# Chapter 1

# Diode Circuits

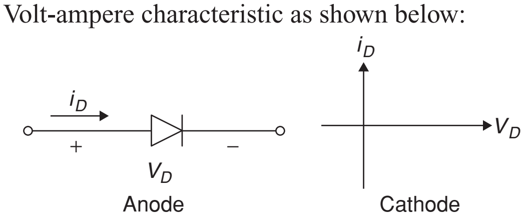
**LEARNING OBJECTIVES**

*After reading this chapter, you will be able to understand:*

- Small signal equivalent circuit of diode
- Practical PN junction diode
- Large signal diode-models
- Open circuit test
- Short circuit test
- Rectifiers
- Half wave rectifier analysis
- Full wave rectifier
- Peak inverse voltage
- Bridge rectifier
- Clipping circuits
- Clamper circuits
- Voltage multipliers
- Power supplies
- Voltage regulators

## Small Signal Equivalent Circuit of Diode

An ideal diode is a two-element device which has the circuit symbol and Volt-ampere characteristic as shown below:




A diode is a two-terminal unipolar device which provides minimum resistance in the forward direction and maximum resistance in the reverse direction.

Ideal diode is an unilateral circuit element, as the current in the device is in one direction only. This behavior is important in switching as it provides an ON-OFF characteristic.

### Practical PN Junction Diode

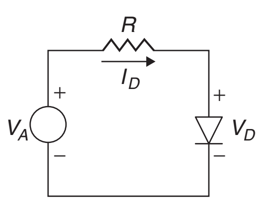



**Figure 1** Diode circuit

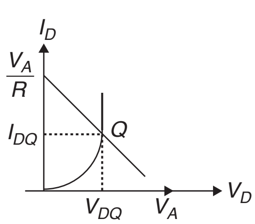



**Figure 2** Diode characteristic and load line

From the circuit, $-V_A + I_D R + V_D = 0$ (KVL) $I_D = \frac{-1}{R}V_D + \frac{V_A}{R} A$

This equation defines a straight line, called load line. The load line and diode characteristic must be satisfied simultaneously, at their point of intersection $Q$, called Quiescent or operating point. The values of current in and voltage across the diode are denoted by $I_{DQ}$, and $V_{DQ}$ respectively.

### Large Signal Diode-Models

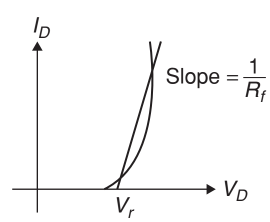



**Figure 3** Piecewise linear diode forward characteristic

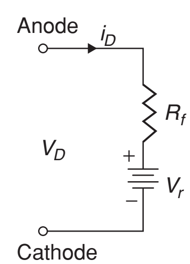



**Figure 4** Diode model for forward bias

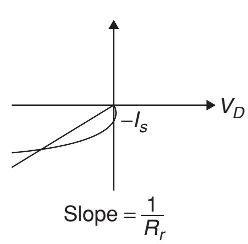



**Figure 5** Piecewise linear reverse based characteristic diode

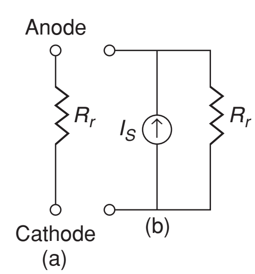
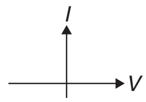
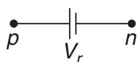
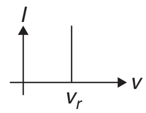
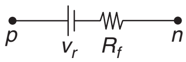
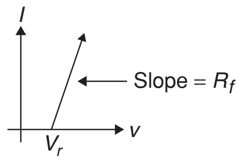



**Figure 6** Diode model on piecewise of linear representation (b) Model to include surface leakage

| Model | Equivalent Circuit | V-I characteristics |
|---|---|---|
| Ideal |  |  |
| Simplified model |  |  |
| Piecewise linearmodel |  |  |

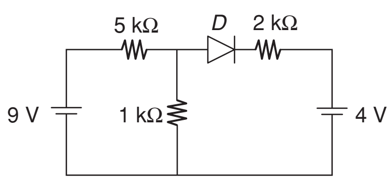
## Open circuit test

(i) Replace the diode with open Circuit
(ii) Find the voltage across the diode from '$p$' to '$n$' side, if it is positive, diode is in Forward Biased. If it is negative, diode is in Reverse Biased.

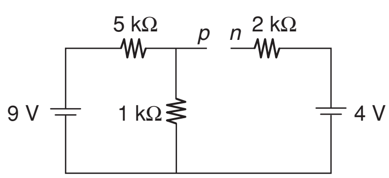
## Short circuit test

(i) Replace all the diodes with short Circuit
(ii) Find the current through the diode from '$p$' to '$n$' side say '$I$'.
If $I > 0$, Diode is in forward biased
$I < 0$, Diode is in reverse biased

**Example 1:** Check whether the diode is in forward biased or not?




**Solution:** '$D$' is open




$$V_p = \frac{9}{6} = 1.5\ \text{V}$$

$$V_n = 4\ \text{V}$$

$$V_p < V_n$$

Hence '$D$' is in reverse biased condition.

# Elementary Diode Applications

## Rectifiers

A device, such as the semiconductor diode, which is capable of converting a sinusoidal input waveform into a unidirectional waveform with a non-zero average component is called rectifier.

### Half wave rectifier

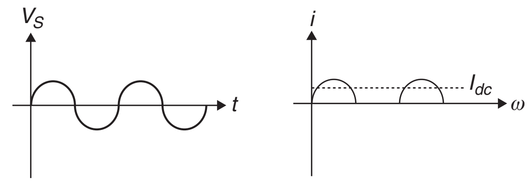



**Figure 7** Volt ($V_s$) and current ($i$) waveforms

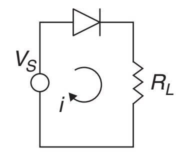



**Figure 8** Half wave rectifier

During the first half of cycle (positive cycle). The diode is ON, and current $\frac{V_s}{R_L}$ exists. The diode is off during negative half cycle of $V_s$ so that the current is zero as the current exists for only one half cycle, it is called halfwave rectifier.

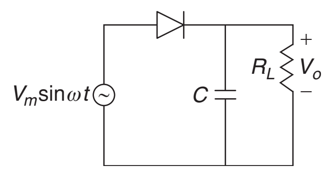



**Figure 9** Rectifier with capacitor filter

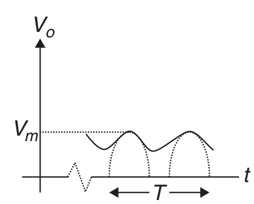



**Figure 10** Output voltage waveform

The circuit uses a capacitor '$C$' as a simple filter to convert the waveform to the nearly constant (DC) level. If the time constant $R_LC$ is much greater than the time period of $T$ of input waveforms, the discharge will be slow.

The peak to peak ripple out of any capacitor input filter is $V_R = \frac{I}{fC}$

$V_R$ – peak to peak ripple voltage
$I$ – DC load current
$f$ – ripple frequency
$C$ – capacitance

$$V_{rms} = \frac{V_{PP}}{2\sqrt{2}}$$

If we use real diode, the equivalent circuit is as shown in Figure 11.

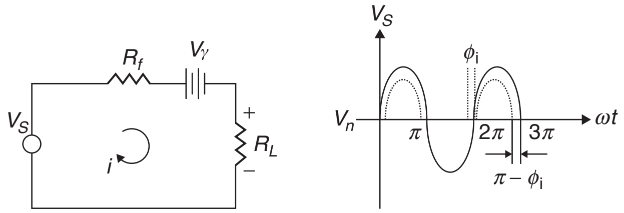



**Figure 11** Rectifier equivalent circuit

The current '$i$' is obtained by KVL

$$i = \frac{V_s - V_\gamma}{R_L} = \frac{V_m \sin \omega t - V_\gamma}{R_L}$$

as it is greater than zero only when $V_s > V_\gamma$. Thus current waveform does not start when $\omega t = 0$, but has a cutin or ignition angle $\phi$, given by $\phi_i = \sin^{-1}\left(\frac{V_\gamma}{V_m}\right)$.

Similarly extinction angle exists at the end of positive cycle its value is $\pi - \phi_i$.

### *Half Wave Rectifier Analysis*

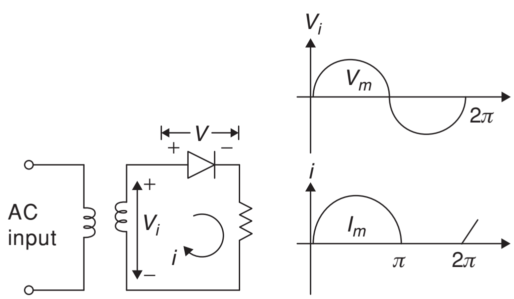



**Figure 12** Basic circuit of half wave rectifier

$V_i = V_m \sin\omega t$, has peak value of $V_m$, which is mostly very high when compared to $V_\gamma$ of diode, assume $V_\gamma = 0$.

