



GumNaaM_Helpers



Mega File for Final Term

All Files in ONE FILE

(Handouts_waqar_moaz_junaaid_vu toper_orange monkey)

الحمد لله گمنام ہیلپرز ان تمام کتابوں میں مدد کرتے ہیں جن کے لنکس نیچے دیئے گئے ہیں
لیذا ہم سے صرف انہی کتابوں کی مدد کا سوال کیا جائے جن کے لنکس نیچے موجود ہیں

Groups Join Krty hi Description Read krna na bhooolyn

جزاک اللہ خیرا و احسن الجزاء

GumNaaM_Helpers All What's App Group Links

- | | | | |
|-------|---|--------|---|
| Cs101 | https://chat.whatsapp.com/KCQ3JK6FcoYEvDYTF1gnBS | Eng101 | https://chat.whatsapp.com/Cwp4Ag9TG6ZKxyRgThqM6S |
| Cs201 | https://chat.whatsapp.com/DrYV1FAXmPpImVZFw6V2R | Eng201 | https://chat.whatsapp.com/EvvxcPtmrM22VTZh5NCTw |
| Cs301 | https://chat.whatsapp.com/EPLvH2f8EB7aH8e1AtidV | Eco401 | https://chat.whatsapp.com/K3NLvyue6BdK0sVMQDFoU2 |
| Cs302 | https://chat.whatsapp.com/BaYfW0P67vNIsI2n36otZM | Mcm301 | https://chat.whatsapp.com/GUyzfdHzu8r43TW16vhZWF |
| Cs304 | https://chat.whatsapp.com/C0mk0wdo0BU46dlhc67IQ | Mgt101 | https://chat.whatsapp.com/BmrYaQYulBOKguHOIT6t2Y |
| Cs401 | https://chat.whatsapp.com/Jz9WDdHX84IKgkrMPAV0Mf | Mgt201 | https://chat.whatsapp.com/DZwztUyxV50D6AshnvWCD |
| Cs402 | https://chat.whatsapp.com/DW9AZLb4i1P9la4XmcCsRz | Mgt211 | https://chat.whatsapp.com/EmX9xloZnbl12pX9m2DZwa |
| Cs403 | https://chat.whatsapp.com/HXV25Lc6MnLKZgrA7xOqf | Mgt301 | https://chat.whatsapp.com/G62QTipycOXFrP0ZxfDIBK |
| Cs408 | https://chat.whatsapp.com/EFy2mrYJodx5d85W1jtII7 | Mgt501 | https://chat.whatsapp.com/H0dTUINbesw0GS4LLSt0W4 |
| Cs411 | https://chat.whatsapp.com/lrOaF8Q3tkJKzeVTHapHR9 | Mgt502 | https://chat.whatsapp.com/L3GSMFgwDl7DAsu9r0vAxl |
| Cs501 | https://chat.whatsapp.com/Eggx3X0SH2LhOysM57SI | Mgt503 | https://chat.whatsapp.com/G7BNxqyLYwP48jftOfkbj |
| Cs502 | https://chat.whatsapp.com/FbLU96Xhmr2F199fnb5Yw | Mgt602 | https://chat.whatsapp.com/HXRpOrEL18vD7lb91nLHTB |
| Cs504 | https://chat.whatsapp.com/Gn7w0UzNCQ2FzRK7Zy4Io | Mgt610 | https://chat.whatsapp.com/BxMcR1ouiao0wuqLLlJ5dB |
| Cs506 | https://chat.whatsapp.com/BL4FFmDKf2S3WIoLSAD2JK | Mth101 | https://chat.whatsapp.com/LHsbl65FbwGH2SNFF9ipSb |
| Cs507 | https://chat.whatsapp.com/EINDZKv4e4zGLGg8ImozR | Mth202 | https://chat.whatsapp.com/GevRebusRaxFh6dgnzRJuM |
| Cs508 | https://chat.whatsapp.com/HTMAwnJ4Bic2ky8MbT3PuW | Mth301 | https://chat.whatsapp.com/EFm472nc2woDProEqnY1j |
| Cs601 | https://chat.whatsapp.com/KYoaAutdXRINDS0Mm5XfzP | Mth401 | https://chat.whatsapp.com/EP7tlcc17TzLtaNaOgD4AcA |
| Cs602 | https://chat.whatsapp.com/FpJkLAFNqpZHRyi6vhl5n8 | Mth501 | https://chat.whatsapp.com/Dy7XUUVqqD5LLw4i5X4Xzi |
| Cs604 | https://chat.whatsapp.com/KjDhHjxawtU43Veo9Eawa4 | Mth601 | https://chat.whatsapp.com/BoD3akuXGK25MFB4UEZcRr |
| Cs605 | https://chat.whatsapp.com/BoF34LtlMIYK1L4nQaEO2Ce | isL201 | https://chat.whatsapp.com/BtoqaMbbELW99MLLTQMgWc |
| Cs610 | https://chat.whatsapp.com/FcNcztKyYfd9szsJElino2 | Pak301 | https://chat.whatsapp.com/KuR9Y7YWeA32enRwKeZJaR |
| Cs615 | https://chat.whatsapp.com/HLVjBNcorFN9bwZhGekFI3 | Phy101 | https://chat.whatsapp.com/GjC6e47vF1zHwRs5iOc13j |
| Cs619 | https://chat.whatsapp.com/FEklYr700ui0ihxqnk55A6 | Phy301 | https://chat.whatsapp.com/lBrOdznEHDi92fGa76Dqmr |
| | | Sta301 | https://chat.whatsapp.com/BchodAnjbydKXLuxFfkGxR |

...Paid Service Available for LMS Activities...

Only for those students who are so busy in office or work or job that they can't watch their LMS due to their Busyness

FOR MORE INFO. CONTACT US ONLY WHAT'S APP 0302-1400084

Circuit Theory (PHY 301)

Lecture Handouts

By

Professor Dr. Tajamul Hussain

Virtual University of Pakistan

Course contents

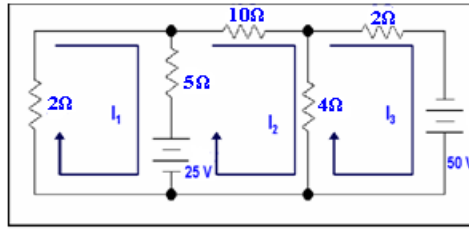
Lecture No.	Topic/Sub topic	Page No.
1	International System of Units - Basic Units - Decimal System - Sub-atomic elements - Electrons and protons in an Atom - Structure of the Atom - Electron Valence - Sub-shells - Particles in the Nucleus - Atomic Number - Orbital Rings - Conductors - Insulators - Semiconductors - The Unit of Electric Charge - Negative and Positive Polarities	1
2	Negative and Positive Polarities of battery - Potential difference - Potential between different charges - Potential difference between the terminals - Volt - Current - Potential difference is necessary for current - Ampere - Resistance - Ohm - Conductance - The closed circuit - Open circuit - Short circuit - Power - Passive sign conventions	14
3	Resistance in Series	21
4	Inductance - Inductance in Series - Inductance in Parallel - Capacitance - Capacitance in parallel - Capacitance in Series - Ohm's Law - The Current " $I=V/R$ " - High Voltage but Low Current - Low Voltage but High Current - The Voltage $V=IR$ - The Resistance $R=V/I$ - The Linear Proportion Between V & I - Volt-Ampere Characteristics - Power Dissipation in Resistance	29
5	Types of sources : Ideal voltage source - Ideal current source - Direct voltage - Direct quantities - Alternating quantities - Dependent or controlled sources - Voltage controlled voltage source - Current controlled voltage source - Voltage Controlled Current Source - Current Controlled Current Source - Voltage dividers and Current dividers - Series Voltage dividers	37
6	Current divider with two parallel resistances -	46
7	Kirchhoff's Laws Kirchhoff's Current Law (KCL) - Node - Branch - Loop - Ground -	54
8	Application of Nodal Analysis	60
9	Application of Nodal Analysis - Reference node	65
10	Super Node - Constraint or Coupling Equation - Examples of Nodal Analysis	72
11	Examples of Nodal Analysis - Super Node technique	76
12	Kirchhoff's Voltage Law (KVL) - Loop - Examples of Loop Analysis	80
13	Applications of Loop Analysis	82
14	Applications of Loop Analysis	84
15	Applications of Loop Analysis	87
16	Applications of Loop Analysis	90
17	Applications of Loop Analysis	96
18	Applications of Loop Analysis - Super Mesh Technique	99
19	Examples of Loop Analysis	105
20	Applications of Loop Analysis - Super Mesh Technique - Coupling equation	108
21	Examples of Loop Analysis by using dependent sources - Coupling equation	112
22	Matrices and determinants	115
23	Superposition Theorem and examples	119
24	Source Transformation and examples	124
25	Thevenin's Theorem and examples	130
26	Examples of Thevenin's Theorem - Thevenin's Theorem and Dependent sources with examples	136

27	Thevenin's Theorem and Dependent sources with examples - Norton's Theorem with examples	143
28	Norton's Theorem with examples - Linearity Principle	150
29	Intrinsic Silicon - Drift - Diffusion - Diffusion Current - Drift Current - Drift Velocity - Doped semiconductors - Diffusion current I_D - The depletion region - The PN Junction under reverse bias and forward biased conditions -	156
30	PN Junction Diode - Ideal Diode - Ideal Diode as a Rectifier	159
31	Terminal characteristics of the Junction diodes - Forward bias region	162
32	Reverse bias region - Break down region - Analysis of diode circuits	166
33	DC or Static Resistance - The constant voltage drop model - AC or Dynamic Resistance	170
34	Small Signal Model and its applications	174
35	Transformers - Secondary voltage and current - Transformer Input/Output phase relationship	180
36	Negative Half Wave Rectifiers - Load voltage and current - Average Load voltage and current -	184
37	Peak Inverse Voltage (PIV) - Full wave rectifier	189
38	Negative full wave rectifier - Full wave bridge rectifier -	193
39	Filters - Clippers - Series clippers -	198
40	Parallel clippers - Clamper	206
41	Diode logic gates (OR Gate) (AND Gate) - Voltage multipliers - Half wave voltage doubler - Zener diode - Zener diode shunt regulator	212
42	Applications of Zener diode shunt regulator - Characteristic of light emitting diodes - PIN Photodiodes - Tunnel diode	218
43	Bipolar Junction Transistor (BJT) - NPN Transistor - Operating configuration of BJT - Directions of Currents in BJT - Modes of operation of BJT	223
44	The Currents of a BJT - DC biasing-BJT - Forward bias of Base Emitter - Load line analysis - DC BIASING-BJT Emitter-Stabilized Bias Circuit - Base Emitter Loop - Collector Emitter Loop	229
45	Emitter-Stabilized Bias Circuit Load Line Analysis - DC BIASING-BJT Voltage Divider Bias Circuit and its application	237

LECTURE 23

(Superposition Theorem and examples)

Example: Find current I_1 , I_2 and I_3 By using Cramer's rule.



Solution: We will use Cramer's rule to solve this example

KVL equation for loop 1

$$\begin{aligned} 2I_1 + 5(I_1 - I_2) &= -25 \\ 2I_1 + 5I_1 - 5I_2 &= -25 \\ 7I_1 - 5I_2 &= -25 \quad \text{----- (A)} \end{aligned}$$

KVL equation for loop 2

$$\begin{aligned} 10I_2 + 4(I_2 - I_3) + 5(I_2 - I_1) &= 25 \\ 10I_2 + 4I_2 - 4I_3 + 5I_2 - 5I_1 &= 25 \\ -5I_1 + 19I_2 - 4I_3 &= 25 \quad \text{----- (B)} \end{aligned}$$

KVL equation for loop 3

$$\begin{aligned} 2I_3 + 4(I_3 - I_2) &= 50 \\ 2I_3 + 4I_3 - 4I_2 &= 50 \\ -4I_2 + 6I_3 &= 50 \quad \text{----- (C)} \end{aligned}$$

We will write equation A, B and C in matrix form

$$\begin{bmatrix} 7 & -5 & 0 \\ -5 & 19 & -4 \\ 0 & -4 & 6 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} -25 \\ 25 \\ 50 \end{bmatrix}$$

The determinant of the coefficient matrix is

$$|A| = \begin{vmatrix} 7 & -5 & 0 \\ -5 & 19 & -4 \\ 0 & -4 & 6 \end{vmatrix}$$

$$|A| = 536$$

By Cramer's rule

$$I_1 = \frac{\begin{vmatrix} -25 & -5 & 0 \\ 25 & 19 & -4 \\ 50 & -4 & 6 \end{vmatrix}}{\begin{vmatrix} 7 & -5 & 0 \\ -5 & 19 & -4 \\ 0 & -4 & 6 \end{vmatrix}}$$

$$I_1 = (-700) \div 536$$

$$I_1 = -1.31 \text{ A}$$

By Cramer's rule

$$I_2 = \frac{\begin{vmatrix} 7 & -25 & 0 \\ -5 & 25 & -4 \\ 0 & 50 & 6 \end{vmatrix}}{\begin{vmatrix} 7 & -5 & 0 \\ -5 & 19 & -4 \\ 0 & -4 & 6 \end{vmatrix}}$$

$$I_2 = 1700/536$$

$$I_2 = 3.17 \text{ A}$$

By Cramer's rule

$$I_3 = \frac{\begin{vmatrix} 7 & -5 & -25 \\ -5 & 19 & 25 \\ 0 & -4 & 50 \end{vmatrix}}{\begin{vmatrix} 7 & -5 & 0 \\ -5 & 19 & -4 \\ 0 & -4 & 6 \end{vmatrix}}$$

$$I_3 = 5600/536$$

$$I_3 = 10.45 \text{ A}$$

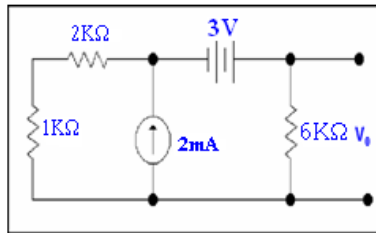
Superposition Theorem :

The principle of superposition, which provides us with the ability to reduce a complicated problem to several easier problems – each containing only a single independent source – states that

"In any linear circuit containing multiple sources, the current or voltage at any point in the circuit may be calculated as the algebraic sum of the individual contributions of each source acting alone."

When determining the contributions due to independent sources, any remaining current sources are made zero by replacing them by open circuit and any voltage sources are made zero by replacing them by short circuit.

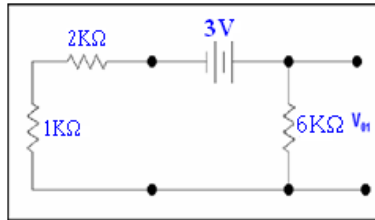
Example: Calculate V_o by applying principle of superposition.



Solution:

Applying principle of superposition, we will take effect of the sources one by one.

Only voltage source is acting

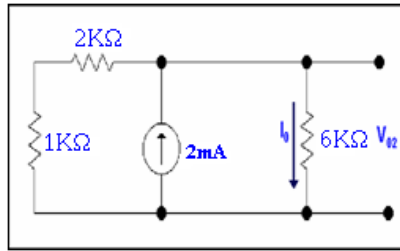


Applying voltage division rule

$$V_{R1} = \frac{R_1 \times V_1}{R_1 + R_2}$$

$$V_{o1} = V_{6k} = (6 \times 3) / 3 + 6$$

$$V_{o1} = 2 \text{ volts}$$

Only current source is acting

Let the current through 6k resistor is I_0
by applying current division rule

$$I_{R1} = \frac{R_2 \times I(t)}{R_1 + R_2}$$

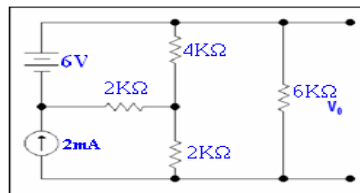
$$I_0 = (3 \times 2)/9 = 2/3 \text{ mA}$$

$$V_{02} = I_0 \times 6k = 2/3 \text{ mA} \times 6k = 4V$$

So V_0 will be

$$\begin{aligned} V_0 &= V_{01} + V_{02} \\ &= 2V + 4V \\ V_0 &= 6V \end{aligned}$$

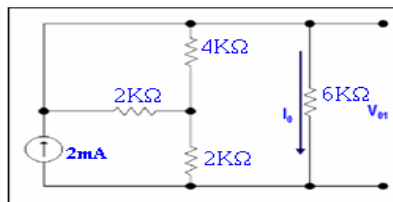
Example: Calculate V_o by applying principle of superposition.



Solution:

We want to calculate the voltage V_o . Superposition theorem can be applied as

Only current source is acting



Let I_0 be the current following through the 6k resistor then

$$2k \parallel 4k = (2 \times 4)/(2+4) = 8/6 = (4/3)k$$

$(4/3)k$ is in series to $2k$

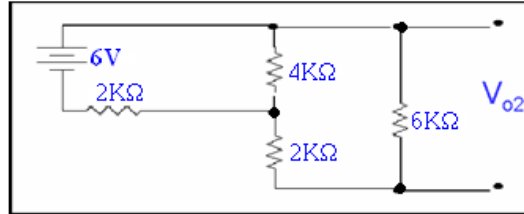
$\therefore (4/3)k + 2k \parallel 6k$, hence applying current division rule

$$I_{R1} = \frac{R_2 \times I(t)}{R_1 + R_2}$$

$$I_o = \frac{(4/3) + 2}{(4/3 + 2) + 6} 2mA = \frac{20}{3(28/3)} = \frac{20}{28}$$

$$V_{o1} = \frac{20}{28} 6 = \frac{30}{7} V$$

Making only voltage source to act



Or it can be redrawn as

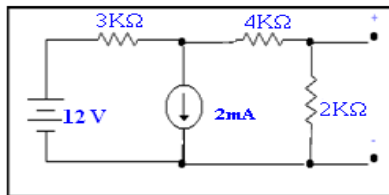
$$R_{ab} = 8k \parallel 4k = \frac{8 \times 4}{8 + 4} = \frac{8}{3} k$$

$$V_{ab} = \frac{\frac{8}{3} k}{\frac{8}{3} k + 2k} 6 = \frac{24}{7}$$

$$V_{o2} = \frac{24}{7} \times \frac{6k}{6k + 2k} = \frac{18}{7} \text{ Volts.}$$

$$V_o = V_{o1} + V_{o2} = \frac{30}{7} + \frac{18}{7} = \frac{48}{7} \text{ Volts}$$

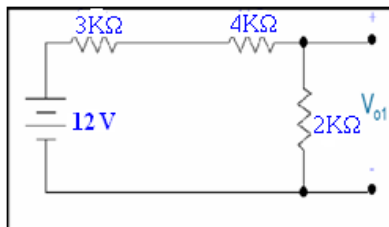
Example: Calculate V_o by applying principle of superposition.



Solution:

We want to calculate V_o .

When only voltage source is acting

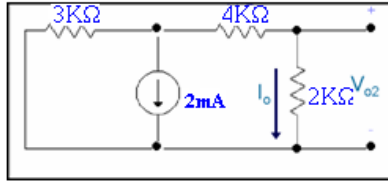


Applying voltage division rule

$$V_{R1} = \frac{R_1 \times V_1}{R_1 + R_2}$$

$$V_{o1} = (12 \times 2) / (7 + 2) = 24/9V$$

When only current source is acting



Let I_o flows through $2k\Omega$. applying current division rule

$$I_{R1} = \frac{R_2 \times I(t)}{R_1 + R_2}$$

$$I_o = (-2)3/(6+3) = -6/9 = -2/3 \text{ mA}$$

$$V_{o2} = 2 \times -2/3 = -4/3 \text{ Volts}$$

Therefore,

$$\begin{aligned} V_o &= V_{o1} + V_{o2} \\ &= 24/9 - 4/3 \\ V_o &= 4/3 \text{ Volts} \end{aligned}$$

LECTURE 24

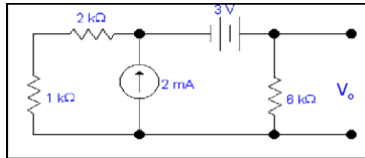
(Source Transformation and examples)

Source Transformation:

If we have any source embedded within a network, say this source is a current source having a value I & there exists a resistance having a value R , in parallel to it. We can replace it with a voltage source of value $V=IR$ in series with same resistance R . The reverse is also true that is a voltage source V , in series with a resistance R can be replaced by a current source having a value $I=V/R$

In parallel to the resistance R . Parameters within circuit, for example an output voltage remains unchanged under these transformations.

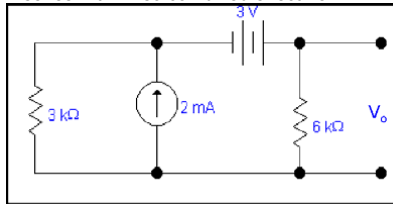
Example: Calculate the voltage V_o using source transformation method.



Solution:

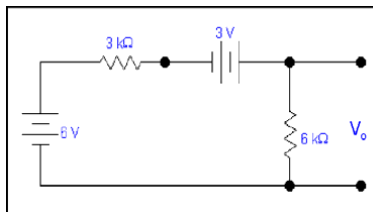
We want to calculate the voltage V_o using source transformation method. We proceed as

1k is in series with 2k so combined effect =3k

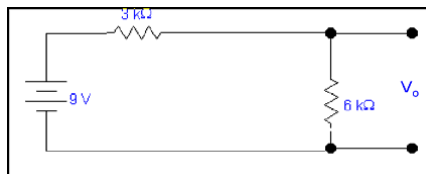


Now 2mA source is in parallel with 3k resistor. So it can be changed to a voltage source of value = $2\text{m} \times 3\text{k}$ (by ohm's Law)
= 6Volts.

3k resistor will become in series with this source as shown in the circuit below



Positive terminal of the 6 volts battery is connected with the negative terminal of 3 volts battery so they will be summed up as shown in the circuit below



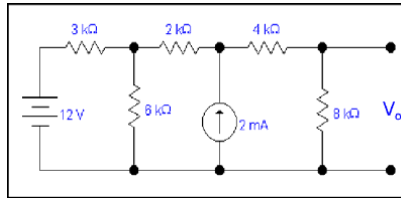
Applying voltage division rule

$$V_{R1} = \frac{R_1 \times V_1}{R_1 + R_2}$$

$$V_o = (6 \times 9)/9$$

$$= 6 \text{ Volts}$$

Example: Calculate the voltage V_o using source transformation method.



Solution:

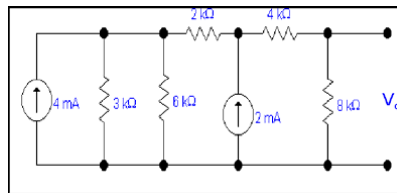
We want to calculate the voltage V_o using source transformation method. We

proceed as

3k is in series with 12 volts battery. So it can be converted into a current source of value $=12/3k$ (by ohm's Law)

$$= 4mA$$

Now voltage source has transformed in the current source as shown below

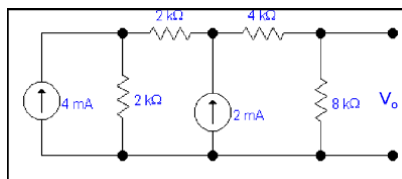


Now 3k resistor is in parallel with 6k resistor so

$$3k || 6k = (3k \times 6k) / (3k + 6k)$$

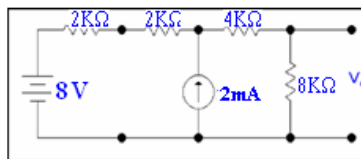
$$= 2k$$

Now we will replace 3k and 6k resistance with 2k as shown in the circuit below

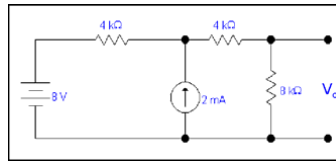


4mA source is parallel with 2k resistor. So it can be converted into a voltage

source. By using ohm's Law we have the value of voltage source = 8 volts which is in series with a resistor of 2k, so our modified circuit will be



In the above circuit 2k is in series with 2k so modified circuit will be

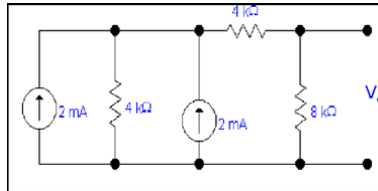


8V source is in series with 4k resistor. So it can be converted into a current source of value $= 8/4k$ (by using Ohm's Law)

$$= 2\text{mA}$$

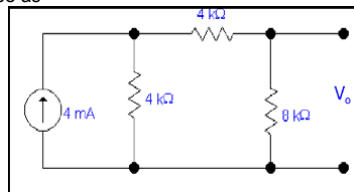
2mA current source is in parallel to 4k

Our modified circuit will be as

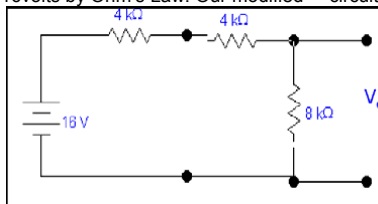


In the above circuit two current sources are parallel to each other, so current sources will add up to give value of 4mA.

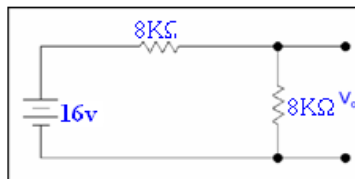
Our modified circuit will be as



In the above circuit 4mA source is in parallel with 4k resistor. So it can be converted into a voltage source of value 16volts by Ohm's Law. Our modified circuit will be as



In the above circuit 4k and 4k are in series so our modified circuit will be



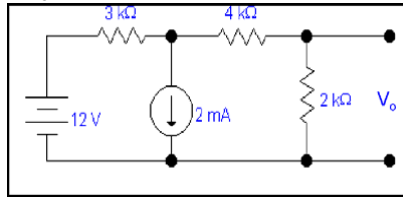
Now applying voltage division rule

$$V_{R1} = \frac{R_1 \times V_1}{R_1 + R_2}$$

$$V_0 = 8k/16k \times 16V$$

$$V_0 = 8\text{volts}$$

Example: Calculate the voltage V_o using source transformation method.



Solution:

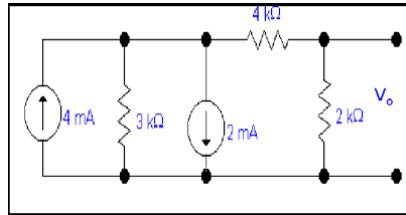
We want to calculate the voltage V_o using source transformation method. We

Proceed as

12 volt source is in series with 3k resistor. So it can be converted into current source of value

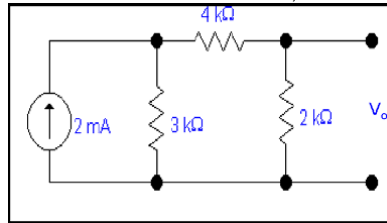
$$I = 12/3k = 4mA \quad (\text{by Ohm's Law})$$

In modified circuit 4mA current source and resistor 3k will be in parallel. So modified circuit will be as



Now we will combine current sources as $4mA - 2mA = 2mA$, so our modified

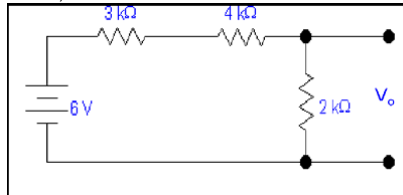
circuit will be as,



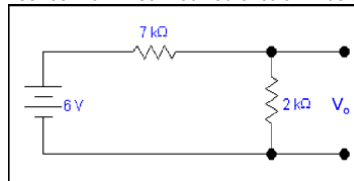
2mA source is in parallel with 3k source so it can be converted into a voltage source of value

$$V = 2 \times 3 = 6\text{volts (by Ohm's Law)}$$

Our modified circuit will be as,



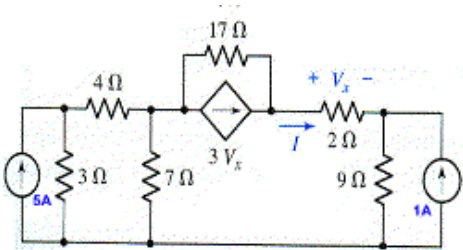
In the above circuit 3k is in series with 4k so modified circuit will be as



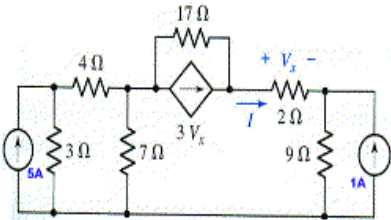
Now applying voltage division rule

$$V_{R1} = \frac{R_1 \times V_1}{R_1 + R_2}$$
$$V_0 = 2k/9k \times 6$$
$$= 12/9$$
$$V_0 = 4/3 \text{ volts}$$

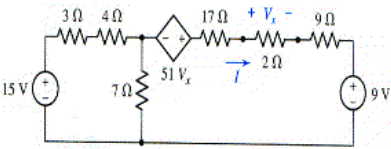
Example: Calculate the current I using source transformation method.



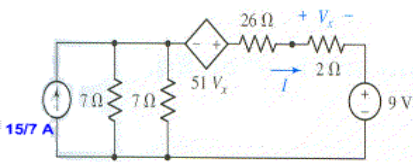
Solution: we want to calculate the current I by source transformation.



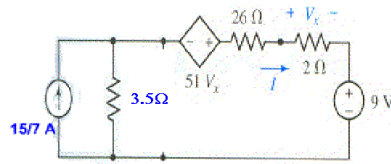
3 Ohms resistor is in parallel with 5A source. So it can be converted into a voltage source 15V.



3 Ohms resistor 4 Ohms are in series and the resultant is in series with 15V so it can be converted into a current Source.

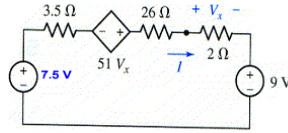


$$7 || 7 = 7 \times 7 / 7 + 7 = 49/14 = 3.5 \text{ ohm}$$



Current source is in parallel with 3.5 ohms resistance. So it can be converted into a Voltage source by using Ohm's Law

$$V = IR = 15/7 \times 3.5 = 7.5 \text{ Volts}$$



The current I can be found using KVL

$$-7.5 + 3.5I - 51V_x + 28I + 9 = 0 \text{ ----- (A)}$$

Where

$$V_x = 2I$$

putting the value of V_x in (A) we have

$$-7.5 + 3.5I - 51(2I) + 28I + 9 = 0$$

$$3.5I - 102I + 28I + 1.5 = 0$$

$$-70.5I + 1.5 = 0$$

$$I = 1.5/70.5$$

$$I = 21.28 \text{ mA}$$

LECTURE 25

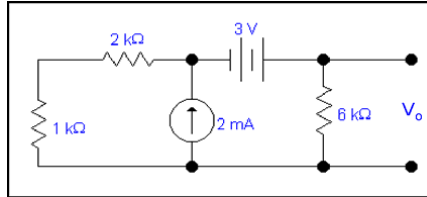
(Thevenin's Theorem)

THEVENIN'S THEOREM:

In solving any problem by Thevenin's theorem. We will follow the steps as stated below

- (1) First of all we will remove the load resistor (The resistor we want to calculate the unknown quantity that is voltage, current or power) from the circuit leaving behind an open circuit.
- (2) Calculating the V_{th} at open terminals of the open circuit by any method.
- (3) Calculating the R_{th} (The total resistance in the Thevenin's circuit) by open circuiting all current sources and short circuiting all voltage sources.
- (4) After calculating V_{th} and R_{th} , re-inserting the load resistance R_L in the circuit in series with R_{th} and considering the V_{th} as a battery in series with these two resistances.

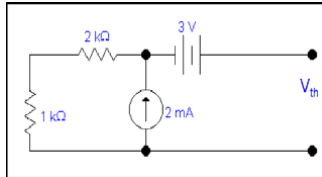
Example: Calculate the voltage V_o by using Thevenin's theorem.



Solution:

We want to calculate V_o by using Thevenin's theorem. We will follow the steps given earlier.

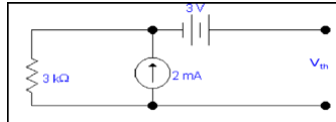
First step: Removing R_L



Here R_L is 6k resistor at which we want to calculate the voltage V_o .

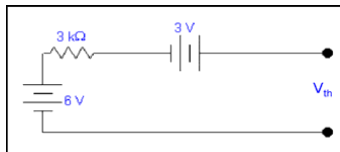
Second step: Calculating V_{th}

1k is in series with 2k so modified circuit will be as

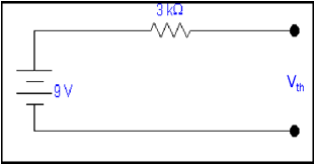


3k is in parallel with 2mA source, so by source transformation
Now 2mA source is in parallel with 3k resistor. So it can be changed to a voltage source of value = $2\text{m} \times 3\text{k}$ (**by ohm's Law**)
= 6 Volts.

3k resistor will become in series with this source as shown in the circuit below



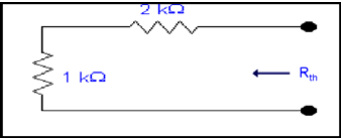
Now the combined effect of these two source will be 9 volts.



So

$$V_{th} = 9 \text{ volts}$$

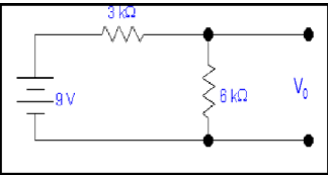
Third step: Calculating R_{th}



$$R_{th} = 3k$$

Fourth step: Calculating the unknown quantity.

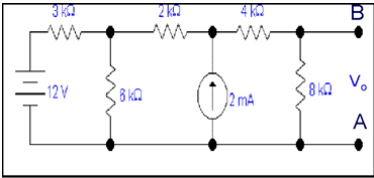
After calculating V_{th} and R_{th} , re-inserting the load resistance R_L in the circuit in series with R_{th} and considering the V_{th} as a battery in series with these two resistances.



$$V_o = (6k/9k) \times 9$$

$$V_o = 6 \text{ volts}$$

Example: Calculate the voltage V_o by using Thevenin's theorem .

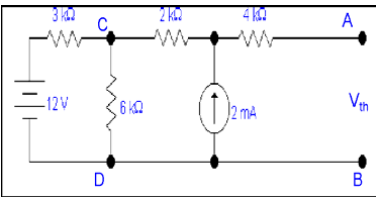


Solution:

We want to calculate V_o by using Thevenin's theorem .we will follow the steps given earlier.

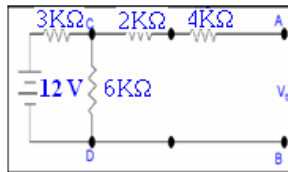
First step: Removing R_L

Here R_L is 8k resistor at which we want to calculate the voltage V_o .



Second step: Calculating V_{th}

Now we will follow the **superposition method** to calculate V_{th} .

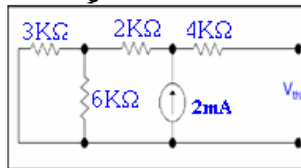
Only voltage source is acting

No current in 'CA' branch so voltage drop across 4k and 2k resistor is zero so

$$V_{CD} = V_{th1}$$

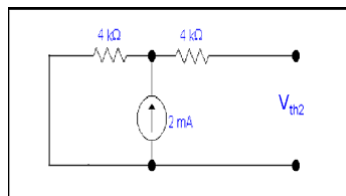
Applying voltage division rule

$$V_{CD} = V_{th1} = V_{6k} = (12 \times 6) / (3 + 6) = 8 \text{ volts}$$

Only current source is acting

$$3k \parallel 6k = (3k \times 6k) / (3k + 6k) = 2k$$

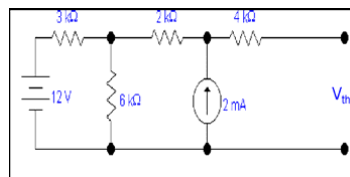
$$2k \text{ is in series with } 2k = 4k$$



Current through open circuit is zero by ohm's law so

$$V_{th2} = 4k \times 2m$$

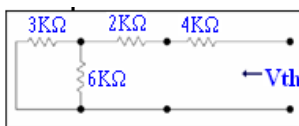
$$V_{th2} = 8 \text{ volts}$$



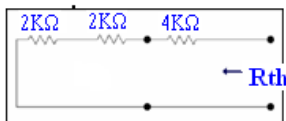
So

$$V_{th} = V_{th1} + V_{th2} = 8 + 8$$

$$V_{th} = 16 \text{ volts}$$

Third step: Calculating R_{th} 

$$3k \parallel 6k = (3k \times 6k) / 9k = 2k$$

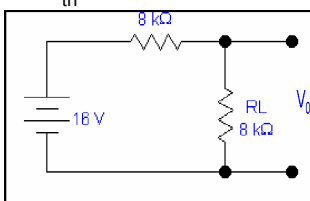


$$R_{th} = 2k + 2k + 4k$$

$$R_{th} = 8k$$

Fourth step: Calculating unknown quantity.

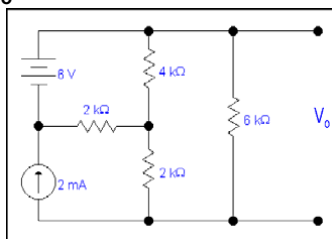
After calculating V_{th} and R_{th} , re-inserting the load resistance R_L in the circuit in series with R_{th} and considering the V_{th} as a battery in series with these two resistances.



$$V_0 = (8k / 16k) \times 16$$

$$V_0 = 8 \text{ volts}$$

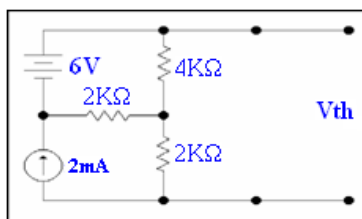
Example: Calculate the voltage V_0 by using Thevenin's theorem.

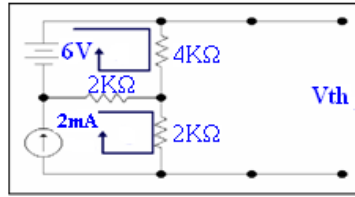
**Solution:**

We want to calculate V_0 by using Thevenin's theorem. We will follow the steps given earlier.

First step: Removing R_L

Here R_L is 6k resistor at which we want to calculate the voltage V_0 .



Second step: Calculating V_{th} 

Apply KVL to the circuit

Here

$$I_2 = 2\text{mA}$$

For loop 1

$$4kI_1 + 2k(I_1 - I_2) = 6$$

$$4kI_1 + 2kI_1 - 2kI_2 = 6$$

$$6kI_1 - 2kI_2 = 6$$

Putting value of I_2

$$6kI_1 - 4 = 6$$

$$I_1 = 10/6\text{k}$$

$$I_1 = 1.6\text{mA}$$

Now voltage across 4k resistor

$$V_{4k} = 1.6\text{m} \times 4\text{k} = 20/3$$

$$V_{4k} = 6.66\text{volts}$$

Voltage across 2k resistor

$$V_{2k} = 2\text{m} \times 2\text{k}$$

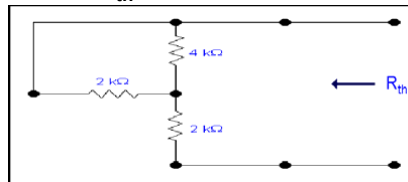
$$V_{2k} = 4\text{volts}$$

So

$$V_{th} = V_{4k} + V_{2k}$$

$$= 20/3 + 4 = 6.66 + 4$$

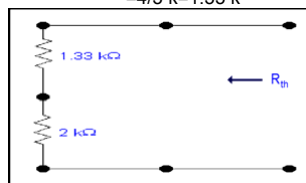
$$V_{th} = 10.66\text{ volts}$$

Third step: Calculating R_{th} 

$$4k || 2k = 4k \times 2k / 6k$$

$$= 8/6\text{ k}$$

$$= 4/3\text{ k} = 1.33\text{ k}$$



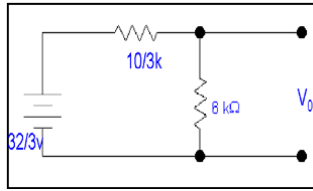
They are in series so

$$R_{th} = 1.33\text{k} + 2\text{k} = 10/3\text{k}$$

$$R_{th} = 3.33\text{k}$$

Fourth step: Calculating unknown quantity.

