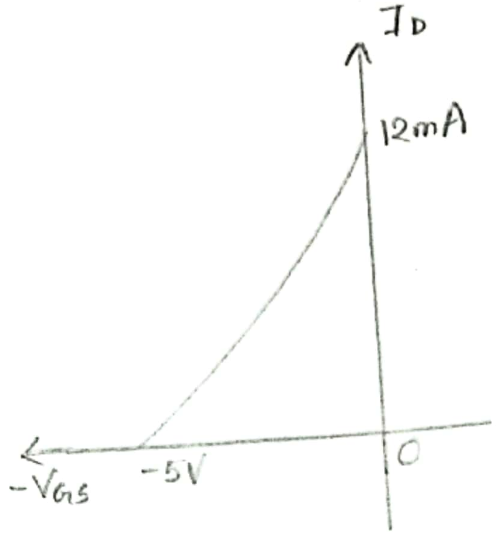
Field effect transistor

Problem-1 This figure shows the trans-fer characteristics curve of JFET. Write the equation for drain current.



Solution: From figure, we have

$$I_{DSS} = 12\,mA$$
$$V_{GS(off)} = -5V$$

$$\therefore I_D = I_{DSS}\left[1 - \frac{V_{GS}}{V_{GS(off)}}\right]^2$$

$$\text{or, } I_D = 12\left[1 + \frac{V_{GS}}{5}\right]^2 mA$$

(Ans)

Problem-02 A JFET has the following parameters: $I_{DSS} = 32\,mA$, $V_{GS(off)} = -8V$, $V_{GS} = -4.5V$. Find the value of Drain current.

Solution:

$$I_D = I_{DSS}\left[1 - \frac{V_{GS}}{V_{GS(off)}}\right]^2$$
$$= 32\left[1 - \frac{(-4.5)}{-8}\right]^2$$
$$= 6.12\,mA$$

(Ans)

Problem-03 A JFET has a drain current of 5mA. If $I_{DSS} = 10\,mA$ and $V_{GS(off)} = -6V$. Find the value of (i) V_{GS} and (ii) V_P.

Solution: (i) $I_D = I_{DSS}\left[1 - \frac{V_{GS}}{V_{GS(off)}}\right]^2$

or, $5 = 10\left[1 - \frac{V_{GS}}{(-6)}\right]^2$

or, $5 = 10\left[1 + \frac{V_{GS}}{6}\right]^2$

or, $\sqrt{\frac{5}{10}} = 1 + \frac{V_{GS}}{6}$

or, $V_{GS} = (\sqrt{5/10} - 1) \cdot 6$

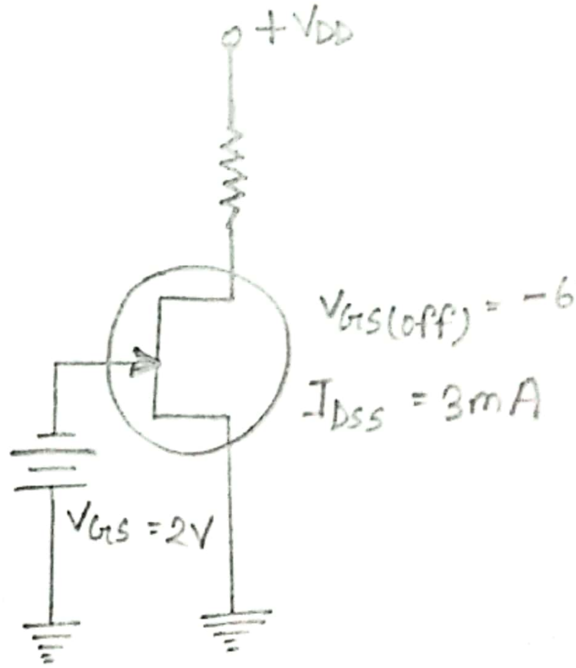
$\therefore V_{GS} = -1.76\,V$

(ii) $V_P = -V_{GS(out)}$

$= 6V$

(Ans)

Problem-4 Determine the value of drain current for the circuit shown in figure.



