Chapter 1 : 15, 16, 18, 19, 27, 28, 29, 31

9. Majority carriers are those carriers of a material that far exceed the number of any other carriers in the material.
Minority carriers are those carriers of a material that are less in number than any other carrier of the material.

10. Same basic appearance as Fig. 1.7 since arsenic also has 5 valence electrons (pentavalent).

11. Same basic appearance as Fig. 1.9 since boron also has 3 valence electrons (trivalent).

12.

13.

14. For forward bias, the positive potential is applied to the p-type material and the negative potential to the n-type material.

15. a. $V_T = \frac{kT_K}{q} = \frac{(1.38\times10^{-23}\ \text{J/K})(20^\circ\text{C}+273^\circ\text{C})}{1.6\times10^{-19}\ \text{C}}$ = Thermal voltage, $V_T = \frac{K\,T_K}{q}$

$= \mathbf{25.27\ mV}$

T_K = Absolute temp. $= (20^\circ\text{C} + 273)$ K

b. $I_D = I_s(e^{V_D/nV_T} - 1)$

$= 40\ \text{nA}(e^{(0.5\ \text{V})/(2)(25.27\ \text{mV})} - 1)$

$= 40\ \text{nA}(e^{9.89} - 1) = \mathbf{0.789\ mA}$

16. a. $V_T = \frac{kT_K}{q} = \frac{(1.38\times10^{-23}\ \text{J/K})(100^\circ\text{C}+273^\circ\text{C})}{1.6\times10^{-19}\ \text{C}}$ $= V_T = \frac{K\,T_K}{q}$, $T_K = 100 + 273 = 373$ K

$= \mathbf{32.17\ mV}$

b. $I_D = I_s(e^{V_D/nV_T} - 1)$

$= 40\ \text{nA}(e^{(0.5\ \text{V})/(2)(32.17\ \text{mV})} - 1)$ $\quad I_D = \underset{40\,\text{nA}}{I_s}(e^{\frac{V_D}{nV_T}} - 1)$

$= 40\ \text{nA}(e^{7.77} - 1) = \mathbf{11.84\ mA}$ $\quad n = 2$, $V_T = 32.17$ mV, $V_D = 0.5$ V

17. a. $T_K = 20 + 273 = 293$

$V_T = \frac{kT_K}{q} = \frac{(1.38\times10^{-23}\ \text{J/K})(293)}{1.6\times10^{-19}\ \text{C}}$

$= \mathbf{25.27\ mV}$

b. $I_D = I_s(e^{V_D/nV_T} - 1)$

$= 0.1\ \text{A}(e^{10/(2)(25.27\ \text{mV})} - 1)$

$= 0.1\ \text{A}(e^{197.86} - 1)$

$\cong \mathbf{0.1\ A}$

18. $_TV\ \frac{kT_K}{q}\ \frac{(1.38\times10^{23}\text{ J/K})(25\text{C}+273\text{C})}{1.6\times10^{19}\text{ C}} = \frac{kT_K}{q} = V_T$; $T_K = 25 + 273 = 298\text{ K}$

=25.70 mV

$I_D = I_s(e^{V_D/nV_T} - 1)$

8mA $= I_s(e^{(0.5\text{V})/(1)(25.70\text{ mV})} - 1) = I_s \times (28\ 10^8)$ $\quad I_D = I_s(e^{V_D/nV_T} - 1)$

$I_s = \frac{8\text{ mA}}{2.8\times10^8}$ = **28.57 pA** $\quad I_s = \frac{I_D \ 8\text{mA}}{e^{V_D/nV_T} - 1}$; $I_D = 8\text{ mA}$, $V_D = 0.5\text{ V}$, $n = 1$, $V_T = 25.7\text{ mV}$

0.5 V $\quad n=1 \quad V_T = 25.7$ mv

19. $I_D = I(e^{V_D/nV_T} - 1)$

6 mA=1 nA$(e^{V_D/(1)(26\text{ mV})} - 1)$

$6\times10^6 = e^{V_D/26\text{ mV}} - 1$

$e^{V_D/26\text{ mV}} = 6\ 10^6 + 1 \cong 6\ 10^6$

$\log_e e^{V_D/26\text{mV}} = \log_e(6\ 10\ ^6)$, $\log_e(e^{V_D/26\text{mv}}) = \ln(e^{V_D/26\text{mv}}) = \frac{V_D}{26\text{mV}}$

$\frac{V_D}{26\text{ mV}} = 15.61$ $\quad \log_e = \ln$; $\ln e^x = x$

$V_D = 15.61(26\text{ mV})$ **0.41 V**

20. (a)

x	$y = e^x$
0	1
1	2.7182
2	7.389
3	20.086
4	54.6
5	148.4

(b) $y = e^0 = 1$

(c) For $x = 0$, $e^0 = 1$ and $I = I_s(1\ 1) =$ **0 mA**

21. $T = 20\text{C}$: $I_s = 0.1$ A

$T = 30\text{C}$: $I_s = 2(0.1\text{ A}) = 0.2$ A (Doubles every 10C rise in temperature)

$T = 40\text{C}$: $I_s = 2(0.2\text{ A}) = 0.4$ A

$T = 50\text{C}$: $I_s = 2(0.4\text{ A}) = 0.8$ A

$T = 60\text{C}$: $I_s = 2(0.8\text{ A}) =$ **1.6 A**

1.6 A: 0.1 A 16:1 increase due to rise in temperature of 40C.

22. For most applications the silicon diode is the device of choice due to its higher temperature capability. Ge typically has a working limit of about 85 degrees centigrade while Si can be used at temperatures approaching 200 degrees centigrade. Silicon diodes also have a higher current handling capability. Germanium diodes are the better device for some RF small signal applications, where the smaller threshold voltage may prove advantageous.

