* **Semiconductors** : Their conductivity lies between conductors & insulators.
  eg: $\underline{Si, Ge}$ imp.

* **Energy Band** $[E_g]$: Energy given to an e^- for reaching the conduction band.
  $E_g)_{Si} \simeq 0.7\,eV$ $E_g)_{Ge} \simeq 0.3\,eV$ {at Room temprature}

  also as $[T\uparrow \;\; E_g\downarrow \;\; \sigma\uparrow \;\; R\downarrow]$

* **Currents in a semiconductor**
  1. Hole current :
  2. Electron current :

  e^- & hole move in opposite drn but current flow in same direction.

  Net : Hole current + Electron current

---

* **Maths of General s.c.**

$$i_{sc} = i_n + i_p \quad \& \quad i = JA = nAeV_d = \sigma EA$$

$$\boxed{\sigma = ne\mu} = ne\frac{V_d}{E} = \sigma$$

$$\boxed{\sigma_{sc} = e[n\mu_n + p\mu_p]}$$ imp.

μ = mobility
J: Current density
σ : conductivity
E : EF
V_d : Drift current
e : 1.61×10^{-19} C

also for neutrality : $\boxed{\underbrace{n + N_p}_{\text{negative charges}} = \underbrace{N_n + p}_{\text{+ve charges}}}$

& by mass action law

$$\boxed{np = n_i^2}$$

n → electron charge density
p → hole charge density
n_i → insintric charge density

Types of Semiconductors :

Intrinsic

$p + N_n = n + N_p$

$N_n = 0 = N_p$ ✓

$p = n$ ✓

$\boxed{n = n_i = p}$

$\boxed{\sigma = n_i e [\mu_n + \mu_p]}$

Extrinsic

Grp 13 → p-type [B, Al, Ga, In]

$p >> n$

$N_n = 0$

$N_p \approx p$

$\boxed{n = \frac{n_i^2}{N_p}}$

$\sigma \approx N_p \cdot \mu_p e$

Grp 15 → n-type [P, As, Sb]

$p << n$

$N_p = 0$

$N_n \approx n$

$\boxed{p = \frac{n_i^2}{N_n}}$

$\sigma \approx N_n \mu_n e$

SemiConductor Diode :

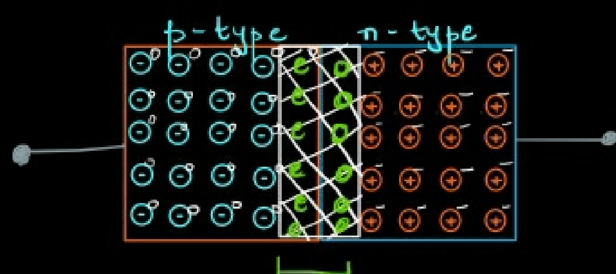
→ diffusion begins from n region to p of the e⁻s or i_d [$p \longrightarrow n$]

→ p n

⊖ ⊕

$0 \vdash \ominus \rightarrow V_b$ → Barrier Potential → Built in potential

$\mathcal{E} \longleftarrow$



here: $J_{net} = 0 = \underbrace{i_{diff}}_{p \to n} - \underbrace{i_{drift}}_{n \to p}$

$[i_{drift} = i_{diff}]$

for no biasing or Potential

applied.

V_B

and for no bias :

$$V_B = V_T \ln\left[\frac{N_p \cdot N_n}{n_i^2}\right] \qquad V_T = \left(\frac{k}{e}\right)T$$

where $k \Rightarrow$ boltzmann constant

$e \Rightarrow 1.61 \times 10^{-19}$ C

$$k/e = 1/11600$$

[V_B]

$$\boxed{V_B = \frac{T}{11600} \ln\left\{\frac{N_p \cdot N_n}{n_i^2}\right\}} \; *$$

$$\boxed{V_T = T/11600} \; *$$

for $T = 300$ K or RT

$V_T = 0.026$ V

$$V_B = 0.026 \ln\left[\frac{N_p \cdot N_n}{n_i^2}\right]$$

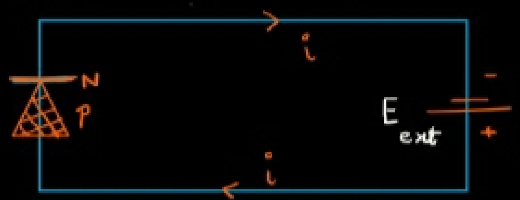
[W_D] width

$$\boxed{W_D = \sqrt{\frac{2\varepsilon}{e} \cdot \left[\frac{1}{N_p} + \frac{1}{N_n}\right] V_T \cdot \ln\left(\frac{N_p N_n}{n_i^2}\right)}}$$