After calculating V_{th} and R_{th} , re-inserting the load resistance R_L in the circuit in series with R_{th} and considering the V_{th} as a battery in series with these resistances.

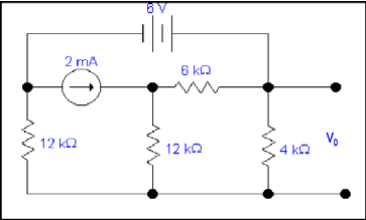


$$\begin{aligned}
 V_0 &= 32/3 \times 6 \times 1/(10/3+6) \\
 &= 64 \times 3/10 + 18 \\
 &= 192/28 \\
 \mathbf{V_0} &= \mathbf{48/7 \text{ volts}}
 \end{aligned}$$

LECTURE 26

(Examples of Thevenin's Theorem - Thevenin's Theorem and Dependent sources with examples)

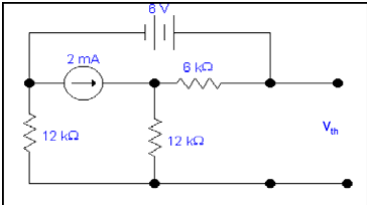
Example: Calculate the voltage V_o by using Thevenin's theorem .



Solution:

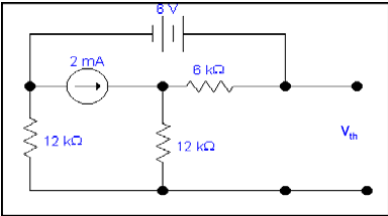
We want to calculate V_o by using Thevenin's theorem .we will follow the following steps .

First step: Removing R_L

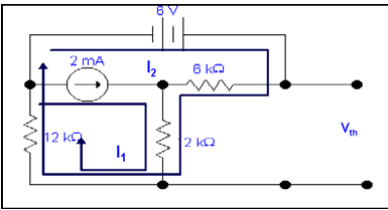


Here R_L is 4k resistor at which we want to calculate the voltage V_o .

Second step: Calculating V_{th}



We want to calculate V_{th} . Apply KVL in two loops to calculate the individual loop currents.



Here

$$I_1 = 2mA$$

KVL for the super mesh

$$-6 + 6kI_2 + 12k(I_1 + I_2) + 12k(I_1 + I_2) = 0$$

$$-6 + 6kI_2 + 12kI_2 + 12kI_2 + 24kI_1 = 0$$

$$30kI_2 - 6 + 24k(2m) = 0$$

$$30kI_2 - 6 + 48 = 0$$

$$I_2 = -42/30mA$$

$$I_2 = -1.4mA$$

Now we will calculate the voltage across 6k and 12 k to find the value of V_{th}

Therefore,

$$V_{6k} = 6kI_2$$

$$= 6k(-1.4mA)$$

$$V_{6k} = -8.4volts$$

$$V_{12k} = 12k(I_1 + I_2)$$

$$= 12k(2mA - 1.4mA)$$

$$V_{12k} = 7.2volts$$

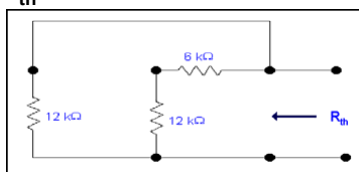
So,

$$V_{th} = V_{6k} + V_{12k}$$

$$= -8.4 + 7.2$$

$$V_{th} = -1.2volts$$

Third step: Calculating R_{th}



6k is in series with 12k. The resultant of these two is in parallel with 12k.

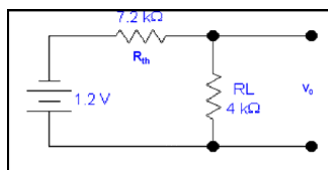
$$(6k + 12k) \parallel 12k = 18k \times 12k / (12k + 18k)$$

$$R_{th} = 7.2k$$

Fourth step: Calculating the unknown quantity.

After calculating V_{th} and R_{th} , re-inserting the load resistance R_L in the circuit in series with

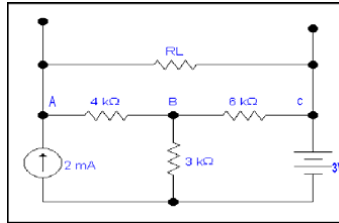
R_{th} and considering the V_{th} as a battery in series with these two resistances.



$$V_0 = -1.2 \times 4k / (7.2k + 4k)$$

$$V_0 = -0.4285 \text{ volts}$$

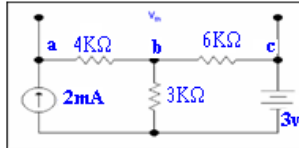
Example: Calculate the value of R_L and the maximum power dissipation across it by Thevenin's Theorem.



Solution:

We want to calculate R_L and the maximum power across it by using Thevenin's theorem. We will follow the steps given earlier.

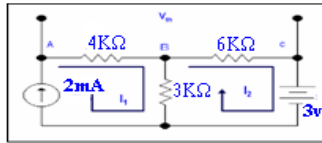
First step: Removing R_L



To remove R_L to calculate V_{th} . In this case our R_{th} is our R_L .

Second step: Calculating V_{th}

We want to calculate V_{th} . Apply KVL in two loops to calculate the individual loop currents.



Here

$$I_1 = 2 \text{ mA}$$

Applying KVL to loop 2

$$6kI_2 + 3k(I_2 - I_1) + 3 = 0$$

$$9kI_2 - 3kI_1 + 3 = 0$$

$$9kI_2 - 6 + 3 = 0$$

$$I_2 = 1/3 \text{ mA}$$

$$I_2 = 0.33 \text{ mA}$$

Now we will calculate the voltage across 4k and 6k to find the value of V_{th} . Therefore,

$$V_{AB} = 4k(I_1)$$

$$= 4k(2 \text{ mA})$$

$$V_{AB} = 8 \text{ volts}$$

$$V_{BC} = 6k(I_2)$$

$$= 6k \times 0.33 \text{ mA}$$

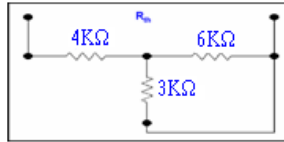
$$V_{BC} = 2 \text{ volts}$$

So

$$V_{th} = V_{AB} + V_{BC}$$

$$= 8 + 2$$

$$V_{th} = 10 \text{ volts}$$

Third step: Calculating R_{th} 

To calculate R_{th} Short circuiting the voltage source and open circuiting the current source.

3k is in parallel with 6k and 4k is series with these two so

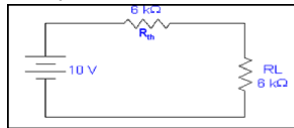
$$\begin{aligned} 3k \parallel 6k + 4k &= 3k \times 6k / (3k + 6k) + 4k \\ &= 2k + 4k \\ &= 6k = R_{th} = R_L \end{aligned}$$

$$R_{th} = R_L = 6k$$

Fourth step: Calculating unknown quantity.

After calculating V_{th} and R_{th} , re-inserting the load resistance R_L in the circuit in series with

R_{th} and considering the V_{th} as a battery in series with these two resistances.



For maximum power dissipation

$$R_L = R_{th} = 6k$$

$$P_L = I^2 R \text{ ----- (A)}$$

From Ohm's law $V=IR$ and $I = V/R$

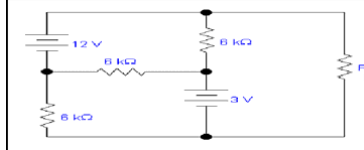
so $I = 10/12$ put in A we have

$$P_L = (10/12k)^2 (6k)$$

$$= (0.83)^2 \times 6$$

$$P_L = 4.1 \text{ mW}$$

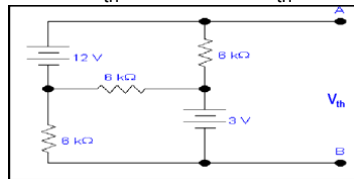
Example: Calculate the value of R_L and the maximum power dissipation across it by Thevenin's Theorem.

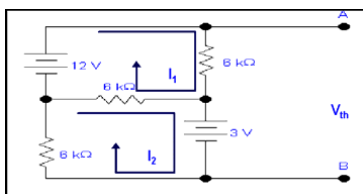
**Solution:**

We want to calculate R_L and the maximum power across it by using Thevenin's theorem. We will follow the following steps.

First step: Removing R_L

To remove R_L to calculate V_{th} . In this case our R_{th} is our R_L .

**Second step: Calculating V_{th}**



Apply KVL to the circuit

For loop1

$$\begin{aligned}
 -12 + 6I_1 + 6(I_1 - I_2) &= 0 \\
 -12 + 12I_1 - 6I_2 &= 0 \\
 2I_1 - I_2 &= 2 \text{ ----- (A)}
 \end{aligned}$$

For loop 2

$$\begin{aligned}
 12I_2 - 6I_1 + 3 &= 0 \\
 4I_2 - 2I_1 + 1 &= 0 \\
 2I_1 &= 4I_2 + 1
 \end{aligned}$$

put in equation (A) we have

$$\begin{aligned}
 4kI_2 + 1 - 1kI_2 &= 2 \\
 3kI_2 &= 1 \\
 I_2 &= 0.33\text{mA}
 \end{aligned}$$

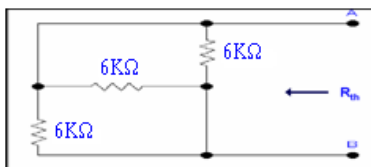
from equation (A)

$$\begin{aligned}
 I_1 &= (12 + 2)/2 \\
 &= 0.33 + 2/2 \\
 I_1 &= 1.166\text{mA}
 \end{aligned}$$

Now voltage across 6k resistor

$$\begin{aligned}
 V_{R6k} &= 6kI_1 \\
 &= 6k(1.166\text{mA}) \\
 V_{R6k} &= 7\text{volts} \\
 V_{th} &= 7V + 3V \\
 V_{th} &= 10\text{ volts}
 \end{aligned}$$

Third step: Calculating R_{th}



We want to calculate R_{th} , 6k is in parallel with 6k. The resultant is again parallel with third 6k resistor.

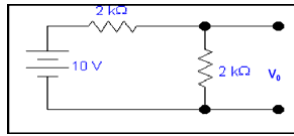
$$\begin{aligned}
 6k \parallel 6k &= (6k \times 6k) / (6k + 6k) \\
 &= 3k \\
 3k \parallel 6k &= 6k \times 3k / (6k + 3k) \\
 &= 2k
 \end{aligned}$$

So

$$R_{th} = R_L = 2k$$

Fourth step: Calculating unknown quantity.

After calculating V_{th} and R_{th} , re-inserting the load resistance R_L in the circuit in series with R_{th} and considering the V_{th} as a battery in series with these resistances.



$$V_{RL} = 10 \times 2k/4k \\ = 5 \text{ volts}$$

To calculate the power dissipation we have

$$P_L = V^2/R = 25/2k$$

$$P_L = 12.5\text{mW}$$

THEVENIN'S THEOREM AND DEPENDENT SOURCES:

Working with dependent sources is different from working with independent sources while applying Thevenin's theorem.

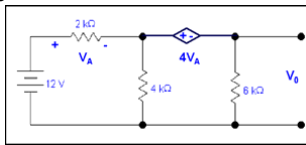
While calculating R_{th} we can simply open circuit current sources and short circuit voltage sources.

Because the voltage or current of the dependent sources is dependent on the voltage or current of these independent sources.

While calculating R_{th} we will short circuit the open terminals of the Thevenin circuit and will calculate the I_{sc}

and then divide V_{th} with I_{sc} to calculate R_{th} .

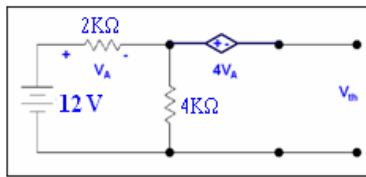
Example: Calculate the voltage V_o by using Thevenin's theorem.



Solution:

We want to calculate V_o by using Thevenin's theorem. We will follow the following steps.

First step: Removing R_L



Here R_L is 6k resistor at which we want to calculate the voltage V_o .

Second step: Calculating V_{th}

Voltage across 4k resistor

$$V_{4k} = (4k/6k) 12$$

$$V_{4k} = 8\text{volts}$$

Voltage across 2k resistor

$$V_{2k} = (2k/6k) 12$$

$$V_A = V_{2k} = 4\text{volts}$$

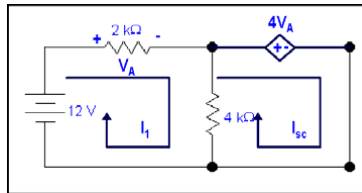
$$V_{th} = 8 - 4V_A$$

$$= 8 - 4(4)$$

$$= 8 - 16$$

$$V_{th} = -8 \text{ volts}$$

Third step: When we use dependent sources we will use the following technique. In the above circuit output which is opened after removing the load resistance now we will replace this open circuit with short circuit. As in the circuit below.



We will first find I_{sc} to calculate R_{th} .

Here

$$V_A = 2kI_1$$

Applying KVL to loop 1

$$-12 + 2kI_1 + (I_1 - I_{sc})4k = 0$$

$$-12 + 2kI_1 + 4kI_1 - 4kI_{sc} = 0$$

$$6kI_1 - 4kI_{sc} = 12$$

For other loop

$$(I_{sc} - I_1)4k + 4V_A = 0$$

$$4kI_{sc} - 4kI_1 + 4(2kI_1) = 0$$

$$4kI_{sc} - 4kI_1 + 8kI_1 = 0$$

$$I_1 = -I_{sc}$$

Putting in equation for loop1

$$3I_1 - 2I_{sc} = 6$$

$$3(-I_{sc}) - 2I_{sc} = 6$$

$$I_{sc} = -6/5 \text{ mA}$$

So

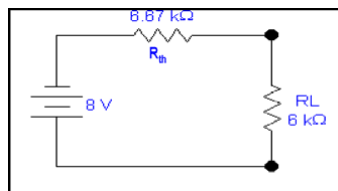
$$R_{th} = V_{th}/I_{sc}$$

$$= -8/(-6/5 \text{ m})$$

$$R_{th} = 6.67k$$

Fourth step:

After calculating V_{th} and R_{th} , re-inserting the load resistance R_L in the circuit in series with R_{th} and considering the V_{th} as a battery in series with these resistances.



So

$$V_0 = (6k/6k + 6.67k) \times 8$$

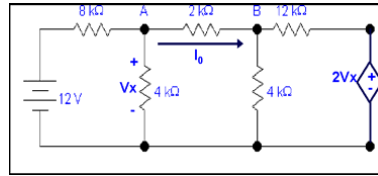
$$= 6k/12.67k \times 8$$

$$V_0 = 3.78 \text{ volts}$$

LECTURE 27

(Thevenin's Theorem and Dependent sources with examples - Norton's Theorem with examples)

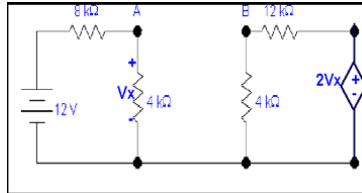
Example: Calculate the current I_o by using Thevenin's theorem.



Solution:

We want to calculate I_o by using Thevenin's theorem. We will follow the following steps.

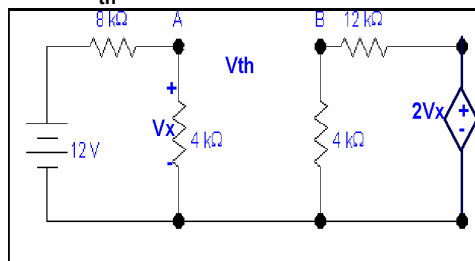
First step: Removing R_L to calculate V_{th}



Removing R_L to calculate V_{th} .

Here R_L is 2k resistor at which we want to calculate the current I_o .

Second step: Calculating V_{th}



Now we will calculate the voltage V_{th} .

Voltage at node A

$$V_x = (4 \times 12) / (4 + 8) \\ = 4 \text{ volts} = V_A$$

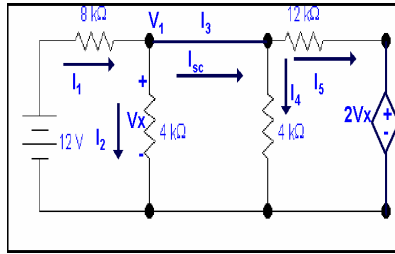
Now voltage at node B

$$V_B = (4 \times 2V_x) / 12 + 4$$

$$V_B = (4 \times 8) / 16 \quad \text{where } V_x = 4 \text{ volts} \\ = 2 \text{ volts}$$

So

$$V_{AB} = 4 - 2 = 2 \text{ volts} = V_{th}$$

Third step: Calculating R_{th} 

Now to find I_{sc}

For node 1

$$(V_1 - 12)/8k + V_1/4k + V_1/4k + (V_1 - 2V_x)/12k = 0$$

$$\text{From the fig } V_x = V_1$$

$$(V_1 - 12)/8k + V_1/4k + V_1/4k + (V_1 - 2V_1)/12k = 0$$

$$3V_1 - 36 + 6V_1 + 6V_1 + 2V_1 - 4V_1 = 0$$

$$V_1 = 36/13$$

$$I_1 = (12 - V_1)/8k \\ = (12 - 36/13)/8k \\ = 15/13 \text{ mA}$$

$$I_1 = 1.15 \text{ mA}$$

$$I_2 = (36/13)/4k \\ = 9/13$$

$$I_2 = 0.692 \text{ mA}$$

$$I_4 = (36/13)/4$$

$$I_4 = 9/13 \text{ mA} = 0.692 \text{ mA}$$

$$I_5 = (36/13 - 2(36/13))/12k$$

$$= -3/13 \text{ mA}$$

$$I_5 = 0.23 \text{ mA}$$

$$I_3 = I_{sc} = I_5 + I_4 \\ = 0.692 - 0.23$$

$$I_3 = 0.46 \text{ mA}$$

So

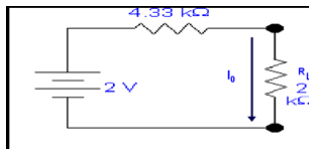
$$R_{th} = V_{th}/I_{sc}$$

$$= 2/0.46 \text{ m}$$

$$R_{th} = 4.33 \text{ k}$$

Fourth step: Calculating the unknown quantity.

After calculating V_{th} and R_{th} , re-inserting the load resistance R_L in the circuit in series with R_{th} and considering the V_{th} as a battery in series with these two resistances.

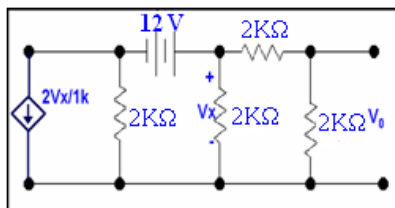


So

$$I_0 = 2/(2k + 4.33k)$$

$$I_0 = 0.315 \text{ mA}$$

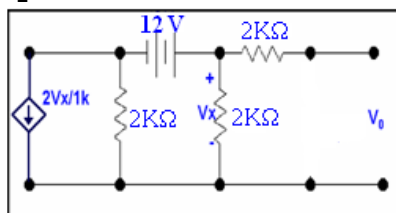
Example: Calculate the voltage V_0 by using Thevenin's theorem .



Solution:

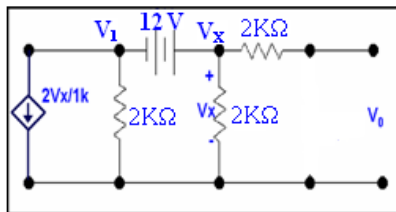
We want to calculate V_0 by using Thevenin's theorem .we will follow these steps .

First step: Removing R_L



To remove R_L to calculate V_{th} .

Second step:



$$V_x = 12 + V_1$$

For node 1

$$V_1/2k + 2V_x/1k + V_x/2k = 0$$

$$V_1 + 4V_x + V_x = 0$$

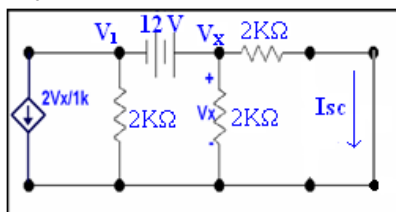
Putting the value of V_1

$$V_x - 12 + 4V_x + V_x = 0$$

$$6V_x = 12$$

$$V_x = 2 \text{ volts} = V_{th}$$

Third step: Calculating R_{th}



There is dependent source in the circuit we will short circuit the open circuit so we have here

$$V_x = V_1 + 12$$

$$\begin{aligned} V/2k + 2Vx/1k + Vx/2k + Vx/2k &= 0 \\ Vx - 12 + 4Vx + Vx + Vx &= 0 \\ 7Vx &= 12 \end{aligned}$$

$$I_{sc} = 12/7 \times 1/2$$

$$= 6/7 \text{ mA}$$

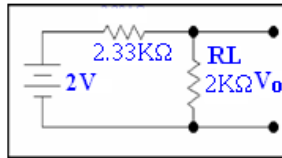
$$R_{th} = V_{th} / I_{sc}$$

$$= 2/(6/7) \text{ m}$$

$$R_{th} = 7/3 \text{ k} = 2.33 \text{ k}$$

Fourth step: Calculating unknown quantity.

After calculating V_{th} and R_{th} , re-inserting the load resistance R_L in the circuit in series with R_{th} and considering the V_{th} as a battery in series with these two resistances.



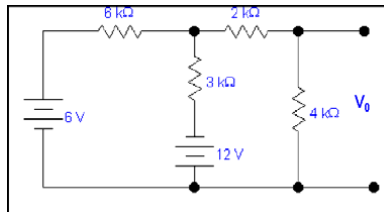
$$V_0 = 2 \times 2k/2k + 2.33k$$

$$V_0 = 0.92 \text{ volts}$$

NORTON'S THEOREM

- Working with Norton's theorem is same as working with Thevenin's theorem.
- We will follow the same four steps.
- But in second step instead of finding V_{th} we will find I_{Nor} by short circuiting the open terminals of the circuit.
- In fourth step our circuit will consist of a current source of value equal to I_{Nor} and the Norton resistance will become parallel with R_L .

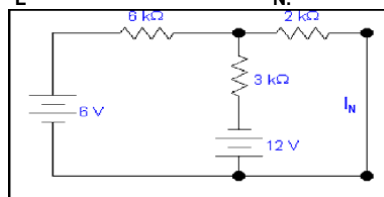
Example: Calculate the voltage V_0 by using Norton's theorem.



Solution:

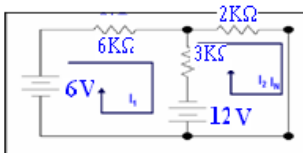
We want to calculate V_0 by using **Norton's theorem**. we will follow these steps.

First step: Replacing R_L with a short circuit to find I_N .



Here R_L is 4k resistor.

Second step:



We want to calculate I_N .

KVL for loop1

$$6kI_1 + 3k(I_1 - I_2) - 12 - 6 = 0$$

$$9kI_1 - 3kI_2 = 18$$

KVL for loop 2

$$2kI_2 + 12 + 3k(I_2 - I_1) = 0$$

$$-3kI_1 + 5kI_2 = -12$$

Solving equations for loop1 and loop2

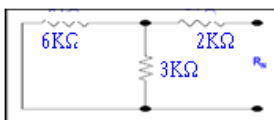
$$I_2 = -1.5\text{mA}$$

So,

$$I_N = -1.5\text{mA}$$

Third step: Calculating R_N

To calculate R_N we will short circuit all voltage sources. Now 3k is in parallel with 6k and 2k is in series with them.



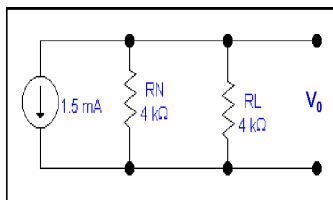
$$6k \parallel 3k + 2k = (6k \times 3k) / (6k + 3k) + 2k$$

$$= 2k + 2k$$

$$= 4k = R_N$$

Fourth Step:

After calculating I_N and R_N , re-inserting the load resistance R_L in the circuit in parallel R_N and considering the I_N current source parallel with these two resistances.



Current through $R_L = (-1.5\text{mA} \times 4k) / 8k$ (using current division rule)

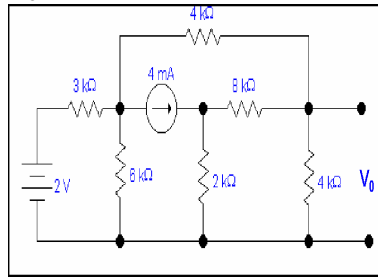
$$I_0 = -0.75\text{mA}$$

SO

$$V_0 = (-0.75\text{mA})(4k)$$

$$V_0 = -3 \text{ volts}$$

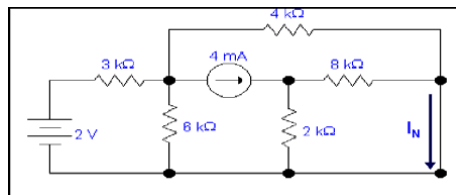
Example: Calculate the voltage V_0 by using Norton's theorem .



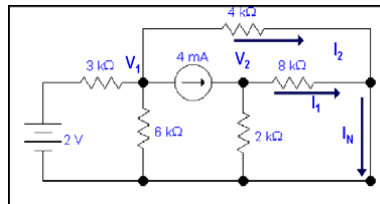
Solution:

We want to calculate V_0 by using **Norton's theorem**. we will follow these steps .

First step: Replacing R_L with a short circuit to find I_N . Here R_L is 4k resistor.



Second step:



$$I_{sc} = I_1 + I_2$$

For node 1

$$\begin{aligned} V_1/4k + (V_1 - 2)/3k + V_1/6k + 4m &= 0 \\ 3V_1 + 4V_1 - 8 + 2V_1 + 48 &= 0 \\ 9V_1 + 40 &= 0 \\ \text{Or } V_1 &= -4.44V \end{aligned}$$

For node 2

$$\begin{aligned} V_2/2k + V_2/8k - 4 &= 0 \\ 4V_2 + V_2 - 32 &= 0 \\ 5kV_2 &= 32 \\ V_2 &= 32/5 \\ V_2 &= 6.4V \end{aligned}$$

Now

$$I_1 = V_2/8k$$

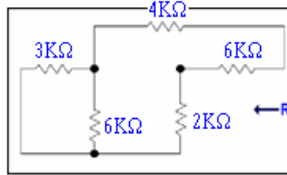
$$\begin{aligned}
 &= 6.4/8k \\
 I_1 &= 0.8 \text{ mA} \\
 I_2 &= V_1/4k \\
 &= 4.44/4k \\
 &= -1.11 \text{ mA}
 \end{aligned}$$

So,

$$\begin{aligned}
 I_N &= I_1 + I_2 \\
 I_N &= (1.11 + 0.8) \\
 I_N &= -0.31 \text{ mA}
 \end{aligned}$$

Third step: Calculating R_N

To calculate R_N we will short circuit all voltage sources and open the current sources.

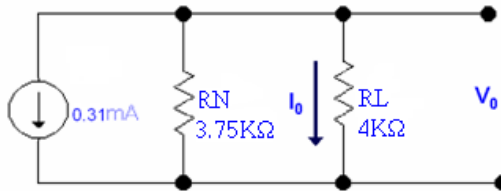


For R_N

$$\begin{aligned}
 3k \parallel 6k &= 2k \\
 2k \text{ is in series with } 4k &= 2k + 4k \\
 &= 6k \\
 8k \text{ is in series with } 2k &= 8k + 2k \\
 &= 10k \\
 10k \parallel 6k &= 10 \times 6/16 \\
 &= 60/16 \\
 R_N &= 3.75k
 \end{aligned}$$

Fourth Step:

After calculating I_N and R_N , re-inserting the load resistance R_L in the circuit in parallel R_N and considering the I_N current source parallel with these two resistances.



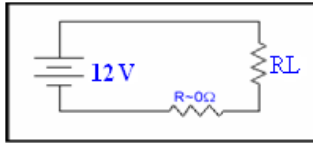
To calculate V_0

$$\begin{aligned}
 I_0 &= 0.31 \text{ mA} \times 3.75k \times 1/(4k + 3.75k) \\
 &= 0.14 \text{ mA} \\
 V_0 &= 4k \times 0.14 \text{ mA} \\
 V_0 &= 0.56 \text{ Volts}
 \end{aligned}$$

LECTURE 28

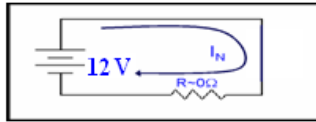
(Norton's Theorem with examples - Linearity Principle)

Example: Find Norton equivalent circuit.



Solution:

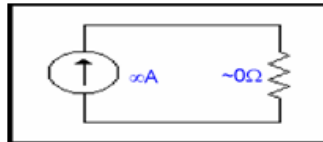
First step: Removing R_L replace open circuit with short circuit



by ohm's Law we have

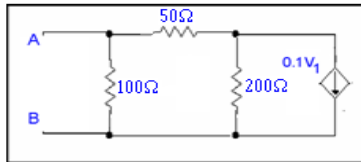
$$I_N = 12/0 \rightarrow \infty A$$

Now we will insert the resistance $R=0$ parallel to current source.



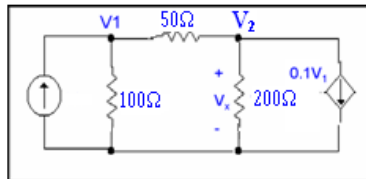
So we have the Norton's equivalent circuit.

Example: Calculate Norton's current through the circuit.



Solution:

Inject a 1A current source into the port and define V_x across 200Ω so that



For node 1

$$1 = (V_1/100) + (V_1 - V_x)/50$$

$$100 = V_1 + 2V_1 - 2V_x$$

$$3V_1 - 2V_x = 100 \text{ ----- (A)}$$

For node 2

$$-0.1V_1 = (V_x/200) + (V_x - V_1)/50$$

$$-20V_1 = V_x + 4V_x - 4V_1$$

$$5V_x + 16V_1 = 0 \text{ -----(B)}$$

Solving simultaneously A and B we have

$$\begin{aligned} 10V_x + 32V_1 &= 0 \\ 10V_x + 15V_1 &= 500 \end{aligned}$$

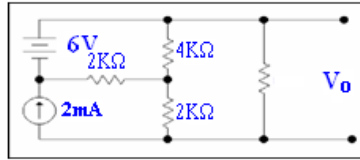
$$47V_1 = 500$$

$$V_1 = 10.64V$$

$$\text{Also } R_{th} = R_n = V_1 / I_A = 10.64\Omega$$

Since no independent source is involved in the circuit, hence $I_N = 0$

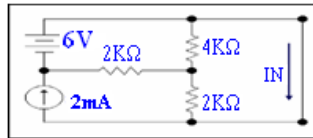
Example: Calculate the voltage V_o by using Norton's theorem, do not use loop and node methods. Use super position method.



Solution:

We want to calculate V_o by using **Norton's theorem**. we will follow these four steps.

First step: Replacing R_L with a short circuit to find I_N .



Here R_L is 6k resistor.

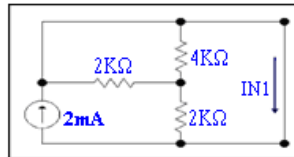
Second step:

We can't use loop or node methods, so let's use super position method to calculate I_N

To apply super position method we will remove all circuits one by one i.e. after removing voltage source we will replace it with short circuit and current source with open circuit.

Hint: Don't remove all circuits simultaneously.

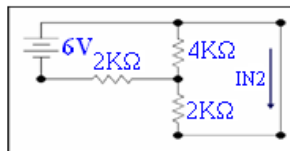
Only current source is acting.



Due to short circuit all current will follow through the short circuit so

$$I_{N1} = 2mA \text{ -----(A)}$$

Only voltage source is acting.



4k is in parallel with 2k resistor which in return is in series with 2k resistor. So total resistance.

$$\begin{aligned} R &= (4k \parallel 2k) + 2k \\ &= 8/6 k + 2k \end{aligned}$$

So

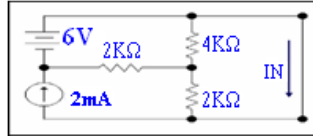
$$R = 3.33 \text{ k}$$

$$I_{N2} = 6/3.33\text{k}$$

$$I_{N2} = 1.80\text{mA} \text{ ----- (B)}$$

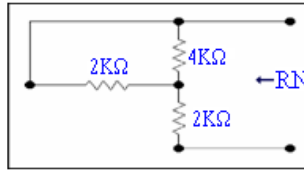
total I_N from both sources so from equation A and B we have

$$\begin{aligned} I_N &= I_{N1} + I_{N2} \\ &= 2\text{mA} + 1.80\text{mA} \\ &= 3.80\text{mA} \end{aligned}$$



Third step: Calculating R_N

To calculate R_N we will short circuit all voltage sources and open circuit all current sources.

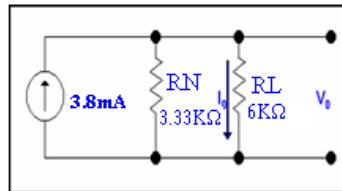


4k is in parallel with 2k. The combined effect of these is in series with 2k.

$$\begin{aligned} 4\text{k} \parallel 2\text{k} + 2\text{k} &= 1.33 + 2\text{k} \\ &= 3.33\text{k} \\ &= R_N \end{aligned}$$

Fourth Step:

After calculating I_N and R_N , re-inserting the load resistance R_L in the circuit in parallel R_N and considering the I_N current source parallel with these two resistances. So our Norton equivalent circuit will be.



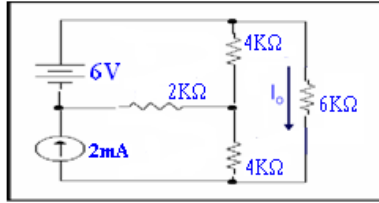
by current divider rule we have

$$\begin{aligned} I_0 &= (3.80\text{mA}) \left(\frac{3.33}{3.33 + 6} \right) \\ &= 1.356 \text{ mA} \end{aligned}$$

By ohm's Law we have

$$V_0 = 6\text{k} \times 1.35 = 8.143 \text{ volts}$$

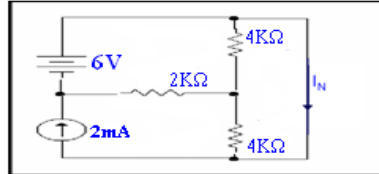
Example: Calculate the current I_o by using Norton's theorem .



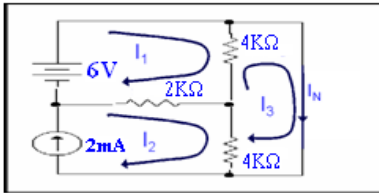
Solution:

We want to calculate I_o by using **Norton's theorem**. we will follow these steps .

First step: Replacing R_L with a short circuit to find I_N . Here R_L is 6k resistor.



Second step: Calculate current I_N



From loop 2, we can write

$$I_2 = 2\text{mA}$$

For loop 1

$$4k(I_1 - I_N) + 2k(I_1 - I_2) - 6 = 0$$

$$4kI_1 - 4kI_N + 2kI_1 - 2kI_2 - 6 = 0$$

$$6kI_1 - 4kI_N - 2kI_2 = 6$$

Putting the value of I_2

$$6kI_1 - 4kI_N - 2k(2\text{mA}) = 6$$

$$6kI_1 - 4kI_N = 10$$

For Loop 3

$$4k(I_N - I_2) + 4k(I_N - I_1) = 0$$

$$4kI_N - 4kI_2 + 4kI_N - 4kI_1 = 0$$

$$-4kI_1 + 8kI_N = 8$$

Solving equations for loops 1 and 3

$$12kI_1 - 8kI_N = 20$$

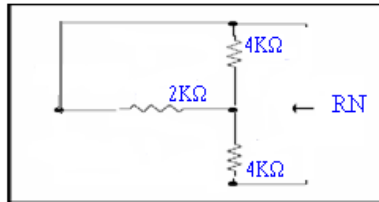
$$-12kI_1 + 24kI_N = 24$$

$$16kI_N = 44$$

$$I_N = 2.75 \text{ mA}$$

Third step: Calculating R_N

To calculate R_N we will short circuit all voltage sources and open the current sources.



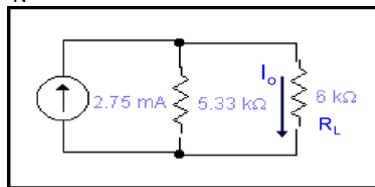
For R_N

$$2k \parallel 4k + 4k = ((2k \times 4k) / (2k + 4k)) + 4k$$

$$R_N = 5.33k\Omega$$

Fourth Step:

After calculating I_N and R_N , re-inserting the load resistance R_L in the circuit in parallel R_N and considering the I_N current source parallel with these two resistances.



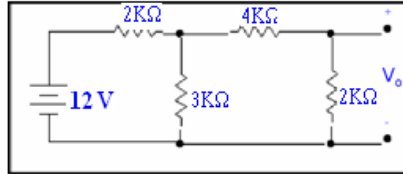
$$I_O = (2.75 \text{ m}) (5.33k) \times 1 / (6 + 5.33)k$$

$$I_O = 1.29 \text{ mA}$$

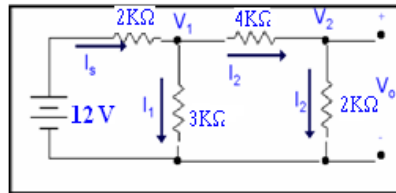
Linearity Principle

In this technique we assume the unknown quantity and analyze the circuit in reverse manner. Until we reach the source which is producing all voltages or currents and calculate its value. Now by comparing this value with the original value of the source we calculate the exact unknown quantity of the circuit.

Example: Calculate V_o by linearity principle.

**Solution:**

We want to calculate V_o by linearity principle. Let us assume that V_o is 1 Volt.



Our assumption is $V_o = 1V$

Therefore, $V_2 = 1V$

Hence $I_2 = 1/2k = 0.5mA$

Also, $V_{4k} = (0.5mA)(4k) = 2V$

Now, $V_1 = V_{4k} + V_2 = 2 + 1 = 3V$

Then, $I_1 = 3/3k = 1mA$

Also, $I_s = I_2 + I_1 = 0.5mA + 1mA = 1.5mA$

$V_{2k} = I_s(2k) = 2k(1.5mA) = 3V$

$V_s = V_{2k} + V_1 = 3 + 3 = 6V$

When V_o is 1, source voltage is 6V, but original source voltage is 12V, hence output voltage will be 2 Volts.

LECTURE 29

(Basic semiconductor concepts)

INTRINSIC SILICON:

- A crystal of pure or intrinsic silicon has a regular lattice structure. Where the atoms are held at their fixed positions by bonds, called Covalent bonds, formed by four valence electrons associated with four each silicon atom.
- At sufficiently low temperature these covalent bond are intact and not (very few) free electrons are available to conduct electric current.
- Thermal ionization results in free electrons and holes in equal numbers and hence equal concentrations. These free electrons and holes move randomly through silicon crystal structure, and in this process some electrons may fill some of the holes. This process is called **RECOMBINATION**
- It results in disappearance of free electrons and holes. The recombination rate is proportional to the number of free electrons and holes, which in turn is determined by ionization rate.

CONDUCTION BAND:

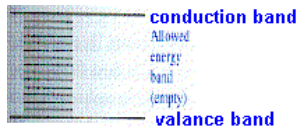
In semiconductors and insulators, there is a band gap above the valence band, called a conduction band. In a semiconductor, the range of electron energy, higher than that of the valence band, sufficient to make the electrons free to move from atom to atom under the influence of an applied electric field and thus constitute an electric current.

