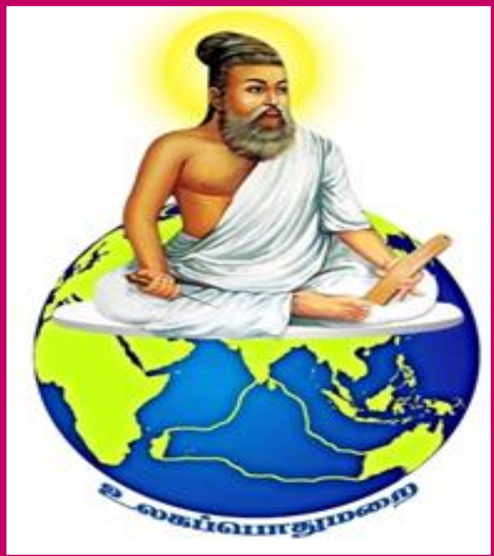
HIGHER SECONDARY
SECOND YEAR



PHYSICS

UNIT - 10

ELECTRONICS AND COMMUNICATIONS

PROBLEMS AND SOLUTIONS

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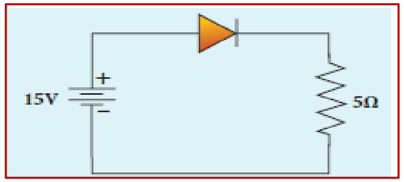
EXAMPLE PROBLEMS

1. An ideal diode and a 5 Ω resistor are connected in series with a 15 V power supply as shown in figure below. Calculate the current that flows through the diode.



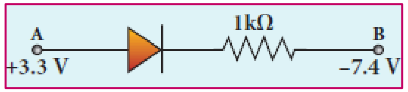
Solution :

- The diode is forward biased and it is an ideal one. Hence, it acts like a closed switch with no barrier voltage. Therefore, current that flows through the diode can be calculated using Ohm's law.

$$V = I\,R$$

$$(or) \qquad I = \frac{V}{R} = \frac{15}{5} = \mathbf{3\ A}$$

2. A silicon diode is connected with 1kΩ resistor as shown. Find the value of current flowing through *AB*.



Solution : $R = 1\,k\,\Omega = 1000\,\Omega$

- The barrier voltage for silicon diode ; $V_b\ (Si) = 0.7\ V$
- The P.D. between A and B is given by ;

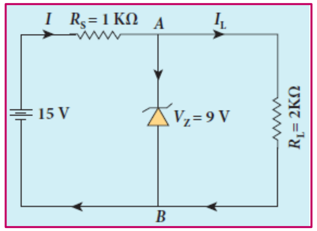
$$V = [V_A - V_B] - V_b\,(Si) = [3.3 - (-7.4)] - 0.7 = 10.7 - 0.7 = \mathbf{10\ V}$$

- The value of current flowing through *AB* can be obtained using Ohm's law.

$$V = I\,R$$

$$(or) \qquad I = \frac{V}{R} = \frac{10}{1000} = \frac{1}{100} = 10^{-2}\ A = \mathbf{10\ m\ A}$$

3. Find the current through the Zener diode when the load resistance is 2 kΩ. Use diode approximation.



Solution : $V = 15\ V$; $R_S = 1\,k\,\Omega = 1000\,\Omega$

$V_Z = 9\ V$; $R_L = 2\,k\,\Omega = 2000\,\Omega$

- From figure, $V_R = V - V_Z = 15 - 9 = 6\ V$
- From Ohm's law, current through 'R_S'

$$I = \frac{V_R}{R_S} = \frac{6}{1000} = 6\ X\ 10^{-3}\ A = \mathbf{6\ m\ A}$$

- And current through load resistance R_L

$$I_L = \frac{V_L}{R_L} = \frac{V_Z}{R_L} = \frac{9}{2000} = \frac{4.5}{1000} = 4.5\ X\ 10^{-3}\ A = \mathbf{4.5\ m\ A}$$

- If I_Z be the current through Zener diode, then using Kirchoff's current law at junction A gives,

$$I = I_L + I_Z$$

$$(or) \qquad I_Z = I - I_L = 6 - 4.5$$

$$\mathbf{I_Z = 1.5\ mA}$$

4. Determine the wavelength of light emitted from LED which is made up of GaAsP semiconductor whose forbidden energy gap is 1.875 eV. Mention the colour of the light emitted (Take *h* = 6.6 × 10^{-34} Js).

