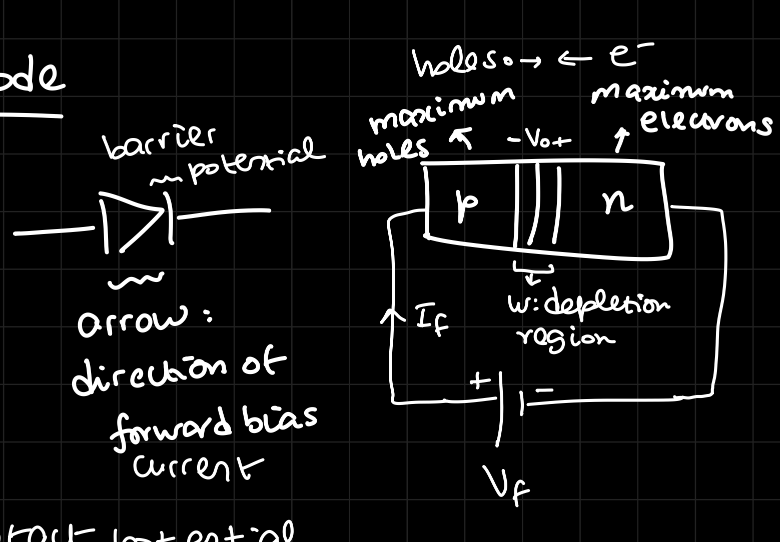
→ TF taking the lecture

Zener Diode

barrier potential



arrow: direction of forward bias current

V_0: contact potential

$$V_0 = \frac{KT}{q} \ln\left[\frac{N_A N_D}{n_i^2}\right] \text{ Volt}$$

$V_T = \frac{KT}{q}$ at room temp, $T = 298K$

$K = 1.38 \times 10^{-23}$ J/K

$q = 1.6 \times 10^{-19}$ C

$$V_T = \frac{T}{11{,}600} \text{ Volt} \simeq 25mV$$

$$W = \sqrt{\frac{2\varepsilon}{q}\left(\frac{1}{N_A} + \frac{1}{N_D}\right)V_0 - V}$$

W: width of depletion region

ε = electric permittivity

$\varepsilon = \varepsilon_0 \varepsilon_r$

$\varepsilon_0 = 8.854 \times 10^{-12}$ F/m

V = applied voltage

V_0 = contact potential

in reverse bias → applied voltage = -ve = V

$V_0 - V$ = +ve

W = +ve ↑

Width of depletion region increases in reverse bias

In forward bias, depletion layer decreases
In reverse bias, depletion layer increases
wrt no bias

Diode general current equation

$$I = I_S\left[e^{\frac{V}{\eta V_T}} - 1\right]$$

$\eta = 1$ for Ge and 2 for Si
2.7 for GaAs

I_S = leakage current

V_f = forward bias voltage

$$\frac{V_F}{V_T} \to \frac{V_F}{\sim 25 \times 10^{-3}} = \frac{V_F}{25} \times 10^3 > 1 \checkmark$$ for forward bias

$e^{V_F/V_T} >>> 1$

neglect the -1 wrt e^{V_F/V_T} in above eqn

$$\boxed{I_F \simeq I_S\left(e^{V_F/V_T}\right)}$$

for reverse bias,

$$V = -ve = -V_R$$

$$e^{-V_R/V_T} <<< 1$$

$$\boxed{I_R \simeq -I_0}$$

Si → 14 → 2,8,4

Ge → 32 → 2,8,18,4

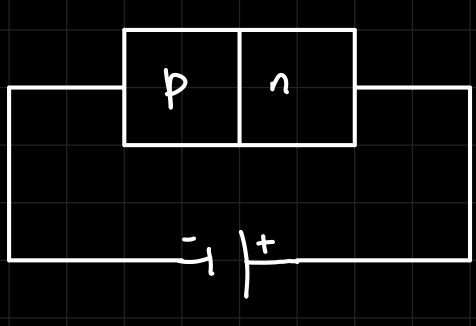
valence e⁻ easier to leave for Ge but we still use Si why?

