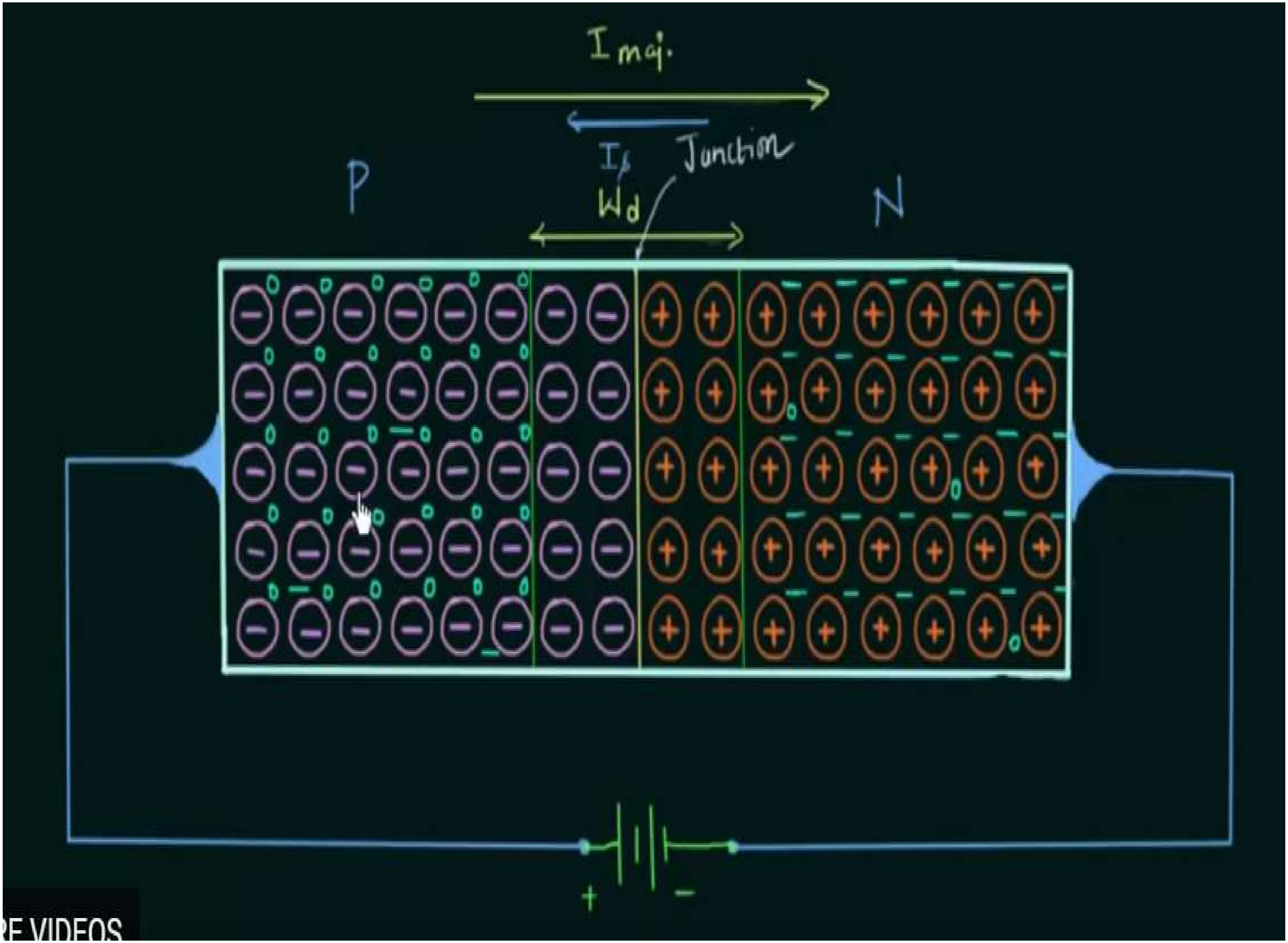
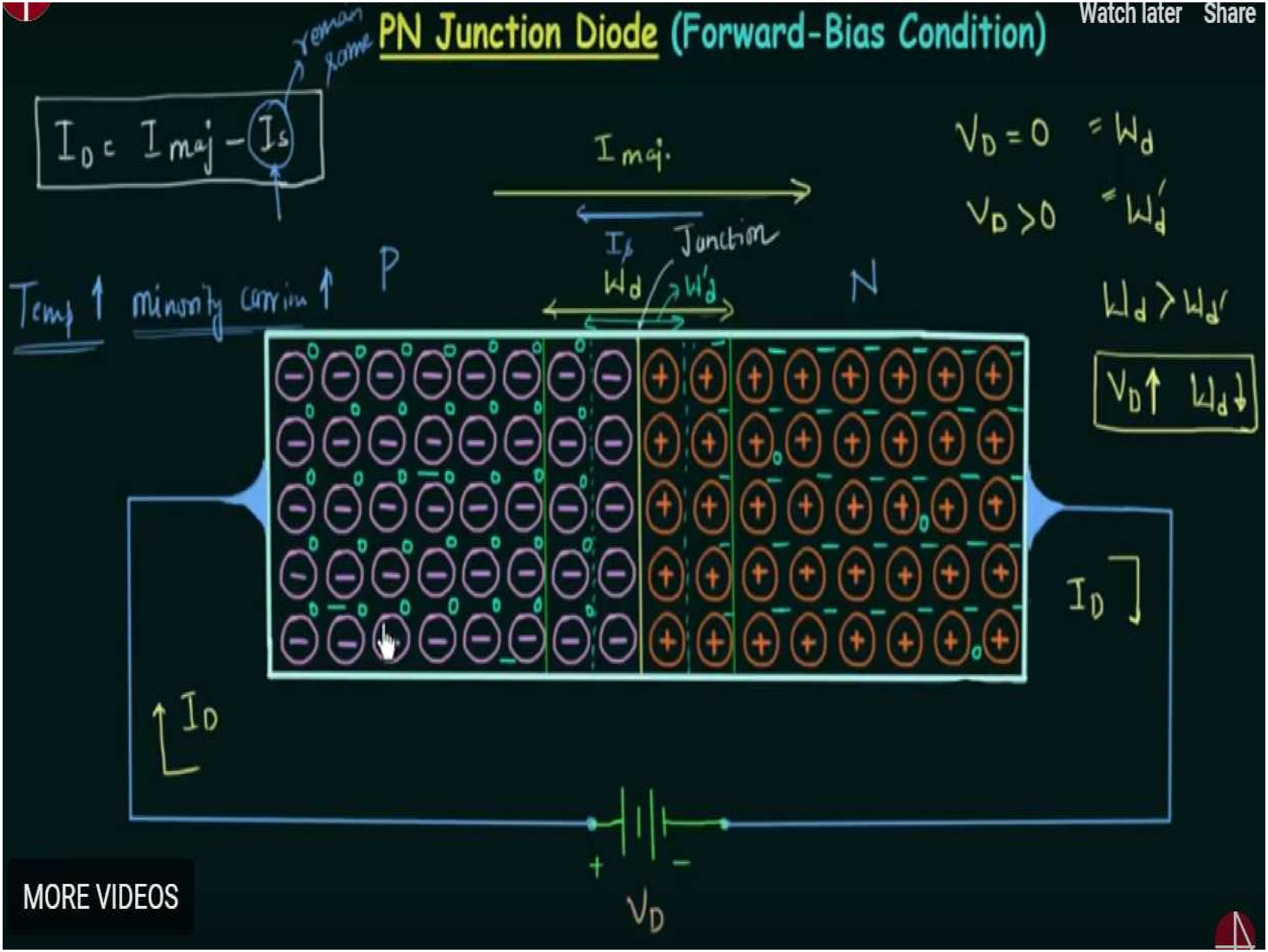
UNIT 1- PN Junction



I maj.
Junction
P
N
+
−
RE VIDEOS



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PN Junction Diode (Forward-Bias Condition)
remain same
$I_D = I_{maj} - I_s$
$I_{maj.}$
I_s
Junction
W_d
W_d'
$V_D = 0 \quad = W_d$
$V_D > 0 \quad = W_d'$
$W_d > W_d'$
$V_D \uparrow \quad W_d \downarrow$
Temp ↑ minority carriers ↑
P
N
I_D
I_D
+
−
V_D
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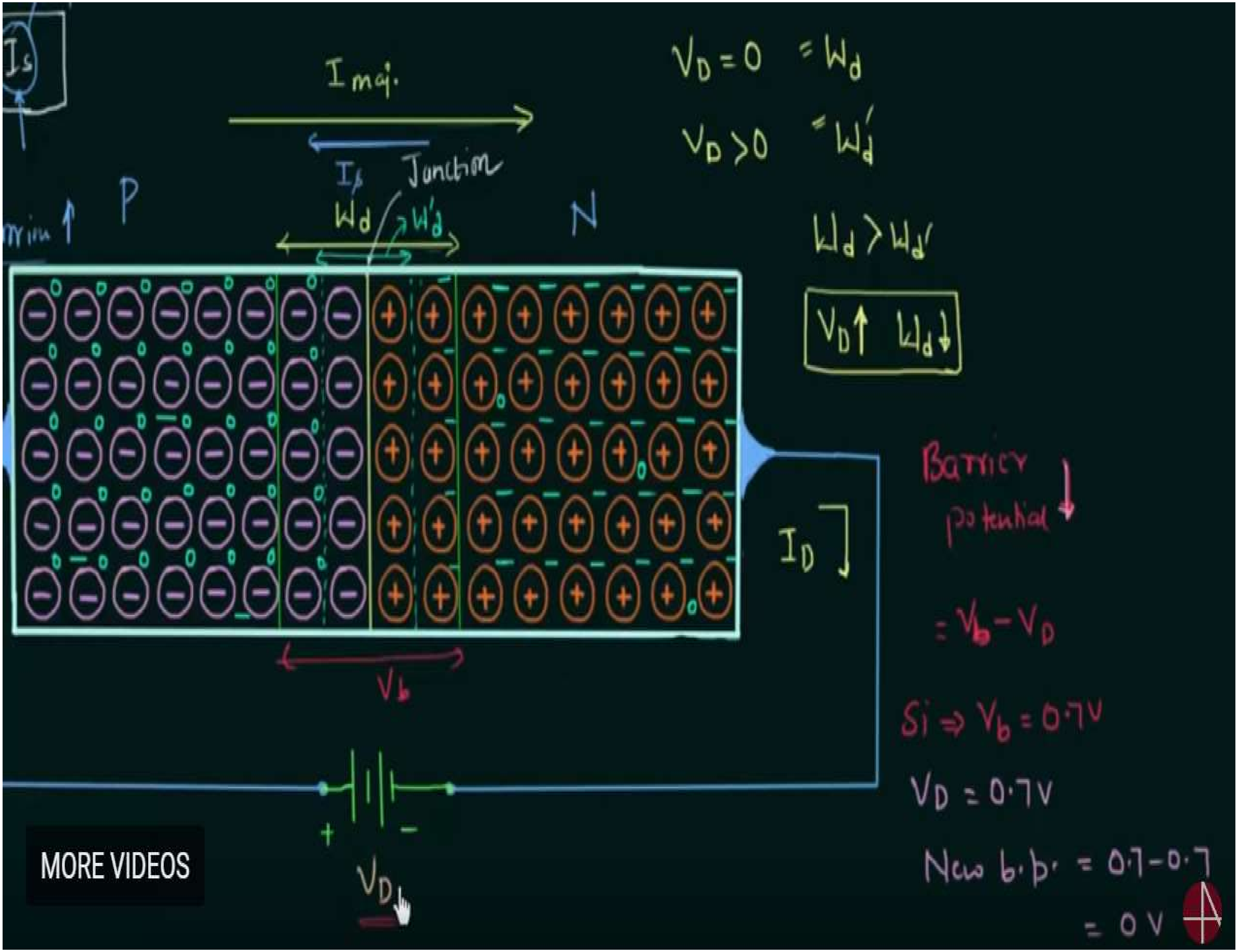

Is
I maj.
Is
Junction
min
P
Wd
W'd
N
VD = 0 = Wd
VD > 0 = W'd
Wd > Wd'
VD ↑ Wd ↓
Barrier potential ↓
ID
= Vb − VD
Vb
Si ⇒ Vb = 0.7V
VD = 0.7V
New b.p. = 0.7−0.7
= 0 V
+
−
VD
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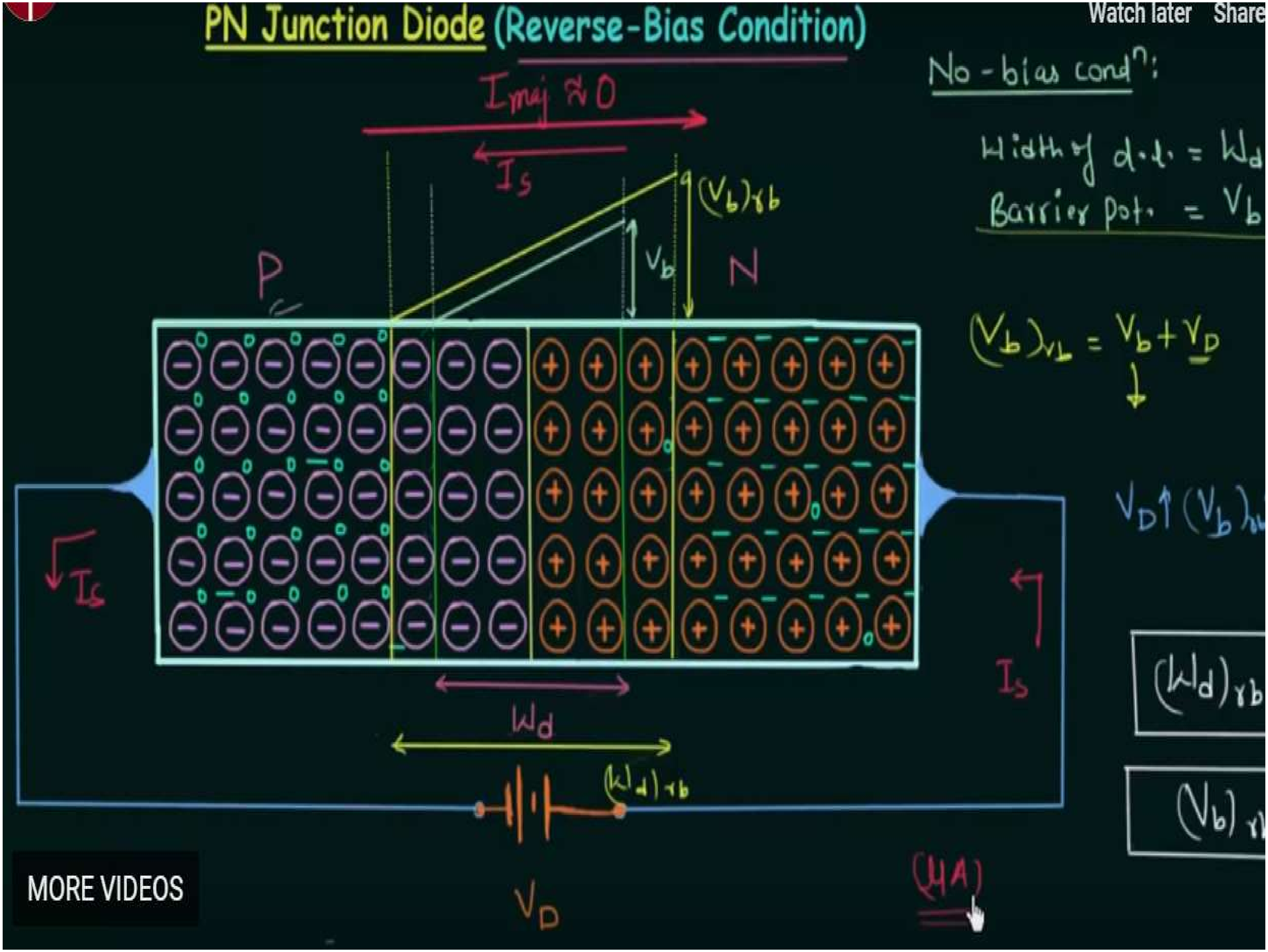
PN Junction Diode (Reverse-Bias Condition)
Watch later
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No-bias condn:
Width of d.l. = Wd
Barrier pot. = Vb
Imaj ≈ 0
Is
(Vb)rb
Vb
P
N
(Vb)rb = Vb + VD
VD↑ (Vb)rb
Is
Is
Wd
(Wd)rb
VD
(μA)
(Wd)rb
(Vb)rb
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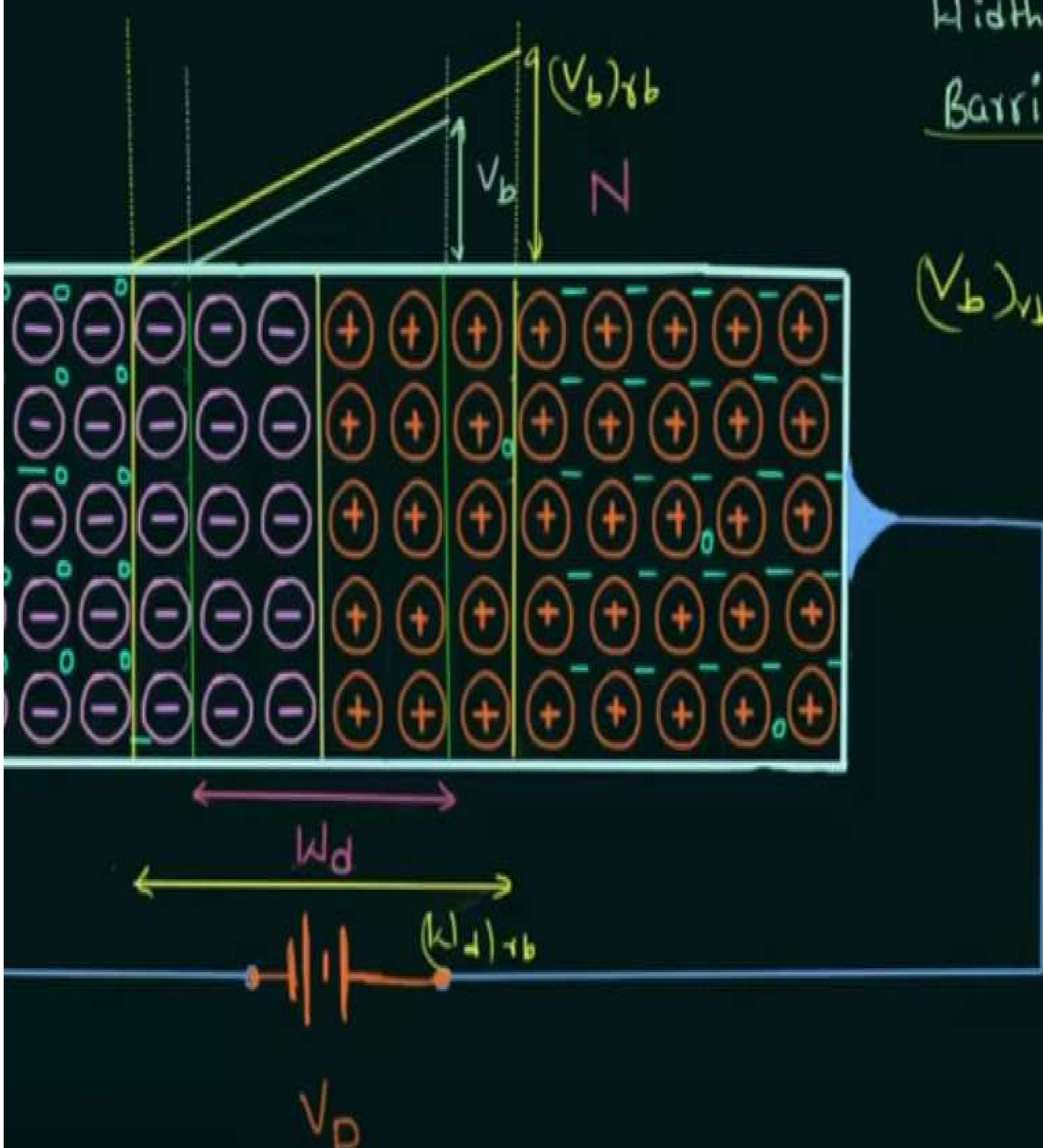
...nction Diode (Reverse-Bias Condition)



