UGANDA BUSINESS AND TECHNICAL EXAMINATIONS BOARD (UBTEB)
November/December 2019 Examination Series

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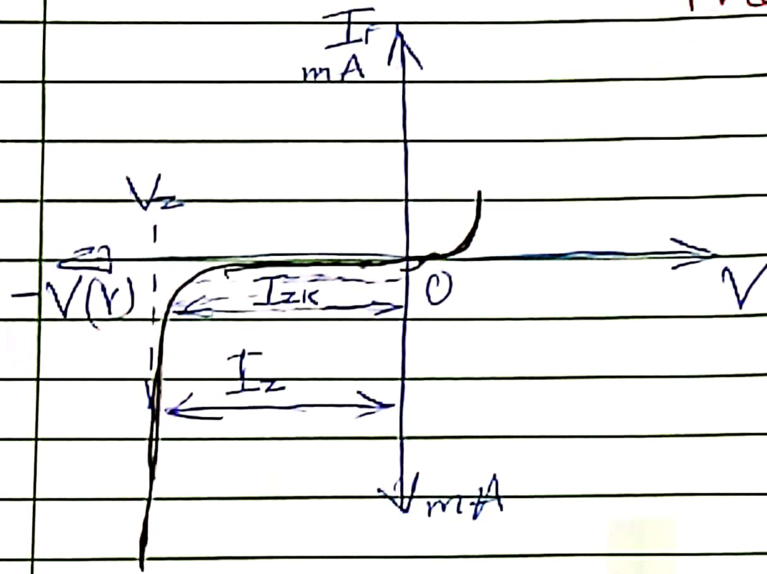
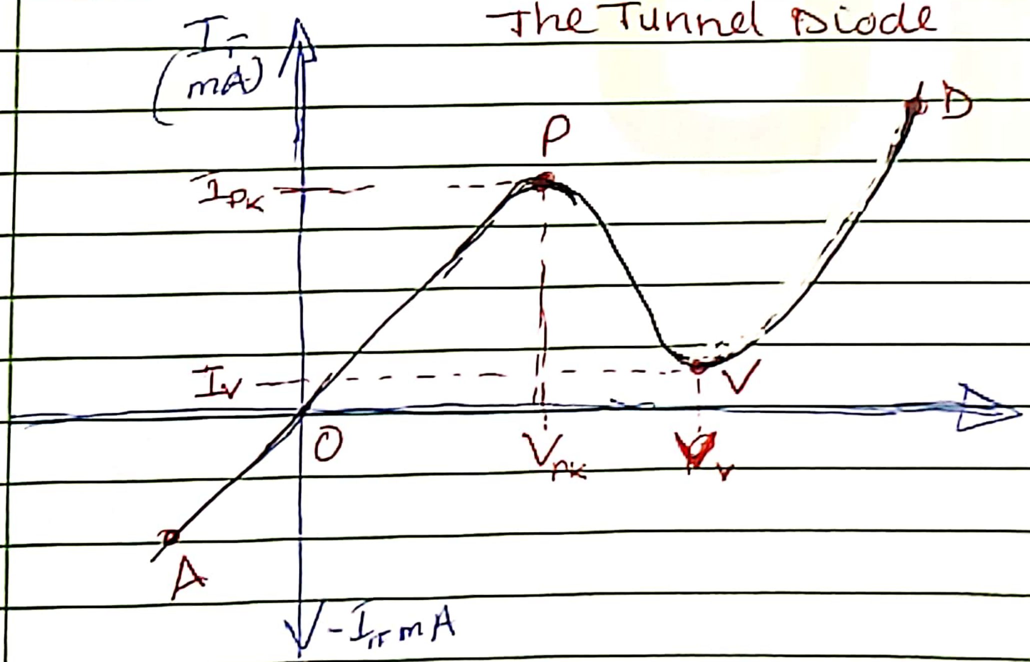
The I-V X-tics of some diodes

The Zener Diode



The Tunnel Diode



- Btn AP, current flow is mainly due to tunnelling
- Failure to sustain tunnelling gives rise to the -ve resistance region PV