Valence BAND:

At 0°C the outermost electrons of an atom of a semiconductor material (such as silicon and germanium) are present in valence-orbits. Associated with these orbits is a band of energies that is termed as valence band of energy.

BAND GAP:

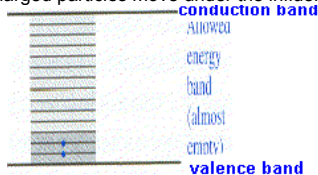
The difference of energy between valence band and conduction band is called band gap energy.



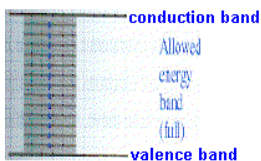
In the above fig upper line is denoted as conduction band while lower line is valence band. There are no electrons available in these energy bands.

Drift

The process whereby charged particles move under the influence of electric field.

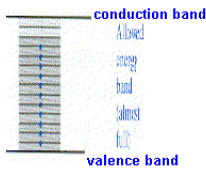


In the above fig there are few electrons present in the near by valence band if we apply some electric field to such a material then these electrons due to applied electric field may drift hence we can observe some activity into electrical property of the material therefore some flow of current also observe and we say this is a conductor.



In the above fig all the energy levels are fully filled with electron if we apply any electric field to such a material then these electrons have no space to drift hence such material act as insulator. Insulators are such material which offers maximum resistance to the flow of electrons and their conductivity is very

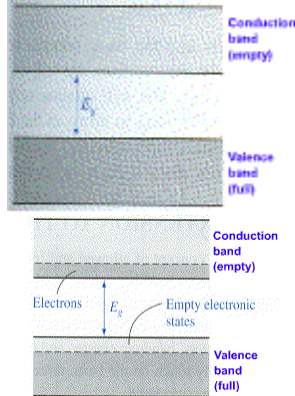
low.



in the above fig almost all energy levels are full except two levels are kept empty if we apply electric field to such a material then these electrons have some space to drift therefore we will observe some flow of current through such a material so these material are called conductors. Conductors are such materials which offers zero resistance to the flow of electrons and their conductivity is maximum.

BAND GAP ENERGY:

It is the energy required to excite an electron from its valence band to a conduction band and denoted as E_g as show in the fig below



Diffusion

The process of flow of particles from a region of high concentration to a region of low concentration.

Diffusion Current

The current that results from the diffusion of charged particles.

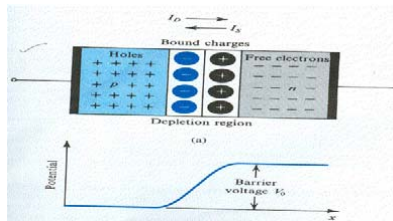
Drift Velocity

The average velocity of charged particles in the presence of an electric field.

DOPED SEMICONDUCTORS

- Doped semiconductors are the materials in which carrier of one kind (electrons or holes) predominate.
- Doped silicon in which the majority of charge carriers are negatively charged electrons is called n type.
- While silicon doped so that majority of charge carriers are positively charged holes is called p type.
- Doping of silicon to turn it into p type or n type is achieved by a small number of impurity atoms.
- For instance, introducing impurity atoms of a pentavalent element such as phosphorus results in n type silicon.

NO BIAS

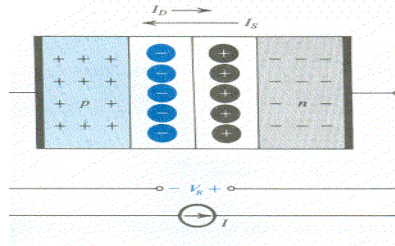


THE DIFFUSION CURRENT I_D

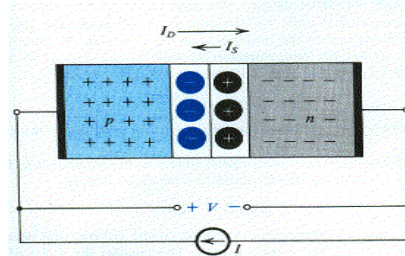
- Because the concentration of holes is high in the p region and low in the n region, holes diffuse across the junction from the p region to the n region.
- Similarly, electrons diffuse the junction from n side to p side.
- These two current components add together to form the diffusion current I_D . Whose direction is from p side to n side, as indicated in the figure.

THE DEPLETION REGION

- The electrons that diffuse across the region quickly recombine with some of the majority holes present in the p region and thus disappear from the scene.
- This results also in disappearance of some majority holes, causing some of the bound negative charge to be uncovered (i-e no longer neutralized by holes). Thus in the p material close to the junction that is depleted of free electrons.
- This p region will contain uncovered bound negative charge, as indicated in the figure.
- From the above it follows that a carrier depletion region will exist on both sides of the junction.
- With n side of this region positively charged and p side negatively charged. This carrier depletion region or simply, depletion region is also called the SPACE CHARGE REGION.

THE P-N JUNCTION UNDER REVERSE BIAS CONDITION.

- The pn junction is excited by a constant current source I in the reverse direction. To avoid breakdown, I kept smaller than I_S .
- Note that the depletion layer widens and the barrier voltage increases by V_R volts, which appears between the terminals as reverse voltage.
- The current I will be carried by electrons flowing in the external circuit from the n material to p material (that is, in direction opposite to that of I).
- This will cause electrons to leave the n material and holes to leave p material. Thus reverse current I will result in an increase in the width of, and the charge stored in the depletion layer. Which will increase the voltage across depletion region?

THE P-N JUNCTION UNDER FORWARD BIAS CONDITION.

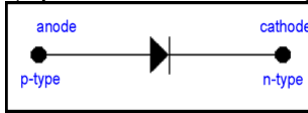
- The pn junction is excited by a constant current source supplying a current I in forward direction. The depletion layer narrows and barrier voltage decreases by V volts, which appears as an external voltage in the forward direction.
- This current causes majority carriers to be supplied to both sides of the junction by the external circuit. Holes to the p material and electrons to the n material.
- These majority carriers will neutralize some of the uncovered, causing less charge to be stored in the depletion region. Thus the depletion layer narrows and the depletion barrier voltage reduces.
- This reduction in voltage cause more electrons to move from n side to p side and more holes to move from p side to n side. So that diffusion currents increases until equilibrium is achieved.

LECTURE 30

(PN Junction Diode - Ideal Diode - Ideal Diode as a Rectifier)

INTRODUCTION TO THE PN- JUNCTION DIODE.

The schematic symbol for the pn-junction diode is shown in the fig.



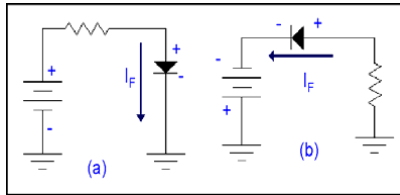
A diode will conduct when it meets the condition that the voltage difference between the anode and the cathode exceeds the barrier voltage of approximately 0.3 volts for a germanium diode and 0.7 for a silicon diode.

THE FORWARD BIASED PN-JUNCTION (DIODE)

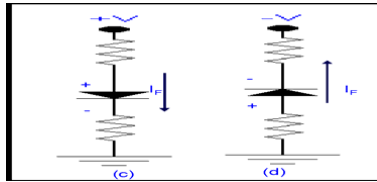
When positive terminal of a battery is connected to the anode or P-side and negative terminal to the cathode or to the N-side of a diode (PN-junction), the diode is said to be **FORWARD-BIASED**.

In the figures to follow it may be noted that the arrow points to the more negative potential in each case. In **fig. a** below the positive terminal of a battery through a resistor is connected the anode whereas the cathode is attached to the neutral terminal and now the condition of the forward biased is fulfilled.

In **fig. b** below the negative terminal of a battery is connected to the cathode whereas the anode is attached through a resistor to the neutral terminal and now the condition of the forward biased is fulfilled where I_F shows the forward conventional current.



In **fig. c** below the positive volts has been applied to the anode of the diode through a resistance and cathode terminal of the diode is connected to the neutral terminal through resistance which will fulfill the condition of forward biased. Where I_F shows the forward conventional current.

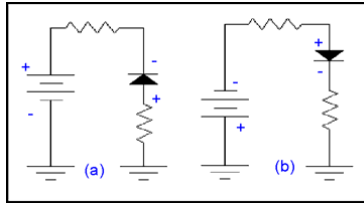


In **fig. d** above the -ve volts has been applied to the cathode of the diode through a resistance and anode terminal of the diode is connected to the neutral terminal through resistance which will fulfill the condition of forward biased. Where I_F shows the forward conventional current will be establish in the diode.

THE REVERSE - BIASED PN-JUNCTION (DIODE)

When positive terminal of a battery is connected to the cathode or N-side and negative terminal to the anode or to the P-side of a diode (PN-junction), the diode is said to be **REVERSED - BIASED**.

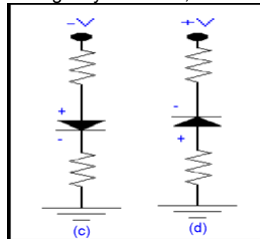
A PN-junction diode is reverse biased when the n type material (cathode) is more positive than the p type material (anode). This causes the depletion region to widen and prevent current. A diode will not conduct when the arrow points to the more positive of the diode potentials.



In **fig. a** the negative of the battery is connected to the anode through a resistor and positive terminal of the battery is connected the cathode therefore no current will flow and we can say that diode is not existing and it will act as an open circuit.

In **fig. b** the negative terminal of the battery is connected to the anode through a resistor and positive terminal of the battery is connected the cathode.

The reverse – biased diode behaves opposite to the forward-biased diode. This means in case of a reverse-biased diode, majority carrier current does not flow and instead of that only minority carrier current can flow. Moreover, the depletion charge layer will expand or enlarged compared to the forward –biased diode where the depletion charge layer shrinks, so it will act as an open circuit.



In **fig. c** the negative voltage has been applied to the anode of the diode through a resistance and cathode terminal of the diode is connected to the neutral terminal through resistance. Which will fulfill the condition of reversed biased.

In **fig. d** the positive voltage has been applied to the cathode of the diode through a resistance and anode terminal of the diode is connected to the neutral terminal through resistance. Which will fulfill the condition of reversed biased

Here we can say that the reverse-biased PN-junction can't support majority carrier current but it will allow the minority carrier current to flow across the junction. This minority carrier current is called as reverse current and is much smaller than the forward majority carrier current of the forward biased PN-junction.

The Ideal Diode

The diode can be considered to be a one Way Street that is it conducts electricity well in one direction but hardly any in the opposite direction. An ideal diode has no resistance in the forward direction and infinite resistance in the reverse direction.

An ideal diode is like a light switch in your home. When the switch is closed, the circuit is completed; and the light turns on. When the switch is open, there is no current and the light is off.

However, the diode has an additional property; it is unidirectional, i.e. current flows in only one direction (anode to cathode internally). When a forward voltage is applied, the diode conducts; and when a reverse voltage is applied, there is no conduction. A mechanical analogy is a rat cat, which allows motion in one direction only.

- The ideal diode may be considered the most fundamental non linear circuit element.
- It is a two terminal device and the i-v characteristic is shown

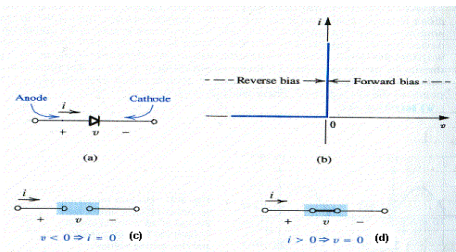
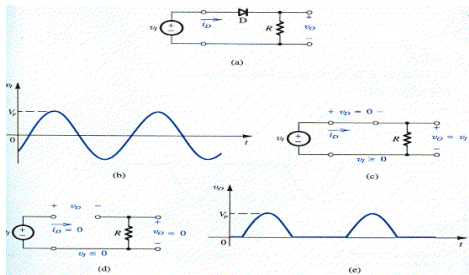


Fig a is diode circuit symbol, fig b is i-v characteristic fig c is equivalent circuit in the reverse direction and fig d is the equivalent circuit in the forward direction. In fig b the terminal characteristic of the ideal diode can be interpreted as. If a negative voltage is applied to the diode, no current flows and the diode behaves as an open circuit as shown in the fig c. Diodes operated in this mode are said to be reverse –biased. An ideal diode has zero current when operated in the reverse direction and is said to be cut off. On the other hand, if a positive voltage is applied to the ideal diode, zero voltage drop appears across the diode .In other words ideal diode behaves as a short circuit in the forward direction as show in the fig d , it passes any current with zero voltage drop. A forward –conducting diode is said to be turned on.

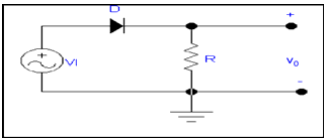
The Ideal Diode as a Rectifier

Rectification is generally defined as the process of converting an alternating current to a unidirectional current. A rectifier device conducts current substantially in one direction only. An ideal rectifier diode would be an open circuit in one direction and short circuit in the other direction. It also would not dissipate power during the rectification process.

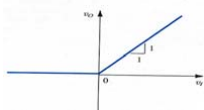


The rectifier circuit shown in the fig a . This circuit consists of series connection of a diode D and a resistor R. Let the input voltage be sinusoid as shown in fig b and assume the diode to be ideal. During the positive half cycle of the input sinusoid ,the positive v_1 will cause current to flow through the diode in its forward direction. It follows that the diode voltage V_D will be very small i.e ideally zero. Thus the circuit will have the equivalent show in the fig (c) and the output voltage V_O will be equal to the input voltage v_1 . On the other hand ,during the negative half cycle of v_1 the diode will not conduct .Thus the circuit will have the equivalent show in the fig (d), and V_O will be zero .Thus, the output voltage will have the waveform shown in fig (e).Note that when V_1 alternates in polarity and has a zero average value , V_O is unidirectional and has a finite average value or a dc component. Thus the circuit of fig (a) rectifier the signal and hence is called a rectifier.

Example: For the circuit draw transfer characteristic v_O VS v_I



Solution:

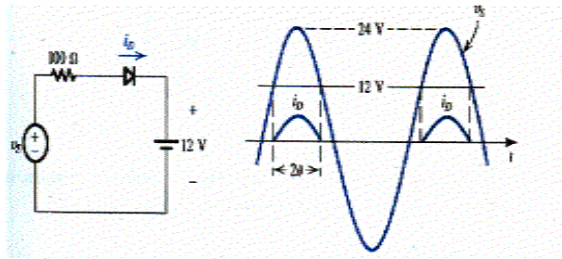


LECTURE 31

(Terminal characteristics of the Junction diodes - Forward bias region)

Example

Fig shows a circuit for charging a 12 volts battery. If v_s is a sinusoid with 24 volts peak amplitude, find the fraction of each cycle during which the diode conducts also find the peak value of the diode current and the maximum reverse biases voltage that appears across the diode.



Solution :

The diode conducts when v_s exceeds 12 volts as shown in the previous fig. The conduction angle is 2θ , where θ is given by

$$\begin{aligned} 24\cos\theta &= 12 \\ \cos\theta &= 1/2 \\ \theta &= \cos^{-1}(1/2) \end{aligned}$$

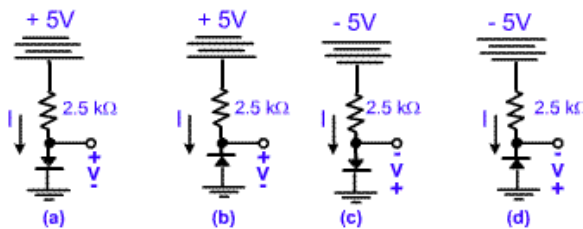
Thus $\theta = 60^\circ$ and the conduction angle is 120° or one third of the cycle.

The peak value of the diode current is given by

$$\begin{aligned} I_d &= (24 - 12)/100 \\ &= 0.12 \text{ A} \end{aligned}$$

The maximum reverse voltage across the diode occurs when v_s is at its negative peak and is equal to $24 + 12 = 36$ volts

Example: Assuming the diodes to be ideal .Find the value of I and V in the circuit shown in figure below.



Solution :

We are using ideal diode here. In fig (a) positive 5 Volt battery is connected to the anode of the diode through a resistance of 2.5 k ohm. The cathode terminal of the diode is connected with the neutral terminal. The diode is in forward biased condition. From the fig we see that all components are in series so the same current will flow.

so by Ohm's Law we have

$$\begin{aligned} I &= 5/2.5 \\ I &= 2\text{mA} \end{aligned}$$

diode acting as short circuit so,

$$V = 0 \text{ volts}$$

In fig (b) the circuit is same only the diode has reversed. 5 Volt battery is connected to the cathode of the diode through a resistance of 2.5 k ohm. The anode terminal of the diode is connected with the neutral terminal. Now the diode is in reversed biased condition so, it will act as an open circuit therefore no current will flow.

$$I = 0\text{mA}$$

whole voltage of 5 volts will appear at positive terminal.

$$V = 5\text{volts}$$

In fig (c) negative 5 Volt battery has been connected to the anode of the diode through a resistance of 2.5 k ohm. The cathode terminal of the diode is connected with the neutral terminal. The diode is in reversed biased condition and it will act as an open circuit therefore current will flow.

$$I = 0\text{mA}$$

whole voltage of 5 volts will appear

$$V = -5\text{volts}$$

In fig (d) the circuit is same only the diode has reversed. negative 5 Volt battery has been connected to the cathode of the diode through a resistance of 2.5 k ohm. The anode terminal of the diode is connected with the neutral terminal. Now the diode is in forward biased condition so, it will act as an short circuit therefore current will flow.

so by Ohm's Law we have

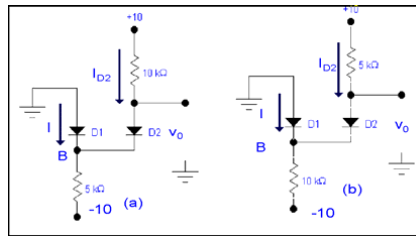
$$I = 5/2.5$$

$$I = 2\text{mA}$$

diode acting as short circuit so,

$$V = 0\text{ volts}$$

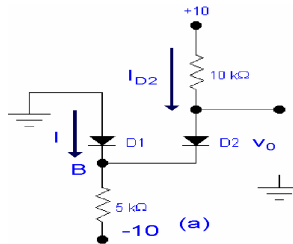
Example Assuming the diodes to be ideal, find the values of I and V_0 in the circuits.



Solution :

For the circuit in the fig (a) we shall assume that both diodes are conducting. It follows that $V_B = 0$ and $V_0 = 0$. The current through D_2 can now be determined from

$$I_{D2} = (10 - 0)/10 \\ = 1\text{mA}$$



Writing node equation at B,

$$I + 1 = 0 - (-10)/5$$

Results in $I = 1\text{mA}$. Thus D_1 is conducting as originally assumed, and the final result is

$$I = 1\text{mA}$$

and

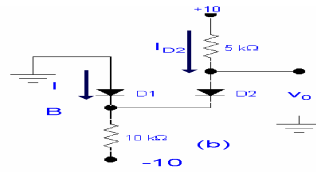
$$V = 0\text{ volts}$$

For the circuit in fig (b), if we assume that both diodes are conducting, then $V_B = 0$

and $V_0 = 0$. The current in D_2 is obtained

from

$$I_{D2} = (10 - 0)/5 = 2\text{mA}$$



$$I + 2 \text{ m} = 0 - (-10)/10\text{k}$$

Which yields $I = -1\text{mA}$. Since this is not possible, our assumption is not correct. we start again, assuming that D_1 is off and D_2 is on.

The current I_{D2} is given by

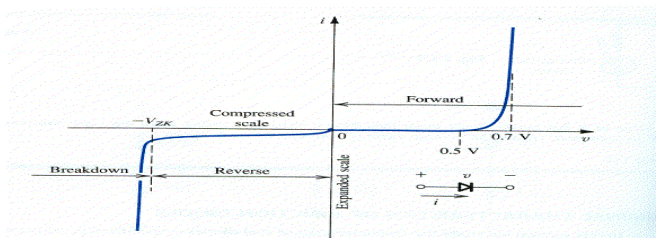
$$I_{D2} = 10 - (-10)/15 \\ = 1.33\text{mA}$$

and the voltage at node B is

$$V_B = -10 + 10 \times 1.33 = 3.3 \text{ volts}$$

Thus D_1 is reversed biased as assumed, and the final result is $I = 0$ and $V_0 = 3.3 \text{ volts}$

TERMINAL CHARACTERISTICS OF THE JUNCTION DIODES



As indicated the characteristic curve consist of three distinct regions:

- (1) The forward bias region, determined by $v > 0$
- (2) The reverse bias region determined by $v < 0$
- (3) The breakdown region determined by $v < -V_{ZK}$

These three regions of operations described in the following.

THE FORWARD BIAS REGION:

- The forward bias or simply forward region is entered when the terminal voltage v is positive. In the forward region the i - v relationship is closely approximated as

$$i = I_s (e^{\frac{v}{nV_T}} - 1)$$

- In this equation I_s is a constant for a given diode at a given temperature and it is directly proportional to the area of the diode.
- The Voltage V_T is a constant and given as

$$V_T = kT/q$$

where

k = Boltzmann,s constant

$$= 1.38 \times 10^{-23} \text{ joules/kelvin}$$

T = absolute temperature in kelvin

q =magnitude of the electronic charge

$$= 1.60 \times 10^{-19} \text{ coulombs}$$

- At room temperature (20°C) the value of V_T is 25.2mV.
- In the diode equation the constant n has a value between 1 and 2 depending on the material and physical structure of the diode.

- For appreciable current I in the forward direction, $i \gg I_s$. The diode equation can be modified as

$$i = I_s e^{v/nVT}$$

This expression can be given alternatively in algorithmic form

$$v = nV_T \ln(i/I_s)$$

- Let us consider the forward i - v relationship and evaluate the current I_1 corresponding to the diode voltage V_1 :

$$I_1 = I_s e^{V_1/nVT}$$

Similarly, if the voltage V_2 the diode current I_2 will be

$$I_2 = I_s e^{V_2/nVT}$$

These two equations can be combined to produce

$$I_2/I_1 = e^{(V_2 - V_1)/nVT}$$

Which can be rewritten as

$$V_2 - V_1 = nVT \ln(I_2/I_1)$$

EXAMPLE:

A silicon diode said to be 1mA device displays a forward voltage of 0.7 V at a current of 1mA. Evaluate the junction scaling constant I_s in the event that n is either 1 or 2. What scaling constant would apply for a 1A diode of the same manufacture that conducts 1A at 0.7V.

SOLUTION:

Since

$$i = I_s e^{v/nVT}$$

Then

$$I_s = i e^{-v/nVT}$$

for 1mA diode:

$$\text{if } n=1 : I_s = 10^{-3} e^{-700/25}$$

$$I_s = 6.9 \times 10^{-16} \text{ A}$$

$$\text{If } n=2 : I_s = 10^{-3} e^{-700/50}$$

$$I_s = 8.3 \times 10^{-10} \text{ A}$$

The diode conducting 1A at 0.7V corresponds to 1000mA in parallel with a total junction area 1000 times greater. Thus I_s is also 1000 times greater.

LECTURE 32

(Reverse bias region - Break down region - Analysis of diode circuit)

Example: Consider a silicon diode with $n = 1.5$. Find the change in voltage if the current changes from 0.1mA to 10mA.

Solution:

$$i = I_s e^{v/nV_T}$$

$$I_1 = I_s e^{v_1/nV_T}$$

$$I_2 = I_s e^{v_2/nV_T}$$

$$I_1/I_2 = e^{(v_1 - v_2)/nV_T}$$

$$v_1 - v_2 = nV_T \ln(I_1/I_2)$$

here,

$$V_T = 25 \text{ mV}$$

$$= 1.5 \times 25 \ln(10/0.1)$$

so change in the voltage will be

$$v_1 - v_2 = 172.7 \text{ mV}$$

Example: A silicon junction diode with $n = 1$ has $v = 0.7$ volts at $i = 1\text{mA}$. Find the voltage drop at $i = 0.1\text{mA}$ and $i = 10\text{mA}$.

Solution:

$$v_2 - v_1 = nV_T \ln(i_2/i_1)$$

$$v_1 = 0.7 \text{ V}$$

$$i_1 = 1 \text{ mA}$$

and $n = 1$ thus

$$v_2 = 0.7 + V_T \ln(i_2)$$

for

$$i_2 = 0.1 \text{ mA}$$

$$V_T = 25 \text{ mV} = 0.025 \text{ volts}$$

$$v_2 = 0.7 + 0.025 \ln(0.1)$$

$$v_2 = 0.64 \text{ volts}$$

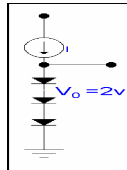
For

$$i_2 = 10 \text{ mA}$$

$$v_2 = 0.7 + 0.025 \ln(10)$$

$$v_2 = 0.76 \text{ volts}$$

Example: The circuit in the fig. utilize three identical diodes having $n=1$ and $I_s = 10^{-14}$ A. Find the value of the current I to obtain an output voltage $V_o = 2\text{V}$, if a current of 1mA is drawn away, what is the change in output voltage.



Solution:

For $V_o = 2\text{V}$, so the voltage drop across each diode is $2/3\text{V}$.
Thus I must be

$$I = I_s e^{v/nV_T}$$

$$V_T = 25 \text{ mV} = 0.025 \text{ volts}$$

$$= 10^{-14} e^{2/3 \times 0.025}$$

$$= 3.8 \text{mA}$$

If a current of 1mA is drawn away from the terminals by means of a load, the current through the diodes reduces to

$$3.8 - 1 = 2.8$$

Thus the voltage across each diode changes by

$$\Delta V = V_2 - V_1 = nV_T \ln(i_2/i_1)$$

$$\Delta V = nV_T \ln(2.8/3.8)$$

$$= -7.63 \text{mV}$$

The total decrease in V_0

$$V_0 = 3 \times 7.63$$

$$= 22.9 \text{mV}$$

Example: A particular diode conducts 1A at a junction voltage of 0.65 volts and 2A at a junction voltage 0.67 volts. What are its values of n and I_s , what current will follow if its junction voltage is 0.7volts?

Solution:

$$I = I_s e^{V_D/nV_T} \text{----- (A)}$$

V_D is a diode voltage.

$$V_T = 25 \text{ mV} = 0.025 \text{ volts}$$

$$1 = I_s e^{0.65/n(0.025)} \text{----- (B)}$$

$$2 = I_s e^{0.67/n(0.025)} \text{----- (C)}$$

Taking natural log of (B) and (C) and subtracting we have

$$\ln(1) = \ln(I_s e^{0.65/n(0.025)}) \text{----- (B)}$$

$$\ln(2) = \ln(I_s e^{0.67/n(0.025)}) \text{----- (C)}$$

Subtracting (B) and (C) we have

$$-\ln 2 = -0.02/n(0.025)$$

$$n = 0.02/0.025 \ln 2$$

$$n = 1.154$$

put the value of n in equation B we have

$$I_s = e^{-0.65/1.154(0.025)}$$

$$= 1.64 \times 10^{-10}$$

so from equation A we have

$$I_D = 1.64 \times 10^{-10} e^{0.7/1.154(0.025)}$$

$$I_D = 1.64 \times 10^{-10} \times 3.4 \times 10^{10}$$

$$I_D = 5.66 \text{A}$$

THE REVERSE BIAS REGION:

The reverse bias region of operation is entered when the diode voltage is made negative. The previous equation indicates that if v is negative and a few times larger than V_T in magnitude the exponential term becomes negligibly small as compared to unity and diode current becomes

$$i = -I_s$$

that is, the current in the reverse direction is constant and equal to I_s . This constancy is the reason behind the term saturation current.

A good part of the reverse current is due to the leakage effect.

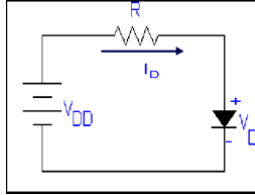
The leakage currents are proportional to the junction area, just as I_s . Its dependence on temperature is however, different from that of I_s .

THE BREAKDOWN REGION:

- The break down region is entered when the magnitude of the reverse voltage exceeds a threshold value specific to a particular diode and is called the **BREAKDOWN VOLTAGE**.

- It is the voltage at the knee of i-v curve and is denoted by V_{ZK} .
- In the break down region reverse current increases rapidly, while the associated change in voltage is very small this fact is used in voltage regulation.

ANALYSIS OF DIODE CIRCUITS:



Consider the circuit shown in the fig. We wish to analyze this circuit to determine the diode current I_D and voltage V_D .

The diode is obviously biased in forward direction.

Assuming that V_{DD} is greater than 0.5V or so, the diode current will be much greater than I_s and we can represent i-v characteristics by the exponential relationship resulting in

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

The other that governs circuit operations is obtained by writing a KVL equation resulting in

$$I_D = (V_{DD} - V_D) / R \quad (2)$$

if we put $I_D = 0$ in equation 2 we will get

$$V_{DD} = V_D$$

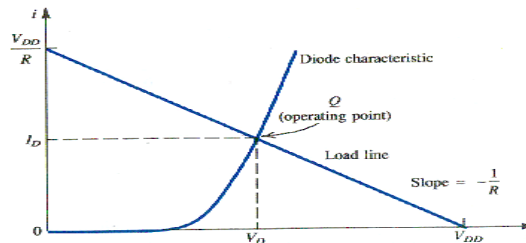
if we put $V_D = 0$

$$I_D = V_{DD} / R$$

We draw current along Y-axis and voltage across X-axis

GRAPHICAL ANALYSIS:

- Graphical analysis is performed by plotting the relationships of equations (1) and (2) on the i-v plane. The solution can then be obtained as the point of intersection of the two graphs.

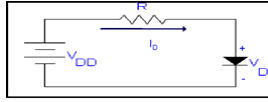


- A sketch of the graphical construction is shown in the fig. The curve represents the exponential diode equation and the straight line represents the equation (2). Such a straight line is known as load line. The load line intersects the diode curve at point Q, which represents the operating point of the circuit. Its co-ordinates give values of I_D and V_D .

ITERATIVE ANALYSIS:

- Equations (1) and (2) can be solved using a simple iterative procedure, as illustrated in the following example

EXAMPLE: Determine the current I_D and the diode voltage V_D for the circuit in the fig. with $V_{DD} = 5V$ and $R = 1k$. Assume that the diode has a current of $1mA$ at a voltage of $0.7V$ and its voltage drop changes by $0.1V$ for every decade change in current.



SOLUTION:

To begin the iteration, we assume that $V_D = 0.7V$ and the equation (2) determines the current

$$\begin{aligned} I_D &= (V_{DD} - V_D) / R \\ &= (5 - 0.7) / 1 \\ &= 4.3mA \end{aligned}$$

Now from our previous knowledge

$$V_2 - V_1 = nV_T \ln(I_2 / I_1)$$

$$\log_{10} x = (\ln x) / (\ln 10) \text{ where } \ln 10 = 2.3$$

$$\text{so } 2.3 \log_{10} x = \ln x$$

now the equation of log to the base 10 form will be as

$$V_2 - V_1 = 2.3nV_T \log_{10} I_2 / I_1$$

For our case, $2.3 nV_T = 0.1\text{volts}$

$$V_2 = V_1 + 0.1 \log_{10} I_2 / I_1$$

Substituting $V_1 = 0.7V$, $I_1 = 1mA$ and $I_2 = 4.3mA$

$$V_2 = 0.763V$$

Thus the results for the first iteration are

$$I_D = 4.3mA \text{ and } V_D = 0.763V$$

The second iteration proceeds in the similar manner

$$I_D = (V_{DD} - V_D) / R$$

$$\text{Here } V_D = 0.763V$$

$$I_D = (5 - 0.763) / 1$$

$$= 4.237mA$$

$$V_2 = 0.763 + 0.1 \log_{10}(4.237/4.3)$$

$$= 0.762V$$

Thus the second iteration yields

$$I_D = 4.23mA \text{ and } V_D = 0.762V$$

Since these values are not much very different from the values obtains after the first iteration, no further iterations are necessary and the

Solution is $I_D = 4.23mA$ and $V_D = 0.762V$

LECTURE 33

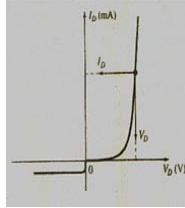
(DC or Static Resistance-The constant voltage drop model - AC or Dynamic Resistance)

DC OR STATIC RESISTANCE:

- When diode is subjected to a dc voltage its operating point on the characteristic curve does not change with time. Hence the resistance of the diode can be found easily

$$r_D = v_D / i_D$$

- It may also be seen on the curve that the resistance in the reverse bias is quite high.



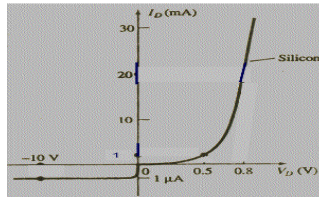
Example:

Determine the resistance level for the diode having characteristics as shown in the graph below at

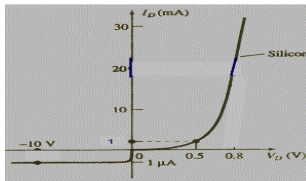
(1) $I_D = 1\text{mA}$

(2) $I_D = 20\text{mA}$

(3) $V_D = -10\text{V}$



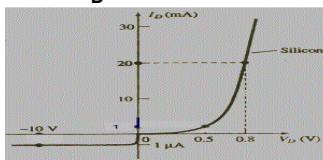
SOLUTION:



- (1) From the curve
For $I_D = 1\text{mA}$, $V_D = 0.5\text{volts}$

$$R_D = 0.5/1\text{m}$$

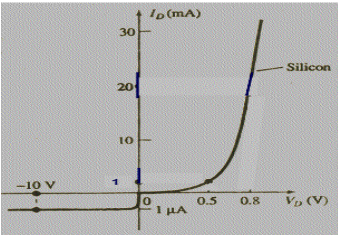
$$R_D = 500 \text{ ohms}$$



- (2) For $I_D = 20\text{mA}$, $V_D = 0.8\text{volts}$

$$R_D = 0.8/20\text{m}$$

$$R_D = 40 \text{ ohms}$$

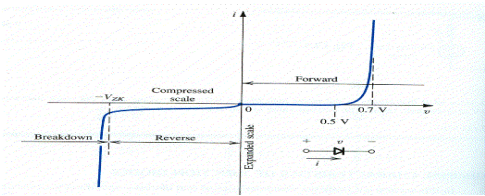


(3) For $V_D = -10V,$ $I_D = -1\text{microA}$

$$R_D = 10/10^{-6}$$
$$R_D = 10\text{Mohms}$$

THE CONSTANT VOLTAGE DROP MODEL:

- We use a vertical straight line to approximate the fast rising part of the exponential curve, as shown in the fig.



Ideal Model:

We have seen that the diode behaves essentially as a **switch**: on when forward biased, off when reverse biased. The ideal diode characteristic is shown in Figure B. Corresponding to this is the ideal diode model, Figure C.

Figure B: Ideal diode characteristic.

✓ Ideal-diode volt-ampere characteristic

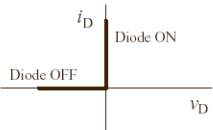
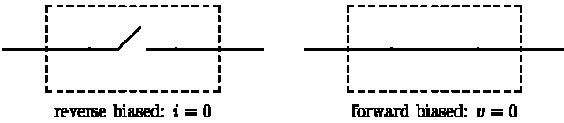


Figure C: Ideal diode model.



When the diode is reverse biased, we replace it with an open switch, and when the diode is forward biased, we use a closed switch.

PRACTICAL MODEL:

In practice we find that there is a voltage drop of about 0.7 V across the diode (silicon; germanium is 0.3 V) when it is forward biased, and so it is often useful to include this voltage drop in circuit analysis. Accordingly, the **practical model** is the ideal model with the addition of a voltage source in the forward bias model. Figure D shows the practical model characteristic. The practical model is shown in Figure E.

Figure D: Practical diode characteristic.

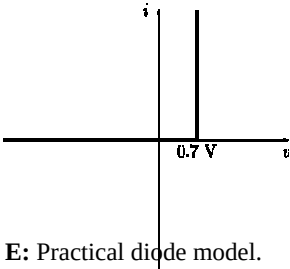
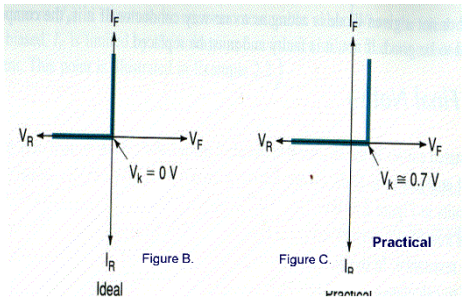
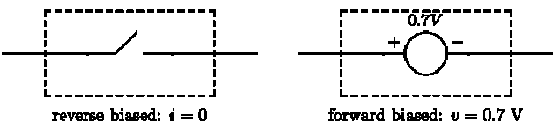
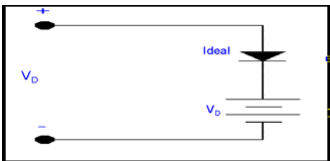


Figure E: Practical diode model.

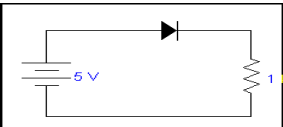


- The resulting model simply says that a forward conducting diode exhibits a constant voltage drop V_D . The value of V_D is usually taken to be as 0.7 volts in case of silicon diode. The constant voltage drop model can be represented by the equivalent model shown in the fig.



THE EFFECT OF THE FORWARD VOLTAGE DROP ON CIRCUIT ANALYSIS

To illustrate this effect consider this circuit,



According to the KVL, the sum of the component voltages in the circuit must be equal to the applied voltage. By formula

$$V_s = V_F + V_R$$

V_s = voltage of source

V_F = forward voltage across the diode

V_R = voltage drop across 1 ohm resistance

if we consider diode is a silicon so, $V_F = 0.7$ volts and arrange this equation for V_R then

$$V_R = V_s - 0.7V$$

According to ohms law

$$I_T = V_R / R$$

Putting the value of V_R from this equation

$$I_T = V_s - 0.7 / R$$

Putting the value of R we have

$$= 5 - 0.7 / 1$$

$$= 4.3A$$

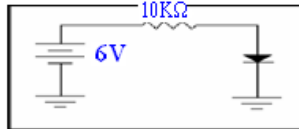
If we consider this diode to be **ideal** then no voltage drop will occur across it and we will get

$$V_s = V_R$$

$$V_F = 0$$

$$I_T = 5mA$$

Example: Find voltage across R_1 . Consider silicon diode so that 0.7 V drop is assumed across it.



Solution:

By KVL

$$V_s = V_R + V_f$$

$$V_R = V_s - 0.7$$

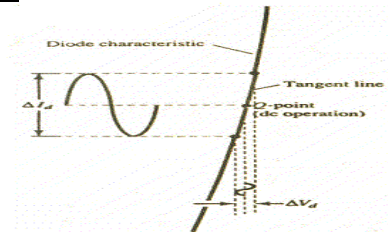
$$V_R = 6 - 0.7$$

$$= 5.3 \text{ volts} \approx 5 \text{ Volts.}$$

THE CONSTANT VOLTAGE DROP MODEL:

- (1) Diode current will remain at zero until the knee voltage is reached.
- (2) Once the applied voltage reaches the value of V_k , the diode turns on and the forward conduction occurs.
- (3) As long as the diode conducting, the value of V_F is approximately equal to V_k . In other words the value of V_F is assumed to be 0.7volts regardless of the value of I_F .

AC OR DYNAMIC RESISTANCE:



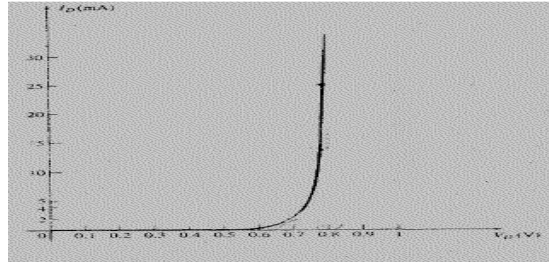
$$r_D = \Delta V_D / \Delta I_D$$

Δ shows a finite change in the quantity. The resistance in the vertical rise region is small, whereas resistance is much larger at low current levels.