Solution : $E_g = 1.875\ eV = 1.875\ X\ 1.6\ X\ 10^{-19}\ J$; $h = 6.6\ X\ 10^{-34}\ J\ s$

- By definition,

$$E_g = h\,\nu = \frac{h\,c}{\lambda}$$

$$\therefore \quad \lambda = \frac{h\,c}{E_g} = \frac{6.6\ X\ 10^{-34}\ X\ 3\ X\ 10^{8}}{1.875\ X\ 1.6\ X\ 10^{-19}} = \frac{19.8\ X\ 10^{-7}}{3}$$

$$\lambda = 6.6\ X\ 10^{-7}\ m = 660\ X\ 10^{-9}\ m = \mathbf{660\ nm}$$

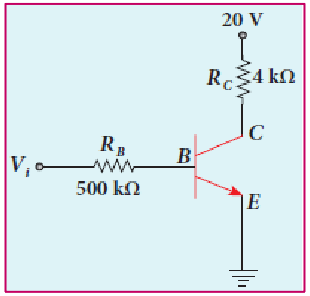
- The wavelength 660 nm corresponds to red colour light.

5. In a transistor connected in the common base configuration $\alpha = 0.95$, $I_E = 1\ mA$. Calculate the values of I_C and I_B.

Solution : $\alpha = 0.95$, $I_E = 1\ mA$

- Current gain in common base mode ; $\alpha = \dfrac{I_C}{I_E}$
- Hence, $I_C = \alpha\,I_E = 0.95\ X\ 1 = \mathbf{0.95\ mA}$
- Also, $I_E = I_B + I_C$ (or) $I_B = I_E - I_C = 1 - 0.95 = \mathbf{0.05\ mA}$

6. In the circuit shown in the figure, the input voltage V_i is 20 V, V_{BE} = 0 V and V_{CE} = 0 V. What are the values of I_B , I_C , β?



Solution : $R_B = 500\,k\,\Omega$; $R_C = 4\,k\,\Omega$

- Voltage across R_B ; $V_B = V_i - V_{BE}$

Since, $V_{BE} = 0\ V$ we have, $V_B = V_i$ Hence

$$I_B = \frac{V_B}{R_B} = \frac{V_i}{R_B} = \frac{20}{500\ X\ 10^3} = 0.04\ X\ 10^{-3}$$

$$I_B = 40\ X\ 10^{-6}\ A = \mathbf{40\ \mu\ A}$$

- Similarly, voltage across R_C ; $V_C = V_{CC} - V_{CE}$

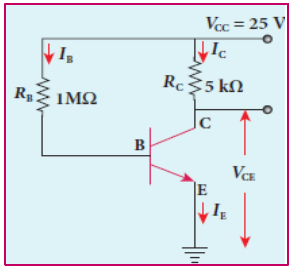
Since, $V_{CE} = 0\ V$ we have, $V_C = V_{CC}$ Hence

$$I_C = \frac{V_C}{R_C} = \frac{V_{CC}}{R_C} = \frac{20}{4\ X\ 10^3} = 5\ X\ 10^{-3} = \mathbf{5\ m\ A}$$

- And current gain,

$$\beta = \frac{I_C}{I_B} = \frac{5\ X\ 10^{-3}}{40\ X\ 10^{-6}} = 0.125\ X\ 10^3 = \mathbf{125}$$

7. The current gain of a common emitter transistor circuit shown in figure is 120. Draw the DC load line and mark the *Q* point on it. (V_{BE} to be ignored).