No-bias condⁿ:

Width of d.l. = W_d

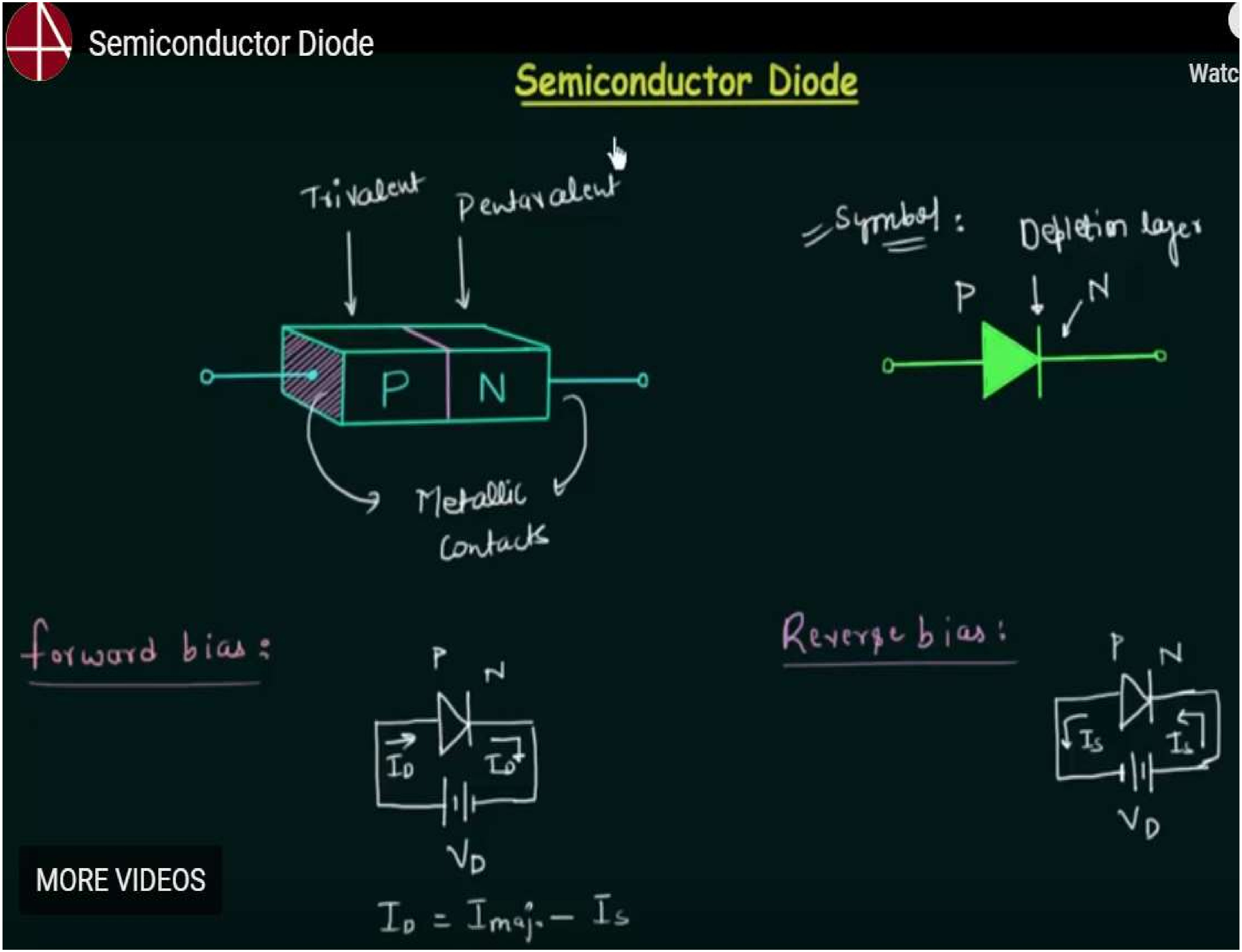
Barrier pot. = V_b

$(V_b)_{rb} = V_b + V_D$

$V_D \uparrow (V_b)_{rb} \uparrow (W_d)_{rb} \uparrow$

$$\boxed{(W_d)_{rb} > (W_d)_{nb} > (W_d)_{fb}}$$

$$\boxed{(V_b)_{rb} > (V_b)_{nb} > (V_b)_{fb}}$$



Semiconductor Diode
Semiconductor Diode
Watc
Trivalent
Pentavalent
P
N
Metallic contacts
Symbol :
Depletion layer
P
N
forward bias :
P
N
I_D
I_D
V_D
$I_D = I_{maj.} - I_s$
Reverse bias :
P
N
I_s
I_s
V_D
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Current components of a diode

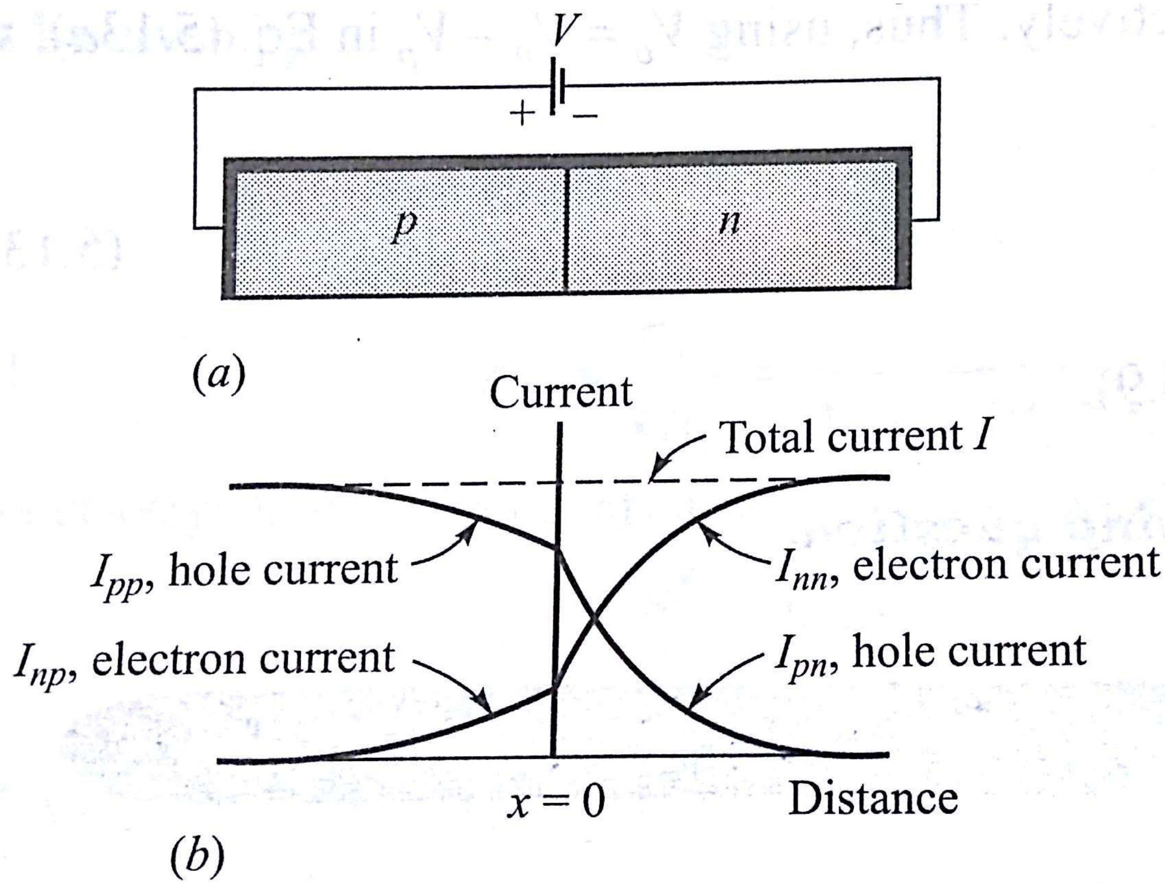


Fig. 5.5 *The hole and electron-current components vs. distance in a p-n junction diode. The space-charge region at the junction is assumed to be negligibly small*

- As the number of injected minority carriers falls off exponentially with distance from the junction, so does the current, as diffusion current of minority carriers is proportional to the concentration gradient.
- $J \alpha\, dp/dx$
- $I = J.\, A$
- Two minority currents are present, i.e. I_{pn} and I_{np}
- 1st letter is type of carrier; 2nd letter is type of material.
- I_{pn} is the hole current in the n-material.
- Electrons crossing the junction at x = 0 from R to L constitute a current in the same direction as hole crossing the junction from L to R. Therefore, total current I at x = 0 is
  - $I = I_{pn}(0) + I_{np}(0)$

- Since current is the same throughout a series circuit, I is independent of x and is indicated by a horizontal line.
- $I_{pp}(x) = I - I_{np}(x)$
- In forward-bias p-n diode, the current enters the p-side as a hole-current and leaves the n-side as an electron current of the same magnitude.
- Hence, the current in a p-n diode is bipolar in character (made of both positive & negative carriers of electricity).
- Total current is constant throughout but proportion due to holes and electrons varies with distance.

Diode Equation

rent - Voltage Relation :

$$\boxed{I_D = I_s\left(e^{\frac{k V_D}{T_k}} - 1\right)}$$

$$V_T = \frac{T_k}{11600}$$

$$V_T = \frac{T_k}{k\eta}$$

I_D = Diode Current

V_D = voltage across diode

I_s = Rev. Sat. Current

T_k = Temp. in K $(273^\circ C + T_c)$

$$\frac{k}{T_k} = \frac{1}{V_T \eta}$$

$$\boxed{k = \frac{11600}{\eta}} \Rightarrow 11600 = k\eta$$

$\eta \rightarrow$ Ideality factor

Range between 1 and 2

* $\eta = 1$ for Ge, $\eta = 2$ for Si] I_D low

* $\eta = 1$ for Ge & Si $\rightarrow$ I_D high

– Voltage Relation :

$$\boxed{I_D = I_s\left(e^{\frac{kV_D}{T_k}} - 1\right)}$$

$$\boxed{I_D = I_s\left(e^{\frac{V_D}{\eta V_T}} - 1\right)}$$

$$V_T = \frac{T_k}{11600}$$

$$V_T = \frac{T_k}{k\eta}$$

= Diode Current

= Rev. Sat. Current

V_D = voltage across diode

T_k = Temp. in K $(273^\circ C + T_c)$

$$\frac{k}{T_k} = \frac{1}{V_T \eta}$$

$$\boxed{k = \frac{11600}{\eta}} \Rightarrow 11600 = k\eta$$

$\eta \rightarrow$ Ideality factor

* $\eta = 1$ for Ge
$\eta = 2$ for Si] I_D low

Range between 1 and 2

* $\eta = 1$ for Ge & Si, → I_D high

Example: A Germanium diode displays a forward voltage of 0.25 V at 10 mA current at room temperature. Find the reverse saturation current.

Sol:

$V_D = 0.25\ V$

$I_D = 10\ mA$

$T_c = 27^\circ c$

$T_k = (273+27)\ k$

$T_k = 300\ K$

$V_T = \frac{T_k}{11600}$

$= \frac{300}{11600} = 0.026\ V$

$I_s = ?$

$\eta = 1$

$I_D = I_s\left(e^{\frac{V_D}{\eta V_T}} - 1\right)$

$10 = I_s\left(e^{\frac{0.25}{1 \times 0.026}} - 1\right)$

$$10 = I_s\left(e^{\frac{0.25}{1 \times 0.026}} - 1\right)$$

$$10 = I_s\left(e^{9.615} - 1\right)$$

$$10 = I_s(14987.922 - 1)$$

$$10 = I_s(14986.922)$$

$$I_s = \frac{10}{14986.922} \Rightarrow I_s = 6.67 \times 10^{-4}\ mA$$

$$= 6.67 \times 10^{-7}\ A$$

$$= 0.667 \times 10^{-6}\ A$$

- ***Forward Bias***
- When voltage V is positive and several times thermal voltage, unity in parenthesis may be neglected.
- Hence, the current increases exponentially with voltage.
- ***Reverse Bias***
- When voltage V is negative and several times thermal voltage, $I \approx - I_o$
- The reverse current is constant and independent of the applied reverse-bias
- I_o is the reverse saturation current.

- Two different scales are used to display forward and reverse characteristics (because forward current is many orders of magnitude larger than the reverse saturation current).

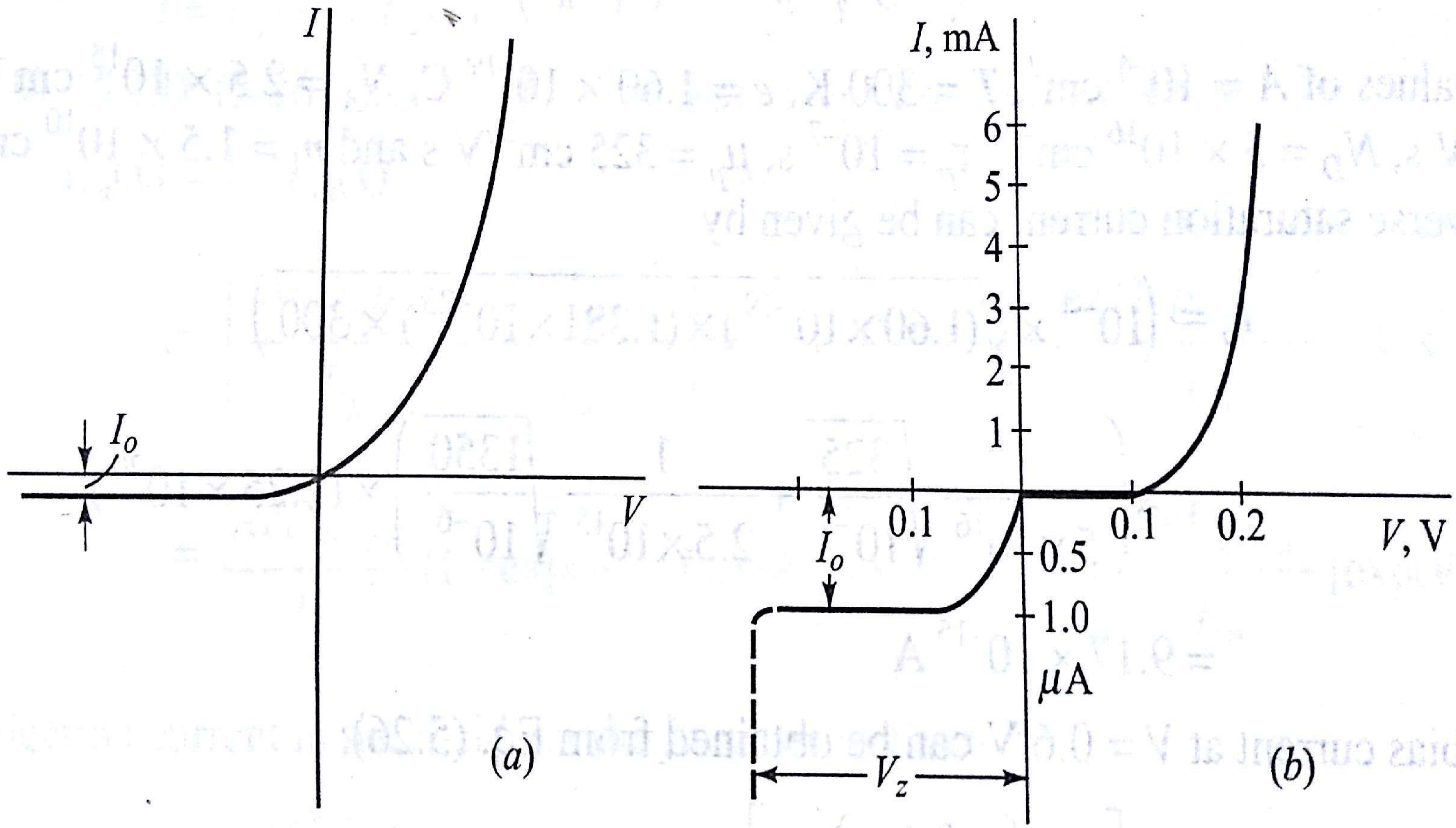


Fig. 5.7 *(a) The volt-ampere characteristic of an ideal p-n diode. (b) The volt-ampere characteristic for a germanium diode redrawn to show the order of magnitude of currents. Note the expanded scale for reverse currents. The dashed portion indicates breakdown at V_Z.*