LECTURE 34

(Small Signal Model and its applications)

EXAMPLE: Find the AC resistance for the curve shown at
 (1) $I_D = 2\text{mA}$
 (2) $I_D = 25\text{mA}$



SOLUTION:

(1) Choosing a swing of pulse minus 2mA
 For

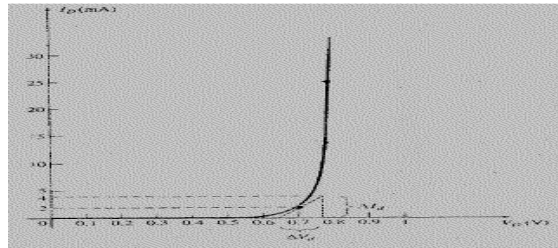
$$I_D = 4\text{mA}, V_D = 0.76\text{V}$$

$$\text{And } I_D = 0\text{mA}, V_D = 0.65\text{V}$$

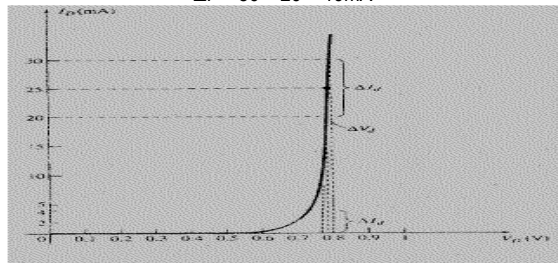
$$\Delta I_D = 4 - 0 = 4\text{mA}$$

$$\Delta V_D = 0.76 - 0.65 = 0.11\text{V}$$

$$r_D = 0.11/4\text{m} \\ = 27.5 \text{ ohms}$$



(2) Choose a swing of pulse minus 5mA
 $\Delta I = 30 - 20 = 10\text{mA}$

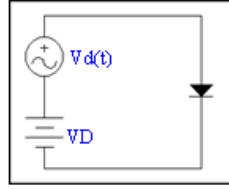


$$\Delta V_D = 0.8 - 0.78 \\ = 0.02\text{V}$$

$$r_D = 0.02/10 \\ = 10 \text{ ohms}$$

SMALL SIGNAL MODEL

In some applications circuit is supplied to a bias to operate in the forward region and also a small ac signal is super imposed on dc quantity consider the circuit shown



When there is no ac, diode voltage is V_D so that

$$I_D = I_S e^{V_D / nV_T}$$

and when signal $V_d(t)$ is applied, then instantaneous voltage $V_d(t)$ is

$$v_D(t) = V_D + v_d(t)$$

so that instantaneous diode current will be

$$i_D(t) = I_S e^{v_D / nV_T}$$

Substituting for v_D

$$i_D(t) = I_S e^{(V_D + v_d) / nV_T}$$

$$\text{Or } = I_S e^{V_D / nV_T} \cdot e^{v_d / nV_T}$$

$$\text{Or } i_D(t) = I_D e^{v_d / nV_T} \text{ ----- (A)}$$

If the amplitude of the signal is sufficiently smaller than 1, so that $V_d / nV_T \ll 1$ expanding the previous equation in the form of a Taylor series i.e

$$e^x = 1 + x + \frac{x^2}{2!} + \dots$$

Above expression is a Taylor series expansion of exponential function e^x in the equation (A) $x = V_d / nV_T$, so we solve the equation (A) upto two terms by Taylor series

$$e^{v_d / nV_T} = (1 + v_d / nV_T)$$

put this value in equation (A) we have

$$i_D(t) = I_D (1 + v_d / nV_T) = I_D + I_D / nV_T v_d \text{ ----- (B)}$$

Or we may write

$$I_D / nV_T v_d = i_d \text{ put in equation (B) we have}$$

$$i_D = I_D + i_d$$

From previous equation we may see that the quantity I_D / nV_T has the dimensions of conductance given in mho's and is called diode small signal conductance. The inverse of it is called small signal resistance or incremental resistance given by

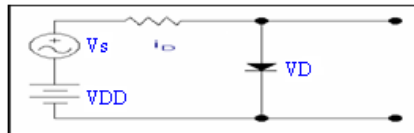
$$r_d = nV_T / I_D$$

$$r_d \propto 1 / I_D$$

nV_T are constants and are provided by the manufacturer.

APPLICATION:

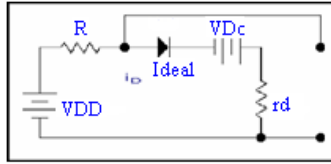
Consider the circuit as shown, for analysis purposes, we can split the circuit into two parts that is ac and dc



DC source having the value of V_{DD}

we replace the ac and replace diode with constant drop model

For dc analysis the Circuit will be



in case of DC we consider only DC current I_D is flowing and no effect of the ideal diode because this ideal diode is forward biasing and it results in short circuit therefore

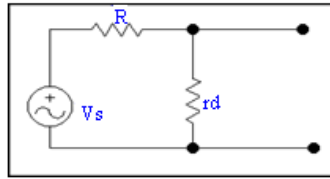
From KVL

$$V_{DD} - I_D R - V_{D0} - I_D r_d = 0$$

$$V_{DD} = I_D R + V_{D0} + I_D r_d \quad \text{----- (A)}$$

in case of DC only DC current I_D is flowing the

For ac analysis we will remove DC sources which are the part of the original circuit and also remove the DC source which appear in the previous effective circuit and we also remove the ideal circuit so our circuit will be as



For ac analysis

$$v_s = i_d (R + r_d) \quad \text{----- (B)}$$

by combining (A) and (B)

Overall analysis is

$$V_{DD} + v_s = I_D R + V_{D0} + I_D r_d + i_d (R + r_d)$$

$$= I_D (R + r_d) + i_d (R + r_d) + V_{D0}$$

$$V_{DD} + v_s = (R + r_d)(I_D + i_d) + V_{D0} \quad \text{----- (C)}$$

But

$$I_D + i_d = i_D$$

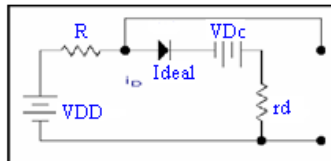
therefore

$$V_{DD} + v_s = (R + r_d)(I_D + i_d) + V_{D0}$$

separating the dc and signal quantities on both sides of equation (C)

$$V_{DD} = I_D R + V_{D0}$$

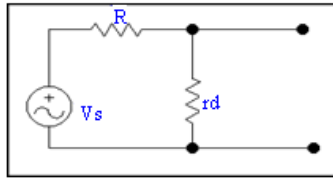
which is represented by the circuit in the figure below



and for the signal

$$v_s = i_d (R + r_d)$$

which is represented by the circuit in the figure below



However, if we carefully see the ac equivalent circuit, it is nothing more than a voltage divider. Hence the diode signal voltage will be

$$V_d = V_s r_d / (r_d + R)$$

EXAMPLE:

Find the value of the diode small signal resistance r_d at bias current of 0.1, 1 and 10mA.

Assume $n = 1$

SOLUTION:

$$r_d = n V_T / I$$

$$\text{where } V_T = 25 \text{ mV}$$

$$= 1 \times 25 \text{ mV} / I$$

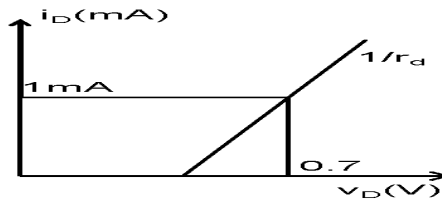
$$\text{for } I = 0.1 \text{ mA}, \quad r_d = 250 \text{ ohms}$$

$$I = 1 \text{ mA}, \quad r_d = 25 \text{ ohms}$$

$$I = 10 \text{ mA}, \quad r_d = 2.5 \text{ ohms}$$

EXAMPLE:

For the diode that conducts 1mA at a forward voltage drop of 0.7 V and whose $n = 1$. Find the equation of the straight line tangent at $I_D = 1 \text{ mA}$.

SOLUTION:

$$\text{Slope} = 1 / r_d$$

$$= I / n V_T$$

$$= 1 \text{ mA} / 1 \times 25 \text{ mV}$$

$$= 1 / 25 \text{ ohms}$$

Now on V_D axis it will be

$$= 0.7 - 1 \text{ m} (25)$$

$$= 0.7 - 0.025$$

$$= 0.675 \text{ V}$$

So

by the equation of straight line $y - y_1 = m (x - x_1)$

here m is a slope $= 1 / 25 \text{ ohms}$

$$i_D = 1 / 25 (V_D - 0.675)$$

$$V_D - 0.675 - i_D (25) = 0$$

Which is the required equation of straight line.

EXAMPLE: Consider a diode with $n = 2$ biased at 1mA. Find the change in current as a result of changing the voltage by

(a) -20 mV (b) -10 mV (c) -5 mV

(d) $+5 \text{ mV}$ (e) $+10 \text{ mV}$ (f) $+20 \text{ mV}$

In each case do calculations

(1) using small signal model

(2) using the exponential model.

SOLUTION:

For small signal model we have

$$\Delta v = r_d \Delta i$$

$$\Delta i = \Delta v / r_d$$

But

$$\begin{aligned} r_d &= n V_T / I \\ &= 2 \times 25\text{m} / 1\text{m} \\ &= 50\text{ohms} \end{aligned}$$

$$\Delta i = \Delta v / 50$$

Now from exponential model

$$i = I_S e^{v / nVT}$$

Also we know that

$$I_D + \Delta i = I_D e^{\Delta v / nVT}$$

$$I_D + \Delta i = I_D e^{\Delta v / nVT}$$

$$\Delta i = I_D (e^{\Delta v / nVT} - 1)$$

but

$$I_D = 1\text{mA} \text{ thus}$$

$$\Delta i = (e^{\Delta v / nVT} - 1)$$

(a) For $V = -20\text{ mV}$

$$\begin{aligned} (1) \Delta i &= -20/50 \\ &= -0.4\text{mA} \end{aligned}$$

$$\begin{aligned} (2) \Delta i &= e^{-20\text{m}/50\text{m}} - 1 \\ &= 0.33\text{mA} \end{aligned}$$

(d)

$$\Delta v = 5\text{mV}$$

$$(1) \Delta i = 5/50 = 0.10\text{mA}$$

$$\begin{aligned} (2) \Delta i &= e^{5/50} - 1 \\ &= 0.11\text{mA} \end{aligned}$$

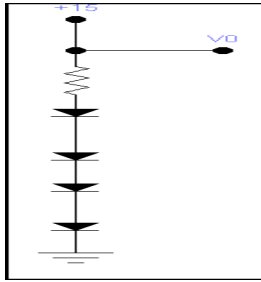
(f)

$$\Delta v = 20\text{mV}$$

$$\begin{aligned} (1) \Delta i &= 20/50 \\ &= .40\text{mA} \end{aligned}$$

$$\begin{aligned} (2) \Delta i &= e^{20/50} - 1 \\ &= 0.49\text{mA} \end{aligned}$$

EXAMPLE: Design the circuit in the fig. so that $V_0 = 3V$ when $I_L = 0$, and V_0 changes by 40mV per 1mA of load current. Find the value of R . (assume four diodes are identical) relative to a diode with 0.7 drop at 1 mA current. Assume $n = 1$



SOLUTION:

$V_0 = 3V$, when $I_L = 0$, therefore each diode should exhibit a drop of 0.75V. If $I_L = 1mA$, then V_0 changes by 40mV and a change due to each diode is 10mV.

Hence

$$r_d = 10\text{mV}/1\text{mA} \\ = 10 \text{ Ohms}$$

but

$$r_d = nV_T / I_D \\ 10 = 1 \times 25\text{m} / I_D \\ I_D = 2.5\text{mA}$$

Hence

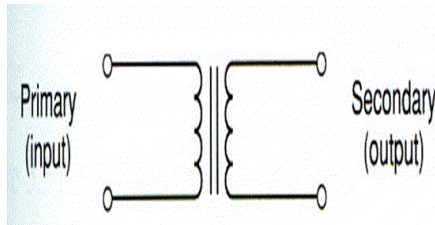
$$15 - 3 - I_D R_D = 0 \\ R = (15 - 3) / I_D \\ = (15 - 3) / 2.5\text{mA} \\ = 4.8\text{k Ohms.}$$

LECTURE 35

(Transformers - Secondary voltage and current - Transformer Input/Output phase relationship)

TRANSFORMERS:

- Transformers are not semiconductor devices; however, they play an integral role in the operations of most of power supplies.
- The basic schematic symbol for the transformer is as shown in figure,

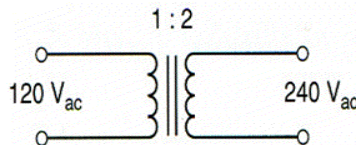


- The transformer basically consists of two inductors, which are in close proximity to each other.
- However, they are not physically connected.
- The device consists of two windings called the primary and secondary windings.
- The input to the transformer is applied to the primary.
- The output is taken from the secondary of the device.
- An alternating voltage is applied to the primary which induces an alternating voltage in the secondary.
- However, keep in mind that primary and secondary windings are physically isolated.
- A transformer can be designed in three modes.

1. STEP UP TRANSFORMER:

The step up transformer provides a secondary voltage which is greater in amplitude as compared to primary.

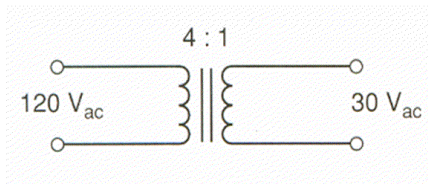
For example, a step up transformer may provide a 240 Vac out put against 120 Vac at the in put. A step up transformer is shown



2. STEP DOWN TRANSFORMER:

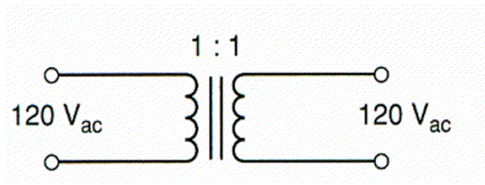
The step down transformer provides a secondary voltage which is less than the primary voltage.

For example, a transformer shown in the figure provides 30Vac at the out put against 120Vac input, as shown

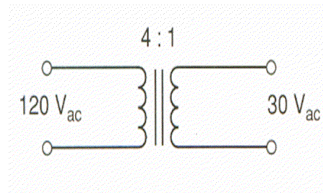


3.ISOLATION TRANSFORMER:

An isolation transformer provides an out put voltage that is equal to the input voltage. These are used to electrically isolate power supplies from the power lines.

**TURN RATIO:**

- The turn ratio of a transformer is the ratio of number of turns in the primary to the number of turns in the secondary.
- For example, the step down transformer shown has a turn ratio of 4:1, which means there are four turns in the primary against each turn in the secondary.



- The turn ratio of the transformer is equal to the voltage ratio of the two components, so that

$$\frac{N_2}{N_1} = \frac{V_2}{V_1}$$

Where

- N_2 =Number of turns in the secondary winding.
- N_1 = Number of turns in the primary winding.
- V_2 =Voltage in the secondary.
- V_1 =Voltage to the primary.

CALCULATING SECONDARY VOLTAGE

When turn ratio and the primary voltage is known, the secondary voltage can be found as

$$V_2 = (N_2/N_1)V_1$$

For example the step down transformer in the previous fig. has 120 Vac input. The secondary voltage can be found as

$$\begin{aligned} V_2 &= (N_2/N_1) V_1 \\ &= 1/4(120\text{Vac}) \\ V_2 &= 30\text{Vac} \end{aligned}$$

CALCULATING SECONDARY CURRENT:

Ideally, transformers are 100 percent efficient. This means that the ideal transformer can transfer 100 percent of its input power to the secondary. So that by formula we may write

$$P_2 = P_1$$

Since power is equal to the product of voltage and current

$$V_2 I_2 = V_1 I_1$$

and

$$I_1/I_2 = V_2/V_1$$

The current ratio is inverse to the voltage ratio. This means that

(1) For step down transformer, $I_2 > I_1$

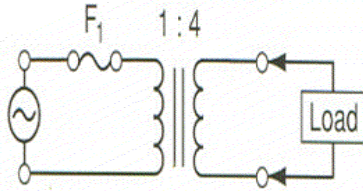
(2) For step up transformer, $I_2 < I_1$

- In other words, current varies opposite to the variation in voltage. If voltage increases, current decreases and vice versa.
Since the Voltage ratio of a transformer is equal to the turn ratio therefore, the previous equation can be written as

$$\begin{aligned} I_1/I_2 &= N_2/N_1 \\ I_2 &= (N_1/N_2)I_1 \end{aligned}$$

EXAMPLE:

The fuse in the figure is used to limit the current in the primary of the transformer. Assuming that the fuse limits the value of I_1 to 1A, what is the limit on the value of the secondary current.

**SOLUTION:**

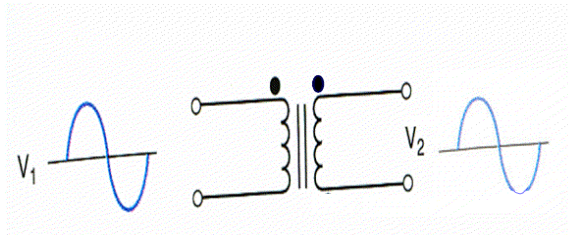
The maximum secondary current is found using the limit on I_1 and the turn's ratio as follows:

$$\begin{aligned} I_2 &= N_1/N_2 I_1 \\ &= (1/4)1A \\ I_2 &= 250mA \end{aligned}$$

If the secondary current tries to exceed the 250mA limit, the primary current will exceed its limit and blow off the fuse.

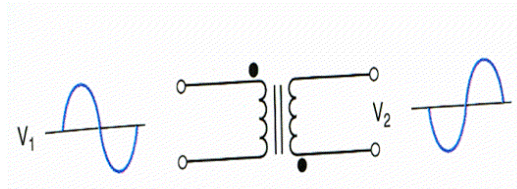
TRANSFORMER INPUT/OUTPUT PHASE RELATIONSHIP:

- In the schematic symbol, there are two dots : one on the top side of the primary and the other on top of secondary. In this case we will be working with a transformer which does not produce any phase difference between the input and out put.
-



- In the schematic symbol, there are two dots : one on the top side of the primary and one on the bottom side of the secondary, in this case

We are working with a transformer whose output voltage is 180° out of phase with its input voltage as shown in fig.



HALF WAVE RECTIFIERS:

- The half wave rectifier is made up of a diode and a resistor as shown in the fig. The half wave rectifier is used to eliminate either positive or negative part of the input.

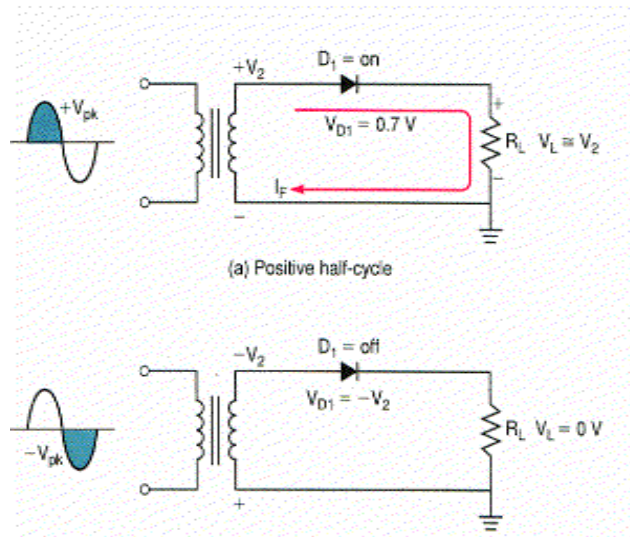
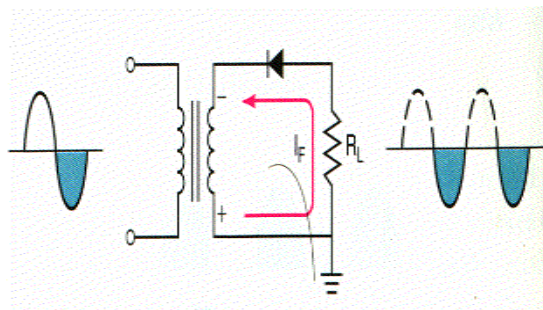
**Negative Half Wave Rectifiers:**

Fig. shows a half wave rectifier with diode direction is reversed. In this circuit the diode will conduct on the negative half cycle of the input, and

$$V_L = V_2.$$

The diode will be reversed biases for the positive half cycle of the input and

$$V_D = V_2.$$

As a result positive half cycle of the input is eliminating. The operating principle of the negative half wave rectifier is same as the positive half wave rectifiers. The only difference is the polarity of the output will be reversed.

LECTURE 36

(Half Wave Rectifiers)

Negative Half Wave Rectifiers:

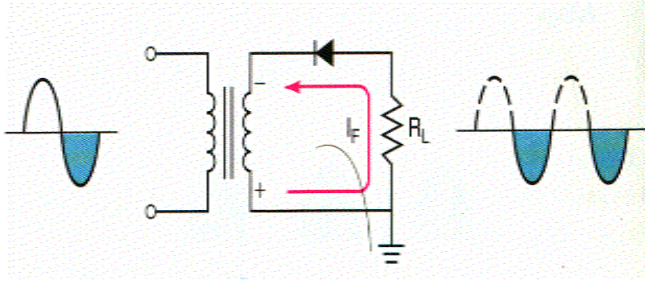


Fig. shows a half wave rectifier with diode direction is reversed. In this circuit the diode will conduct on the negative half cycle of the input, and

$$V_L = V_2$$

The diode will be reversed biases for the positive half cycle of the input and

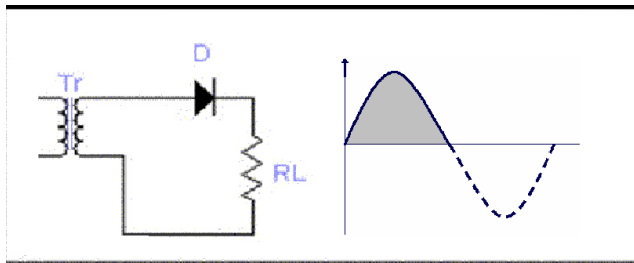
$$V_D = V_2$$

As a result positive half cycle of the input is eliminating. The operating principle of the negative half wave rectifier is same as the positive half wave rectifiers. The only difference is the polarity of the output will be reversed.

GENERAL RULES:

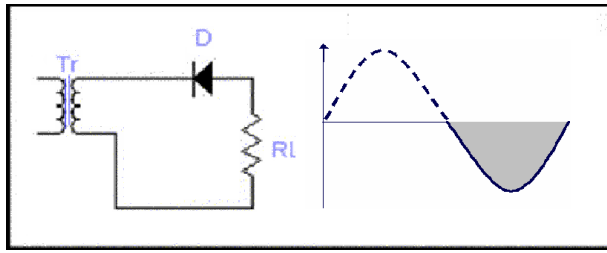
- (1) When the diode points towards the load (R_L), the output from the rectifier will be positive.

The point made so far is summarized in the fig below.



- (2) When the diode points toward the transformer, the output from the rectifier will be negative.

The point made so far is summarized in the fig below.



CALCULATING LOAD VOLTAGE AND CURRENT VALUES.

The load voltage in half wave rectifier can be found as

$$V_{L(pk)} = V_{2(pk)} - V_F$$

$V_{2(pk)}$ is the secondary voltage of the transformer, found as

$$V_{2(pk)} = (N_2/N_1) V_1$$

where

N_2/N_1 = (The turn ratio of transformer secondary turns to primary turn)

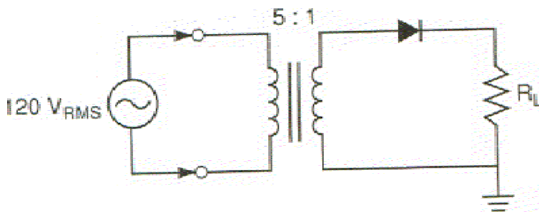
$V_1(pk)$ = (The peak transformer primary voltage)

Above equation assumes that the transformer is given as a peak value.

More often than not, source voltages are given as **rms** values. When this is the case, the source voltage is converted into peak value as follows:

$$V_{pk} = V_{rms} / 0.707$$

EXAMPLE: Determine the peak load voltage for the circuit shown in the fig.



SOLUTION:

First, the ac input to the transformer is converted to a peak value, as follows

$$\begin{aligned} V_1(pk) &= V_{1rms} / 0.707 \\ &= 120 / 0.707 \\ &= 169.7 V_{pk} \end{aligned}$$

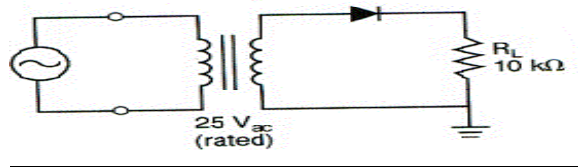
Now, the voltage values in the secondary circuit are found as

$$\begin{aligned} V_{2(pk)} &= N_2/N_1 (V_1(pk)) \\ &= 1/5 (169.7) \\ &= 33.94 V_{pk} \end{aligned}$$

And

$$\begin{aligned} V_{Lpk} &= V_{2(pk)} - V_F \\ \text{diode is a silicon diode} \\ &= 33.94 - 0.7 \\ V_{Lpk} &= 33.24 V_{pk} \end{aligned}$$

EXAMPLE: Determine the peak load voltage for the circuit shown in the fig.



SOLUTION:

The transformer is shown to have a $25V_{ac}$ rating. This value of V_2 is converted into peak form as

$$V_{2(pk)} = V_{2(rms)} / 0.707$$

$$= 25V_{rms} / 0.707$$

$$V_{2(pk)} = 35.36V_{pk}$$

Now the value of V_{pk} is found as

$$V_{L(pk)} = V_{2(pk)} - 0.7$$

$$= 35.36 - 0.7$$

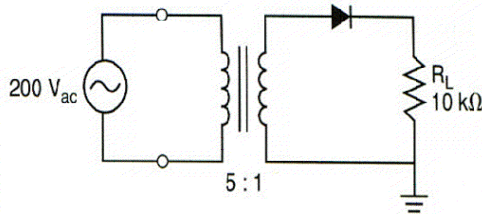
$$V_{L(pk)} = 34.66V_{pk}$$

CALCULATING LOAD CURRENT:

Once the peak voltage is determined, the peak load current is found as

$$I_{L(pk)} = V_{L(pk)} / R_L$$

EXAMPLE: What is the peak load current for the circuit shown in fig.



SOLUTION:

The input voltage is given an rms value. This value is converted to a peak value as follows:

$$V_{1(pk)} = V_{1(rms)} / 0.707$$

$$= 200V_{ac} / 0.707$$

$$V_{1(pk)} = 282.9V_{pk}$$

Now, the load voltage and current are found, after finding peak voltage, as

$$V_{2(pk)} = N_2 / N_1 \cdot V_{1(pk)}$$

$$= (1/5)(282.9V_{pk})$$

$$V_{2(pk)} = 56.6V_{pk}$$

Finally, the load voltage and current and current values are found as:

$$V_{L(pk)} = V_{2(pk)} - V_F$$

$$= 56.6 - 0.7$$

$$V_{L(pk)} = 55.9V_{pk}$$

and the current will be

$$I_{L(pk)} = V_{L(pk)} / R_L$$

$$= 55.9 \text{ V}_{pk} / 10 \text{ k}$$

$$I_{L(pk)} = 5.59 \text{ mA}_{pk}$$

AVERAGE LOAD VOLTAGE AND CURRENT:

- Since rectifiers are used to convert ac to dc, V_{ave} is a very important value. For a half wave rectifier, V_{ave} is found as

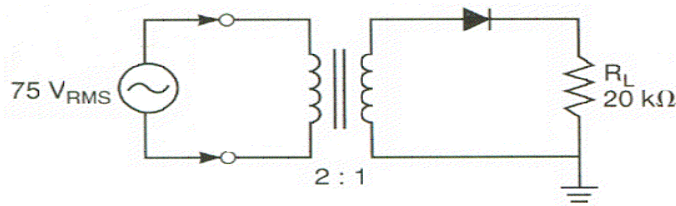
$$V_{ave} = V_{pk} / \pi$$

Another form of this equation is

$$V_{ave} = 0.318(V_{pk}) \text{ (half wave rectified)}$$

Where $0.318 = 1/\pi$. Either of these equations can be used to determine the dc equivalent load voltage for a half wave rectifier. Let's take some examples to illustrate this

EXAMPLE: Determine the value of V_{ave} for the circuit shown in fig.



SOLUTION:

$$V_{1(pk)} = V_{1(rms)} / 0.707$$

$$= 75 \text{ V}_{ac} / 0.707$$

$$V_{1(pk)} = 106.1 \text{ V}_{pk}$$

$$V_{2(pk)} = N_2/N_1 V_{1(pk)}$$

$$= 1/2(106.1)$$

$$V_{2(pk)} = 53.04 \text{ V}_{pk}$$

$$V_{L(pk)} = 53.04 - 0.7$$

$$V_{L(pk)} = 52.34 \text{ V}_{pk}$$

$$V_{ave} = V_{pk} / \pi$$

$$= 52.34 / \pi$$

$$V_{ave} = 16.66 \text{ V}_{dc}$$

CALCULATING AVERAGE CURRENT:

- THE VALUE OF I_{ave} can be calculated in one of two ways
 - (1) We can determine the value of V_{ave} and then use Ohm's law as follows
- $$I_{ave} = V_{ave} / R_L$$
- (2) We can convert I_{pk} to average from using same basic equations, that

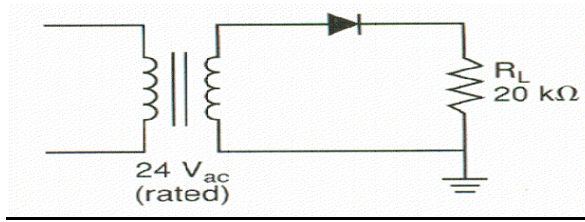
We used to convert V_{pk} to V_{ave} . The current forms of these equations are

$$I_{ave} = I_{pk} / \pi$$

And

$$I_{ave} = 0.318(I_{pk})$$

EXAMPLE: Determine the dc load current for the rectifier shown in fig.



SOLUTION:

The transformer has 24 V_{ac} rating. Thus, the peak secondary voltage is found as

$$V_{2(pk)} = 24V_{ac} / 0.707$$

$$V_{2(pk)} = 33.9 V_{pk}$$

The peak load voltage is now found as

$$V_{L(pk)} = V_{2(pk)} - 0.7$$

$$V_{L(pk)} = 33.2 V_{pk}$$

$$I_{L(pk)} = V_{L(pk)} / R_L$$

$$= 33.2 / 20k$$

$$I_{L(pk)} = 1.66mA_{pk}$$

$$I_{ave} = I_{pk} / \pi$$

$$= 1.66m / \pi$$

$$I_{ave} = 529.13 \text{ micro A}$$

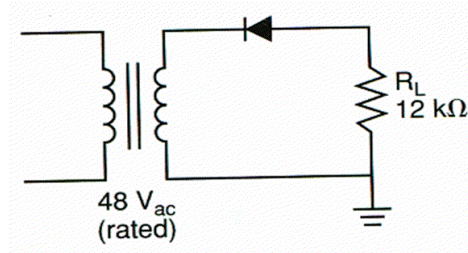
LECTURE 37

(Peak Inverse Voltage (PIV) - Full wave rectifier)

Negative Half Wave Rectifiers:

- The analysis of negative half wave rectifier is nearly identical to that of positive half wave rectifier. The only difference is that the voltage polarities are reversed. We can make a simple method for performing the mathematical analysis of negative half wave rectifier.
 - (1) Analyze the circuit as if it was a positive half wave rectifier.
 - (2) After completing calculations, change all voltage polarity signs from positive to negative.

EXAMPLE: Determine the dc output voltage for the circuit shown in the fig.



SOLUTION:

We shall start by solving the circuit as if it was a positive half wave rectifier. First,

$$\begin{aligned} V_{2(pk)} &= 48V_{ac} / 0.707 \\ &= 67.9 V_{pk} \end{aligned}$$

And

$$\begin{aligned} V_{L(pk)} &= V_{2(pk)} - 0.7 \\ V_{L(pk)} &= 67.2 V_{pk} \end{aligned}$$

Finally,

$$\begin{aligned} V_{ave} &= V_{pk} / \pi \\ &= 21.39 V_{dc} \end{aligned}$$

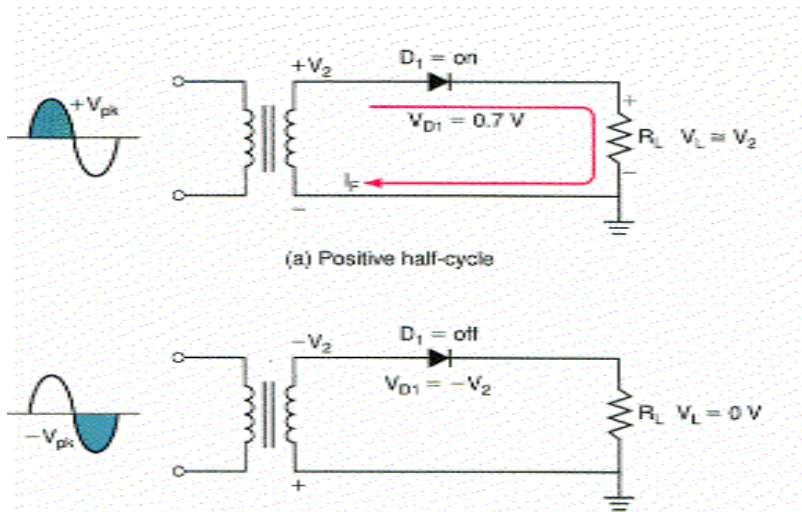
Now we will simply change all positive voltage values to negative voltage values.

$$\begin{aligned} V_{2(pk)} &= - 67.9 V_{pk} \\ V_{L(pk)} &= - 67.2 V_{pk} \\ V_{ave} &= - 21.39 V_{dc} \end{aligned}$$

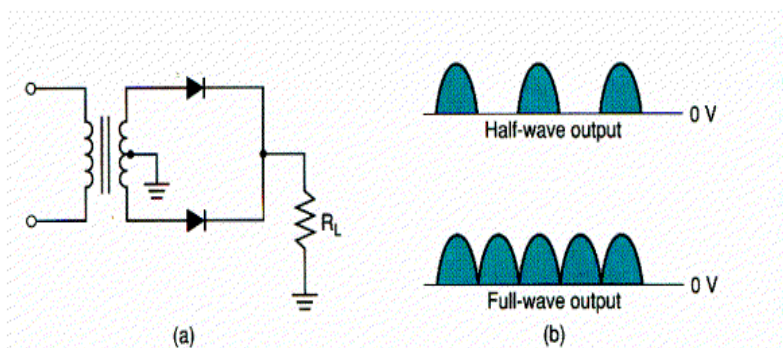
PEAK INVERSE VOLTAGE (PIV):

- The maximum amount of reverse bias that a diode will be exposed to in a rectifier is called the peak inverse voltage or PIV of the rectifier. For the half wave rectifier, the value of PIV is found as

$$PIV = V_{2(pk)}$$
- The basis for this equation can be seen by referring to figure. When diode is reversed biased, there is no voltage drop across the load.
- Therefore, all of V_2 is dropped across the diode in the rectifier.

**FULL WAVE RECTIFIER:**

- The full wave rectifier consists of two diodes and a resistor, as shown in the fig (a).



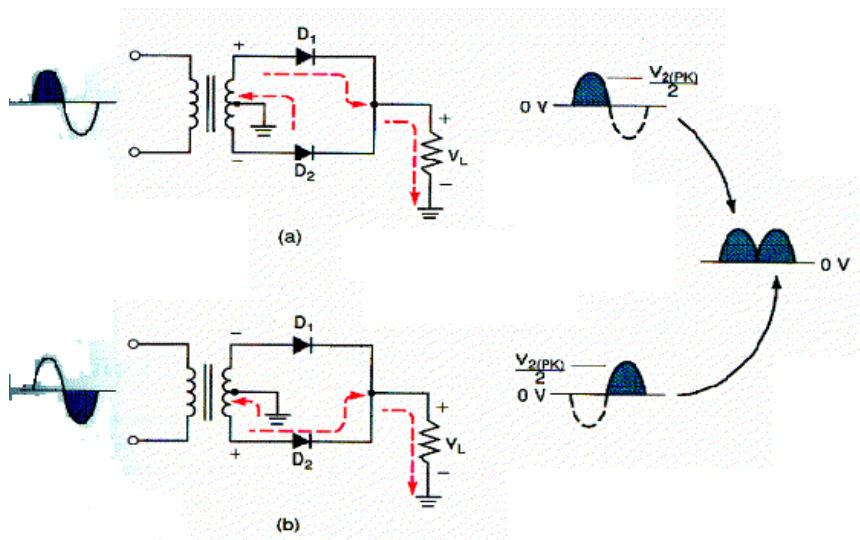
- The result of this change in circuit is illustrated in fig (b).
- In the fig (b), the output from the full wave rectifier is compared with that of a half wave rectifier.

Note that the full wave rectifier has two positive half cycle out for every one produced by the half wave rectifier.

- The transformer shown in the fig. is center tapped transformer.
- This type of transformer has a load connected to the center of the secondary winding.
- The voltage from the center tap to each of the outer winding is equal to one half of the secondary voltage. For example, let's say we have a 24V center tapped transformer. The voltage from the center tap to each of outer winding terminal is 12V.
- Center tapping of the transformer plays a major role in the operation of the full wave rectifier. For this reason, the full wave rectifier can not be line operated, that is it can not be connected directly to the ac input like the half wave rectifier can.

BASIC CIRCUIT OPERATION

- Figure shows the operation of the full wave rectifier during one complete cycle of the input signal. During the positive half cycle of the input D_1 is forward biased. Using ideal operating characteristics of the diode V_L can be found as

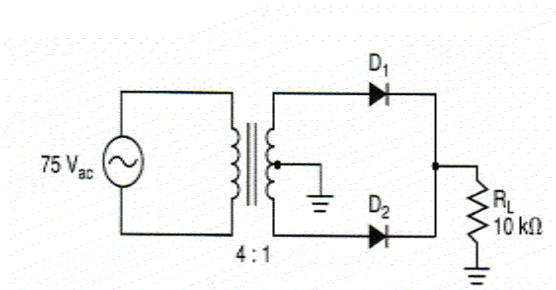


When the polarity of the input reverses, D_2 is forward biased, and D_1 is reverse biased. The direction of the current through the load will not change even though the polarity of the transformer secondary will. Thus another positive half cycle is produced across the load

CALCULATING LOAD VOLTAGE and CURRENT VALUES:

- Using practical diode model, the peak load voltage for a full wave rectifier is found as
$$V_{L(pk)} = V_{2(pk)}/2 - 0.7$$
The full wave rectifier will produce twice as many output pulses as the half wave rectifier.
- For this reason, the average load voltage for the full wave rectifier is found as
$$V_{ave} = 2V_{L(pk)}/\pi$$
Or
$$V_{ave} = 0.636V_{L(pk)}$$

EXAMPLE: Determine the dc load voltage for the circuit shown in the fig.



