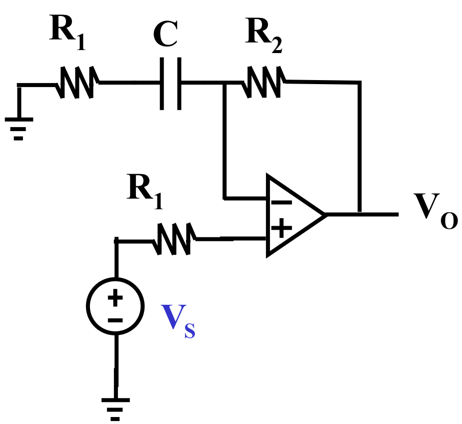
(16)

2

Find V_O / V_S in terms of R, C and jw. If C = 1μF , R_1 = 1kΩ, R_2 = 10kΩ, find the complex transfer function G (= V_O / V_S). Is the op amp circuit a low pass filter? Assume the op amp is ideal. (16)



$$G = \frac{V_O}{V_S} = 1 + \frac{R_2}{R_1 + \frac{1}{j\omega C}}$$

$$= 1 + \frac{R_2}{R_1}\frac{1}{1 + j\frac{-1}{\omega C R_1}} = 1 + \frac{R_2}{R_1}\frac{1}{1 - j\frac{1}{\omega * 1\mu * 1k\Omega}}$$

$$= 1 + \frac{10}{1 - j\frac{1k}{\omega}}$$

(12)

Circuit is a high pass filter **(4)**

(21)

3

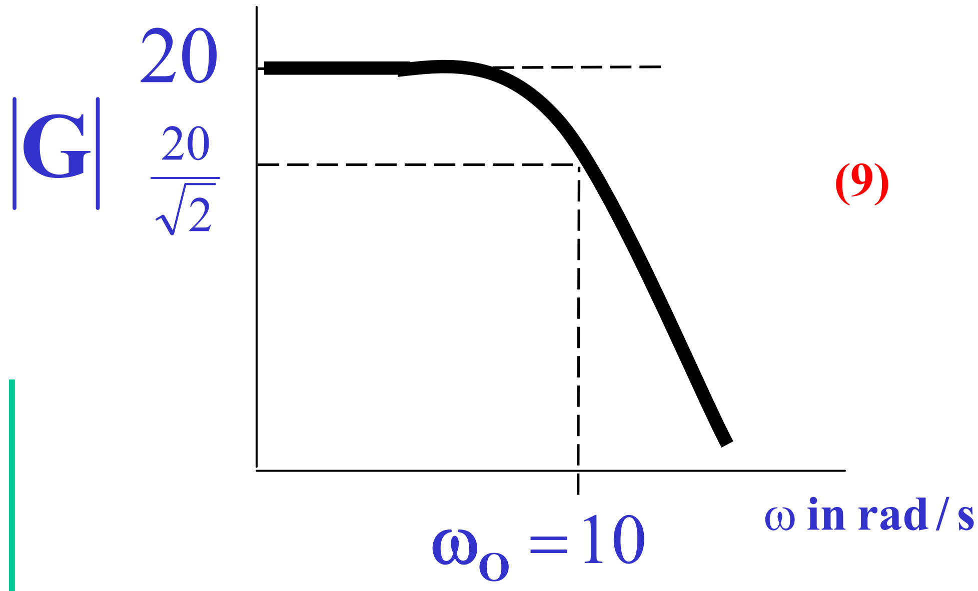
In an op amp filter circuit, the complex transfer function G $(= V_O / V_S)$ is given as. $\dfrac{20}{1 + j\omega CR}$

(a) Find ω_O and plot the magnitude of G (| G |) versus the angular frequency ω. Show clearly the value of | G | when $\omega = \infty$ and $\omega = \omega_O$ in your plot.

(b) If $V_S(t) = 1\cos 2\omega_O t$ V , find $V_O(t)$.