Solution : $\beta = 120$; $V_{CC} = 25\ V$; $R_B = 1\ M\Omega$;

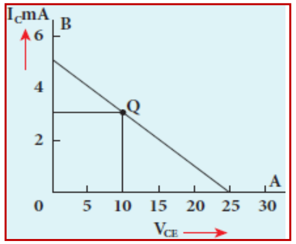
$R_C = 5\ k\Omega$

- Voltage across R_B ; $V_B = V_{CC} - V_{BE}$

Since, $V_{BE} = 0\ V$ we have, $V_B = V_{CC}$ Hence

$$I_B = \frac{V_B}{R_B} = \frac{V_{CC}}{R_B} = \frac{25}{1\ X\ 10^6} = 25\ X\ 10^{-6}\ A = \mathbf{25\ \mu\ A}$$

- By definition, current gain ; $\beta = \frac{I_C}{I_B}$
- Hence collector current,
  $I_C = \beta I_B = 120 X 25 X 10^{-6} = 3000 X 10^{-6} A$
  $\boldsymbol{I_C} = 3 X 10^{-3} A = \mathbf{3\ m\ A}$
- From figure, $V_{CE} = V_{CC} - V_C = V_{CC} - I_C R_C$
  $V_{CE} = 25 - (3 X 10^{-3} X 5X 10^3)$
  $\boldsymbol{V_{CE}} = 25 - 15 = \mathbf{10\ V}$



8. Calculate the range of the variable capacitor that is to be used in a tuned-collector oscillator which has a fixed inductance of 150 μH. The frequency band is from 500 kHz to 1500 kHz.

Solution : $L = 150\ \mu\ H$

- Resonance frequency ; $f_o = \frac{1}{2\pi\sqrt{LC}}$ (or) $f_o^2 = \frac{1}{4\pi^2 L C}$
- Hence capacitance ; $C = \frac{1}{4\pi^2 L f_o^2}$
- When, $f_o = 500\ kHz$,

$$C = \frac{1}{4 X (3.14)^2 X 150 X 10^{-6} X (500 X 10^3)^2}$$
$$C = \frac{1}{4 X 9.8596 X 150 X 250000}$$
$$C = 6.761 X 10^{-10} F = 676.1 X 10^{-12} F$$
$$\boldsymbol{C \approx 676\ pF}$$

No	Log
1	0. 0000
4	0. 6021
9.8596	0. 9939
150	2. 1761
250000	5. 3979
(+)	9. 1700
Nr	0. 0000
Dr	9. 1700
(-)	10. 8300
ALog	$6.761 X 10^{-10}$

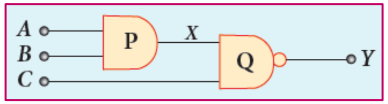
- When, $f_o = 1500\ kHz$

$$C = \frac{1}{4 X (3.14)^2 X 150 X 10^{-6} X (1500 X 10^3)^2}$$
$$C = \frac{1}{4 X 9.8596 X 150 X 2250000}$$
$$C = 7.511 X 10^{-11} F = 75.11 X 10^{-12} F$$
$$\boldsymbol{C \approx 75\ pF}$$

No	Log
1	0. 0000
4	0. 6021
9.8596	0. 9939
150	2. 1761
2250000	6. 3522
(+)	10. 1243
Nr	0. 0000
Dr	10 1243
(-)	11. 8757
ALog	$7.511 X 10^{-11}$

- *Therefore, the capacitor range is* $\mathbf{75\ pF - 676\ pF}$

9. What is the output Y in the following circuit, when all the three inputs A, B, and C are first 0 and then 1?

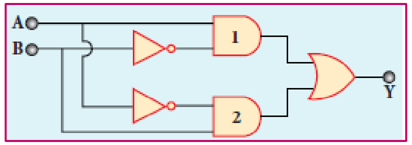


Solution :

- Out put of *AND* gate P : $\boldsymbol{X = A . B}$
- Out put of *NAND* gate Q : $\boldsymbol{Y = \overline{X . B}}$

A	B	C	$X = A . B$	$Y = \overline{X . B}$
0	0	0	0	**1**
1	1	1	1	**0**

10. In the combination of the following gates, write the Boolean equation for output Y in terms of inputs A and B.



Solution :