{ε : permittivity $= \varepsilon_r \varepsilon_0$}

[V_T : $T/11600$]

Forward Bias

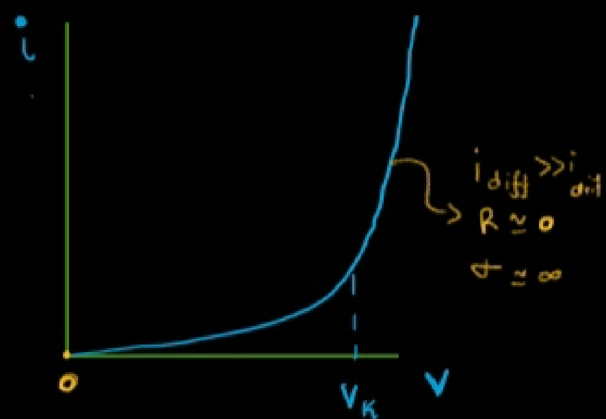


$i = i_{diff} - i_{drift}$

here {$V_B' = V_B - E_{ext}$}

$\longrightarrow$ here Barrier potential $\downarrow$

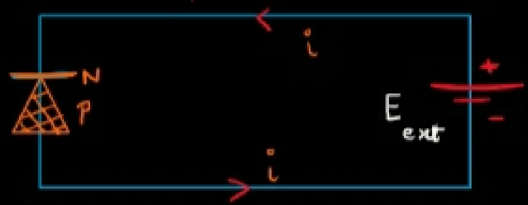
$i_{diff} >> i_{drift} \longrightarrow i = i_{diff}$



Reverse Bias

V_Z

Reverse Bias

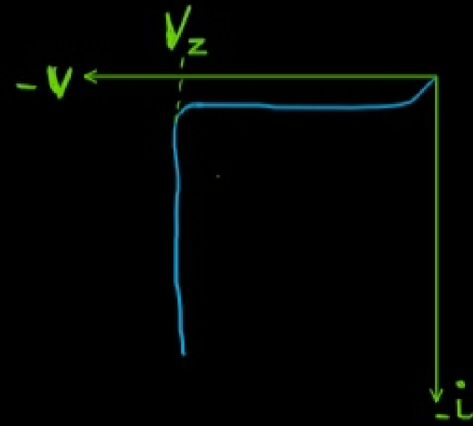


$i = -i_{diff} + i_{drift}$

here $\{ V_B' = V_B + E_{ext} \}$

→ here Barrier potential ↓

→ $i = i_{diff}$



* Diode-Voltage Relationship :

[V_d = Voltage across diodes]

$$\frac{I_{diode}}{I_{saturation}} = e^{\frac{k V_d}{T}} - 1$$

$$\boxed{\frac{I_d}{I_s} = e^{\frac{V_d}{V_t} \cdot \frac{1}{n}} - 1}$$

Imp.

$k = \frac{e}{K n} = \frac{11600}{n}$

e: 1.6×10^{-19}

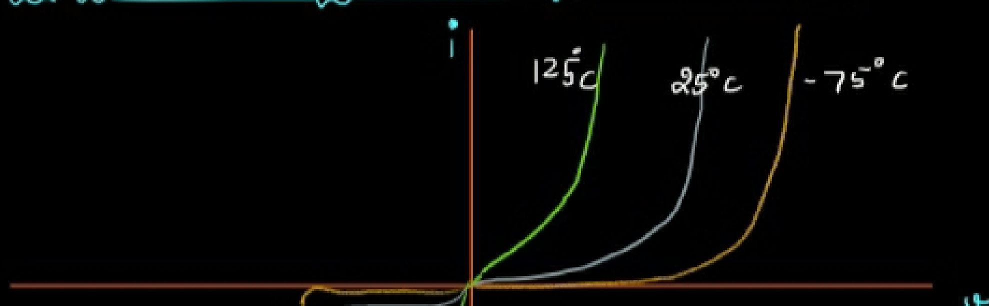
K: Boltzmann constant

$n = 1$: Ge, Si (for high I_d)

