Second Semester Examination
2018/2019 Academic Session

June 2019

EEE133 – Electronic Devices and Circuits
(Peranti dan Litar Elektronik)

Duration : 3 hours
(Masa : 3 jam)

Please check that this examination paper consists of THIRTEEN (13) pages and THREE (3) pages of printed appendix material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi TIGA BELAS (13) muka surat dan TIGA (3) muka surat lampiran yang bercetak sebelum anda memulakan peperiksaan ini.]

Instructions: This question paper consists of **FIVE (5)** questions. Answer **ALL** questions. All questions carry the same marks.

[***Arahan:*** *Kertas soalan ini mengandungi **LIMA (5)** soalan. Jawab **SEMUA** soalan. Semua soalan membawa jumlah markah yang sama.]*

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

1. (a)

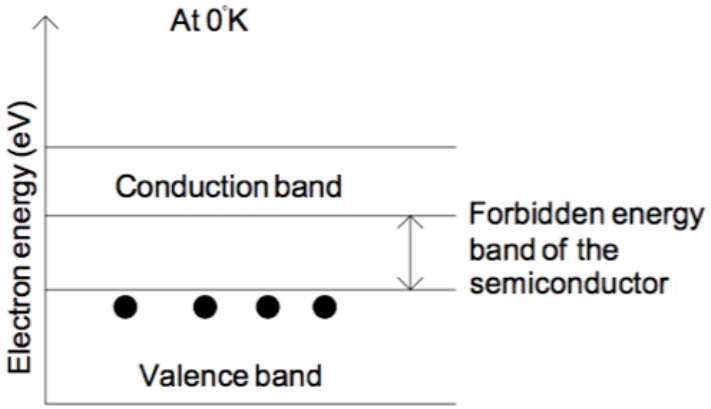

Figure 1.1
Rajah 1.1

Figure 1.1 illustrates the energy band diagram of an intrinsic semiconductor at temperature, T = 0 K. From the figure, it can be seen that all the electrons (denoted by the black dots) are in the valence band. By referring to this diagram, describe the movements of electrons and their respective holes when the temperature is increased to T = 300 K.

Rajah 1.1 menggambarkan rajah jalur tenaga bagi semikonduktor intrinsik pada suhu, T = 0 K. Melalui rajah tersebut, semua elektron (yang diwakili oleh titik-titik hitam) dilihat berada di jalur valens. Terangkan pergerakan elektron dan lubang yang berkaitan dengannya apabila suhu dinaikkan kepada T = 300 K dengan merujuk kepada rajah jalur tenaga.

(10 marks/*markah*)

(b)

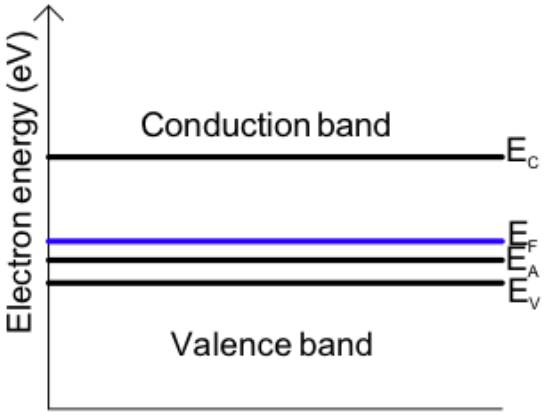

Figure 1.2
Rajah 1.2

Figure 1.2 illustrates the energy band diagram of an extrinsic (doped) semiconductor. Based on the diagram, identify:

Rajah 1.2 menggambarkan rajah jalur tenaga bagi semikonduktor ekstrinsik (didopkan). Dengan menggunakan rajah tersebut, kenalpasti:

(i) Dopant type;
Jenis dopan;

(ii) Majority carrier;
Pembawa majoriti;

(iii) Minority carrier;
Pembawa minoriti:

(iv) Type of fixed charges/ions;
Jenis cas/ion tetap:

(10 marks/*markah*)