Given that the op amp is ideal , $C = 1 \times 10^{-4}$ F , R = 1kΩ , $\omega_O = 1/CR$. (21)

(21)



(9)

(a)

$$\omega_O = \frac{1}{CR} = \frac{1}{0.1\text{mF} * 1\text{k}\Omega} = 10\,\text{rad/s}$$

(3)

(b)

$$V_O = 1\angle 0 * \frac{20}{1 + 2j} = \frac{20}{\sqrt{5}\angle 63.4^\circ}$$

(9)

$$V_O(t) = \frac{20}{\sqrt{5}}\cos(10t - 63.4^\circ)\,\text{V}$$

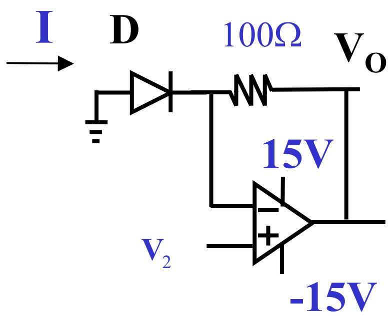
(12)

4 . In the ideal op amp circuit, the diode equation is

$$I_D = I_O[e^{\frac{V_D}{25mV}} - 1]$$.

where $I_O = 1x10^{-12}$ A . Find V_O if $V_2 = -0.62V$.

Show clearly your steps and reasons. (12)



(a) If V2 = - 0.62V D is a ON diode

$$\therefore I_2 \cong I_O \exp(\frac{V_2}{25mV})$$

$$= (1pA)\exp(\frac{620mV}{25mV}) \cong 59mA$$

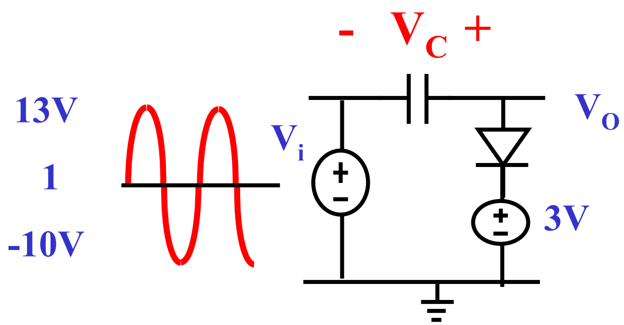
$$\therefore V_O \cong -I * 100\Omega - 0.62V \cong -6.52V$$

(12)

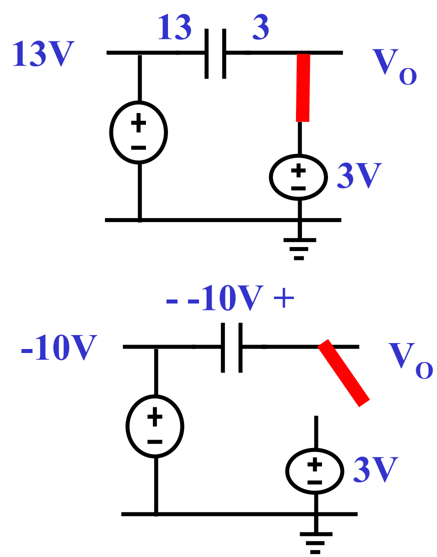
(12)

4

(b) In the ideal diode circuit, find Vc and sketch Vo(t). Label clearly $V_O(t)$. Assume the diode is ideal. (12)



(b)

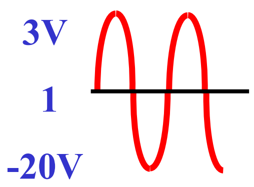


Vc = - 10V

(8)

V_O = Vi + Vc
= - 10 – 10
= - 20 V

(4)

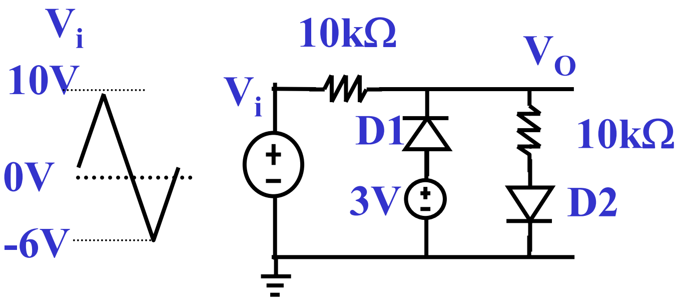


(13)

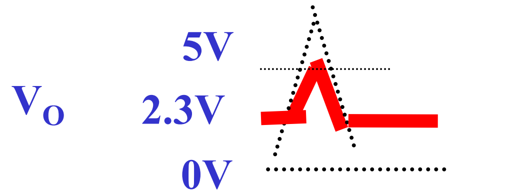
4

(c) In the diode circuit, sketch and label clearly $V_O(t)$.

