1. (a) **Concept:**

Determinant = Product of eigen values
Trace = Sum of eigen values

Solution:
Options (b) and (d) satisfy product property only, (c) satisfies sum property only, but only (a) satisfies both.

Reference: Higher Engineering Mathematics by B S Grewal, Properties of eigenvalues.

2. (c) **Concept:**

1. If $\lambda_1, \lambda_2, \lambda_3 \ldots \lambda_n$ are eigen values of A then $\lambda_1^m, \lambda_2^m, \lambda_3^m \ldots \lambda_n^m$ are eigen values of A^m.
2. If λ is eigen value of A then the eigen value of A^m+kI is λ^m+k.
3. Determinant = Product of eigen values.

Solution:
The eigen values of $A^{100} + 2I$ are

$$(-1)^{100} + 2 = 3,$$
$$(-1)^{100} + 2 = 3,$$
$$(0)^{100} + 2 = 2,$$
$$(1)^{100} + 2 = 3,$$
$$(1)^{100} + 2 = 3.$$

$$|A^{100} + 2I| = 3 \times 3 \times 2 \times 3 \times 3$$
$$|A^{100} + 2I| = 162$$

Reference:
Higher Engineering Mathematics by B S Grewal, properties of eigenvalues, page 73

3. (c) **Concept and Solution:**

The charging time constant R_sC must be short compared with the carrier period $1/f_c$ that is $R_sC << 1/f_c$, so that the capacitor C charges rapidly and thereby follows the applied voltage up to the positive peak when the diode is conducting. On the other hand, the discharging time constant R_lC must be long enough to ensure that the capacitor discharges slowly through the load resistor R_l between positive peaks of the carrier wave, but not so long that the capacitor voltage will not discharge at the maximum rate of change of the modulating wave, that is $1/f_c<<R_lC<<1/W$, where W is the message bandwidth.

$$\Rightarrow R_sC \ll \frac{1}{f_c} \ll R_LC \ll \frac{1}{W}$$

For another explanations refer:
http://www.st-andrews.ac.uk/~www_pa/Scots_Guide/RadCom/part9/page2.html

4. (c) **Concept:**

Image Rejection Ratio=$\sqrt{1+Q^2\rho^2}$, Where $\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}}$

Solution:

$f_s = 1000\text{KHz}, \text{IF} = 455\text{KHz}, \text{Q} = 100$

$f_{si} = f_s + 2(IF) = 1910KHz$

$\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}}$ =1.386

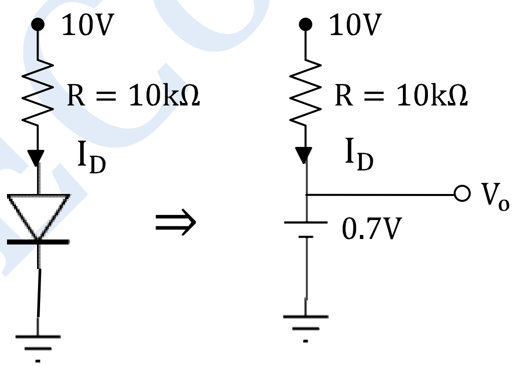
Thus, Image Rejection Ratio= $\sqrt{1+Q^2\rho^2}$ = 138.64

5. (d) **Concept:** In case of semiconductor devices analysis: first, do dc analysis to find the biasing of the device, then ac analysis because dc analysis will give the region in which device is operating.

Solution: $V(t) = 10 + \sin 100\pi t$

So, we have to compute biasing current for diode, then calculate small resistance & find small signal due to ac component - sin 100πt.

DC Analysis:



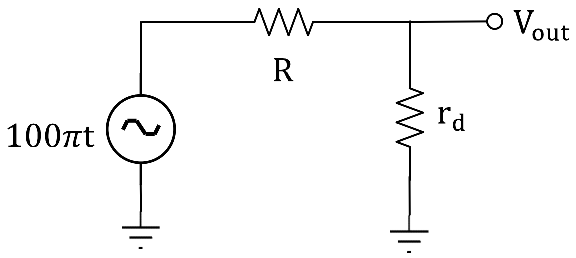
$\therefore 10 - I_D \times 10k = 0.7$

$\therefore I_D = 9.3\text{mA}$

Now, small signal resistance

$$r_d = \frac{\eta V_T}{I_D} = \frac{2 \times 26 \times 10^{-3}}{0.93 \times 10^{-3}} = 55.91\Omega$$

AC Analysis:



$$V_{out} = \frac{r_d}{r_d + R} \cdot V_{in} = 5.56 \times 10^{-3} \sin 100\pi t$$

$$V(t) = DC_{component} + AC_{component}$$

$$V(t) = 0.7 + 5.56 \times 10^{-3} \sin 100\pi t$$

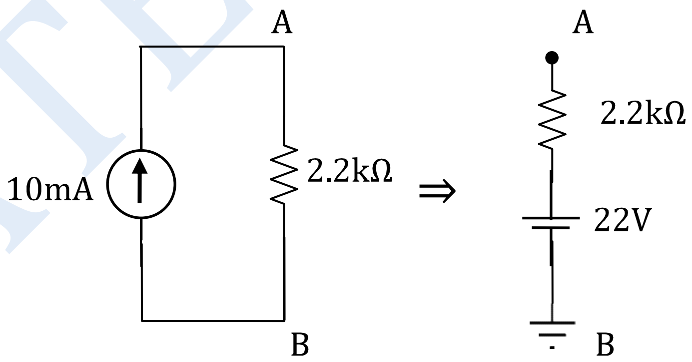
Reference: Electronic devices and circuit theory by Boylestead

6.(c) **Concept:**

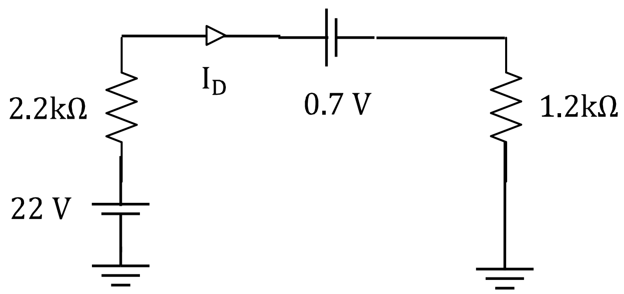
1. Whenever the cut-in voltage for diode is given, replace it by DC voltage of that value with appropriate polarity, if it is forward-biased.
2. Convert voltage source to current source or vice versa whichever simplifies the problem. E.g. voltage source is easier to deal in a series circuit, while current source in parallel circuit.

Solution:

Reducing left part by source transformation



The Circuit reduces to



$$I_D = \frac{22 - 0.7}{2.2 + 1.2} = 6.264 \times 10^{-3}\text{A}$$

$$V_{out} = I_D \times 1.2\text{k}$$

$$V_{out} = 7.517 \text{ Volts}$$

7. (d) **Concept**:

Dominant Pole: In multi pole system, pole with the lowest value is dominant if difference is more than or equal to 10. (Since we assume any exponential response dies after 5 time constants, pole with high value will have less time constant as τ is inversely proportional to –ve of the pole.)