Solution: From figure, $V_{GS} = -2V$

$\therefore I_D = I_{DSS}\left[1 - \frac{V_{GS}}{V_{GS(off)}}\right]^2$

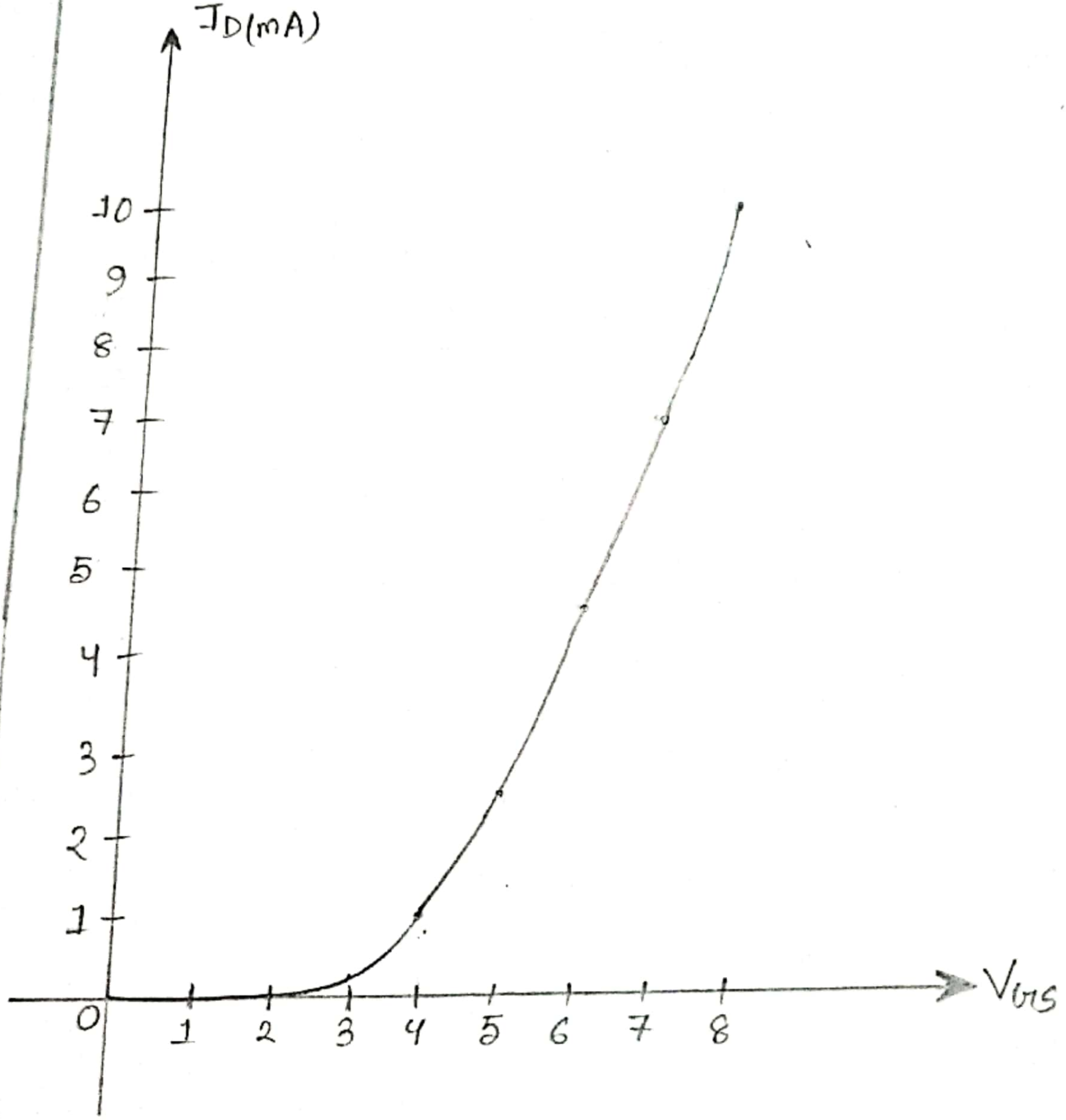
$= 3\,mA\left(1 - \frac{-2}{-6}\right)^2$

$= 1.33\,mA$

(Ans)