SOLUTION:

Primary voltage is in rms so we can calculate the peak voltage

$$\begin{aligned} V_{1(pk)} &= V_{rms} / 0.707 \\ &= 75 / 0.707 \\ &= 106.08 V_{pk} \end{aligned}$$

Primary voltage and turn ratio is known so we can determine the secondary voltage

$$\begin{aligned} V_{2(pk)} &= (N_2/N_1) V_{1(pk)} \\ &= 1/4 (106.08) \\ &= 26.52 V_{pk} \end{aligned}$$

Now load voltage can be calculated as

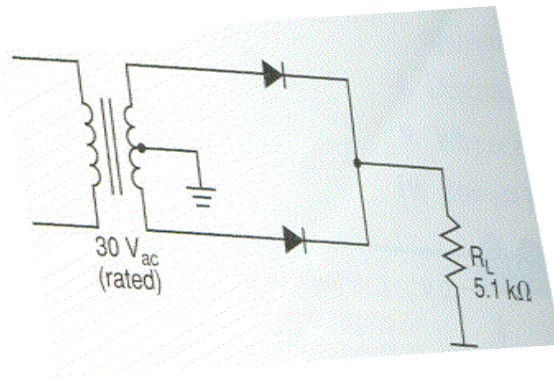
$$\begin{aligned} V_{L(pk)} &= V_2 / 2 - 0.7 \\ &= 26.52 / 2 - 0.7 \\ &= 12.56 V_{pk} \end{aligned}$$

Now dc value of the voltage can be calculated as

$$\begin{aligned} V_{ave} &= 2 V_{L(pk)} / \pi \\ &= 0.636 V_{L(pk)} \\ &= 0.636 (12.56) \\ &= 7.98 V_{dc} \end{aligned}$$

EXAMPLE:

Determine the values of $V_{L(pk)}$ and V_{ave} for the circuit shown in the fig.

**SOLUTION:**

The transformer is rated at $30 V_{ac}$. Therefore, the value of $V_{2(pk)}$ is found as

$$\begin{aligned} V_{2(pk)} &= 30 V_{ac} / 0.707 \\ &= 42.2 V_{pk} \end{aligned}$$

The peak load voltage can now found as

$$\begin{aligned} V_{L(pk)} &= V_{2(pk)} / 2 - 0.7 \\ &= 21.2 - 0.7 \\ &= 20.5 V_{pk} \end{aligned}$$

Finally the dc load voltage is found as

$$\begin{aligned} V_{ave} &= 2 V_{L(pk)} / \pi \\ &= 41 V_{pk} / \pi \\ V_{ave} &= 13.05 V_{dc} \end{aligned}$$

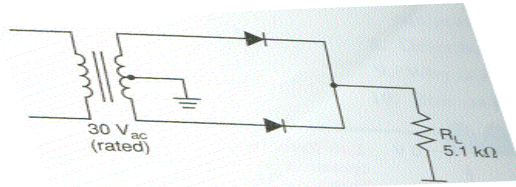
LECTURE 38

(Negative full wave rectifier - Full wave bridge rectifier)

CALCULATING CURRENTS:

- Once the peak and average load voltage values are known, it is easy to determine the values of $I_{L(pk)}$ and I_{ave} with the help of Ohm's law.

EXAMPLE: Determine the values $I_{L(pk)}$ and I_{ave} for the circuit in last lecture.



SOLUTION:

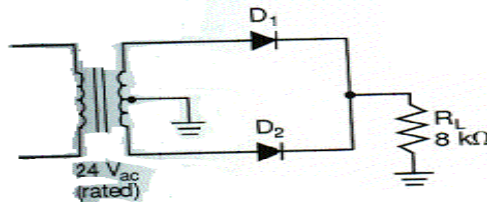
In the previous lecture, we calculated peak and average output voltages for the circuit. Using these value we can determine current as follows

$$\begin{aligned} I_{L(pk)} &= V_{L(pk)} / R_L \\ &= 20.5 / 5.1k \\ &= 4.02 \text{ mA}_{pk} \end{aligned}$$

And

$$\begin{aligned} I_{ave} &= V_{ave} / R_L \\ &= 13.05 / 5.1k \\ &= 2.56 \text{ mA}_{dc} \end{aligned}$$

EXAMPLE: Determine the values of $V_{L(pk)}$, V_{ave} , $I_{L(pk)}$ and I_{ave} for the circuit shown in the fig.



SOLUTION:

Rated value of the transformer is given so the peak value can be calculated as

$$\begin{aligned} V_{2(pk)} &= 24V_{ac} / 0.707 \\ V_{2(pk)} &= 33.94V_{pk} \end{aligned}$$

Now

$$\begin{aligned} V_{L(pk)} &= V_2 / 2 - 0.7 \\ V_{L(pk)} &= 16.27V_{pk} \end{aligned}$$

And

$$\begin{aligned} V_{ave} &= 2V_{L(pk)} / \pi \\ &= 0.636 V_{L(pk)} \\ V_{ave} &= 10.34V_{dc} \end{aligned}$$

Now for currents

$$I_{L(pk)} = V_{L(pk)} / R_L$$

$$= 16.27/8k$$

$$I_{L(pk)} = 2.03mA_{pk}$$

And

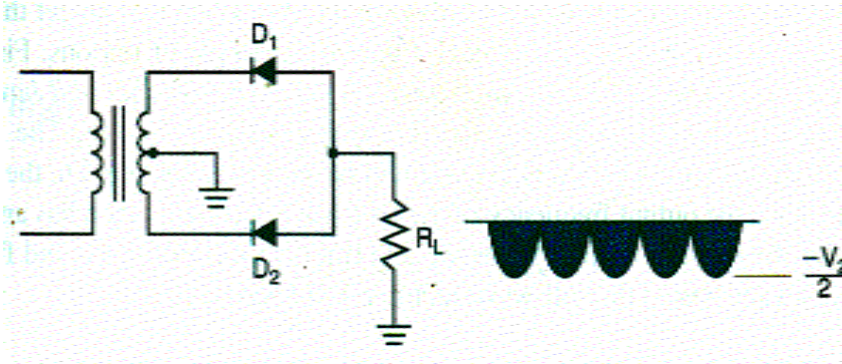
$$I_{ave} = V_{ave}/R_L$$

$$= 10.34/8k$$

$$I_{ave} = 1.29mA$$

NEGATIVE FULL WAVE RECTIFIER:

- The main differences between the positive and negative full wave rectifier are the direction that the diodes are pointing and the polarity of the output voltage.
- The analysis of the negative full wave rectifier circuit is same as negative half wave rectifier.
- If we reverse the direction of the diodes in the positive full wave rectifier, we will have a negative full wave rectifier as shown in the fig.

**PEAK INVERSE VOLTAGE:**

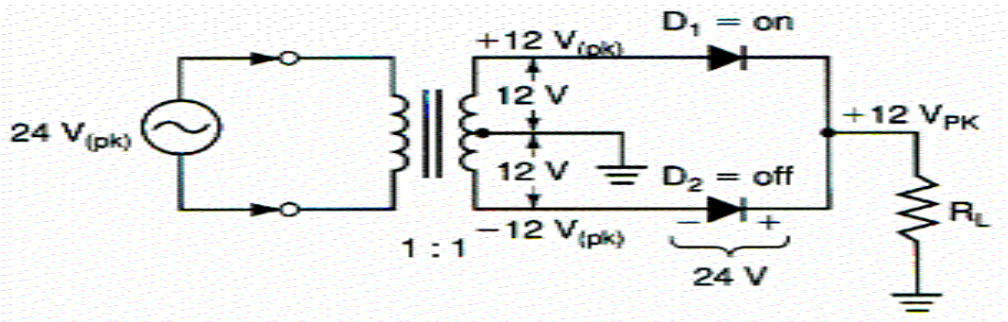
- When one of the diodes in a full wave rectifier is reverse biased, the voltage across it is approximately equal to V_2 .
- The peak load voltage supplied by the full wave rectifier is equal to the one half of the secondary voltage V_2 . Therefore, the reverse voltage will be twice the peak load voltage. By formula

$$PIV = 2V_{L(pk)}$$

Since the peak load voltage is half the secondary voltage, we can also find value of PIV as

$$PIV = V_2(pk)$$

- When calculating the PIV in practical diode circuit, the 0.7 drop will be also be taken into consideration. In the fig. when D_1 is on and will have voltage drop of 0.7



Since D_1 is in series with D_2 the PIV across D_2 will be reduced by the voltage across D_1 . The equation

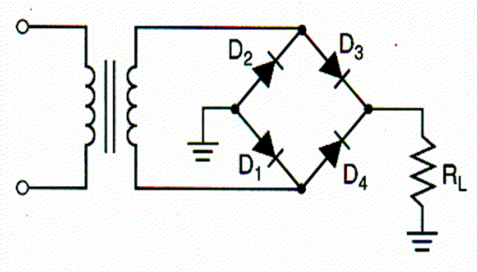
$$\text{PIV} = V_{2(pk)} - 0.7$$

Gives a more accurate PIV voltage.

Rectifier type:	Half-wave	Full-wave
Schematic diagram:		
Typical output waveform:		
Peak output voltage:	$V_{2(pk)} - 0.7 \text{ V}$	$\frac{V_{2(pk)}}{2} - 0.7 \text{ V}$
Dc output voltage:	$\frac{V_{L(pk)}}{\pi}$	$\frac{2V_{L(pk)}}{\pi}$
PIV:	Equal to $V_{2(pk)}$	$V_{2(pk)} - 0.7 \text{ V}$

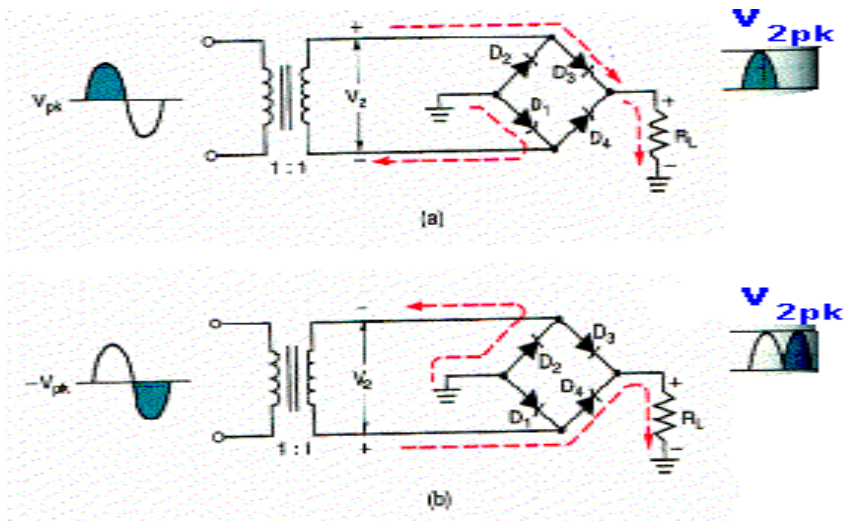
FULL WAVE BRIDGE RECTIFIER:

- The bridge rectifier is the most commonly used full wave rectifier circuit for several reasons
- (1) It does not require the use of center-tapped transformer, and therefore can be coupled directly to the ac power line, if desired.
- (2) Using a transformer with the same secondary voltage produces a peak output voltage that is nearly double the voltage of the full wave center-tapped rectifier. This results in the higher dc voltage from the supply.



BASIC CIRCUIT OPERATION:

The bridge rectifier shown in the fig. consists of four diodes and a resistor. The full wave rectifier produces its output by alternating the circuit conduction



between the two diodes. When one is on(conducting), the other is off(non conducting), and vice versa. The bridge rectifier works basically in the same way. The main difference is that the bridge rectifier alternates conduction between two diodes pairs.

- When D_1 and D_3 are on, D_2 and D_4 are off and vice versa. This circuit operation is illustrated in the fig.
- The current direction will not change in either condition.

CALCULATING THE LOAD VOLTAGE AND CURRENT VALUES:

- The full wave rectifier has an output voltage equal to the one half of the secondary voltage. The center-tapped transformer is essential for the full wave rectifier to work, but it cuts the output voltage to half.
- The bridge rectifier does not require the use of center-tapped transformer. Assuming the diodes to be ideal, the rectifier will have a peak output voltage of

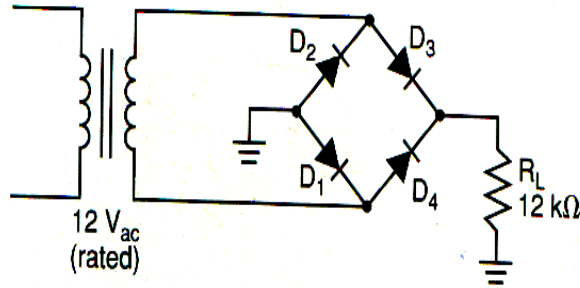
$$V_{L(pk)} = V_{2(pk)} \quad (\text{ideal})$$

- When calculating the circuit output values, we will get more accurate results if we take the voltage drops across the two conducting diodes into account. To include these values, we will use the following equation

$$V_{L(pk)} = V_{2(pk)} - 1.4$$

The 1.4 volts represents the sum of diode voltage drops.

EXAMPLE: Determine the dc load voltage and current values for the circuit shown in the fig.



SOLUTION:

With the $12V_{ac}$ rated transformer, the peak secondary voltage is found as

$$\begin{aligned} V_{2(pk)} &= 12/0.707 \\ &= 16.97V_{pk} \end{aligned}$$

The peak load voltage is now found as

$$\begin{aligned} V_{L(pk)} &= V_2 - 1.4 \\ \mathbf{V_{L(pk)} = 15.57V_{pk}} \end{aligned}$$

The dc load voltage is found as

$$\begin{aligned} V_{ave} &= 2V_{L(pk)}/\pi \\ &= 31.14/\pi \\ \mathbf{V_{ave} = 9.91 V_{dc}} \end{aligned}$$

Finally the dc load current is found as

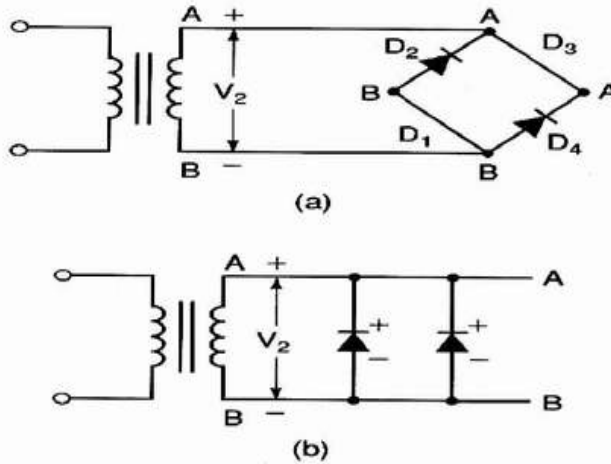
$$\begin{aligned} I_{ave} &= V_{ave}/R_L \\ &= 9.91/12k \\ \mathbf{I_{ave} = 825.8\mu A} \end{aligned}$$

LECTURE 39

(Filters - Clippers - Series clippers)

PEAK INVERSE VOLTAGE:

Using the ideal diode model, the PIV of each diode in the bridge rectifier is equal to V_2 . This is the same voltage that was applied to the diode in the full-wave center-tapped rectifier. Following fig helps us to illustrate this point. In fig a below, two things have been done :



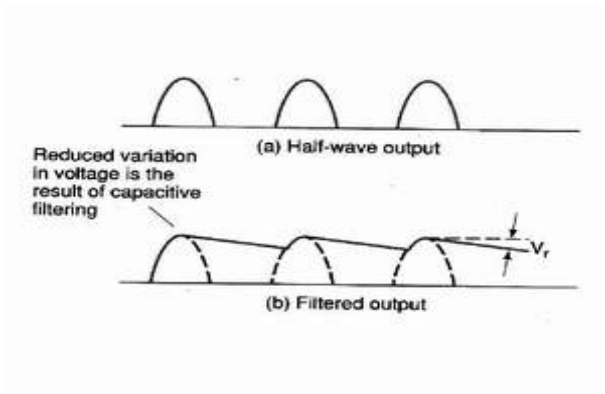
- (1) The conducting diodes (D_1 and D_3) have been replaced by straight wires. Assuming that the diodes are ideal they will have the same resistance as wire; therefore replacement is valid.
- (2) The positive side of the secondary has been labeled **A** and the negative side has been labeled **B**.

Connecting the common **A** point along a straight line and doing the same with **B** points gives us the circuit shown in the **fig b**. With the equivalent circuit, you can see that two reverse-biased diodes and the secondary of the transformer are all in parallel. Since parallel voltages are equal, the **PIV** across each diode is equal to V_2 . The same situation will exist for **D1 and D3** when they are reverse-biased.

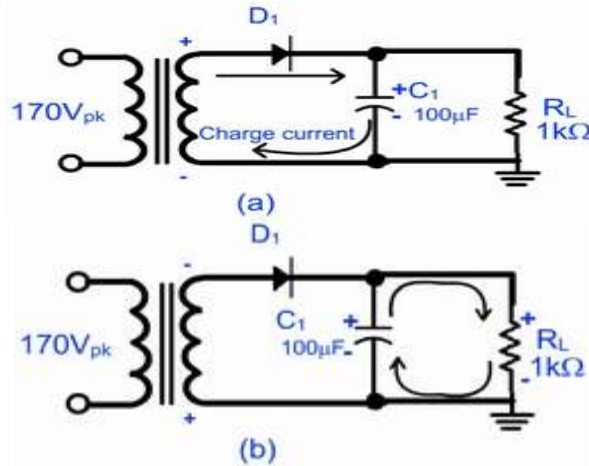
SUMMARY ILLUSTRATION:

Rectifier type:	Half-wave	Full-wave	Bridge
Schematic diagram:			
Typical output waveform:			
Peak load voltage:	$V_{2(pk)} - 0.7\text{ V}$	$\frac{V_{2(pk)}}{2} - 0.7\text{ V}$	$V_{2(pk)} - 1.4\text{ V}$
dc load voltage:	$\frac{V_{L(pk)}}{\pi}$	$\frac{2V_{L(pk)}}{\pi}$	$\frac{2V_{L(pk)}}{\pi}$
dc load current:	$\frac{V_{avg}}{R_L}$	$\frac{V_{avg}}{R_L}$	$\frac{V_{avg}}{R_L}$
PIV:	Equal to $V_{2(pk)}$	$V_{2(pk)} - 0.7\text{ V}$	$V_{2(pk)} - 0.7\text{ V}$

- FILTERS:**
- Filters are used in power supplies to reduce the variations in the rectifier output signal. Since our goal is to produce a constant dc output voltage, it is necessary to remove as much of the rectifier output variations as possible.
 - The overall result of using a filter is illustrated



The capacitor filter is the most basic filter type and the most commonly used. This filter is simply a capacitor connected in parallel with the load resistance, as shown in the fig a below. The filtering action is



based on the charge /discharge action of the capacitor .During the positive half-cycle of the input, D_1 will conduct and the capacitor will charge rapidly as shown in the **fig (a)** above. As the input starts to go negative D_1 will turn off, and the capacitor will slowly discharge through the load resistance in **fig (b)**. As the input from the rectifier drops below the charged voltage of the capacitor , the capacitor acts as the voltage source for the load. It is the difference between the charge and discharge times of the capacitor that reduces the variation in the rectifier output voltage. The difference between charge and discharge times of the capacitor is caused by two distinct RC time constant in the circuit.

CLIPPERS:

- There are variety of diode networks called clippers that have the ability to clip off a portion of the input signal without distorting the remaining part of the alternating waveform. The half wave rectifier studied earlier is a simplest form of diode clipper.
- Depending on the orientation of the diode, the positive or negative region of the input signal is "clipped" off.

IMPORTANT POINTS FOR CLIPPERS:

- (1) Make a sketch in your mind about the response of the network.
- (2) Determine the applied voltage (Transition Voltage) that causes change in the diode bias.
- (3) Be continuously aware of the defined terminal and polarity of V_o .
- (4) Sketch the input signal on the top and the output at the bottom to determine the output at instantaneous points of the input.

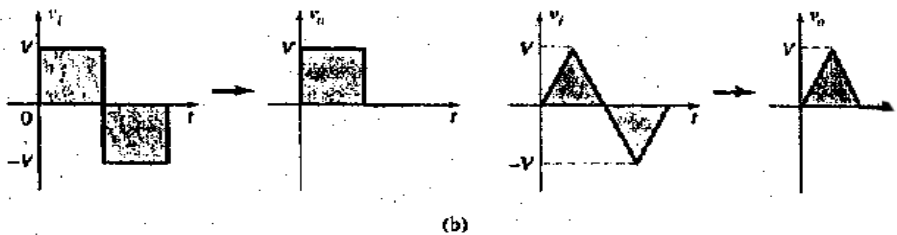
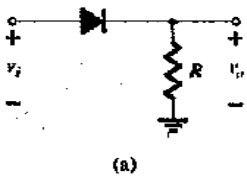
TYPES OF CLIPPERS:

- There are two general categories of the clippers.
 - (1) **Series**
 - (2) **Parallel**

SERIES CLIPPERS:

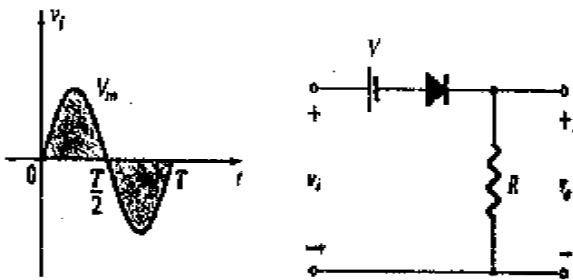
- The series configuration is defined as one where the diode is in series with the load as half wave rectifier.

EXAMPLES:

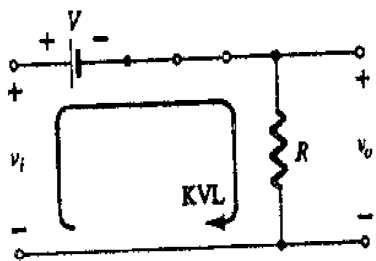


ADDITION OF A BATTERY IN THE SERIES CLIPPER CIRCUIT:

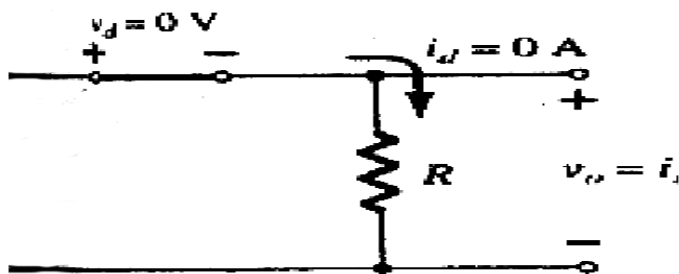
- In the fig. the direction of the diode suggests that the signal V_i must be positive to turn it on. The dc supply further requires that the voltage V_i be



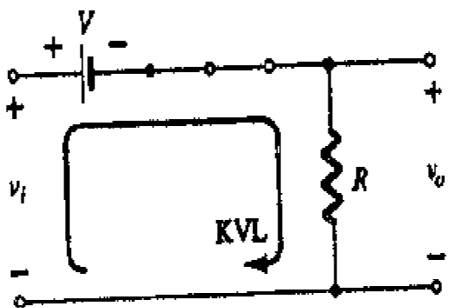
greater than V volts to turn the diode on. The negative region of the input signal is pressuring the diode into off region.



- Now we determine the applied voltage that will cause a change in state for the diode. The ideal diode transition occur at the point on the characteristic where $V_d = 0$ and $I_d = 0$

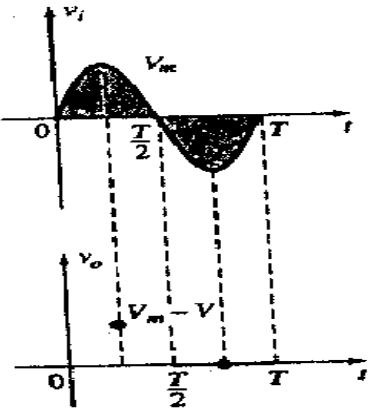


- In this case transition will occur at $V_i = V$



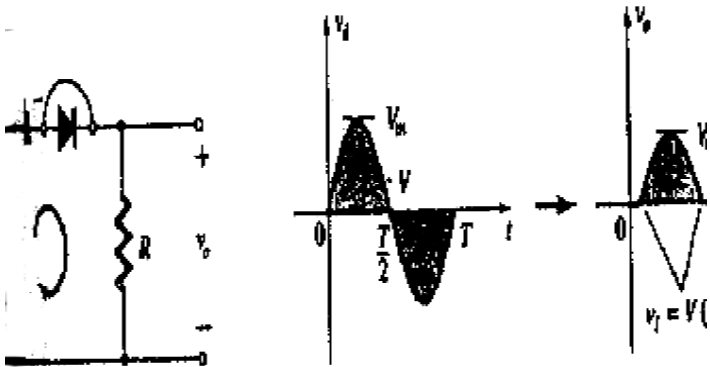
When the diode is short circuited as shown in the fig. The out put voltage V_0 can be calculated by applying KVL

$$V_i - V - V_0 = 0$$
$$V_0 = V_i - V$$

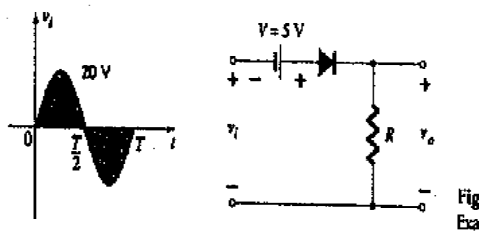


In this case

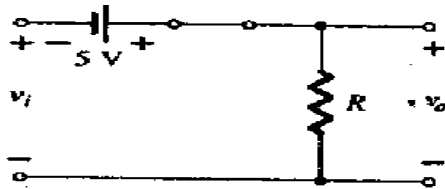
$$V_0 = V_m - V$$



EXAMPLE: Determine the output waveform for the network shown



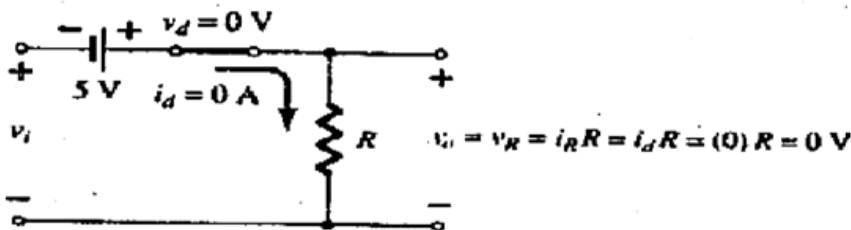
SOLUTION: The equivalent circuit will be



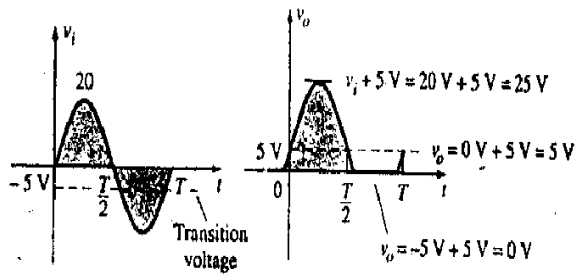
Applying KVL

$$V_0 = V_i + 5V$$

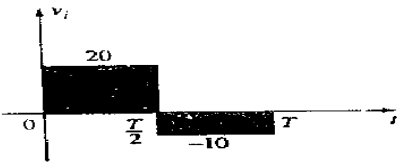
Transition voltage = 5V



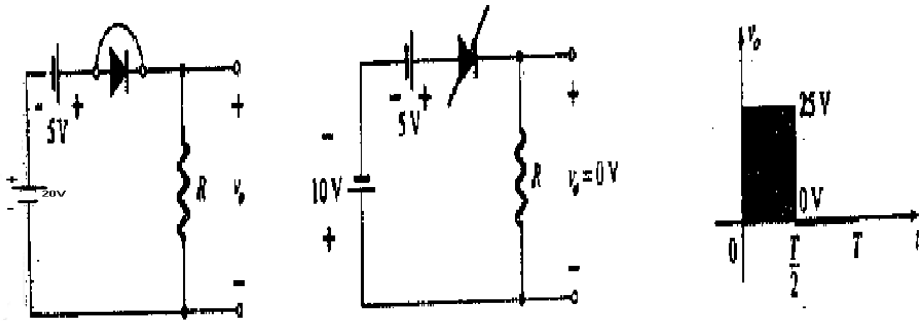
$V_o = V_R = i_d R = (0) R = 0V$ (no diode current is flowing)



EXAMPLE: Determine the output for the square wave input shown in the fig.
Error!



SOLUTION:
In positive half cycle. The diode is in the short circuit condition and by KVL
 $V_o = 20 + 5 = 25V$
For the negative half cycle $V_i = -10V$ the result in placing the diode in the reverse condition.

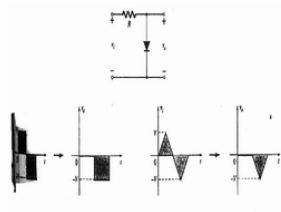


LECTURE 40

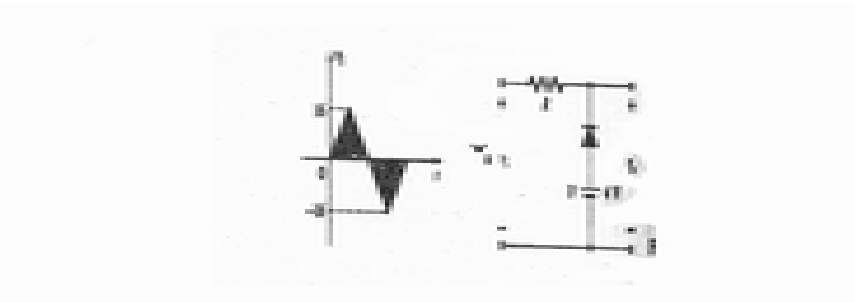
(Parallel clippers - Clamper)

PARALLEL CLIPPER:

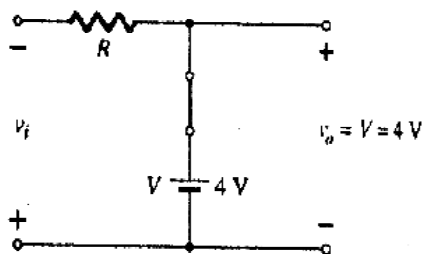
- The parallel configuration is defined as while the parallel variety has the diode in a branch parallel to the load.



EXAMPLE: Determine the output voltage for the network shown in the fig.



SOLUTION: Diode will be on for the –ve half cycle .So the effective circuit is shown in the fig.

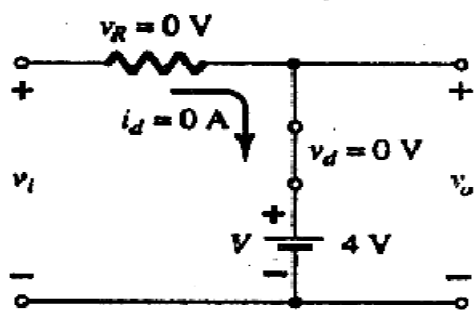


Apply $I_d = 0$, $V_d = 0$ to get transition voltage so that

$$V_i - I_d R - 4V = 0$$

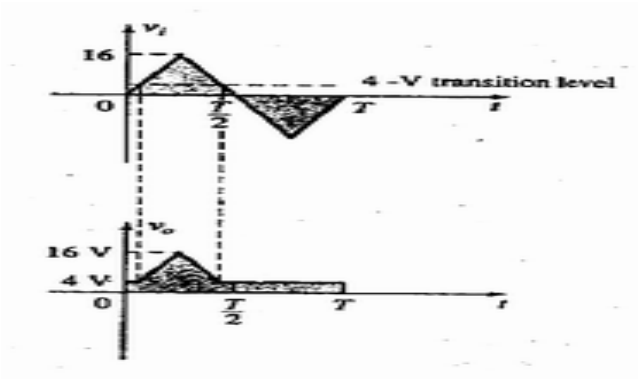
$$V_i - 0R - 4V = 0$$

$V_i = 4V$ is transition voltage.

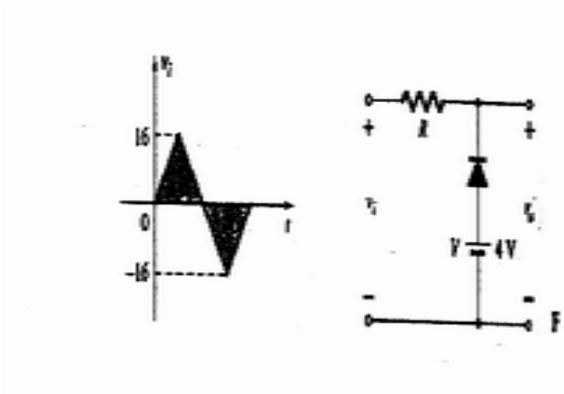


hence for the positive half cycle so that

$$V_L = V_0$$
$$V_L = 16\text{ Volts.}$$



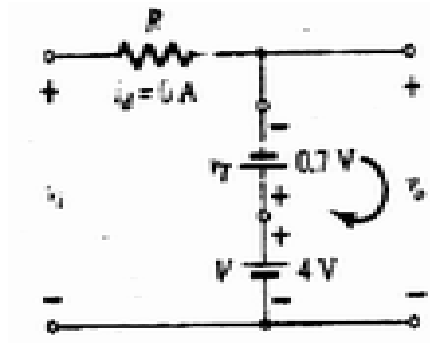
EXAMPLE: Consider in previous example the diode is silicon diode and draw its output.



SOLUTION:

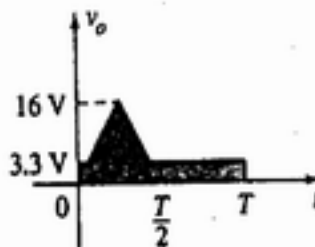
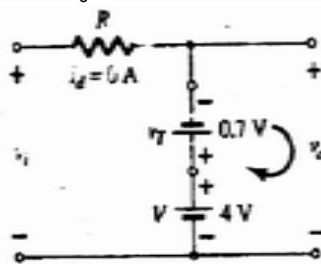
The diode will be on for the negative half cycle. Apply $I_d = 0$, $V_d = 0.7$ to get transition voltage

$$\begin{aligned} V_i + V_T - V &= 0 \\ V_i &= V - V_T \\ &= 4 - 0.7 \\ &= 3.3 \text{ V} \end{aligned}$$



3.3 is the transition voltage will be 4V, hence for positive half cycle

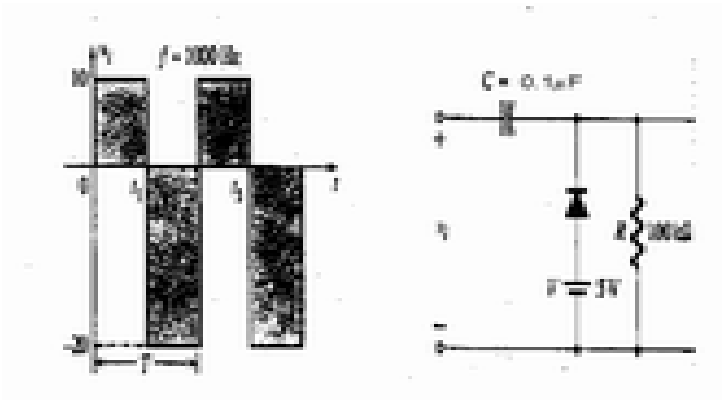
$$\begin{aligned} V_L &= V_0 \\ V_0 &= 16 \text{ V} \end{aligned}$$

**CLAMPERS:**

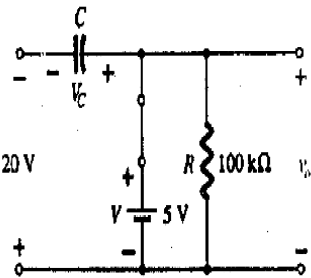
These are the circuits which clamp the input signal to a different level depending upon the configuration of the clamper circuit. For carrying out analysis following points to be remember

- (1) The total swing of the output is equal to the total swing of the input signal.
- (2) Start the analysis by considering that part of the input which will forward bias the diode.
- (3) During the period, the diode is 'ON', assume that the capacitor will charge up instantaneously to a level determined by the network.
- (4) During the period for which the diode is 'OFF' assume that capacitor will hold its charge.
- (5) Throughout the analysis keep complete awareness of the polarity for V_0 . So that the proper value of V_0 is determined.

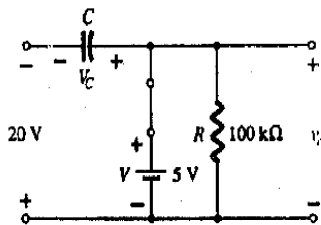
EXAMPLE: Determine v_0 for the network shown in the fig.



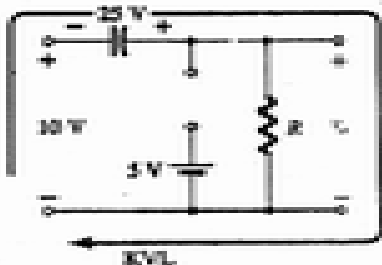
SOLUTION: Our analysis will begin at time t_1 to t_2 ,our circuit will behave as shown in the fig. Applying KVL to input loop

$$-20 + V_c - 5 = 0$$
$$V_c = 25V$$


The capacitor will therefore charge up to 25V. In this case the resistor will not be shorted by the diode, but a Thevenin's equivalent circuit for that portion of the network which includes the battery and resistor will result in $R_{th} = 0$, with $E_{th} = V = 5V$.



For the period t_2 to t_3 the circuit is shown in the fig.



KVL across the outer loop
 $10 + 25 - V_0 = 0$

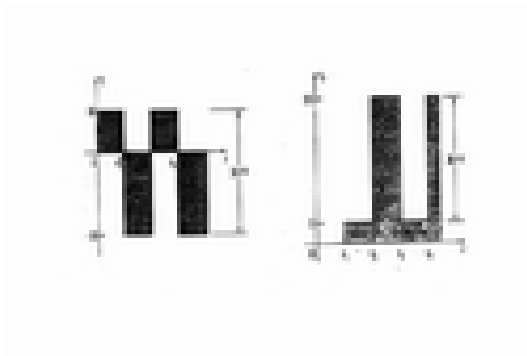
And

$$V_0 = 35V$$

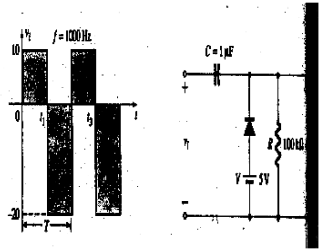
The time constant of the discharging network of fig. is determined by the product of RC and has magnitude

$$T = RC = 0.01S$$

The output wave form will get the shape as

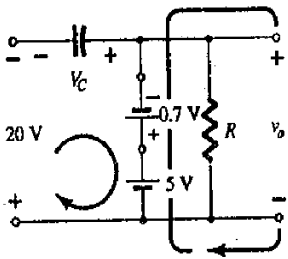


EXAMPLE: Repeat the previous example using silicon diode with $V_T = 0.7V$



SOLUTION:

For the short circuit state the network now takes the appearance of the fig. and V_0 can be determined by KVL in the output section



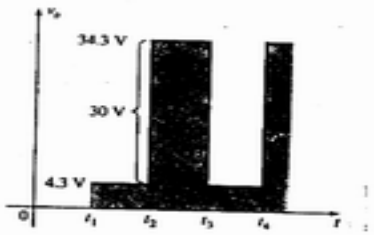
$$+5 - 0.7 - V_0 = 0$$
$$V_0 = 4.3V$$

For the input section KVL will result in

$$-20 + V_C + 0.7 - 5 = 0$$
$$V_C = 25 - 0.7$$
$$= 24.3V$$

For the period t_2 to t_3 the network will now appear as in fig. By KVL

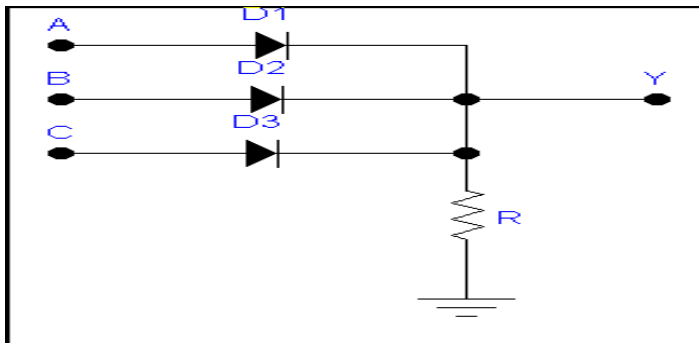
$$10 + 24.3 - V_0 = 0$$
$$V_0 = 34.3V$$



LECTURE 41

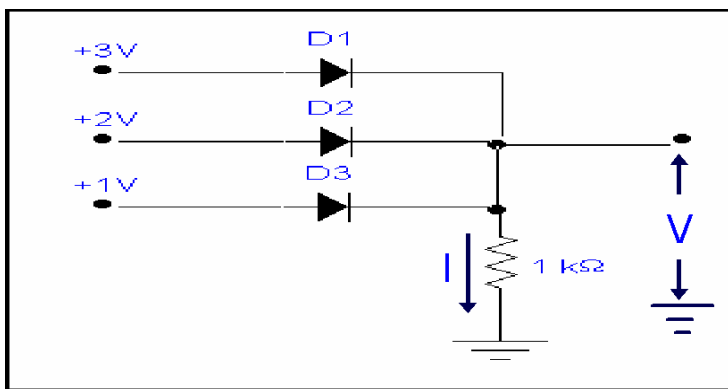
(Diode)

DIODE LOGIC GATES (OR GATE):



$$Y = A + B + C$$

EXAMPLE: Find V and I.