(c) An intrinsic silicon crystal is doped with arsenic of concentration 5 x 10^{16} cm^{-3}. At room temperature, the intrinsic carrier concentration of silicon is 1 x 10^{10} cm^{-3}, whereas the electron and hole mobility is given as μ_e = 1450 cm^2/Vs and μ_h = 500 cm^2/Vs respectively. Based on the information given, determine:

Hablur semikonduktor intrinsik telah didopkan dengan arsenik yang mempunyai kepekatan 5 x 10^{16} cm^{-3}. Pada suhu bilik, kepekatan pembawa intrinsik ialah 1 x 10^{10} cm^{-3}, manakala mobiliti elektron dan lubang masing-masing diberikan sebagai μ_e = 1450 cm^2/Vs dan μ_h = 500 cm^2/Vs. Melalui informasi yang diberikan, tentukan:

(i) The minority carrier concentration;
Kepekatan pembawa minoriti;

(ii) The conductivity of the doped material;
Kebolehaliran bahan yang didopkan;

(iii) The type of this doped material. Explain your reasoning.
Jenis bahan yang didopkan. Terangkan alasan anda.

(30 marks/*markah*)

(d) (i) Describe Hall effect and explain the semiconductor parameters that can be determined from Hall measurement.

Nyatakan kesan Hall dan terangkan parameter-parameter semikonduktor yang boleh ditentukan melalui pengukuran Hall.

(20 marks/*markah*)

(ii) An extrinsic semiconductor with 1-kΩ resistance has a length of 25 mm, a width of 5 mm and a thickness of 0.5 mm. If it is placed under a 0.25 Weber/m^2 of magnetic field, a current of 25 mA and a Hall voltage of 5 mV, determine the majority carrier concentration and the carrier mobility.

Semikonduktor ekstrinsik berkerintangan 1 kΩ mempunyai kepanjangan sebanyak 25 mm, kelebaran sebanyak 5 mm dan ketebalan sebanyak 0.5 mm. Sekiranya ia diletakkan bawah pengaruh magnetik sebanyak 0.25 Weber/m^2, melalui arus sebanyak 25 mA dan mempunyai voltan Hall sebanyak 5 mV, tentukan kepekatan pembawa majoriti dan seterusnya, mobiliti pembawa.

(30 marks/*markah*)

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2. (a) Determine the current across the diode, I_d and the voltage across output resistance, V_{out} in Figure 2.1 under the following conditions:

Tentukan arus yang melalui diod, I_d dan voltan yang merentasi perintang keluaran, V_{out} dalam Rajah 2.1 mengikut keadaan-keadaan yang berikut:

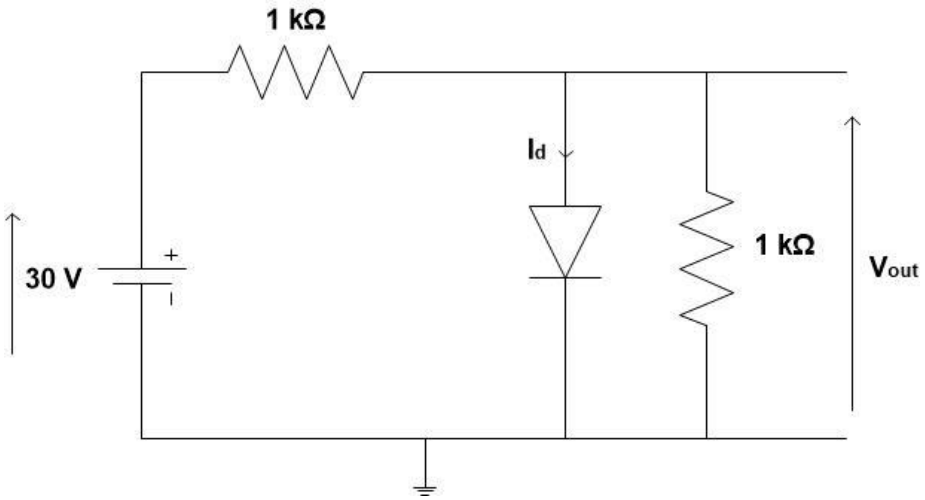

Figure 2.1
Rajah 2.1

(i) The diode is assumed to be ideal;

Diod diandaikan ideal;

(ii) The potential barrier, V_O of the diode is considered. (where V_O = 0.7V)

Sawar keupayaan diod, V_O diambil kira. (V_O diberikan sebagai 0.7 V)

(20 marks/*markah*)

(b) Determine the current across the diode, I_d and the voltage across output resistance, V_{out} in Figure 2.2 by using Piecewise Linear Model. The potential barrier, V_O of the diode and its internal resistance, r_d are given as 0.7 V and 100 Ω, respectively.