Cut-in voltage, V_Y

- Offset/break-point/threshold voltage
- Below which the current is very small (say, less than 1 percent of maximum rated value).
- Beyond V_Y, current rises very rapidly
- Approx 0.2 V for Ge

  0.6 V for Si
- Si-diode is offset about 0.4 V w.r.t. Ge-diode.
  - I_o of Ge-diode is about 1000 than that of Si-diode.

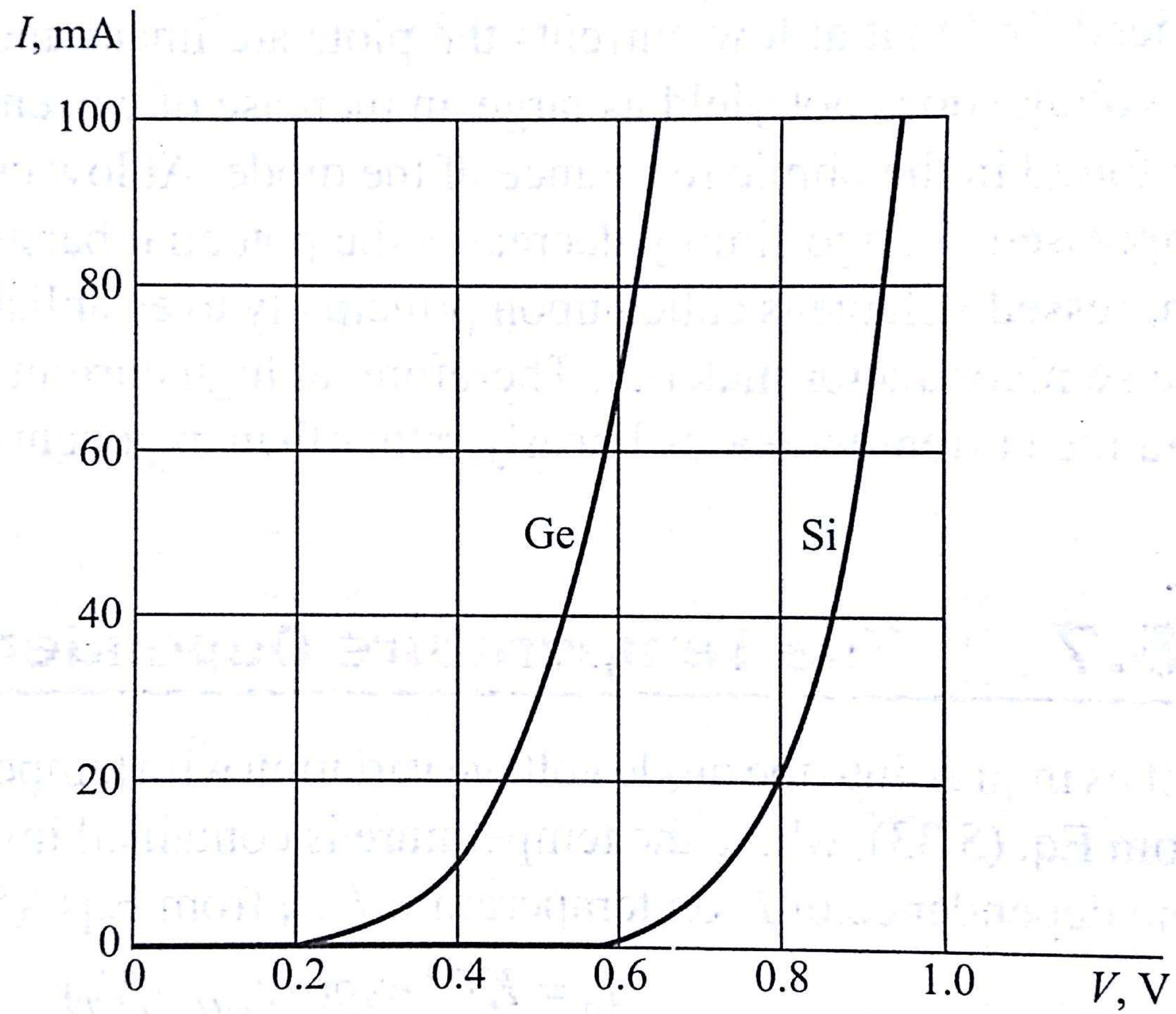
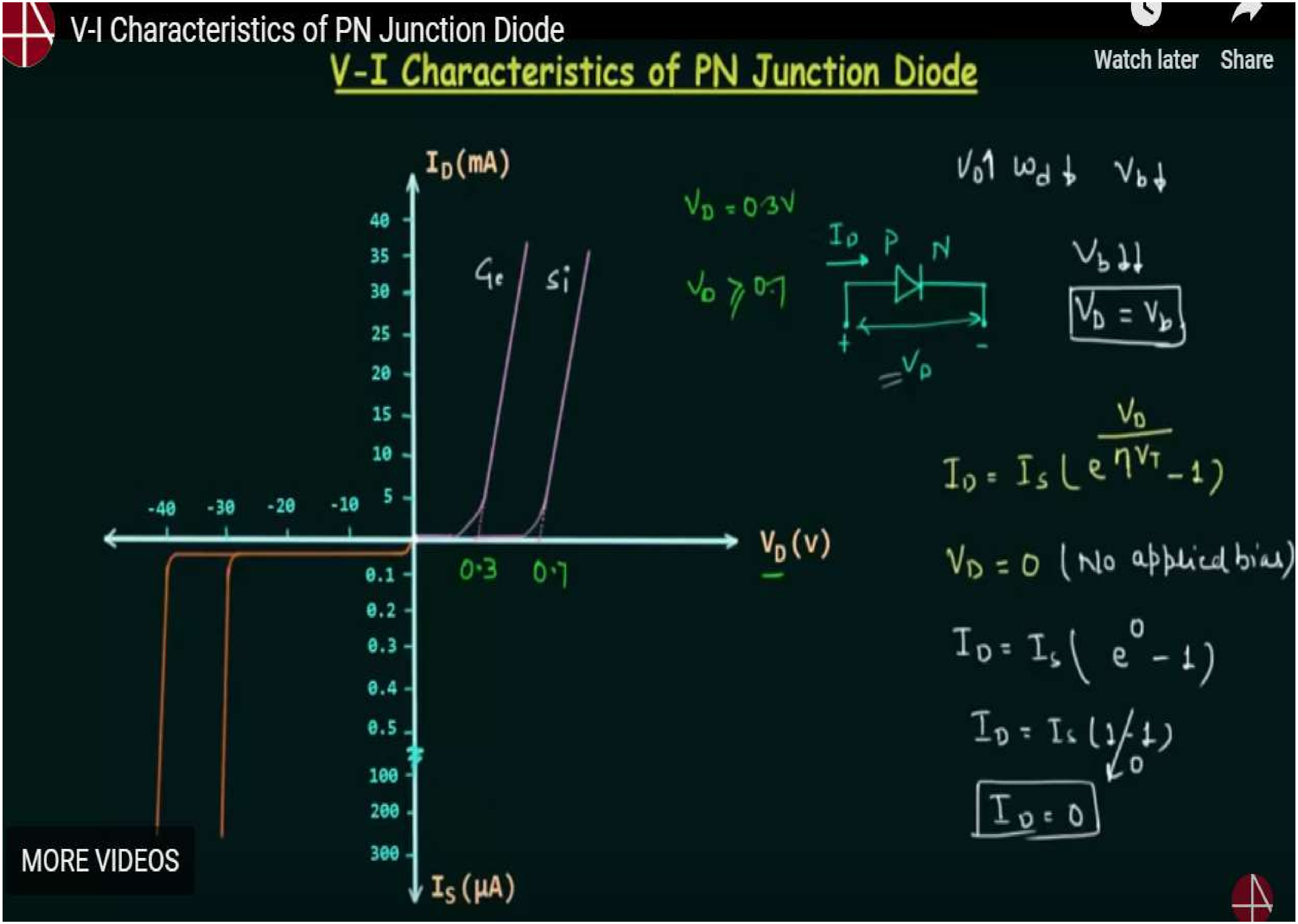


Fig. 5.8 *The forward volt-ampere characteristics of a germanium (1N270) and a silicon (1N3605) diode at 25°C*


V-I Characteristics of PN Junction Diode
Watch later
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V-I Characteristics of PN Junction Diode
I_D (mA)
40
35
30
25
20
15
10
5
-40
-30
-20
-10
Ge
Si
V_D (v)
0·3
0·7
0.1
0.2
0.3
0.4
0.5
100
200
300
I_S (µA)
V_D = 0.3V
V_D ≥ 0.7
I_D
P
N
+
-
V_D
V_D↑ ω_d↓ V_b↓
V_b↓↓
V_D = V_b
I_D = I_s (e^(V_D/ηV_T) − 1)
V_D = 0 (No applied bias)
I_D = I_s (e^0 − 1)
I_D = I_s (1 − 1)
0
I_D = 0
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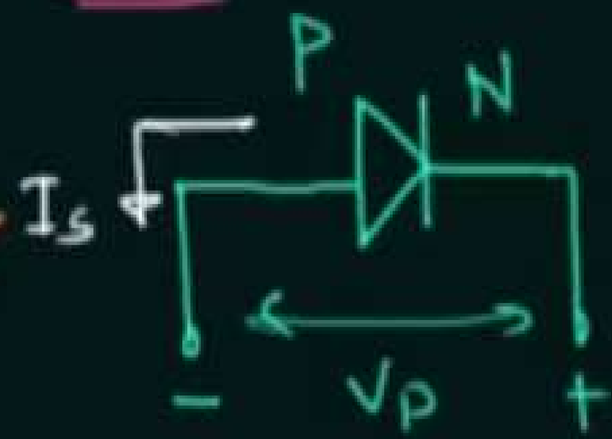
R.B.C