$n = 2$: Si [for low I_d]

$$\frac{k}{T} = \left(\frac{e}{kT}\right)\frac{1}{n} = \frac{1}{n \cdot V_T}$$

* Effect of Temprature on V-I characteristics

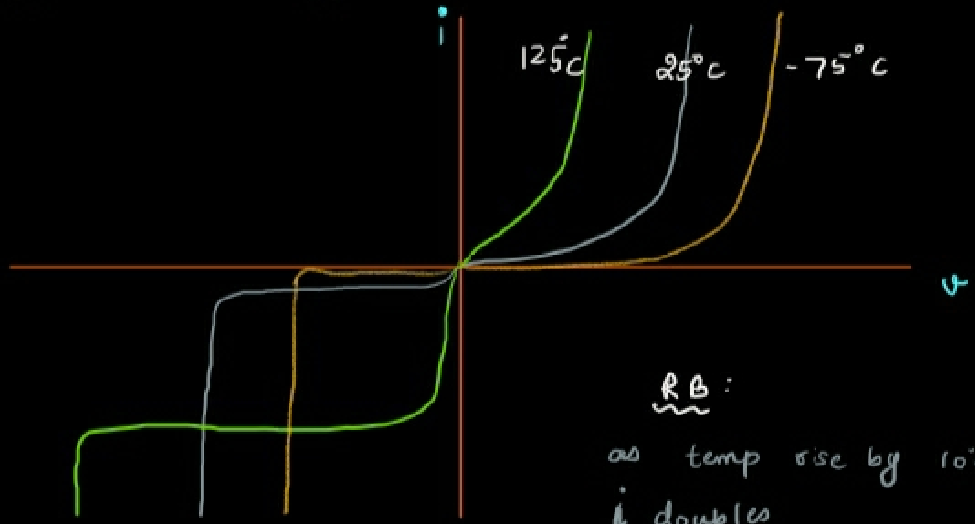


FB :

as temprature inc the V_0 decrease by 0.25 v / 100°c

$V_{T'} = V_T - \left(\frac{25}{\ }\right) \Delta T$

* Effect of Temprature on V-I characteristics



FB :

as temprature inc the V_b decrease by 0.25 v / 100°c

$$V_{T'} = V_T - \left(\frac{25}{10^4}\right)\Delta T$$

$[V_b \propto \Delta T]$

RB :

as temp rise by 10°C ⟶ the $i_{sat.}$ doubles

$$i_{T'} = i_T \,(2)^{\frac{T'-T}{10}}$$

---

* Diode Equivalent ckt :

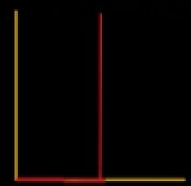
Ideal : $\{R_d = 0 = V_d\}$

i) Piece-wise Defined ckt :

fb

ii) for constant Voltage / Simplified eqvⁿ ckt

$R_d = 0 \quad V_d \neq 0$



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* Load Line Analysis :

$V - V_d = (R_L + R_D)\,i$

or $\boxed{\dfrac{V - V_d}{R_L + R_D} = i}$

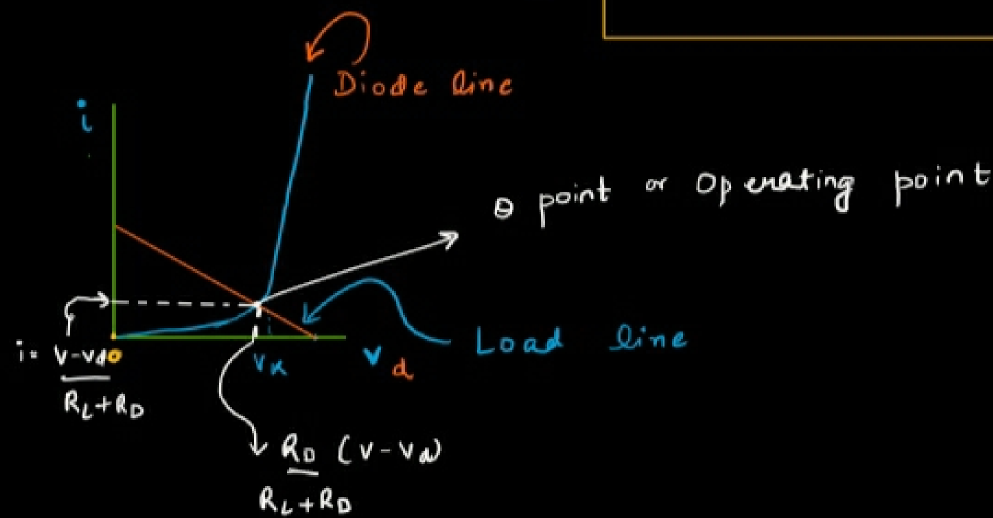
Q point or Operating point

$V_d = V - iR_L$

* Load Line Analysis :