Tentukan arus yang melalui diod, I_d dan voltan yang merentasi perintang keluaran, V_{out} dalam Rajah 2.2 dengan menggunakan Model Linear Piecewise. Sawar keupayaan diod, V_O dan perintang dalaman, r_d masing-masing diberikan sebagai 0.7 V dan 100 Ω.

(20 marks/*markah*)

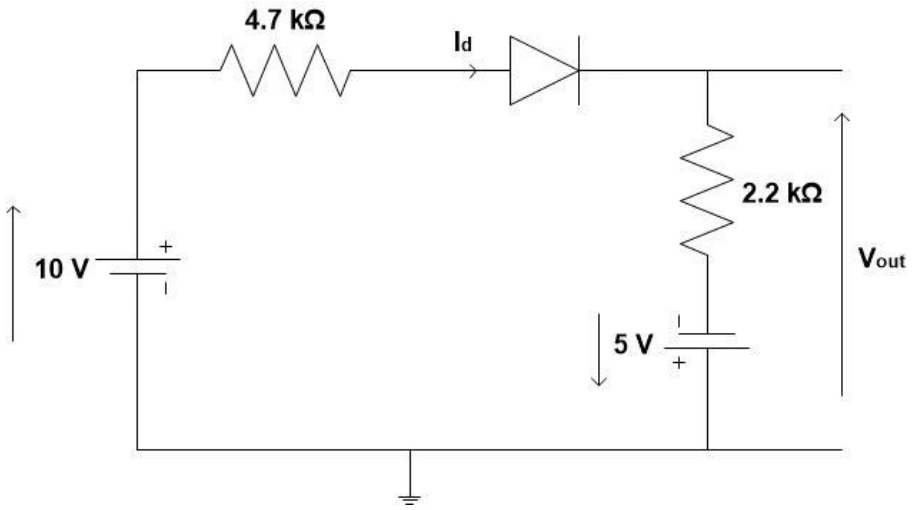

Figure 2.2
Rajah 2.2

(c) Based on the circuit configuration in Figure 2.3,
Berdasarkan konfigurasi litar dalam Rajah 2.3,

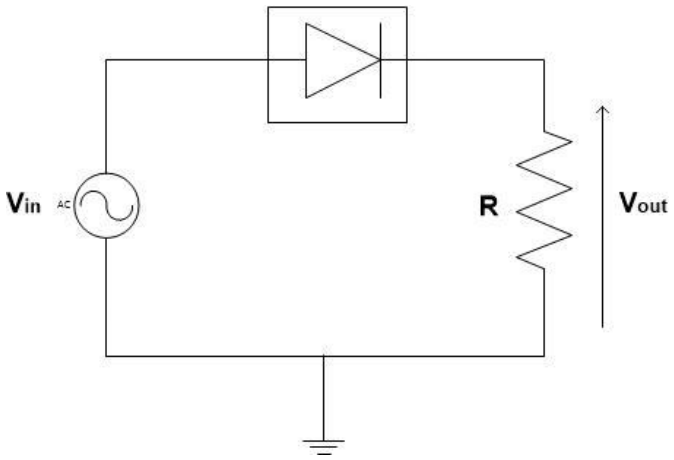

Figure 2.3
Rajah 2.3

(i) Sketch the input voltage waveform of the circuit, V_{in} for a sinusoidal wave with a frequency of 50 Hz and a peak voltage of 10 V. Label all the important parameters.

