V_0) is 11.3 V.

(c) Current through zener diode is 15.63 mA.

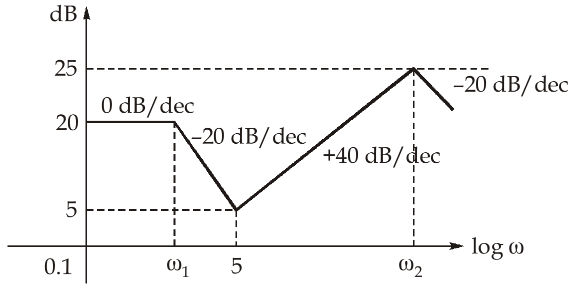
(d) Output voltage (V_0) is 10.7 V.

■■■■

Detailed Explanations

51. **(b)**

The given Bode plot is



Here, at frequency ω_1 the slope of the line changes from 0 dB/dec to –20 dB/dec hence,

$$G_1(s) = \frac{1}{\left(1+\frac{s}{\omega_1}\right)}$$

where, ω_1 can be calculated as,

$$-20 = \frac{20-5}{\log\omega_1 - \log 5}$$

$$-20 = \frac{-15}{\log\left(\frac{5}{\omega_1}\right)}$$

$$\log\left(\frac{5}{\omega_1}\right) = \frac{15}{20}$$

$$\omega_1 = \frac{5}{5.623} = 0.89 \text{ rad/sec}$$

At the corner frequency of 5 rad/sec the slope of the line again changes to +40 dB/dec hence,

$$G_2(s) = \left(1+\frac{s}{5}\right)^3$$

Now, at corner frequency of ω_2 the slope of the line changes to –20 dB/dec.

$$\therefore \qquad G_3(s) = \frac{1}{\left(1+\frac{s}{\omega_2}\right)^3}$$

where, ω_2 can be calculated as

$$40 \text{ dB/dec} = \frac{25-5}{\log\omega_2 - \log 5}$$

$$40 = \frac{20}{\log\left(\frac{\omega_2}{5}\right)}$$

$$\log\left(\frac{\omega_2}{5}\right) = \frac{1}{2}$$

$$\omega_2 = 5 \times 3.16$$
$$= 15.81 \text{ rad/sec}$$

∴ Overall transfer function becomes,

$$T(s) = K \times G_1(s) \times G_2(s) \times G_3(s)$$

$$= \frac{K\left(1+\frac{s}{5}\right)^3}{\left(1+\frac{s}{0.89}\right)\left(1+\frac{s}{15.81}\right)^3}$$

∵ $20 \log K = 20$

∴ $K = 10$

and therefore, $T(s) = \dfrac{10\times 0.89\times 15.81^3 (s+5)^3}{5^3\,(s+0.89)(s+15.81)^3} = \dfrac{281.37(s+5)^3}{(s+0.89)(s+15.81)^3}$

52. (12.5) (12 to 13)

Resonance peak,

$$M_r = \frac{1}{2\xi\left(\sqrt{1-\xi^2}\right)}$$

Here, $G(s) = \dfrac{K}{s(1+0.1s)}$

∴ $T(s) = \dfrac{K}{s+0.1s^2+K} = \dfrac{10K}{s^2+10s+10K}$

On comparing with second order transfer function, we have,

$$2\xi\omega_n = 10$$

$$\omega_n = \sqrt{10\text{ K}}$$

Now, $M_r = \dfrac{1}{2\xi\sqrt{1-\xi^2}} = 1.25$

∴ $4\xi^2(1-\xi^2) = \left(\dfrac{1}{1.25}\right)^2 = 0.64$

$$\xi^4 - \xi^2 + 0.16 = 0$$

$$\xi^2 = 0.8 \text{ and } 0.2$$

∴ $\xi = 0.89$ and 0.447

For $\xi = 0.447$

$$\omega_n = \frac{10}{2\xi} = \frac{10}{2\times 0.447} = 11.18$$

and $K = \dfrac{\omega_n^2}{10} = 12.5$

53. (a)