The diode idealized to be a resistance $R_f$ in the ON state, and an open circuit in the OFF state, the currenti in the diode or load $R_L$ is

$$\begin{aligned} i &= I_m \sin \omega t \text{ if } 0 \le \omega t \le \pi \\ &= 0, \text{ if } \pi \le \omega t \le 2\pi \end{aligned}$$

And $I_m = \dfrac{V_m}{R_f + R_L}$

DC current of value (Average current)

$$I_{\mathrm{DC}} = \frac{1}{2\pi}\int_0^{2\pi} i\, d(\omega t)$$

For half wave circuit, $I_{\mathrm{DC}} = \dfrac{1}{2\pi}\displaystyle\int_0^{\pi} I_m \sin(\omega t) d(\omega t) = \dfrac{I_m}{\pi}$

The DC (average) output voltage is given as

$$V_{\mathrm{DC}} = I_{\mathrm{DC}} \cdot R_L = \frac{I_m R_L}{\pi} = \frac{V_m}{\pi}$$

The DC voltage across diode is not given by $I_{\mathrm{DC}} R_f$, as diode acts as resistance which has two values

$R_f$ in the ON state, and $\infty$ in the OFF state

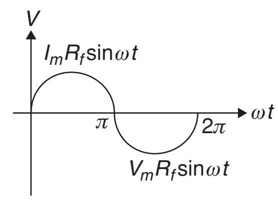



**Figure 13** Voltage across the diode

$$\text{So } V_{\mathrm{DC}} = \frac{1}{2\pi}\left[\int_0^{\pi} I_m R_f \sin \omega t d(\omega t) + \int_0^{2\pi} V_m \sin(\omega t) d(\omega t)\right]$$

$$= \frac{1}{\pi}(I_m R_f - V_m)$$

$$= \frac{1}{\pi}[I_m R_f - I_m (R_f + R_L)]$$

$V_{\mathrm{DC}} = \dfrac{-I_m R_L}{\pi}$, so the DC diode voltage is seen to be equal to the negative of average voltage across the load resistor.

$$\text{The AC current } I_{rms} = \left(\frac{1}{2\pi}\int_0^{2\pi} i^2 d(\omega t)\right)^{1/2} = \frac{I_m}{2}$$

$$V_{rms} = I_{rms} R_L$$

$$V_{rms} = \frac{I_m}{2} R_L = \frac{V_m}{2}$$

### *Regulation*

The variation of DC output voltage as a function of DC load current is called regulation.

$$\% \text{ of regulation } = \frac{V_{\text{noload}} - V_{\text{load}}}{V_{\text{load}}} \times 100\%$$

No load refers to zero current, load indicates the normal load current

**Note:** ideal power supply has percentage regulation zero

$$I_{\mathrm{DC}} = \frac{I_m}{\pi} = \frac{V_m/\pi}{R_f + R_L}, \quad V_{\mathrm{DC}} = I_{\mathrm{DC}} R_L$$

The DC output voltage varies as

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

### *Full wave rectifier*

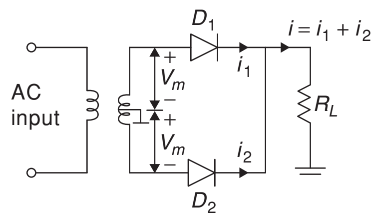



**Figure 14** A full wave rectifier circuit

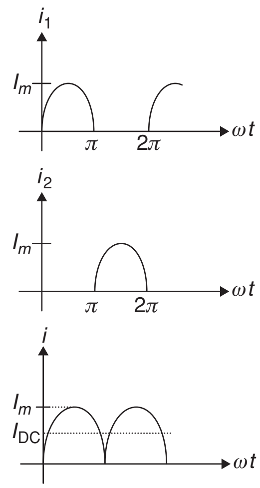



**Figure 15** The diode currents $i_1$ and $i_2$ and load current $i$, output voltage $V_o = iR_L$

The circuit, is seen to comprise of two half wave rectifiers, connected so that conduction takes place through one of the diodes at one half cycle.

$$I_{\mathrm{DC}} = \frac{2I_m}{\pi}$$

$$I_{rms} = \frac{I_m}{\sqrt{2}}$$

$$V_{\mathrm{DC}} = \frac{2I_m R_L}{\pi}$$

$$V_{\mathrm{DC}} = \frac{2V_m}{\pi} - I_{\mathrm{DC}} R_f$$

If we include $V_\gamma$, of the diode

$$\theta_1 = \sin^{-1}\frac{V_\gamma}{V_m}, \theta_2 = \pi - \theta_1$$

The average current $I_{\mathrm{DC}}$

$$I_{\mathrm{DC}} = \frac{V_m}{\pi(R_f + R_L)}\cos\theta_1 - \frac{\pi - 2\theta_1}{2\pi}\frac{V_\gamma}{R_f + R_L} \quad \text{(half wave rectifier)}$$

$$I_{\mathrm{DC}} = \frac{2V_m}{\pi(R_f + R_L)}\cos\theta_1 - \frac{\pi - 2\theta_1}{2\pi}\frac{V_\gamma}{R_f + R_L} \quad \text{(full wave rectifier)}$$

**Example 2:** A diode with an internal resistance of 10 Ω is used as a rectifier to supply power to a 500 Ω load from a 220 V (rms) source of supply. Calculate (a) the peak load current (b) the DC load current (c) the rms load current d) the DC diode voltage (e) the total input power to the circuit (f) percentage regulation from no-load to the given load.

**Solution:** A diode is used as rectifier, so half wave rectifier, if two diodes are used, it will be full wave rectifier.

(a) $I_m = \dfrac{V_m}{R_f + R_L} = \dfrac{\sqrt{2}V_{rms}}{R_f + R_L} = \dfrac{\sqrt{2}.220}{(10 + 500)}$

$= 0.61$ A

(b) $I_{\mathrm{DC}} = \dfrac{I_m}{\pi} = 0.19$ A

(c) $I_{rms} = \dfrac{I_m}{2} = 0.305$ A

(d) $V'_{\mathrm{DC}} = \dfrac{I_m R_L}{\pi} = -0.61 \times \dfrac{500}{\pi}$

$= -97.1$ V

(e) Power delivered $= V_{rms} I_{rms}$
$= (220 \text{ V})\ (0.305 \text{ A}) = 67.1$ W

(f) % regulation $= \dfrac{I_{\mathrm{DC}} R_L}{\dfrac{V_m}{\pi} - I_{\mathrm{DC}} R_f} \times 100$

$$= \frac{\dfrac{V_m}{\pi(R_f + R_L)} \cdot R_f}{\left(\dfrac{V_m}{\pi} - \dfrac{V_m}{\pi(R_f + R_L)} R_f\right)} \times 100$$

$$= \frac{R_F}{R_L} \times 100$$

As $R_L$ goes from ∞ (no-load) to 500 Ω, percentage regulation will go from 0 to 2%.

#### *Peak Inverse Voltage*

For each rectifier circuit there is a maximum voltage to which the diode can be subjected. This potential is called peak inverse voltage (PIV). For half wave rectifier, the peak inverse voltage is $V_m$ and for full wave rectifier PIV is $2V_m$. In full wave circuit, independent of the filter used, the PIV across each diode is twice the maximum transformer voltage (center tap to other end).

Peak inverse voltage is the maximum voltage across the non-conducting diode of rectifier, the voltage must be less than the break down voltage of the diode otherwise the diode will be destroyed.

PIV of half wave rectifier with capacitor input filter PIV = $2V_m$.

Bridge rectifier with capacitor input filter, PIV = $V_m$

## *Bridge rectifier*

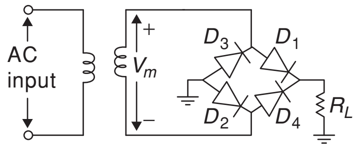



**Figure 16** A Bridge rectifier

The bridge rectifier is similar to a full wave rectifier because it produces a full wave output voltage, diodes $D_1$ and $D_2$ conduct on the positive half cycle and $D_3$ and $D_4$ conduct on the negative half cycle. As result rectified output flows during both half cycles.

## Features

(i) The current drawn in both the primary and the secondary of the supply transformer are sinusoidal, and therefore a smaller transformer may be used than for the full wave circuit for the same input.

(ii) A transformer without center tap is used.