Lakarkan bentuk gelombang voltan masukan litar, V_{in} untuk gelombang sinusoidal yang mempunyai frekuensi 50 Hz dan voltan puncak 10 V. Labelkan semua parameter penting.

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(ii) Sketch the corresponding output voltage waveform of the circuit, V_{out} with input voltage waveform as stated in (i). Label all the important parameters.

Lakarkan bentuk gelombang voltan keluaran litar, V_{out} yang merujuk kepada bentuk gelombang voltan masukan seperti yang dinyatakan dalam (i). Labelkan semua parameter penting.

(iii) Identify the name of the circuit and state its function.

Kenalpasti nama litar tersebut dan nyatakan fungsinya.

(iv) A filter capacitor can be incorporated into the circuit to reduce the rise and fall of the output voltage characteristics. Illustrate this component in the circuit configuration dan sketch the new output voltage waveform of the circuit, V_{out}.

Kapasitor penapis boleh dimasukkan ke dalam litar untuk mengurangkan kenaikan dan kejatuhan ciri-ciri voltan keluaran. Ilustrasikan komponen ini di dalam konfigurasi litar dan lakarkan bentuk gelombang voltan keluaran, V_{out} yang baru untuk litar tersebut.

(v) Determine the ripple factor (in %) of the output characteristics if the load resistance, R and the filter capacitor, C are given as 220 Ω and 550 μF, respectively.

Tentukan faktor alunan (dalam %) ciri-ciri voltan keluaran sekiranya perintang muatan, R dan kapasitor penapis, C masing-masing diberikan sebagai 220 Ω dan 550 μF.

(60 marks/*markah*)

3. (a) A silicon-based p-n junction is formed by a p-type material doped with acceptor concentration, N_A of 5 x 10^{18} cm^{-3} and an n-type material doped with donor concentration, N_D of 1 x 10^{16} cm^{-3} at room temperature. The minority carrier lifetime in p-type and n-type is 25 µs and 50 µs, respectively. The cross-sectional area of the junction is 0.01 cm^2. The hole mobility, μ_h = 450 cm^2/Vs, the electron mobility μ_e = 1450 cm^2/Vs and the intrinsic concentration, n_i = 1.5 x 10^{10} cm^{-3}. By assuming that the p-type and n-type regions are much longer than the minority carrier diffusion length, determine:

Persimpangan p-n yang berasaskan silikon telah dibentuk oleh jenis-p yang didopkan dengan kepekatan penerima, N_A sebanyak 5 x 10^{18} cm^{-3} dan jenis-n yang didopkan dengan kepekatan penderma, N_D sebanyak 1 x 10^{16} cm^{-3} pada suhu bilik. Jangka hayat pembawa minoriti dalam jenis-p dan jenis-n masing-masing adalah 25 µs dan 50 µs. Keluasan keratan rentas persimpangan tersebut ialah 0.01 cm^2. Mobiliti lubang μ_h = 450 cm^2/Vs, mobiliti elektron, μ_e = 1450 cm^2/Vs dan kepekatan intrinsik, n_i = 1.5 x 10^{10} cm^{-3}. Dengan mengandaikan kawasan-kawasan jenis-p dan jenis-n adalah lebih panjang daripada kepanjangan resapan pembawa minoriti, tentukan:

(i) The reverse saturation current, I_S;

Arus tepu balik, I_S;

(ii) The forward voltage, V required to generate a 1-mA forward current, I_F across the p-n structure.

Voltan depan, V yang diperlukan untuk menjana arus depan, I_F sebanyak 1 mA merentasi struktur p-n tersebut.

(50 marks/*markah*)

(b) (i) Draw the relevant diagram to show on the current carriers that flow across the two P-N junctions and also on the current carrier that flows due to the recombination at the base (B) for a PNP BJT. The BJT is biased for normal mode of operation (as an amplifier) and is in the common base (CB) configuration.

Lukis gambarajah berkaitan untuk menunjukkan pembawa-pembawa arus yang mengalir merentasi dua simpang P-N dan juga pembawa arus yang mengalir disebabkan oleh gabungan semula di tapak (B) bagi satu BJT PNP. BJT berkenaan terpincang bagi operasi mod biasa (sebagai satu penguat) dan dalam konfigurasi tapak sepunya (CB).