D2 is an ideal diode and D1 is an offset diode with VF = 0.7V. (13)



(c)

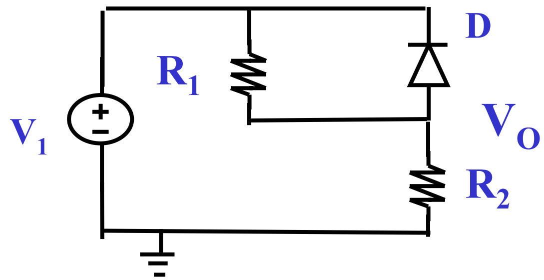


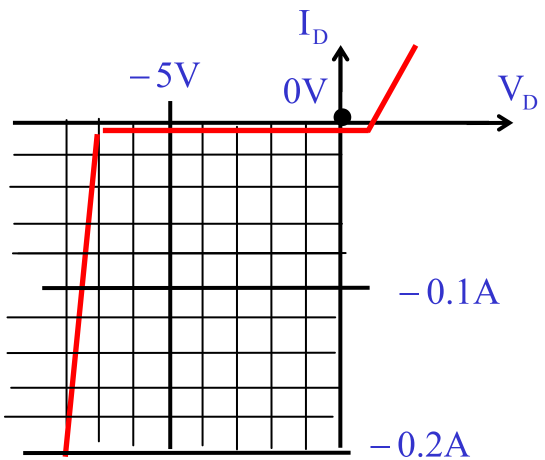
(13)

(22)

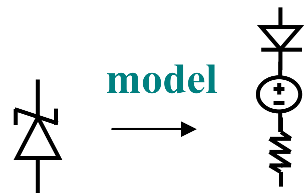
5

In the diode circuit, the diode has the forward, reverse and breakdown characteristics as shown.
(a) Draw the circuit model of the diode at breakdown.
(b) If $V_1 = 16V$, $R_1 = 50\Omega$, $R_2 = 50\Omega$, find V_O .
Show clearly your reasons. (22)





a



$V_{ZK} = 7V$

$r_Z = 5\Omega$

(7)

b

$$V_O = V_1 * \frac{R_2}{R_1 + R_2} = 16V * \frac{50\Omega}{50\Omega + 50\Omega} = 8V$$

diode is BREAKDOWN

$$\frac{16V - V_O}{50\Omega} + \frac{16 - V_O - 7V}{5\Omega} = \frac{V_O}{50\Omega}$$

$$16V - V_O + 10(16V - V_O - 7V) = V_O$$

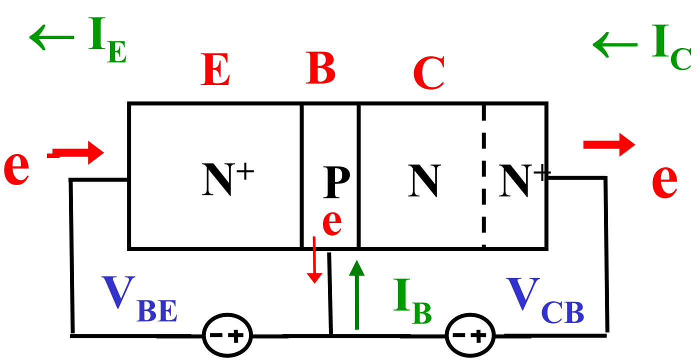
$$V_O = \frac{90V + 16V}{12} \cong 8.83V$$

(15)

(16)