The advantage of this type of full wave rectification over the center tapped version in the conventional full wave rectifier, is entire secondary voltage of transformer can be used DC output $(V) = \dfrac{2V_m}{\pi}$

$$I_{DC} = \frac{2I_m}{\pi}$$

Current through each diode $= I_{\text{diode}} = \dfrac{I_{DC}}{2}$

**Example 3:** In a bridge rectifier, the input AC source has an amplitude of 5 V, and the load resistance is 100 Ω. The diodes have an on resistance of 10 Ω, $V_r = 0.6$ V. The DC output voltage is ___

(A) 1.69 V (B) 1.81 V
(C) 2.35 V (D) 2.38 V

**Solution:** (A)

$$V_{DC} = 2\left[\frac{V_m R_L}{\pi(R_F + R_L)} - V_r\right]$$

$$\cong 2\left[\frac{5}{\pi}\frac{100}{(100+10)} - 0.6\right] = 1.69$$

**Table 1** *Unfiltered rectifiers*

| | Half Wave | Full Wave | Bridge |
|---|---|---|---|
| Number of diodes | 1 | 2 | 4 |
| Peak output ideal | $V_m$ | $\frac{V_m}{2}$ (center tapped) | $V_m$ |
| Peak output (practical) | $V_m - 0.7$ V | $\frac{V_m}{2} - 0.7$ V | $V_m - 1.4$ V |
| DC output | $V_p(\text{out})/\pi$ | $2\ V_p(\text{out})/\pi$ | $\frac{2\ V_p(\text{out})}{\pi}$ |
| Ripple frequency | $f_{in}$ | $2f_{in}$ | $2f_{in}$ |

$V_m$ – peak secondary voltage
$V_p$(out) – peak output voltage

## *Voltage multiplier*

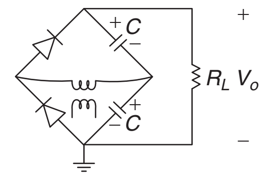
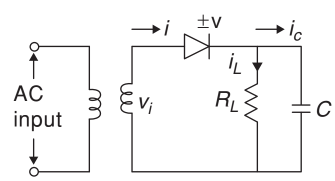


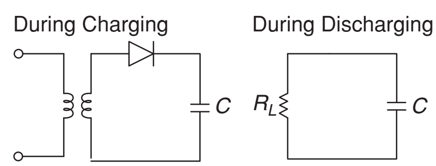

**Figure 17** Bridge rectifier as voltage doubler

A common voltage doubling circuit which delivers a dc voltage approximately, equal to twice the transformer maximum voltage at no load. The circuit is operated by alternately charging each of two capacitors, to the transformer peak voltage $V_m$, current being continuously drained from capacitors through load. The capacitors also act to smooth out the ripple in the output.

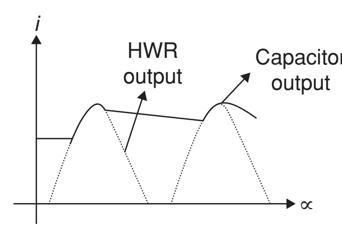
## *Capacitor filters*




Capacitor stores the energy during the conduction period and delivers this energy to the load during non-conducting.




Diode having less forward resistance, and capacitor charges very fastly and the value of $R_L$ is designed to be so high to get the small ripple at the output




Full wave rectifier with a capacitor filter is obtained by placing a capacitor '$C$' across $R_L$

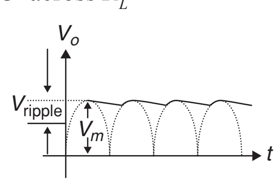



**Figure 18** Approximate load voltage waveform for full wave rectifier with capacitive filter

The average value of the voltage is approximately

$$V_{\text{DC}} = V_m - \frac{V_{\text{ripple}}}{2}$$

$$V_{\text{ripple}} = \frac{I_{\text{DC}}}{2fC} \quad \text{(for full wave rectifier)}$$

$$V_{\text{DC}} = V_m - \frac{I_{\text{DC}}}{4fC}$$

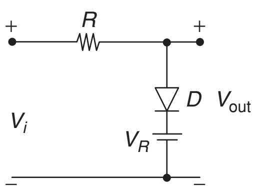
## Clipping Circuits: Voltage Slicers

(i) An electronic circuit which cuts the given input wave form

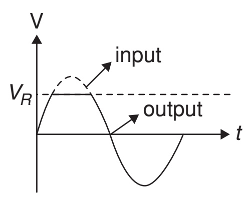
(ii) The amount of clipping is decided by the supply voltage by which the circuit is driven

### *Considering ideal diode*

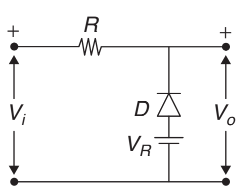
(i)

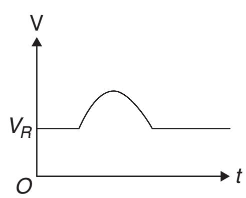



When $V_i > V_R$ : Diode is forward biased $\Rightarrow V_o = V_R$
$V_i < V_R$ : Diode is reverse biased $\Rightarrow V_o = V_i$



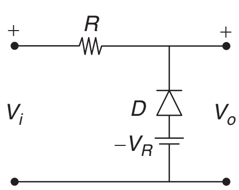

(ii)



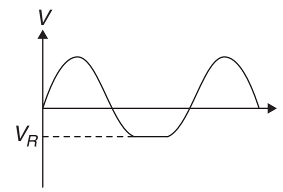




When $V_i > V_R$ : Diode is reverse biased $\Rightarrow V_o = V_i$
$V_i < V_R$ : Diode is forward biased $\Rightarrow V_o = V_R$

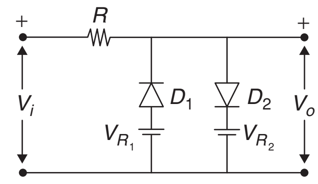
(iii)




When $V_i > (-V_R)$ : Diode is reverse biased $\Rightarrow V_o = V_i$
$V_i < (-V_R)$ : Diode is forward biased $\Rightarrow V_o = V_R$

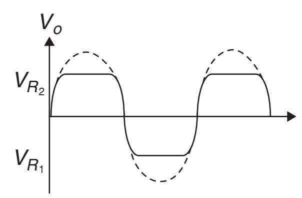



### *Clipping at two independent levels*

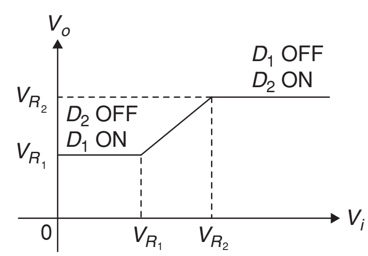



$(V_{R_2} > V_{R_1})$

| Input | Diode state | $V_0$ |
|---|---|---|
| $V_i \le V_{R_1}$ | $D_1$ ON, $D_2$ OFF | $V_{R_1}$ |
| $V_{R_1} \le V_i < V_{R_2}$ | $D_1$ OFF, $D_2$ OFF | $V_i$ |
| $V_i \ge V_{R_2}$ | $D_1$ OFF, $D_2$ ON | $V_{R_2}$ |




Transfer Characteristics:




Clipping circuits are used to select for transmission, that part of a waveform which lies above or below same reference level.

### *Considering practical diode*

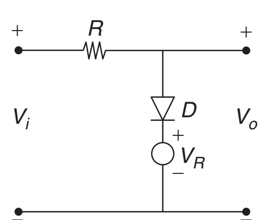



**Figure 19** Diode clipping circuit

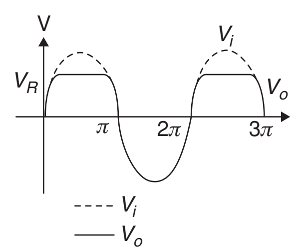



**Figure 20** Input and output voltage waveforms

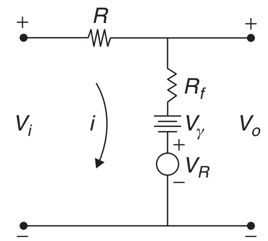



**Figure 21** Model for circuit in forward bias $V_{in} > V_R + V_\gamma$

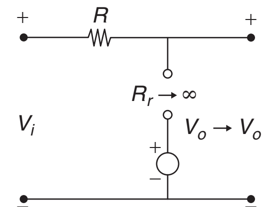



**Figure 22** Model for circuit in reverse bias $V_{in} < V_R + V_\gamma$

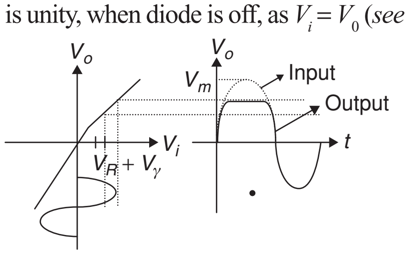
The diode will be ON during forward bias, as shown in Figure 21 by applying KVL

$$i = \frac{V_i - V_R - V_\gamma}{R_f + R}$$

$$V_0 = iR_f + V_\gamma + V_R = \frac{R_f}{R_f + R} V_i + \frac{R}{R + R_f}(V_R + V_\gamma)$$

The translation from OFF to ON occurs when $V_i$ equals to $V_\gamma + V_R$.