$V - V_d = (R_L + R_D)\, i$

or $\boxed{\frac{V - V_d}{R_L + R_D} = i}$



$V_d = V - iR_L$

$\frac{-V_d}{R_L} + \frac{V}{R_L} = i$

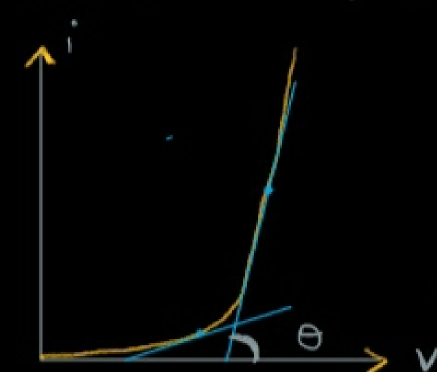
---

* Resistances

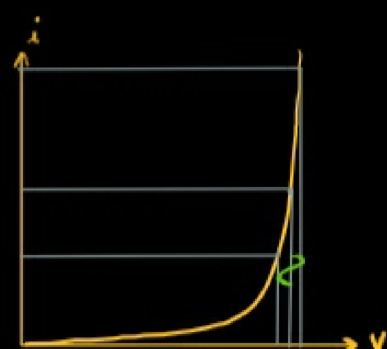
i) DC Resistance →

for DC voltage connected this graph dont varies.

$R = \frac{1}{\text{slope}} = \frac{i}{V}\Big|_{\text{point}}$



ii) AC Resistance



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

$\frac{dI_d}{dV_d} = I_s \cdot \frac{1}{\eta V_T} \cdot e^{V_d/\eta V_T}$

$R = \frac{dV_d}{dI_d}$

$R = \frac{\eta V_T}{I_s e^{V_d/\eta V_T}} = \frac{\eta V_T}{I_d + I_s}$

$I_s \ll I_d \longrightarrow R = \frac{\eta V_T}{I} = \frac{\eta \cdot T}{11600\, I}$

$T = 300K$

$\boxed{R = 52mV}$ or $\boxed{R = 26mV} \longleftarrow T = 300K$

$$R = \frac{\eta V_T}{I_s e^{V_d/\eta V_T}} = \frac{\eta V_T}{I_d + I_s} \qquad I_s << I_d \longrightarrow R = \frac{\eta V_T}{I} = \frac{\eta \cdot T}{11600\, I}$$

$$\boxed{R = \frac{52\,mV}{I}} \quad \text{or} \quad \boxed{R = \frac{26\,mV}{I}} \longleftarrow \begin{matrix} T = 300K \\ \eta = 1 \end{matrix}$$

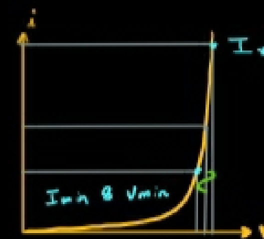
for $\boxed{\eta = 2}$

low I value.

high values of I for Si or Ge (all)

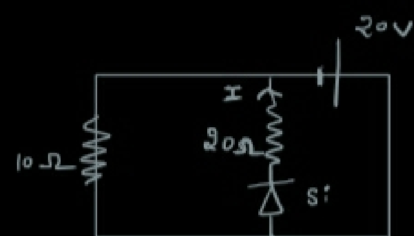
iii) Avg. AC Resistance:

$$\text{avg AC } R = \frac{V_{max} - V_{min}}{I_{max} - I_{min}}$$



Questions:

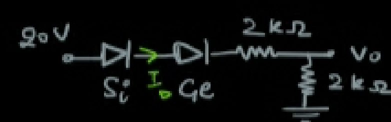
Q_1: find I.



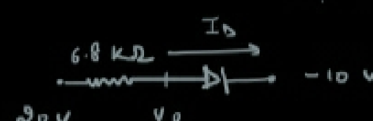
Q_2: find V_o & I_D. $\{R_D \approx 0\}$

a)

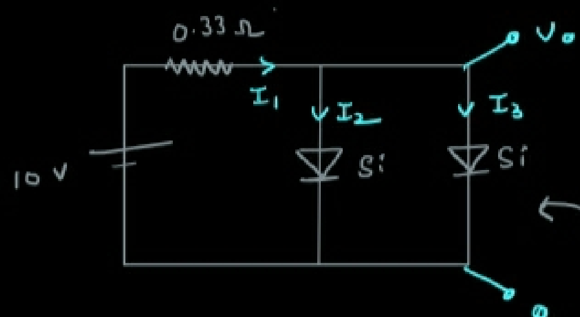
b)



c)



Q_3

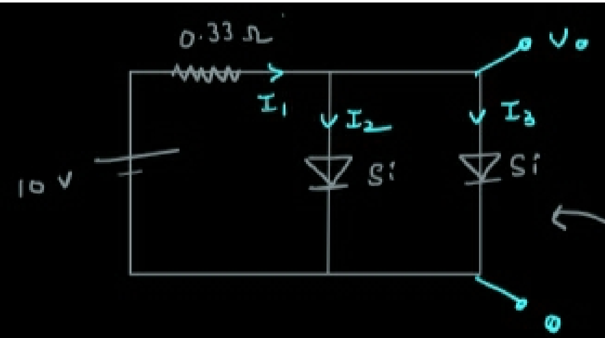


find all unknowns.