Solution:

$$H(s) = \frac{1}{(s+1)(s+10)(s+100)} = \frac{A}{s+1} + \frac{B}{s+10} + \frac{C}{s+100}$$

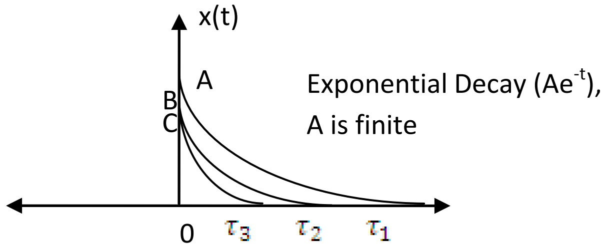
$\Rightarrow$ A=0.001 and,

$$\Longrightarrow h(t) = A.e^{-t} + B.e^{-10t} + C.e^{-100t}$$

Here, $\tau_1 = 1,\ \tau_2 = 0.1,\ \tau_3 = 0.01$

τ_2, τ_3 are very small compared to τ_1, hence, the responses related to τ_2, τ_3 will die quickly and will be negligible compared to response related to τ_1.

So, the equivalent impulse response is $h(t) = A.e^{-t} \ \Longrightarrow H(s) = \frac{A}{s+1}$



Shortcut: Write H(s) in standard form and remove the pole having difference 10 with the lowest pole.

Reference: Control systems Engineering. By Nagrath, Gopal

8. (c) **Concept:** $C(\omega) = H(\omega)R(\omega) \Longrightarrow c(t) = h(t) \otimes r(t)$

If $r(t) = e^{-j\omega_0 t}$,

$$c(t) = h(t) \otimes e^{-j\omega_0 t} = \int h(\tau)\, e^{-j\omega_0(t-\tau)} d\tau = \int h(\tau)\, e^{-j\omega_0 t} e^{j\omega_0 \tau} d\tau$$

$$= e^{-j\omega_0 t}. \int h(\tau)\, e^{j\omega_0 \tau} d\tau = e^{-j\omega_0 t}\, H(\omega_0)$$

$$\Longrightarrow c(t) = H(\omega_0). e^{-j\omega_0 t}$$

Solution: Here, r(t)= 5cos(6t+36^0) ; $\omega_0 = 6$

$$c(t) = \frac{1}{j6+3}\, r(t) = \frac{1}{\sqrt{36+9}} \angle(-\tan^{-1} 2)\, r(t)$$

$$= \frac{5}{\sqrt{45}} \cos(6t + 36^0 - \tan^{-1} 2)$$

$$= \frac{\sqrt{5}}{3} \cos(6t - 27.43^0)$$

Hint: We do not know exact value of $\tan^{-1} 2$ but can say it is greater than 45^0, because, tan is increasing and $\tan^{-1} 1 = 1$

9. (a and b)

Concept: Reflection coefficient, $|\Gamma| = \left|\frac{Z_L - Z_0}{Z_L + Z_0}\right|$ and VSWR= $\frac{1+|\Gamma|}{1-|\Gamma|}$

Solution:

(a) Short Load, Reflection Coefficient $|\Gamma| = \left|\frac{Z_L - Z_0}{Z_L + Z_0}\right| = 1$ since Z_L=0 and, VSWR= $\frac{1+|\Gamma|}{1-|\Gamma|} = \infty$

(b) Open Load, Reflection Coefficient $|\Gamma| = \left|\frac{Z_L - Z_0}{Z_L + Z_0}\right| = \lim_{Z_L \to \infty} \left|\frac{1 - \frac{Z_0}{Z_L}}{1 + \frac{Z_0}{Z_L}}\right| = 1$ and,

VSWR= $\frac{1+|\Gamma|}{1-|\Gamma|} = \infty$

(c) For matched Load, Reflection Coefficient $|\Gamma| = \left|\frac{Z_L - Z_0}{Z_L + Z_0}\right| = 0$ *as* $Z_L = Z_0$ and,

VSWR= $\frac{1+|\Gamma|}{1-|\Gamma|} = 1$

Reference: Elements of Electromagnetics by Sadiku.

10. (b) **Concept and Solution:**

At the dielectric boundary, Tangential component of Electric field is continuous where as Normal component is Discontinuous.

$$E_{t_1} = E_{t_2},\ D_{n_1} = D_{n_2},\ B_{n_1} = B_{n_2}$$

For $\mathbf{a_n} \times (H_{t2} - H_{t1}) = J_S$=0 since there is no free space charge density,$\rho_s = 0$, so J_s=0.

Reference: Elements of Electromagnetics by Sadiku, Section5.9 Boundary Conditions, Page183

11. (b) **Concept:** Mesh analysis

Solution: Using KCL, Voltage Source = 30V

$$\frac{V-0}{4} + \frac{V-30}{4} - 10 = 0$$

⇨ $V - 40 + V - 30 = 0$
⇨ $V = 35V$
⇨ $i = \frac{V}{4}$
⇨ $V_x = -\left(\frac{V}{4}\right) \times 2 = -17.5V$

Reference: Network theory by K M Soni

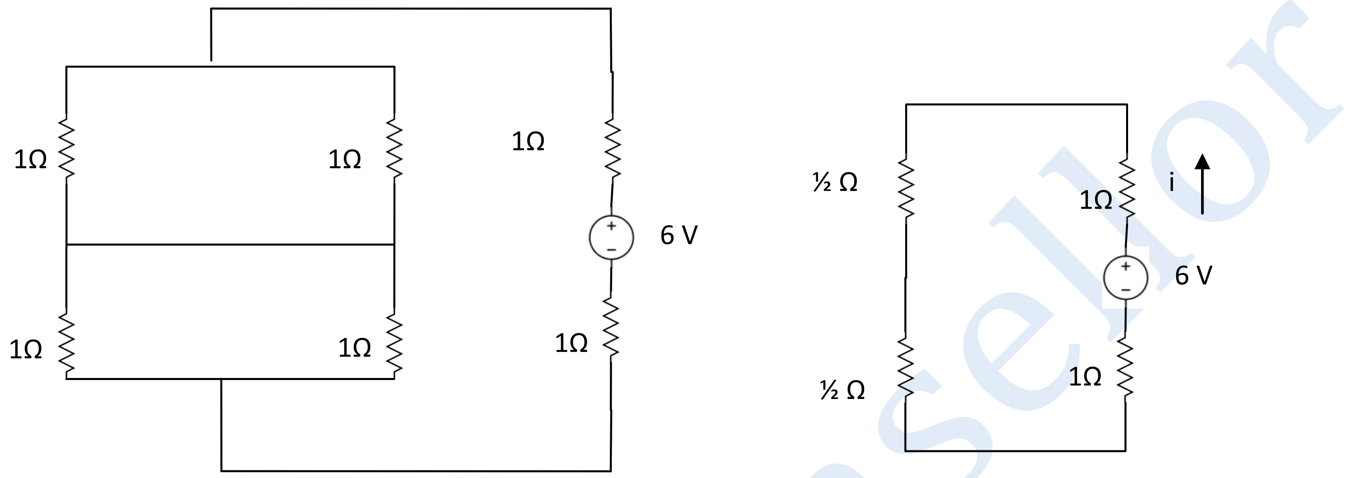
12. (d) **Concept:**

Power delivered by a source = voltage across the source multiplied by current through the source

Solution: On simplifying the circuit:

$$I = \frac{6}{3} = 2A$$

Power delivered by the source = VI = 6V × 2A = 12W



13. (b) **Concept:**
Number of IC's Required = Total Memory Size/ Size of One Memory IC
Sometimes, calculation needs to be done carefully, given example will give you the fare idea of concept.
Solution:
In the interfacing we have to use pair of 4K Nibble IC's to get 4K Byte. So for 24K Byte we require 12 (4K Nibble) IC's. Now we are left with 2K Byte memory. Since, we can't get 2K Byte from a single 4K Nibble IC, we should two IC's. So total IC's required= 14 IC's.