$I_{S_{Si}}$ = nA $\qquad I_{S_{Ge}}$ = μA

because leakage current is way higher in case of germanium

ZENER DIODE

① Always works under reverse bias
② In forward bias, it acts as normal pn junction diode
③ Zener diode works always under high electric field



$$E = \frac{|V_R|}{W}$$

③ As we increase the reverse voltage, depletion layer also increases

$$W = \sqrt{\frac{2\varepsilon}{q}\left(\frac{1}{N_A} + \frac{1}{N_D}\right)V_0}$$

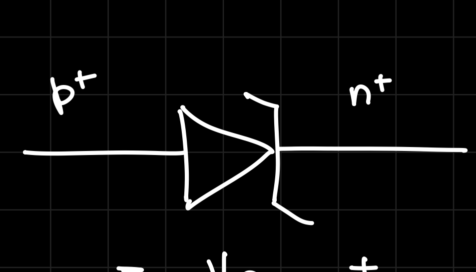
$$W \propto \frac{1}{\sqrt{\text{doping concentration}}}$$

and since $E \propto \frac{1}{W}$

works in very high electric field ≡ very high current

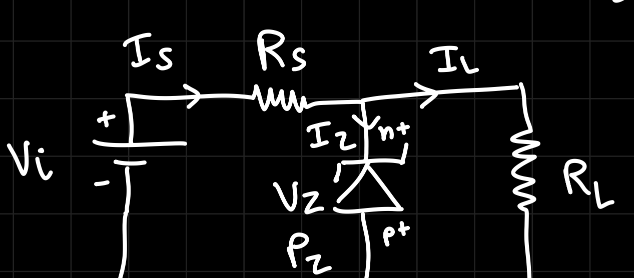
④ Zener diode is a very highly doped pn junction

1 impurity in every 10^3 atom (Si/Ge)
normal pn junction diode → $1:10^6$



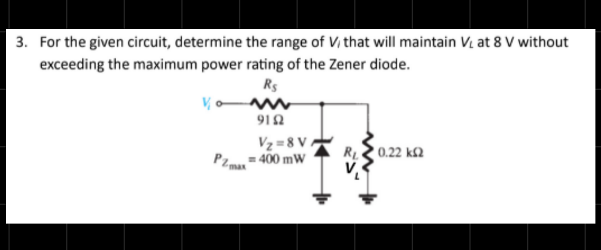
p^+, n^+: highly doped

Application: as a...
voltage regulator
shunt regulator



$$I_S = I_Z + I_L$$

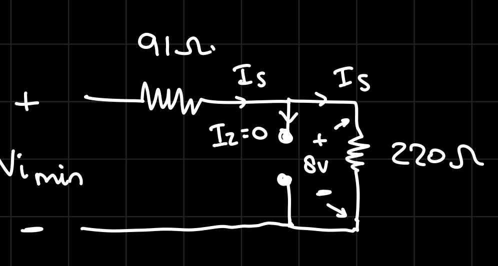
Q3)


3. For the given circuit, determine the range of V_i that will maintain V_L at 8 V without exceeding the maximum power rating of the Zener diode.

Range = $V_{i_{min}} - V_{i_{max}}$

in case of $V_{i_{min}}$, Zener diode acts as open circuit

in case of V_i maximum, Zener diode replaced by its equivalent cutoff voltage V_Z

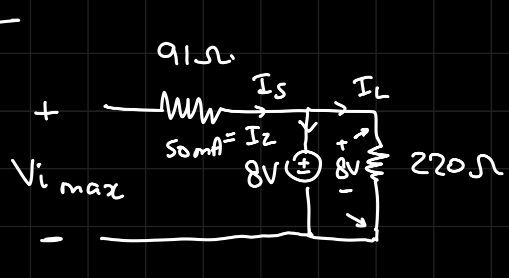


$P_Z = 400$ mW
$V_Z = 8V$
$P_Z = V_Z I_Z$
$I_Z = 50mA$ when zener diode works properly

$$\frac{V_{i_{min}} \times 220}{220 + 91} = 8$$

$$V_{i_{min}} = \underline{11.3V}$$

$V_{i_{max}}$ →



$$-8 + I_L(220) = 0$$
$$I_L = 36.36mA$$

$$I_S = I_Z + I_L = 50 + 36.36 = 86.36mA$$

$$8 - V_{i_{max}} + 91(86.36 \times 10^{-3}) = 0$$
$$V_{i_{max}} = \underline{15.858V}$$