Q_5.

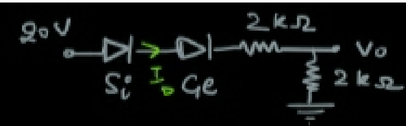
Q_4 Determine V_o & I_D.

Q3

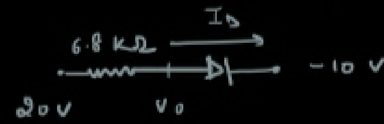


find all unknowns.

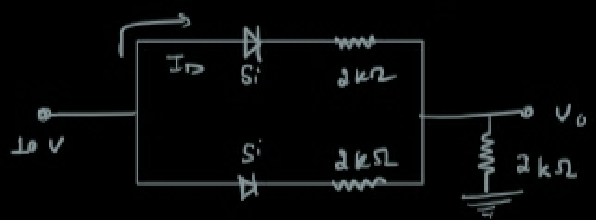
b)



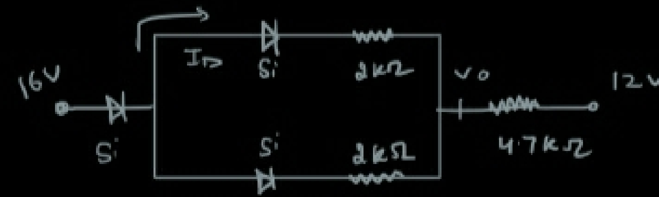
c)



Q4 Determine V_o & I_D.



Q5.



Rectifiers :

Terms used :

a) avg value or DC value : $\dfrac{\int_0^{2\pi} f(\omega t)\cdot d(\omega t)}{2\pi}$

b) Rms value : $\sqrt{\dfrac{\int_0^{2\pi} [f(\omega t)]^2 \, d\omega t}{2\pi}}$

c) Form-factor or FF : $\dfrac{V_{rms}}{V_{dc}}$

d) Ripple factor (γ) :

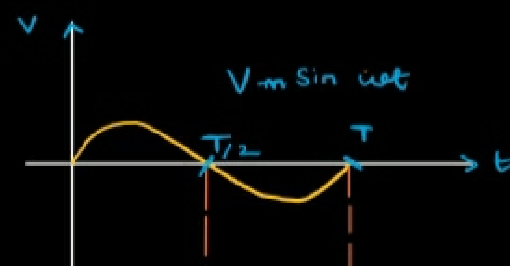
(Ac comp. in output) $\gamma = \sqrt{F.F^2 - 1}$ or $\gamma = \dfrac{\text{Rms value of ac component}}{\text{avg. value of output.}}$

e) η (Efficiency) $= \dfrac{P_{avg}}{P_{rms}} \cdot 100 = \dfrac{100}{(FF)^2}$

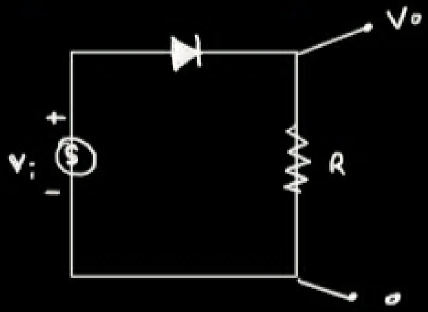
i) Half wave Rectifier :

fb :

$$\left[V_i - V_d = V_o\right]$$



i) Half wave Rectifier :