14. (c) **Concept:** Which instructions affect which flags in microprocessor.
Solution:
1. SP←2400H
2. C←01H
3. PUSH B means SP decreases to 23FEH,
   23FFH(Address)←XXH and 23FEH(Address)←01H
4. POP PSW means A←XXH, Flag register←01H=$(00000001)_2$
5. RET.

So CY=1 i.e. set and Z=0 i.e. reset
Reference: 8085 Microprocessor by Gaonkar

15. (b) **Concept:**

If f is any function of a surface then∇f(grad f) will the normal to the surface. If we take the dot product of grad f and the given directional unit vector (if not unit vector we have to convert) we'll get the Directional derivative in the direction of the given vector.

Solution:

$$\nabla f = \left(\hat{\imath}\frac{\partial}{\partial x} + \hat{\jmath}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}\right) f = 4x\hat{\imath} + 6y\hat{\jmath} + 2z\hat{k}$$

$$\nabla f \text{ at P} = \nabla f|_P = 8\hat{\imath} + 6\hat{\jmath} + 6\hat{k}$$

Directional derivative in the direction of a is:

$$\nabla f|_P \cdot \hat{a} = (8\hat{\imath} + 6\hat{\jmath} + 6\hat{k}) \cdot \frac{(\hat{\imath} - 2\hat{k})}{\sqrt{1+4}} = \frac{8-12}{\sqrt{5}} = \frac{-4}{\sqrt{5}} = -1.789$$

Reference: Elements of electromagnetics by Sadiku

16. (a) **Concept:** Instability of I_c mainly depend on three factors:

1. Reverse Saturation Current, I_{co}, which doubles for every 10ºC increase in temperature.
2. Base emitter Voltage V_{BE}, which decreases at the rate of 2.5 mV/ºC for both Ge and Si Transistors.
3. β,which increases with temperature.

Total change in collector current can be calculated by summing the individual changes due to above three factors.

Here, we are looking variation of I_c with respect to I_{co} only, as we assume β is constant and sensitivity (Stabilization Factor) of Emitter Bias Configuration circuit with respect to I_{co} is defined as,

$$S(I_{co}) = \frac{\partial I_c}{\partial I_{co}} = (\beta + 1)\frac{1 + R_B/R_E}{1 + \beta + R_B/R_E}$$

Higher value of $S(I_{co})$ corresponds to higher Instability or sensitivity.

Solution: In Circuit A, $R_B \gg \beta R_E$

$$\Rightarrow S(I_{co}) \simeq \beta + 1$$

And, In Circuit B, $R_B \ll \beta R_E$

$$\Rightarrow S(I_{co}) \simeq 1$$

So, Circuit A is more sensitive to temperature variation.

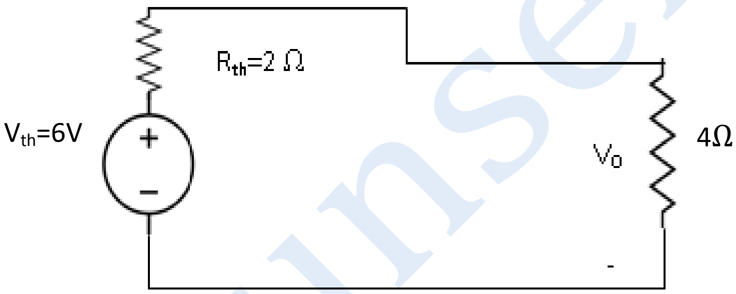
THINK!!: Why Sensitivity depends only on these three factors?

Reference:

Integrated Electronics, Millman Halkias, Chapter 9, Section 9-4, Page Number 290.

17. (a) **Concept:** Use the definition of Thevenin's voltage and Norton current for creating equivalent circuit of the two-port network.

Solution:
When R = ∞, V_0 = 6 V, i.e. Thevenins Voltage V_{th} = 6 V
When R = 0, I = 3 A, i.e. Nortons Current $I_N = I_{SC}$ = 3 A
Therefore Thevenin Resistance $R_{TH} = V_{TH} / I_{SC}$ = 6V/3A = 2Ω
So, the equivalent circuit is



Hence V_0=4V

Reference: Network Theory by K M soni

18. (c) **Concept:** Any signal is power signal if energy is infinite and average power is finite. Any signal is said to be energy signal if energy is finite but average power is zero. A signal may be neither energy signal nor power signal.

Time period of non periodic signal is infinity and average power for the same is

$$P_{av} = \lim_{T\to\infty} \frac{1}{2T}\left[\int_{-T}^{T} |x(t)|^2 dt\right] \text{ for non periodic signals}$$

Solution:

$$P_{av} = \lim_{T\to\infty} \frac{1}{2T}\left[\int_{-T}^{0} A^2 dt + \int_{0}^{T} Ae^{-2t} dt\right]$$

$$P_{av} = \lim_{T\to\infty} \frac{1}{2T}\left[A^2 T + \frac{Ae^{-2T}}{-2}\right]$$

$$P_{av} = \frac{A^2}{2}\left[\because \lim_{T\to\infty} \frac{1}{T} e^{-2T} \to 0\right]$$

$$E_\infty = \int_{-\infty}^{\infty} x^2(t)dt = \infty\ ;\ E_T \text{ is finite but } E_\infty = \lim_{T\to\infty} E_T = \infty$$

$P_{av}$is finite as A is finite and $E_\infty = \infty$.

So, x(t)is a power signal with $P = \frac{A^2}{2}$

Reference: Shaum series on analog and digital communication, Energy Content of a signal and Parseval's theorem, Section 1.3.

19. (d) **Concept:**

$$x[n] = x_e[n] + x_o[n] = \text{odd part} + \text{Even part}$$

$$E_{x[n]} = E_{x_e[n]} + E_{x_o[n]}, \text{since } \sum x_e[n].x_o[n] = 0$$

$$E_{x[n]} = \sum_{n=-\infty}^{\infty} (x[n])^2$$

Proof:

$$E_{x[n]} = \textstyle\sum_{n=-\infty}^{\infty} |x[n]|^2 = \sum_{n=-\infty}^{\infty} |x_e[n] + x_o[n]|^2$$

$$= \textstyle\sum_{n=-\infty}^{\infty} |x_e[n]|^2 + \sum_{n=-\infty}^{\infty} |x_o[n]|^2 + 2\sum_{n=-\infty}^{\infty} x_e[n].x_o[n]$$

$$\therefore\ x_e[n] = \frac{x[n]+x[-n]}{2}\ , x_o[n] = \frac{x[n]-x[-n]}{2}$$

$$\therefore\ \textstyle\sum x_e[n].x_o[n] = \frac{x[n]^2-x[-n]^2}{4} = 0\ ,\ \because\ |x[n]| = |x[-n]|$$