(ii) Explain on the reason for the movement of carriers in b(i).

Terangkan sebab kepada pergerakan pembawa-pembawa dalam b(i).

(13 marks/*markah*)

(c) (i) Show the flow direction of all the currents generated by the carriers' movements in (b)(i).

Tunjukkan arah aliran semua arus yang dihasilkan oleh pergerakan pembawa-pembawa arus yang ditunjukkan dalam (b)(i).

(ii) Show the flow direction of the total emitter (E) current, total base (B) current and total collector (C) current due to the movement of carriers in b(i).

Tunjukkan arah aliran bagi arus jumlah pemancar (E), arus jumlah bagi tapak (B) dan arus jumlah bagi pengumpul (C) disebabkan oleh pergerakan pembawa-pembawa dalam b(i).

(7 marks/*markah*)

(d) A PNP transistor has 10^{19} cm^{-3}, 10^{17} cm^{-3} and 5 x 10^{15} cm^{-3} impurity density in each E, B and C, respectively. The lifetime of minority carriers is 10^{-8} s, 10^{-7} s and 10^{-6} s in each E, B and C, respectively. Assume that the cross-section area, A = 0.05 mm^2 and the E-B junction is forward biased by a 0.6 V. Calculate the common-base (CB) current gain, α_o. Other device parameters are D_E = 1 cm^2/s, D_B = 10 cm^2/s, D_C = 2 cm^2/s, intrinsic electron-hole pair density = 9.65x10^9 cm^{-3} and W = 0.5 μm. The device is under room temperature. Assume that W<< L_{pB}.

Satu transistor PNP mempunyai ketumpatan bendasing 10^{19} cm^{-3}, 10^{17} cm^{-3} dan 5 x 10^{15} cm^{-3} masing-masing dalam E, B dan C. Masa hayat pembawa minoriti ialah 10^{-8} s, 10^{-7} s dan 10^{-6} s masing-masing dalam E, B dan C. Anggap bahawa luas keratan rentas, A = 0.05 mm^2 dan simpang E-B terpincang ke depan oleh 0.6 V. Kirakan gandaan arus tapak-sepunya (CB), α_o. Parameter peranti yang lain ialah D_E = 1 cm^2/s, D_B = 10 cm^2/s, D_C = 2 cm^2/s, ketumpatan pasangan elektron-lubang intrinsik = 9.65x10^9 cm^{-3} dan W = 0.5 μm. Peranti adalah di bawah suhu bilik. Anggap bahawa W<< L_{pB}.

(30 marks/*markah*)

4. (a) Determine V_{CE} and I_C for the voltage divider circuit in Figure 4.1. Given V_{BE} = 0.7 V and β = 100.

Tentukan V_{CE} dan I_C bagi litar pembahagi voltan dalam Rajah 4.1. Diberikan V_{BE} = 0.7 V dan β = 100.

(30 marks/*markah*)

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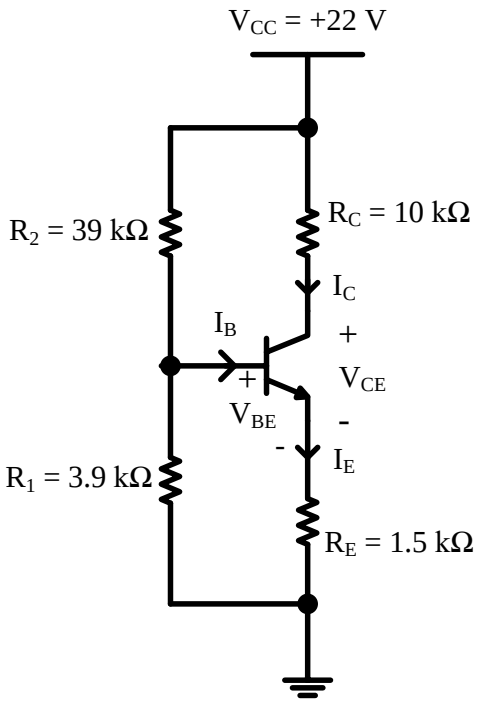

Figure 4.1
Rajah 4.1

(b) Determine I_{CQ} and V_{CEQ} for the circuit in Figure 4.2. Given V_{BE} = 0.7 V and β = 90.