$$G(s) = \frac{K}{s(1+s)(1+0.1s)}$$

$$= \frac{K}{s(1+s+0.1s+0.1s^2)}$$

$$= \frac{K}{(0.1s^3+1.1s^2+s)}$$

converting $s = j\omega$ we get,

$$G(j\omega) = \frac{K}{-1.1\omega^2 + j\omega(1-0.1\omega^2)}$$

at the phase crossover frequency ω_{PC} the imaginary part is zero, hence, by putting $\omega = \omega_{PC}$ in the imaginary part and equating it to zero, we get,

$$\omega_{PC}\left(1-0.1\omega_{PC}^2\right) = 0$$

$$1-0.1\omega_{PC}^2 = 0$$

$$\omega_{PC} = \sqrt{10} = 3.162 \text{ rad/sec}$$

$\because$ $GM = 20$ dB

$\therefore$ $20 \log GM = 20$ dB

$GM = 10$

Hence,
$$\frac{1}{|G(j\omega)|_{\omega=\omega_{PC}}} = 10$$

$$\frac{1}{0.0909K} = 10$$

or
$$K = \frac{1}{0.0909\times 10} = 1.101$$

54. (4)

$$\frac{K}{s^2}+1 = 0$$

$$\Rightarrow \quad \frac{K}{(j2)^2}+1 = 0$$

$$\Rightarrow \quad -\frac{K}{4}+1 = 0$$

$$\Rightarrow \quad K = 4$$

55. (a)

The steady state error can be calculated as

$$e_{ss} = \lim_{s \to 0} \frac{sR(s)}{1+G(s)H(s)}$$

For unit step input, $R(s) = \frac{1}{s}$

$$e_{ss} = \lim_{s \to 0} \frac{1}{1+G(s)} = 0.5 \quad \text{(given)}$$

or

$$\frac{1}{1+G(0)} = 0.5$$

$$1 + G(0) = 2$$

$$G(0) = 1 \quad \text{...(i)}$$

For the given input,

$$r(t) = 50\,[u(t) - u(t-5)]$$

$$R(s) = 50\left[\frac{1}{s} - \frac{1}{s}e^{-5s}\right]$$

$$R(s) = 50\left(\frac{1-e^{-5s}}{s}\right)$$

∴ Steady state error

$$e_{ss}' = \lim_{s \to 0} \frac{s \times 50(1-e^{-5s})}{s(1+G(s))}$$

$$= \frac{50(1-e^{0})}{1+G(0)} = 25(1-1) = 0$$

56. (100)

$$(K_V)_{\text{uncompensated}} = \lim_{s \to 0} sG(s)H(s)$$

$$= \lim_{s \to 0} \frac{100}{(s+1)} = 100$$

$$(K_V)_{\text{compensated}} = \lim_{s \to 0} s \times G(s)H(s) \times G_c(s)$$

$$= \lim_{s \to 0} s \times \frac{100}{s(s+1)} \times \frac{(s+10)}{(s+a)}$$

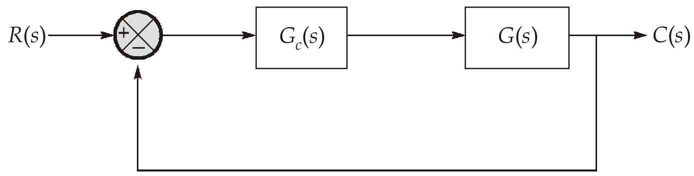
$$10 = \frac{100 \times 10}{a} \quad \text{or} \quad a = 100$$