$V_D \rightarrow$ negative

$V_D < 0$

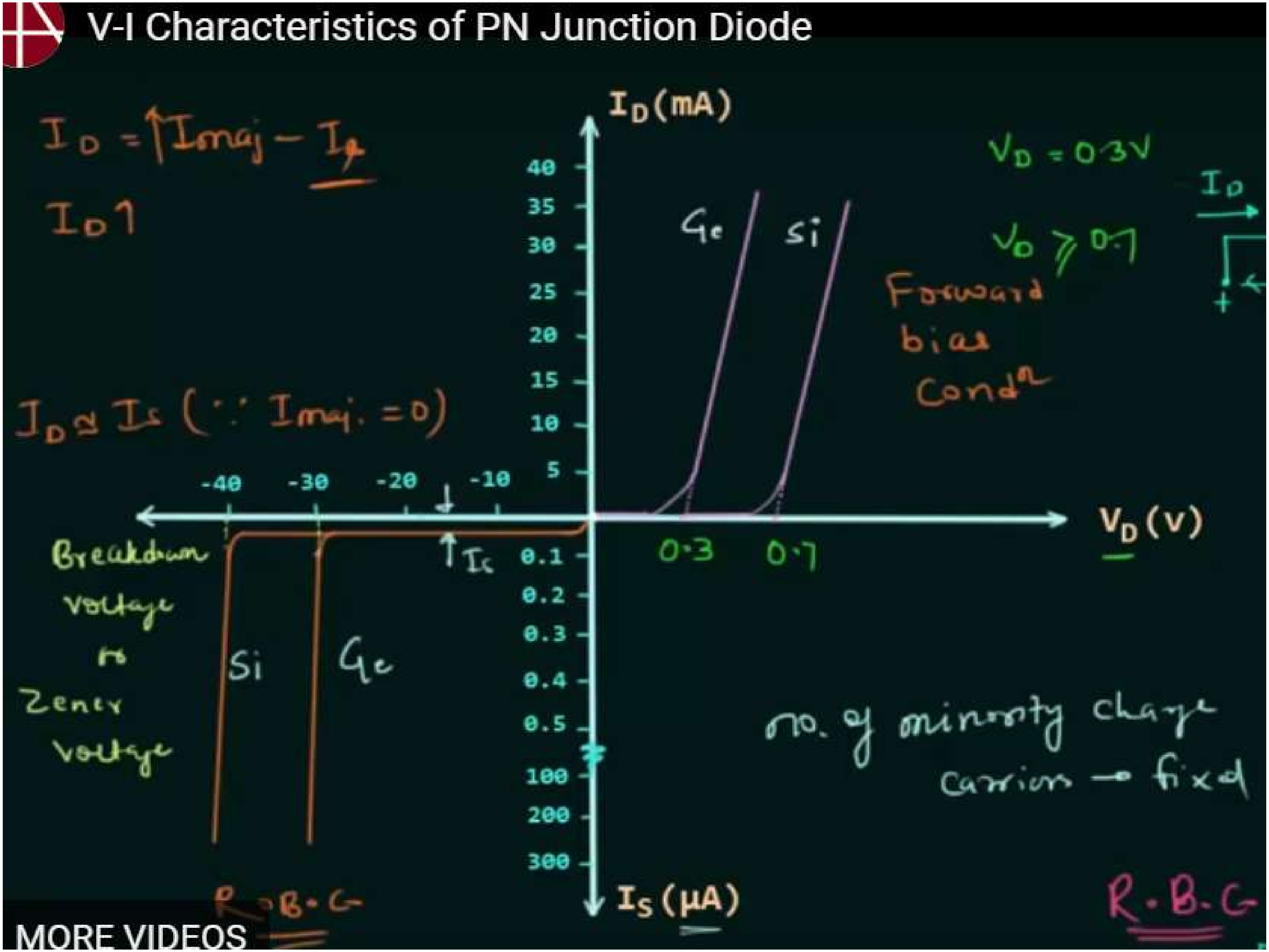
Leakage Current

$e^{\frac{V_D}{\eta V_T}} << 1 \; (V_D < 0)$

$$I_D = I_s\left(e^{\frac{V_D}{\eta V_T}} - 1\right)$$

$$I_D = I_s(-1)$$

$$I_D = -I_s$$



V-I Characteristics of PN Junction Diode
I_D = ↑I_maj − I_s
I_D ↑
I_D ≃ I_s (∵ I_maj = 0)
I_D(mA)
40
35
30
25
20
15
10
5
Ge
Si
V_D = 0.3V
V_D ≥ 0.7
Forward bias condn
I_D
-40
-30
-20
-10
V_D(v)
0.3
0.7
I_s
0.1
0.2
0.3
0.4
0.5
100
200
300
I_S(µA)
Breakdown voltage or Zener voltage
Si
Ge
no. of minority charge carriers → fixed
R.B.C
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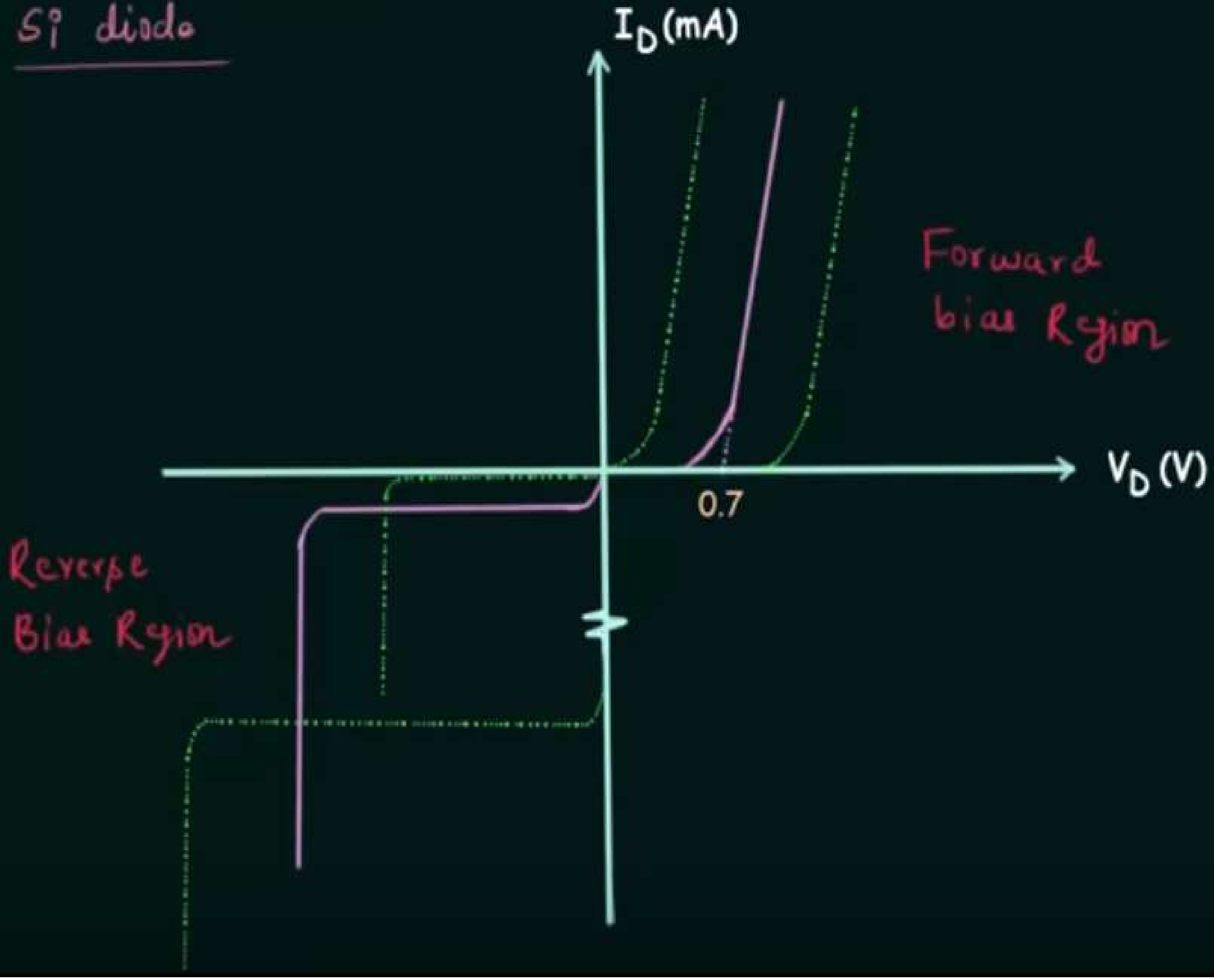
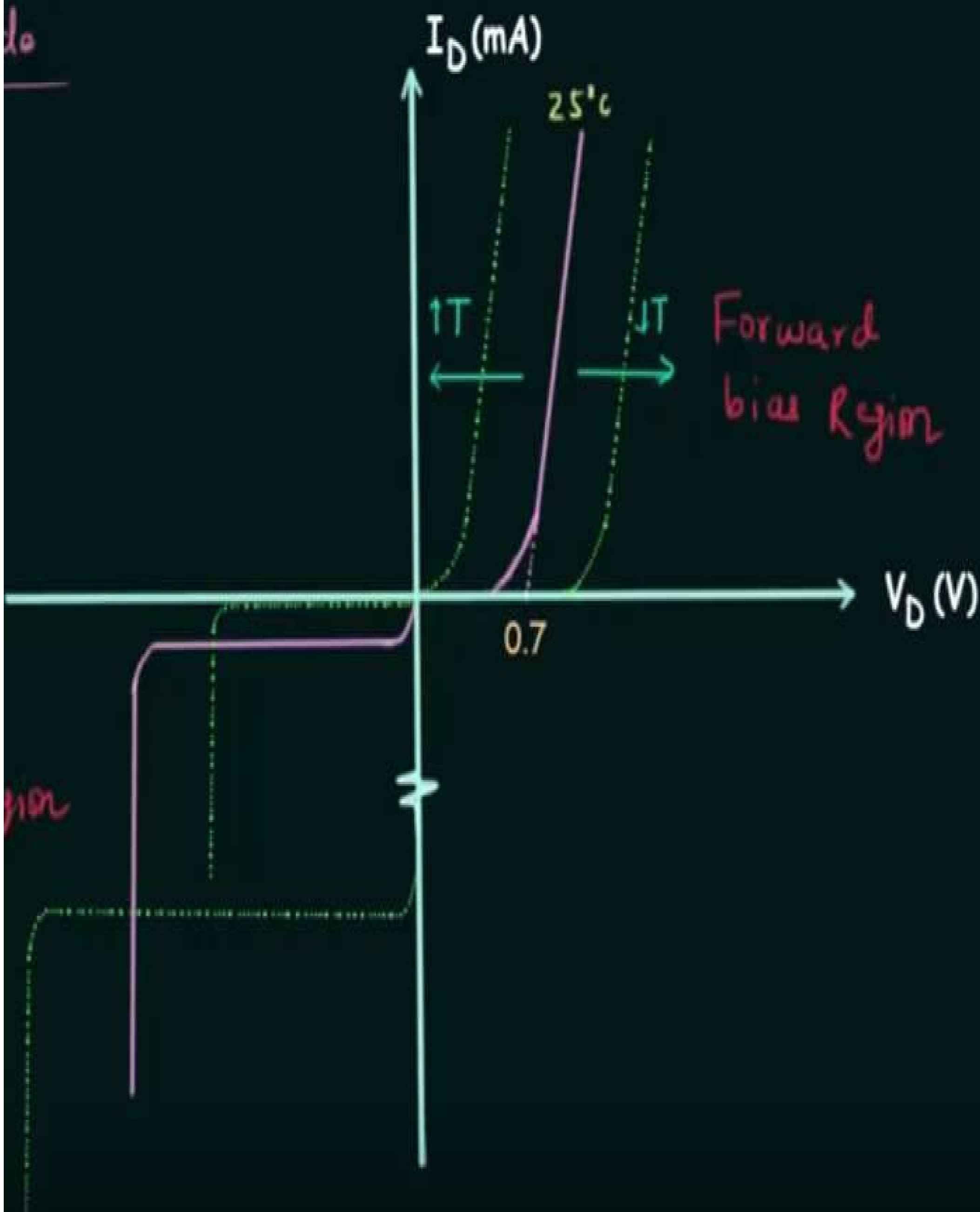
Effects of Temperature on V-I Characteristics





forward bias Cond^n:

"In case of forward bias region the ch. of Si diode shift to the left at a rate of 2.5 mV per degree centigrade rise in temp."

ex: 25°c ⟶ $V_D = 0.7V$

⟶ for 100°c ↑ in temp or at 125°c

Ex: $25^\circ C \longrightarrow V_D = 0.7V$

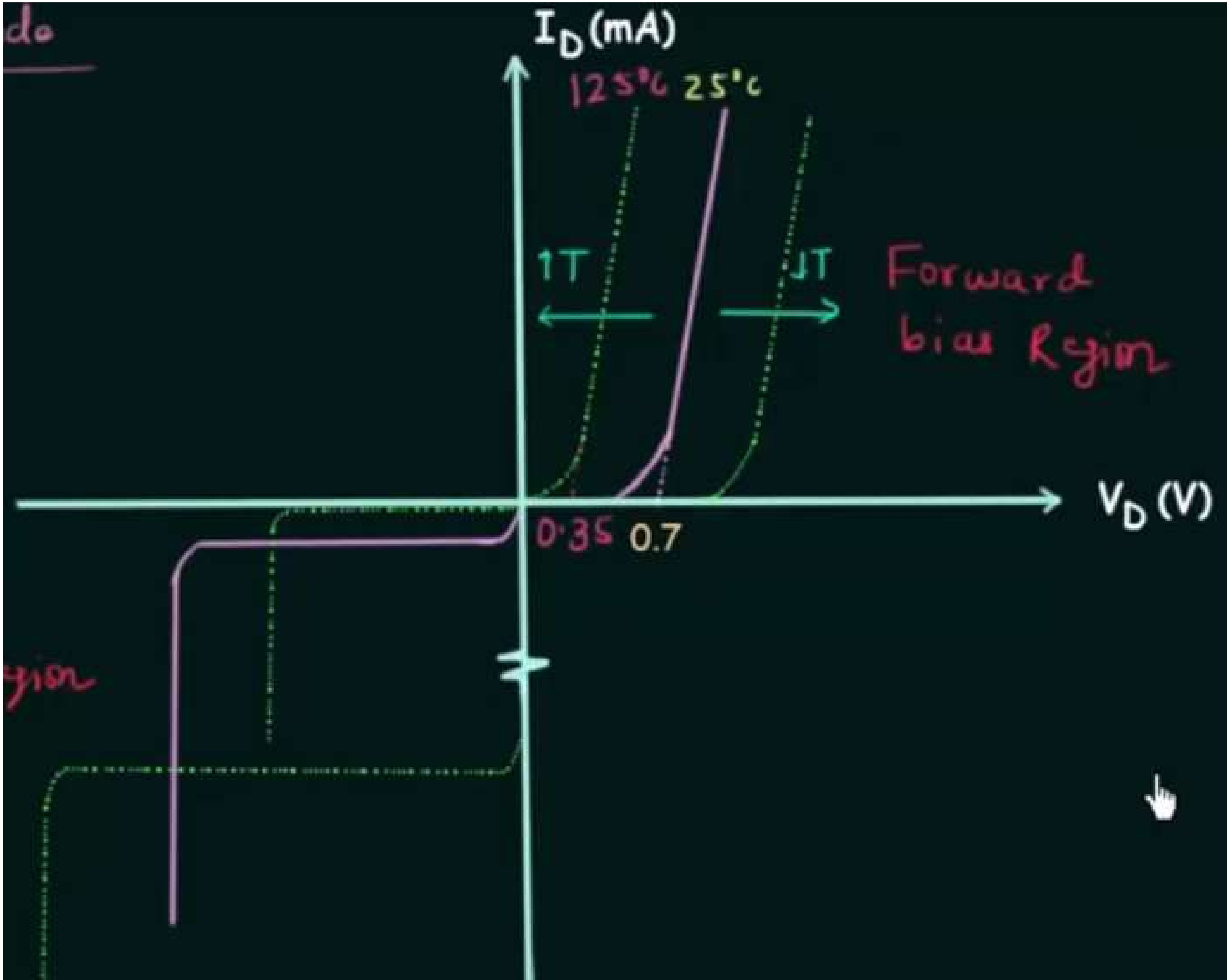
$\longrightarrow$ for $100^\circ C$ $\uparrow$ in temp or at $125^\circ C$

$100 \times 2.5\,mV = 0.25V$

$\therefore V_D \downarrow$ by $0.25V$

New $V_D = (0.7 - 0.25)V$

$= 0.35V$



ID (mA)
125°c
25°c
↑T
↓T
Forward bias Region
VD (V)
0.35
0.7

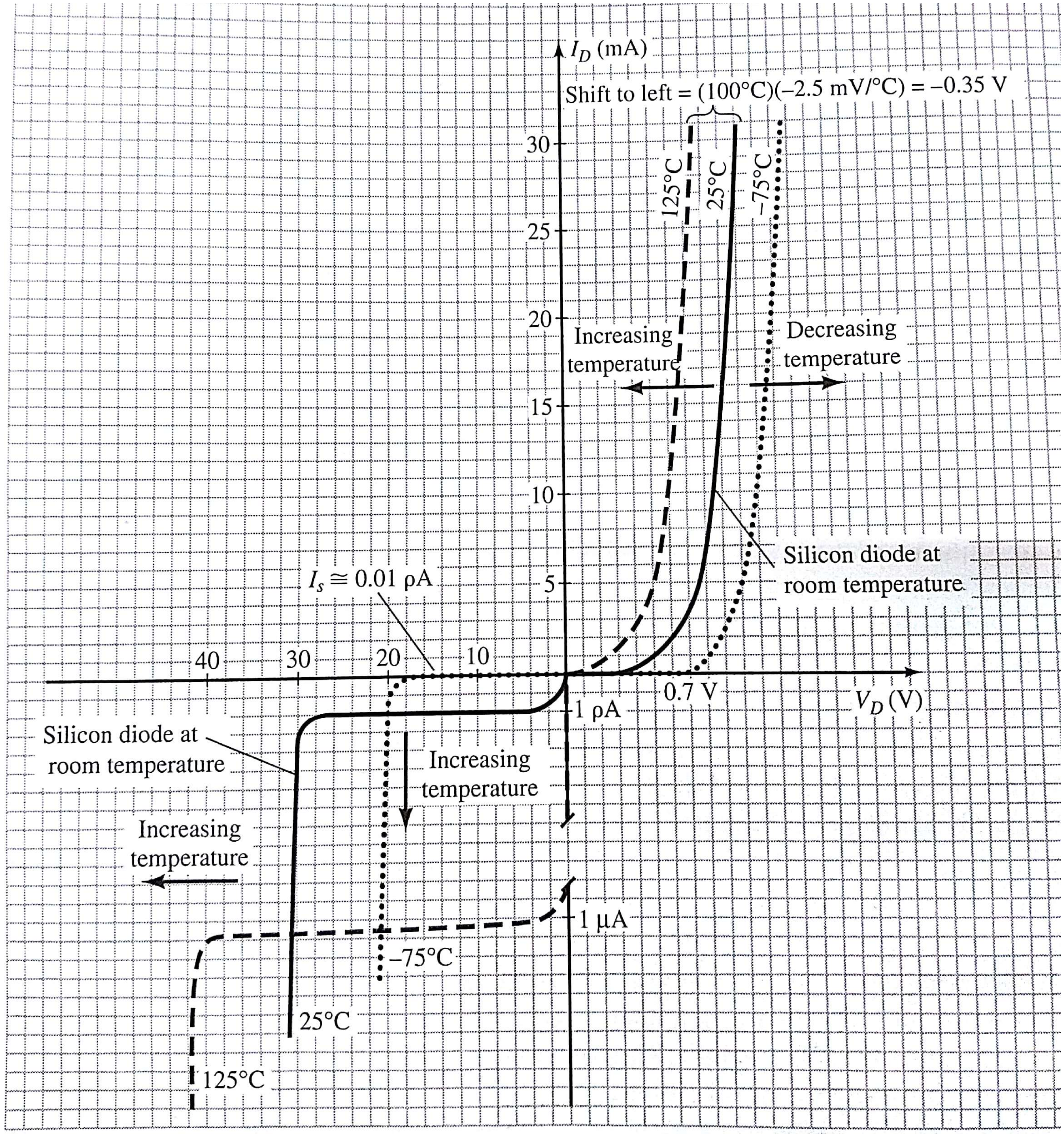
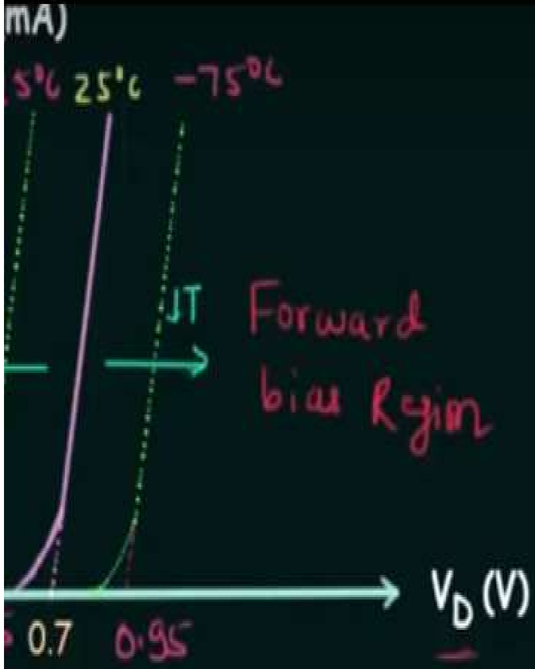


FIG. 1.19

Variation in Si diode characteristics with temperature change.



forward bias Condⁿ:

"In case of forward bias region the ch. of Si diode shift to the left at a rate of 2.5 mV per degree centigrade rise in temp."

ex: $25°C \longrightarrow V_D = 0.7V$

→ for 100°C ↑ in temp or at 125°C

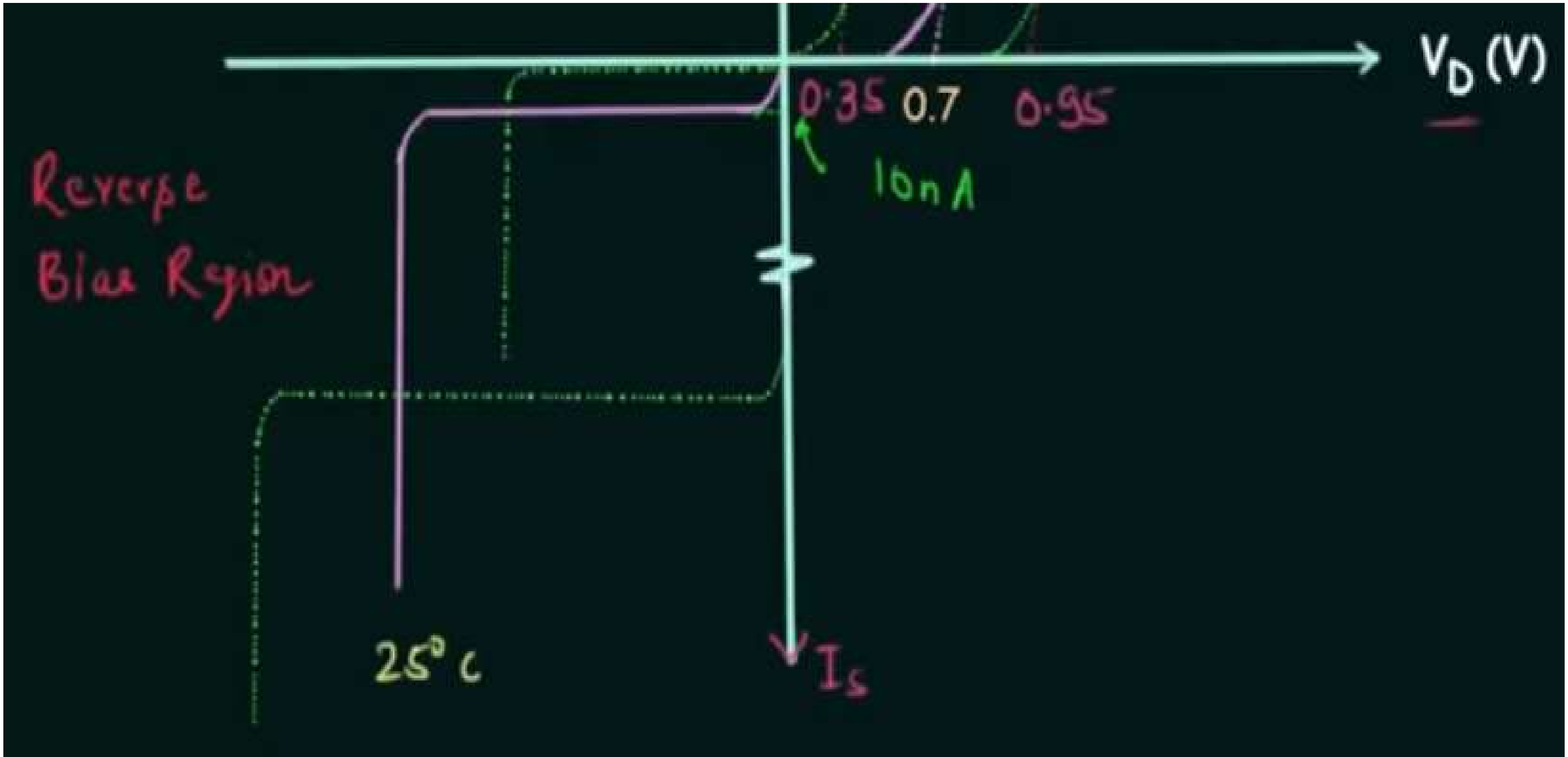
$100 \times 2.5\,mV = 0.25V$

$\therefore V_D \downarrow$ by 0.25V

→ for 100°C ↓ in temp (−75°C)