- The output at the 1st AND gate $= \boldsymbol{A . \overline{B}}$
- The output at the 2nd AND gate $= \boldsymbol{\overline{A} . B}$
- The output at the OR gate ; $\boldsymbol{Y = A . \overline{B} + \overline{A} . B}$

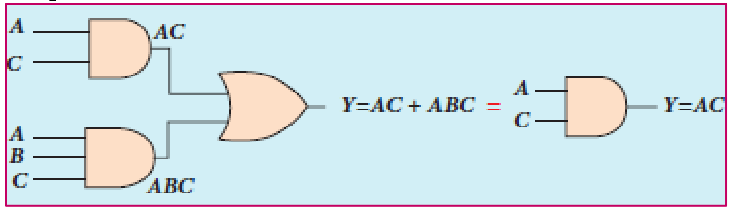
11. Prove the Boolean identity AC + ABC = AC and give its circuit description.

Solution :

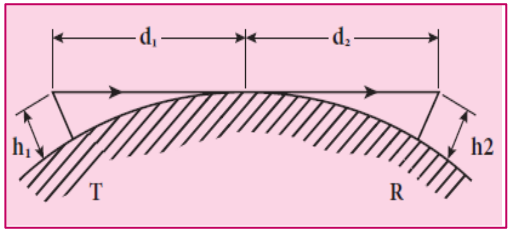
$$A\,C + A\,B\,C = A\,C . (1 + B) \qquad \text{[OR law-2]}$$
$$= A\,C . 1 \qquad \text{[AND law – 2]}$$
$$\boldsymbol{A\,C + A\,B\,C = A\,C}$$

- Thus the Boolean identity is proved.

Circuit description:



12. **A transmitting antenna has a height of 40 m and the height of the receiving antenna is 30 m. What is the maximum distance between them for line-of-sight communication? The radius of the earth is 6.4×10⁶ m.**



Solution :

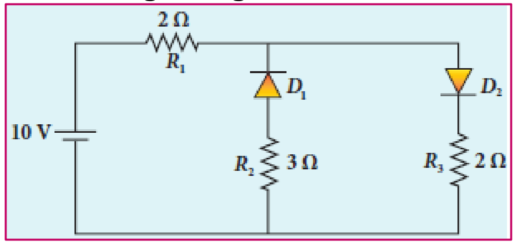
- The total distance *d* between the transmitting and receiving antennas will be the sum of the individual distances of coverage.

$$d = d_1 + d_2 = \sqrt{2\,R\,h_1} + \sqrt{2\,R\,h_2} = \sqrt{2\,R}\,\left(\sqrt{h_1} + \sqrt{h_2}\right)$$
$$d = \sqrt{2 X 6.4 X 10^6}\,\left(\sqrt{40} + \sqrt{30}\right)$$
$$d = \sqrt{2 X 6.4 X 10^6 X \sqrt{10}}\,\left(\sqrt{4} + \sqrt{3}\right)$$
$$d = \sqrt{2 X 6.4 X 10^7}\,\left(\sqrt{4} + \sqrt{3}\right)$$
$$d = \sqrt{2 X 64 X 10^6}\,\left(\sqrt{4} + \sqrt{3}\right)$$
$$d = 1.414 X 8 X 10^3\,(2 + 1.732)$$
$$d = 1.414 X 8 X 10^3 X 3.732$$
$$\boldsymbol{d = 42.21 X 10^3\ m = 42.21\ km}$$

No	Log
1.414	0. 1504
8	0. 9031
3.732	0. 5719
(+)	1. 6254
ALog	$4.221 X 10^1$

EXERCISE PROBLEMS

1. **The given circuit has two ideal diodes connected as shown in figure below. Calculate the current flowing through the resistance R_1.**



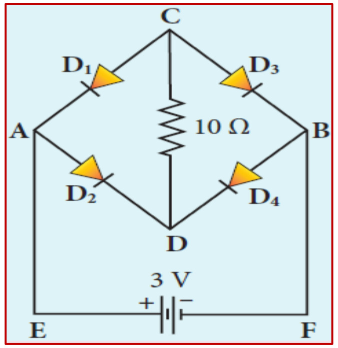
Solution :