57. **(c)**

Let us assume that the transfer function of the compensator is

$$G_c(s) = \frac{K(s+a)}{(s+b)}$$

∴ The block diagram of the system can be drawn as



$$\frac{C(s)}{R(s)} = \frac{G_c(s)G(s)}{1+G_c(s)G(s)}$$

$$= \frac{\frac{K(s+a)}{(s+b)} \times \frac{10}{s(s+2)}}{1+\frac{K(s+a)}{(s+b)} \times \frac{10}{s(s+2)}}$$

$$= \frac{10K(s+a)}{s(s+2)(s+b)+10K(s+a)}$$

$$= \frac{10K(s+a)}{s^3+2s^2+s^2b+2bs+10Ks+10Ka}$$

Characteristic equation is

$s^3 + (2 + b)s^2 + (2b + 10K)s + 10\,Ka = 0$ ...(i)

according to the question the new characteristic equation is

$$(s + 1)(s + 3)(s + 5) = 0$$

$$(s^2 + s + 3s + 3)(s + 5) = 0$$

$$s^3 + s^2 + 3s^2 + 3s + 5s^2 + 20s + 15 = 0$$

$$s^3 + 9s^2 + 23s + 15 = 0 \quad \text{...(ii)}$$

From equation (i) and (ii)

$$2 + b = 9$$

$\Rightarrow$ $b = 7$

$$2b + 10K = 23$$

$$10K = 23 - 14$$

$$10K = 9$$

$\Rightarrow$ $K = 0.9$

and $10Ka = 15$

$\Rightarrow$ $a = \frac{15}{10} \times \frac{10}{9} = 1.67$

∴ $G_c(s) = \frac{0.9(s+1.67)}{(s+7)}$

58. **(9.89) (9.50 to 10.00)**

The characteristic equation of the closed loop system is

$$1 + G(s)H(s) = 0$$

$$1+\frac{K(s+2)}{s(s-1)} = 0$$

$$s^2 + (K-1)s + 2K = 0 \quad \text{...(i)}$$

Using Routh's tabular form, we have,

s^2	1	$2K$
s^1	$K-1$	0
s^0	$2K$	

For system to be stable,

$$K - 1 > 0$$

or $$K > 1$$

$\therefore$ On comparing equation (i) with standard characteristic equation, we have

$$\omega_n = \sqrt{2K}$$

and $$2\xi\omega_n = (K-1)$$

For $\xi = 1$,

$$2 \times \omega_n = (K-1)$$

or $$2\times\sqrt{2K} = (K-1)$$

or $$4(2K) = K^2 - 2K + 1$$

$$K^2 - 10K + 1 = 0$$

$\therefore$ $$K = 0.10 \text{ and } 9.89$$

$\because$ $K > 1$ for stable operation.

$\therefore$ $K = 9.89$ is the valid answer.

59. **(c)**

$$\text{Gain} = -\frac{R_L}{R_1} = \frac{-R_2(1\pm x\%)}{R_1(1\pm x\%)}$$

$\therefore$ $$G_{max} = \frac{-R_2(1+x\%)}{R_1(1-x\%)} = \frac{-R_L\left(1+\frac{5}{100}\right)}{R_1\left(1-\frac{5}{100}\right)}$$

$$= \frac{-100(1+0.05)}{10(1-0.05)} = -10\times\frac{1.05}{0.95} \approx -11 \text{ V/V}$$

$$G_{min} = \frac{-R_L\left(1-\frac{5}{100}\right)}{R_1\left(1+\frac{5}{100}\right)} = -10\times\frac{0.95}{1.05} \approx -9 \text{ V/V}$$

60. **(c)**

The diodes D_1, D_3 and D_z will limit the voltage for positive cycle and diodes D_2, D_4 and D_z will limit the output voltage in the (negative) cycle.

Note : The Zener diode will always be in reverse biased for both the cases.

$\therefore \quad V_{in} = V_{out}$

for $-(0.65 \times 2 + 8.2) < V_{in} < (0.65 \times 2 + 8.2)$

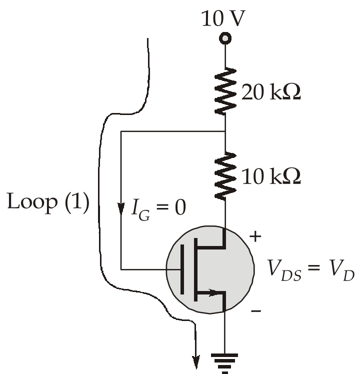
$-9.5 < V_{in} < 9.5$

and $\quad V_{out} = kV_{in} + b$ for $|V_{in}| > 9.5$

Hence, only figure (c) is according to the given conditions.