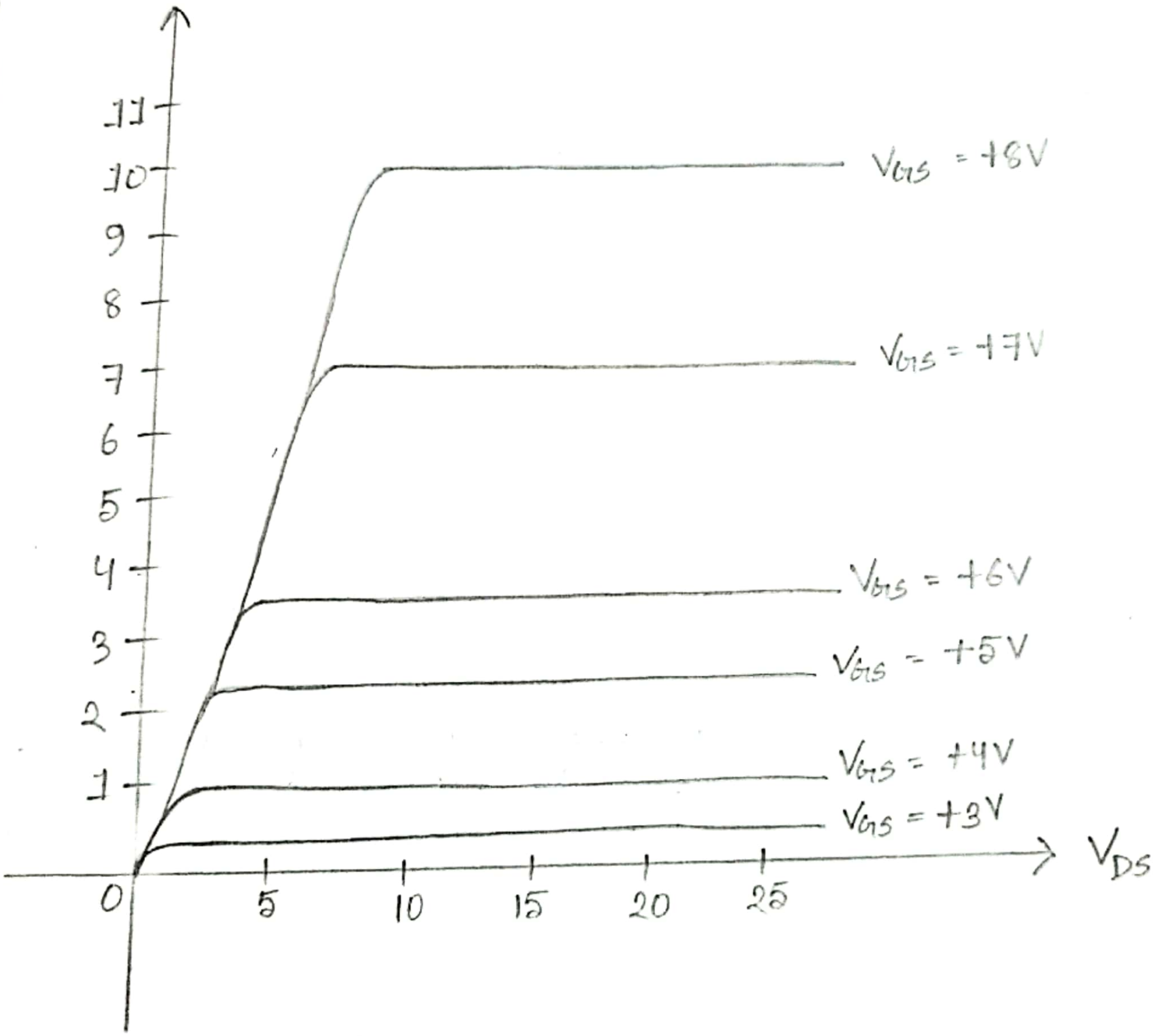
Problem-5 Sketch the transfer characteristics for an n-channel enhancement type MOSFET from the drain characteristics.

Solution:



Problem-6 Sketch the drain characteristics for an n-channel enhancement type MOSFET from the transfer characteristics.

Solution:



Drain characteristics

Problem-07 Sketch the transfer and drain characteristics of an n-channel enhancement type MOSFET if $V_T = 4V$ and $k = 0.5 \times 10^{-3}$ A/V².