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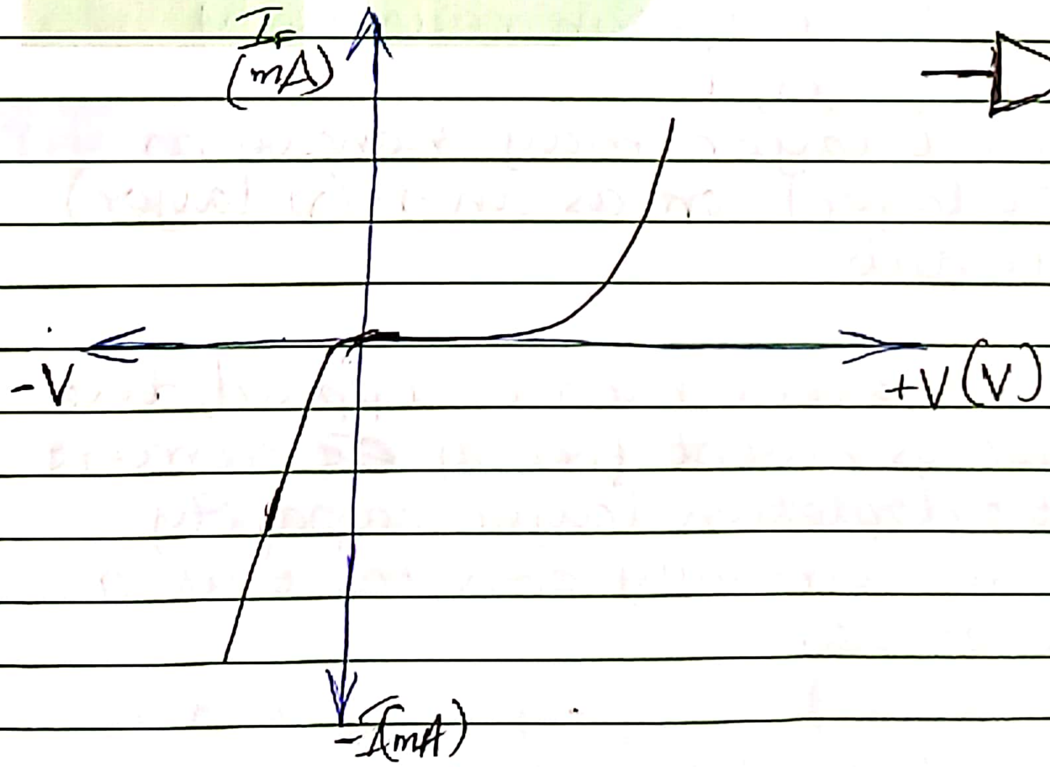
Btn V.P.,
normal conduction is resumed.

Tunnel diodes can switch btn P and V in a matter of picoseconds, hence their use in fast-switching circuitry.

- When operated (biased) in the -ve resistance region, tunnel diodes can be used in hf oscillators and amplifiers.

The Backward diode:



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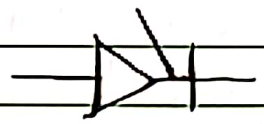
The pin diode



The p-and n-regions are heavily doped (order of
and are denoted by p^+ and n^+ and separated by a high resistivity intrinsic layer, i

\# This i-layer may behave as p (π-layer) or as an n (ν-layer) material.

When a reverse-bias is applied, the π-layer is swept free of ~~e's~~ carriers and the depletion-layer capacity remains virtually constant at a small value.

\# The diode has a high impedance even at μ-wave freqs.

- Under forward-bias conditions, holes from the p layer and e's from the

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n-layer are injected into the i-region, making its h-f imped low & mainly resistive.

Hence, pin diodes are often
- used μ-wave striplines, as:
  - variable impedances,
  - and as switches.
- pins diodes are also used as good H.V rectifiers.

This is possible when the width of the i-region is large. And by this, the reverse-voltage required to ~~break~~ produce a breakdown is enormous, ie high.

The step-recovery (or snap) diode.

The PIN structure is also used in step-recovery diodes.
The width of the i-region is made small & as the stored charge lies in this region, it is quickly removed ~~as~~ when the bias on the diode is changed from a forward to a reverse state.
Thus, the voltage across the diode at first stays low and then abruptly changes to a high reverse value.