61. **3.10 (2.80 to 2.40)**

Applying KVL in drain to source loop, we get,



$$10 - (30\text{ k})I_D - V_{DS} = 0$$

$\therefore \quad V_{DS} = 10 - 30I_D \qquad$ (Assuming I_D to be in mA)

now, $\quad I_D = \dfrac{\mu_n C_{ox} W}{2L}(V_{GS} - V_T)^2$

Applying KVL in loop (1), we get,

$$V_{GS} = 10 - 20I_D$$

$$I_D = 12.5 \times 10^{-3}[10 - 20I_D - 1]^2$$

On solving, we get, $\quad I_D = 1$ mA and 0.2 mA

Now, $\quad V_{GS} = 10 - 20I_D = 10 - 20 \times 1 = -10 \qquad$ which is not possible

Hence $I_D = 0.2$ mA

$\therefore \quad V_{DS} = 10 - 30 \times 0.2$

$\qquad = 10 - 6 = 4$ V

and $\quad V_{GS} = 10 - 20 \times 0.2 = 6$ V

$\therefore V_{DS} < V_{GS} - V_T$

Hence, MOS is working in linear region.

Thus, $\quad I_D = \dfrac{\mu_n C_{ox} W}{2L}\left[2(V_{GS} - V_T)V_{DS} - V_{DS}^2\right]$

$$I_D = 12.5 \times 10^{-3}\,[2 \times (10 - 20I_D - 1)\,(10 - 30I_D) - (10 - 30I_D)^2]$$

Thus the equation reduces to

$$300I_D^2 - 420I_D + 80 = 0$$

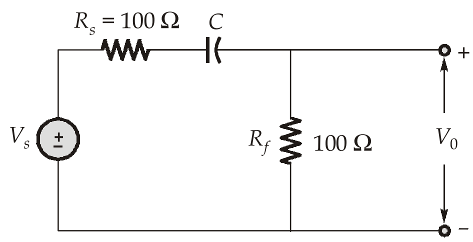
$\therefore \quad I_D = 1.17 \text{ mA}, 0.23 \text{ mA}$

$\therefore \quad I_D = 0.23 \text{ mA}$

$\therefore \quad V_{DS} = 10 - 30 \times 0.23 = 3.1 \text{ V}$

62. 1.84 (1.60 to 2.00)

The capacitor is initially uncharged hence for the first positive cycle the circuit can be redrawn as



$$\therefore \quad V_0 = 10 \times \frac{100}{100+100} = 5 \text{ V}$$

thus for $t = 0$, $V_0 = 5$ V

Now, the capacitor will start charging with time constant τ

$\therefore \quad \tau = (100 + 100) \times 1 \times 10^{-6} = 200 \text{ μF}$

$$\therefore \quad V_0\left[t = \frac{T}{2}\right] = 5 \cdot e^{\frac{-T/2}{T}} = 5e^{-1/2} = 3.03 \text{ V}$$

Thus for (positive) cycle, the value of $V_0 = V_s - V_c$

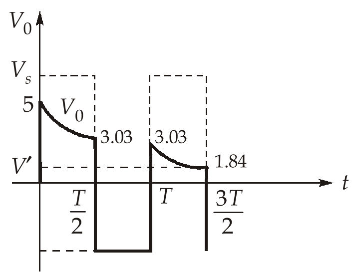
Where V_s = Input voltage = 0 V

V_c = Voltage across capacitor = –3.94 V

Now, for the second cycle, the amplitude will again be equal to 3.03 V.

$$\therefore \quad V_0\left[t = \frac{3T}{2}\right] = 3.03\,e^{-1/2} = 1.837 \approx 1.84 \text{ V}$$

$$V' = 1.84 \text{ V}$$



63. (b)