This transition indicates abrupt change in slope in the plot of $V_0$ versus $V_i$, called transfer characteristic. The slope is unity, when diode is off, as $V_i = V_0$ (*see* Figure 22)




Transfer characteristic of clipping circuit

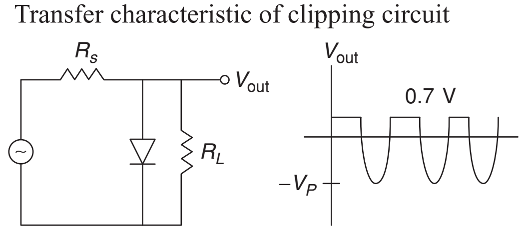



**Figure 23** Positive clipper

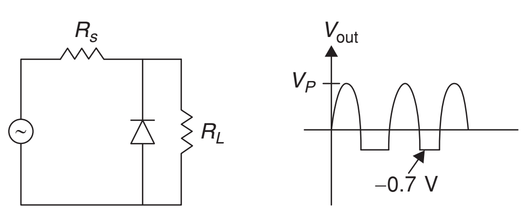



**Figure 24** Negative clipper

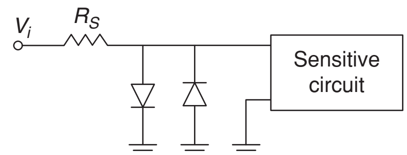



**Figure 25** Limiter or diode clamp

If the input signal is so small (say 20 mV), none of the diode will be turned ON, so these small voltages will be not effected, but for higher voltages than ±0.7 V one of the diode will be forward biased and the input to sensitive circuit will never cross ±0.7 V.

A limiter on the input side of an op-amp will prevent excessive input voltage from being accidently applied.

### *Biased clippers*

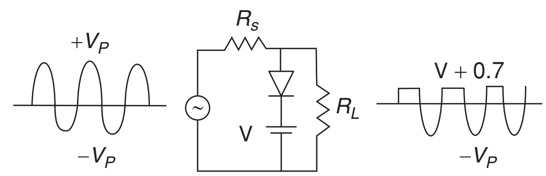



**Figure 26** Positive clipper

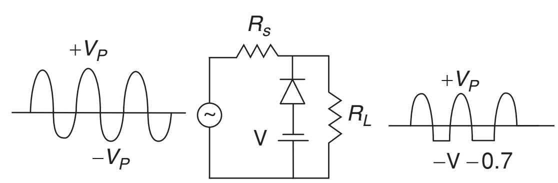



**Figure 27** Negetive clipper

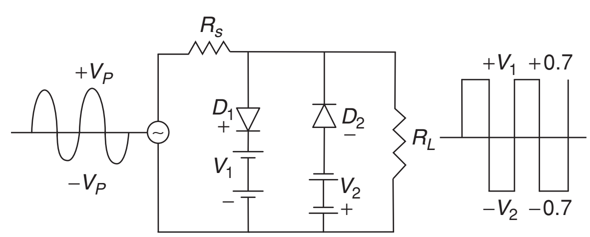



**Figure 28** Biased positive-negetive clipper

In the above combination clipper diode $D_1$ clips off positive parts above positive bias level, and diode $D_2$ clips off parts below the negative bias level. If input voltage is very large compared to the bias levels, the output signal is a square wave

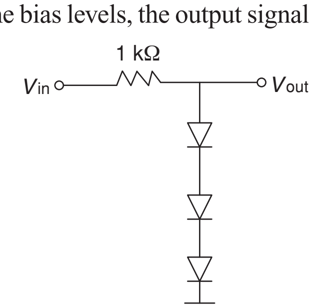



**Figure 29** Clipper with three offset voltages

Since each diode has an offset of around 0.7 V, three diodes produce a clipping level of +2.1 V, we can use the same circuit (*see* Figure 29) as a diode clamp to protect sensitive circuit, that cannot tolerate more than 2.1 V input

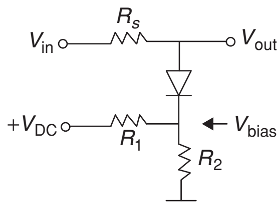



**Figure 30** Voltage divider biases clipper

This is another way to bias a clipper without batteries. The voltage divider $R_1$ and $R_2$ to set the bias level, given by $V_{bias} = \frac{R_2}{R_1 + R_2} V_{DC}$.

In this case the output voltage is clipped or limited when the input is greater than $V_{bias} + 0.7$ V

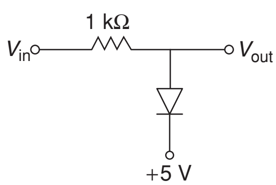



**Figure 31** Diode clamp protects above 5.7 V

The circuit in Figure 31, it can be used to protect, sensitive circuits from excessive input voltages,

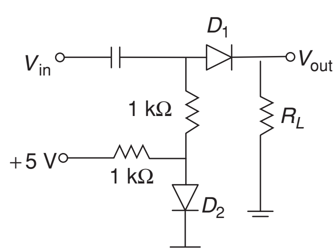



**Figure 32** Circuit with zero off set

The circuit shown in Figure 32 is used to remove offset of limiting diode $D_1$.

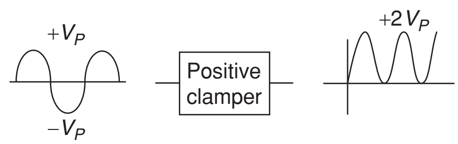
The diode $D_2$ is biased slightly into forward conduction, so it has 0.7 V across it, this 0.7 V is applied to $D_1$ and $R_L$ via 1 kΩ. This means that diode $D_1$ is on the verge of conduction. Therefore when a signal carried in, diode $D_1$ conducts near 0 V.

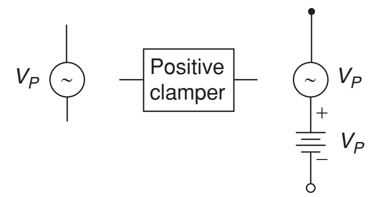
## Clamper Circuits

When a positive clamper has a sine wave input, it adds a positive dc voltage, to the sine wave,

Stiff clamper: $R_L C > 100\ T$, $T$–time period.

The positive clamper shifts the AC reference level upto a DC level.



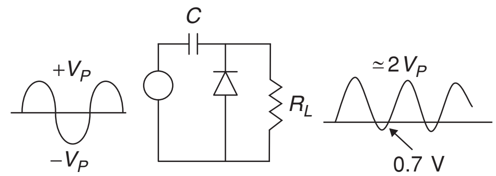




**Figure 33** Practical clamper

The first quarter of the cycle charges the capacitor fully, then the capacitor retains almost all of its charge during subsequent cycles. The small charge that is lost between cycles, is replaced by diode conduction.

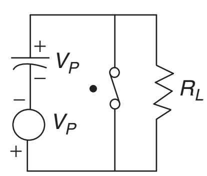



**Figure 34** At positive peak

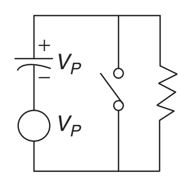



**Figure 35** Beyond positive peak capacitor acts as battery

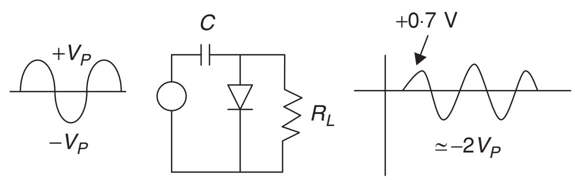



**Figure 36** Negative clamper

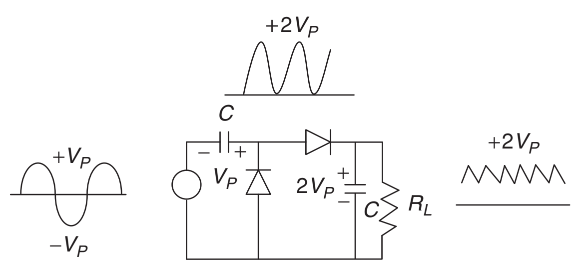



**Figure 37** Peak to peak detector

A half wave rectifier with a capacitor input filter produces a DC output voltage approximately equal to the peak of input signal.

If we cascade a clamper and a peak detector, we will get a peak to peak detector.

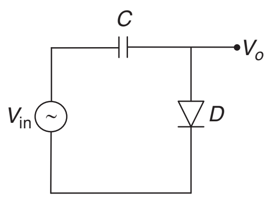
The RC time constant should be much greater than the period of the signal ($T$) to get good clamping.

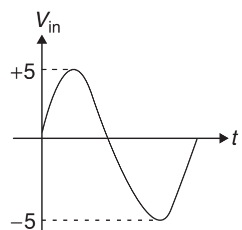
### *Steps to draw clamper output*

(i) Find the voltage across the capacitor at input peak state.

(ii) Replace the diode with open circuit, and draw the output waveform.