- Here diode D_1 is reverse biased. So it acts as open switch (OFF) and hence it does not allows current to pass through it.
- But diode D_2 is forward biased. So it acts as closed switch (ON) and hence it allows current to pass through it.
- From Ohm's law, $V = I\,R_S$

$$(or)\qquad I = \frac{V}{R_S} = \frac{10}{(2+2)} = \frac{10}{4} = \mathbf{2.5\,A}$$

2. **Four silicon diodes and a 10 Ω resistor are connected as shown in figure below. Each diode has a resistance of 1Ω. Find the current flows through the 10Ω resistor.**

Solution :



- Here diode D_1 & D_4 is reverse biased. So it acts as open switch (OFF) and hence it does not allows current to pass through it.
- But diode D_2 & D_3 is forward biased. So it acts as closed switch (ON) and hence it allows current to pass through it.
- Hence the given circuit is simplified as shown.
- Since the barrier voltage of silicon is 0.7 V and hence voltage across **10 Ω** resistor,

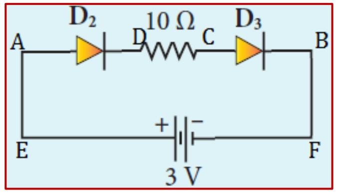
$$V_{10} = 3 - 0.7 - 0.7 = \mathbf{1.6\ V}$$

- Total resistance of the circuit,

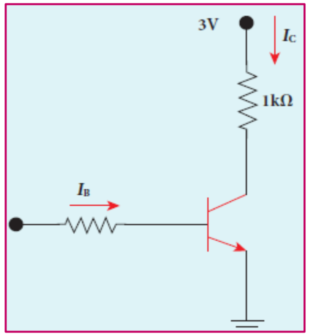
$$R_S = 1 + 10 + 1 = \mathbf{12\ \Omega}$$

- Then the current through **10 Ω** resistor,

$$I = \frac{V_{10}}{R_S} = \frac{1.6}{12} = \mathbf{0.133\ A}$$



3. **Assuming V_{CEsat} = 0.2 V and β = 50, find the minimum base current (I_B) required to drive the transistor given in the figure to saturation.**



Solution : $V_{CC} = 3\,V$; $R_C = 1\,k\Omega = 1000\,\Omega$

- From figure, $V_{CC} = I_C R_C + V_{CE}$

$$(or)\qquad I_C R_C = V_{CC} - V_{CE}$$

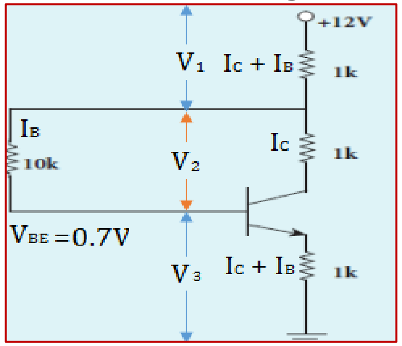
$$(or)\qquad I_C = \frac{V_{CC} - V_{CE}}{R_C} = \frac{3 - 0.2}{1000}$$

$$I_C = \mathbf{2.8\ X\ 10^{-3}\ A}$$

- Then current gain ; $\beta = \frac{I_C}{I_B}$. Hence,

$$I_B = \frac{I_C}{\beta} = \frac{2.8\ X\ 10^{-3}}{50} = 0.056\ X\ 10^{-3}\ A = 56\ X\ 10^{-6} = \mathbf{56\ \mu A}$$

4. **A transistor of α = 0.99 and V_{BE} = 0.7 V is connected in the common emitter configuration as shown in the figure. If the transistor is in saturation region, find the value of collector current.**



Solution :

- If $\alpha = 0.99$ then,

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.99}{1-0.99} = \frac{0.99}{0.01} = 99$$