Solution: Given, $E_{x[n]} = 12$ units; $x_e[n] = \left(\frac{1}{3}\right)^{|n|}$

$$E_{x_e[n]} = \textstyle\sum_{n=-\infty}^{\infty} \left(\frac{1}{3}\right)^{2|n|} = 2\sum_{n=-\infty}^{\infty} \left(\frac{1}{3}\right)^{2n} - 1 = 1.25$$

$$\therefore\ E_{x_o[n]} = E_{x[n]} - E_{x_e[n]} = 10.75$$

20. (d) **Concept and Solution:**

1. $T_1 = \frac{2\pi}{50}\ , T_2 = \frac{2\pi}{50\pi}$ and $\frac{T_1}{T_2} = \pi \Rightarrow$ Irrational $\Rightarrow$ Aperiodic

2. $T_1 = \frac{4\pi}{3}\ , T_2 = \frac{2\pi}{3}$ and $\frac{T_1}{T_2} = 2 \Rightarrow$ Rational $\Rightarrow$ Periodic

3. $T_1 = \frac{2\pi}{5}\ , T_2 = \frac{2\pi}{7}\ , T_3 = \frac{2\pi}{3}$ and $\frac{T_1}{T_2}, \frac{T_2}{T_3}, \frac{T_3}{T_1} = \frac{7}{5}, \frac{3}{7}, \frac{5}{3} \Rightarrow$ Rational $\Rightarrow$ Periodic

4. $N_1 = \frac{2\pi m}{2\pi/5} = 5m\ , N_2 = \frac{2\pi k}{\pi/7} = 14k$ and $N = LCM(N_1, N_2) = 70 \Rightarrow$ Integer $\Rightarrow$ Periodic

21. (d) **Concept:** Put X = 1 and use Boolean rules to simplify.

Solution: If X = 1 the expression becomes,

$$\overline{Y}Z(Z+0+YZ)+YZ(0+Y)=1$$

$$\overline{Y}Z+0+0+YZ=1$$

$$(\overline{Y}+Y)Z=1$$

$$Z=1 \because \overline{Y}+Y=1$$

Reference: Digital electronics by Morris Mano

22. (b) **Concept and Solution:** Truth table for multiplexer is,

A	B	F
0	0	I_0 = C.D
0	1	I_1= C
1	0	I_2 = C+D
1	1	I_3 = D

So we can write F as function of A, B, C, D as,
$F = A'B'[C.D] + A'B[C] + AB'[C + D] + AB[D]$

where[·] denotes the values at the input lines of MUX.

$$F = A'B'CD + A'BC + AB'C + AB'D + ABD$$

$$F = A'B'CD + A'BC + AB'C + AB'D + ABD$$

$$F = (\overline{A+B}).CD + (A \oplus B).C + AD$$

Reference: Digital electronics by Morris Mano

23.(d) **Concept:** A Flash ADC needs $2^n - 1$ comparators to divide analog value in $2^n - 1$ levels.

24. (a) **Concept:** Use Fourier Transform properties.

Method 1: (Shift then Scale)

$x(t) \leftrightarrow X(\omega)$

$y_1(t) = x(t+b) \leftrightarrow Y_1(\omega) = e^{jb\omega}X(\omega)$

$y_2(t) = y_1(at) = x(at+b) \leftrightarrow Y_2(\omega) = \frac{1}{|a|}Y_1\left(\frac{\omega}{a}\right) = \frac{1}{|a|}e^{jb\frac{\omega}{a}}X\left(\frac{\omega}{a}\right)$

Method 2: (Scale then Shift)

$$x(t) \leftrightarrow X(\omega)$$

$$y_1(t) = x(at) \leftrightarrow Y_1(\omega) = \frac{1}{|a|} X\left(\frac{\omega}{a}\right)$$

$$y_2(t) = y_1(t+b) = x(a(t+b)) = x(at+ab) \leftrightarrow Y_2(\omega) = e^{jb\omega} Y_1(\omega) = \frac{1}{|a|} e^{jb\omega} X\left(\frac{\omega}{a}\right)$$

Reference: Signals and Systems by Oppenheim

25. (d) **Concept:** Methods to calculate residues from poles,

$$\operatorname*{Res}_{z=z_0} f(z) = \lim_{z\to z_0} (z-z_0) f(z)$$

Solutions:

$$\frac{z}{z^2+1} = \frac{z}{(z+i)(z-i)}$$

$$\text{Res}_{z=i} f(z) = \lim_{z\to i} \cancel{(z-i)} \frac{z}{(z+i)\cancel{(z-i)}}$$

$$\text{Res}_{z=i} f(z) = \lim_{z\to i} \frac{z}{(z+i)} = \frac{i}{2i} = \frac{1}{2}$$

Similarly $\text{Res}_{z=-i} f(z) = \frac{1}{2}$

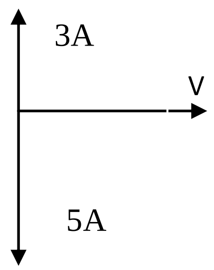
$\therefore$ Sum of residues $= 1$

Reference: Higher engineering Mathematics by B S Grewal, Calculation of residues, section 20.19,

26. (c) **Concept:**

1. In parallel connection voltage across the connected devices will be the same.
2. Current in an inductor lags while current in a capacitor leads the voltage by 90^0.

Solution: By phasor diagram



$\therefore$ Reading of ammeter A is $= 5 - 3 = 2A$

27. (c) **Concept:** Definition of time constant form, type and degree for a system:

Time constant form is like,

$$H(s) = \frac{k.(1+sT_1)^{p1}......}{s^n.(1+sT_a)^{n1}.(1+sT_b)^{n2}.....}$$

Then,

n= Type Number of the system = Number of Poles at the origin

Order = Total number of poles = Degree of the denominator polynomial

k= System gain = $s^n H(s)|_{s=0}$ and T_1, T_a, T_b are Time constants.

Solution:

H(s) can be written in time constant form as:

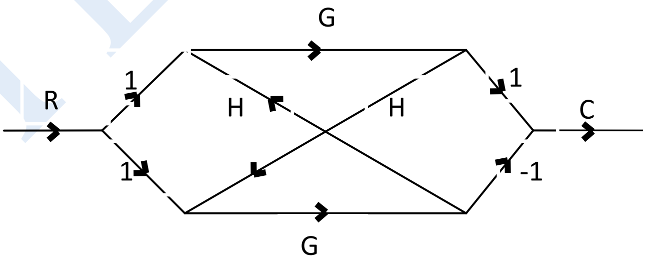
$$H(s) = \frac{C(s)}{R(s)} = \frac{70(s+9)^3}{s^2(s+7)^2(s+4)^3} = \frac{70.9^3.(1+{}^s/_9)^3}{7^2.4^3.s^2.(1+{}^s/_7)^2.(1+{}^s/_4)^3}$$

So, k= $\frac{70.9^3}{7^2.4^3} = 16.27$

Type = 2 and order = 7

28. (b) **Concept:** Convert to Signal flow Graph (SFG) and use Mason's formula

Solution: The SFG of the system is:



Here, we have 4 forward paths:

P_1= G, Δ_1= 1 ; P_2=G^2H , Δ_2= 1; P_3=G ,Δ_3= -1 ; P_4=G^2H , Δ_4= -1;

Δ= $1 - G^2H^2$

By Mason's rule $\frac{C(s)}{R(s)} = \sum_i \frac{P_i\Delta_i}{\Delta} = \frac{G+G^2H-G-G^2H}{1-G^2H^2} = 0$

Reference: Modern Control Engineering by Ogata

29.(d) **Concept:** Find impulse response from transfer function and analyze which waveform suits it best. E.g. if a sinusoidal term is multiplied, the waveform will have modulation following the envelope.