$100 \times 2.5\,mV = 0.25V$

New $V_D = (0.7 + 0.25)$
$= 0.95V$



for Rev. bias condⁿ → I_s doubles for every 10°c ↑ in temp

→ for 100°c ↑ in temp. [125°c]

for Rev. bias cond^n $\rightarrow$ I_s doubles for every 10°C ↑ in temp

$\rightarrow$ for 100°C ↑ in temp. [125°C]

$$10°C \begin{cases} 25°C \longrightarrow 10\,nA \\ 35°C \longrightarrow 20\,nA \end{cases}$$

45° C $\longrightarrow$ 40 nA

65° C $\longrightarrow$ 80 nA

⋮

125°C $\longrightarrow$ 10240 nA or 10.24 μA

Imp. Points

→ If $I_S = I_{S1}$ at temp T_1, then at any temp T I_S is given as :-

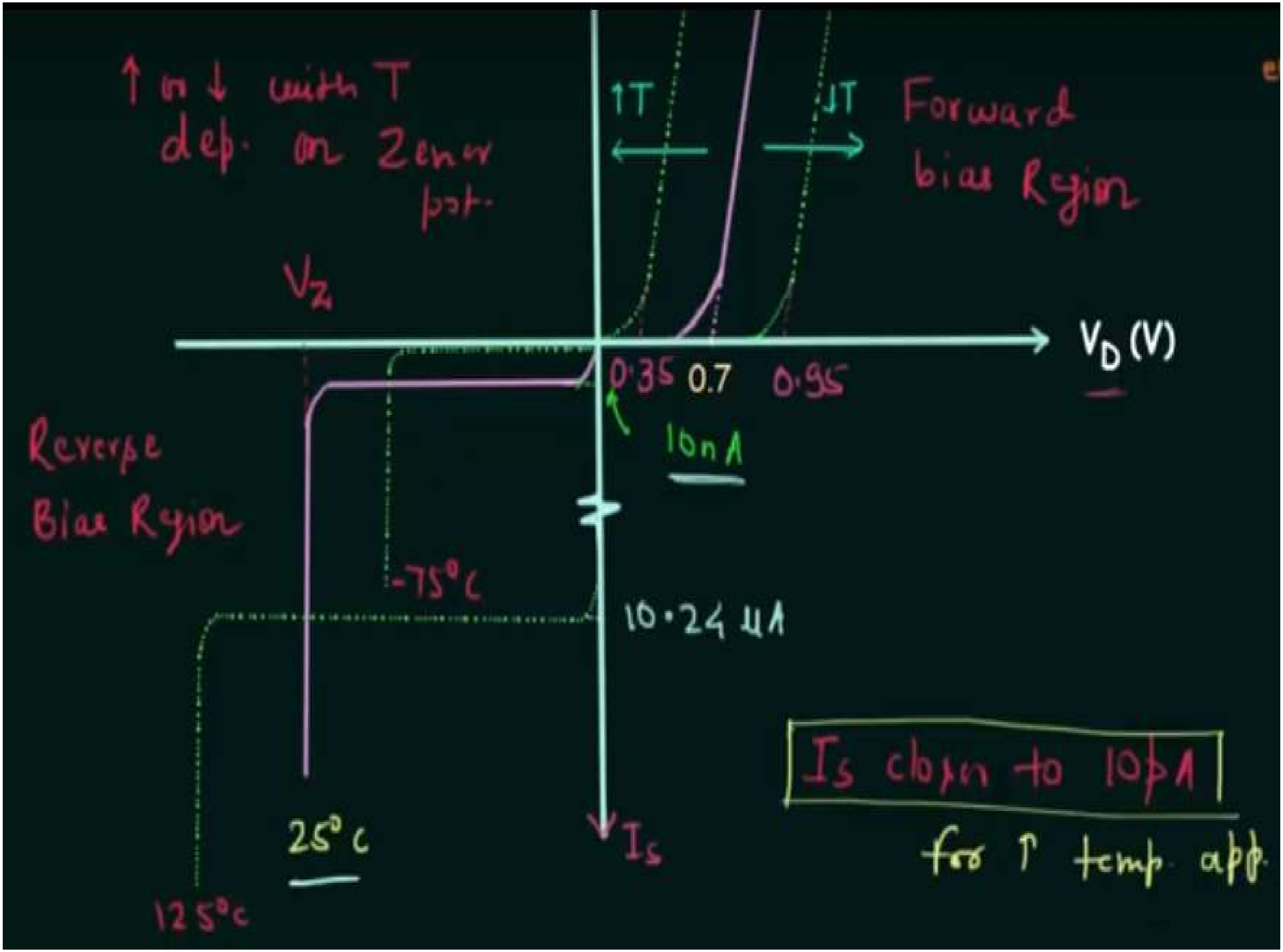
$$I_S(T) = I_{S1} \times 2^{(T-T_1)/10} \quad — (15)$$

☆ for eg. in last ques:

$$I_S[125°C] = 10nA \times 2^{(125-25)/10}$$

$$= 10nA \times 2^{100/10}$$

$$= 10nA \times 2^{10} = 10240\ nA$$



↑ or ↓ with T
dep. on Zener pot.
V_Z
↑T
↓T
Forward bias Region
V_D (V)
0.35
0.7
0.95
10nA
Reverse Bias Region
-75°C
10·24 uA
I_s close to 10pA
for ↑ temp. app.
25°C
I_s
125°C

1.10 TRANSITION AND DIFFUSION CAPACITANCE

It is important to realize that:

Every electronic or electrical device is frequency sensitive.

That is, the terminal characteristics of any device will change with frequency. Even the resistance of a basic resistor, as of any construction, will be sensitive to the applied frequency. At low to mid-frequencies most resistors can be considered fixed in value. However, as we approach high frequencies, stray capacitive and inductive effects start to play a role and will affect the total impedance level of the element.

→ at low f & low C

Reactance $X_C = \frac{1}{2\pi f C}$

X is very high

⇒ Open ckt

For the diode it is the stray capacitance levels that have the greatest effect. At low frequencies and relatively small levels of capacitance the reactance of a capacitor, determined by $X_C = 1/2\pi f C$, is usually so high it can be considered infinite in magnitude, represented by an open circuit, and ignored. At high frequencies, however, the level of X_C can drop to the point where it will introduce a low-reactance "shorting" path. If this shorting path is across the diode, it can essentially keep the diode from affecting the response of the network.

In the p–n semiconductor diode, there are two capacitive effects to be considered. Both types of capacitance are present in the forward- and reverse-bias regions, but one so outweighs the other in each region that we consider the effects of only one in each region.

→ at high f

Recall that the basic equation for the capacitance of a parallel-plate capacitor is defined by $C = \epsilon A/d$, where ϵ is the permittivity of the dielectric (insulator) between the plates of area A separated by a distance d. In a diode the depletion region (free of carriers) behaves essentially like an insulator between the layers of opposite charge. Since the depletion width (d) will increase with increased reverse-bias potential, the resulting transition capacitance will decrease, as shown in Fig. 1.33. The fact that the capacitance is dependent on the applied reverse-bias potential has application in a number of electronic systems. In fact, in Chapter 16 the varactor diode will be introduced whose operation is wholly dependent on this phenomenon.

This capacitance, called the transition (C_T), barriers, or depletion region capacitance, is determined by

$$\boxed{C_T = \frac{C(0)}{(1 + |V_R/V_K|)^n}} \tag{1.9}$$

As RB ↑
Wd ↑
∴ $C_T = \frac{\epsilon A}{d}$ ↓

RB · — CT

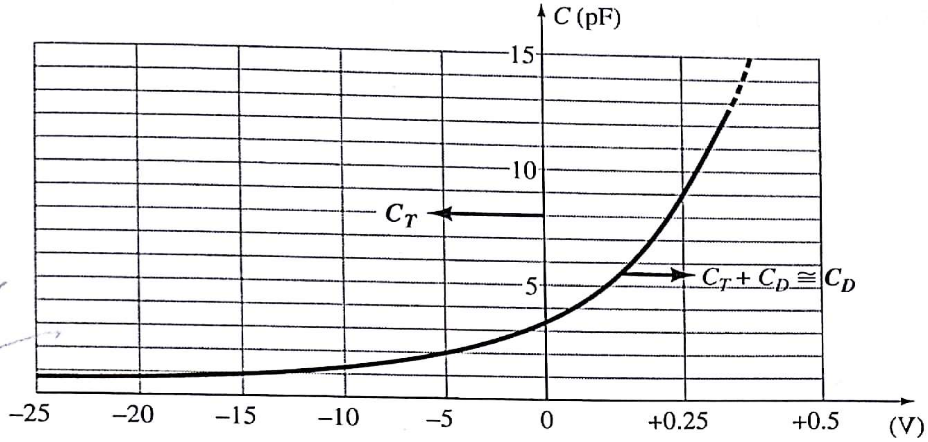


FIG. 1.33
Transition and diffusion capacitance versus applied bias for a silicon diode.

F·B — C_D

where $C(0)$ is the capacitance under no-bias conditions and V_R is the applied reverse bias potential. The power n is ½ or ⅓ depending on the manufacturing process for the diode.

Although the effect described above will also be present in the forward-bias region, it is overshadowed by a capacitance effect directly dependent on the rate at which charge is injected into the regions just outside the depletion region. The result is that increased levels of current will result in increased levels of diffusion capacitance (C_D) as demonstrated by the following equation:

As I ↑s
C ↑s

$$\boxed{C_D = \left(\frac{\tau_T}{V_K}\right) I_D} \qquad \textbf{(1.10)}$$

V_K → battery voltage

where τ_T is the minority carrier lifetime—the time is world take for a minority carrier such as a hole to recombine with an electron in the n-type material. However, increased levels of current result in a reduced level of associated resistance (to be demonstrated shortly), and the resulting time constant ($\tau = RC$), which is very important in high-speed applications, does not become excessive.

More curr; less R
∴ τ doesn't be excessive

In general, therefore,

the transition capacitance is the predominant capacitive effect in the reverse-bias region whereas the diffusion capacitance is the predominant capacitive effect in the forward-bias region.

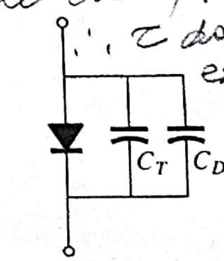


FIG. 1.34
Including the effect of the transition or diffusion capacitance on the semiconductor diode.

The capacitive effects described above are represented by capacitors in parallel with the ideal diode, as shown in Fig. 1.34. For low- or mid-frequency applications (except in the power area), however, the capacitor is normally not included in the diode symbol.

Space-Charge Capacitance

With no applied voltage the width d of the depletion region can be calculated to be 5×10^{-5} cm = 5×10^{-4} mm = 0.0005 mm and is mostly in the N-type material.* The movement of majority holes and electrons across the junction causes opposite charges to be stored at this distance 'd' apart. This is effectively a parallel plate capacitor whose capacitance C_T (often called space-charge capacitance) can be calculated to be approximately 20 pF with no external bias.

As forward bias is applied (5 mA current) the depletion region decreases to approximately 4×10^{-4} mm, and the capacitance C_T increases to 25 pF. Under reverse-bias conditions, (−4V), the depletion region increases to approximately 12×10^{-4} mm, with a corresponding decrease of C_T to 8 pF. The variation in space-charge capacitance (sometimes called transition capacitance) with applied reverse voltage is shown in Fig. 5-20 for a TIV 308 silicon voltage-variable-capacitance diode, used in an automatic frequency control (AFC) circuit in an FM tuner.

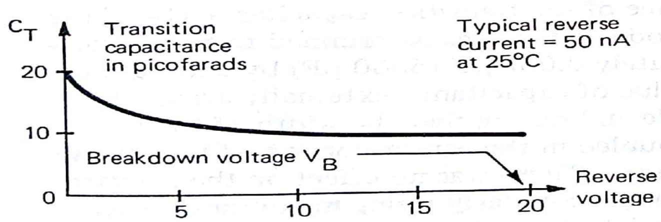


Fig. 5-20. Graph showing variation in capacitance with voltage for a TIV 308 diode.

*Gibbons, J., *Semiconductor Electronics*, McGraw-Hill, New York, 1966, Section 5.6.

The application of this property, voltage variable capacitance, appears in varactors, varicaps, or voltacaps. If a diode is used in the reverse-biased manner as a capacitor in an LC resonant circuit, the value of C and hence the resonant frequency can be varied by altering the reverse bias applied to the diode; no moving parts required.

The symbol used for these diodes when used in this manner is as shown in Fig. 5-21 with the equivalent circuit.

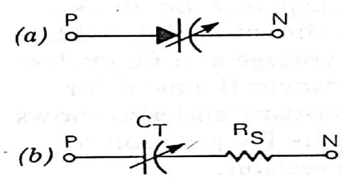


Fig. 5-21. (a) Symbol for voltage-variable-capacitor diode. (b) Equivalent circuit for the diode under reverse bias.

R_S is the body resistance, approximately 1-5 ohms. C_T can be as much as 300 pF in some low voltage Zener diodes.

Diffusion Capacitance

The reason that the capacitance was not shown in Fig. 5-20 for the forward-biased condition is the presence of another capacitance, C_D.

This can be defined by the equation, $C_D = \frac{dq}{dv}$, where dq represents the change in the number of minority carriers stored outside the depletion region when a change in voltage across the diode, dv, is supplied. This is very large in the forward-biased direction, ranging from 8000 pF to as much as 20 μF, certainly swamping out any effect due to C_T.

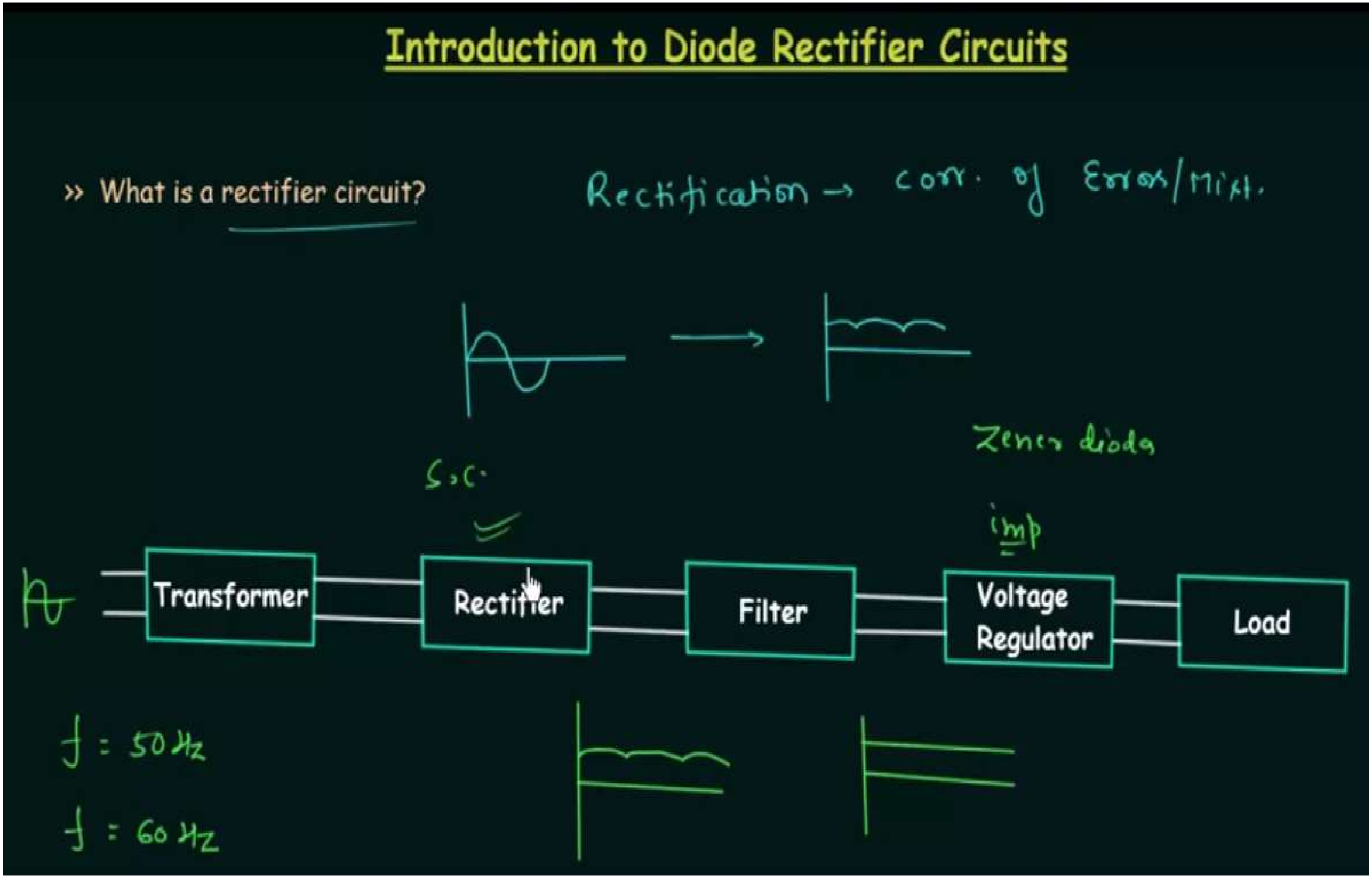
In the reverse direction, however, C_D is smaller than C_T, and C_T predominates. The large value of C_D must be considered along with the extremely small dynamic forward

Diffusion Capacitance

- This is due to the injected charge carriers stored near the junction outside the transition region.