**Example 4:** Find the output of clamper circuit in the given figure

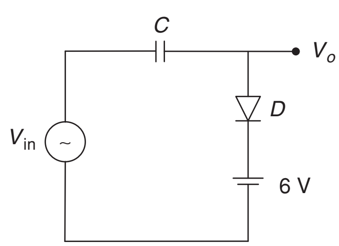


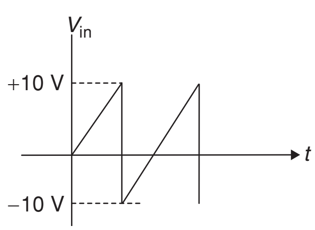




**Solution:** Under peak state $V_c$ = +5 V KVL at input side gives $V_{in} - V_c - V_o = 0$

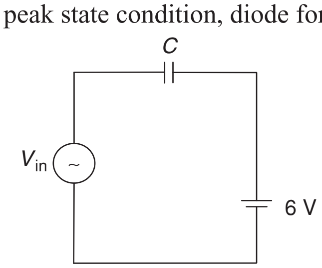
$$\boxed{V_o = V_{in} - 5}$$

**Example 5:** Find the output of clamper circuit in the given figure




**Solution:** At peak state condition, diode forward biased




$\therefore$ $V_c$ (saturation) = 4 V

KVL at input gives, after replacing diode with short circuit

$V_o = V_{in} - 4$

## VOLTAGE MULTIPLIERS

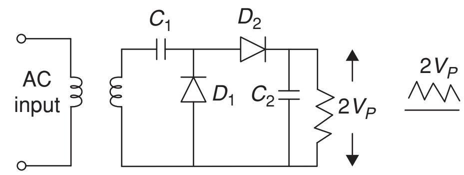



**Figure 38** Voltage doubler with floating loads

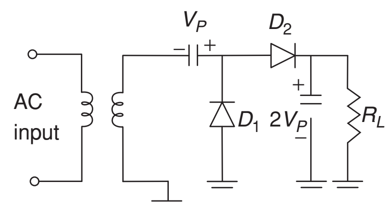



**Figure 39** Voltage doubler with grounded loads

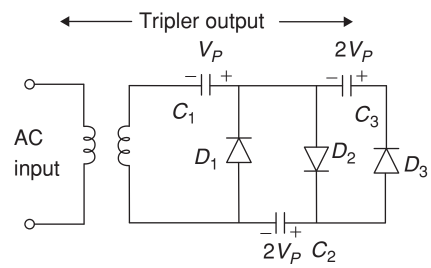



**Figure 40** Voltage tripler with floating load

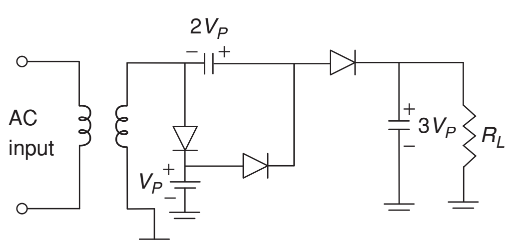



**Figure 41** Voltage tripler with grounded load

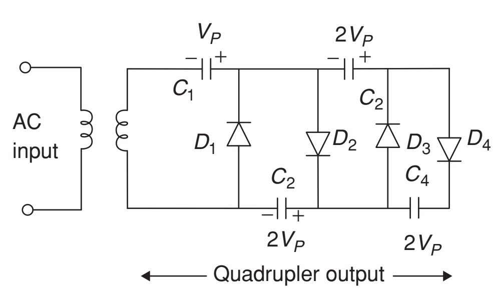



**Figure 42** Voltage quadrupler with floating loads

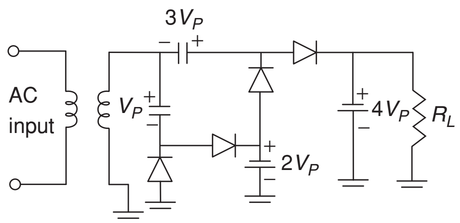



**Figure 43** Voltage quadrupler with grounded load

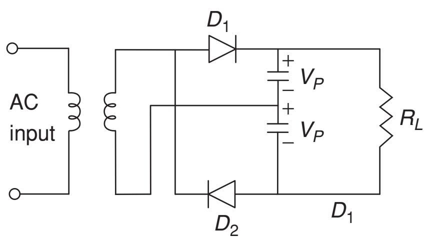



**Figure 44** Voltage multiplier–full wave doubler

Voltage doubler is a redesign of the peak to peak detector, it uses rectifier diodes instead of small-signal diodes. It produces an output equal to the peak value of the rectified signal.

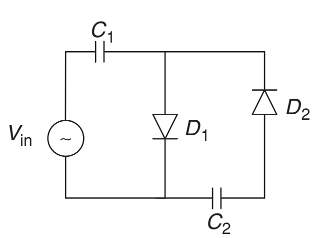
In voltage tripler, the first two sections act like a doubler, at peak of the negative half cycle, $D_3$ is forward biased. This charges $C_2$ to $2V_p$ with the polarity shown in figure 40. The tripler output appears across $C_1$ and $C_3$.

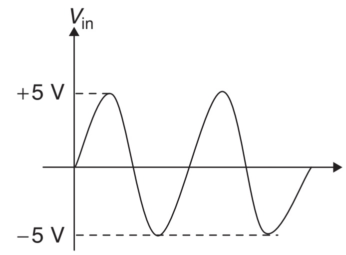
Voltage quadrupler with four sections in cascade, the first three sections are a tripler, and the fourth makes the overall circuit quadrupler. The quadrupler output is across the series connections $C_2$ and $C_4$.

Figure 44 shows a full wave voltage doubler, on the positive half cycle of the source, the upper capacitor charges to the peak voltage with the polarity shown, on the peak next half cycle, lower capacitor charges to the voltage, with indicated polarity, final output voltage is approximately $2V_p$.

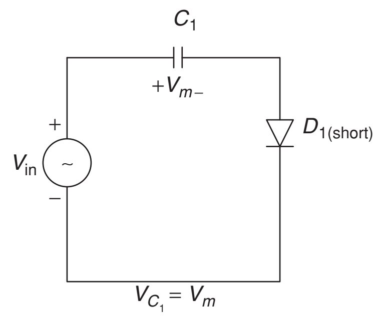
The voltage multipliers shown in figure 38–43 are half wave designs, i.e., the output ripple frequency is same as input frequency, but full wave voltage doubler, output ripple is double the input frequency. So its easy to filter the ripple and PIV is also $V_p$ only.

## Voltage doubler analysis

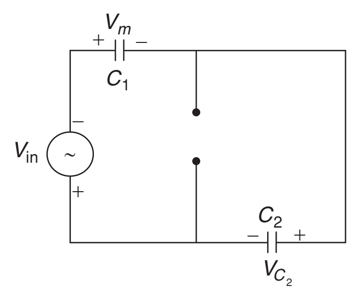



During positive half cycle $D_1$ is ON and hence '$C_1$' is charged to $+V_m$

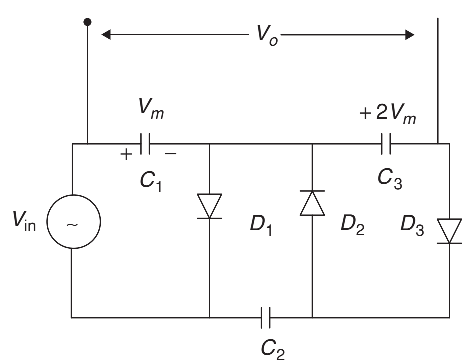



During negative cycle:




$$-V_{in} - V_m - V_{c_2} = 0$$
$$V_{c_2} = -V_{in} - V_m$$
$$V_{c_2} = -2V_m$$

## Voltage tripler analysis



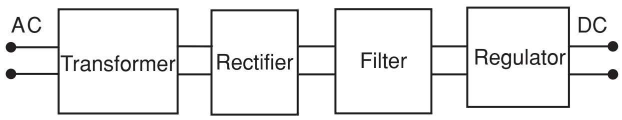
During first positive half cycle $D_1$ is ON. During next negative half cycle $D_2$ alone ON

$$\therefore\ V_o = V_{c1} + V_3 = 3V_m$$

During second positive half cycle $D_1$ and $D_3$ ON

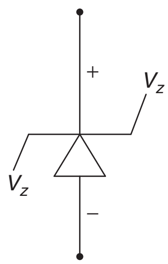
## Power Supplies

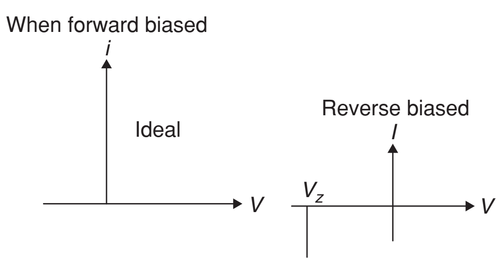
Transformers are used for step-up or step down the level of input ac voltage.



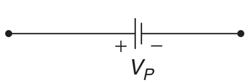

### Voltage Regulators

Zener diode can be used as a voltage regulator.

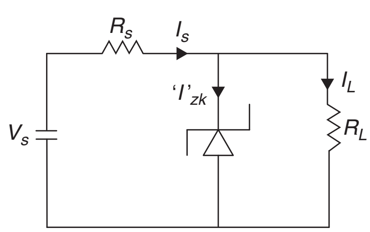


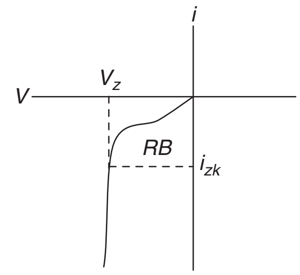

Zener reverse ON condition:




### *Zener voltage regulator*




*I-V* Characteristics:




When source voltage varying:

$$I_s\,(\text{min}) = I_z\,(\text{min}) + I_L\,(\text{fix})$$
$$I_s\,(\text{max}) = I_z\,(\text{max}) + I_L\,(\text{fix})$$

When load is varying:

$$I_s\,(\text{fix}) = I_z\,(\text{min}) + I_z\,(\text{max})$$
$$I_s\,(\text{fix}) = I_z\,(\text{max}) + I_z\,(\text{min})$$

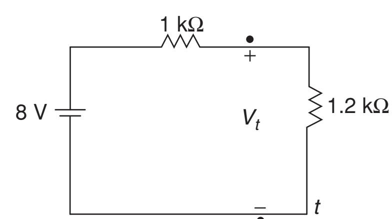
Zener diode withstand the current variations due to variations in source and load resistance when it is in reverse 'ON' condition and hence produces a constant output voltage across the Load.