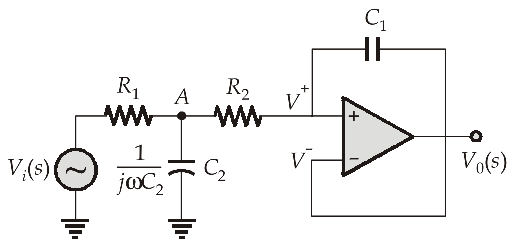
$$A_v = \frac{V_0}{V_i}$$

now, $$V_i = V_s - V_f = 100 - 95 = 5 \text{ mV}$$

$$A_v = \frac{10}{5} \times 10^3 = 2 \times 10^3 \text{ V/V}$$

and $$\beta = \frac{V_f}{V_0} = \frac{95 \times 10^{-3}}{10} = 9.5 \times 10^{-3} \text{ V/V}$$

64. (d)



In ideal op-amp $\quad V^+ = V^-$

So, $\quad V^+ = V^- = V_0 \quad$ (Due to virtual grouding)

(Since the voltage drop across capacitor is zero, thus there will be no current flowing through capacitor C_1 and thus no current will flow through R_2)

$\therefore \quad V_A = V_0(s)$

Applying KCL at node A,

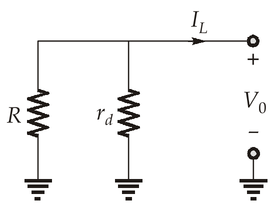
$$\frac{V_0(s) - V_i(s)}{R_1} + \frac{V_0(s) - 0}{1/j\omega C_2} = 0$$

So, $$V_0(s)\left[\frac{1 + j\omega C_2 R_1}{R_1}\right] = \frac{V_i(s)}{R_1}$$

$$\frac{V_0(s)}{V_i(s)} = \frac{1}{1 + j\omega R_1 C_2}$$

65. 4.987 (4.50 to 5.50)

Drawing the small signal equivalent of the circuit, we get,



$\therefore$ $$\Delta V_0 = -I_L(R \parallel r_d)$$

$$\frac{\Delta V_0}{I_L} = -R \parallel r_d$$

$$\frac{\Delta V_0}{I_L} = -\frac{1}{\frac{1}{R} + \frac{1}{r_d}}$$

now, $r_d = \frac{\eta V_T}{I_D} = \frac{V_T}{I_D}$ $[\because \eta = 1]$

and $R = \frac{V^+ - 0.7}{I_D}$

thus, $\frac{\Delta V_0}{I_L} = \frac{-1}{\frac{I_D}{V^+ - 0.7} + \frac{I_D}{V_T}}$

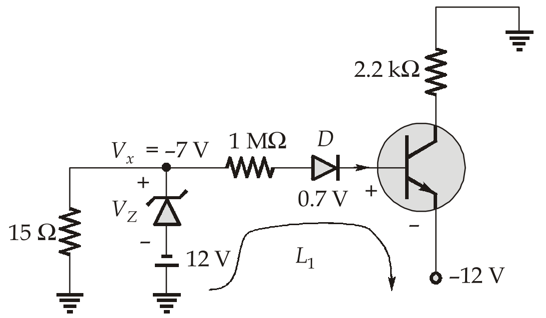
$$\frac{\Delta V_0}{I_L} = -\frac{V_T}{I_D} \cdot \frac{V^+ - 0.7}{V^+ - 0.7 + V_T}$$

$$\therefore \quad -\frac{V_T}{I_D} \cdot \frac{V^+ - 0.7}{V^+ - 0.7 + V_T} = \frac{5 \times 10^{-3}}{10^{-3}}$$

$$-\frac{0.025}{I_D} \cdot \frac{10 - 0.7}{10 - 0.7 + 0.025} = 5$$

$$|I_D| = \frac{0.025}{5} \times \frac{10 - 0.7}{10 - 0.7 + 0.025} = 4.987 \text{ mA}$$

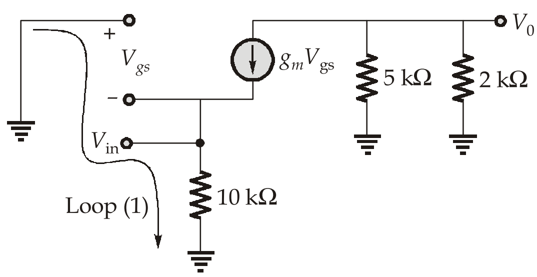
66. 0.108 (0.08 to 0.12)