Solution: We know that, $I_D = k(V_{GS} - V_T)^2$

Here, $V_T = 4V$ and $k = 0.5 \times 10^{-3}$ A/V²

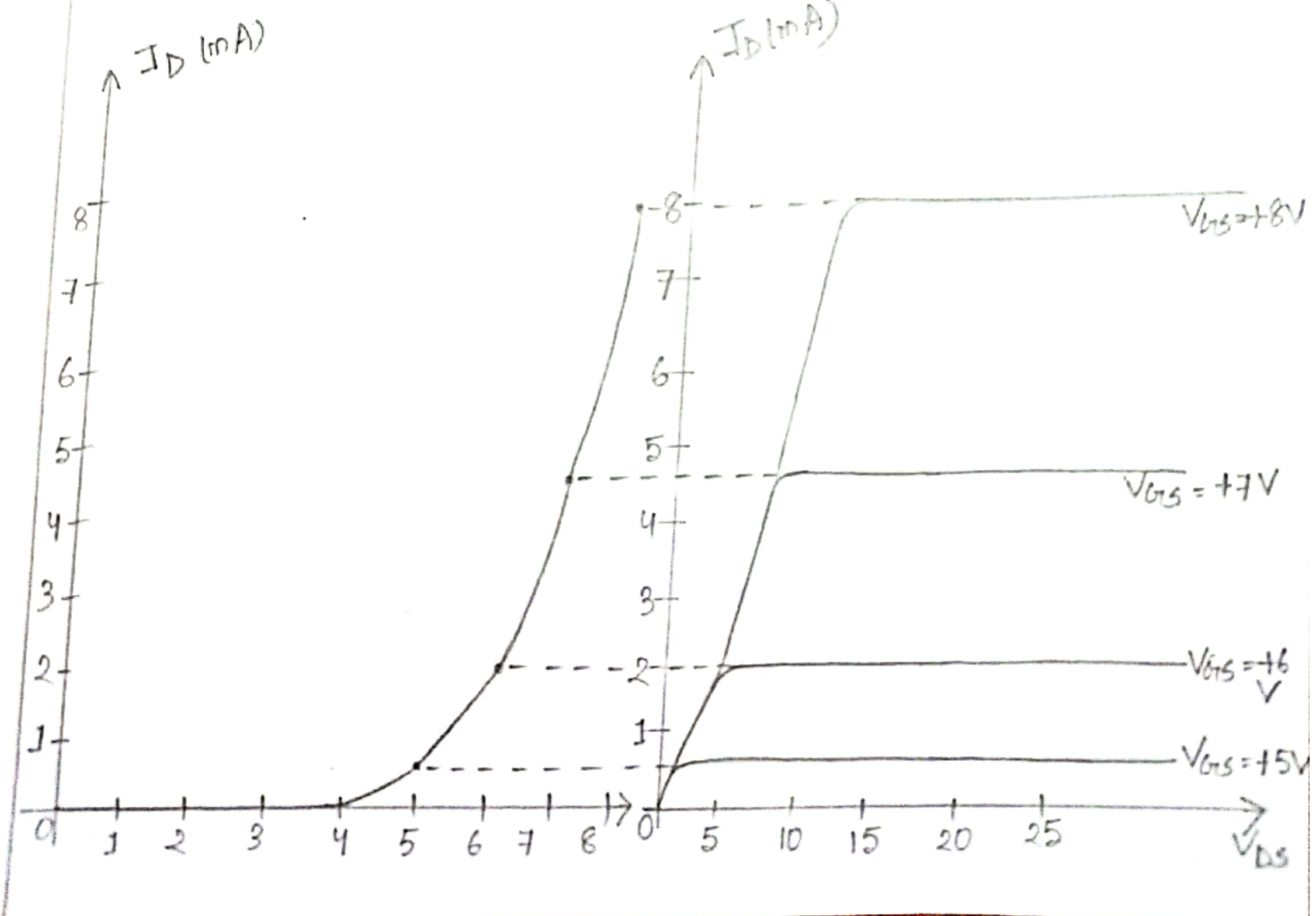
First, a horizontal line is drawn at $I_D = 0mA$. from $V_{GS} = 0V$ to $V_{GS} = 4V$ as shown in the figure. Next, a level of V_{GS} greater than V_T such as 5V is chosen and substituted into equation. To determine the resulting level of I_D as follows:

For $V_{GS} = 5$; $I_D = 0.5 \times 10^{-3}(5-4)^2 = 0.5mA$

For $V_{GS} = 6$; $I_D = 0.5 \times 10^{-3}(6-4)^2 = 2mA$

For $V_{GS} = 7$; $I_D = 0.5 \times 10^{-3}(7-4)^2 = 4.5mA$

For $V_{GS} = 8$; $I_D = 0.5 \times 10^{-3}(8-4)^2 = 8mA$



Problem-8 Sketch the transfer and drain characteristics of an n-channel enhancement type of MOSFET if $V_T = 2V$ and $k = 0.4 \times 10^{-3}\ A/V^2$.

Solution: We know that, $I_D = k\,(V_{GS} - V_T)^2$

Here, $V_T = 2V$

$k = 0.4 \times 10^{-3}\ A/V^2$

First, a horizontal line is ~~known~~ drawn at $I_D = 0mA$ from $V_{GS} = 0V$ to $V_{GS} = 2V$ as shown in drawn figure. Next, a level of V_{GS} greater than V_T such as 3V is chosen and substituted into equation to determine the resulting level of I_D as follows:

$$I_D = 0.4 \times 10^{-3}\,(3-2)^2 = 0.4\,mA$$

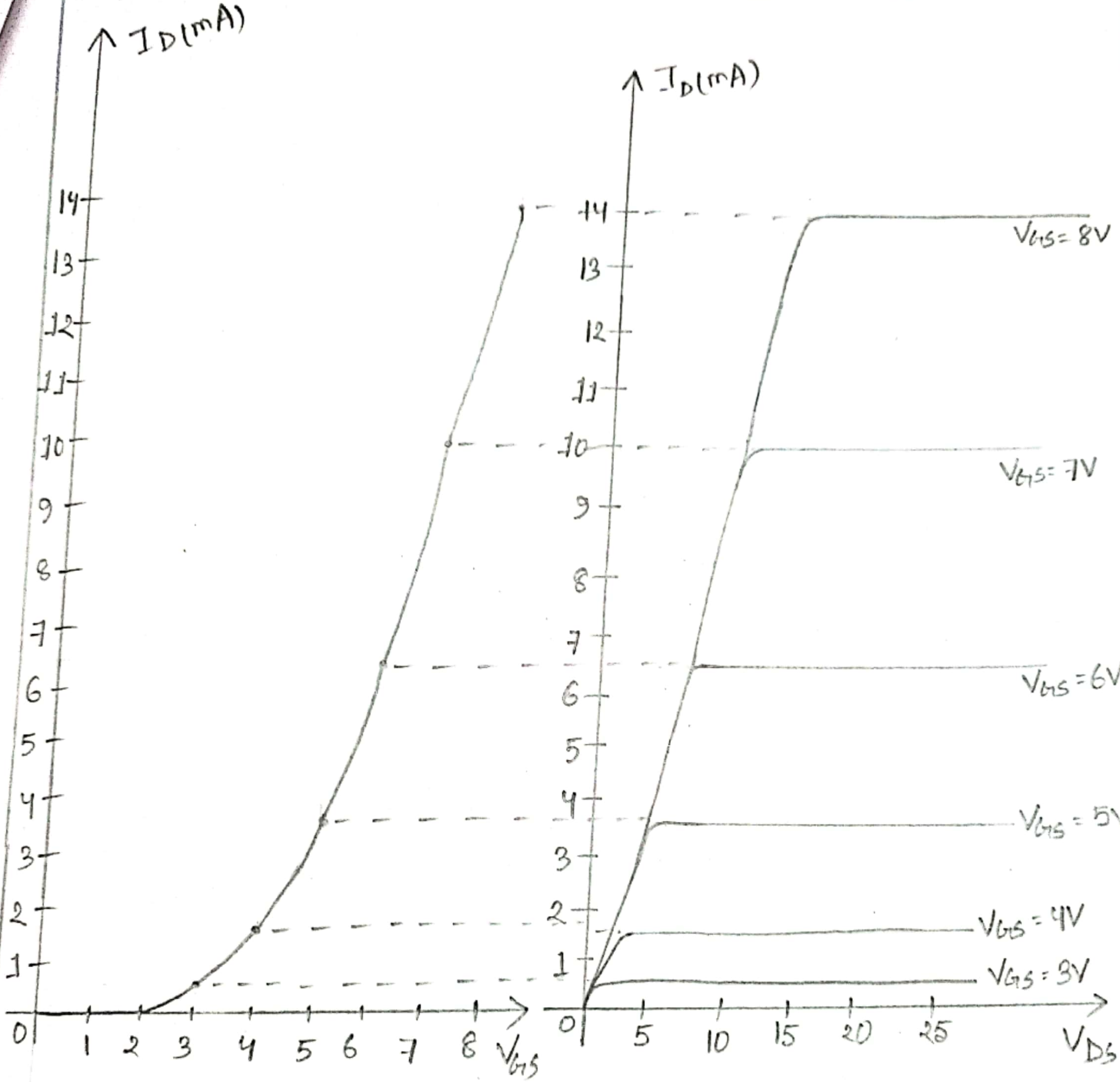
For, $V_{GS} = 4$; $I_D = 0.4 \times 10^{-3}\,(4-2)^2 = 1.6\,mA$

For, $V_{GS} = 5$; $I_D = 0.4 \times 10^{-3}\,(5-2)^2 = 3.6\,mA$

For, $V_{GS} = 6$; $I_D = 0.4 \times 10^{-3}\,(6-2)^2 = 6.4\,mA$

For, $V_{GS} = 7$; $I_D = 0.4 \times 10^{-3}\,(7-2)^2 = 10\,mA$

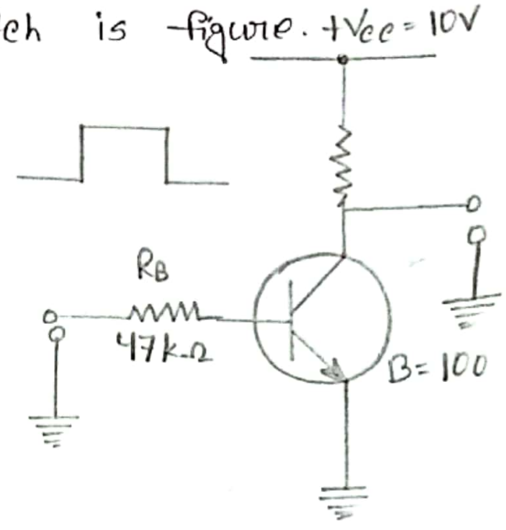
For, $V_{GS} = 8$; $I_D = 0.4 \times 10^{-3}\,(8-2)^2 = 14.4\,mA$



ID(mA)
ID(mA)
VGS = 8V
VGS = 7V
VGS = 6V
VGS = 5V
VGS = 4V
VGS = 3V
VGS
VDS

Switching circuit

Problem-9 Determine the minimum high input voltage required to saturate the transistor switch is figure.



Solution: Assuming the transistor to be ideal,

$$I_{C(sat)} = \frac{V_{CC}}{R_C}$$

$$= \frac{10V}{1k\Omega}$$

$$= 10mA$$

$$\therefore I_B = \frac{I_{C(sat)}}{B}$$

$$= \frac{10mA}{100}$$

$$= 0.1mA$$

Now, $+V = I_B R_B + V_{BE}$

$$= 0.1 \times 47 + 0.7$$

$$= 4.7 + 0.7$$

$$= 5.4 \quad \text{(Ans)}$$

Problem-10 A transistor is used as a switch. If $V_{CC} = 10V$, $R_C = 1k\Omega$ and $I_{CBO} = 10\mu A$. Determine the value of V_{CE} when the transistor is (i) cut off and (ii) saturated.