6

Draw the cross sectional structure of a NPN BJT transistor operated in the amplifier mode, describe the movement of electrons, and explain briefly why $I_C / \alpha \cong I_E$.
If $I_C \cong \beta I_B$, find β in terms of α. (16)



1. EB Junction is a forward bias (on) diode and BC is reverse bias (off) diode

2. E is very heavily doped (N^+ for NPN). E has many electrons,

3. B is very thin. So most electrons injected from E (to B) are attracted to C and

$$I_C \cong \alpha I_E \qquad (10)$$

$$I_E \cong \frac{I_C}{\alpha} = I_B + I_C = \frac{I_C}{\beta} + I_C$$

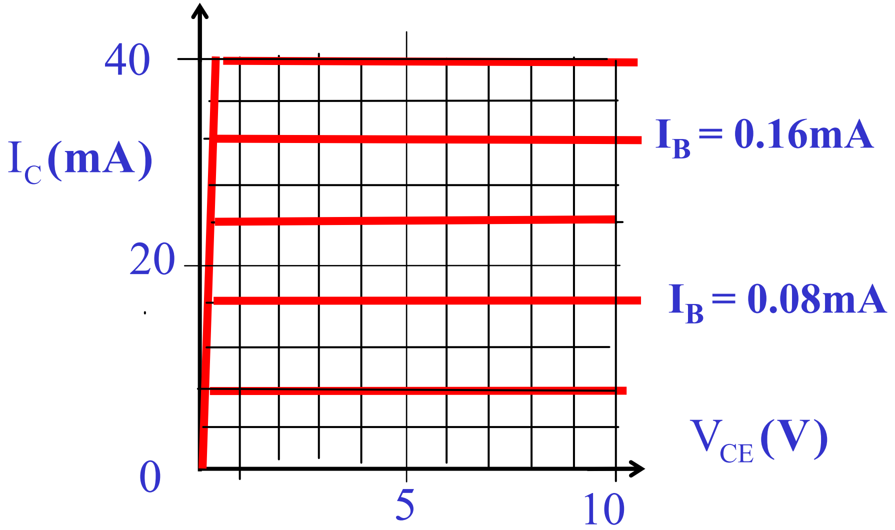
$$\text{hence } \frac{1}{\alpha} = \frac{1}{\beta} + 1$$