Applying KCL in loop 'L_1' we get,
$12 - 5 + 1 \times I_B + 0.7 + 0.7 - 12 = 0$

$$I_B = 3.6 \text{ μA}$$
$$I_C = 30 \times 3.6 \text{ μA}$$
$$= 108 \text{ μA} = 0.108 \text{ mA}$$

67. (c)



Applying KVL in loop (1), we get,

$$V_{in} + V_{gs} = 0$$

$$V_{in} = -V_{gs}$$

now, $$i_{in} = g_m V_{gs}$$

$\therefore$ $$R_{in} = \frac{V_{in}}{i_{in}} = \frac{V_{gs}}{g_m V_{gs}} = \frac{1}{g_m} = \frac{1}{5\times10^{-3}} = 200\ \Omega$$

68. (a)

Let, $$R_1' = R_1 \| R_c$$

$\therefore$ $$G' = \frac{-R_2/R_1}{1+\frac{1}{A}\left(1+\frac{R_2}{R_1}\right)} \qquad [\because \text{'}A\text{' is finite}]$$

Expected Gain $$G = \frac{-R_2}{R_1}$$

$\therefore$ We are asked condition for $G' = G$.

$\therefore$ $$\frac{-R_2/R_1'}{1+\frac{1}{A}\left(1+\frac{R_2}{R_1'}\right)} = \frac{-R_2}{R_1}$$

$$\frac{1}{R_1} + \frac{1}{R_1 A}\left[1+\frac{R_2}{R_1'}\right] = \frac{1}{R_1'}$$

now, $$R_1' = \frac{R_1 R_C}{R_1 + R_C}$$

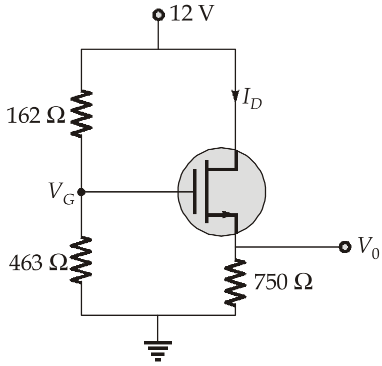
$\therefore$ $$\frac{R_1+R_C}{R_1 R_C} = \frac{1}{R_1}\cdot\left[1+\frac{1+R_2\left(\frac{R_1+R_C}{R_1 R_C}\right)}{A}\right]$$

$$(R_1 + R_C)A = AR_C + R_C + \frac{R_2}{R_1}(R_1+R_C)$$

$$R_1 A = R_C + GR_1 + GR_C \qquad \left[\because \frac{R_2}{R_1} = G\right]$$

$\therefore$ $$R_C = \frac{A-G}{1+G}R_1$$

69. **11.28 (11.00 to 11.50)**



$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_T)^2$$

$$\frac{8.88-V_{GS}}{750\ \Omega} = 4\times10^{-3}(V_{GS}-1.5)^2$$

$$3V_{GS}^2-8V_{GS}-2.13 = 0$$

$$\therefore \quad V_{GS} = 2.91\text{ V},\ -0.243\text{ V}$$

$$V_{GS} = 2.91\text{ V}$$

$$g_m = \mu_n C_{ox}\frac{W}{L}(V_{GS}-V_T) = 2\times4\times10^{-3}(2.91-1.5)$$

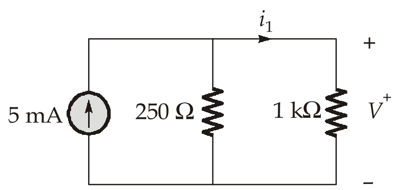
$$g_m = 11.28\text{ mA/V}$$

70. **0.6 (0.40 to 0.80)**

$$V_{out} = V^+$$

Since op-amp is used as a voltage buffer $V_0 = V^+$

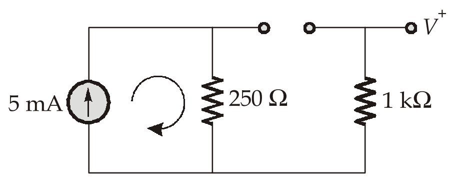
Thus, $V^+(0)$ can be given as



$$i_1 = \frac{250}{250+1000}\times5\times10^{-3}\text{ A} = \frac{250}{1250}\times5\times10^{-3}$$

$$i_1 = 1\text{ mA}, \qquad \therefore\ V^+(0^+) = 1\times10^3\times1\times10^{-3} = 1\text{ V}$$