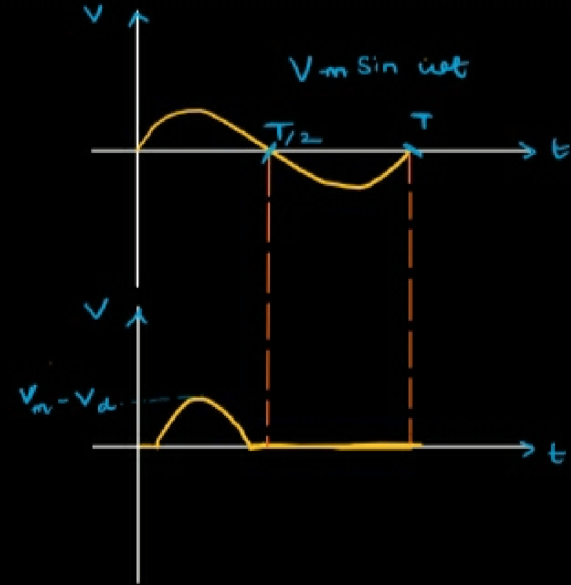
fb :

$$\left[V_i - V_d = V_o \right]$$

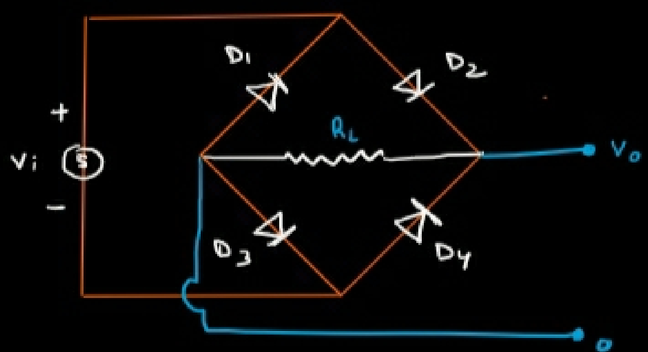
Rb :

$i = 0$

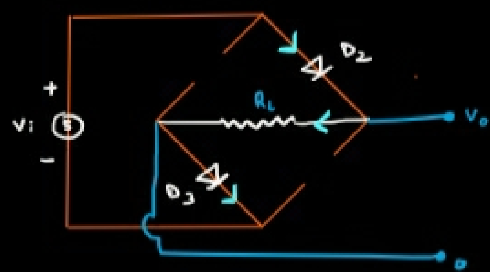
$\{ V_o = 0 \}$



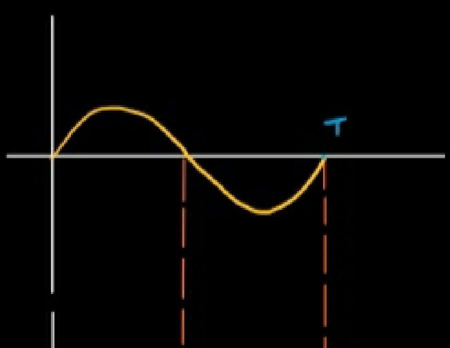
ii) Full - wave Rectifier :



fb :

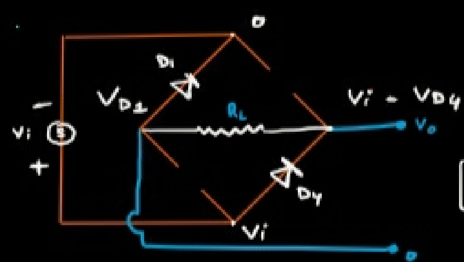


$$\left[V_i - V_{D_2} - V_{D_3} = V_o \right]$$



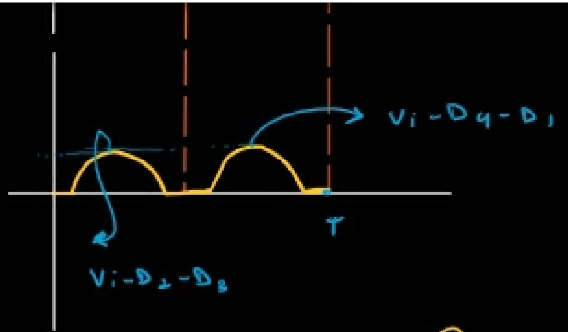
rb :

(wrt D_2 & D_3)