Solution: (i) A cut off, $I_C = I_{CBO} = 10\mu A$

$$\therefore V_{CE} = V_{CC} - I_{CBO} R_C$$

$$= 10V - 10\mu A \times 1k\Omega$$

$$= 10V - 10mV = 9.99V$$

(ii) At saturation, $I_{C(sat)} = \frac{V_{CC} - V_{knee}}{R_C}$

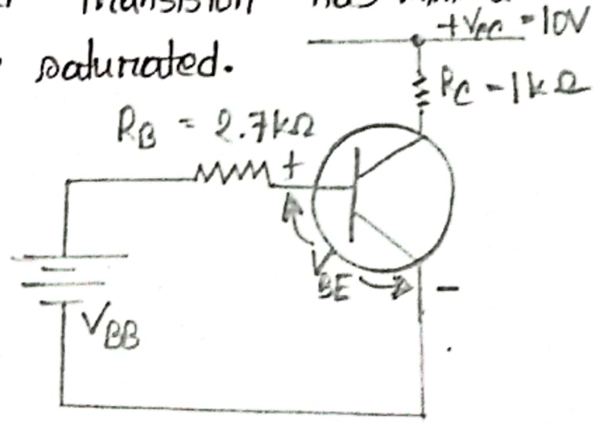
$\therefore V_{CE} = V_{knee} = 0.7V$

(Ans)

Problem-11 This figure shows the transistor switching circuit. Given that $R_B = 2.7k\Omega$, $V_{BB} = 2V$, $V_{BE} = 0.7V$ and $V_{knee} = 0.7V$.

(i) Calculate the minimum value of β for saturation.

(ii) If V_{BB} is changed to 1V and transistor has minimum $\beta = 50$, will the transistor be saturated.



Solution: (i) $I_B = \frac{V_{BB} - V_{BE}}{R_B}$

$= \frac{2-0.7}{2.7}$

$= \frac{1.3}{2.7}$

$= 0.48mA$

Now, $I_{C(sat)} = \frac{V_{CC} - V_{knee}}{R_C}$

$= \frac{10-0.7}{1k\Omega}$

$= \frac{9.3}{1}$

$= 9.3mA$

$\therefore$ minimum, $\beta = \frac{I_{C(sat)}}{I_B} = \frac{9.3mA}{0.48mA} = 19.4$

(ii) $I_B = \frac{V_{BB} - V_{BE}}{R_B}$

$= \frac{1 - 0.7}{2.7}$

$= 0.111 mA$

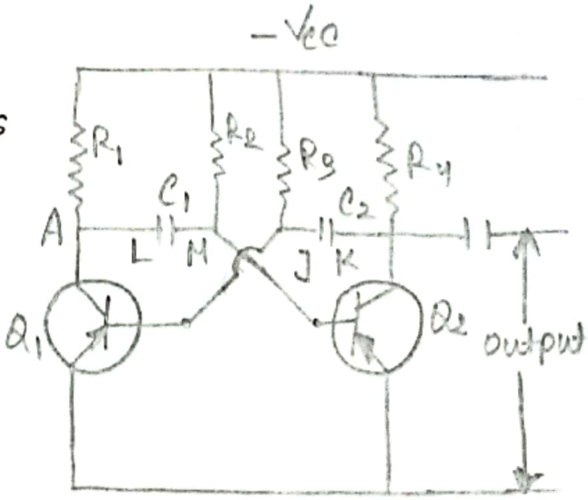
$\therefore I_C = \beta I_B = 50 \times 0.111 = 5.55 mA$

Since, the collector current is less than saturation current $(= 9.9 mA)$. the transistor will not be saturated.

Problem-12 In the astable multivibrator shown in figure $R_2 = R_3 = 10 k\Omega$ and $C_1 = C_2 = 0.01 \mu F$. Determine the time period and frequency of the square wave.

Solution: Here, $R = 10 k\Omega = 10^4$

$C = 0.01 \mu F = 10^{-8} F$



Time period of the square wave is

$T = 1.4 RC$

$= 1.4 \times 10^4 \times 10^{-8}$ second

$= 1.4 \times 10^{-4}$ second

$= 1.4 \times 10^{-4} \times 10^3$ m sec

$= 0.14$ m sec

Frequency of the square wave is,

$f = \frac{1}{T \text{ in second}}$ Hz

$= \frac{1}{1.4 \times 10^{-4}}$ Hz

$= 7 \times 10^3$ Hz

$= 7$ kHz (Ans)

operation Amplifier Fundamentals

Problem_13

Solution: $A_{CL} = \frac{-R_f}{R_i}$

$A_{CL} = -100$
$R_i = 2.2 k\Omega$
$R_f = ?$

or, $-100 = -\frac{R_f}{2.2}$

or, $R_f = 100 \times 2.2$

or, $R_f = 220 k\Omega$

(Ans)

Problem – 14

Solution: $A_{CL} = -\frac{R_f}{R_i}$

$R_f = 200 k\Omega$
$R_i = 2 k\Omega$
$V_{in} = 2.5 mV$

$= \frac{-200 k\Omega}{2 k\Omega}$

$= -100$

∴ output voltage gain, $V_{out} = A_{CL} \times V_{in}$

$= (-100) \times (2.5 mV)$

$= -250 mV$

$= -0.25 V$

(Ans)

Problem-15

Solution: Voltage gain, $A_{CL} = -\frac{R_f}{R_i}$

$= -\frac{1 k\Omega}{1 k\Omega} = -1$

Since the voltage gain of the circuit is -1. the output will have the same amplitud but 180° phase shift.