At $t = \infty$, we have



Thus, $\quad V^+(\infty) = 0\text{ V}$

Time constant, $\quad \tau = R_{eq}C$

$$R_{eq} = 250 + 1000 = 1250\ \Omega$$

$$\therefore \quad \tau = 1250 \times 8 \times 10^{-3} \text{ sec}$$
$$= 10 \text{ sec}$$

$$\therefore \quad V^+(t) = V^+(\infty) + (V^+(0^+) - V^+(\infty))e^{-t/\tau} = V^+(0)\cdot e^{-t/\tau} = e^{-t/10} \text{ Volts}$$

for $t = 5$ sec

$$V^+(5) = \exp\left[-\frac{5}{10}\right]\text{Volts} = \exp\left[-\frac{1}{2}\right] = \exp(-0.5)$$
$$V_0 = V^+(5 \text{ sec}) = 0.6 \text{ Volts}$$

71. (d)

For figure 2, we have

$$\frac{V_{out}}{V_{in}} = \frac{R_X}{R_X + \frac{1}{sC_X}} = \frac{(R_X C_X)s}{s(R_X C_X)+1}$$

From figure 1 applying KCL at input node A, we get,

$$\frac{V_{in} - V_A}{1/sC_1} = \frac{V_X - V_{out}}{R_1}$$

now, $$V_A = \frac{-V_{out}}{A_0}$$

$$\therefore \quad \frac{V_{out}}{V_{in}} = \frac{-(R_1C_1)s}{1 + \frac{1}{A_0} + \frac{R_1C_1 s}{A_0}}$$

$\therefore$ Equating the poles of the two system, we get,

$$\frac{1}{R_X C_X} = \frac{A_0 + 1}{R_1 C_1}$$
$$C_X = C_1$$
$$\therefore \quad R_X = \frac{R_1}{1 + A_0}$$
or $$R_X = R_1$$
$$C_X = \frac{C_1}{1 + A_0}$$

72. (b)

$$I_D = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS} - V_T)^2$$
$$= K(V_{GS} - V_T)^2$$

now, $V_G = 0$ and $V_s = +I_D R_S - V_{SS}$

$$\therefore \quad I_D = K(V_{SS} - I_D R_S - V_T)^2$$

$$\frac{\partial I_D}{\partial K} = (V_{SS} - I_D R_S - V_T)^2 + 2K(V_{SS} - I_D R_S - V_T)(-R_S)\cdot\frac{\partial I_D}{\partial K}$$

$$\frac{\partial I_D}{\partial K} = \frac{I_D}{K} - 2R_s\sqrt{\frac{I_D}{K}}\cdot K\frac{\partial I_D}{\partial K}$$

$$\therefore \quad \frac{\partial I_D / I_D}{\partial K / K} = \frac{1}{1 + 2R_S\sqrt{I_D K}}$$

now, given K = 100 μA/V, $\frac{\Delta K}{K} = 10\%$, V_T = 1 V, I_D = 100 μA and $\frac{\Delta I_D}{I_D} = 1\%$

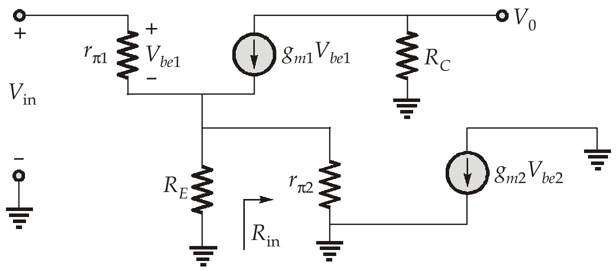
$$\frac{1}{10} = \frac{1}{1 + \left(2\sqrt{100\times10^{-3}\times100\times10^{-3}\times10^{-6}}\right)R_S}$$

$$1 + \left(2\sqrt{10\times10^{-3}\times10^{-6}}\right)R_S = 10$$

$$R_S = 45 \text{ k}\Omega$$

73. (1.428) (1.30 to 1.60)

