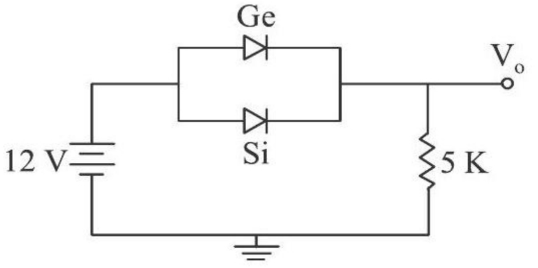
Semiconductor Electronics: Materials, Devices and Simple Circuits

1. Mobility of electrons in a semiconductor is defined as the ratio of their drift velocity to the applied electric field. If, for an n-type semiconductor, the density of electrons is $10^{19}\ m^{-3}$ and their mobility is $1.6\ m^2/(V.s)$ then the resistivity (in Ωm) of the semiconductor (since it is an n-type semiconductor contribution of holes is ignored) is

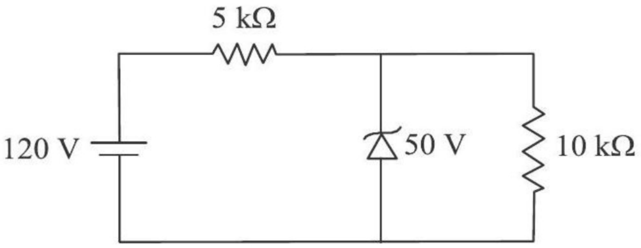
2. Ge and Si diodes start conducting at 0.3 V and 0.7 V respectively. In the following figure if Ge diode connection are reversed, the value of V_o (in volt) changes by : (assume that the Ge diode has large breakdown voltage)



3. Copper, a monovalent, has molar mass 63.54 g/mol and density $8.96\ g/cm^3$. What is the number density n (in m^{-3}) of conduction electron in copper?

4. An LED is constructed from a p-n junction based on a certain Ga − As − P semiconducting material whose energy gap is 1.9 eV. What is the wavelength (in nm) of the emitted light?

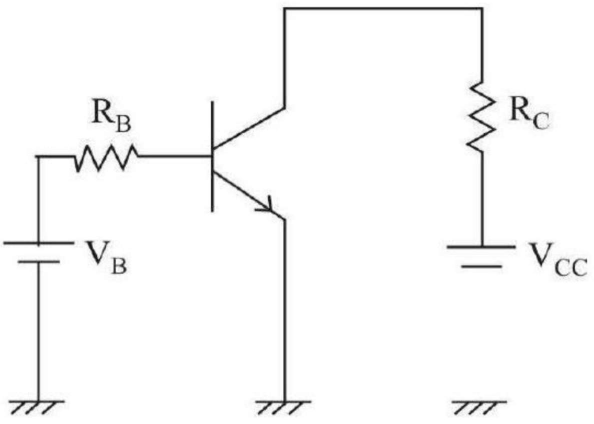
5. For the circuit shown below, the current (in mA) through the Zener diode is:



6. An npn transistor operates as a common emitter amplifier, with a power gain of 60 dB. The input circuit resistance is 100 W and the output load resistance is 10 kW. The common emitter current gain b is :

7. In half-wave rectification, what is the output frequency (in Hz) if the input frequency is 50 Hz ?

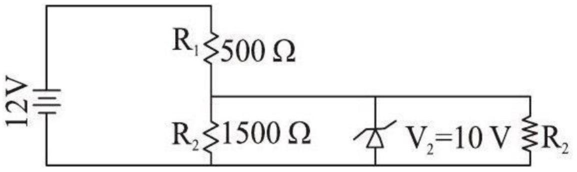
8. A common emitter amplifier circuit, built using an npn transistor, is shown in the figure. Its dc current gain is 250, $R_C = 1\text{k}\Omega$ and $V_{CC} = 10$ V. What is the minimum base current (in μA) for V_{CE} to reach saturation?



9. In a photodiode, the conductivity increases when the material is exposed to light. It is found that the conductivity changes only if the wavelength is less than 620 nm. What is the band gap (in eV)?

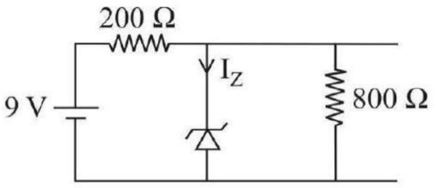
10. When the base current in a transistor is changed from 30μ A to 80μ A, the collector current is changed from 1.0 mA to 3.5 mA. Find the current gain β.