Range: $11.3V < V_i < 15.85V$

AC analysis of PN Junction diode

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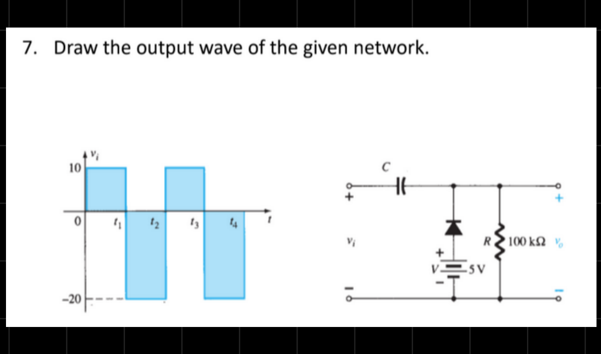
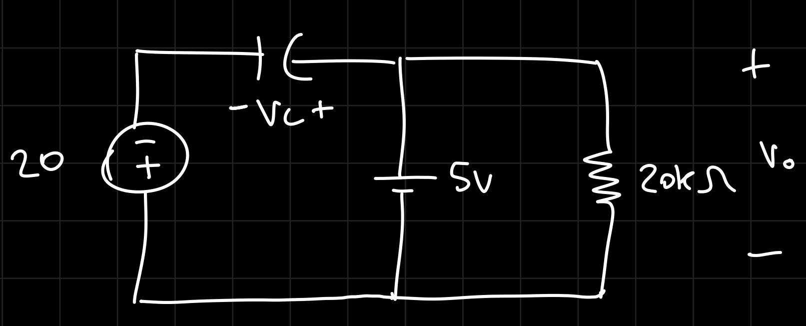
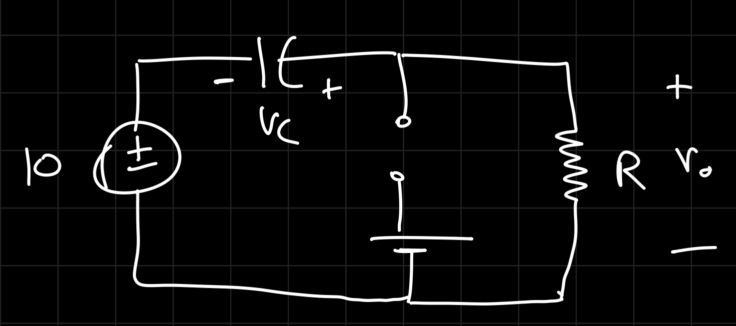

7. Draw the output wave of the given network.

Clamper ckt



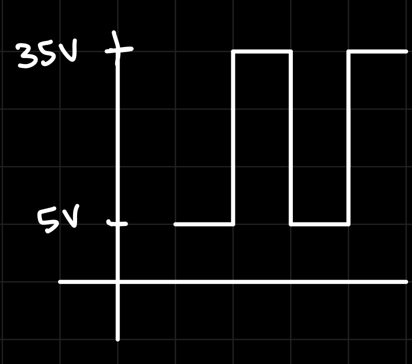
$$20 - V_C + 5 = 0$$
$$V_C = 25V$$
$$V_0 = 5V$$

NOTE: capacitor doesn't allow sudden change of voltage



$$-10 - V_C + V_0 = 0$$
$$V_0 = 10 + V_C = 10 + 25 = 35V$$

NOTE: we take case where diode is on first



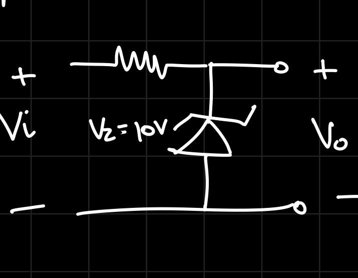
delay because ckt starts from -ve cycle

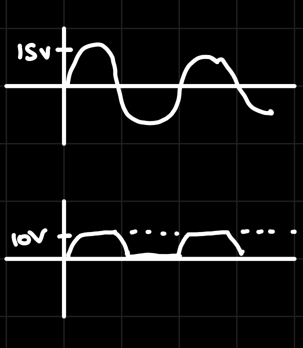
negative clamper because diode was ^n_p

positive clamper shifts waveform downwards

Clipper

$15\sin\omega t = V_i$





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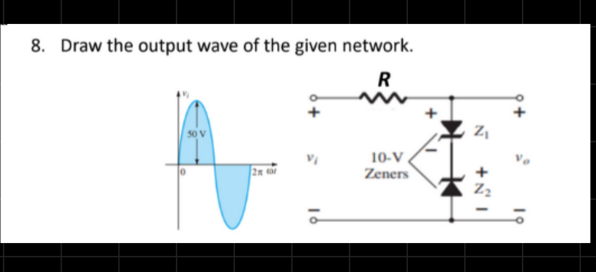
8. Draw the output wave of the given network.

+ve half cycle → 0 - 10V
Z_2 → off