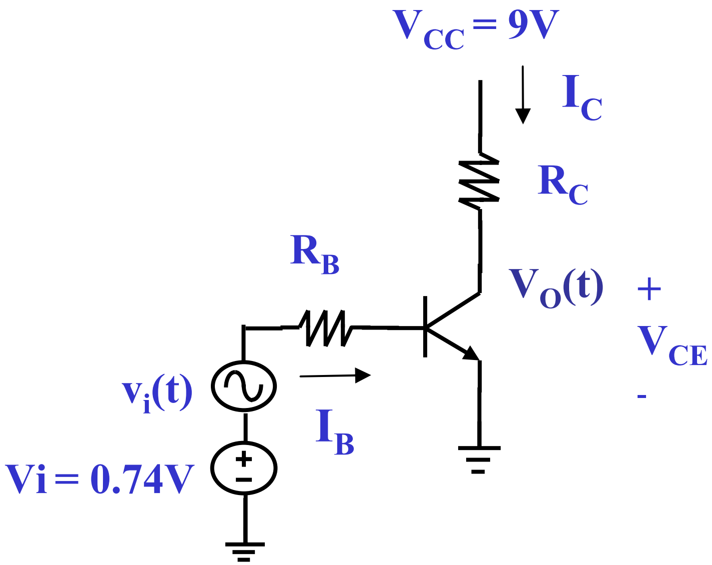
$$\alpha = \frac{\beta}{\beta + 1}$$

$$\beta = \frac{\alpha}{1 - \alpha} \qquad (6)$$

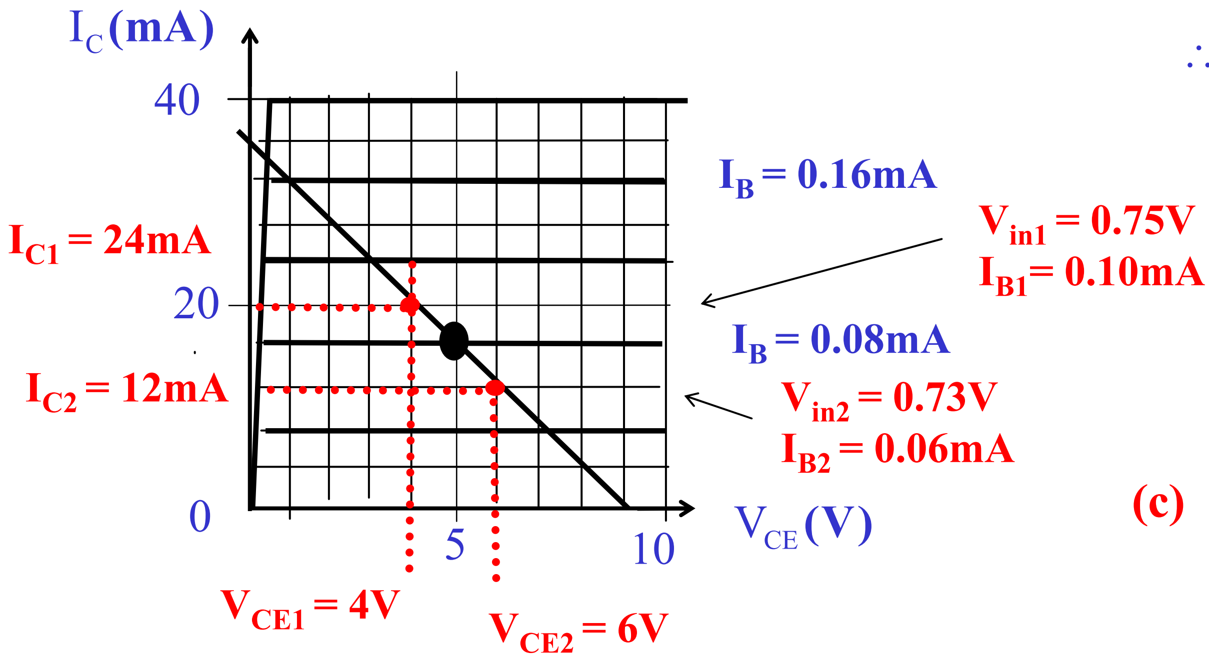
7

Given the BJT circuit below and the I_C-V_{CE} curve of the BJT. The Q point is chosen as IC = 18mA and VCE = 5V. (a) Draw the load line $V_{CE} = V_{CC} - I_C R_C$. (b) Find RB RC. .
(b) If $v_i(t) = 0.01\cos\omega t$ V, estimate the voltage gain from the I-V curve and sketch $V_O(t)$.
(28)
For the BJT, given $V_{BE(ON)} = 0.7V$, $V_{CESAT} = 0.2V$, $r\pi = 0\Omega$





(a) Draw load line,



(8)

(b)

$$\therefore R_C = \frac{V_{CC}}{I_C} = \frac{9\text{V}}{36\text{mA}} = 250\Omega \qquad (5)$$

$$\therefore R_B = \frac{0.74\text{V} - 0.7\text{V}}{0.08\text{mA}} = 500\Omega \qquad (5)$$

(c)

$$\text{voltage gain } A_v = \frac{dV_{CE}}{dV_{in}} = \frac{V_{CE2} - V_{CE1}}{V_{in2} - V_{in1}}$$

$$\cong \frac{6\text{V} - 4\text{V}}{0.73\text{V} - 0.75\text{V}} = -100$$

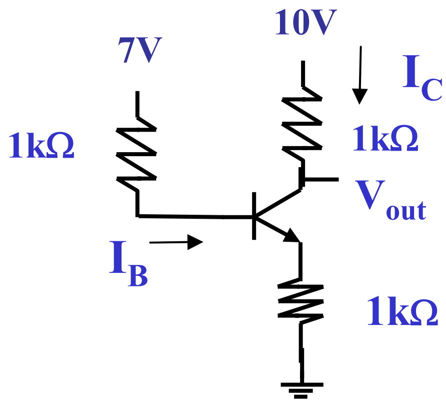
(10)