SOLUTION:

D1 is ON because it is in forward biased. As 3V potential difference is applied across diode D1 and it will go in more in conduction than D2 and D3.

D2 and D3 are off.

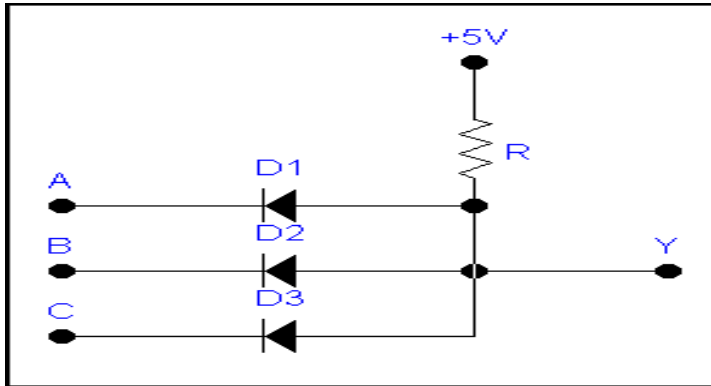
Therefore,

$$V = 3V$$

Also by Ohm's Law

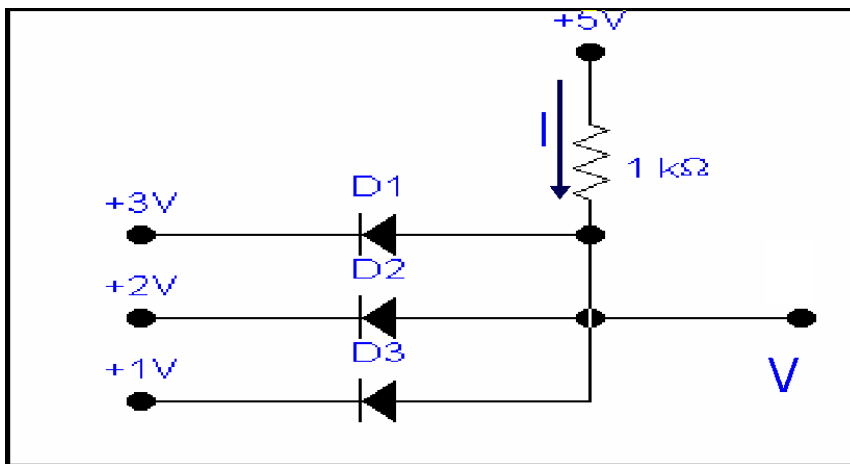
$$I = (3-0)/1k$$

$$I = 3mA$$

DIODE LOGIC GATES (AND GATE):

$$Y = A.B.C$$

EXAMPLE: Find V and I.

**SOLUTION:**

D3 is ON.

In diode D3 case:

The applied voltage at the cathode terminal of the diode **D3 is +1V** and applied voltage at the anode terminal of the diode **D3 is +5V** so the potential difference is 4V. Its mean the anode terminal of the diode D3 is more positive as compared the cathode terminal of the diode the D3 so it will be in forward biased condition i.e **D3 is ON**.

D1 and D2 are off.

In diode D2 and D1 case:

The potential difference across the diode D2 is 3 V. Its mean the anode terminal of the diode D2 is more positive as compared the cathode terminal of the diode D2 however potential difference is less than as in case of diode D3, so diode D2 is in forward biased condition but it is not as much forward –biased as in the case of the diode D3 because we are considering the case of ideal diodes we consider that the when diode D3 is fully forward biased and it will pass more current than diode D2 and D1.

Due to the forward biasing of diode D3 this potential difference will supply on output and this potential difference operate the diode D2 and D1 in reverse –biased.

D1 and D2 are off.

D3 is ON

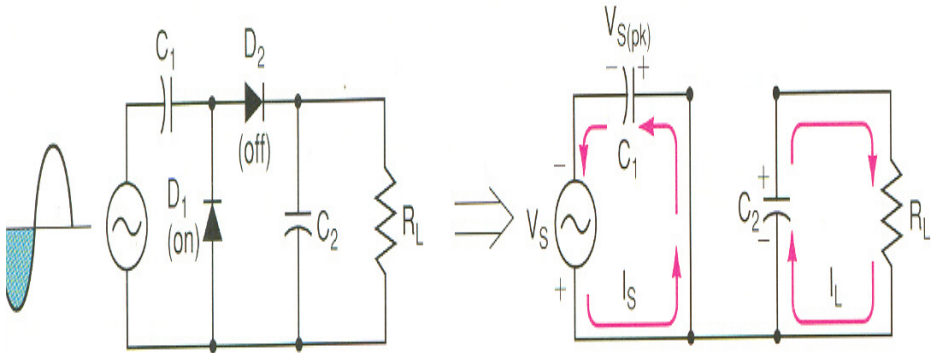
$$\begin{aligned} \text{Therefore } V &= +1V \\ \text{Also by Ohm's Law} \\ I &= (5-1)/1k \\ I &= 4mA \end{aligned}$$

VOLTAGE MULTIPLIERS:

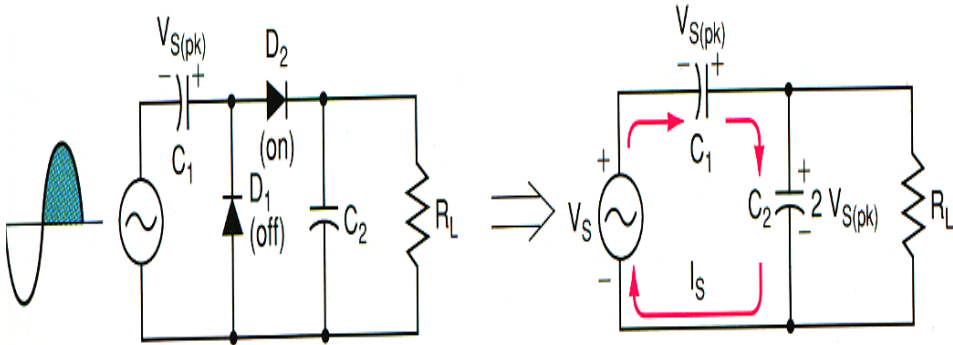
- Voltage multipliers are circuits that provide a dc output which is multiple of the peak input voltage. For example, a voltage doubler provides a dc output voltage that is twice the peak input voltage, and so on.
- While voltage multipliers provide an output voltage that is much greater than the peak input voltage, they are not power generators. When a voltage multiplier increases the peak input voltage by a given factor, the current is decreased by approximately the same factor.
- Because of this, voltage multipliers are usually used in low current high voltage applications. (As in cathode ray tube in a television).

HALF-WAVE VOLTAGE DOUBLERS:

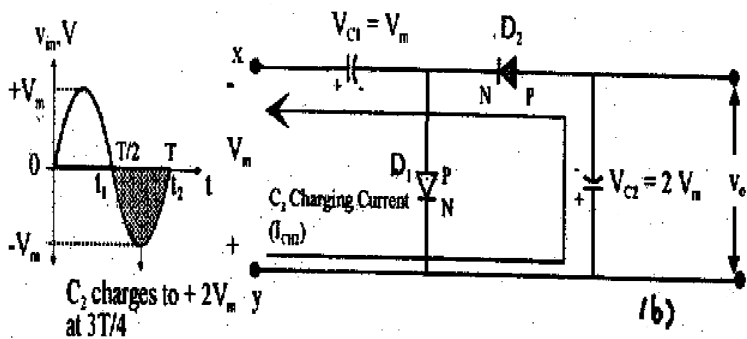
The operation of the half-wave doubler is easier to understand if we assume that the diodes are ideal components. During the negative alternation of the input as shown in the fig, D₁ is forward-biased and D₂ is reverse-biased by the input signal polarity. If we represent D₁ as a short circuit and D₂ as open, we get the equivalent shown in the fig. As you can see, C₁ will charge until its plate-to-plate voltage is equal to the source voltage. At the same time, C₂ will be in the process of discharging through the load resistance R_L.



When the input polarity reverses, we have the circuit conditions shown in the fig below. Since D₁ is off, it is represented as an open in the equivalent circuit. Also, D₂ (which is on) is represented as a short. Using the equivalent circuit, it is easy to see that C₁ (which is charged to the peak value of V_s) and the source voltage now act as series-aiding voltage sources. Thus, C₂ will charge to the sum of the series peak voltages, 2V_{S(pk)}.

**HALF WAVE VOLTAGE DOUBLER:**

- During the first half cycle point x is positive with respect to point y of the input. A charging current will be forced through capacitor C₁ and diode D₁ which will be forward biased.
- Capacitor C₁ will charge to the peak for the time T/4. During the same time D₂ will remain off.



During the negative half cycle of the input point x will be negative with respect to y and voltage of C_1 (V_{c1} and V_{in}) are in series or additive.

A current will try to follow from y to x but D_1 does not allow as it is off. However D_2 will be conducting. This permits C_2 to charge up due to the current I_{ch2} will follows from point y through C_2 through D_2 and back to point x. Voltage on C_2 will be of magnitude $2V_m$.

Applying KVL we can write

$$-V_{c1} - V_{in} = V_o$$

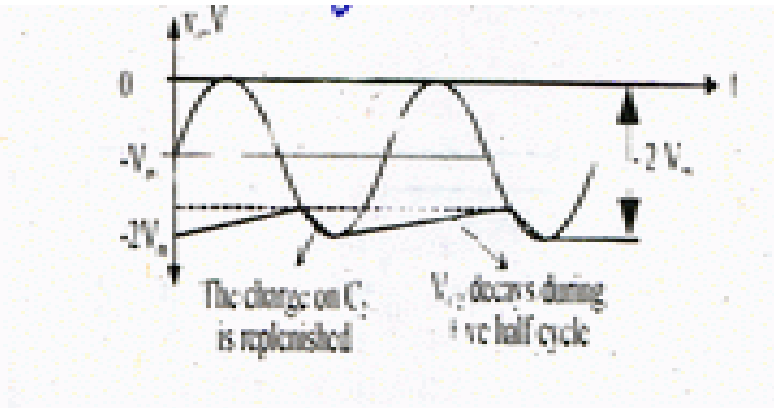
but

$$V_{c1} = V_{max}$$

Hence

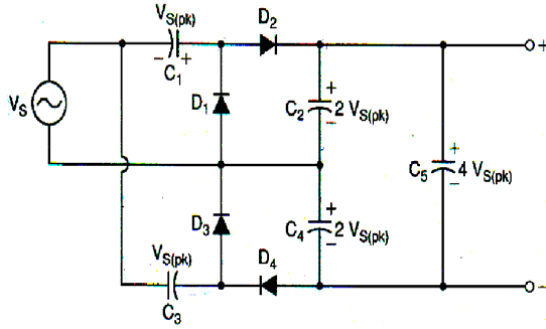
$$V_o = -2V$$

Output waveform will be like this

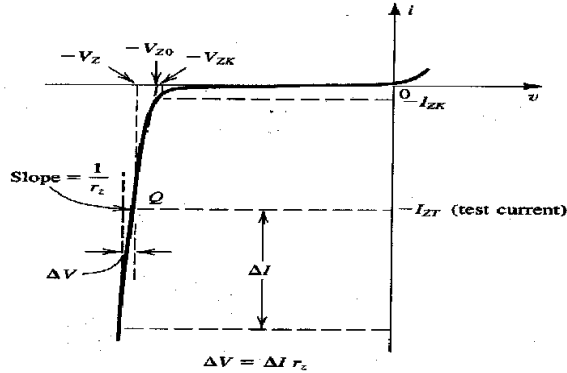


Dual Power Supply:

A dual –polarity power supply is one that provides both positive and negative dc output voltages. One such supply is show in fig below.



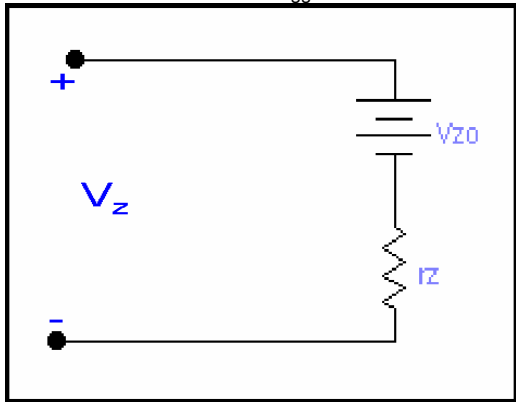
ZENER DIODE:



- In case of zener diode the differential voltage and current in the zener region of the characteristic curve is given by

$$\Delta V = r_z \Delta I$$

- Where r_z = inverse of the slope or incremental resistance of zener diode at operating point.
- The almost linear i-v chracteristic of zener diode suggests that the device can be modeled as shown



- In practice, values of knee voltage and V_{Z0} are considered same. From the model

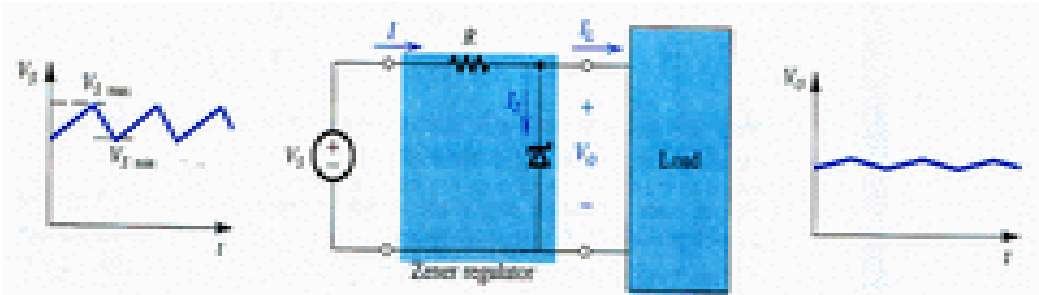
$$V_Z = V_{Z0} + r_z I_Z$$

When $I_Z > I_{ZK}$

$V_z > V_{zo}$

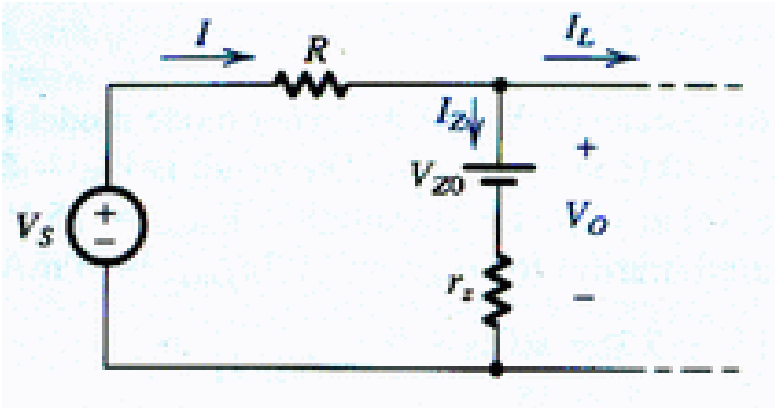
ZENER DIODE SHUNT REGULATOR:

- A regulator must posses two properties
- (1) No change in V_o .with any change in V_s .
- (2) No change in V_o with any change in I_L . Therefore two parameters are related as



- (1) line regulation = $\Delta V_o / \Delta V_s$
- (2) Load regulation = $\Delta V_o / \Delta I_L$

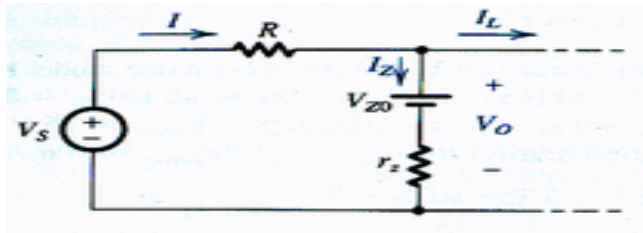
Another method to describe these regulations



LECTURE 42

(Zener diode-LED-PIN Photodiodes - Tunnel diode)

ZENER DIODE SHUNT REGULATOR:



From the circuit shown

$$\text{regulation} = r_z / (R + r_z)$$

$$\text{regulation} = -r_z \parallel R$$

$$\text{Current in the network} = (V_s - V_{z0}) / (R + r_z)$$

Voltage across r_z is

$$V_{rz} = V_{z0} + (V_s - V_{z0}) r_z / (R + r_z)$$

Therefore applying Thevenin's Theorem

$$V_o = V_{z0} + (V_s - V_{z0}) r_z / (R + r_z) \times R_L / (R_L + R \parallel r_z)$$

$$\text{Therefore } R \times (\text{Total current}) = V_{s\min} - V_{z0} - r_z I_{z\min}$$

Or

$$R = (V_{s\min} - V_{z0} - r_z I_{z\min}) / (I_{z\min} + I_{L\max})$$

Example:

A zener diode whose nominal voltage is 10V at 10mA has an incremental resistance of 50Ω. What voltage Ahmad Tulaib must expect if Bilal disturbs the settings to half the diode current. What is the value of V_{z0} of the zener model.

Solution:

When the current is changed by -5mA, then voltage

$$V_z = 10 - r_z I_z = 10 - 5(0.05) = 9.75V$$

When the current is doubled i.e. increased by 10mA, then

$$V_z = 10 + 10(0.05) = 10.5V$$

V_{z0} is the intercept of the tangent to characteristic at (10V, 10mA) is the voltage change, when the current decreases by 10mA, hence

$$V_{z0} = 10 - 10(0.05) = 9.5V$$

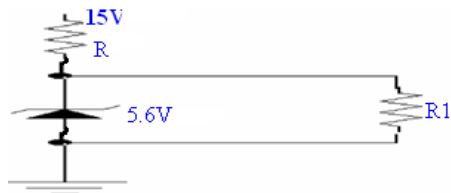
V_{z0} is the intercept of the tangent to characteristic at (10V, 10mA) is the voltage change, when the current decreases by 10mA, hence

$$V_{z0} = 10 - 10(0.05) = 9.5V$$

Example:

A zener diode exhibits a constant voltage of 5.6V for currents greater than five times the knee current I_{zk} is specified to be 1mA. It is to be used in the design of a shunt regulator fed from a 15V supply. The load current varies over the range 0 to 15mA. Find a suitable value for the resistance R. What is the maximum power dissipation to the zener diode.

Solution:



The minimum Zener current is

$$I_{zk} = 5(1\text{mA}) = 5\text{mA}$$

$\therefore$ Load current may be 15mA, so that the value of R, is such that with $I_L = 15\text{mA}$, zener current of 5mA is available, therefore,

$$R = (15 - 5.6) / 20\text{mA}$$

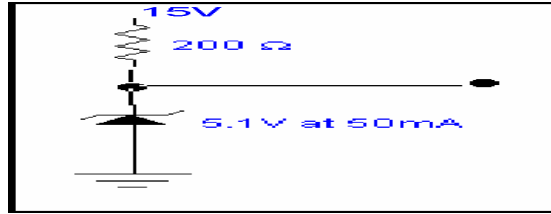
$$R = 470\Omega$$

The maximum power dissipated in the zener occurs when, $I_L = 0$, in which case the zener current must be 20mA, therefore

$$P = 20\text{mA}(5.6) = 112\text{mW}$$

Example: A shunt regulator utilizes a zener diode whose voltage is 5.1V at a current of 50mA and whose incremental resistance is 7Ω . The diode is fed from a supply of 15 V nominal voltages through a 200 Ω resistor. What is the output voltage at no load? Find the line regulation and load regulation.

Solution:



$$V_{zo} = 5.1 - 7(50\text{m})$$

$$= 4.75\text{V}$$

At no load condition

$$V_o = (15 - 4.75) / 207 + 4.75$$

$$= 5.1\text{V}$$

$$\text{Line regulation} = r_z / (R + r_z)$$

$$= 7 / 207 = 33.8\text{mV/V}$$

$$\text{Load Regulation} = - (r_z || R)$$

$$= - (7 || 200)$$

$$= - 6.8\Omega$$

$$= - 6.8\text{mV/mA}$$

Example: Ghania is trying to design a shunt regulator, of about 20V, for her sister Azka's toy. Two kinds of zener diodes are available: 6.8V devices with r_z of 10Ω and 5.1V devices with r_z of 30Ω . For the two choices possible, find load regulation. In this calculation neglect the effect of regulator resistance R.

Solution:

Choices

- In order make up 20V using 6.8V zener, three diodes will be needed, therefore $3 \times 6.8 = 20.4\text{V}$, so is the resistance, $3 \times 10 = 30\Omega$. Therefore load regulation, neglecting load resistance = -30Ω .
- 4 diodes of 5.1 will make up 20.4 volts, therefore $4 \times 5.1 = 20.4\text{V}$, so is the resistance of the zener i.e.

$$4 \times 30 = 120\Omega.$$

$$\text{Load regulation (Neglecting R)} = -120\Omega$$

Example: It is required to design a shunt regulator to provide a regulated voltage of about 10V. The available 10V, 1W zener of type 1N4740 is specified to have a 10V drop at a test current of 25mA. At this current its r_z is 7Ω . The raw supply available has a nominal value of 20V but can vary as much as $\pm 25\%$. The regulator is required to supply a load current of 0 to 20mA. Design for a minimum zener current of 5mA.

- Find V_{zo} .
- Calculate the required value of R.
- Find the line regulation. What is the change in V_o expressed in %age, corresponding to the $\pm 25\%$ change in V_s .
- Find the load regulation. By what percentage does V_o change from no load to full load condition.
- What is maximum current that the zener in your design should be able to conduct? What is the zener power dissipation under this condition?

Solution:

The provided data is

$$V_z = 10V, I_z = 25mA, r_z = 7\Omega, V_s = 20V \pm 25\%, I_{zk} = 5mA, \Delta I_L = 20mA.$$

- $V_{zo} = V_z - I_z r_z = 10 - 25m(7) = 9.82V$
- Minimum current $I_{zk} = 5mA$ will occur when Load current I_L is maximum i.e. 20mA and V_s is at minimum, so that $V_s = 20 - 5 = 15V$.

Therefore

$$R \leq \frac{V_{s \min} - V_{zo} - r_z I_{z \min}}{I_{z \min} + I_{L \max}}$$

$$R \leq \frac{15 - 9.825 - (5 \times 10^{-3})7}{5m + 20m}$$

$$R \leq 205.6\Omega \cong 205\Omega.$$

c).

$$\text{Line Regulation} = \Delta V_o / \Delta V_s = r_z / (R + r_z)$$

$$7/212 = 33mV/V.$$

$$\pm 25\% \text{ change in } V_s = \pm 5V$$

Therefore V_o changes by $\pm 5 \times 33m$

$$= \pm 165mV$$

$$\text{Percentage} = \pm 0.165(100)/10 = \pm 1.65\%.$$

d).

$$\text{Load Regulation} = -r_z / R = -7/205$$

$$= -6.77\Omega = -6.77V/A$$

$$\Delta V_o = -6.67(20m) = -135.4mV$$

Which in % $= -135.4(100)/10 = -1.35\%$

- e). Maximum zener current occurs at no load and $V_s = 20(1 + 0.25) = 25V$

$$\text{Current} = (25 - 9.825)/(205 + 7) = 71.6mA$$

$$\text{Zener Power Dissipation} = 71.6m(10) = 716mW$$

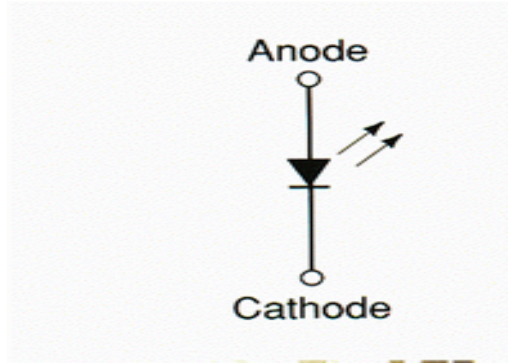
Or more precisely

$$V_z = 9.825 + 71.6m(7) = 10.326V$$

$$P_z = 71.6m(10.326) = 739.4mW.$$

LIGHT EMITTING DIODES:

- LED's are diodes that will emit light when biased properly. The graphic symbol for an LED is shown in figure.



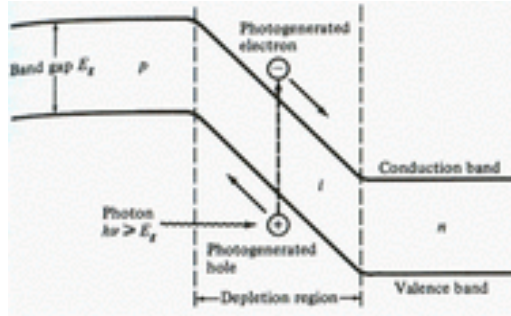
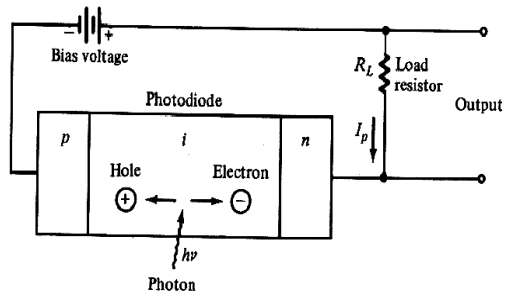
When sufficient voltage is applied to the chip across the leads of the LED, electrons can move easily in only one direction across the *junction* between the *p* and *n* regions. In the *p* region there are many more positive than negative charges. In the *n* region the electrons are more numerous than the positive electric charges. When a voltage is applied and the current starts to flow, electrons in the *n* region have sufficient energy to move across the junction into the *p* region. Once in the *p* region the electrons are immediately attracted to the positive charges due to the mutual Coulomb forces of attraction between opposite electric charges. When an electron moves sufficiently close to a positive charge in the *p* region, the two charges "re-combine". Each time an electron *recombines* with a positive charge; electric potential energy is converted into electromagnetic energy. For each recombination of a negative and a positive charge, a quantum of electromagnetic energy is emitted in the form of a photon of light with a frequency characteristic of the semi-conductor material (usually a combination of the chemical elements gallium, arsenic and phosphorus). Only photons in a very narrow frequency range can be emitted by any material. LED's that emit different colors are made of different semi-conductor materials, and require different energies to light them

- LED's are available in many of emitting colors as well as infrared (which is not visible), red, green, yellow, orange, and blue, the schematic symbol is the same for all colors. Since LED's have clear cases, there is normally no label on the case to identify the leads.
- The leads are normally in one of three ways
 - (1) The leads may have different lengths.
 - (2) One of the leads may be flattened. The flattened lead is usually the cathode.
 - (3) One side of the case may be flattened, the lead closest to the flattened side is usually the cathode.

LED CHARACTERISTICS:

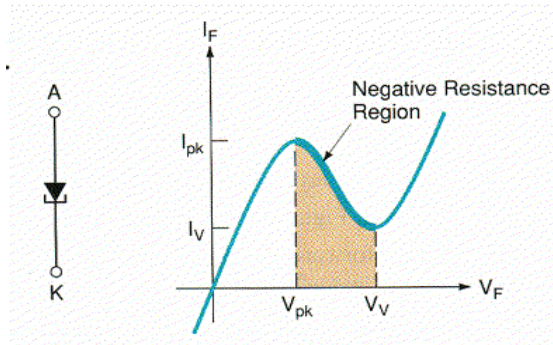
- LED's have characteristic curves that are very similar to those for pn junction diodes. However, they tend to have higher forward voltage (V_F) values and lower reverse break down voltage ratings. The typical ranges for these values are as follows
 - (1) Forward voltage: +1.2 to +4.3V
 - (2) Reverse break down voltage : -3 to - 10V

PIN Photodiodes:



TUNNEL DIODE:

- Tunnel diodes are used in ultra high frequency (UHF) and microwave frequency range. They have application in high frequency communication electronics. The schematic symbol and characteristic curve is shown in the fig.

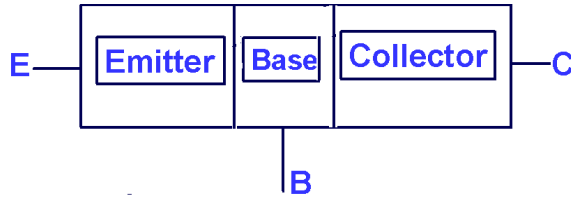


- The operating curve is a result of extremely heavy doping used in the manufacturing of the tunnel diode. In fact, the tunnel diode is doped approximately 1000 times as heavily as standard pn junction diodes.
- In the forward operating region of the tunnel diode, we are interested in the area between the peak voltage (V_{pk}) and the valley voltage (V_V).
- At $V_F = V_{pk}$, forward current is called peak current (I_{PK}). As V_F is increased to the value of V_V , I_F decreases to its minimum value called Valley current (I_V).
- The term used to describe a device whose current and voltage are inversely proportional is negative resistance.
- Thus, the region of operation between V_{pk} and V_V is called negative resistance region.

LECTURE 43

(Bipolar Junction Transistor (BJT))

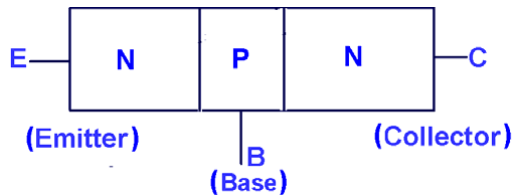
BIPOLAR JUNCTION TRANSISTOR (BJT) CONSTRUCTION:



It is three layer semiconductor device, consisting of either two n- and one p-type layers of material or two p- and one n-type layers. Since three layers are involved in this device, therefore it will have three terminals. These terminals are known as:-

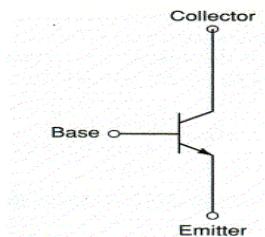
1. **Emitter.**
2. **Base.**
3. **Collector.**

- Emitter layer is heavily doped.
 - Base layer is lightly doped.
 - Collector is very lightly doped.
 - The base layer is very thin as compared to other two, normally in the range of 150:1.
- The designated terminology for three terminals is as follows:-
- Emitter:** This layer emits electrons.
- Base:** It helps minority carriers to transfer rapidly from emitter to collector. Electric field is created in base by non-uniform doping, so that minority carriers are accelerated from emitter to collector.
- Collector:** This layer collects the emitted electrons.
- Two basic types of BJTs
 - These types are in equation to constructional arrangement of layers.
 - The arrangement shown in the figure is called NPN Transistor.
 -

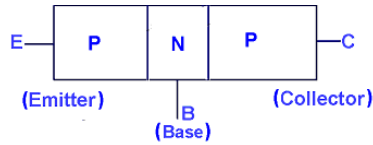


BIPOLAR JUNCTION TRANSISTOR THE SYMBOL FOR NPN TRANSISTOR:

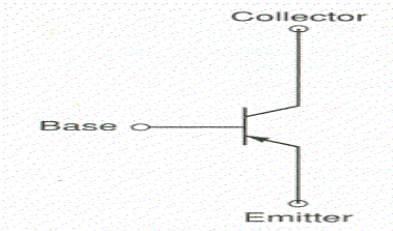
The arrow shows direction of flow of conventional current.



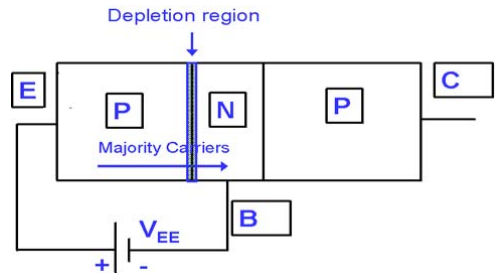
- The arrangement is known as **PNP** transistor.



BIPOLAR JUNCTION TRANSISTOR THE SYMBOL FOR PNP TRANSISTOR:

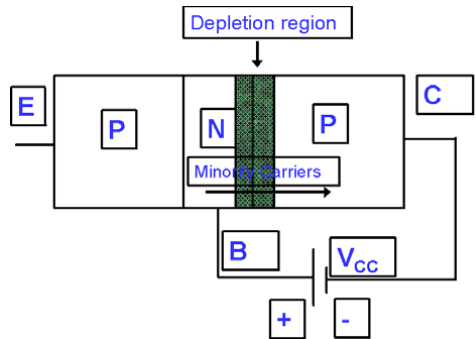


BIPOLAR JUNCTION TRANSISTOR OPERATION IN PNP TRANSISTOR
EMITTER BASE JUNCTION:

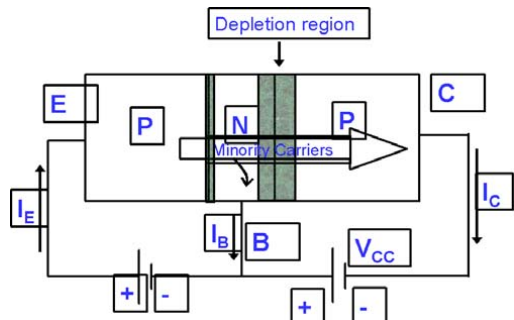


This fig shows the emitter base junction where emitter is made up of p-type material and Base is made up of N-type material .In the fig +ve terminal of the battery is connected to Emitter while –ve terminal is connected to the the Base. Its mean this junction will go in forward-biased condition and depletion layer will shrink. That is majority carriers will start crossing the junction of these particular layers.

COLLECTOR BASE JUNCTION:



This fig shows the Collector-base junction where collector is made up of P-type material and Base is made up of N-type material .In the fig +ve terminal of the battery is connected to Base while –ve terminal is connected to the the Collector. Its mean this junction will go in to reverse-biased mode and depletion layer will be widened and the current will flow due to minority carriers.

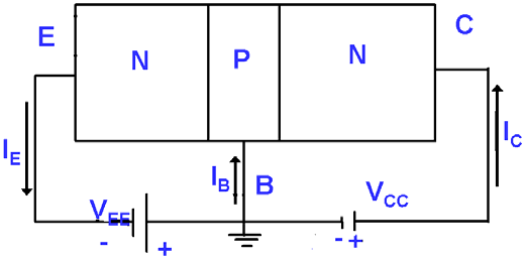


In the fig above +ve terminal of the battery is connected to Emitter while –ve terminal of V_{EE} is connected to the Base while on the right side of this fig +ve terminal of the battery V_{CC} is connected to Base while –ve terminal is connected to the the Collector. There are two depletion layers in the fig one is small while the other is bit wider and this is due to the forward biased of emitter-base junction and reverse biased due to the collector-base junction. We also see the emitter current I_E will flow inward i.e. pointing into the transistor, however the base current I_B and collector current I_C is shown going outward from the transistor.

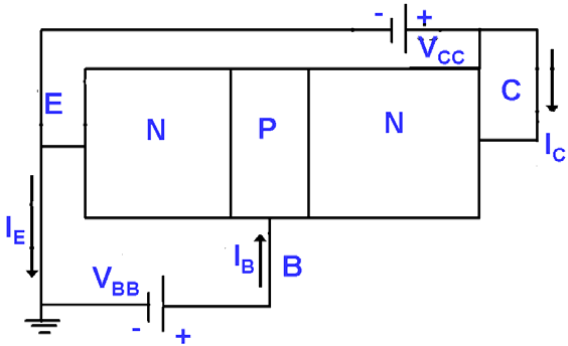
OPERATING CONFIGURATIONS OF BJT:

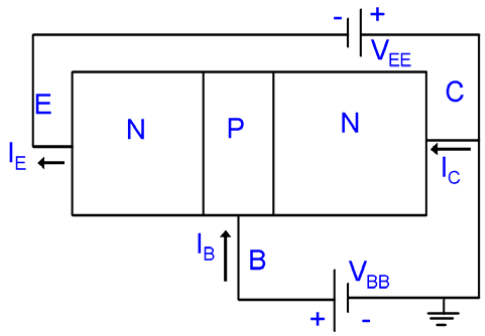
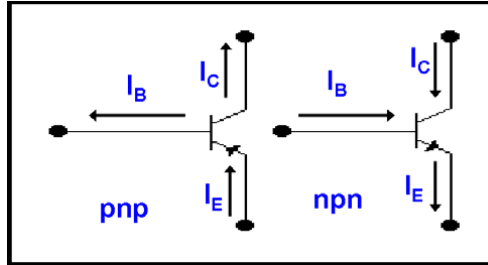
- There are three basic configurations under which transistor may be operated; these configurations depend upon the situation and requirements. These configurations are called
 1. **Common Base Configuration.**
 2. **Common Emitter Configuration.**
 3. **Common Collector Configuration.**

COMMON BASE CONFIGURATION:



COMMON EMMITER CONFIGURATION:



COMMON COLLECTOR CONFIGURATION:**Directions of Currents in BJT:****MODES OF OPERATION OF BJT:**

- There are three modes of operation for BJT
 - Cut Off**

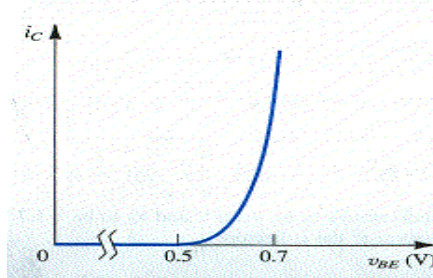
When both the PN-junction of transistor are reverse-biased, the resulting mode of operation of the transistor is known as cut-off or simply as off-mode. This means that the BJT will be "OFF" and no current will flow through it. The fully supply voltage will exist across it. In everyday life an off switch will not permit any current to flow through an electric bulb and the full supply voltage will be present across the switch.

2. Active Mode

When BEJ of a transistor is forward-biased but BCJ is reverse biased the mode of operation of a transistor is referred to as its active-mode. A bipolar junction transistor in its active-mode of operation is called as an amplifier and is able to amplify voltage or current signals both.

3. Saturation

If both the PN-junctions, that is, the base-emitter junction (BEJ) and the base-collector junction (BCJ) are forward-biased, the transistor is said to be in its saturation (or ON) mode of operation.

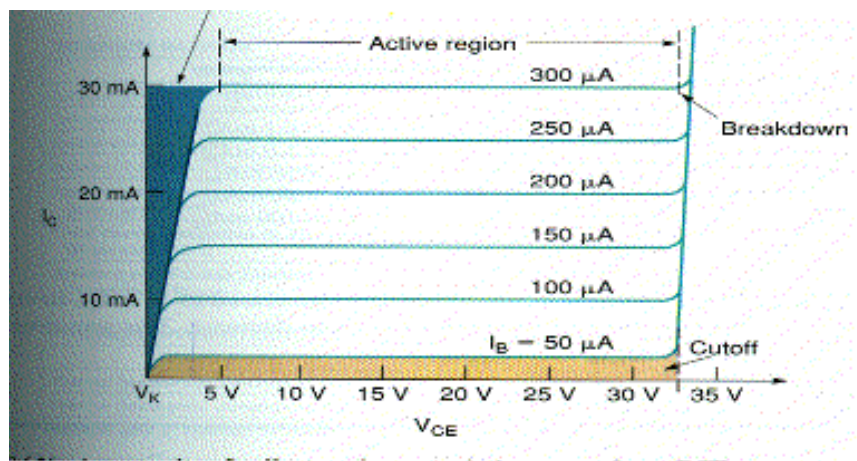
Graphical Presentation of BJT:

This curve has been drawn between the voltage across BEJ and the collector current. We can observe that the exponential rise in this collector current starts almost after 0.5 volts and saturated at 0.7 volts.