- By definition. current gain,

$$\beta = \frac{I_C}{I_B}\ (or)\qquad I_B = \frac{I_C}{\beta} = \frac{I_C}{90}$$

- Here one thing must be remember that, transistor in saturation region have, $V_{BE-sat} = 0.8\,V$ and $V_{CE-sat} = 0.2\,V$
- From figure, for input applying Kirchoff's voltage law

$$V_1 + V_2 + V_3 = V_{CC} - V_{BE-sat}$$

$$1000\,(I_C + I_B) + 10000\,I_B + 1000\,(I_C + I_B) = 12 - 0.8$$

$$2000\,I_C + 12000\,I_B = 11.2 \quad ------ (1)$$

- Similarly for output applying Kirchoff's voltage law

$$V_1 + V_2 + V_3 = V_{CC} - V_{CE-sat}$$

$$1000\,(I_C + I_B) + 10000\,I_B + 1000\,(I_C + I_B) = 12 - 0.2$$

$$3000\,I_C + 2000\,I_B = 11.8 \quad ------ (2)$$

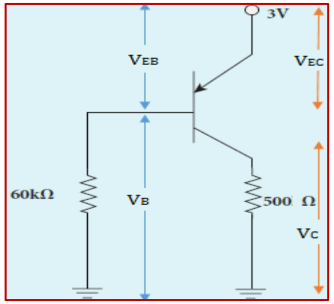
- (2) X 6 ⇒ $18000\,I_C + 12000\,I_B = 70.8 \quad ------ (3)$
- (3) - (1) ⇒ $16000\,I_C = 59.6$

$$I_C = \frac{59.6}{16000} = 3.724\ X\ 10^{-3}\ A$$

$$I_C = \mathbf{3.724\ X\ 10^{-3}\ A = 3.724\ mA}$$

No	Log
59.6	1. 7752
16000	4. 2041
(-)	$\bar{3}$. 5711
ALog	$3.724\ X\ 10^{-3}$

5. In the circuit shown in the figure, the BJT has a current gain (β) of 50. For an emitter – base voltage VEB = 600 mV, calculate the emitter – collector voltage V_{EC} (in volts).



Solution : $V_E = 3\,V$; $R_B = 60K\Omega$; $R_C = 500\,\Omega$

- From figure, , $V_E = V_{EB} + V_B$

  (or) $V_B = V_E - V_{EB}$

  $60000\, I_B = 3 - 600\, X\, 10^{-3}$

  $60\, X\, 10^3\, I_B = 3 - 0.6 = 2.4$

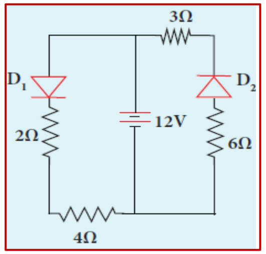
  $$I_B = \frac{2.4}{60\, X\, 10^3} = 0.04\, X\, 10^{-3} A$$

  $= 40\, X\, 10^{-6}\, A = \mathbf{40\, \mu\, A}$
- By definition, current gain $\beta = \frac{I_C}{I_B}$

  (or) $I_C = \beta\, I_B = 50\, X\, 40\, X\, 10^{-6} = 2000\, X\, 10^{-6}\, A = 2\, X\, 10^{-3} = \mathbf{2\, m\, A}$
- Hence, $V_{EC} = V_E - V_C = V_E - I_C R_C = 3 - (2\, X\, 10^{-3}\, X\, 0.5\, X\, 10^3)$

  $\mathbf{V_{EC} = 3 - 1 = 2\, V}$

6. Determine the current flowing through 3Ω and 4Ω resistors of the circuit given below. Assume that diodes *D₁* and *D₂* are ideal diodes.



Solution :

- Here diode D_1 is forward biased (closed switch) and D_2 is reverse biased (open switch)
- So D_1 conducts while D_2 do not conduct the current.
- For ideal diode, there is no barrier voltage (i.e.) $V_B = 0$
- Let 'I' be the current through D_1,then by Ohm's Kirchoff's voltage law,

  $\mathbf{2\,I + 4\,I = 12 \quad (or) \quad 6\,I = 12 \quad (or) \quad I = 2\,A}$
- Since D_2 will not conduct, no current flows through diode D_2
- Thus current flowing through 3Ω and 4Ω resistors of the circuit are **0 and 2 A** Respectively.