### *Steps to determine the state of Zener Diode*

(i) Replace the Zener diode with open circuit.
(ii) Find the terminal voltage across the diode from '$n$' to '$p$' side let say $V_t$.
(iii) If $V_t > V_z$ then Zener is reverse ON and diode is replaced with a voltage source of $V_z$.
(iv) If $V_t < V_z$, then Zener is OFF and hence replace it with open circuit.

**Example 6:** Check the status of Zener diode when
(i) $R_L = 1.2\ \text{k}\Omega$
(ii) $R_L = 3.6\ \text{k}\Omega$
[Given $V_z = 6$ V and $V_s = 8$ V, $R_s = 1\ \text{k}\Omega$ determine the output voltage]

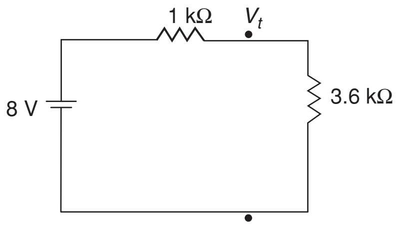
**Solution:** Case (1):
$R_L = 1.2\ \text{k}\Omega$




$$V_t = \frac{8(1.2)}{2.2} = 4.3\ \text{V}$$

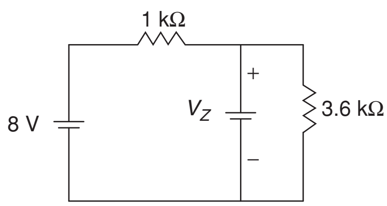
$V_t < V_z$, hence Zener diode is in OFF condition.
$\therefore\ V_o = 4.3$ V

Case (2): $R_L = 3.6\ \text{k}\Omega$




$$V_t = \frac{8(3.6)}{4.6} = 6.26087$$

$V_t < V_z$, hence Zener is in 'ON' condition.




$\therefore\ V_o = V_z = 6\ \text{V}$

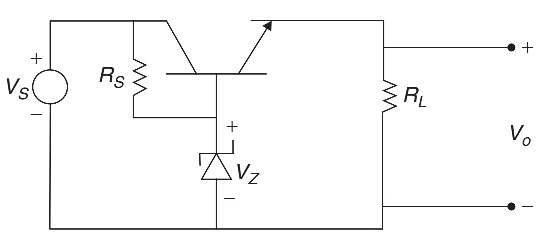
**Note:** The conventional direction of Zenar voltage is considered to be opposite to the direction of ordinary PN junction diode, because PN junction is used in FB direction, and Zenar diode is used in RB direction.

## Characteristics of a ideal voltage regulator

(i) It should maintain a constant output voltage irrespective of variations in input and the load.

(ii) Load current should depend on $R_L$.

## Voltage regulator using BJT




as '$V_s$' changes $\Rightarrow V_z$ constant

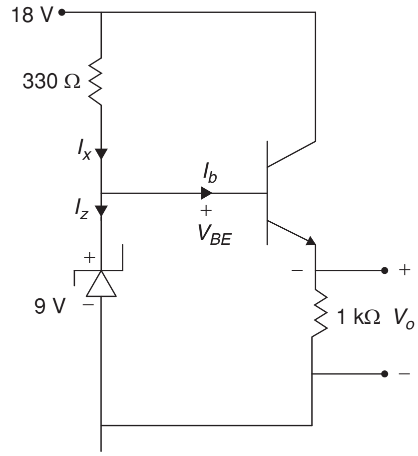
$\Rightarrow I_b$ is constant

$I_E = (\beta + 1)\ I_b$

Hence $I_E$ = constant

$\therefore\ V_o = I_E R_L$ = constant irrespective of variations in the input circuit.

**Example 7:**




Find current $I_z$ if $\beta = 99$ and $V_{BE} = 0.7\ \text{V}$

(A) 0.0264 A
(B) 0.352 A
(C) 0.476 A
(D) 0.0123 A

**Solution:** (A)

KVL at input side gives $-9 + 0.7 + V_L = 0$

KCL $\Rightarrow I_x = I_b + I_z$

$I_z = I_x - I_b$

$$I_x = \frac{18-9}{330\ \Omega} = 0.02727\ \text{A}$$

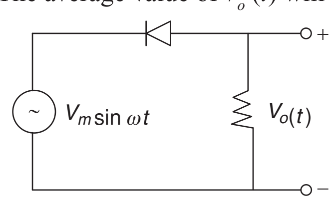
$$I_b = \frac{1}{100}\cdot\frac{V_L}{1\ \text{k}\Omega} = \frac{8.3}{100\ \text{k}\Omega} = 0.083\ \text{mA}$$

$\therefore\ I_z = 0.0264\ \text{A}$

## Solved Examples

**Directions for questions 1 to 8:** Select the correct alternative from the given choices.

**Example 1:** The average value of $V_o(t)$ will be




(A) 0
(B) $\dfrac{-V_m}{\pi}$
(C) $\dfrac{-V_m}{\sqrt{2}}$
(D) $-V_m$

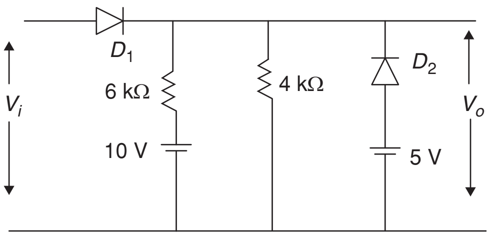
**Solution:** (B)

$$V_{av} = \frac{\int_{\pi}^{2\pi} V_m \sin \omega t d\omega t}{2\pi}$$

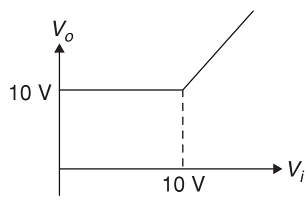
$$= \frac{V_m\left[-\cos\omega t\right]_{\pi}^{2\pi}}{2\pi} = \frac{-V_m}{\pi}$$

The diode will be ON for $\pi$ to $2\pi$.

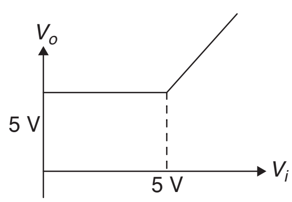
**Example 2:** If $D_1, D_2$ diode are ideal, which of the following represents transfer characteristics of circuit:



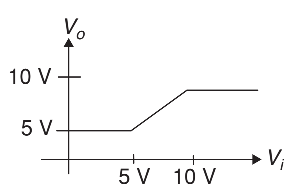

(A)



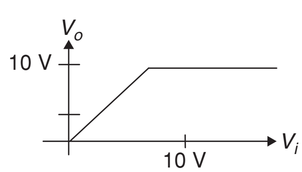

(B)




(C)




(D)




**Solution:** (B)

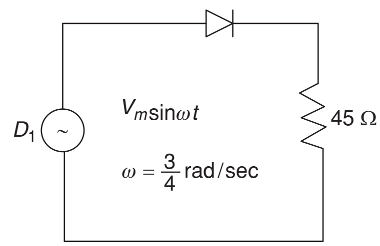
For $0 \le V_i \le 5$ V, $D_2$ is ON and $V_o = 5$ V

For $5 \le V_i \le 10$ V, $D_2$ is off and $V_o = V_i$

For $V_i > 10$ V, $D_1$ is ON, $D_2$ is OFF

$V_o = V_i$

**Example 3:** The forward resistance of the diode shown in circuit is 5 Ω, and the other parameters are the same as those of an ideal diode. Then what is the DC component of the source current?