Input or driving point characteristics

$$I_C = I_S e^{V_{BE}/V_T}$$

GRAPHICAL PRESENTATION OF BJT OUTPUT OR COLLECTOR CHARACTERISTIC FOR COMMON BASE CONFIGURATION:

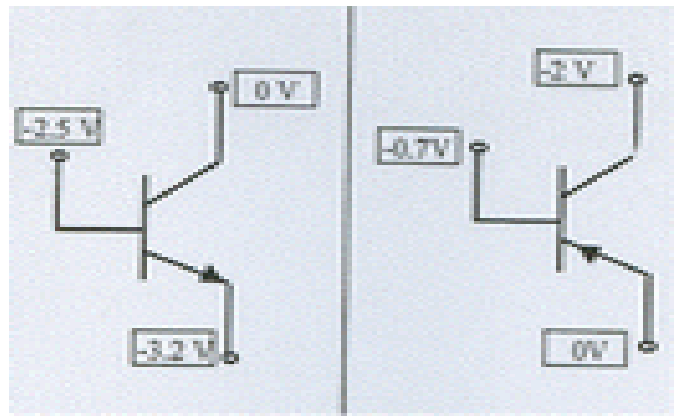


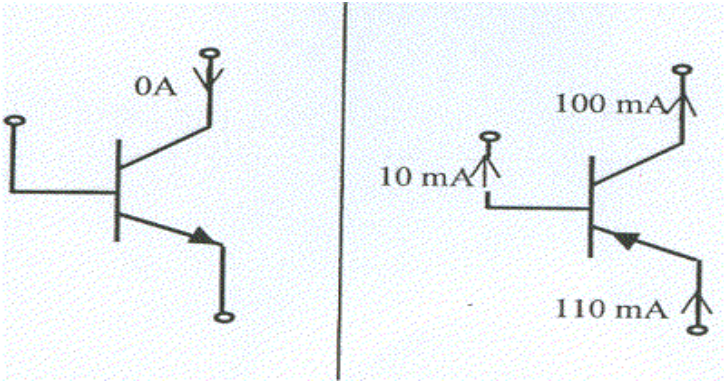
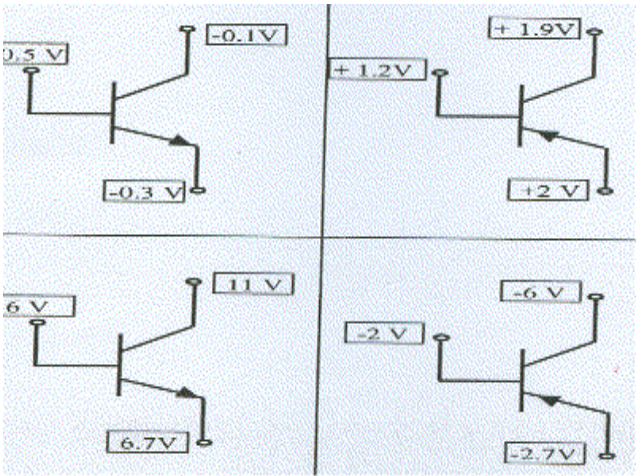
Along x-axis we are taking V_{CE} and along y-axis we are taking current collector current I_C . In the above fig below the 50 μA is the cut off region of the transistor. Another shaded area along y-axis this area is a saturation region in this area we have maximum value of collector current i.e. I_C exist while the value of V_{CE} is minimum so in this area transistor will go in saturation. The un shaded area is called active region and it depends upon three parameters i.e. collector current base current and the applied voltage.

MODES OF OPERATION OF BJT:

	EBJ	CBJ
● Cut Off	Reverse	Reverse
● Active	Forward	Reverse
● Saturation	Forward	Forward

For the transistors shown, state mode of operation.





LECTURE 44

(Bipolar Junction Transistor (BJT))

THE CURRENTS OF A BJT:

1. The collector current.
2. The base Current.
3. The Emitter Current.

- Collector Current

It can be expressed as $I_C = I_S e^{(V_{BE}/V_T)}$

I_S = saturation current or current scale factor.

- The Base Current

It is given by $I_B = I_C / \beta$

Where β is a constant for particular transistor and is known as common emitter current gain, since

$$I_C / I_B = \beta$$

- The Emitter Current

Since the total current which enters a transistor must leave it, hence we may write

$$I_E = I_B + I_C$$

$$\text{But } I_B = I_C / \beta$$

Therefore,

$$I_E = I_C + I_C / \beta$$

Or

$$I_E = I_C (\beta + 1) / \beta$$

Or

$$I_E = I_S e^{(V_{BE}/V_T)} (\beta + 1) / \beta$$

Alternatively, we may write

$$I_C = \alpha I_E \quad \alpha = \beta / (\beta + 1)$$

Or

$$I_E = (I_C / \alpha) e^{(V_{BE} / V_T)}$$

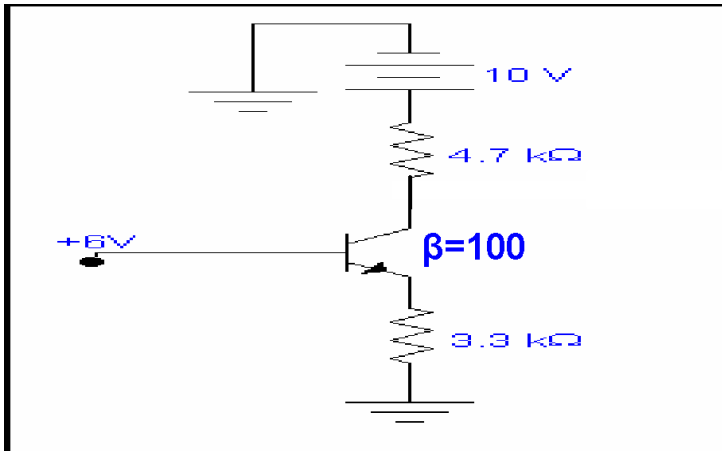
Also we may write

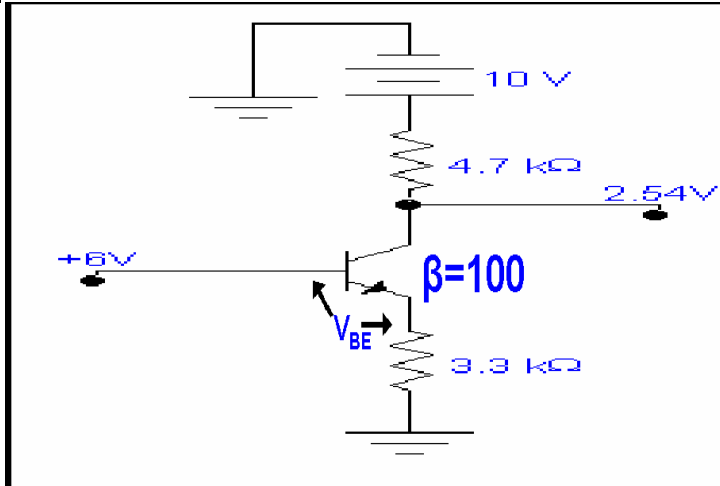
$$\beta = \alpha / (1 - \alpha)$$

α is known as **common base current gain**.

Example:

Show the transistor is in saturation.



SOLUTION:

For input loop, applying KVL

$$6 - V_{BE} - I_E(3.3k) = 0$$

Rearranging

$$I_E = (6 - 0.7) / 3.3k = 1.61mA$$

Therefore

$$I_B = I_E / 101 = 1.61m / 101 = 15.94\mu A$$

$$\text{Also } V_E = I_E R_E = 1.61m(3.3k) = 5.3V$$

$$I_C = 15.94\mu(100) = 1.59mA$$

Therefore KVL Equation for the out put loop is

$$10 - 1.59m(4.7k) - V_C = 0$$

$$\therefore V_C = 10 - 7.49 = 2.50V$$

$$\therefore V_C < V_B$$

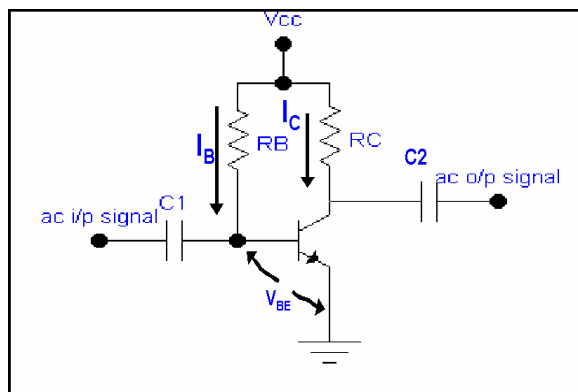
Hence the transistor is in saturation.

DC BIASING-BJT:

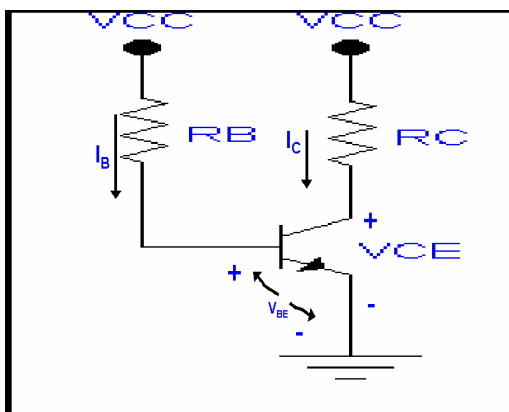
1. Fixed bias circuit.
2. Emitter stabilized biased circuit.
3. Voltage divider bias.

DC BIASING-BJT:

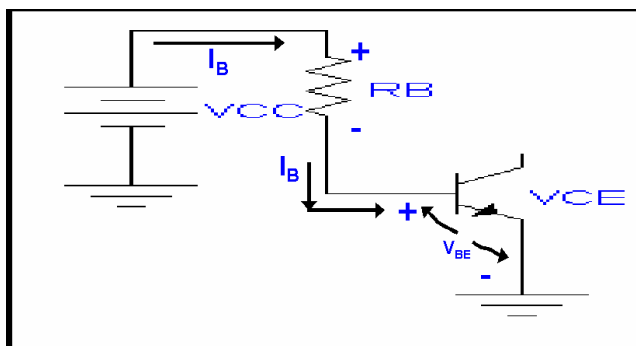
Fixed Bias Circuit



DC EQUIVALENT OF THE CIRCUIT:



Forward bias of Base Emitter:



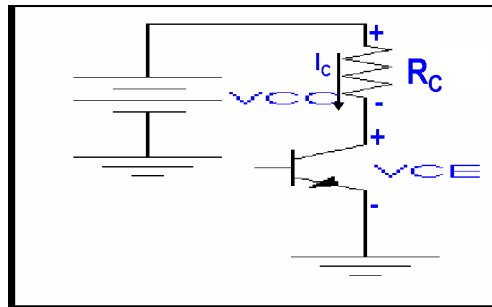
KVI Equation for the loop is

$$V_{CC} - I_B R_B - V_{BE} = 0$$

or

$$I_B = (V_{CC} - V_{BE}) / R_B$$

Collector Emitter Loop:



Applying KVL

$$V_{CE} + I_C R_C - V_{CC} = 0$$

or $V_{CE} = V_{CC} - I_C R_C$

Also we may write

$$V_{CE} = V_C - V_E$$

$$\therefore V_E = 0 \text{ in this case}$$

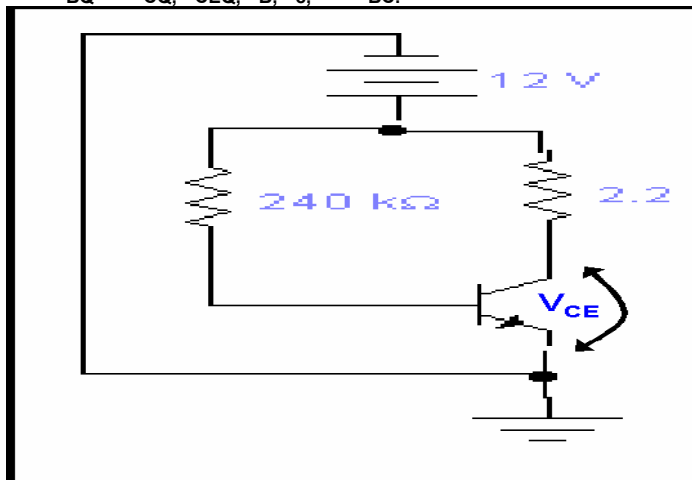
$$\therefore V_{CE} = V_C$$

$$\text{Also } V_{BE} = V_B - V_E$$

And $V_E = 0$, thus

$$V_{BE} = V_B$$

Example: Find I_{BQ} and I_{CQ} , V_{CEQ} , V_B , V_C , and V_{BC} . Consider $\beta = 50$.



SOLUTION:

$$I_{BQ} = \frac{V_{CC} - V_{BE}}{R_B} = \frac{12 - 0.7}{240k} = 47.08 \mu A$$

Also we know that

$$I_{CQ} = \beta \cdot (I_{BQ}) = 50(46.08 \times 10^{-6}) = 2.35 \text{ mA}$$

$$V_{CEQ} = V_{CC} - I_{CQ}R_C$$

$$V_{CEQ} = 12 - (2.35 \times 10^{-3})(2.2\text{k}) = 6.38 \text{ V}$$

$$V_B = V_{BE} = 0.7 \text{ V}$$

$$V_C - V_{CE} = 6.83 \text{ V}$$

$$V_{BC} = V_B - V_C = 0.7 - 6.83 = -6.13 \text{ V}$$

LOAD LINE ANALYSIS:

The output equation of fixed bias circuit is given as

$$V_{CE} = V_{CC} - I_C R_C$$

Which is an equation of a straight line. The corresponding x and y axes intercepts can be calculated by inserting appropriate values equal to zero. Therefore by putting

$$I_C = 0$$

$$\text{We have } V_{CE} = V_{CC} - (0)R_C$$

$$V_{CE} = V_{CC}$$

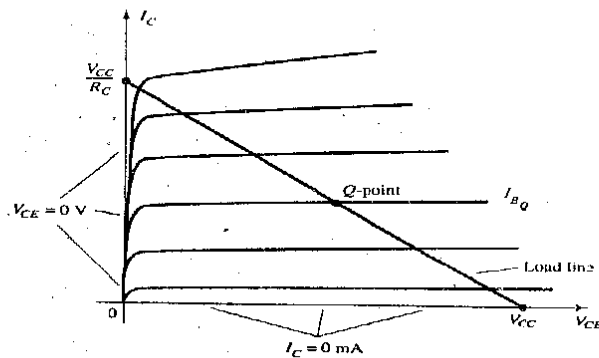
Y intercept can be found by putting

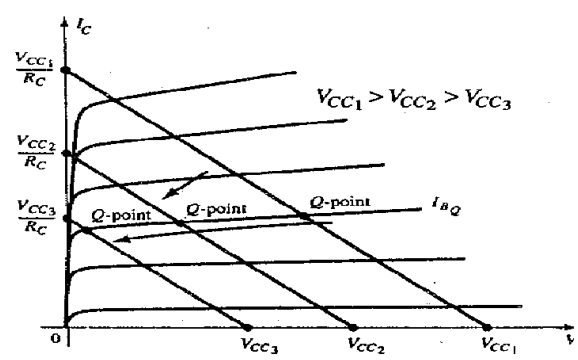
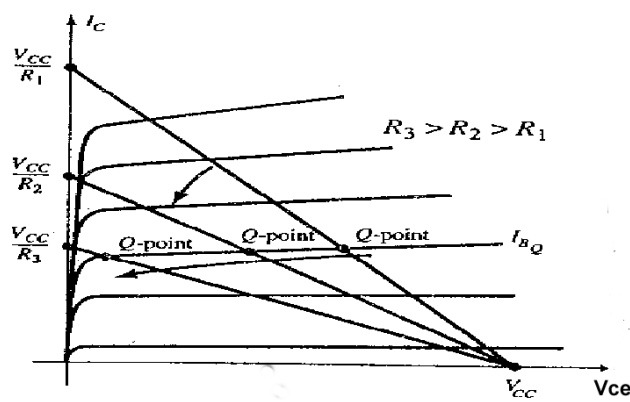
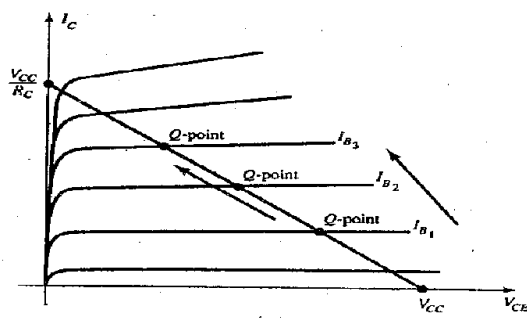
$$V_{CE} = 0 \text{ volts so that}$$

$$0 = V_{CC} - I_C R_C$$

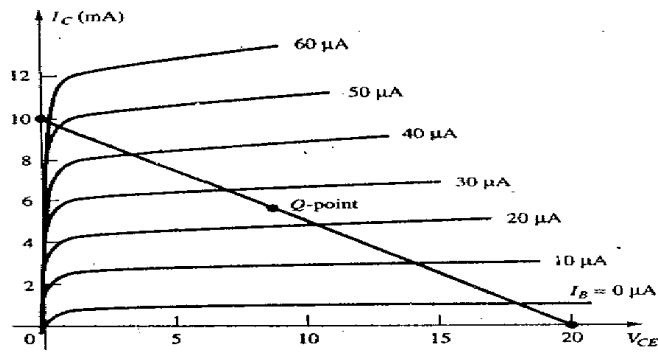
$$I_C = V_{CC}/R_C$$

Which defines the slope of the load line.





Example: Given a curve find V_{CC} , R_C , and R_B for fixed bias circuit.

**Solution:**

From the graph we have, for $I_C = 0$

$$V_{CE} = V_{CC} = 20V$$

Also at $V_{CE} = 0$

$$I_C = V_{CC} / R_C$$

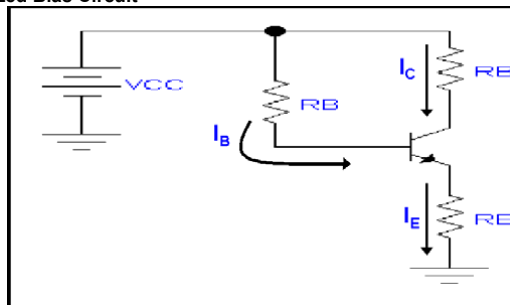
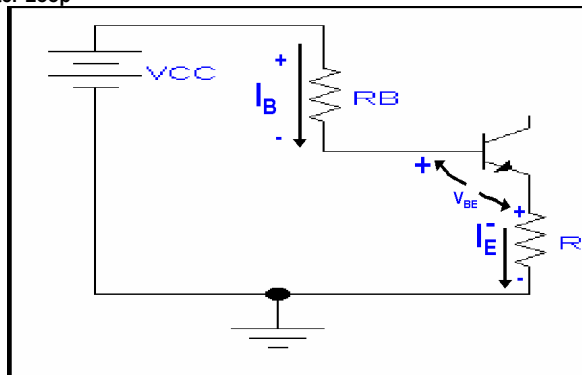
$$R_C = V_{CC} / I_C = 20 / 10\text{mA} = 2\text{k}\Omega$$

Now

$$I_B = (V_{CC} - V_{BE}) / R_B$$

Or

$$\begin{aligned} R_B &= (V_{CC} - V_{BE}) / I_B \\ &= (20 - 0.7) / 25\mu\text{A} \\ &= 772\text{k}\Omega. \end{aligned}$$

DC BIASING-BJT:**Emitter-Stabilized Bias Circuit****Base Emitter Loop**

KVI Equation for the loop is

$$V_{CC} - I_B R_B - V_{BE} - I_E R_E = 0$$

But

$$I_E = (\beta + 1) I_B$$

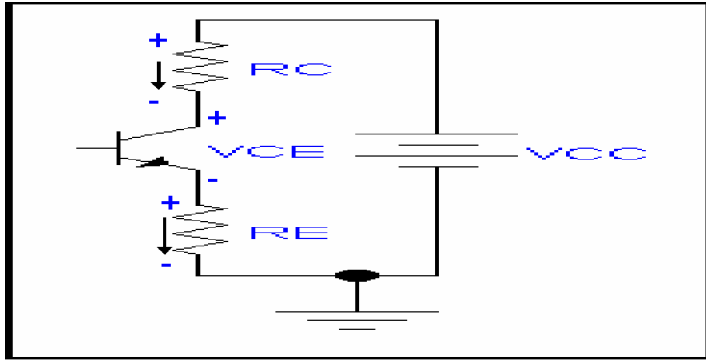
Therefore,

$$V_{CC} - I_B R_B - V_{BE} - (\beta + 1) I_B R_E = 0$$

$$-I_B (R_B + (\beta + 1) R_E) + V_{CC} - V_{BE} = 0$$

$$I_B = (V_{CC} - V_{BE}) / (R_B + (\beta + 1) R_E)$$

Collector-Emitter Loop



$$I_E R_E + V_{CE} + I_C R_C - V_{CC} = 0$$

$$\text{But } I_E = I_C$$

$$V_{CE} - V_{CC} + I_C (R_C + R_E) = 0$$

$$V_{ce} = V_{cc} - I_c (R_c + R_e)$$

Now V_E is the voltage between the Emitter terminal and the ground, given by

$$V_E = I_E R_E$$

Also Collector to ground voltage will be

$$V_{CE} = V_C - V_E$$

$$V_C = V_{CE} + V_E$$

Also

$$V_C = V_{CC} - I_C R_C$$

Voltage at the base w.r.t ground will be

$$V_B = V_{CC} - I_B R_B$$

$$V_B = V_{BE} + V_E$$

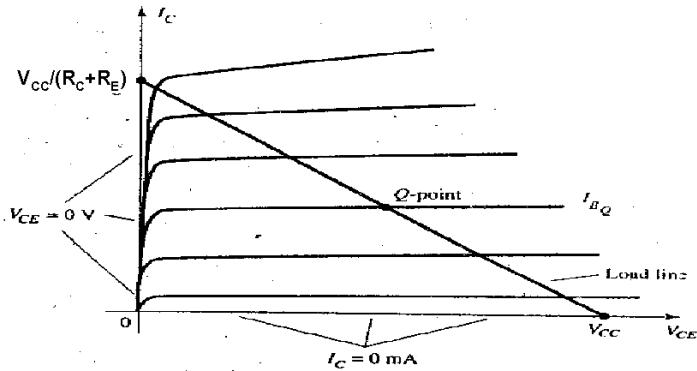
Stabilization:

Due to addition of the emitter resistance the values of DC bias currents and voltages remain constant with any changes in the Temperature and transistor beta.

LECTURE 45

(Bipolar Junction Transistor BJT-circuit analysis)

Emitter-Stabilized Bias Circuit: Load Line Analysis



The collector emitter loop equation defining load line is

$$V_{CE} = V_{CC} - I_C(R_C + R_E)$$

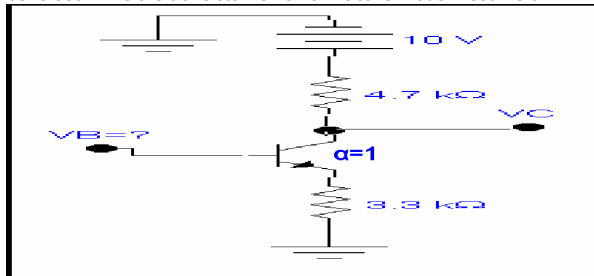
For $I_C = 0 \text{ mA}$

$$V_{CE} = V_{CC}$$

And for $V_{CE} = 0$, we get

$$I_C = V_{CC} / (R_C + R_E)$$

Example: Zammad is designing an amplifier circuit as shown in the figure. Find the highest voltage to which the base can be raised while the transistor remains in active mode. Assume $\alpha = 1$.



Solution:

Lets consider that the voltage to which base can be raised for active operation be V .

For the transistor to operate in active mode, consider $V_B = V_C = V$, therefore, for output loop, we have

$$10 - 4.7kI_C - V_C = 0 \quad (1)$$

Also for base-emitter loop we have

$$V_B - V_{BE} - I_E R_E = 0 \quad (2)$$

$$\because \alpha = 1, \text{ therefore } I_C = I_E$$

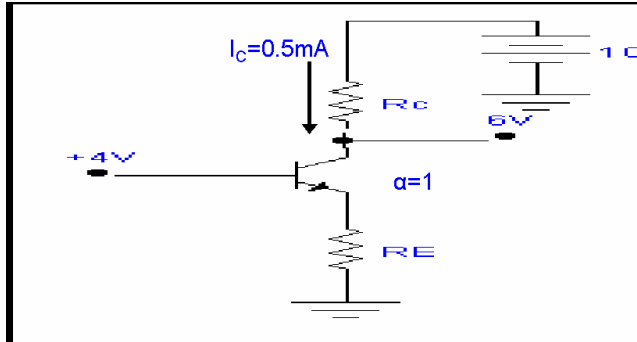
From Equation (2)

$$I_E = (V_B - V_{BE}) / R_E$$

Putting the value of I_E in equation (1)

$$\begin{aligned}
 10 - (V_B - V_{BE}) R_C / R_E - V_C &= 0 \\
 10 - (V - 0.7) 4.7 / 3.3 - V &= 0 \\
 3.3(10) - 4.7V - 3.29 - V(3.3) &= 0 \\
 \therefore 8V &= 29.71 \\
 \mathbf{V} &= \mathbf{3.71V}
 \end{aligned}$$

Example: For the circuit shown find R_E & R_C .



Solution:

The given parameters are

$$I_C = 0.5\text{mA} \text{ \& } \alpha = 1,$$

$$\text{also } V_{CB} = 2\text{V}$$

Therefore, for the output loop we have by KVL

$$(10 - 6) / 0.5\text{m} = R_C$$

$$R_C = 8\text{k}\Omega$$

$$\therefore \alpha = 1,$$

Therefore,

$$I_C = I_E = 0.5\text{mA}$$

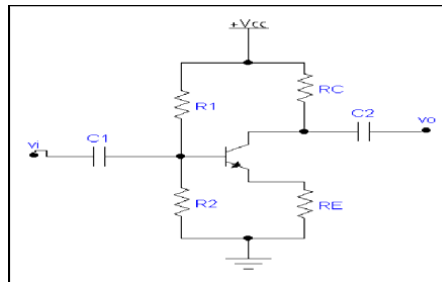
Hence for the base emitter loop by KVL

$$(4 - 0.7) / 0.5\text{m} = R_E$$

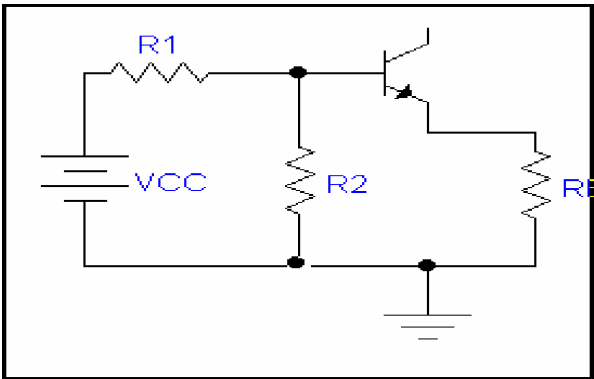
$$R_E = 6.6\text{k}\Omega$$

DC BIASING-BJT:

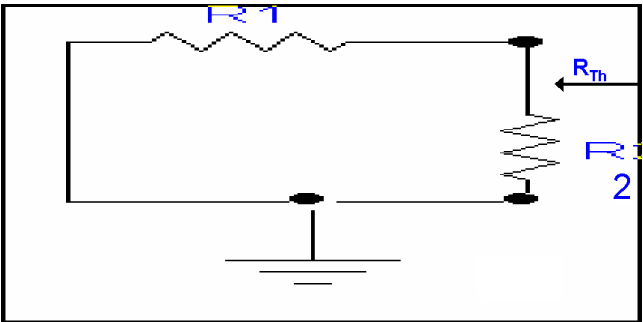
Voltage Divider Bias Circuit



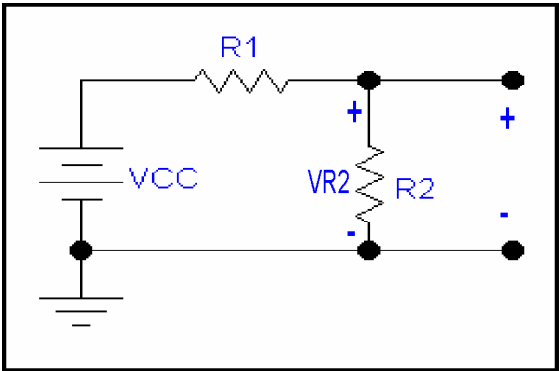
The input loop of the circuit will be



Applying Thevenin's theorem

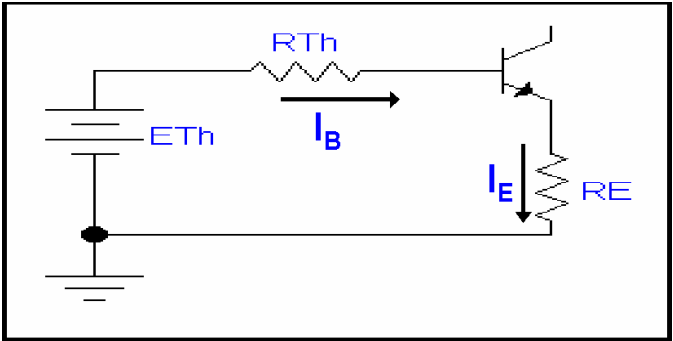


$R_{Th}=R_1||R_2$



$E_{Th}=V_{R2}=R_2V_{cc}/(R_1+R_2)$

The Thévenin Equivalent circuit is



Therefore the KVL equation will be

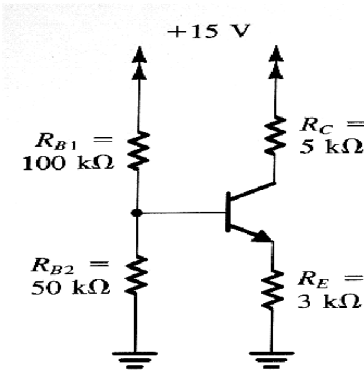
$$E_{Th} - I_B R_{Th} - V_{BE} - I_E R_E = 0$$

Putting $I_E = (\beta + 1) I_B$ and solving for I_B

$$I_B = \frac{E_{Th} - V_{BE}}{R_{Th} + (\beta + 1) R_E}$$

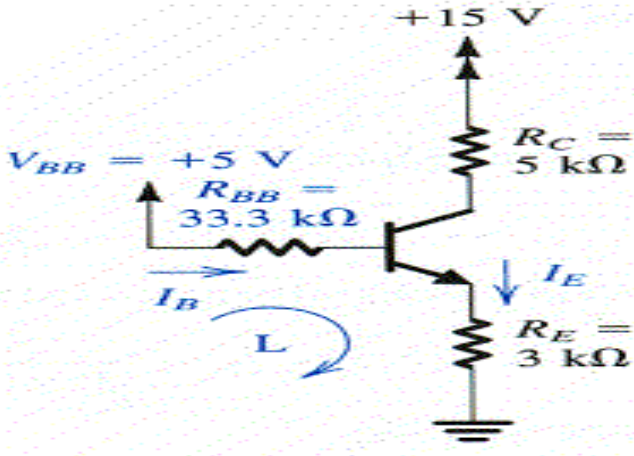
Once I_B is known the remaining problem may be solved exactly as in the previous configurations.

Example: Find voltage at all nodes and current through all branches. Assume $\beta=100$.



Solution:

Using Thevenin's theorem the circuit takes the form as shown in the figure.



By writing

$$V_{BB} = 15(R_{B2}) / (R_{B1} + R_{B2})$$

$$= 15(50) / 150 = 5V$$

$$R_{BB} = R_{B1} \parallel R_{B2}$$

$$= 100 \parallel 50 = 33.3k\Omega$$

Writing the KVL equation for the loop L

$$V_{BB} = I_B R_{BB} + V_{BE} + I_E R_E$$

Put $I_B = I_E / (\beta + 1)$

$$I_E = \frac{V_{BB} - V_{BE}}{R_E + [R_{BB} / (\beta + 1)]}$$

$$I_E = \frac{5 - 0.7}{3 + (33.3 / 101)} = 1.29mA$$

The base current will be

$$I_B = 1.29 / 101 = 0.0128mA$$

Therefore the base voltage will be

$$V_B = V_{BE} + I_E R_E$$

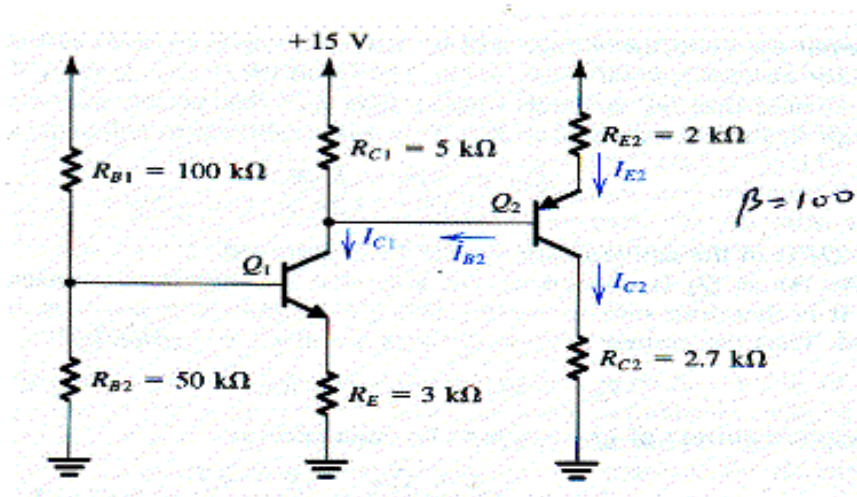
$$= 0.7 + 1.29(3) = 4.57V$$

Assuming active mode the collector current will be

$$I_{C1} = \alpha I_E = 0.99(1.29) = 1.28mA$$

And $V_C = 15 - I_{C1} R_{C1} = 15 - 1.28(5) = 8.6V$

Example: For the circuit shown find the voltages at all nodes and current through all branches.



Solution:

Assume Q1 is in active mode,

Therefore, from previous example

$$V_{B1} = 4.57V$$

$$I_{E1} = 1.29mA$$

$$I_{B1} = 0.0128mA$$

$$I_{C1} = 1.28mA \text{ (assuming } I_{B1} \text{ negligibly small)}$$

Hence

$$V_{C1} = 15 - I_{C1} R_{C1} = 15 - (1.28)5 = 8.6V$$

Now assume that emitter base junction of Q2 is forward bias, hence

$$V_{E2} = V_{C1} + V_{EB} \\ = 8.6 + 0.7 = 9.3V$$

$$\text{Also } I_{E2} = (15 - V_{E2}) / R_{E2} \\ = (15 - 9.3) / 2k$$

$$I_{E2} = 2.85mA$$

Now grounding of Q2 collector through R_{C2} shows, BC junction reverse bias

$$I_{C2} = \alpha I_{E2} \\ = 0.99(2.85m) \\ = 2.82mA \quad (\beta = 100) \\ \therefore V_{C2} = I_{C2} R_{C2} = 7.62V$$

The value of V_{C2} is lower than $V_{B2} = V_{C1}$ by 0.98V, therefore, Q2 is active.

Now errors

$$I_{B2} = I_{E2} / (\beta_2 + 1) \\ = 2.85m / 101 \\ = 0.028mA$$

Now doing iterations for I_{C1} and I_{B2}

$$I_{C1} = I_{C1} - I_{B2} = 1.25mA$$

$$V_{C1} = 15 - 5(1.252m) = 8.74V$$

$$V_{E2} = 8.74 + 0.7 = 9.44V$$

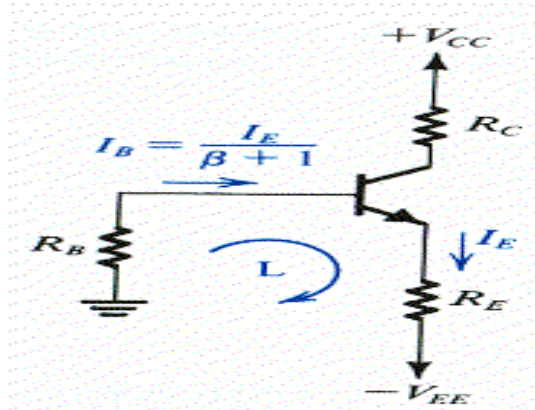
$$I_{E2} = (15 - 9.44) / 2k = 2.78mA$$

$$I_{C2} = 0.99(2.78m) = 2.75mA$$

$$V_{C2} = 2.75(2.7) = 7.43V$$

$$I_{B2} = 2.78 / 101 = 0.0275mA$$

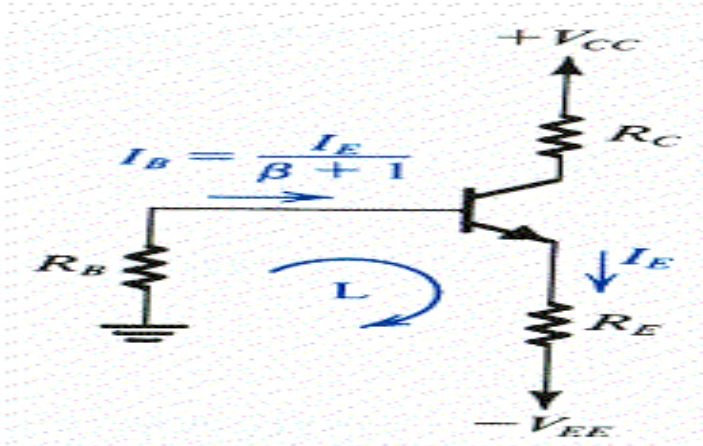
Biasing using two power supplies:



The loop equation for the loop marked as L is

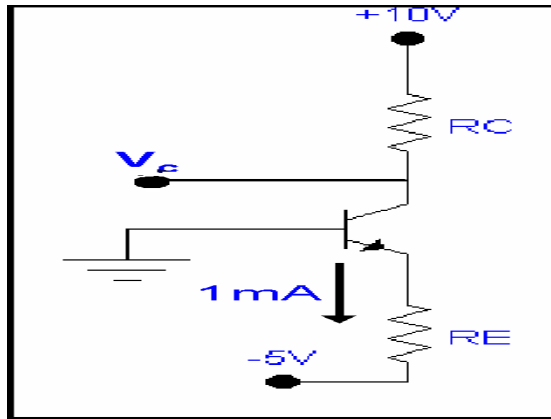
$$I_E = \frac{V_{EE} - V_{BE}}{R_E + R_B / (\beta + 1)}$$

Example: The bias arrangement shown in the figure is to be used in common base amplifier. Design the circuit to establish a dc emitter current of 1mA and provide the highest possible gain while allowing for a maximum signal swing of $\pm 2V$ at the collector. Use +10V and -5V power supplies.



Solution:

Since the amplifier is to use in common base configuration, therefore the circuit will take the form as shown.



hence $R_B = 0$

Considering the base-emitter junction forward biased, the emitter resistance can be found as
 $R_E = (-0.7 - (-5)) / 1\text{mA} = 4.3\text{k}\Omega$

In order to allow for $\pm 2V$ signal swing at the collector, while choosing as larger value of R_C as possible, set $V_C = +2V$, therefore -2V signal would not saturate the BJT. Thus

$$\begin{aligned} R_C &= (10 - 2) / I_C \\ &= 8 / 1\text{mA} \\ R_C &= 8\text{k}\Omega \end{aligned}$$



DOWNLOAD SOLVED FINAL

PAST PAPERS BY WAQAR SIDDHU

More in PDF From

VU Answer

Get All Solutions.