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The Schottky diode

LED / photo diodes

Photodiodes

~~Pho~~ ~~Photoresistors~~ tors

Thermistor

~~The thermistor, Sensistor~~

Sensistor

Some terms expected to be learned:

- Semiconductor
- Intrinsic
- electron
- hole
- resistivity
- doping
- dopant
- donor
- acceptor
- extrinsic
- majority carrier
- minority carrier
- n-type
- p-type
- π-type
- ν-type
- degenerate (semiconductor)

Bi

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{The Zener Regulator}

UGANDA BUSINESS AND TECHNICAL EXAMINATIONS BOARD (UBTEB) 414076
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Date: .... Intake (Tick in appropriate box) March ☐ August ☐

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READ THE INSTRUCTIONS BELOW CAREFULLY BEFORE USING THE ANSWER BOOKLET.

1. Use a blue or black ball pen.
2. List the question numbers in the order attempted, in the left-hand column of the boxes opposite.

   Do not list the multiple choice questions.
3. Write your answers on both sides of each sheet, on ruled pages only.
4. Do your rough work in this answer booklet. Cross through any work you do not want marked
5. Do not tear any part of the answer booklet. All work must be handed in.
6. Check to ensure that you have written the information required on each individual answer booklet used. Tie all the booklets used together with any other necessary materials used.
7. Start each question on a fresh page.
8. Write the number of each question and the candidate's Index number at the top of each page.
9. Answer booklets and other examination materials used or unused, must not be removed by the candidate from the examination room.
10. Writing on any unauthorised material is prohibited.
11. Candidates should note that effective November-December 2019 examinations new regulations will apply. Any attempt to indulge in a malpractice even in one paper will lead to cancellation of results of the entire year/ semester
12. Use the appropriate language required for the paper.
13. **Do not write on the question paper**

Write here the total number of answer booklets you have used.	

Question number attempted	For Examiner's Use only	
	Marks	Examiner's Initials

[A] Design Example, Regulated Supply

You wish to operate a Walkman CD player from the cigar lighter socket on a car dash board. The player requires a 7.5V dc supply and has a 100-mA normal operating current. The car-battery voltage is nominally 12V but when travelling at speed the alternator is charging the battery the terminal voltage could be as high as 14.6V. When stopped at traffic lights the terminal voltage could dip to as low as 11V (courtesy of what

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is operating: lights, wipers, heated rear-screen, etc).

Task:

Designer a simple stabiliser circuit that will ensure that at all times the player has the specified voltage and current and under no conditions does any component suffer from overload.

[A] **Procedure**

1 Start by drawing the basic circuit (Fig Fz)

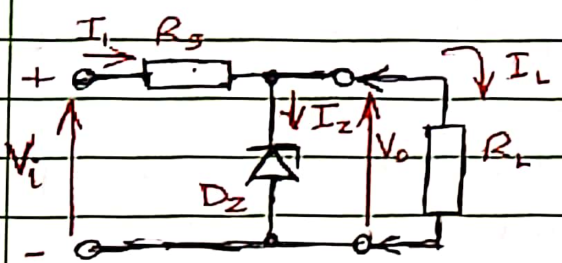

Fig Fz1

2 State the known facts:

$V_i = 11$ to $14.6V$

$V_o = V_z = 7.5V$

$I_L = 100mA$

3 About the unknowns:

a) I_1

Assume D_z is ideal, i.e. $I_{ZK} = 0$.

so, $I_1 = I_L = 100mA$.

b) R_s

R_s is a series resistor whose function is to limit the current flowing in the Zener under no-load conditions.

Yet, 100mA must be available for the load under all conditions:- ie, at $V_{i(min)} = 11V$ to $V_{i(max)} = 14.6V$ (inclusive).

On this range, the worst-case for sufficient I_1 is when $V_i = 11.0V$

~~Next,~~

[B] calculate R_s for $V_{i(min)}$.

$$R_s = \frac{V_{i(min)} - V_z}{I_1}$$

$$= \frac{(11.0 - 7.5)V}{100 \quad mA}$$

$$= 35\Omega$$

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the nearest preferred value (npv) is 33Ω.