(20)

8

(a) Find I_C / I_B. Given $R_E = 1k\Omega$ and Vi = 7V. Show clearly your reasons.
For the BJT, given $V_{BE(ON)}$ = 0.8V, β = 125, V_{CESAT} = 0.2V.. (20)

(a)



$$I_B \cong (10V / 2k\Omega)/125 \cong 0.033mA \quad \text{when } V_{CE} = 0$$

$$\text{But } I_B \cong \frac{7V - 0.8V}{125 * 1k\Omega} \cong 0.05mA$$

$$\therefore \text{BJT is in saturation}$$

$$\therefore I_B = \frac{V_B - V_{BE}}{R_B + (1+\beta^*)R_E} = \frac{V_{CC} - V_{CESAT}}{\beta^* R_C + (1+\beta^*)R_E}$$

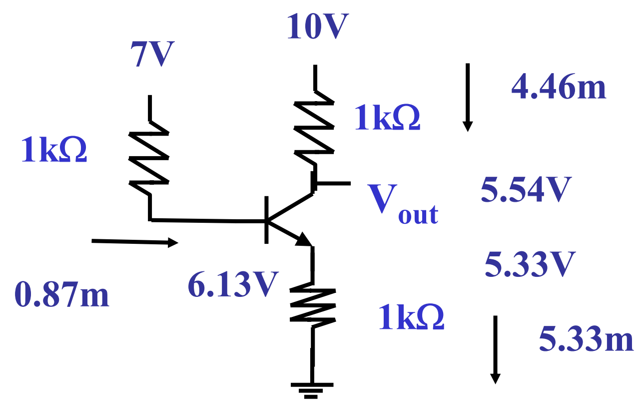
$$\therefore I_B = \frac{7 - 0.8}{1k + (1+\beta^*)1k} = \frac{10 - 0.2}{1k(1+2\beta^*)}$$

$$\therefore 6.2(1+2\beta^*) = 9.8(2+\beta^*)$$

$$\therefore 12.4\beta^* + 6.2 = 19.6 + 9.8\beta^*$$

$$\therefore \beta^* = \frac{19.6 - 6.2}{12.4 - 9.8} \cong 5.15$$

(20)

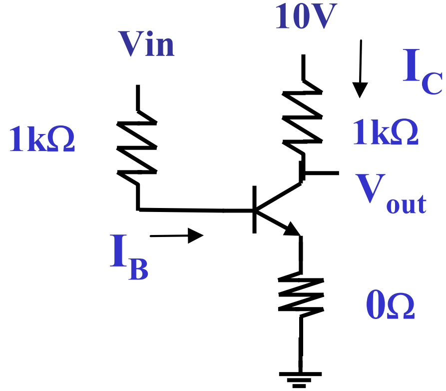


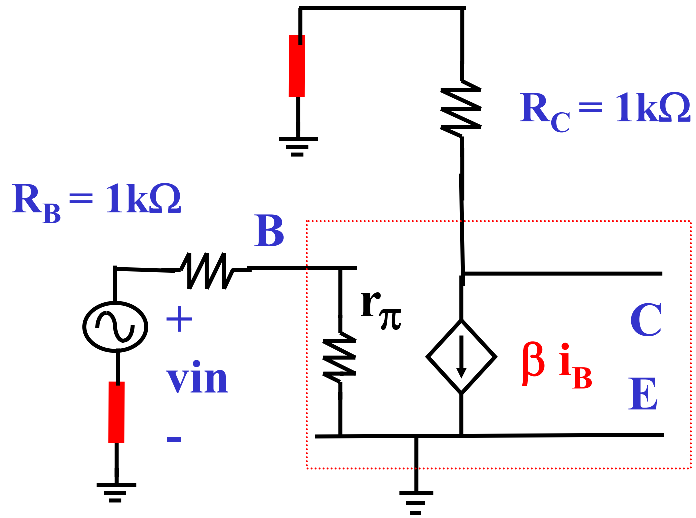
(16)