11. In the given circuit the current (in mA) through Zener Diode is



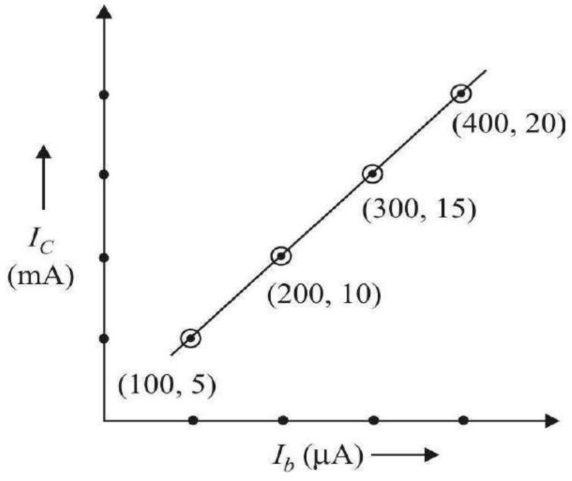
12. In an intrinsic semiconductor the energy gap E_g is 1.2 eV. Its hole mobility is much smaller than electron mobility and independent of temperature. What is the ratio between conductivity at 600 K and that at 300 K ? Assume that the temperature dependence of intrinsic carrier concentration n_i is given by
$n_i = n_0 \exp\left(-\frac{E_g}{2k_BT}\right)$ where n_0 is a constant.
$K_B = 8.62 \times 10^{-5} eVk^{-1}$

13. The reverse breakdown voltage of a Zener diode is 5.6 V in the given circuit.

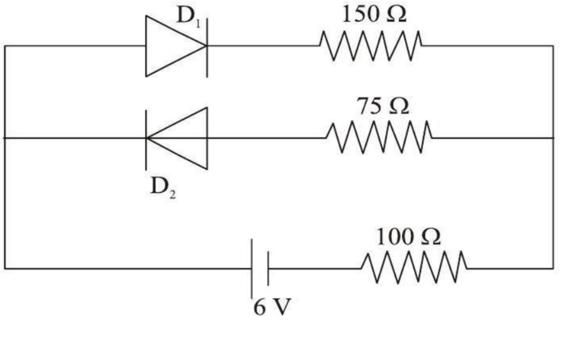


The current I_z (in mA) through the Zener is :

14. The transfer characteristic curve of a transistor, having input and output resistance 100Ω and 100kΩ respectively, is shown in the figure. The Voltage gain is



15. The circuit shown below contains two ideal diodes, each with a forward resistance of 50Ω. If the battery voltage is 6 V, the current through the 100Ω resistance (in Ampere) is :



SOLUTIONS

1. **(0.4)** As we know, current density,

$$j = \sigma E = nev_d$$

$$\sigma = ne\frac{v_d}{E} = ne\mu$$

$$\frac{1}{\sigma} = \rho = \frac{1}{n_e e\mu_e} = \text{Resistivity}$$

$$= \frac{1}{10^{19} \times 1.6 \times 10^{19} - 19 \times 1.6}$$

or $P = 0.4\,\Omega m$

2. **(0.4)** Initially Ge and Si are both forward biased so current will effectively pass through Ge diode

$\therefore V_\circ = 12 - 0.3 = 11.7\text{ V}$

And if "Ge" is revesed then current will flow through "Si" diode

$\therefore V_\circ = 12 - 0.7 = 11.3\text{ V}$

Clearly, $V_\circ$ changes by $11.7 - 11.3 = 0.4\text{ V}$

3. **(8.49×10^{26})** If M is the molar mass and ρ is the density then volume of one mole

$$V = \frac{M}{\rho}.$$

The number of atoms per unit volume

$$= \frac{N_A}{V} = \frac{N_A}{M/\rho} = \frac{N_A\rho}{M}$$

$$= \frac{(6.02 \times 10^{23}) \times (8.96)}{63.54}$$

$$= 8.49 \times 10^{22}\ \text{cm}^{-3}$$

$$= 8.49 \times 10^{28}\ \text{m}^{-3}$$

As each copper (monovalent) atom has one electron, so number of electrons per unit volume