Next

check to see what I_i will actually be if $R_s = 33\Omega$, is used.

$$I_i = \frac{V_i(min) - V_z}{R_s}$$

$$= \frac{11.0 - 7.5}{33} = 106mA$$

Because this is higher than 100mA, 33Ω will be suitable.

Next

What current will flow at $V_i(max)$ conditions?

$$I_i = \frac{V_{i(max)} - V_z}{33}$$

$$= \frac{14.6 - 7.5}{33} = \frac{7.1}{33}$$

$$= 215.1mA$$

For D_z, the worst-case situation will occur when V_i is max & the o/p is occ!

So, $I_z = I_i = 215.1mA$ and the Zener power (P_z) will be:

$$I_z \times V_z$$

$$= 215.1(mA) \times 7.5(V)$$

$$= 1.61W.$$

[c]

Selection of Components:

1) D_z

A 7.5V Zener diode is req'd with a minimum power-rating of 1.61W.

From data sheets, Philips' BZX70C7V5 rated at 2.5W finishes off the Zener.

2) R_s (power rating)

Under worst-case conditions, 215.1mA flows.

$$P = I^2R$$

$$= [215.1(mA)]^2 \times 33(\Omega)$$

$$= 1.526W.$$

a 2-W MF resistor of 33Ω would do the job

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[B] The Zener Regulator

This is the most basic regulator (stabiliser) circuit.

- It comprises:

a) a Zener diode D_Z,

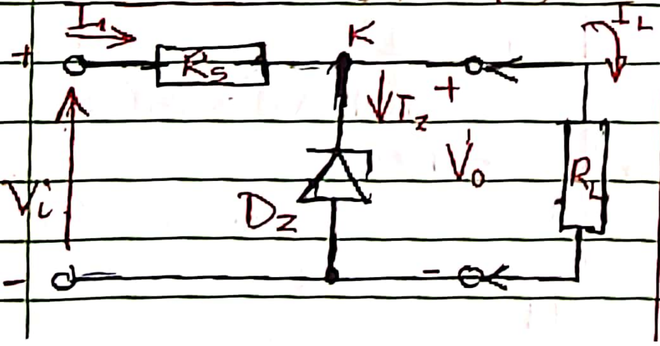
b) a series resitor R_S, and

c) drives a resistive load R_L

d) is supplied from a rectified and filtered supply that may vary.

The purpose of the regulator is to maintain a rated stable o/p voltage V_o (or V_L) at the o/p - despite variations in the line voltage and/or load.

circuit: (Example)



Assume the quotation that:

D_Z is BZX79C6V8 which is 6.8V, 400mW,

$R_L = 390\Omega$ (resistive)

$V_i = 10$ to $13V$

We want to specify R_S.

1) Determine the load current I_L

$I_L = V_o / R_L$

and, here, $V_o = V_Z$.

So, $I_L = V_Z / R_L$

$= \frac{6.8(V)}{390(\Omega)} = 17.4\,mA$

2) I_L can be assumed to be constant because R_L is fixed.

3) Determine the maximum Zener current $I_{Z(max)}$

$I_{Z(max)} = \frac{P_{Z(max)}}{V_Z}$

$= \frac{400\,(mW)}{6.8\,(V)} = 58.8\,mA$

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4) Point K (cathode) forms a Kirchhoff node at which

$I_1 = I_L + I_Z$

and $I_{Z(max)}$ flows when $R_L \to \infty$, ie. OCC o/p.

$\Rightarrow I_L = 0$

so, $I_Z = I_1$.

5) R_S must limit the current so that under no-load conditions, it will not exceed 58.8 mA.

6) $R_S = \frac{V_{i(max)} - V_Z}{I_{Z(max)}}$

$= \frac{13 - 6.8}{58.8} \left(\frac{V}{mA}\right)$

$= \underline{105.4\Omega}$

7) The nearest preferred value (npv) of resistor to 105.4 Ω is 120 Ω — chosen upwards!