Static Derivation:

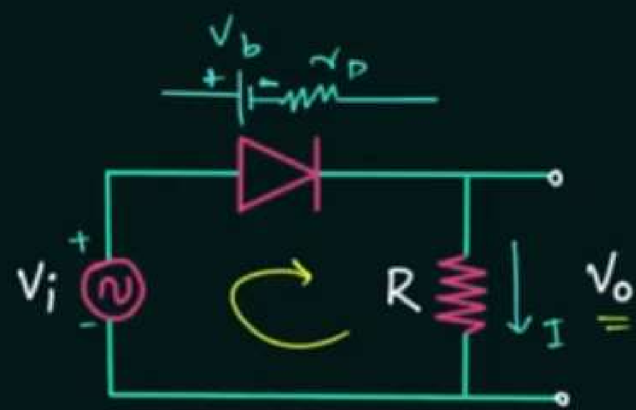
- $C_D = \frac{dQ}{dV} = \tau \frac{dI}{dV} = \tau g = \frac{\tau}{r} = \frac{\tau I}{\eta V_T}$
- C_D is proportional to the diode current.
- For RB, g is small and C_D may be neglected compare to C_T.
- For FB, g is large and C_D is much larger compare to C_T.
- For Ge at I =26 mA, g = 1 mho, $C_D = \tau$. If τ=20 microsSec, then $C_D = 20\ microF$.


Introduction to Diode Rectifier Circuits
» What is a rectifier circuit?
Rectification → corr. of Errors/Mist.
Zener diode
S.C.
imp
Transformer
Rectifier
Filter
Voltage Regulator
Load
f = 50 Hz
f = 60 Hz

Half Wave Rectifier

Half Wave Rectifier

>> Only one half of the ac voltage is rectified, for the other half we get zero voltage.



$$+V_i - V_b - Ir_D - IR = 0$$

$$I = \frac{V_i - V_b}{r_D + R}$$

$$V_o = IR$$

$$= \left(\frac{V_i - V_b}{r_D + R}\right) \times R$$

$$+V_i - V_b - I r_D - IR = 0$$

$$r_D \ll R$$

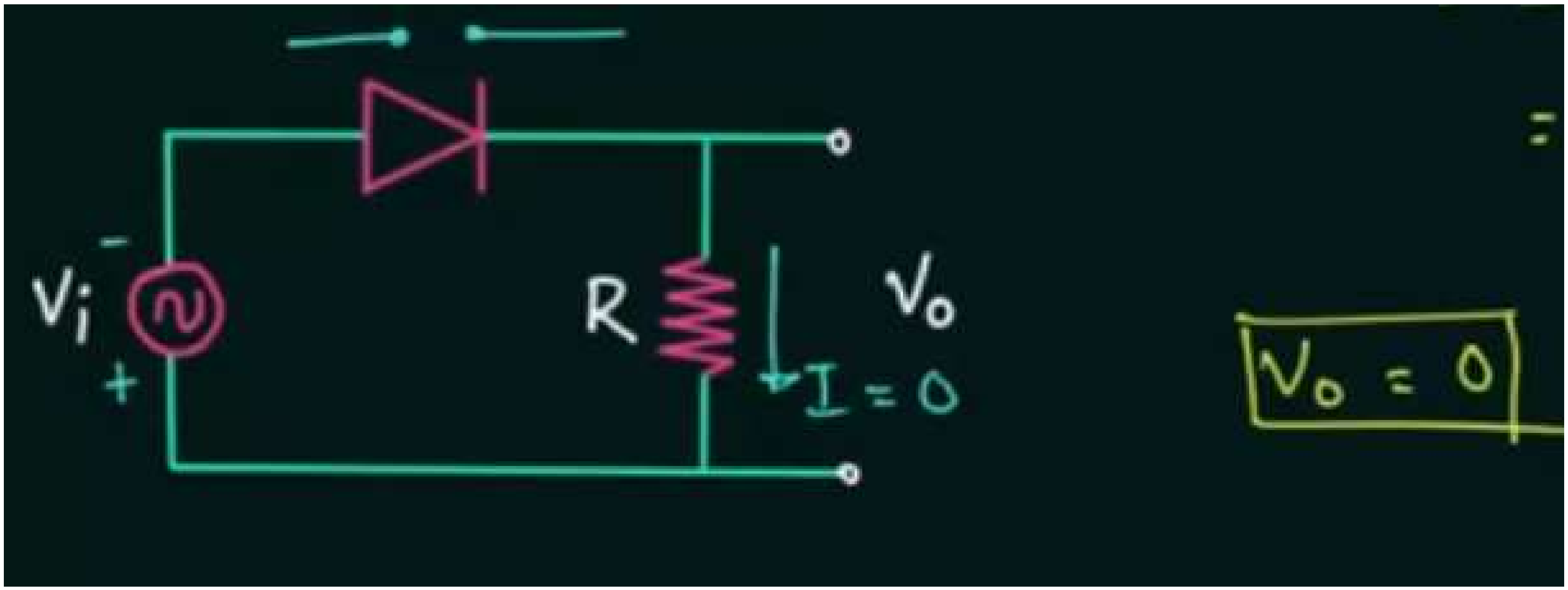
$$I = \frac{V_i - V_b}{r_D + R}$$

$$V_o = IR$$

$$= \left(\frac{V_i - V_b}{r_D + R}\right) \times R \Rightarrow V_o = \left(\frac{R}{r_D + R}\right) V_i - \left(\frac{R}{r_D + R}\right) V_b$$

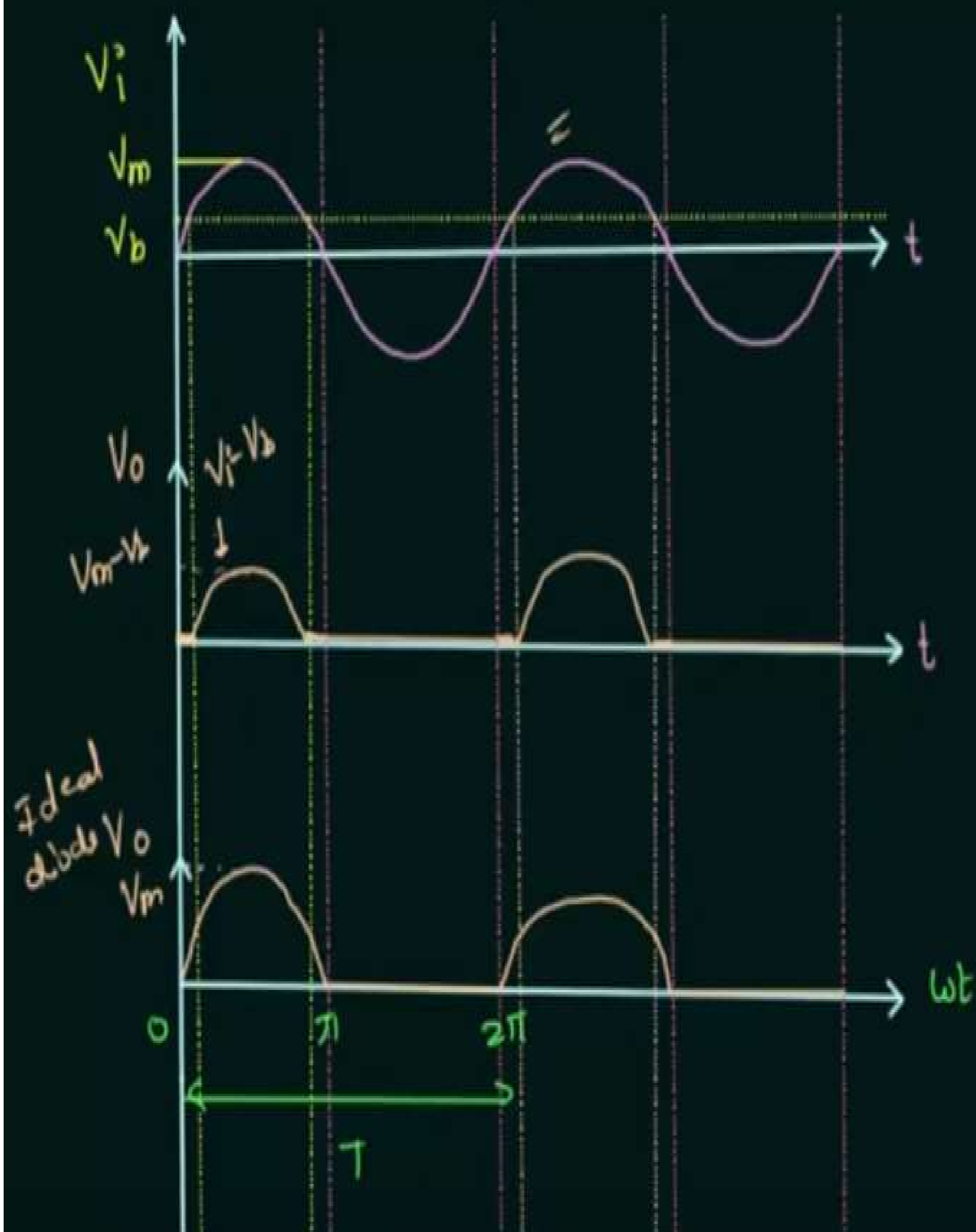
$$\boxed{V_o = V_i - V_b}$$

$$V_b = 0.7V$$
$$0.3V$$



V_i
−
+
R
V_o
$I = 0$
$V_o = 0$

Av. O/p voltage:



$V_o = V_i - V_b$

$V_i < V_b$

$V_o = 0$

Ideal model

$V_b = 0$

$V_o = V_i \rightarrow \oplus^{ve}$

$V_o = 0 \rightarrow \ominus^{ve}$

$V_o = V_m \sin\omega t \quad 0 \leq \omega t \leq \pi$

$V_o = 0 \quad \pi \leq \omega t \leq 2\pi$

$$V_{av} = \frac{\int_0^{2\pi} V_o \, d(\omega t)}{2\pi - 0}$$

$=$

$$= \frac{1}{2\pi}\left[\int_0^{\pi} V_m \sin\omega t \, d(\omega t) + \underbrace{\int_{\pi}^{2\pi} 0 \, d(\omega t)}_{0}\right]$$

$$= \frac{1}{2\pi}\int_0^{\pi} V_m \sin\omega t \, d(\omega t)$$

$$= \frac{V_m}{2\pi}\Big[-\cos\omega t\Big]_0^{\pi}$$

$$= \frac{V_m}{2\pi}\left[-\overset{-1}{\cos\pi} - \left(-\overset{1}{\cos 0}\right)\right]$$

$$= \frac{V_m}{2\pi} \times 2$$

$$\underline{\underline{V_{av}}} = \frac{V_m}{\pi} = \frac{V_m}{3.14} = \underline{0.318 V_m}$$

Av. load Current :

$$I_{av} = \frac{V_{av}}{R}$$

$$= \frac{V_m/\pi}{R}$$

$$I_{av} = \frac{V_m}{R\pi} = \frac{I_m}{\pi}$$

$$
\begin{aligned}
i &= I_m \sin \alpha \qquad && \text{if } 0 \le \alpha \le \pi \\
i &= 0 && \text{if } \pi \le \alpha \le 2\pi
\end{aligned}
\tag{4-9}
$$

where $\alpha \equiv \omega t$ and

$$
I_m \equiv \frac{V_m}{R_f + R_L} \tag{4-10}
$$

The transformer secondary voltage v_i is shown in Fig. 4-16*b*, and the rectified

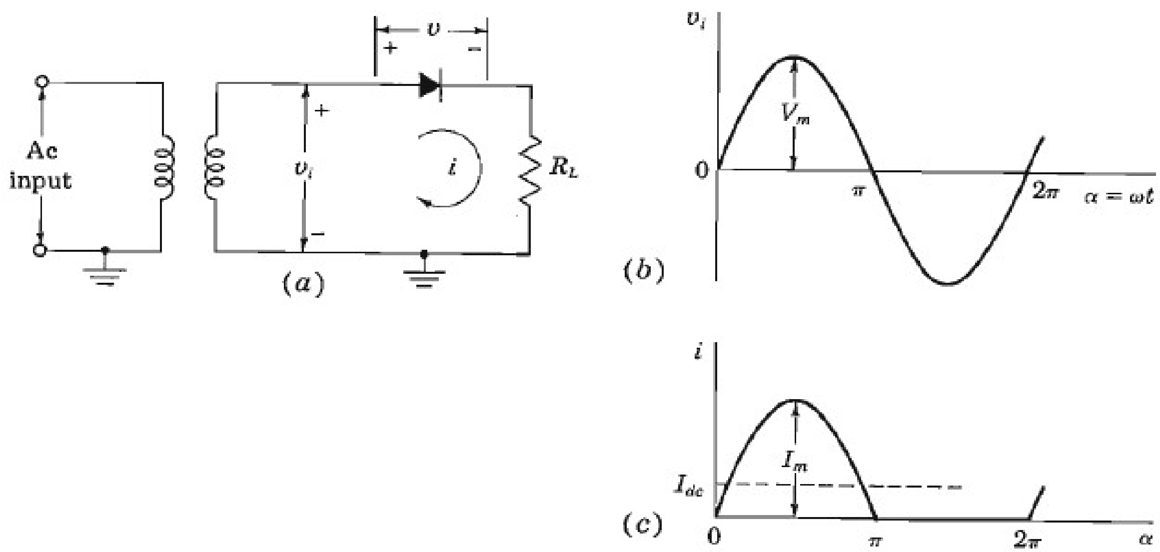


Fig. 4-16 (*a*) Basic circuit of half-wave rectifier. (*b*) Transformer sinusoidal secondary voltage v_i. (*c*) Diode and load current i.

Regulation

Defined as the variation of dc output voltage as a function of dc load current.

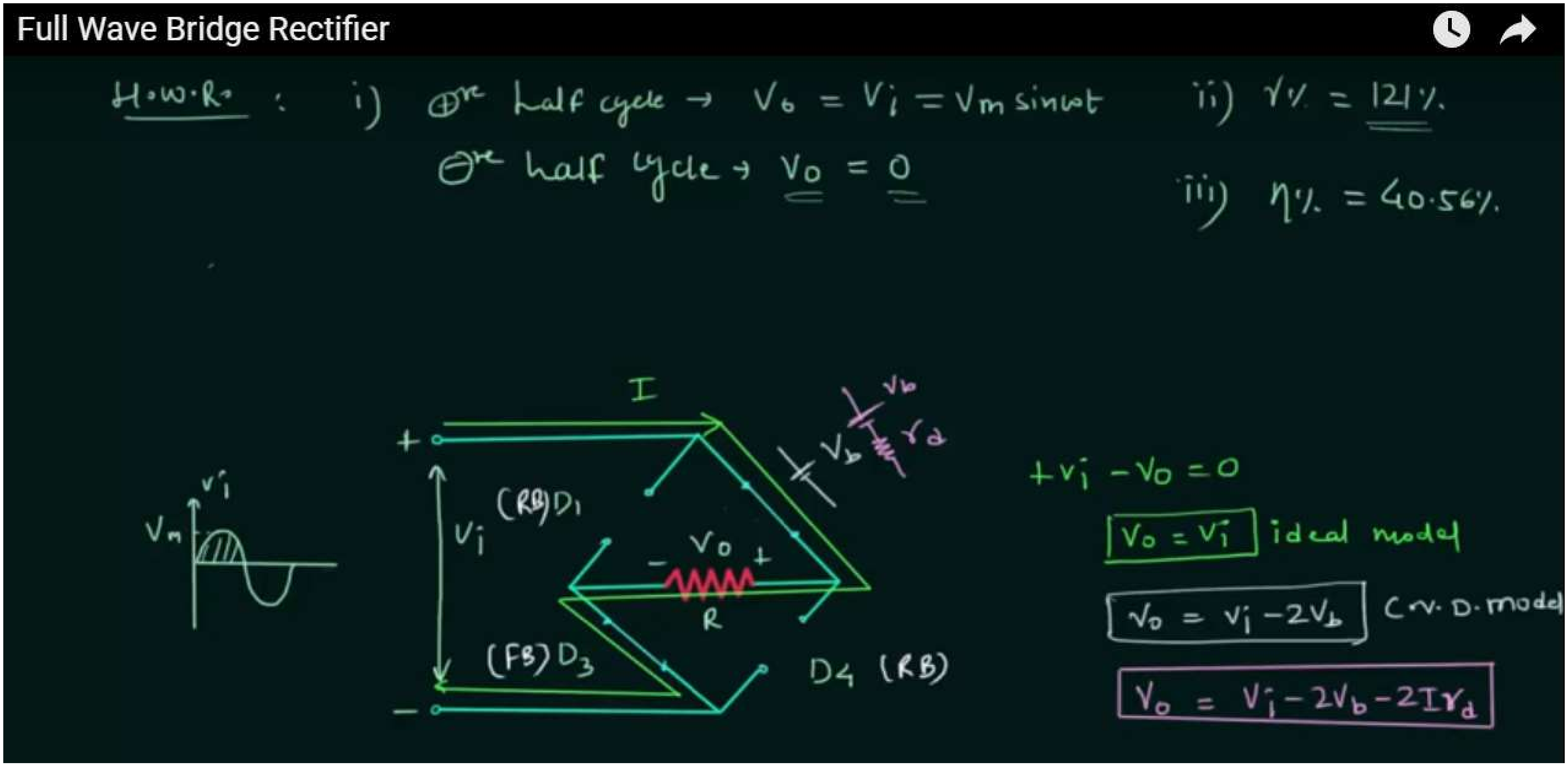
$$I_{dc} = \frac{I_m}{\pi} = \frac{V_m/\pi}{R_f + R_L}$$