(a)$H(s) = \frac{1}{(s+a)^2} \Rightarrow h(t) = t.e^{-at}u(t)$------(A)

(b)$H(s) = \frac{1}{(s+a)^2+b^2} \Rightarrow h(t) = \frac{1}{b}.e^{-at}.\sin(bt)\,u(t)$-----------(D)

(c)$H(s) = \frac{1}{((s+a)^2+b^2)^2} \Rightarrow h(t) = \frac{t}{b}.e^{-at}.\sin(bt)\,u(t)$-----------(B)

(d)$H(s) = \frac{1}{((s-a)^2+b^2)^2} \Rightarrow h(t) = \frac{t}{b}.e^{at}.\sin(bt)\,u(t)$------------(C)

Reference: Signals and Systems by Oppenheim or any other (even B S Grewal) for methods to find inverse Laplace transform

30. (c) **Concept and Solution:** System A is invertible if system B exists such that when A and B are cascaded, the output of B is equal to the input of A. B is referred to as the inverse system of A. Otherwise, A is noninvertible. In an invertible system, For a given output, input can be determined uniquely also, distinct input leads to distinct output.

So, $H(z).H_{inv}(z) = 1 \Rightarrow h[n] * h_{inv}[n] = \delta[n]$

31. (c) **Concept and Solution:** Fourier Transform properties

$$x(t) = \sum_{n=-\infty}^{\infty} C_n\, e^{jn\omega_0 t} \Rightarrow x(\alpha t) = \sum_{n=-\infty}^{\infty} C_n\, e^{jn\omega_0(\alpha t)} = \sum_{n=-\infty}^{\infty} d_n\, e^{jn\omega_0' t}$$

$$\Rightarrow d_n = C_n;\ \omega_0' = \omega_0.\alpha$$

Reference: Signals and Systems by Oppenheim

32. (c) **Concept:** Scattering matrix describes the behavior of a linear, multi port device at a given frequency ω.

$S_{mn} = \frac{\text{Reflected wave amplitude at port n}}{\text{Incident wave amplitude at port m}}$, given that, All of the remaining (unused) ports are loaded with an impedance identical to the system impedance

A lossless network is one which does not dissipate any power, The sum of the incident powers at all ports is equal to the sum of the reflected powers at all ports. This implies that the S-parameter matrix is unitary.

$$\sum_{m=1}^{N} |S_{mn}|^2 = 1 \text{ for all n}$$

A reciprocal network is build of passive components, and Scattering matrix parameters are related as, $S_{mn} = S_{nm}$

Here, Scattering matrix is,

$$\begin{pmatrix} 0.15 & 0.85\angle 45 \\ 0.85\angle 45 & 0.2 \end{pmatrix}$$

Here, $S_{12} = S_{21,}$ it implies Reciprocal Network.

And, $|S_{11}|^2 + |S_{12}|^2 = (0.15)^2 + (0.85)^2 \neq 1$, it implies a lossy network.

Reference: "Foundations of Microwave Engineering" by R. E. Collin, McGraw Hill or any basic book of microwave engineering.

33. (b) **Concept and Solution**: Poynting vector represents the average power flow through the surface.

Reference: Elements of electromagnetics by Sadiku or Field and Wave electromagnetics by D K Cheng

34. (b) **Concept**: At the dielectric boundary Tangential component of Electric field is continuous where as Normal component is Discontinuous.

$$E_{t_1} = E_{t_2},\ D_{n_1} = D_{n_2}$$

This also holds for $B_{n1} = B_{n2}; B = \mu H$

And, $\mathbf{a_n} \times (H_{t2} - H_{t1}) = J_S = 0$, Since there is no free space charge density $\rho_s = 0$, so J_s=0.

So,$H_{t2} = H_{t1}$

Since, $B_{n1} = B_{n2}$ => $\mu_2 H_{n2} = \mu_1 H_{n1}$

And, $H_1 = H_{t1} + H_{n1} \neq H_2$

Reference: Elements of electromagnetics by Sadiku (see boundary conditions)

35. (d) **Concept**: Only INTR is a non-vectored interrupt as the I/O device has to provide the address of subroutine to be carried out after the interrupt.

36. (b) **Concept**:

A Moore machine has its output as a function of its present state only. It is independent of input.

A Mealy machine has its output as a function of its present state as well as inputs supplied.

Reference: Digital computer electronics by Malvino and Brown

37. (d) **Concept and Solution:**

Here we get output '1' only when system is in stateS_2 and input in 1. So the state must go from $S_0 \rightarrow S_2$. For that to happen we need first input to be 1 so state goes from $S_0 \rightarrow S_1$. Now next we need to go from $S_1 \rightarrow S_2$ for which input '0' is needed. Now we go from state $S_2 \rightarrow S_1$ when input is '1'. So whenever sequence '101' occurs we get output '1'.

Reference: See state diagram and state table in Digital Design by Morris Mano

38. (c) **Concept**: 1. Standard diode equation

$$I = I_0\left(e^{V/\eta V_T} - 1\right) \approx I_0 e^{V/\eta V_T}$$

Where,
I_0 = Reverse saturation current
η = Unity for Ge
V_T = Temperature equivalent of voltage

2. For transistor, $I_C = \beta I_B$

Solution: Take Base-Emitter junction,

$I_C = I_s e^{V_{BE}/V_T}$, Here η is taken to be 1, as the diode is sufficiently forward biased.

Reference: Integrated Electronics by Millman and Halkias

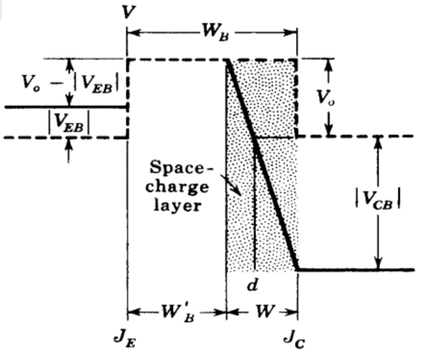
39. (b) **Concept and Solution:**

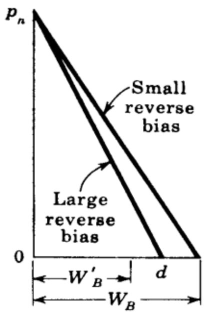
As reverse bias, at base collector junction is increased, the transition region penetrates deeper into base collector junction. Penetration of the transition region into base is a much more pronounced effect as the base is very thin as compared to emitter and collector. The decrease in the base width has the following effects:

1. There is less chance of hole–electron recombination which increases large signal current gain α.

2. As junction is more reverse biased, resistance between base and collector increases.

Reference: Integrated Electronics by Millman and Halkias





40.(c) **Concept and Solution:** $I_C = \beta I_B$ in active region. We know the $V_{BE}-I_B(I_C/\beta)$ curve is like a normal pn junction diode curve shown in (c) or (d). V_{BE} decreases with increase in temperature. So, with rise in temperature, the exponential curve will shift towards left.