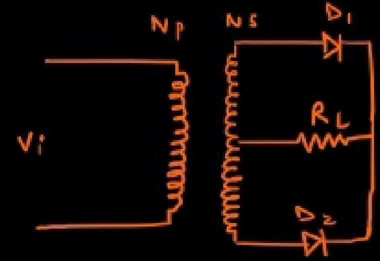


$$\left[V_o = V_i - V_{D4} - V_{D1} \right]$$

or Centre - tapping ↓



or Centre - tapping ↓



fb & sb

$$\left\{ \frac{V_i}{2} \cdot \frac{N_S}{N_P} = V_o \right\}$$

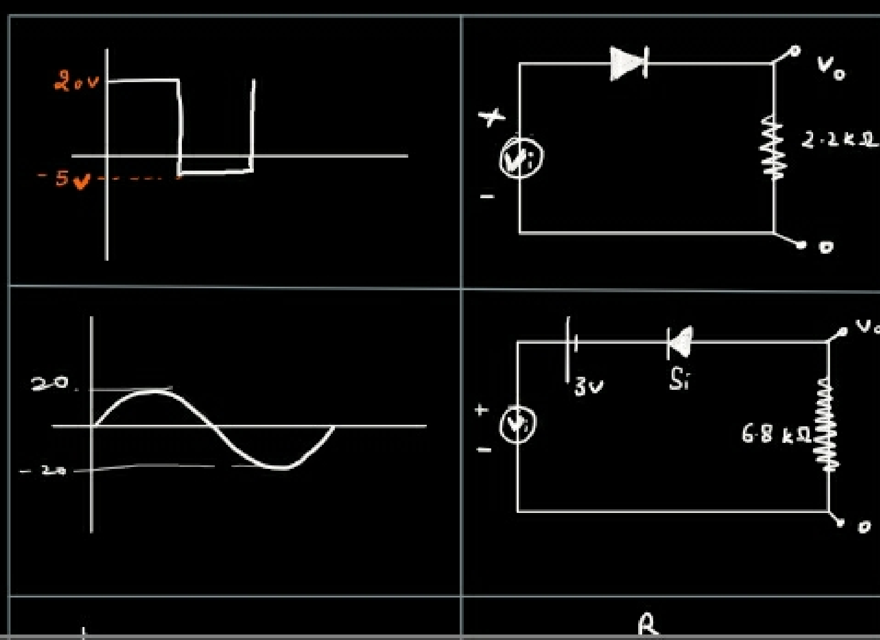
$V = V_m$

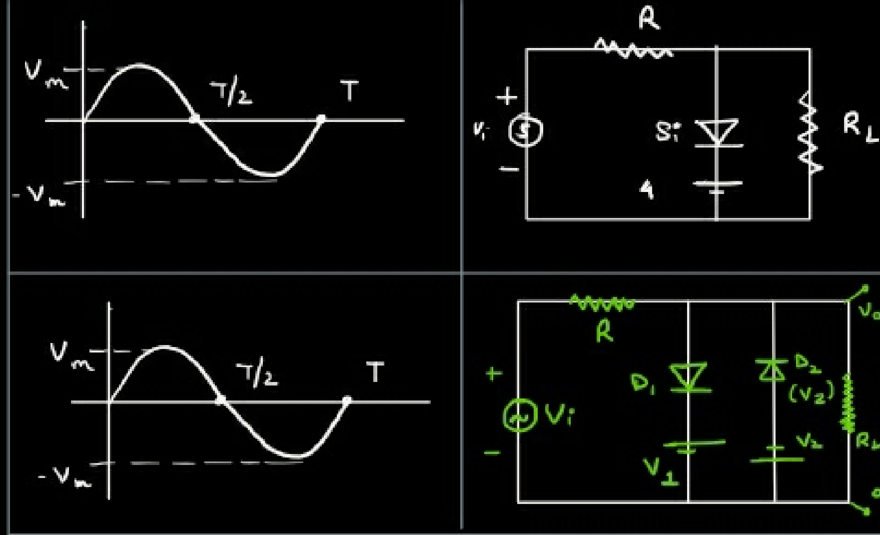
$100\sqrt{(ff)^2 - 1}$ $\qquad$ $100/(ff)^2$

	Avg.	Rms.	Ff (rms/avg)	Ripple %	η
Half wave	V/π	$\frac{V}{2}$	$\pi/2$	121 %	40 %
full wave	$2V/\pi$	$V/\sqrt{2}$	$\pi/\sqrt{8}$	48.39 %	81 %

* Clipper ckts: Used to clip either the positive or negative halves of V_i.

Q: Determin V_o if V_i is (a) & ckt is (b).





[Sol^n in register]

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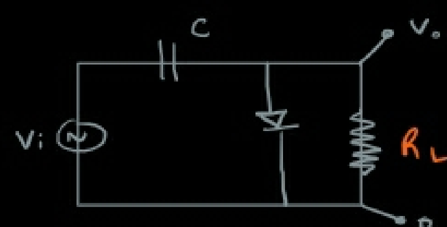
* Clamper : It shifts the votage graphs up or down by some units.