Problem - 16

Solution: Voltage gain, $A_{CL} = -\frac{R_f}{R_i}$

$= \frac{-40k\Omega}{1k\Omega}$

$= -40$

Since the supply voltages are ±15V. the saturation occurs at ±13V. Since the output voltage far exceeds the saturation and it will behave as a non-linear amplifier. This means that the output will not have the same shape as input but will clip at the saturation voltage 180° phase inversion occurs.

Problem-17

Solution: Voltage gain, $A_{CL} = 1 + \frac{R_f}{R_i}$

$= 1 + \frac{240}{2.4}$

$= 1 + 100$

$= 101$

∴ output voltage, $V_{out} = A_{CL} \times V_{in}$

$= 101 \times 120\mu V$

$= 12.12\ mV.$

(Ans)

Problem-18

Solution: Voltage gain, $A_{CL} = 1 + \frac{R_f}{R_i}$

$= 1 + \frac{10}{1}$

$= 10 + 1$

$= 11$

(i) For $V_{in} = 1V$; $V_{out} = A_{CL} \times V_{in} = 11 \times 1V = 11V$

(ii) For. $V_{in} = -1V$; $V_{out} = A_{CL} \times V_{in} = 11 \times (-1V) = -11V$.

(Ans)

Problem-19

Solution: The input signal is 2V peak to peak.

Voltage gain, $A_{CL} = 1 + \frac{R_f}{R_i} = 1 + \frac{5}{1} = 1+5 = 6$

$\therefore$ Peak to peak voltage voltage $= A_{CL} \times V_{inpp}$

$= 6 \times 2$

$= 12V$

(Ans)

Problem-20

Solution: Here, $R_1 = R_2 = R_3 = R_f$

$\therefore \frac{R_f}{R} = 1$

$\therefore V_{out} = -(V_1 + V_2 + V_3)$

$= -(3+1+8)$

$= -12V$

(Ans)

Problem-21

Solution:

$$R_f = 10k\Omega$$

$$R_1 = R_2 = R = 1k\Omega$$

Therefore, gain of amplifier $= -\dfrac{R_f}{R}$

$$= -\frac{10k\Omega}{1k\Omega}$$

$$= -10$$

$$\therefore V_{out} = -\frac{R_f}{R}(V_1+V_2)$$

$$= -\frac{10k\Omega}{10k\Omega}(0.2+0.5)$$

$$= -7V$$

(Ans)

Problem-22

Solution: $R_f = 1k\Omega$

$$R_1 = R_2 = R_3 = R = 10k\Omega$$

Therefore, gain of ~~voltag~~ amplifier $= -\dfrac{R_f}{R}$

$$= -\frac{1}{10} = -1/10$$

$$\therefore V_{out} = -\frac{R_f}{R}(V_1+V_2+V_3)$$

$$= -\frac{1}{10}(10+8+7)$$

$$= -2.5V$$

(Ans)

Problem-23

Solution: $R_f = 200k\Omega$

$R_1 = 400k\Omega$

$R_2 = 100k\Omega$

$V_1 = +0.6V$, $V_2 = -1.4V$

$$\therefore V_{out} = -200\,k\Omega\left(\frac{0.6}{400k\Omega} + \frac{-1.4}{100k\Omega}\right)$$

$$= 2.5V$$

(Ans)

Problem- 24

Solution: The critical frequency for the integrator circuit,

$$f_c = \frac{1}{2\pi R_f C}$$

Here, $R_f = 100k\Omega = 10^5\,\Omega$

$C = 0.01\mu F = 0.01 \times 10^{-6}\,F$

$$f_c = \frac{1}{2\pi R_f C}$$

$$= \frac{1}{2\pi \times (10^5) \times (0.01 \times 10^{-6})}$$

$$= 159\ Hz.$$

(Ans)

Problem-25

Solution: The output voltage of the circuit is

$$V_0 = -\frac{1}{RC}\int_0^t V_i\,dt$$

$$RC = (100k\Omega)(10\mu F) = 1s$$

$$\therefore V_0 = -\int_0^t V_i\,dt$$

The integration of the square wave results in the triangular wave shown in figure. Since the input to the integrator is applied to the inverting input. the output of the circuit will be 180° out of phase with the input, Thus when the input goes positive, the output will be a negative ramp when the input is negative, the output will be a positive ramp.

Problem-26

Solution: output voltage, $V_0 = -RC\frac{dv_i}{dt}$

Now, $RC = (1k\Omega)(0.1\mu F) = (10^3\Omega)(0.1\times10^{-6} F)$

$= 0.1\times10^{-3}$

Also, $\frac{dV_i}{dt} = \frac{5V}{0.1ms} = \frac{5\times10^4}{1} = 5\times10^4\ V/s$

$\therefore V_0 = -(0.1\times10^{-3})(5\times10^4) = 5V$

The signal quickly returns to zero as the input become constant.