Reference: Integrated Electronics by Millman and Halkias

41. (a) **Concept and Solution:**

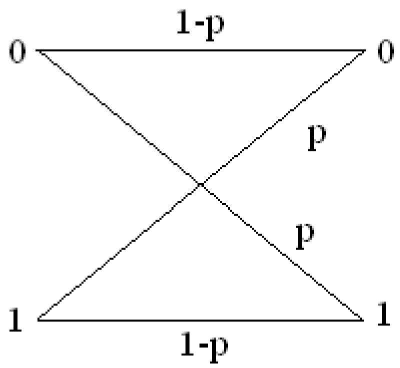


Fig:BSC

$$Pe = \sum_{r=0}^{1} \binom{3}{r} p^{3-r}(1-p)^{r}$$

We have to find the probability of error for bit 1. i.e P(1|0). From the given data, Binary Symmetric Channel is drawn with given probability specifications and if at the receiver the number of one's are less than 2 then the receiver will read it as bit 1 even though the transmitted bit is 1.

Then the probability that the transmitted bit will be received in error is the sum of the probability of the zero 1's(or 000) and the probability only one 1 & two 0's(100 - only combination not permutation) then we will get the probability of error as,

$$P_e = p^3 + 3p^2(1-p)$$

Reference: Principles of Communication systems by Taub, Schilling (see Binary Symmetric Channel).

42. (d) **Concept:** Band width is directly proportional to the number of bits required to encode a symbol.

Solution: Number of levels $L_1 = 4 = 2^2$ and $L_2 = 256 = 2^8$

We know that $L = 2^n$; n = number of bits used for encoding the quantized symbol.

So, $n_1=2$; $n_2=8$

As, B.W.$\propto$ n

Factor= $n_2/n_1 = 4$

Reference: Principles of Communication systems by Taub, Schilling

43. (b) **Concept and Solution:**

Transconductance(g_m) is given by,

$$g_m = \frac{dI_D}{dV_{gs}}$$

Drain current MOSFET in saturation is given by,

$$I_D = K(V_{gs} - V_T)^2$$

$g_m = 2K(V_{gs} - V_T)$: i.e. g_m is linealy varies with $V_{gs} - V_T$.

$g_m = 2\sqrt{K.I_D}$: i.e g_m varies with square root of the I_D.

Reference: Microelectronics circuits by Sedra and Smith

44. (c) **Concept and Solution:**

Given, m(t)= $A_m \cos 2\pi f_m t$

FM: The instantaneous frequency of modulated signal is varied linearly with modulating signal.

$$f_i(t) = f_c + K_f\, m(t)$$

$$\theta_i(t) = 2\pi f_c t + 2\pi\, K_f \int m(t)dt$$

$$\Rightarrow s(t) = A_c \cos[\theta_i(t)] = A_c \cos[2\pi f_c\, t + \beta_{FM} \sin 2\pi f_m t]$$

$$\text{FM Index} = \text{Max Phase Deviation} = \beta_{FM} = \frac{K_f A_m}{f_m}$$

PM: The angle $\theta_i(t)$ is varied linearly with m(t).

$$\theta_i(t) = 2\pi f_c t + K_P m(t) = 2\pi f_c t + K_P A_m \cos 2\pi f_m t$$

$$\Rightarrow s(t) = A_c \cos[2\pi f_c\, t + K_P A_m \cos 2\pi f_m t]$$

$$\text{PM Index} = \text{Max Phase Deviation} = \beta_{PM} = K_P A_m$$

$$f_i(t) = \frac{1}{2\pi}\frac{d\theta_i(t)}{dt} = f_c + K_P A_m f_m$$

$$\text{Max Frequency Deviation} = K_P A_m f_m$$

Reference: Communication Systems by Simon Haykin

45. (a) **Concept and Solution:** Given, P_t=1mW, BW=100MHz, P_L(dB) =-40dB, $N_o=10^{-20}$ W/Hz

S_i(dB)= Input Power – Power Loss = 10 log P_t – 10 log P_L = 10 log (P_t/ P_L)

$S_i = P_t/ P_L = 10^{-3}/10^{-4} = 10^{-7}$ W

$n_i = N_o * BW = 10^{-20} \times 100 \times 10^6$

$S_i/ n_i = 10^{-7}/10^{-12} = 10^5 = 50$(dB)

Note: Since we are given one-sided psd of noise we take it as N_o.

46. (b) **Concept: See Solution 3,** Use, $R_sC \ll \frac{1}{f_c} \ll R_LC \ll \frac{1}{W}$

Solution:$100Hz << f_c << 10kHz$ and W or $f_m << 100Hz$

47. (c) **Concept:**

When 0 transmit, the received pulse should be, y_0=-A+n

When 1 transmit, the received pulse should be, y_1= A+n , where n is AWGN

Probability of eror, P_e = 0.5{p(1/0)+p(1/0)}

For Proof, Please see Reference.

$$P_{e_{NRZ}} = Q\left[\sqrt{\frac{2A^2\,T_b}{N_0}}\right]$$

Solution:$P_{e_{NRZ}} = Q\left[\sqrt{\frac{2A^2\,T_b}{N_0}}\right] = 10^{-5}$

$$4.27 = \sqrt{\frac{2(0.500)^2\,T_b}{10^6 * 2}}$$

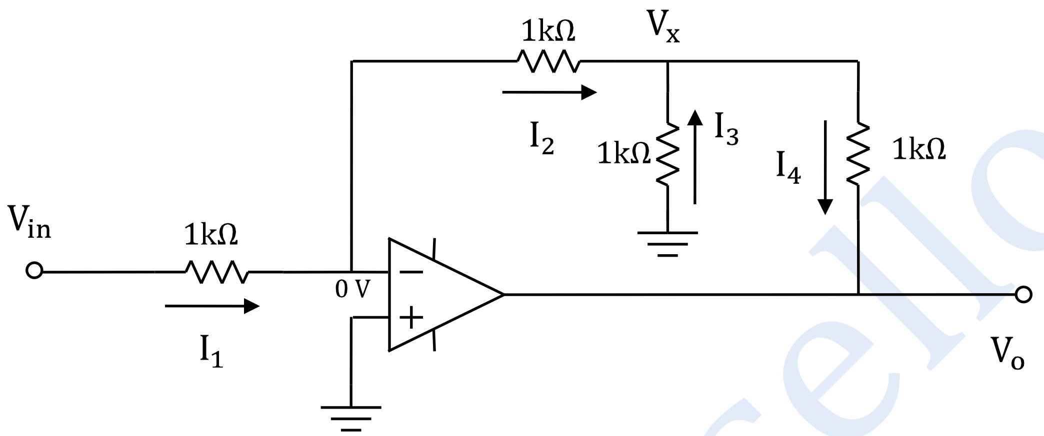
Bit Rate = 1/T_b = 13.71KHz

Reference: B.P.Lathi "Modern digital and analog communication system" 3rd edition, page no.331

48. (a) **Concept:** For ideal op amp,

$$V_+ = V_-$$

Solution: Apply KCL in different Nodes such that relation between V_{in} *and* V_o can be formed.