Tentukan I_{CQ} dan V_{CEQ} bagi litar dalam Rajah 4.2. Diberikan V_{BE} = 0.7 V dan β = 90.

(20 marks/*markah*)

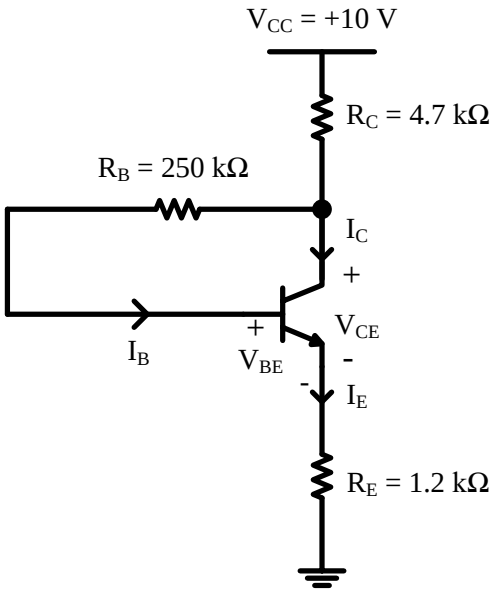

Figure 4.2

Rajah 4.2

(c) You are to bias an NPN transistor to function as an amplifier. The requirement is for the NPN to be maintained or stable in the forward active region throughout its operation. Suggest and explain on the two biasing techniques that you know which can fulfill this application.

Anda dikehendaki untuk memincang satu transistor NPN untuk berfungsi sebagai satu penguat. Keperluan ialah supaya NPN tersebut kekal atau stabil dalam kawasan aktif ke depan sepanjang operasinya. Cadangkan dan beri penerangan tentang dua teknik pemincangan yang anda ketahui yang boleh memenuhi aplikasi anda.

(50 marks/*markah*)

5 (a) Compare (state similarities and differences) between the N-channel JFET and N-channel E-MOSFET (NMOS) in terms of:

Bandingkan (nyatakan persamaan dan perbezaan) di antara JFET saluran-N dan E-MOSFET saluran-N (NMOS) dari segi:

(i) S imple construction/cross-section (label all terminals and semiconductor material type)

Pembinaan/keratan-rentas mudah (labelkan semua terminal dan jenis bahan semikonduktor)

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(ii) biasing for amplifier operation

pincangan bagi operasi penguat

(iii) mechanism of current generation when JFET (E-MOSFET) is in ohmic (triode) region

mekanisma penghasilan arus apabila JFET (E-MOSFET) adalah dalam kawasan ohmik (triod)

(iv) transfer characteristic (label all axes and important voltages and current)

ciri pindah (label semua paksi dan voltan serta arus yang penting)

(57 marks/*markah*)

(b) For the circuit in Figure 5.1, $V_{DS} = ½V_{DD}$, $I_{D(on)} = 4$ mA at $V_{GS(on)} = 6$ V. Determine V_{DD} and R_D. Given $V_{GS(th)}$ (or V_{TN}) = 3 V and $I_D = I_{D(on)}$.

Bagi litar dalam Rajah 5.1, $V_{DS} = ½V_{DD}$, $I_{D(on)} = 4$ mA pada $V_{GS(on)} = 6$ V. Tentukan V_{DD} dan R_D. Diberikan $V_{GS(th)}$ (atau V_{TN}) = 3 V and $I_D = I_{D(on)}$.