Problem - ~~24~~ 27

Solution: Output voltage $V_0 = -RC \frac{dv_i}{dt}$

Now, $RC = (10^4 \Omega) \times (2.2 \times 10^{-6} F)$

$= 2.2 \times 10^{-2}$

Also, $\frac{dv_i}{dt} = \frac{(10-0)}{0.4} = \frac{10}{0.4} = 25 \, V/s$

$V_0 = -(2.2) \times 10^{-2} \times 25 = -0.55 \, V$

The output voltage stays constant at $-0.55 V$.

(Ans)

Op-amp Application

Problem-28

Solution: $A_v = 140$, $A_{vf} = 17.5$

Let m_v be the feedback fraction, Voltage gain with negative feedback is,

$$A_{vf} = \frac{A_v}{1 + A_v m_v}$$

$$\Rightarrow 17.5 = \frac{140}{1 + 140 m_v}$$

$$\Rightarrow 17.5 + 2450 \, m_v = 140$$

$$\therefore m_v = \frac{140 - 17.5}{2450}$$

$$= \frac{1}{20}$$

(Ans)

Problem-29

Solution: (i) Gain voltage feedback, $A_v = 100$

Gain with feedback, $A_{vf} = 50$

Let m_v be the fraction of the output voltage feedback.

Now, $A_{vf} = \frac{A_v}{1+A_v m_v}$

or, $50 = \frac{100}{1+100m_v}$

or, $50 + 5000\, m_v = 100$

or, $m_v = \frac{100-50}{5000} = 0.01.$

(Ans)

(ii) $A_{vf} = 75$

$m_v = 0.01$

$A_v = ?$

$A_{vf} = \frac{A_v}{1+A_v m_v}$

or, $75 = \frac{A_v}{1+0.01A_v}$

or, $75 + 0.75\, A_v = A_v$

$\therefore A_v = \frac{75}{1-0.75} = 300.$

(Ans)

Problem – 30

(i) Gain without feedback, $A_v = \frac{10}{0.25} = 40$

(ii) Gain with feedback, $A_{vf} = \frac{10}{0.5} = 20$

Now, $A_{vf} = \frac{A_v}{1 + A_v m_v}$

or, $20 = \frac{40}{1 + 40 m_v}$

or, $20 + 800 m_v = 40$

or, $m_v = \frac{40 - 20}{800} = \frac{1}{40}$

(Ans)

Problem 31

Solution: $A_{vf} = \frac{A_v}{1 + A_v m_v}$

or, $25 = \frac{50}{1 + 50 m_v}$

or, $m_v = \frac{1}{50}$

(i) Without feedback: The gain of the amplifier without feedback is 50. However due to ageing it falls to 40.

$\therefore$ % age reduction in stage gain $= \frac{50 - 40}{50} \times 100$

$= 20\%$

(ii) With negative feedback:

When the gain without feedback was 50, the gain with negative feedback was 25. Now the gain without feedback falls to 40.

∴ New gain with negative feedback $= \frac{A_V}{1+A_V m_V}$

$= \frac{4}{1+(40\times\frac{1}{30})}$

$= 22.2$

∴ % age reduction is stage gain $= \frac{25-22.2}{25}\times 100$

$= 11.2\%$

(Ans)

Problem-32

Solution: (i) $L_1 = 1000\mu H$

$L_2 = 100\ \mu H$

$M = 20\mu H$

Total inductance, $L = L_1+L_2+\cancel{L_3}\,2M$

$= 1000+100+2\times 20$

$= 1140\times 10^{-6}\,H$

Capacitance, $C = 20pF = 20\times 10^{-12}\,F$

∴ operating frequency, $f = \frac{1}{2\pi\sqrt{L_1 C}}$

$= \frac{1}{2\pi\sqrt{1140\times10^{-6}\times 20\times 20^{-12}}}\ Hz$

$= 1052\ KHz$

(ii) Feedback fraction, $m_V = \frac{L_2}{L_1} = \frac{100\ \mu H}{1000\ \mu H}$

$= 0.1$ (Ans)

Problem – 33

Solution: Feedback fraction, $m_v = \frac{L_2}{L_1}$

or, $0.2 = \frac{L_2}{L_1}$

Now, $f = \frac{1}{2\pi\sqrt{L_T C}}$

or, $L_T = \frac{1}{C(2\pi f)^2}$

$= \frac{1}{(1\times10^{-14})(2\pi\times1\times10^{6})^2}$

$= 25.3\times10^{-3}$

$= 25.3\, mH$

$L_1 + L_2 = 25.3\, mH$

or, $L_1 + L_2 = 25.3$

$\therefore L_1 = 5L_2 = 4.22\times5$

$\therefore L_1 = 5L_2 = 5\times4.22$

$= 21.1\, mH$

(Ans)

Operation Amplifier

- Problem (13-27) → pdf

  Vk Mehta book (25.25-25.28, 25.32 - 25.34, 25.44-25.47) - Page (695)
  (25.50, 25.51, 25.54, 25.55)

OP-Amp Application

- Problem (28- 33) → pdf

  V. K. Mehta book (13.2-13.5), 14.5, 14.6
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