Here, $V_+ = V_- = 0V$

$$\Rightarrow I_1 = \frac{V_{in} - 0}{1K\Omega} = V_{in}\ (mA)$$

Now, $V_x = -I_1 * 1K\Omega = -V_{in}$

Now, $I_3 = \frac{0-(-V_{in})}{1K\Omega} = V_{in}(mA)$

$I_4 = I_2 + I_3 = V_{in} + V_{in} = 2 * V_{in}\ (mA)$

And,

$V_x - V_o = 2 * V_{in} * 1K\Omega(mV) = 2 * V_{in}(V)$

$-V_o = 2\,V_{in} - V_x = 2\,V_{in} - (-V_{in})$

$$\Rightarrow \frac{V_o}{V_{in}} = -3$$

Reference: Op-amps and linear integrated circuits by Ram Gayakwad

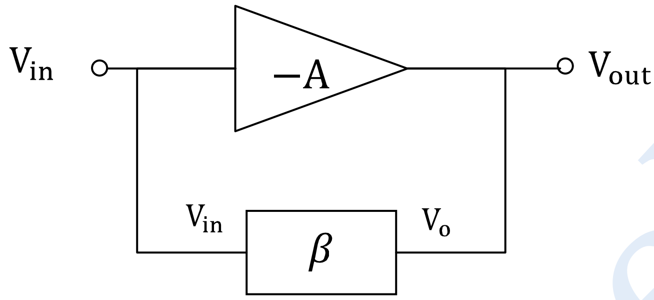
49.(d) **Concept:** An **Electronic Oscillator** is an electronic circuit that produces a repetitive electronic signal.

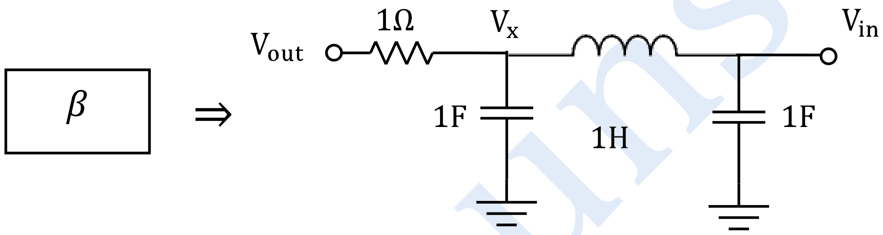
As shown in the figure, Oscillator is an electronic amplifier, output of which connected to input through feedback network. When the power supply to the amplifier is first switched on, the amplifier's output consists only of noise. The noise travels around the loop and re-amplified until it increasingly resembles the desired signal.

$V_{in} = \beta V_o = \beta.(-AV_{in}) = -A\beta V_{in}$

So, for Oscillations to take place, -Aβ=1 (Barkhausen Criterion)

If this condition matches, input will not re-amplified, and sustained and same repetitive signal will be generated from the output, which is the main task of oscillator.





Solution:

By nodal equation,

$V_{out} - V_x = j\omega V_x + \frac{V_x - V_{in}}{j\omega} - (1)$

$and, \frac{V_x - V_{in}}{j\omega} = j\omega V_{in} - (2)$

From 2nd equation, $V_x = V_{in}(1-\omega^2)$

$\Rightarrow V_{out} - V_{in}(1-\omega^2) = j\omega . V_{in}(1-\omega^2) + \frac{-\omega^2 . V_{in}}{j\omega}$

$\Rightarrow \frac{V_{in}}{V_{out}} = \beta = \frac{1}{1-\omega^2 + j(2\omega - \omega^3)}$

For $A\beta = -1+j0$

Imaginary term must vanish,

$$\Rightarrow (2\omega - \omega^3) = 0 \Rightarrow \omega = \sqrt{2}\ rad/s$$

And, f = $\frac{1}{\sqrt{2}\pi}\ rad/s$

Possible Questions: What is the input signal for Oscillator? Oscillator with the above mentioned condition is practically feasible or not?

Reference: Integrated Electronics, Millman and Halkias,Chapter 14, Section 14-15, Page Number 483.

50.(b) **Concept:** In Saturation state, transistor channel is pinched off and constant current flaws through the drain-substrate region.

Solution: So, $I_D = 1\text{mA}$

Now,

$$C_{ox}=\frac{ox}{t_{ox}}=\frac{11.3_o}{10\times10^{-9}}=\frac{11.3\times8.85\times10^{-12}}{10\times10^{-9}}=1\times10^{-6}\frac{F}{cm^2}$$

Transconductance: $g_m = \sqrt{2\mu_n C_{ox}\left(\frac{W}{L}\right) I_D}$

$$g_m = \sqrt{2\times600\times1\times10^{-6}\times50\times1\times10^{-3}}$$

$$= 7.75\times10^{-3}\text{A/V}$$

51.(d) **Concept:** For transistor to be in Saturation

$$V_{DS} > V_{GS} - V_T$$

Solution:

Here, $V_D > V_G - V_T$

Now, $V_G = V_{GG} = 5V,\ V_T = 1V$

$\therefore V_D > 5 - 1$

$V_D > 4V$

Now, $V_D = V_{DD} - I_D R_D > 4$

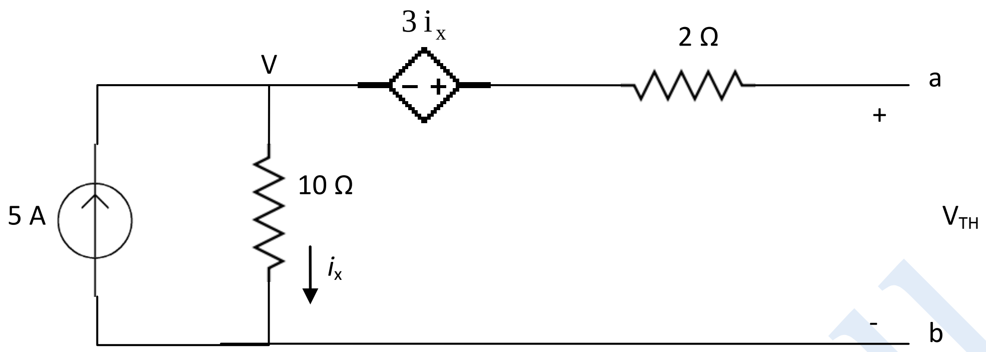
$= V_{DD} - 1\times10^{-3}\times6\times10^{3} > 4$

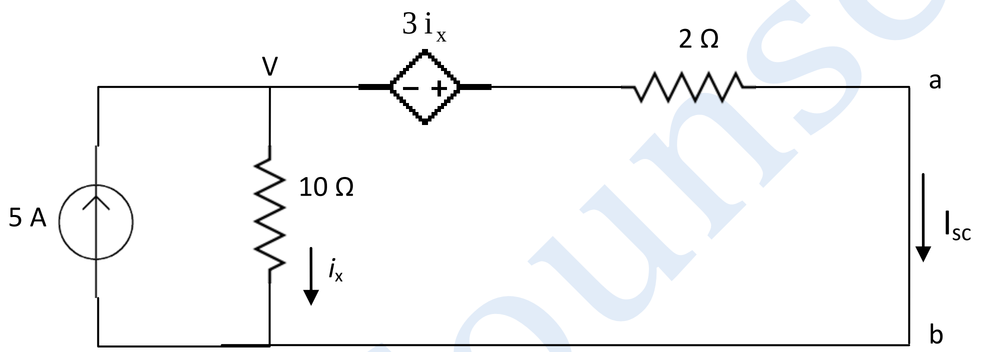
$= V_{DD} > 10$

Minimum value of $V_{DD} = 10V$

Reference: Microelectronics circuits by Sedra and Smith OR Principles of CMOS VLSI Design by Neil Weste OR Electronic devices and circuit theory by Boylestad(see FET)

52.(b) **Concept:** Forming Thevenin equivalent of a two-port network. In case of dependent elements, first find V_{TH}, I_{SC} and then R_{TH}.