$[\tau = RC >> T/2]$

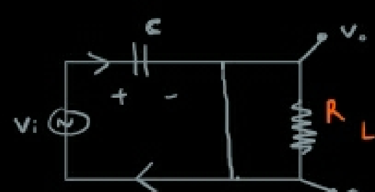
Q1

for



Sol:

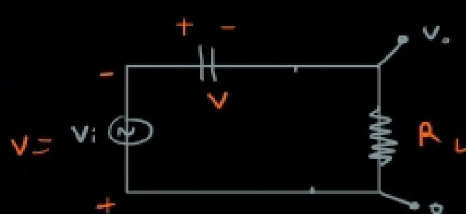
for $0 - T/2$



$V_o = 0 \quad \{ i_L = 0 \}$

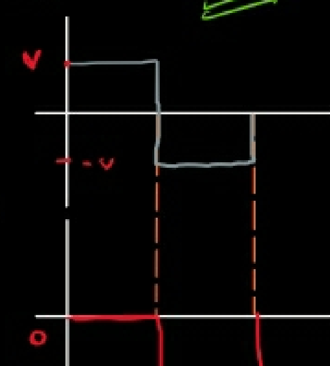
$V_C = +\!-\!\|\!-\!- = V_i = V$

for $T/2 - T$



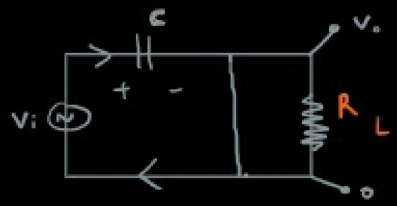
$V_o + V + V = 0$

$V_o = -2V$



Sol:

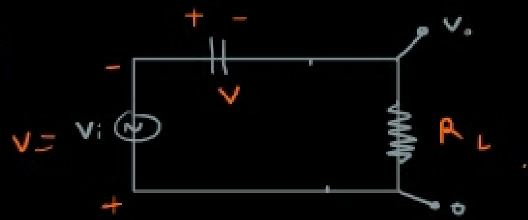
for $0 - T/2$



$V_o = 0 \quad \{ i_L = 0 \}$

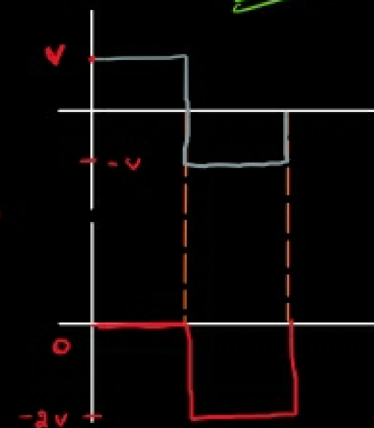
$V_C = \; +\!-\!|\,|\!-\; = V_i = V$

for $T/2 - T$

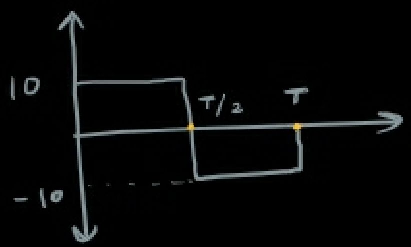


$V_o + V + V = 0$

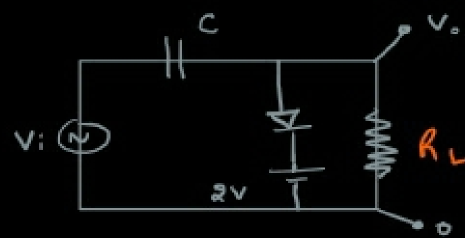
$V_o = -2V$

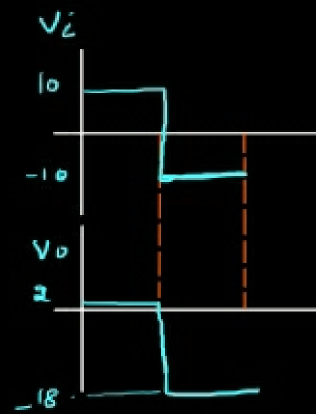


Q2:

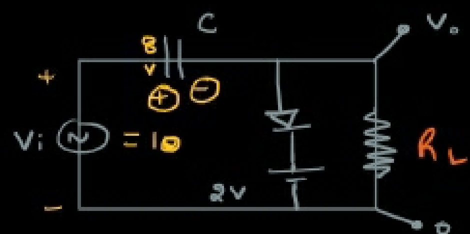


for



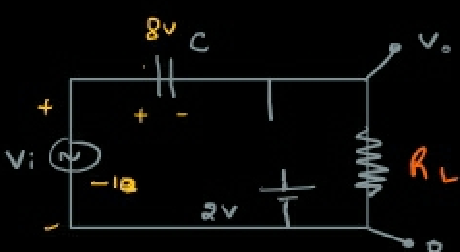


Sol: for $0 - T/2$:



$V_o = 2V$

for $T/2 - T$



$V_o = 18V$