(A) $\dfrac{-V_m}{50\pi}$ (B) $\dfrac{V_m}{45\pi\sqrt{2}}$

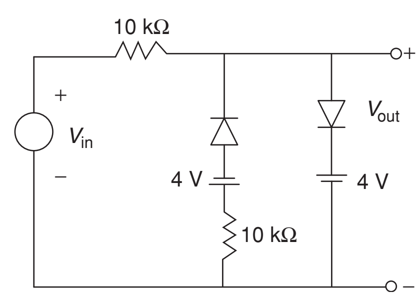
(C) $\dfrac{V_m}{100\pi\sqrt{2}}$ (D) $\dfrac{2V_m}{45}$

**Solution:** (A)

$$I_{DC} = \frac{\int_0^{\pi} V_m \sin\omega t \cdot d\omega t}{2\pi \cdot R} = \frac{\left|V_m \cdot \cos\omega t\right|_0^{\pi}}{2\pi \cdot R} = \frac{V_m}{50\pi}$$

$R = R_{f(\text{diode})} + 45\ \Omega = 5 + 45\ \Omega = 50\ \Omega$

**Example 4:** A voltage signal 10 sin$\omega t$ is applied to the circuit with ideal diode, as shown, The maximum and minimum. values of the output waveform $V_{out}$ of the circuit are respectively

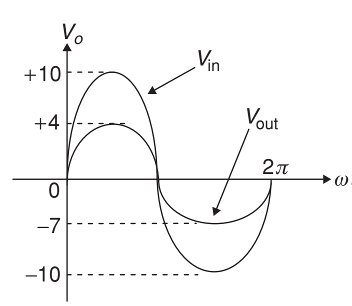


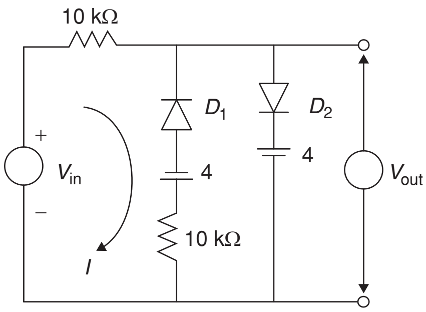

(A) +10 V and –10 V (B) +4 V and –4 V

(C) +7 V and –4 V (D) +4 V and –7 V

**Solution:** (D)

The voltage wavefrom at the output will be as shown below for +ve cycle





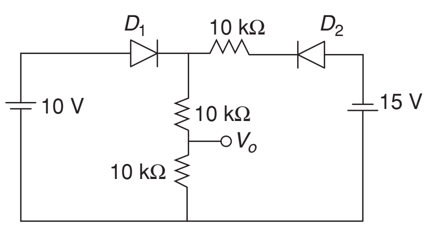

$D_2$ ON, $D_1$ OFF, $V_{out} = 4$ V,
for –ve cycle $D_1$ ON, $D_2$ OFF

$$I = \frac{V_{in} + 4}{20}$$

$$= \frac{-10 + 4}{20} = \frac{-3}{10} \text{ mA}$$

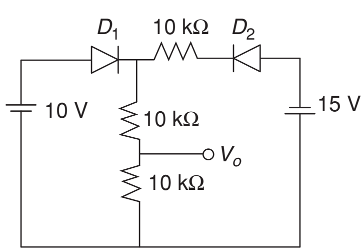
$V_{out} = I \cdot R - 4 = -7$ V

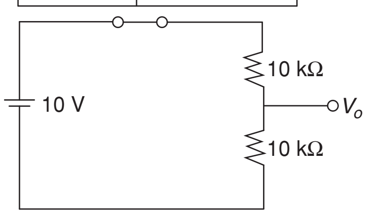
**Example 5:** Assuming that the diode in the given circuit is ideal, the voltage $V_o$ is




(A) 4 V (B) 5 V
(C) 7.5 V (D) 12.1 V

**Solution:** (B)



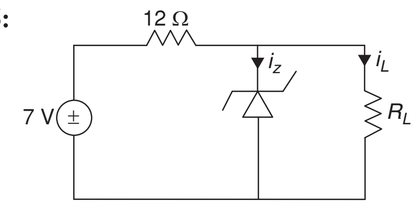




In this case the diode $D_2$ is always reverse biased

$$V_o = \frac{10K}{10K + 10K} \times 10 = 5 \text{ V}$$

**Common Data for Questions 6 to 8:**

**Example 6:**




In the voltage regulator circuit shown, the Zener diode current is to be limited to the range $5 \leq i_z \leq 100$ mA

$$V_z = 4 \text{ V}, R_z = 0\ \Omega$$

The range of posible load current is

(A) $5 \leq i_L \leq 130$ mA
(B) $25 \leq i_L \leq 250$ mA
(C) $10 \leq i_L \leq 110$ mA
(D) $150 \leq i_L \leq 245$ mA

**Solution:** (D)

Current through 12 Ω resistor $i = \dfrac{7-4}{12} = 250$ mA

$i_L = i - i_z$, and $i_z$ is in range of 5 to 100 mA
So $i_L$ will be 150 mA $\leq i_L \leq$ 245 mA.

**Example 7:** Range of possible load resistance is

(A) $60 \leq R_L \leq 375\ \Omega$ (B) $20 \leq R_L \leq 60\ \Omega$
(C) $40.1 \leq R_L \leq 92.1\ \Omega$ (D) $16.3 \leq R_L \leq 26.6\ \Omega$

**Solution:** (D)
$i_L R_L = 4$ V, 150 mA $\leq i_L \leq$ 245 mA
So $R_L$ will be 16.3 Ω $\leq R_L$ Ω 26.67

**Example 8:** The power rating required for load resistance is

(A) 576 mW (B) 480 mW
(C) 360 mW (D) 980 mW

**Solution:** (D)
The power rating required for output resistance is $i_L = 245$ mA, $V_Z = 4$ V, $i_L V_Z = 0.98$ W

## Exercises

### Practice Problems 1

***Directions for questions 1 to 28:*** Select the correct alternative from the given choices.

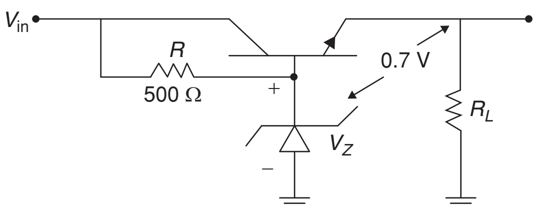
**1.** A power supply having an output resistance 1.5 Ω supplies full load current of 500 mA to a 50 Ω load. What is the % voltage regulation of supply?

(A) 2% (B) 3%
(C) 6% (D) 1.5%

**2.** What is the no-load output voltage of the supply in above problem?

(A) 25 V (B) 24.25 V
(C) 25.75 V (D) 25.25 V

**3.** A transistor series voltage regulator is shown below. The input voltage $V_{in}$ can carry from 18 V to 30 V. If $V_Z = 10$ V, $R_L = 1$ kΩ, $\beta$-very high




The minimum collector to emitter voltage ($V_{CE}$) of the transistor is,

(A) 8.7 V (B) 20.7 V
(C) 7.3 V (D) 19.3 V

**4.** The minimum power dissipated in the transistor is

(A) 0.192 W (B) 2.1 W
(C) 80.9 mW (D) None

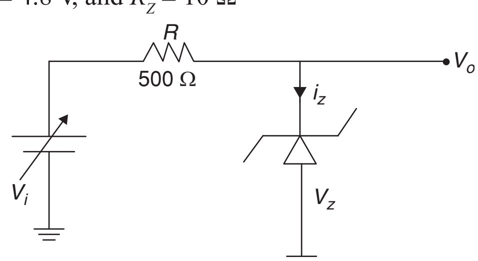
**5.** The max current supplied by $V_{in}$ is

(A) 40 mA (B) 9.3 mA
(C) 24.5 mA (D) 49.3 mA

**6.** A FWR is operated form 230 V, 50 Hz line has a capacitor filter across its output. Calculate the minimum value of capacitance required if the load is 1 kΩ and the ripple must not exceed 5%

(A) 57.8 μF (B) 10 μF
(C) 28.6 μF (D) 5.7 μF

**7.** A Zener diode voltage regulator is given below with following specifications $I_{Z_{min}} = 4$ mA, $I_{z_{max}} = 24$ mA, $V_z = 4.8$ V, and $R_Z = 10$ Ω



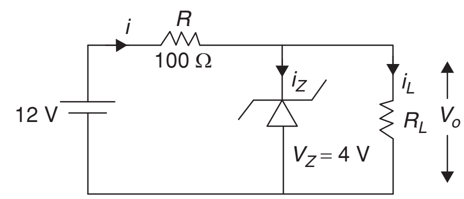

Calculate minimum, and maximum input voltage that can be regulated by Zener diode

(A) 9.8 V and 25.04 V (B) 6.84 V and 25.04 V
(C) 9.8 V and 17.04 V (D) 6.84 V and 17.04 V

**8.** The line regulation is

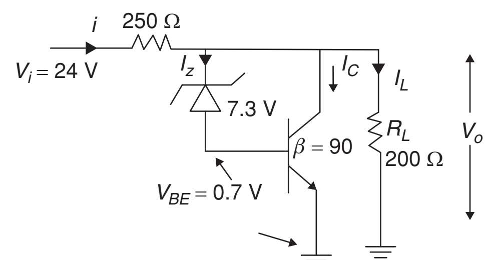
(A) 1.3% (B) 2.5%
(C) 1.96% (D) 0%

**9.** In the circuit shown below, the knee current of ideal Zener diode is 8 mA. To maintain 4 V across $R_L$, the minimum value of $R_L$ and minimum power rating of Zener diode in mW respectively are




(A) 55 Ω and 320 mW (B) 55 Ω and 288 mW
(C) 50 Ω and 320 mW (D) 50 Ω and 288 mW

**10.** A transistor shunt voltage regulator is given below



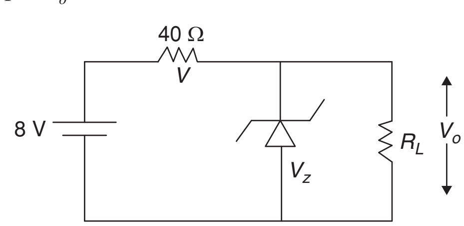

The collector current $i_c$ is

(A) 10 mA (B) 24 mA
(C) 64 mA (D) 40 mA

**11.** The power dissipation in Zener diode is

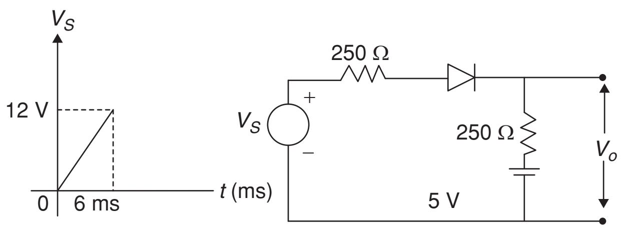
(A) 1.89 mW (B) 2.5 W
(C) 3.1 mW (D) None of these

**12.** A Zener diode in the circuit shown below, has a knee current of 4 mA and power dissipation of 200 mW. What are the minimum and maximum load currents that can be drawn safely from the circuit, keeping the output $V_o = 5$ V.