Which of the following is not basic SI unit

Answer (Please select your correct option)

VuAnswers.com

☐ Ampere

☐ Henry

correct

☐ Second

☐ Kelvin

Made by: Waqar Siddhu

An element with 6 protons and 6 neutrons has atomic no. value

Answer (Please select your correct option)

VuAnswers.com

☐ 6

correct

☐ 12

☐ 18

☐ 8

Made by: Waqar Siddhu

If we connect n inductances in series, total inductance will be

Answer (Please select your correct option)

VuAnswers.com

☐ reciprocal of combined effect of all these inductances

☐ sum of individual inductance

correct

☐ product of all these

☐ sum of first and last inductance

Made by: Waqar Siddhu

With high voltage, the Current can have a Low value when there is

Answer (Please select your correct option)

VuAnswers.com

☐ High resistance

correct

☐ Low resistance

☐ Constant resistance

☐ No resistance

Made by: Waqar Siddhu

Using superposition theorem, for a circuit containing independent sources, any remaining voltage source is

Answer (Please select your correct option)

VuAnswers.com

☐ remain same

☐ made zero by replacing them by open circuit

☐ made zero by replacing them by capacitor

☐ made zero by replacing them by short circuit

correct

Made by: Waqar Siddhu

For proper working of a clamper, time constant of the circuit should be

Answer (Please select your correct option)

VuAnswers.com

☐ Large

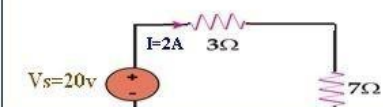
☐ Small

☐ Equal to signal time period

☐ Greater than 5 times the signal time -period

Made by: Waqar Siddhu

For the given figure, Power dissipated through voltage source is



Answer (Please select your correct option)

VuAnswers.com

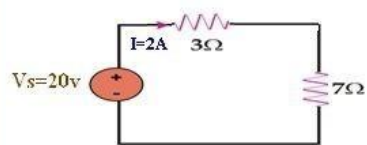
20w

40w

80w

10w

Made by: Waqar Siddhu



Answer (Please select your correct option)

VuAnswers.com

☐ 20w☐ 40w☐ 80w☐ 10w**Made by: Waqar Siddhu**

In source transformation, a current source can be converted into voltage source if

Answer (Please select your correct option)

VuAnswers.com

☐ current source lies in parallel to a resistance R

correct

☐ current source lies in series to a resistance R

☐ two current sources are in series

☐ current and voltage source lie in parallel

Made by: Waqar Siddhu

In thevenin's theorem , while calculating thevenin's resistance, R_{th}

Answer (Please select your correct option)

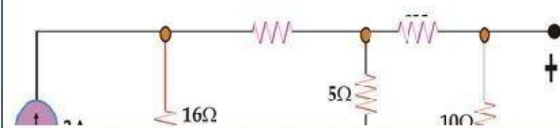
VuAnswers.com

- ☐ just open circuit current source
- ☐ Short circuit the current source and open circuit the voltage source
- ☐ open circuit the current source and short circuit the voltage source
- ☐ insert the load

correct

Made by: Waqar Siddhu

In order to find R_{th} (Thevenin's Resistance), which one is true from the given below options.



Answer (Please select your correct option)

VuAnswers.com

☐ open circuit 3A and short circuit 12v

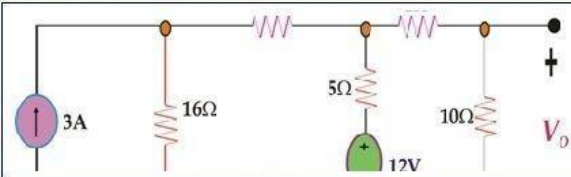
correct

☐ open circuit 12v and short circuit 3A

☐ open circuit both sources

☐ just remove 10 ohm

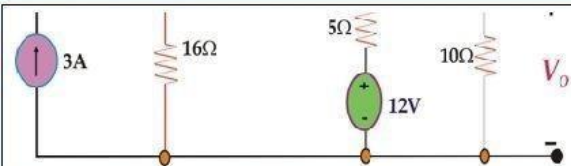
Made by: Waqar Siddhu



Answer (Please select your correct option)

VuAnswers.com

☐ open circuit 3A and short circuit 12vcorrect☐ open circuit 12v and short circuit 3A☐ open circuit both sources☐ just remove 10 ohm**Made by: Waqar Siddhu**



Answer (Please select your correct option)

VuAnswers.com

☐ open circuit 3A and short circuit 12vcorrect☐ open circuit 12v and short circuit 3A☐ open circuit both sources☐ just remove 10 ohm**Made by: Waqar Siddhu**

In Norton's theorem , while calculating R_n

Answer (Please select your correct option)

VuAnswers.com

☐ Short circuit the current source and open circuit the voltage source

☐ open circuit the current source and short circuit the voltage source

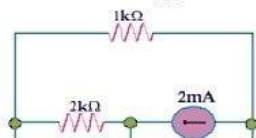
correct

☐ insert the load

☐ just open circuit current source

Made by: Waqar Siddhu

For the given circuit, if Norton's current I_{Ner} is 5A and Norton's Resistance R_N 10 ohm. To find I_o , the Norton's equivalent circuit will have



Answer (Please select your correct option)

VuAnswers.com

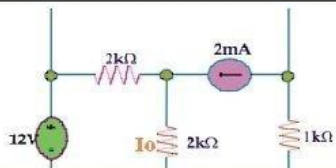
☐ I_{Ner} and R_N in parallel of 1KΩ

☐ I_{Ner} and R_N in series of 2KΩ

☐ I_{Ner} and R_N in parallel of 2KΩ

☐ R_N in parallel of 2KΩ

Made by: Waqar Siddhu

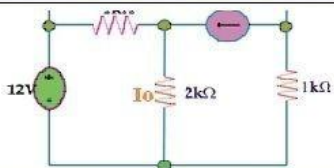


Answer (Please select your correct option)

VuAnswers.com

☐ I_{Ner} and R_N in parallel of $1K\Omega$
☐ I_{Ner} and R_N in series of $2K\Omega$
☐ I_{Ner} and R_N in parallel of $2K\Omega$
☐ R_N in parallel of $2K\Omega$

Made by: Waqar Siddhu



Answer (Please select your correct option)

VuAnswers.com

☐ I_{Ncr} and R_N in parallel of $1K\Omega$ ☐ I_{Ncr} and R_N in series of $2K\Omega$ ☐ I_{Ncr} and R_N in parallel of $2K\Omega$ ☐ R_N in parallel of $2K\Omega$ **Made by: Waqar Siddhu**

Thermal ionization in semiconductor results, creating of

Answer (Please select your correct option)

VuAnswers.com

☐ only free electrons

☐ only holes

☐ both free electrons and holes

correct

☐ nothing

Made by: Waqar Siddhu

For a P-N junction under reverse bias

Answer (Please select your correct option)

VuAnswers.com

☐ more forward current flows

☐ no forward current flows

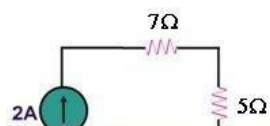
correct

☐ no reverse current flows

☐ infinite reverse current flows

Made by: Waqar Siddhu

Current flowing through 5Ω resistance will be



Answer (Please select your correct option)

VuAnswers.com

☐ 1.1A

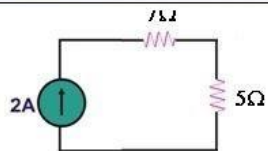
☒ 2A

correct

☐ 10A

☐ 14A

Made by: Waqar Siddhu

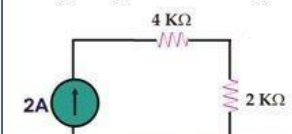


Answer (Please select your correct option)

VuAnswers.com

☐ 1.1A☐ 2A☐ 10A☐ 14A**Made by: Waqar Siddhu**

In the given fig. Current flowing through $4\text{k}\Omega$ resistance will be



Answer (Please select your correct option)

VuAnswers.com

8A

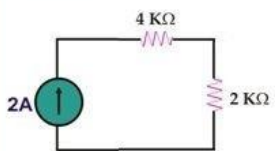
2A

correct

4A

0.6A

Made by: Waqar Siddhu

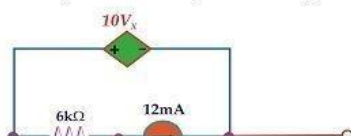


Answer (Please select your correct option)

VuAnswers.com

☐ 8A☐ 2A☐ 4A☐ 0.6A**Made by: Waqar Siddhu**

In the given circuit, the value of dependent voltage source is



Answer (Please select your correct option)

VuAnswers.com

☐ V_x

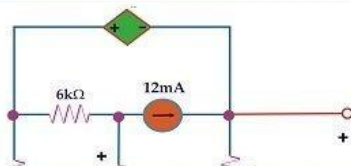
☐ V_o

correct

☐ $10V_x$

☐ $12mA$

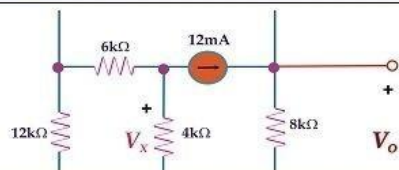
Made by: Waqar Siddhu



Answer (Please select your correct option)

VuAnswers.com

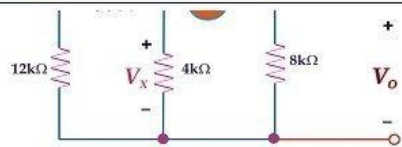
☐ V_x ☐ V_o ☐ $10V_x$ ☐ $12mA$ **Made by: Waqar Siddhu**



Answer (Please select your correct option)

VuAnswers.com

☐ V_x ☐ V_o ☐ $10V_x$ ☐ 12mA **Made by: Waqar Siddhu**



Answer (Please select your correct option)

VuAnswers.com

☐ V_x ☐ V_o ☐ $10V_x$ ☐ $12mA$ **Made by: Waqar Siddhu**

In a loop analysis , which of the following is true?

Answer (Please select your correct option)

VuAnswers.com

☐ No. of equations to be written is equal to No. of loops

correct

☐ No. of equations to be written is equal to 1 minus No. of loops

☐ No. of equations to be written is equal to twice the No. of loops

☐ No. of equations to be written is equal to half the No. of loops

Made by: Waqar Siddhu

When ideal diode acting as short circuit

Answer (Please select your correct option)

VuAnswers.com

☐ V is maximum

☐ V is half of applied voltage

☐ $V=0$

correct

☐ no current flows

Made by: Waqar Siddhu

AC or dynamic resistance of diode is due to

Answer (Please select your correct option)

VuAnswers.com

- ☐ changing value V_D and I_D of diode by applying DC voltage
- ☐ fixed value V_D and I_D of diode by applying DC voltage
- ☐ changing value V_D and I_D of diode by applying varying input signal
- ☐ fixed resistance of diode by applying AC voltage

Made by: Waqar Siddhu

The primary and secondary winding of transformer are

Answer (Please select your correct option)

VuAnswers.com

☐ physically touched

☐ physically isolated

correct

☐ touched with conductor

☐ largely separated

Made by: Waqar Siddhu

For secondary turns of 10 and primary turns of 20, turn ratio is

Answer (Please select your correct option)

VuAnswers.com

☐ 20:20

☐ 10:20

☐ 10:10

☐ 20:10

correct

Made by: Waqar Siddhu

When the turn ratio of a transformer is 5 and primary ac voltage is 10v, the secondary voltage is

Answer (Please select your correct option)

VuAnswers.com

☐ 100v

☐ 25v

☐ 50v

☐ 2v

correct

Made by: Waqar Siddhu

which relation is true for transformer primary and secondary power?

Answer (Please select your correct option)

VuAnswers.com

☐ $V_1 V_2 = I_1 I_2$

☐ $V_2 I_2 = V_1 I_1$

☐ $V_2 I_1 = V_1 I_2$

☐ $I_2 I_1 = V_2 V_1$

Made by: Waqar Siddhu

The PIV of a half wave rectifier is

Answer (Please select your correct option)

VuAnswers.com

☐ $V_{(pk)}$

correct

☐ $2V_m$

☐ $V_m/2$

☐ $3V_m$

Made by: Waqar Siddhu

As diode conducts the electrical current only in one direction, hence it is consider as a

Answer (Please select your correct option)

VuAnswers.com

☐ Switch correct

☐ Amplifier

☐ Capacitor

☐ Inductor

Made by: Waqar Siddhu

Which stage of a power supply uses a Zener as the main component? Select one of the given choice.

Answer (Please select your correct option)

VuAnswers.com

☐ Rectifier

☐ Voltage divider

☐ Regulator

correct

☐ Filter

Made by: Waqar Siddhu

Leakage current of a junction diode

Answer (Please select your correct option)

VuAnswers.com

☐ Decrease with more temperature

correct

☐ Is due to majority carriers

☐ Depends on the method of its fabrication

☐ Is the range of mA or micro Ampere

Made by: Waqar Siddhu

In a properly biased NPN transistor most of the electrons from the emitter

Answer (Please select your correct option)

VuAnswers.com

- ☐ Recombine with holes in base
- ☐ Recombine with emitter itself
- ☐ Pass through the base to the collector
- ☐ Are stopped by the junction barrier

correct

Made by: Waqar Siddhu

The current flow across the base-emitter junction of a p-n-p transistor consists of

Answer (Please select your correct option)

VuAnswers.com

☐ Mainly electrons

☐ Equal numbers of holes and electrons

☐ Mainly holes

correct

☐ The leakage current

Made by: Waqar Siddhu

Which of the following is not correct statement.

Answer (Please select your correct option)

VuAnswers.com

☐ Proton is 1840 times heavier than electron.

☐ The total number of electrons in the outer rings must equal to the number of protons in the nucleus in a neutral atom

☐ The electrons in an atom are bound to the protons in the nucleus by the electromagnetic force

☐ As a whole an atom is not neutral particle

correct

Made by: Waqar Siddhu

How many electron charges are there in the practical unit of one coulomb.

Answer (Please select your correct option)

VuAnswers.com

- ☐ 4.5×10^6
- ☐ 6.5×10^{16}
- ☐ 6.25×10^{18}
correct
- ☐ 1.9×10^{-19}

Made by: Waqar Siddhu

If magnitude of the current is controlled by input current the source is called

Answer (Please select your correct option)

VuAnswers.com

☒ Current controlled current source

correct

☐ Current controlled voltage source

☐ Voltage controlled voltage source

☐ Voltage controlled current source

Made by: Waqar Siddhu

Current divider is used when

Answer (Please select your correct option)

VuAnswers.com

☐ Two or more resistances are in series of a voltage source

☐ Two or more resistances are in parallel of a voltage source

☐ Two or more resistances are in series of a current source

☐ Two or more resistances are in parallel of a current source

correct

Made by: Waqar Siddhu

Leakage current of semiconductor diode is caused by

Answer (Please select your correct option)

VuAnswers.com

☐ chemical energy

☐ heat energy

☐ barrier voltage

☐ doping impurity

correct

Made by: Waqar Siddhu

Distance or link between two nodes is called

Answer (Please select your correct option)

VuAnswers.com

☐	Branch	<u>correct</u>
☐	Loop	
☐	node	
☐	super mesh	

Made by: Waqar Siddhu

Using superposition theorem, for a circuit containing independent sources, any remaining current source is

Answer (Please select your correct option)

VuAnswers.com

☐ replaced by short circuit

☐ made zero by replacing them by open circuit

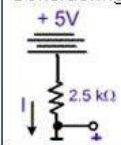
correct

☐ replaced by close circuit

☐ replaced by capacitor

Made by: Waqar Siddhu

Considering diode to be ideal , current flowing through resistance will be



Answer (Please select your correct option)

VuAnswers.com

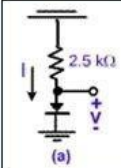
5mA

2mA

zero ampere

2.5mA

Made by: Waqar Siddhu

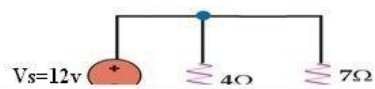


Answer (Please select your correct option)

VuAnswers.com

☐ 5mA☐ 2mA☐ zero ampere☐ 2.5mA**Made by: Waqar Siddhu**

Across which resistance more voltage is dropped



Answer (Please select your correct option)

VuAnswers.com

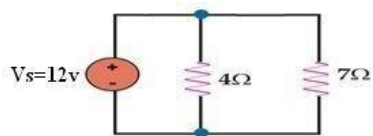
☐ 4Ω

☐ 7Ω

☐ same across both

☐ no voltage drop

Made by: Waqar Siddhu



Answer (Please select your correct option)

VuAnswers.com

☐ 4Ω☐ 7Ωcorrect☐ same across both☐ no voltage drop**Made by: Waqar Siddhu**

Through which resistance least current will flow



Answer (Please select your correct option)

VuAnswers.com

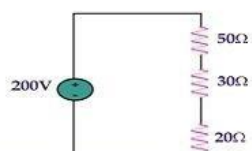
☐ 50Ω

☐ 30Ω

☐ 20Ω

☐ same through all resistance

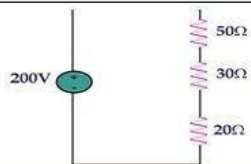
Made by: Waqar Siddhu



Answer (Please select your correct option)

VuAnswers.com

☐ 50Ω☐ 30Ω☐ 20Ω☐ same through all resistance**Made by: Waqar Siddhu**



Answer (Please select your correct option)

VuAnswers.com

☐ 50Ω☐ 30Ω☐ 20Ω☐ same through all resistancecorrect**Made by: Waqar Siddhu**

Which of the following statement is not correct?

Answer (Please select your correct option)

VuAnswers.com

☐ An open circuit has zero current.

☐ A short circuit has excessive current.

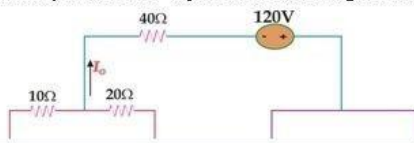
☐ An open circuit and a short circuit have opposite effects on resistance and current.

☐ A closed circuit do not allow flow of current

correct

Made by: Waqar Siddhu

How many sources are dependent sources in given circuit?



Answer (Please select your correct option)

VuAnswers.com

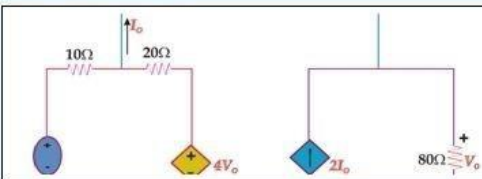
3

2

4

1

Made by: Waqar Siddhu



Answer (Please select your correct option)

VuAnswers.com

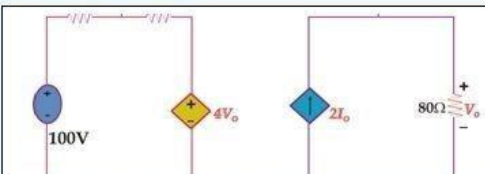
3

2

4

1

Made by: Waqar Siddhu



Answer (Please select your correct option)

VuAnswers.com

3

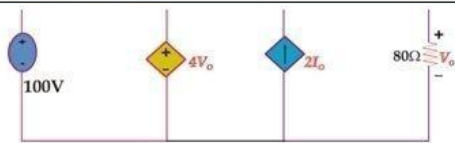
2

correct

4

1

Made by: Waqar Siddhu



Answer (Please select your correct option)

VuAnswers.com

3

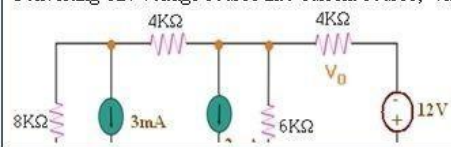
2

4

1

Made by: Waqar Siddhu

Converting 12v voltage source into current source, value of converted current source will be



Answer (Please select your correct option)

VuAnswers.com

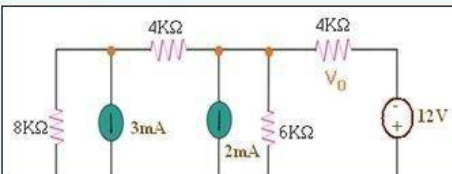
☐ 3mA

☐ 2mA

☐ 48mA

☐ 1mA

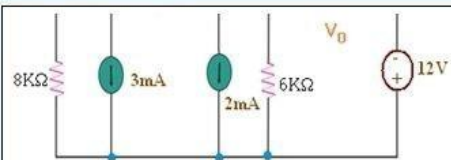
Made by: Waqar Siddhu



Answer (Please select your correct option)

VuAnswers.com

☐ 3mAcorrect☐ 2mA☐ 48mA☐ 1mA**Made by: Waqar Siddhu**



Answer (Please select your correct option)

VuAnswers.com

☐ 3mA☐ 2mA☐ 48mA☐ 1mA**Made by: Waqar Siddhu**

For a circuit containing dependent voltage source, if Thevenin's voltage V_{th} is 10v and I_{sc} is 2A, Thevenin's Resistance R_{th} will be

Answer (Please select your correct option)

VuAnswers.com

☐ 10 Ω

☐ 20 Ω

☐ 5 Ω

☐ 0.5 Ω

Made by: Waqar Siddhu

For a circuit containing dependent voltage source, if Thevenin's voltage V_{th} is 15v and I_{sc} is 5A, Thevenin's Resistance R_{th} will be

Answer (Please select your correct option)

VuAnswers.com

☐ 6Ω

☐ 3Ω

☐ 75Ω

☐ 5Ω

Made by: Waqar Siddhu

In a Norton's theorem ,norton's current I_{nor} is calculated

Answer (Please select your correct option)

VuAnswers.com

☐ at open terminals of the open circuit

☐ by short circuiting the open terminal of the circuit

☐ across the load

☐ any where

Made by: Waqar Siddhu

Semiconductor element in pure form is called

Answer (Please select your correct option)

VuAnswers.com

☐ extrinsic

☐ P type

☐ intrinsic

☐ N type

Made by: Waqar Siddhu

For reverse biased condition of P-N junction, which of the following condition is applied?

Answer (Please select your correct option)

VuAnswers.com

- ☐ -Ve polarity to both N electrode and P electrode
- ☐ +Ve polarity to both N electrode and P electrode
- ☐ +Ve polarity to N electrode and -Ve polarity to P electrode
- ☐ +Ve polarity to P electrode and -Ve polarity to N electrode

Made by: Waqar Siddhu

The characteristics of ideal diode when forward biased are

Answer (Please select your correct option)

VuAnswers.com

☐ diode will have maximum current flow

☐ diode will have no voltage drop across its terminals

☐ all of these

☐ Diode will have minimum resistance

Made by: Waqar Siddhu

A transformer is used for

Answer (Please select your correct option)

VuAnswers.com

- ☐ dc voltage
- ☐ ac voltage
- ☐ both ac and dc voltage
- ☐ none of these

Made by: Waqar Siddhu

For secondary turns of 10 and primary turns of 20, turn ratio is

Answer (Please select your correct option)

VuAnswers.com

☐ 20:20

☐ 10:20

☐ 10:10

☐ 20:10

Made by: Waqar Siddhu

The depletion region of a semiconductor diode is due to

Answer (Please select your correct option)

VuAnswers.com

☐ Absence of current carriers

☐ Reverse biasing

☐ Forward biasing

☐ Crystal doping

Made by: Waqar Siddhu

The PIV of a half wave rectifier is

Answer (Please select your correct option)

VuAnswers.com

☐ $V_{(pk)}$

☐ $2V_m$

☐ $V_m/2$

☐ $3V_m$

Made by: Waqar Siddhu

The leakage current of semiconductor diode is caused by

Answer (Please select your correct option)

VuAnswers.com

☐ Chemical energy

☐ Barrier voltage

☐ Heat energy

☐ Doping impurity

Made by: Waqar Siddhu

As diode conducts the electrical current only in one direction, hence it is consider as a

Answer (Please select your correct option)

VuAnswers.com

☐ Switch

☐ Amplifier

☐ Capacitor

☐ Inductor

Made by: Waqar Siddhu

A general purpose diode is more likely to suffer Avalanche breakdown rather than Zener breakdown because

Answer (Please select your correct option)

VuAnswers.com

☐ Its leakage current is small

☐ It has weak covalent bonding

☐ It is lightly doped

☐ It has low reverse resistance

Made by: Waqar Siddhu

The base region of a p-n-p transistor is

Answer (Please select your correct option)

VuAnswers.com

☐ Very thin and heavily doped with holes

☐ Very thin and heavily doped with electrons

☐ Very thin and lightly doped with holes

☐ Very thin and lightly doped with electrons

Made by: Waqar Siddhu

In a properly biased NPN transistor most of the electrons from the emitter

Answer (Please select your correct option)

VuAnswers.com

- ☐ Recombine with holes in base
- ☐ Recombine with emitter itself
- ☐ Pass through the base to the collector
- ☐ Are stopped by the junction barrier

Made by: Waqar Siddhu

In normal /active operation, the junctions of a p-n-p transistor are:

Answer (Please select your correct option)

VuAnswers.com

- ☐ Both forward biased
- ☐ Base-emitter forward biased and base collector reverse biased
- ☐ Both reverse biased
- ☐ Base-collector forward biased and base-emitter reverse biased

Made by: Waqar Siddhu

For a transistor, if value of α is 0.9, and the emitter current (I_E) is 4mA, then

Answer (Please select your correct option)

VuAnswers.com

☐ The base current is approximately 4.4mA

☐ The collector current (I_C) is approximately 3.6mA

☐ The collector current is approximately 4.4mA

☐ The base current is approximately 3.6mA

Made by: Waqar Siddhu

MORE PAST PAPERS BY WAQAR SIDDHU

Provide Solved in PDF From

VU Answer

Get All Solutions.





DOWNLOAD SOLVED FINAL

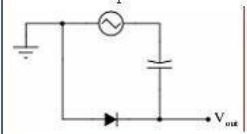
PAST PAPERS BY WAQAR SIDDHU

Get in PDF From

VU Answer

Get All Solutions.

Draw the output waveform shape for this circuit, assuming an ideal diode (no forward voltage drop and no reverse leakage):



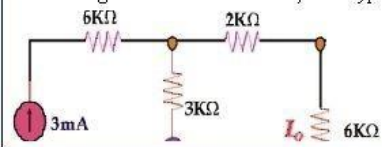
Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

Considering the Norton's theorem, what type of changes you will do in the circuit to find Norton's Resistance R_N . Draw the circuit only.

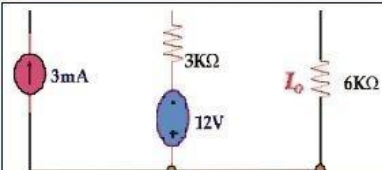


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

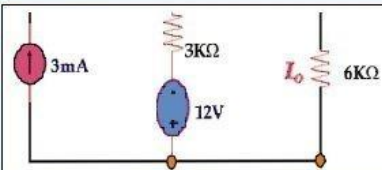


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu



Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

State Kirchhoff's voltage law (KVL).

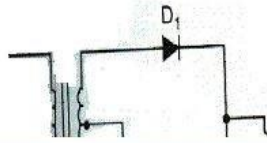
Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

What type of changes you will do in the circuit to make it Negative Full wave rectifier?

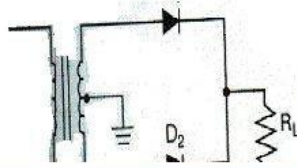


Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

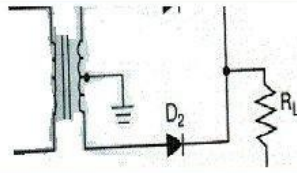


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

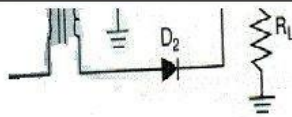


Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu



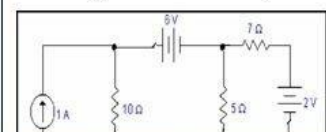
Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

Label the given circuit for node, reference node and super node.

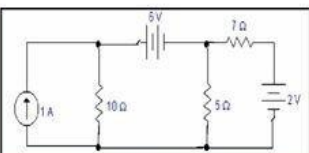


Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

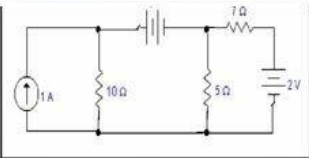


Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu



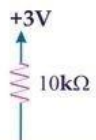
Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

For the circuit shown in the figure below using ideal diode, find the value of the indicated voltage and current.

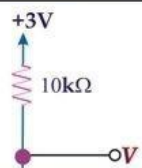


Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

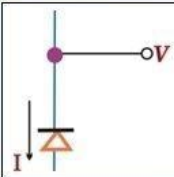


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

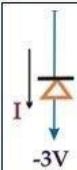


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu



Answer ([Please click here to Add Answer](#))

VuAnswers.com



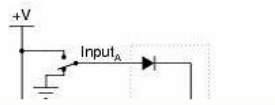
Made by: Waqar Siddhu

Answer (Please [click here](#) to Add Answer)

Made by: Waqar Siddhu

Made by: Waqar Siddhu

Crude logic gates circuits may be constructed out of nothing but diodes and resistors. Take for example this logic gate circuit:

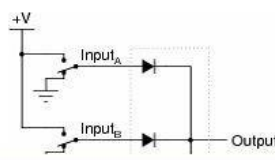


Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

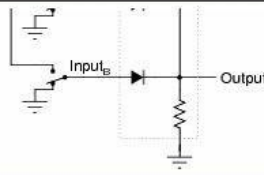


Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

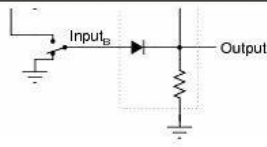


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu



Identify what type of logic function is represented by this gate circuit

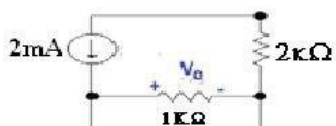
Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

Label the circuit properly. Use any technique to find out the V_o for the given circuit.



Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

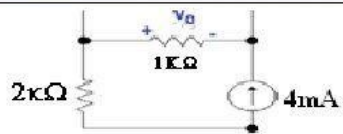


Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu



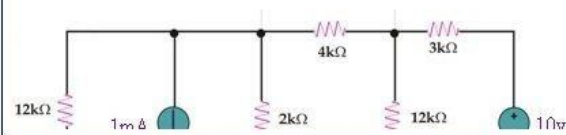
Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

Using the **Source transformation method**, how will you convert **10v** voltage source into current source and **1mA** into voltage source in the following circuit? Draw diagrams of converted circuit.

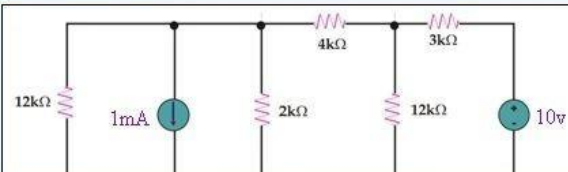


Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

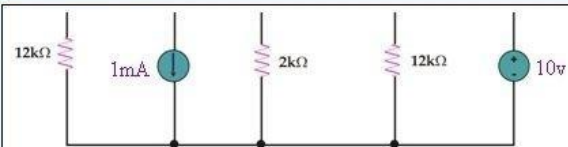


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu



Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

Given below are two figures (a) and (b) having Diode, which diode is forward biased or reversed biased? tell reason.

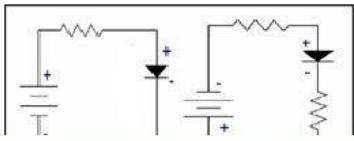


Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

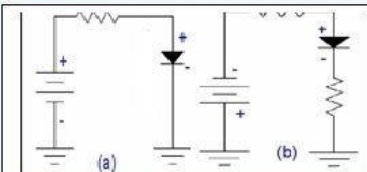


Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu



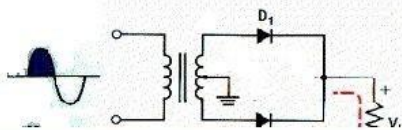
Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

Describe the basic circuit operation of Full wave rectifier for both input signals, shown at left side of given fig..

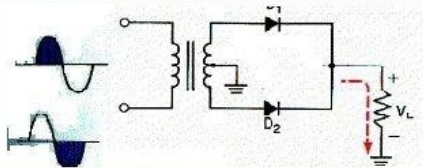


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu



Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

Write a brief description about LEDs.

Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

What will happen when
(I) two like charges come close
(II) two opposite charges come close

Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

Mention the P- type and n -type for Diode symbol given below.



Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

Write the formula to calculate PIV for half wave rectifier.

Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

What is the relationship between the polarity of the voltage applied to the PNP transistor and that applied to the NPN transistor?

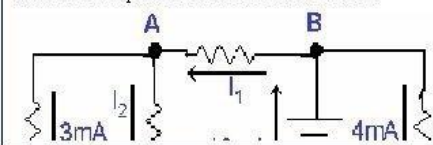
Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

Write KCL equation for node A and node B.

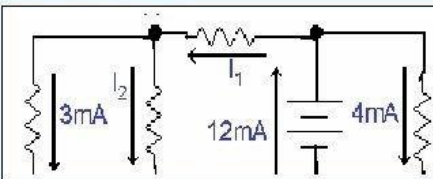


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

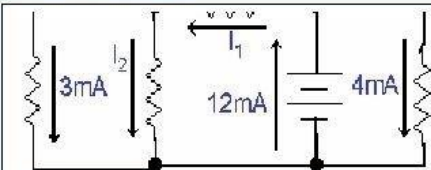


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu



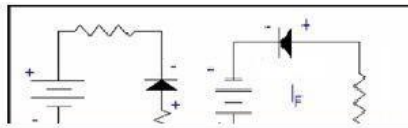
Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

Given below are two figures (a) and (b) having Diode, In which diode current will flow and will not flow? Give its reason.

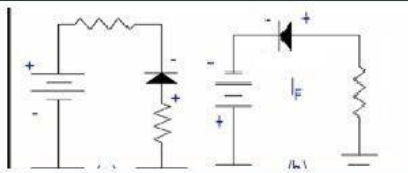


Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

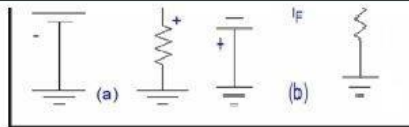


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu



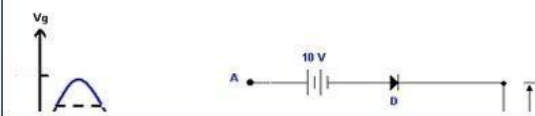
Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

Tell the name of circuit in fig (b) and how it response for input signal of fig. (a)?

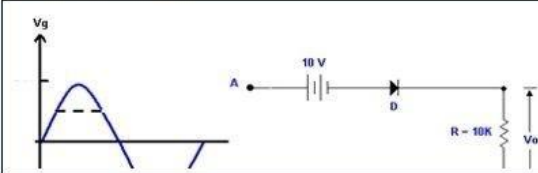


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

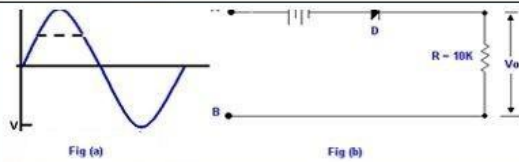


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu



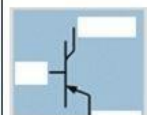
Answer (Please [click here](#) to Add Answer)

VuAnswers.com

Normal Arial 12 B I U

Made by: Waqar Siddhu

Label the given diagram for transistor symbol and write its type as well.



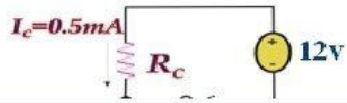
Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

For the circuit shown, find I_E & R_C

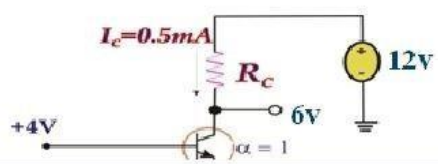


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

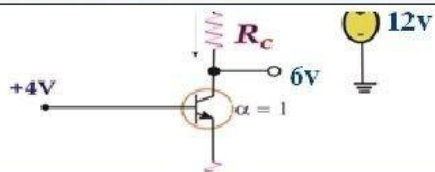


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

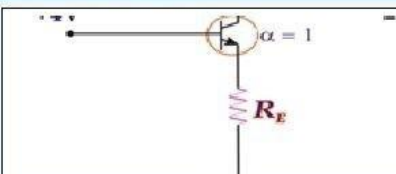


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

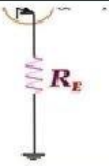


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu



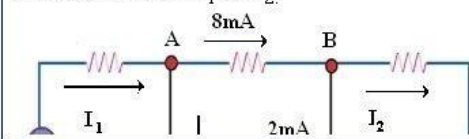
Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

Calculate the values of I_1 and I_2 .

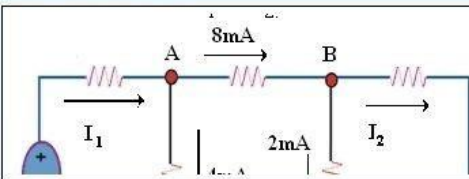


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

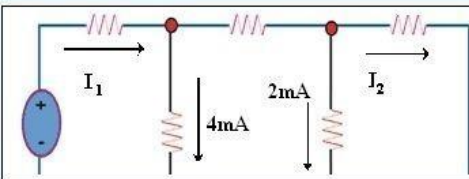


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu



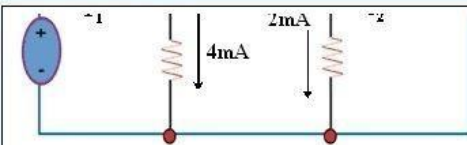
Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Normal Arial 12 B I U

Made by: Waqar Siddhu



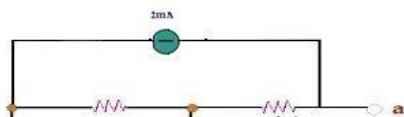
Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

Using the **Thevenin's Theorem**, find Thevenin's Resistance R_{th} to the left of a,b . Draw the circuit.

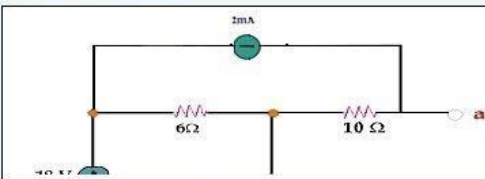


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

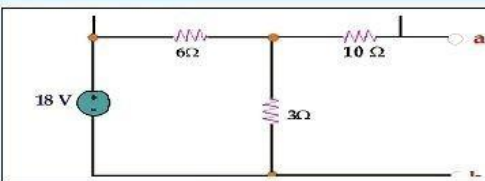


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu



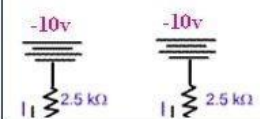
Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

Find the value of current I and voltage V in the circuits shown in figure (a) and (b). (Assuming the diodes to be ideal).

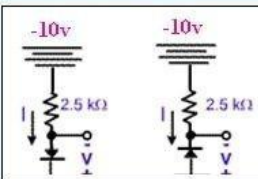


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

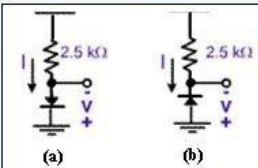


Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu



Answer (Please [click here](#) to Add Answer)

VuAnswers.com



Made by: Waqar Siddhu

Find the value of the diode small signal resistance r_d at bias current of 0.1mA and 10mA. Assume $n=1$

Answer ([Please click here to Add Answer](#))

VuAnswers.com



Made by: Waqar Siddhu

MORE PAST PAPERS BY WAQAR SIDDHU

Provide Solved in PDF From

VU Answer

Get All Solutions.