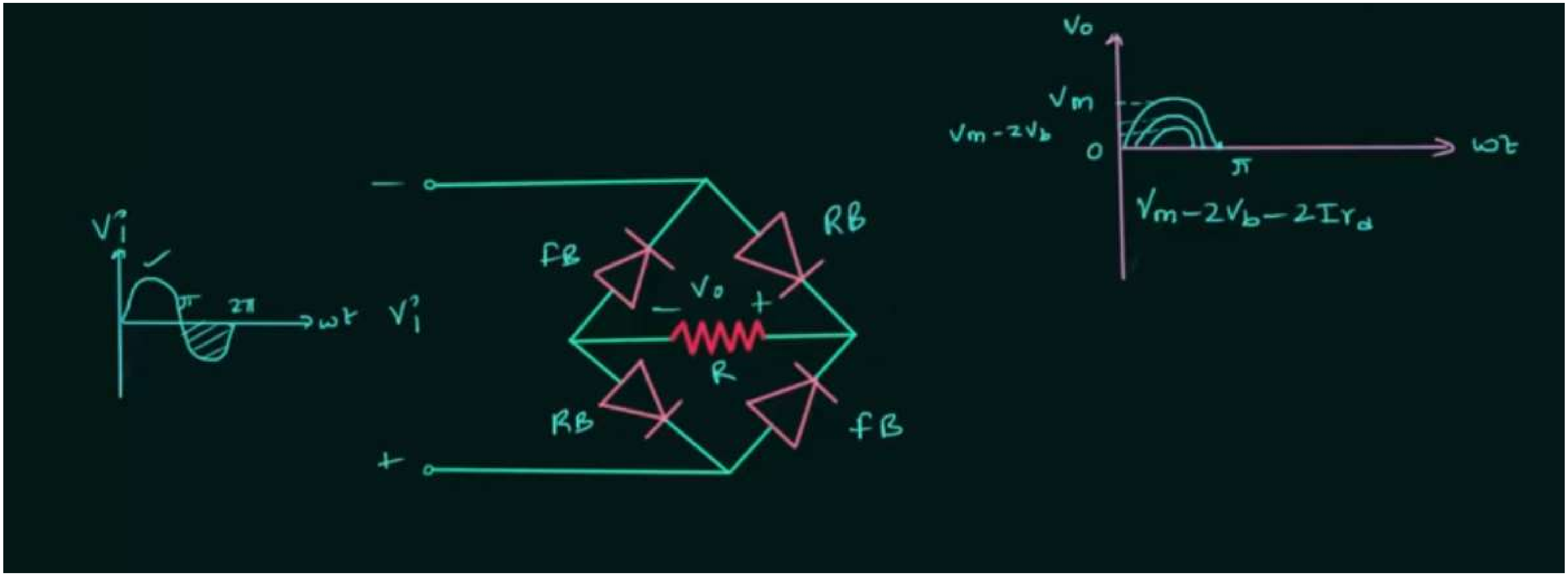
%regulation = $\frac{\text{V (no load)} - \text{V (load)}}{\text{V (load)}}$ x 100%

$$V_{dc} = \frac{V_m}{\pi} - I_{dc}R_f$$

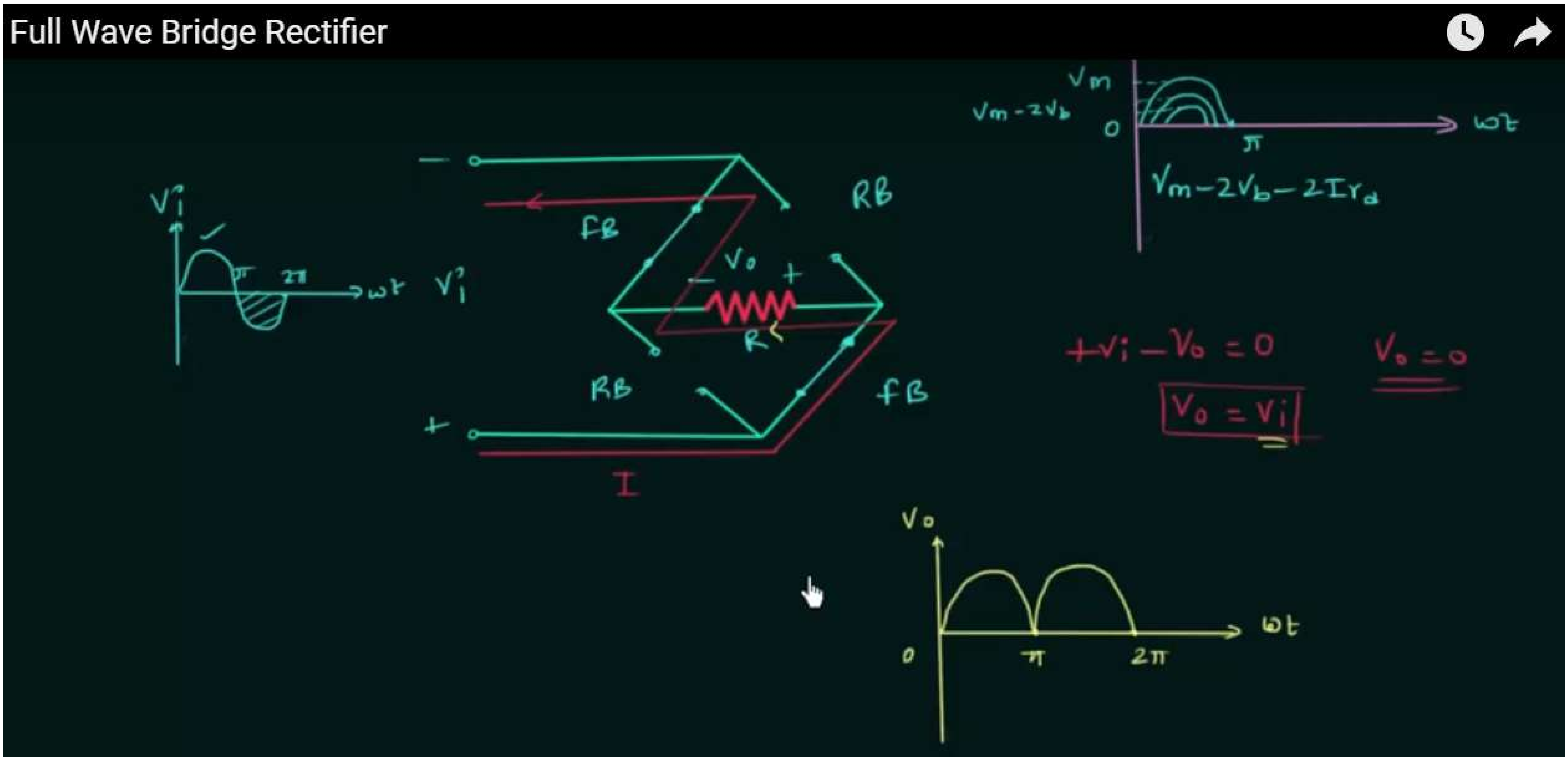
No load refers to zero current.

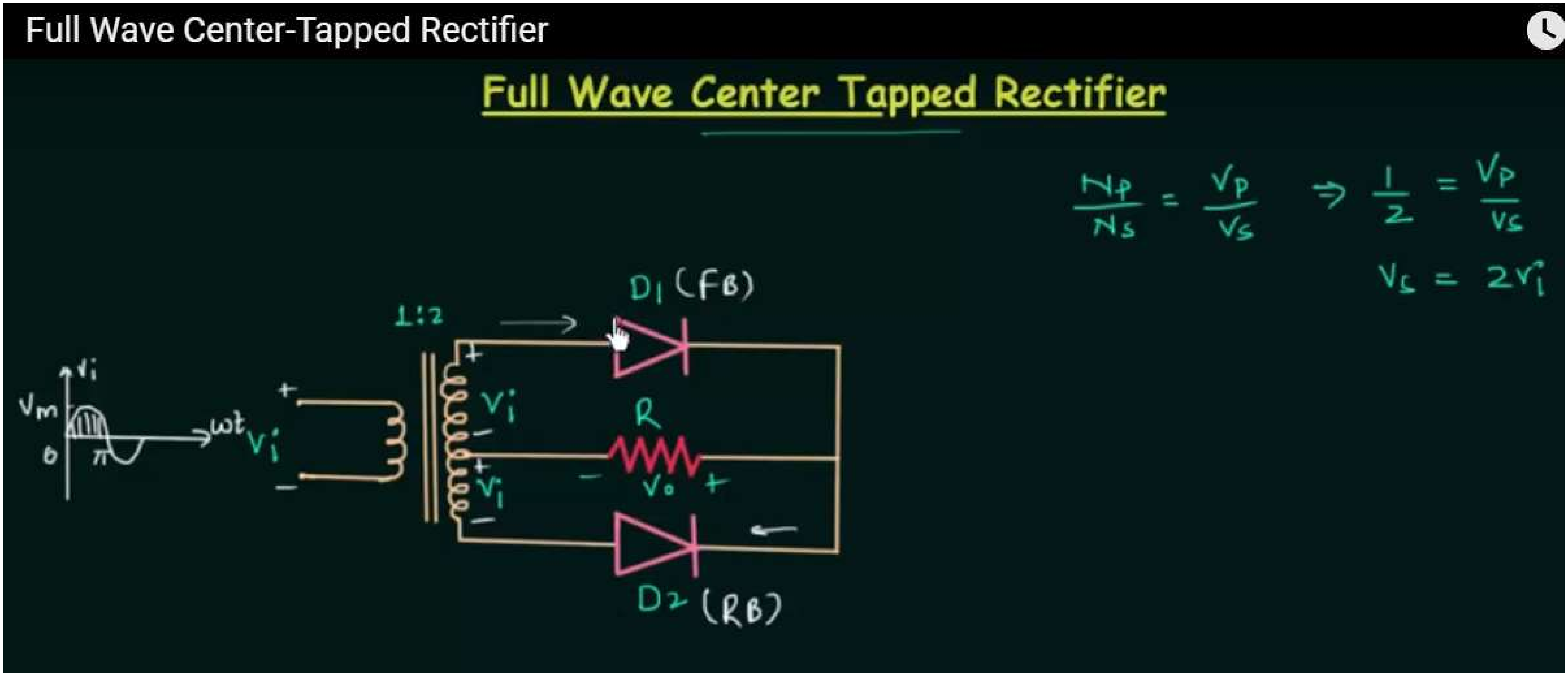
Load refers to normal load current.


Full Wave Bridge Rectifier
H.W.R. :
i) ⊕ve half cycle → Vo = Vi = Vm sinωt
⊖ve half cycle → Vo = 0
ii) γ% = 121%
iii) η% = 40.56%
I
Vb
rd
vi
Vm
Vi
(RB) D1
Vo
R
(FB) D3
D4 (RB)
+vi − Vo = 0
Vo = Vi
ideal model
Vo = Vi − 2Vb
C.V.D. model
Vo = Vi − 2Vb − 2Ird

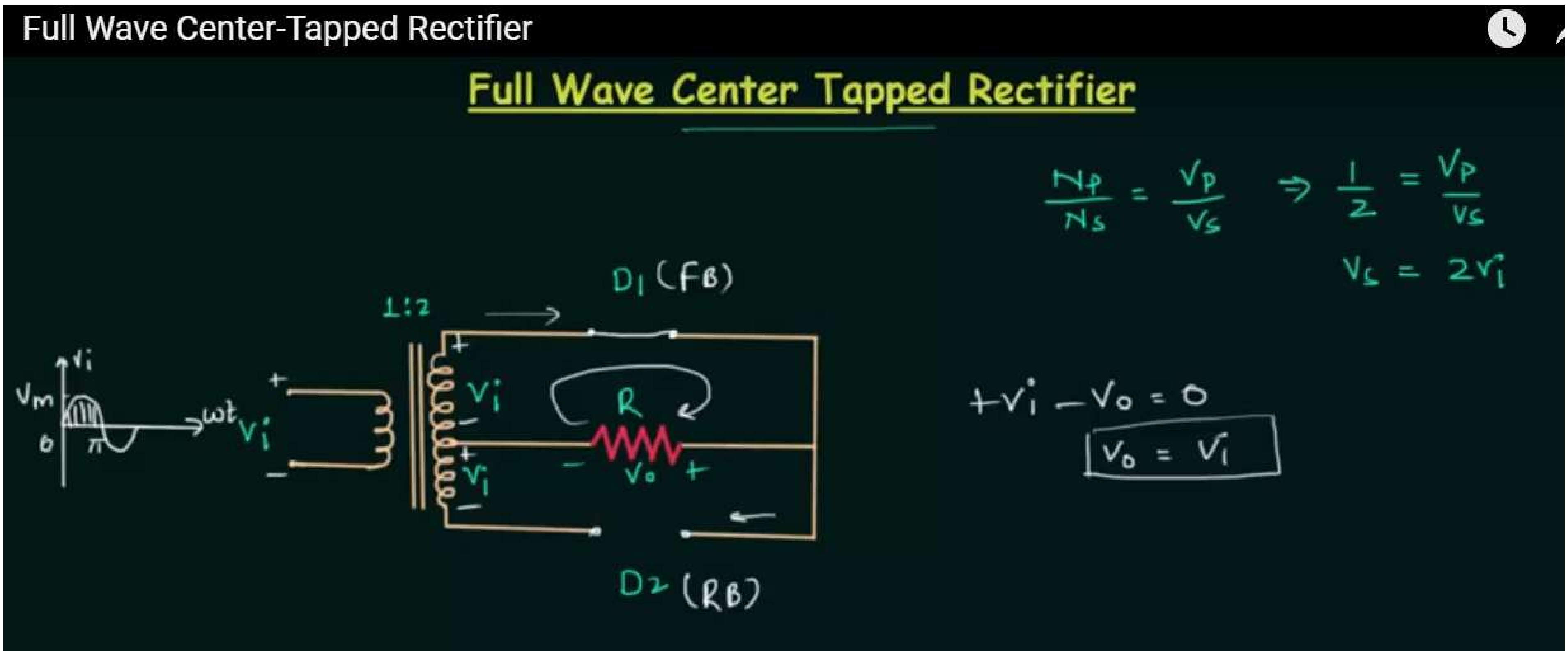


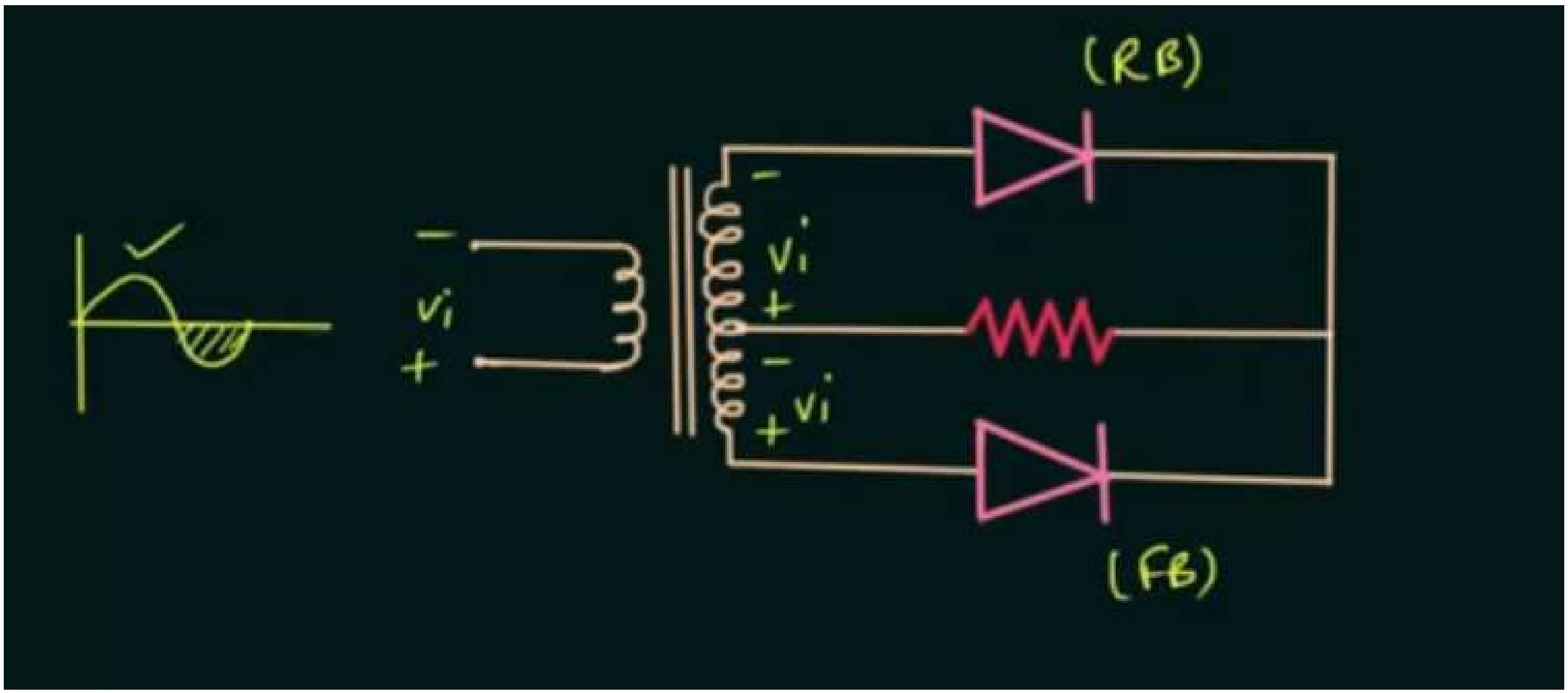
V_o
V_m
$V_m - 2V_b$
0
π
ωt
$V_m - 2V_b - 2Ir_d$
V_i
π
2π
ωt
V_i
−
+
fB
RB
RB
fB
− V_o +
R