8) Make a check at this point: Using $R_S = 120\Omega$, calculate I_Z under $V_{i(max)}$ conditions:

$I_Z = \frac{V_{i(max)} - V_Z}{R_S}$

$= \frac{13 - 6.8}{120}$

$= \underline{51.6\ mA}$

Realise here that if R_S was chosen as 100Ω, I_Z would be 62 mA, which is greater than 58.8 mA!

9) It is necessary to know the Zener current under normal operating conditions when:

a) V_i is at $V_{i(min)}$ or 10V

b) V_i is at $V_{i(max)}$ or 13V.

It should be noted that "normal" ~~here~~ implies that I_L is constant at 17.4 mA

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a) When $V_i = 10V$,

$$I_1 = \frac{V_i - V_z}{R_s}$$

$$= \frac{10 - 6.8}{120} = 26.6mA$$

By KCL,

$$I_z = I_1 - I_L$$
$$= 26.6 - 17.4$$
$$= 9.2mA$$

b) When $V_i = 13V$,

$$I_1 = \frac{V_i - V_z}{R_s}$$

$$= \frac{13 - 6.8}{120} = 51.6mA$$

$$I_z = 51.6 - 17.4$$
$$= 34.2mA$$

10) Power rating for R_s:

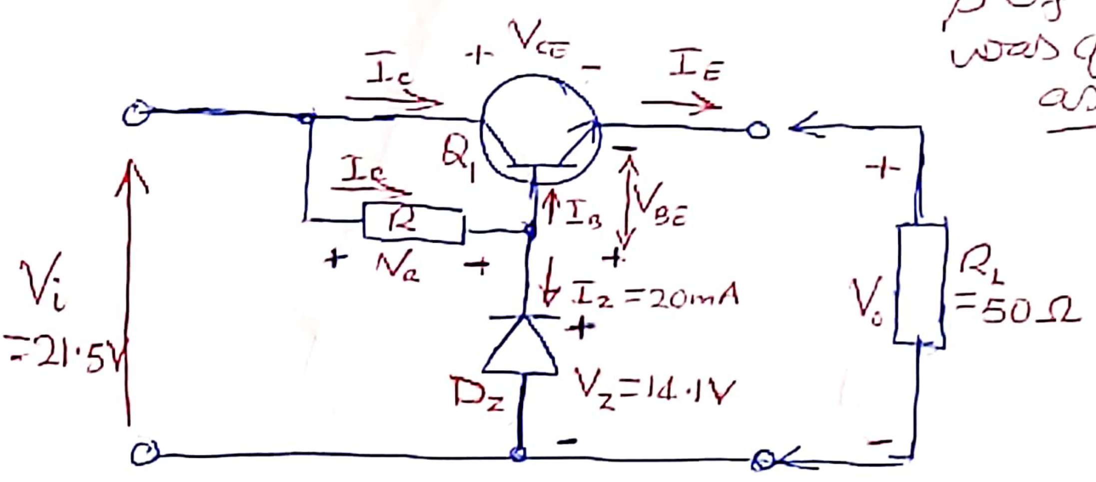
$$P = I^2R$$
$$= [I_1(max)]^2 \times R_s$$
$$= 51.6^2 \times 120 \ (\mu W)$$
$$= 0.319W$$

Suitable power rating of R_s 0.5W, at the minimum.

Zener diodes are also used as limiter or clipping circuits.

The Series Regulator

β of Q_1 was quoted as 55



Load voltage V_o or V_L:

$V_L = V_Z - V_{BE}$ (KVL)

$\simeq 14.1 - 0.7$

$= 13.4V$

Load current I_L

$I_L = I_E = V_L/R_L$

$\simeq \frac{13.4}{50} = 268mA$

$I_B = \frac{I_C}{\beta} \simeq \frac{I_E}{\beta}$

$= 268/55 \simeq 4.8mA$

$I_R = I_B + I_Z$ (KCL)

$\simeq 4.5 + 20 = 24.8mA$

$V_R = V_i - V_Z$

$= 21.5 - 14.1$

$= 7.4V$

$R = V_R / I_R$

$= 7.4V / 24.8(mA)$

$= \cancel{302\Omega}$ 298.4Ω

So, # 330Ω

Regulation

$= \frac{V_{oc} - V_L}{V_L} \times 100\%$

Bi