8

.
Draw the small signal (AC) equivalent circuit of the BJT amplifier and show that the voltage gain $A_V\ (=V_{out}/V_{in})$ is about -20. Given $\beta = 100$, and $V_{CESAT} = 0.2V$, $V_{BE(ON)} = 0.7V$, RE = $r\pi$ = 0Ω. (16)

(b)





(8)

$$\therefore Av = \frac{\mathrm{VOUT}}{\mathrm{Vin}} = \frac{-\beta\, i_B R_C}{i_B(R_B + r\pi)}$$

$$= \frac{-\beta R_C}{R_B + r\pi} = \frac{-(125)(1k\Omega)}{1k\Omega + 0\Omega} = -125$$

(8)

(15)

10

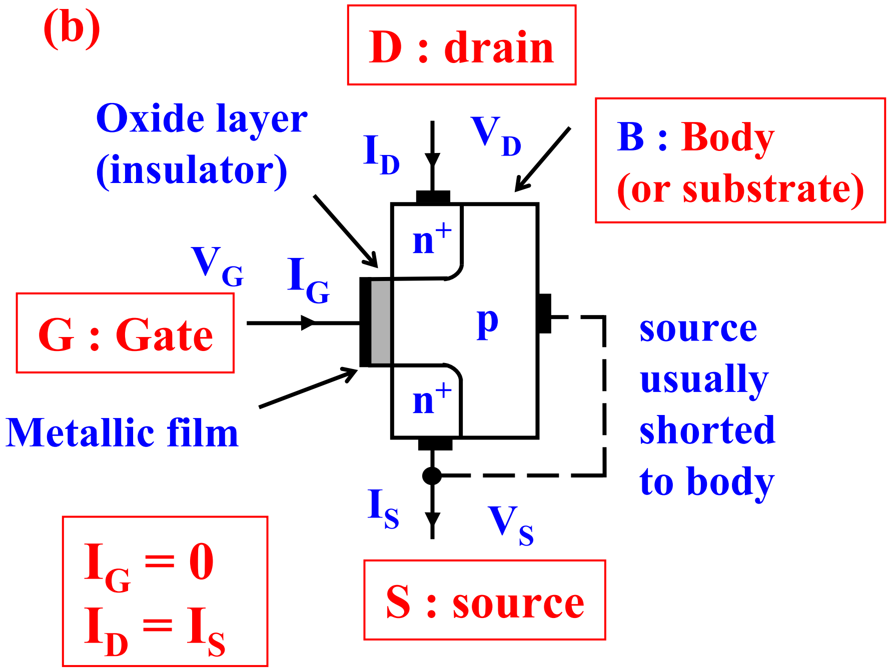
(a) Name two advantages of MOSFET. (b) Draw the cross sectional diagram for an enhancement NMOSFET and describe very briefly the structure.
(15)

(a)

small size (scaled down easily) and low power consumption.

(5)

(b)



An NMOSFET consists of a metal gate insulated from a p-type semiconductor substrate (or body) by an insulating layer of silicon dioxide. On either side of the gate there are n type regions forming the drain and source.

(10)

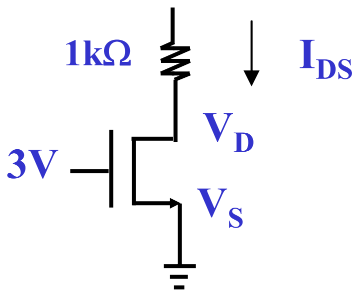
(6)

10

(c) If $I_{DS} = 2mA$, find the mode of the MOSFET. Given that the saturation conditions for NMOS are $V_{GS} \geq V_T$ and $V_{DS} \geq V_{GS} - V_T$. (8)

$V_T = 1V$
$K = 1mA/V^2$

(c)



$$V_{GS} = V_G - V_S = 3V - 0V = 3V$$

$$V_{GS} > V_T$$

$$V_{DS} = 5V - 2mA*1k\Omega = 3V$$

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

$$3 > 3 - 1$$

NMOSFET is in <u>saturation</u> mode

(7)