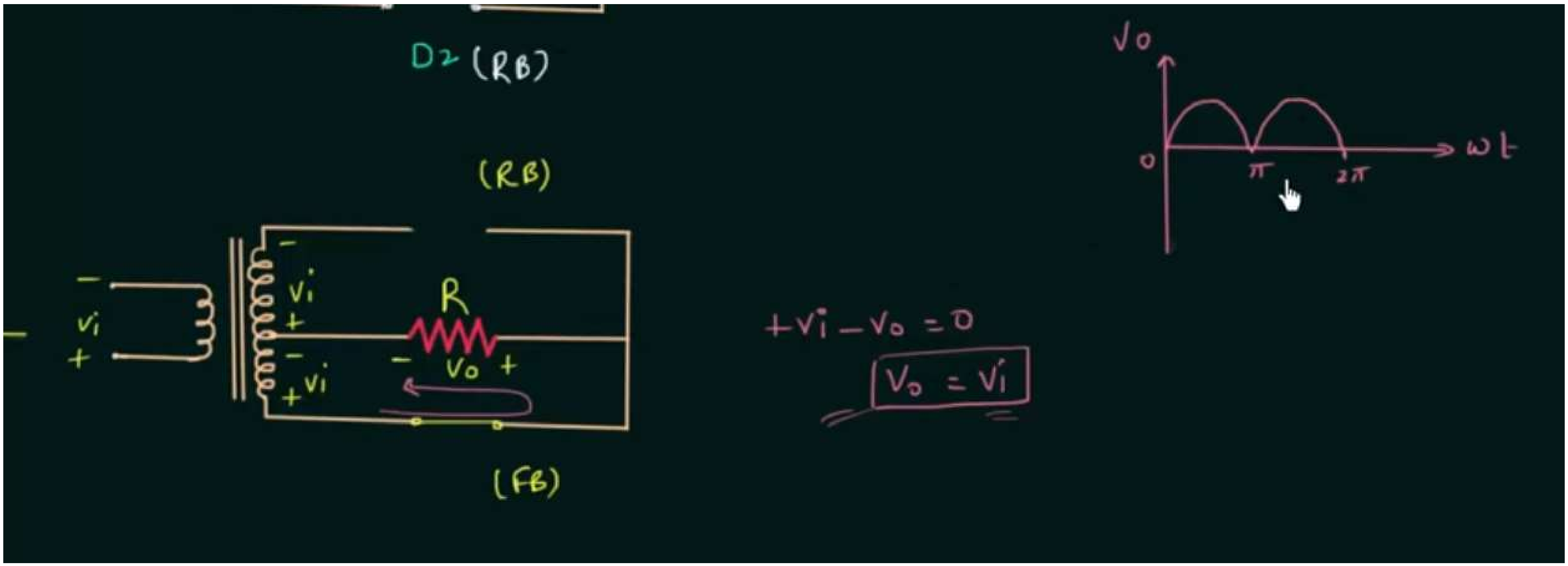

Full Wave Bridge Rectifier
Vm
Vm - 2Vb
0
π
ωt
Vm−2Vb−2IRd
vi
π
2π
ωt
vi
−
+
FB
RB
Vo
R
RB
FB
I
+vi − Vo = 0
Vo = vi
Vo = 0
Vo
0
π
2π
ωt



Full Wave Center-Tapped Rectifier
Full Wave Center Tapped Rectifier
$\frac{N_P}{N_S} = \frac{V_P}{V_S} \Rightarrow \frac{1}{2} = \frac{V_P}{V_S}$
$V_S = 2V_i$
D_1 (FB)
1:2
V_i
R
V_0
V_m
0
π
ωt
D_2 (RB)


Full Wave Center-Tapped Rectifier
Full Wave Center Tapped Rectifier
Np/Ns = Vp/Vs ⇒ 1/2 = Vp/Vs
Vs = 2vi
D1 (FB)
1:2
Vm
vi
0
π
ωt
R
V0
+vi − V0 = 0
V0 = Vi
D2 (RB)


(RB)
−
v_i
+
−
v_i
+
v_i
+
−
(FB)


D2 (RB)
(RB)
R
Vi
Vo
(FB)
+Vi − Vo = 0
Vo = Vi
Vo
0
π
2π
ωt

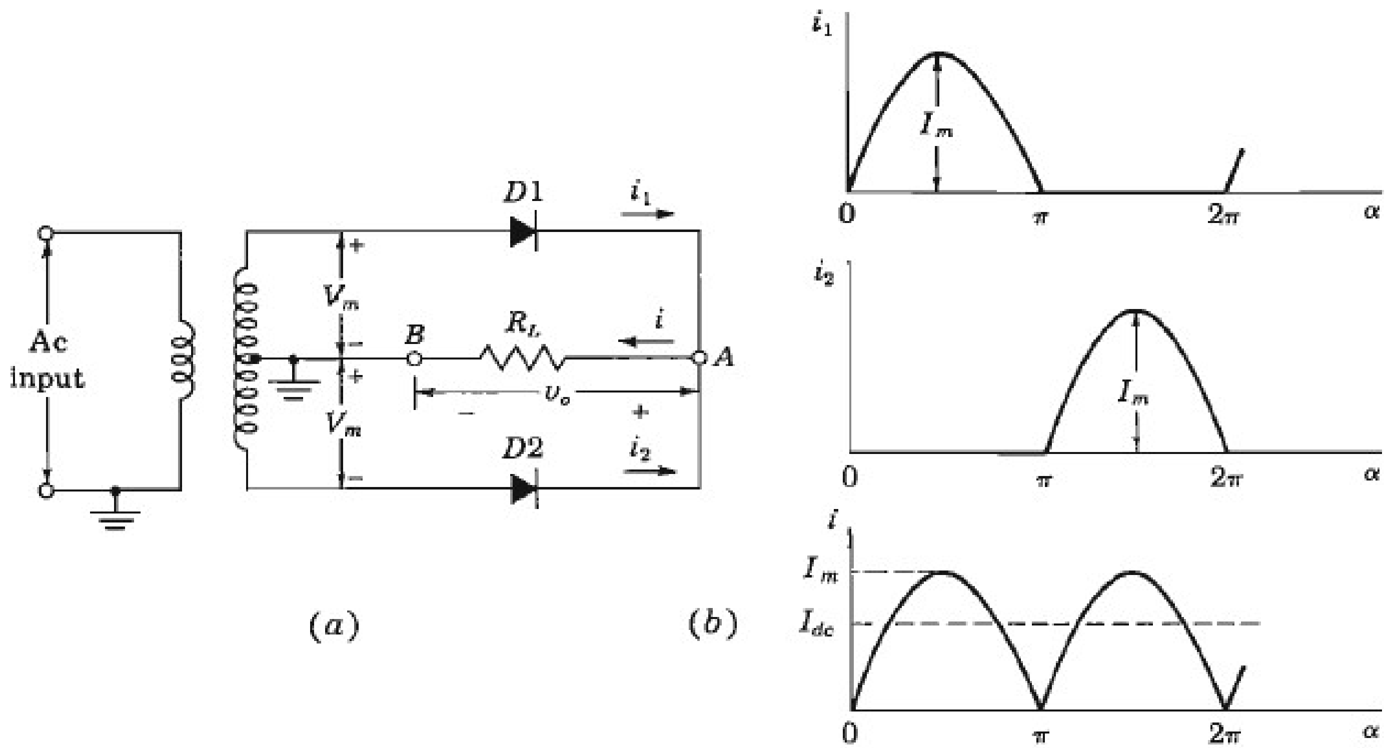


Fig. 4-19 (a) A full-wave rectifier circuit. (b) The individual diode currents and the load current i. The output voltage is $v_o = iR_L$.

		HWR	FWR
1	Avg. load voltage V_{dc} or V_{av}	$\frac{V_m}{\pi}$	$\frac{2V_m}{\pi}$
2	Avg. load current I_{dc} or I_{av}	$\frac{I_m}{\pi}$	$\frac{2I_m}{\pi}$
3	RMS load current I_{rms}	$\frac{I_m}{2}$	$\frac{I_m}{\sqrt{2}}$
4	RMS load voltage V_{rms}	$\frac{V_m}{2}$	$\frac{V_m}{\sqrt{2}}$
5	Form factor $F.F = \frac{V_{rms}}{V_{av}}$	1.57	1.11
6	Ripple factor $\gamma = \sqrt{(FF)^2 - 1}$	121%	48.1%
7	Efficiency $\eta = \frac{P_{load}}{P_{in}} \times 100$	40.56%	81.13%
8	PIV	$PIV \geq V_m$	$PIV \geq V_m$ Bridge $PIV \geq 2V_m$ Center tapped

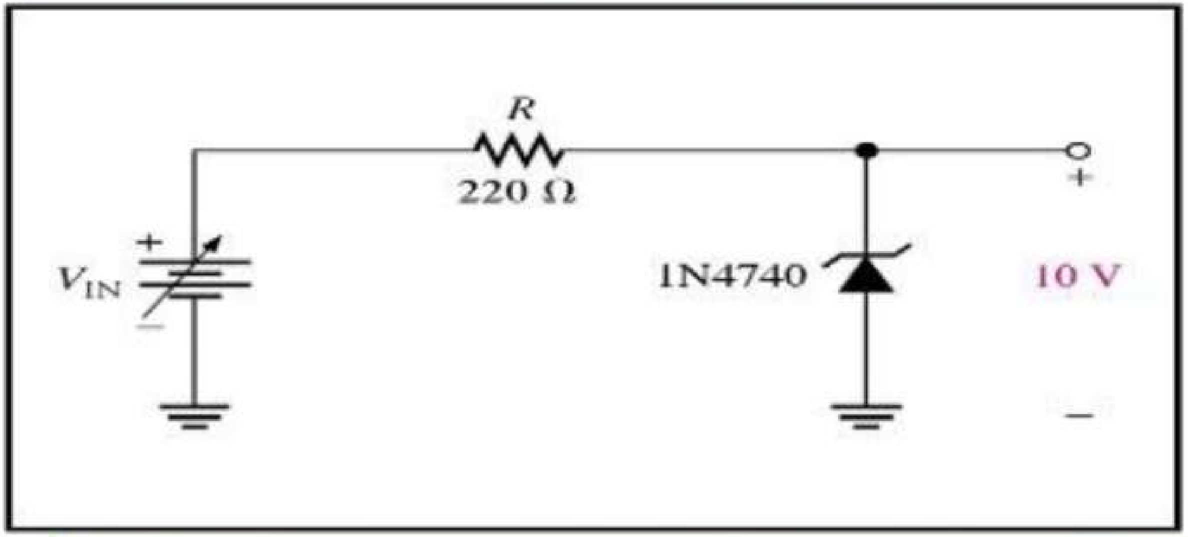
PIV-A maximum voltage to which the diode can be subjected.

Advantages of a bridge rectifier over center-tap (full wave rectifier)

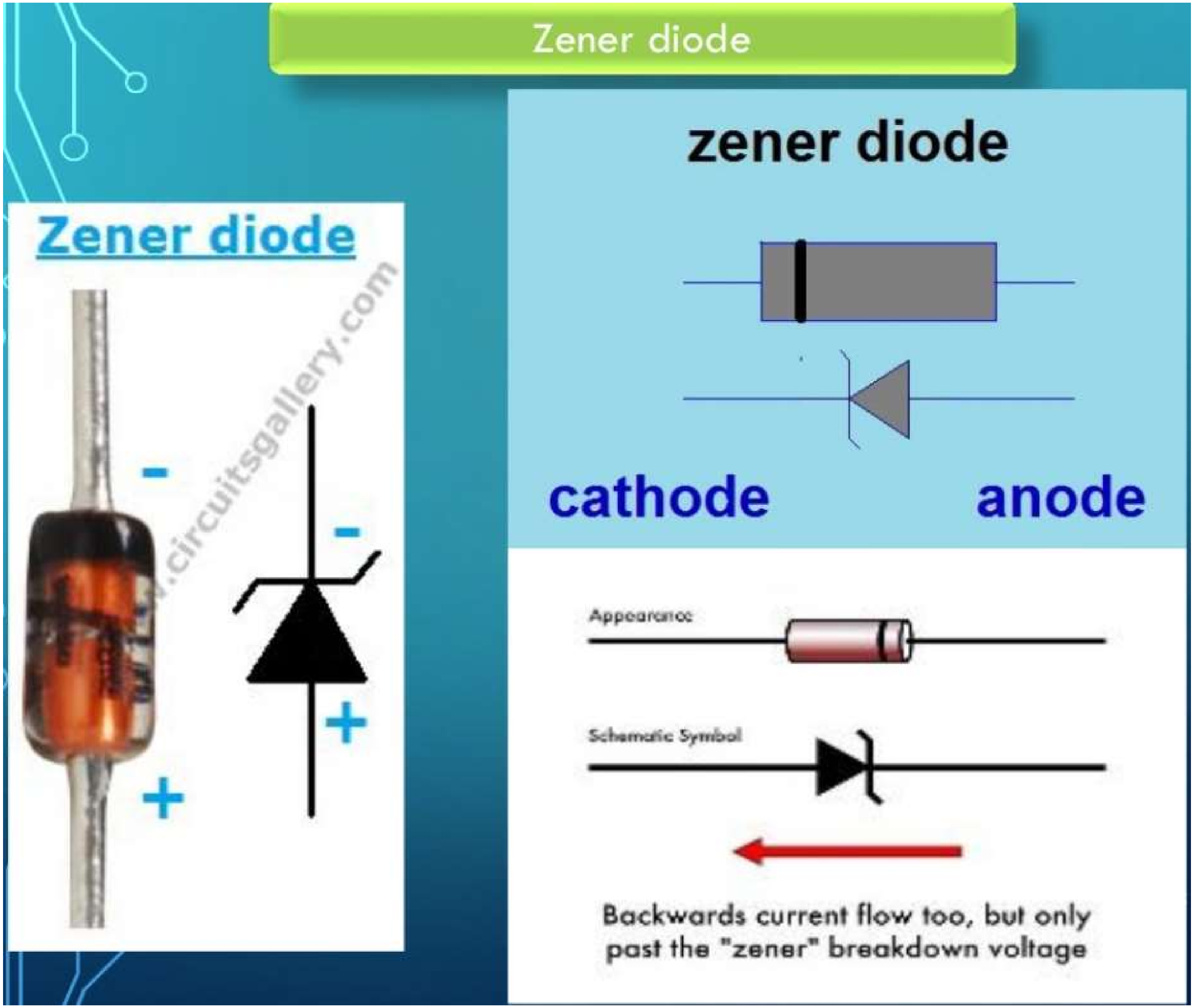
1. Bridge rectifier may use a transformer or may not use a transformer. It depends on the necessity of stepping up or down of voltages.
2. Bridge rectifier utilizes the entire transformer during the entire cycle (100%) of a time period of the voltage/current wave form. Center tap uses only for 50% of the transformer.
3. The size of the transformer used in bridge rectifier is smaller than that in the center tap rectifier.
4. The number of diodes used in bridge rectifiers is 4. The number of diodes used in center tap rectifiers is 2. However, the diodes are usually low cost, highly reliable and small size silicon diodes of latest technologies. So that is not a disadvantage.
5. The Peak Inverse voltage rating (PIV) of the diodes in the bridge rectifier is 1/2 of the PIV rating in case of center tap rectifier. That means that one needs high quality and costlier diodes for center tap rectifiers. PIV is the voltage that can be applied in the reverse bias of the diode without breaking down or avalanching of the diode.

Introduction

The **zener diode** is a silicon pn junction devices that differs from rectifier diodes because *it is designed for operation in the reverse-breakdown region*. The breakdown voltage of a zener diode is set by carefully controlling the level during manufacture. The basic function of **zener diode** is to maintain a specific voltage across it's terminals within given limits of line or load change. Typically it is used for providing a stable reference voltage for use in power supplies and other equipment.



This particular zener circuit will work to maintain 10 V across the load.


Zener diode
Zener diode
www.circuitsgallery.com
-
+
-
+
zener diode
cathode
anode
Appearance
Schematic Symbol
Backwards current flow too, but only past the "zener" breakdown voltage

Avalanche Breakdown

- At V_B, the electrons at p side acquire very high kinetic energy to break the covalent bond and become free.
- Further these free electrons will collide with other electrons and make them also free. Thus the process will go on like a chain reaction.
- Let say, one electron is free, it will collide with another and thus 2 electrons become free. Then, these 2 will collide with another 2 and total 4 electrons are free. This process is called Avalanche multiplication.
- The breakdown process is called avalanche breakdown.
- Zener diodes are specifically use this breakdown process for a purpose.
- **Peak Inverse Voltage**: It is the maximum reverse