$$= 8.49 \times 10^{26}\ \text{m}^{-3}$$

4. **(650)** If λ is the wavelength of emitted light, then

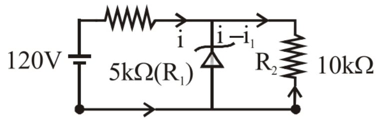
$$E_g = \frac{hc}{\lambda}$$

or $$\lambda = \frac{hc}{E_g}$$

$$= \frac{(6.63 \times 10^{-34}) \times (3 \times 10^8)}{(1.9) \times (1.60 \times 10^{-19})}$$

$$= 6.5 \times 10^{-7}\ \text{m} = 650\ \text{nm}$$

5. **(9)** The voltage across zener diode is constant



$$i_{(R_2)} = \frac{V}{R} = \frac{50}{10\times10^3} = 5\times10^{-3}\,A$$

$$i_{(R_1)} = \frac{V}{R} = \frac{120-50}{5\times10^3} = \frac{70}{5\times10^3} 14\times10^{-3}\,A$$

$\therefore i_{zenerdiode} = 14\times10^{-3} - 5\times10^{-3} = 9\times10^{-3}\,A = 9\,mA$

6. **(100)** Power gain = 60 = $10\log\left(\frac{P_0}{p_i}\right)$

$\Rightarrow \quad 6 = \log\left(\frac{P_0}{p_i}\right)$

$\Rightarrow \quad \frac{P_0}{p_i} = 10^6$

$= \beta^2\left(\frac{R_{out}}{R_{in}}\right)$

$\Rightarrow \quad 10^6 = \beta^2\left(\frac{10000}{100}\right)$

[as R_{out} = 10, 000W R_{in} = 100W]

$\Rightarrow \beta = 100$

7. **(50)** In half wave rectification, output frequency remains same as input i.e., 50Hz.

8. **(40)** Given, b = 250

Voltage gain, $\frac{V_{CC}}{V_B} = \beta\frac{R_C}{R_B}$

$$\frac{10}{V_B} = 250\times\frac{10^3}{R_B}$$

$$\therefore \quad \frac{V_B}{R_B} = \frac{1}{25\times10^3} = 40\mu A$$

9. **(2.0)** The band gap $E_g = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34})\times(3\times10^8)}{620\times10^{-9}}$

$= 3.2\times10^{-19}$ J

$= 2.0$ eV.

10. **(50)** We know that $\beta = \dfrac{\Delta i_c}{\Delta i_B}$

$$= \frac{(3.5-1.0)\times10^{-3}}{(80-30)\times10^{-6}} = 50 .$$

11. **(0)** Since voltage across zener diode does not reach to breakdown voltage therefore its resistance will be infinite & current through it is 0.

12. **(1.1×10^5)** Here, $\dfrac{\Delta E}{2K}\left[\dfrac{1}{T_1}-\dfrac{1}{T_2}\right]$

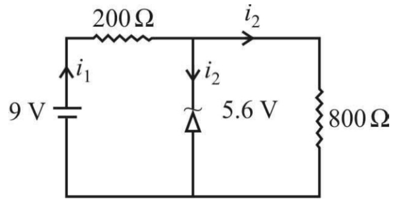
$$= \frac{1.2}{2\times8.62\times10^{-5}}\cdot\left[\frac{1}{300}-\frac{1}{600}\right] = 11.6$$

$$\frac{n_{600}}{n_{300}} = e^{\frac{\Delta E}{2K}\left[\frac{1}{T_1}-\frac{1}{T_2}\right]} = e^{11.6} = (2.718)^{11.6}$$

Solving using logs, $\dfrac{n_{600}}{n_{300}} = 1.089 \times 10^5$

$= 1.1 \times 10^5$

13. **(10)**



P.D. across 800Ω resistors = 5.6 V

so, $I_{800\Omega} = \dfrac{5.6}{800} A = 7$ mA

Now, P.D. across 200Ω resistors = (9 – 5.6) V = 3.4 V

so, $I_{200\Omega} = \dfrac{9-5.6}{200} = 17$ mA

so, current through zener diode

$= I_2 = 17 - 7 = 10$ mA

14. **(20×10^3)** $\beta = \dfrac{\Delta i_c}{\Delta i_b} = \dfrac{200-100}{10-5} = 20$

Voltage gain $= \beta\dfrac{R_2}{R_1} = \dfrac{20\times100\times10^3}{100} = 20 \times 10^3$

15. **(0.02)** As D_2 is reversed biased, so no current through 75Ω resistor.

now $R_{eq} = 150 + 50 + 100$
$= 300\ \Omega$

So, required current $I = \dfrac{\text{Battery Voltage}}{300}$

$I = \dfrac{6}{300} = 0.02$