Drawing small signal equivalent circuit of the circuit, we get,



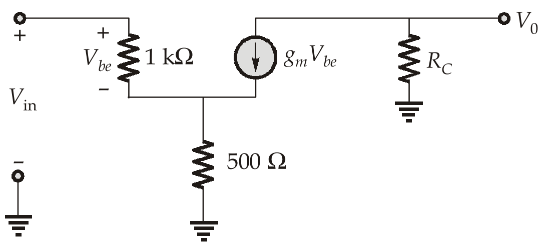
$$R_{in} = r_{\pi_2} = \frac{\beta}{g_{m_2}} = \frac{100}{100\times10^{-3}} = 1\text{ k}\Omega$$

Thus, $$R_E' = R_E \| r_{\pi_2}$$

$$= 1\text{ k}\Omega \| 1\text{ k}\Omega$$

$$= 0.5 \text{ k}\Omega = 500\ \Omega$$

now, the equivalent circuit can be drawn as



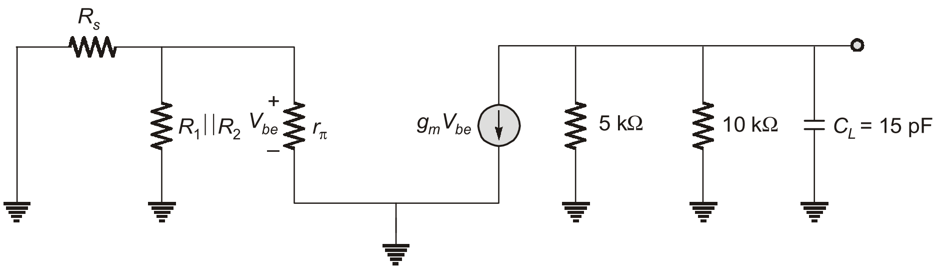
Thus, $$\left|\frac{V_0}{V_{in}}\right| = \frac{g_{m_1}R_C}{1 + g_{m_1}R_E'} = \frac{5\times10^{-3}\times1\times10^3}{1+500\times5\times10^{-3}} = 1.428\text{ V/V}$$

74. (50)

$$\because \quad Z = \frac{-j\times 10^{12}}{30\pi f} = \frac{1}{2\pi f(15\times 10^{-12})}\ \Omega$$

$\therefore$ The value of the load is 15 pF and it is purely capacitive

now drawing the small signal model for the circuit and shorting all the capacitors and sources, we get



Now, current source can be open circuited. Thus

$$\tau_L = (5\text{ k}\Omega\ ||\ 10\text{ k}\Omega)\cdot 15\times 10^{-12}$$

$$= \frac{50}{15}\times 15\times 10^{-9} = 50\text{ nsec}$$

75. (a, b)

$$V_0 = V_z - V_{BE} = 12 - 0.7 = 11.3\text{ V}$$

$$V_{CE} = V_i - V_0 = 15 - 11.3 = 3.7\text{ V}$$

$$I_{220\,\Omega} = \frac{15-12}{220} = 13.63\text{ mA}$$

$$I_{1\text{ k}\Omega} = \frac{V_0}{1}\text{ mA} = \frac{11.3}{1}\text{ mA}$$

$$= 11.3\text{ mA}$$

$$I_C = I_{1\text{ k}\Omega}$$

$$I_B = \frac{I_C}{\beta} = \frac{11.3}{50}\text{ mA}$$

$$= 0.226\text{ mA}$$

$$\therefore \quad I_z = I_{220\,\Omega} - I_B = 13.636 - 0.226$$

$$= 13.41\text{ mA}$$

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