7. Prove the following Boolean expressions using the laws and theorems of Boolean algebra. (i) $(A+B)(A+\bar{B}) = A$ (ii) $A(\bar{A}+B) = AB$ (iii) $(A+B)(A+C) = A+BC$

Solution :

(i) $(A + B)(A + \bar{B}) = A\,A + A\,\bar{B} + B\,A + B\,\bar{B}$ [By AND laws; $A\,A = A$ & $B\,\bar{B} = 0$]

$= A + A\,(\bar{B} + B) + 0$ [By OR laws ; $\bar{B} + B = 1$ & $A + 0 = 0$]

$= A + A\,(1)$ [By AND laws ; $A.1 = A$]

$\mathbf{(A + B)(A + \bar{B}) = A}$ [By OR laws ; $A + A = A$]

(ii) $A\,(\bar{A} + B) = A\,\bar{A} + A\,B$ [By AND laws ; $A\,\bar{A} = 0$]

$= 0 + A\,B$ [By OR laws ; $0 + A = A$]

$\mathbf{A\,(\bar{A} + B) = A\,B}$

(iii) $(A + B)(A + C) = AA + A\,C + B\,A + B\,C$

$= A + A\,C + B\,A + B\,C$

$= A(1 + C + B) + B\,C$ [By OR laws ; $1 + A = 1$]

$= A(1) + B\,C$

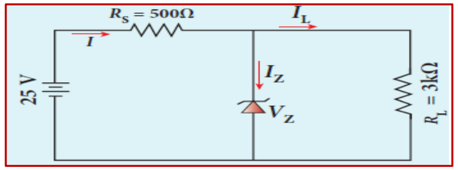
$\mathbf{(A + B)(A + C) = A + B\,C}$

8. Verify the given Boolean equation $A + \bar{A}\,B = A + B$ using truth table.

Solution :

A	B	$\bar{A}$	$\bar{A}\,B$	$A + \bar{A}\,B$	A + B
0	0	1	0	0	0
0	1	1	1	1	1
1	0	0	0	1	1
1	1	0	0	1	1

9. In the given figure of a voltage regulator, a Zener diode of breakdown voltage 15V is employed. Determine the current through the load resistance, the total current and the current through the diode. Use diode approximation.



Solution : $V = 25\,V$; $R_S = 500\,\Omega$; $V_Z = 15\,V$; $R_L = 3\,k\,\Omega = 3000\,\Omega$

- From the figure, $V_{R_S} = V - V_Z = 25 - 15 = 10\,V$
- From Ohm's law Current through load resistance R_L,

  $$I_L = \frac{V_L}{R_L} = \frac{V_Z}{R_L} = \frac{15}{3000} = 5\,X\,10^{-3}\,A = \mathbf{5\,m\,A}$$
- And, current through R_S (i.e.) total current

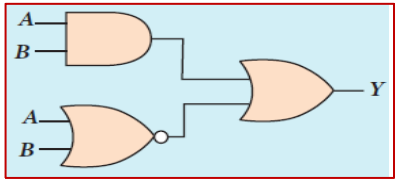
  $$I = \frac{V_{R_S}}{R_S} = \frac{10}{500} = \frac{1}{50} = 0.02\,A = 20\,X\,10^{-3}\,A = \mathbf{20\,m\,A}$$
- If I_Z be the current through Zener diode, then from Kirchoff's current law,

  $I = I_L + I_Z$

  (or) $I_Z = I - I_L = (20\,X\,10^{-3}) - (5\,X\,10^{-3}) = 15\,X\,10^{-3}\,A$

  $\mathbf{I_Z = 15\,mA}$

10. Write down Boolean equation for the output Y of the given circuit and give its truth table.



Solution :

- Output of AND gate= $A.B$
- Output of NOR gate = $\overline{A + B}$
- Thus the final output of OR gate ;

  $Y = (A.B) + (\overline{A + B})$

A	B	A.B	A + B	$\overline{A + B}$	$Y = (A.B) + (\overline{A + B})$
0	0	0	0	1	1
0	1	0	1	0	1
1	0	0	1	0	1
1	1	1	1	0	1