(43 marks/*markah*)

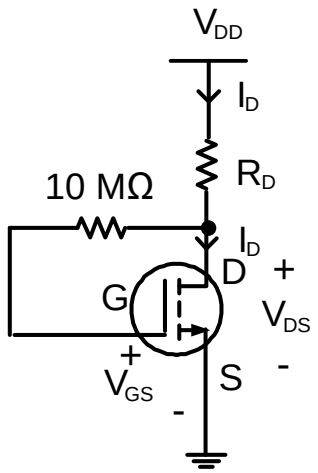

Figure 5.1

Rajah 5.1

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APPENDIX A
LAMPIRAN A

Electronic charge, $q = 1.6 \acute{} \ 10^{-19} C$

Room temperature, $27°C = 300K$

Thermal voltage, $V_T = \frac{kT}{q} \approx 26mV$

Carrier velocity, $u = \mu E$

Conductivity of material, $\sigma = nq\mu_e + pq\mu_h$

Current density, $J = (nq\mu_e + pq\mu_h)E$

Hole current in n-type semiconductor, $I_{pn} = \frac{AqD_p p_n}{L_p}\left(e^{\frac{V}{V_T}} - 1\right)$

Electron current in p-type semiconductor, $I_{np} = \frac{AqD_n n_p}{L_n}\left(e^{\frac{V}{V_T}} - 1\right)$

Diode current, $I = I_S\left(e^{\frac{V}{V_T}} - 1\right)$

Ripple voltage, $V_{r(p-p)} = \left(\frac{1}{fR_L C}\right) V_{P(rect)}$

Average V_{out} in rectifier-filter circuit, $V_{dc} = \left(1 - \frac{1}{2fR_L C}\right) V_{P(rect)}$

BJT

(1) General equations for the currents in a BJT for all mode of operations:

$$I_E = qA\left[\frac{D_p p_{no}}{W} + \frac{D_E n_{Eo}}{L_E}\right]\left[e^{(qV_{EB})/kT} - 1\right] - \left[\frac{qAD_p p_{no}}{W}\right]\left[e^{(qV_{CB})/kT} - 1\right]$$

$$I_C = \frac{qAD_p p_{no}}{W}\left[e^{(qV_{EB})/kT} - 1\right] - qA\left[\frac{D_p p_{no}}{W} + \frac{D_C n_{Co}}{L_C}\right]\left[e^{(qV_{CB})/kT} - 1\right]$$

(2) Equations for the BJT currents in the active mode:

$$I_E = \frac{qAD_p p_{no}}{W} e^{(qV_{EB})/kT} + \frac{qAD_E n_{Eo}}{L_E}\left[e^{(qV_{EB})/kT} - 1\right]$$

$$I_C = \frac{qAD_p p_{no}}{W} e^{(qV_{EB})/kT} + \frac{qAD_C n_{Co}}{L_C}$$

(3) Common base (CB) current gain, $\alpha_o = \beta_{DC} / (1 + \beta_{DC})$, α_o.

(4) DC current gain, $\beta_{DC} = \alpha_o / (1 - \alpha_o)$

(5) $I_{CEO} = I_{CBO} / (1 - \alpha_o)$ where I_{CEO} is the leakage current when B is open and I_{CBO} is the C-B current when E is open

JFET

(1) Transconductance, $$g_m = g_{m0}\left[1 - \frac{V_{GS}}{V_{GS(off)}}\right]$$

where $$g_{m0} = \frac{2I_{DSS}}{|V_{GS(off)}|}$$

(2) $$R_{IN} = \left|\frac{V_{GS}}{I_{GSS}}\right|$$

E-MOSFET

(1) $$I_D = \frac{\mu_n C_{ox}}{2}\frac{W}{L}\left[2(V_{GS} - V_{GS(th)})V_{DS} - V_{DS}^2\right]$$

where $$K = \frac{\mu_n C_{ox}}{2}\frac{W}{L}$$

(2) If channel width modulation is not neglected, drain current in the saturation region:

$$I_D = K(V_{GS} - V_{GS(th)})^2(1 + \lambda V_{DS})$$

where λ = channel length modulation parameter.

APPENDIX B
LAMPIRAN B

Course Outcomes (CO) – Programme Outcomes (PO) Mapping

Pemetaan Hasil Pembelajaran Kursus – Hasil Program

Questions ***Soalan***	**CO**	**PO**
1	1	1
2	2	1
3	1	1
4	3	1
5	4	1