23. From 1.19:

	75C	25C	100C	200C
V_F @ 10 mA	1.1 V	0.85 V	1.0 V	0.6 V
I_s	0.01 pA	1 pA	1 A	1.05 A

V_F decreased with increase in temperature

1.7 V: 0.65 V **2.6:1**

I_s increased with increase in temperature

2 A: 0.1 A = **20:1**

24. An "ideal" device or system is one that has the characteristics we would prefer to have when using a device or system in a practical application. Usually, however, technology only permits a close replica of the desired characteristics. The "ideal" characteristics provide an excellent basis for comparison with the actual device characteristics permitting an estimate of how well the device or system will perform. On occasion, the "ideal" device or system can be assumed to obtain a good estimate of the overall response of the design. When assuming an "ideal" device or system there is no regard for component or manufacturing tolerances or any variation from device to device of a particular lot.

25. In the forward-bias region the 0 V drop across the diode at any level of current results in a resistance level of zero ohms – the "on" state – conduction is established. In the reverse-bias region the zero current level at any reverse-bias voltage assures a very high resistance level the open circuit or "off" state conduction is interrupted.

26. The most important difference between the characteristics of a diode and a simple switch is that the switch, being mechanical, is capable of conducting current in either direction while the diode only allows charge to flow through the element in one direction (specifically the direction defined by the arrow of the symbol using conventional current flow).

27. V_D=0.7 V, I_D = 4 mA → From Fig 1·15. For 4mA current, $V_D = 0{\cdot}7V$

$R_{DC} = \dfrac{V_D}{I_D} = \dfrac{0.7\text{ V}}{4\text{ mA}} = \mathbf{175}\ \Omega$

28. At I_D = 15 mA, V_D = 0.82 V → From Fig 1·15.

$R_{DC} = \dfrac{V_D}{I_D} = \dfrac{0.82\text{ V}}{15\text{ mA}} = \mathbf{54.67}\ \Omega$

As the forward diode current increases, the static resistance decreases.

29. $\cancel{V_D = 10\text{ V}, I_D = I_s = 0.1\text{ A}}$

$\cancel{R_{DC} = \frac{V_D}{I_D} \quad \frac{10\text{ V}}{0.1\text{ A}} = 100\text{ M}}$

$\cancel{V_D = 30\text{ V}, I_D = I_s = 0.1\text{ A}}$

$\cancel{R_{DC} = \frac{V_D}{I_D} \quad \frac{30\text{ V}}{0.1\text{A}} = 300\text{ M}}$

For. $V_D = -10V \rightarrow I_D = 50pA = 50\times10^{-12}A$

$R_{DC} = \frac{V_D}{I_D} = \frac{10V}{50\times10^{-12}A} = \boxed{2\times10^{11}\ \Omega}$

For. $V_D = -30V$, $I_D = 50pA$; $R_{DC} = \frac{30}{50\times10^{-12}} = \boxed{6\times10^{11}\ \Omega}$

As the reverse voltage increases, the reverse resistance increases directly (since the diode leakage current remains constant).

30. $I_D = 10$ mA, $V_D = 0.76$ V

$R_{DC} = \frac{V_D}{I_D} \quad \frac{0.76\text{ V}}{10\text{ mA}} = \mathbf{76}$

$r_d = \frac{V_d}{I_d} \quad \frac{0.79\text{ V } 0.76\text{ V}}{15\text{ mA } \ 5\text{ mA}} \quad \frac{0.03\text{ V}}{10\text{ mA}} = \mathbf{3}$

$R_{DC} >> r_d$

31. (a) $r_d = \frac{V_d}{I_d} = \frac{0.79\text{ V}-0.76\text{ V}}{15\text{ mA}-5\text{ mA}} = \frac{0.03\text{ V}}{10\text{ mA}} = \mathbf{3}\ \Omega$.

Eq. 1.5: $r_d = \frac{\Delta V_d}{\Delta I_d} = \frac{V_2 - V_1}{I_2 - I_1}$

(b) $r_d = \frac{26\text{ mV}}{I_D} = \frac{26\text{ mV}}{10\text{ mA}} = \mathbf{2.6}\ \Omega$

(c) quite close

32. $I_D = 1$ mA, $r_d = \frac{V_d}{I_d} \quad \frac{0.72\text{ V } 0.61\text{ V}}{2\text{ mA } \ 0\text{ mA}} = \mathbf{55}$

$I_D = 15$ mA, $r_d = \frac{V_d}{I_d} \quad \frac{0.8\text{ V } 0.78\text{ V}}{20\text{ mA } \ 10\text{ mA}} = \mathbf{2}$

33. $I_D = 1$ mA, $r_d = 2\ \frac{26\text{ mV}}{I_D} = 2(26\ ) = \mathbf{52}$ vs 55 (#30)

$I_D = 15$ mA, $r_d = \frac{26\text{ mV}}{I_D} \quad \frac{26\text{ mV}}{15\text{ mA}} = \mathbf{1.73}$ vs 2 (#30)

34. $r_{av} = \frac{V_d}{I_d} \quad \frac{0.9\text{ V } 0.6\text{ V}}{13.5\text{ mA } \ 1.2\text{ mA}} = \mathbf{24.4}$

35. $r_d = \frac{V_d}{I_d} \quad \frac{0.8\text{ V } 0.7\text{ V}}{7\text{ mA } \ 3\text{ mA}} \quad \frac{0.09\text{ V}}{4\text{ mA}} = \mathbf{22.5}$

(relatively close to average value of 24.4 (#32))