Assume node voltage = V

$$-5 + \frac{V}{10} + 0 = 0$$

$$\Rightarrow V = 50V$$

$$\Rightarrow i_x = \frac{V}{10} = 5A$$

$$\therefore V + 3i_x - V_{TH} = 0$$

$$\Rightarrow V_{TH} = V + 3i_x$$

$$= 50 + 3(5)$$

$$= 65V$$

$$-5+\frac{V}{10}+\frac{V+3i_x}{2}=0$$

$$i_x=\frac{V}{10}$$

$$\Rightarrow -50+V+5V+15i_x=0$$

$$\Rightarrow 6V-5+15\left(\frac{V}{10}\right)=0$$

$$\Rightarrow 7.5V=50$$

$$\Rightarrow V=\frac{50}{7.5}=6.66$$

$$I_{SC}=\frac{V+3i_x}{2}$$

$$=\frac{V+0.3V}{2}=\frac{1.3V}{2}$$

$$=\frac{1.3\times 6.66}{2}$$

$$=4.33A$$

Now,

$$R_{TH}=\frac{V_{TH}}{I_{SC}}=\frac{65V}{4.33A}=15\Omega$$

53. (b) **Concept:** The **maximum power transfer theorem** states that, to obtain *maximum* external power from a source with a finite internal resistance, the resistance of the load must be equal to the resistance of the source as viewing from the output terminals.

Solution: Maximum power = (Current through load)^2 X Load Resistance(=R_{th})

$$=\left(\frac{4.33}{2}\right)^2\times 15$$

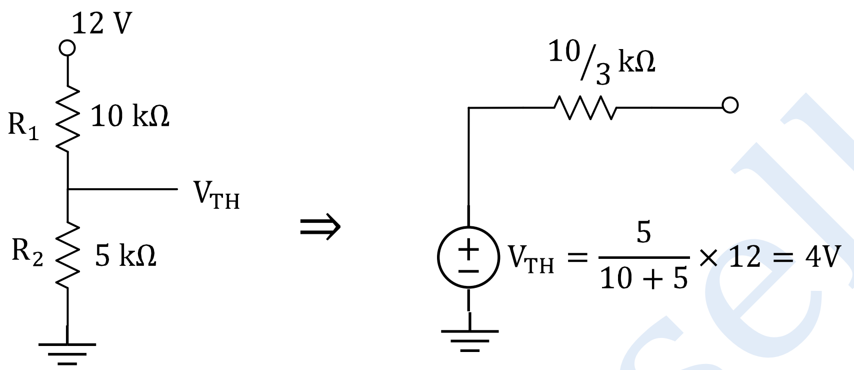
$$=70.42W$$

Reference: Network theory by K M Soni

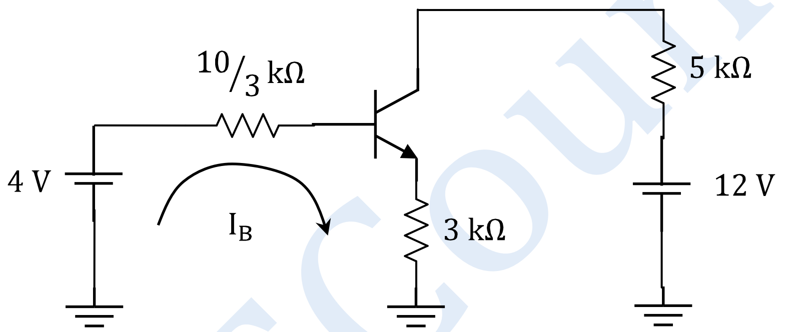
54. (c) **Concept:** The operating point, Q-Point, quiescent point, bias point is the DC voltage and current which need to be fixed for desired operation of device.

Solution: During DC analysis**,** we do take only DC voltages and consider capacitor as an open circuit(for DC, f=0 and Xc =1/(2*pi*f) = infinite).

Now, The Thevenin Equivalent of bias circuit is



The equivalent circuit is,



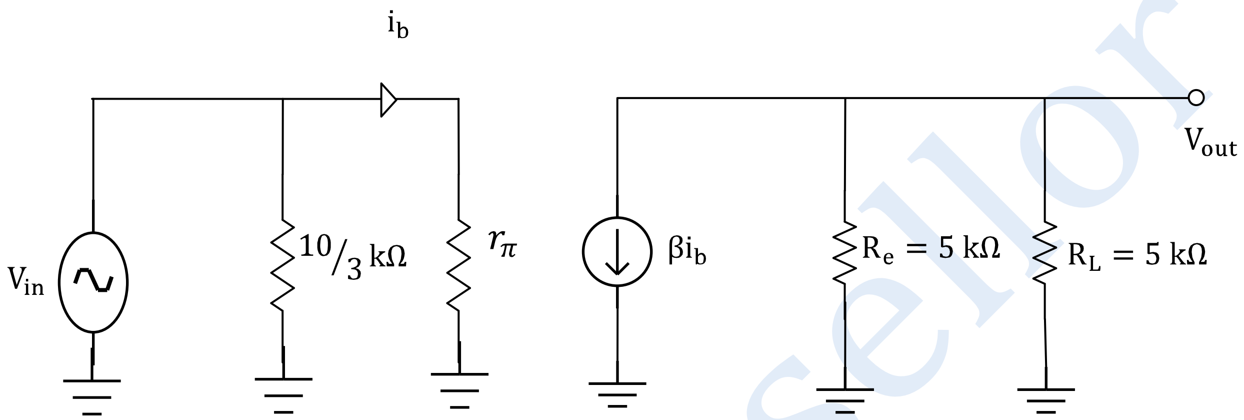
After applying KVL theorem, we get,

$$I_{B_Q} = \frac{V_{TH} - V_{BE(ON)}}{R_B + (\beta + 1) R_E} = 0.0211\text{mA}$$

$$I_{C_Q} = \beta I_{B_Q} = 1.05\text{mA}$$

$$V_{CE} = V_{CC} - I_C R_C - I_E R_E = 3.52\text{V}$$

55. (c) **Concept and Solution:** For AC analysis, we represent the transistor in its small equivalent model called as simplified Hybrid-pi model or T-model specially for mid frequency range. All external capacitors in the circuit will act as a short circuit and bias voltages are grounded.



Now,

$r_\pi = \frac{V_T}{I_B} = \frac{26\times10^{-3}}{0.0211\times10^{-3}} = 1.232\text{k}\Omega$

Input resistance, $R_i = R_1 \| R_2 \| r_\pi = 10 \| 5 \| 1.232$

$= 0.73\text{k}\Omega$

Also Voltage gain = $\frac{V_o}{V_{in}} = \frac{-\beta i_b (R_C \| R_L)}{i_b r_\pi} = \frac{-\beta (R_C \| R_L)}{r_\pi} = -101.5$

Reference: Integrated Electronics, Millman and Halkias