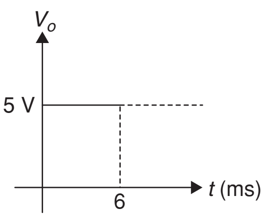



(A) 0 mA and 200 mA (B) 4 mA and 11 mA
(C) 35 mA and 71 mA (D) 35 mA and 200 mA

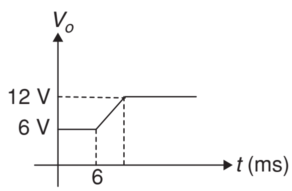
**13.** Sketch the output $V_o$ of the circuit given for $0 \le t \le 6$ ms, assume the diode is ideal



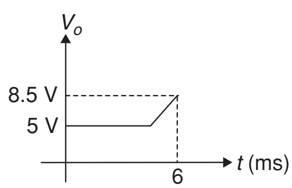

(A)



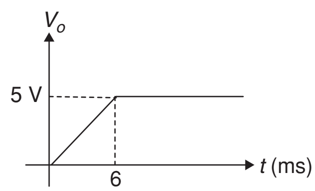

(B)



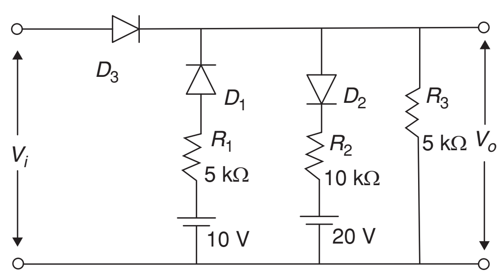

(C)



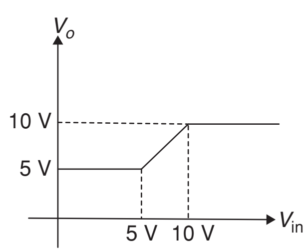

(D)



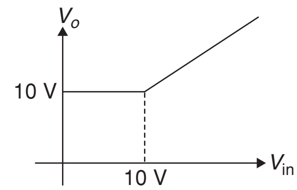

**14.** Draw the transfer characteristic ($V_o$ $V_s$ $V_i$) for the circuit given below.



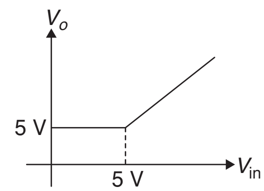

(A)



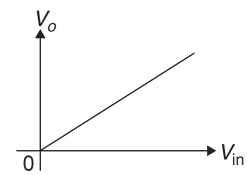

(B)



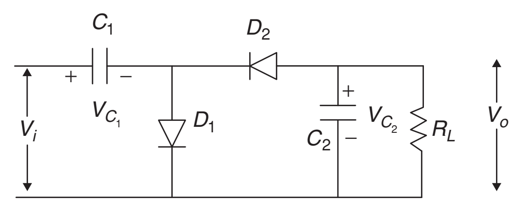

(C)




(D)




**15.** A voltage doubler is given below.




Where $V_i = 6 \sin \omega t$ V

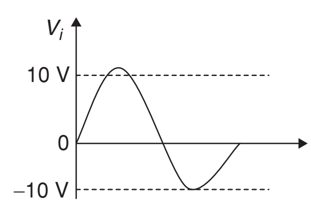
The voltage across $C_1$ and $C_2$ are

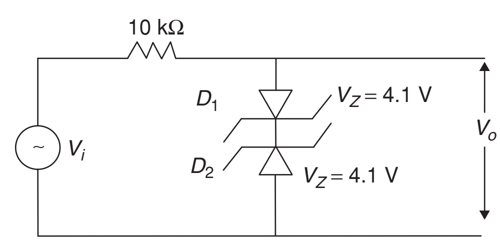
(A) 6 V and 6 V
(B) 6 V and –12 V
(C) 6 V and 12 V
(D) –6 V and –12 V

**16.** The PIV of $D_1$ and $D_2$ are

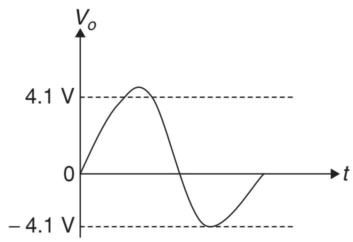
(A) 6 V and 6 V
(B) 6 V and 12 V
(C) 12 V and 12 V
(D) 12 V and 6 V

**17.** Draw the output $V_o$ of the figures given.

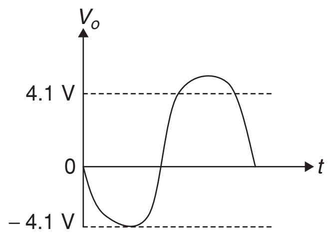


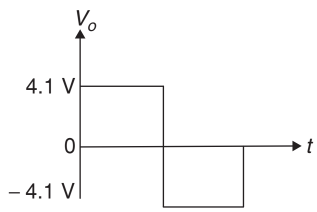
(A)



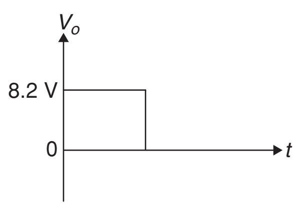

(B)




(C)

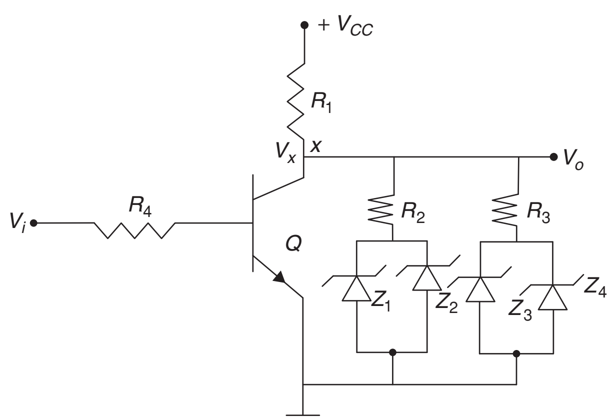



(D)



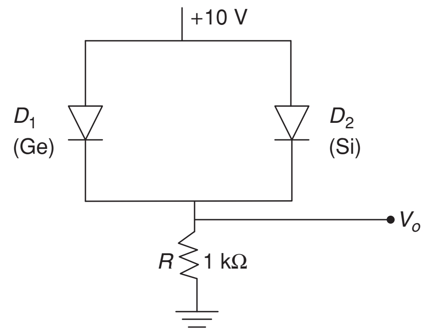

**18.** In the circuit given below, assume that $V_{CC}$ = 12 V, $Z_1$, $Z_2$, $Z_3$ and $Z_4$ are identical Zener diodes with break down voltage of 4 V. $R_1 = R_4$ = 4 kΩ and $R_2 = R_3$ = 8 kΩ.

Calculate $V_o$ when $Q$ is OFF.



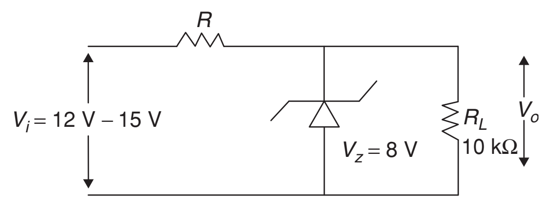

(A) 7.3 V (B) 8 V
(C) 10 V (D) 8.5 V

**19.** In the given circuit, two diodes made up of Ge (cut in voltage = 0.3 V) and Si (cut in voltage = 0.7 V) are used. What is the value of $V_o$.



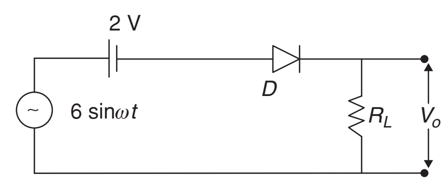

(A) 10 V (B) 9 V
(C) 9.7 V (D) 9.3 V

**20.** What is the minimum value of $R$ to maintain $V_o$ = 8 V constant and $I_z$ is negligible.

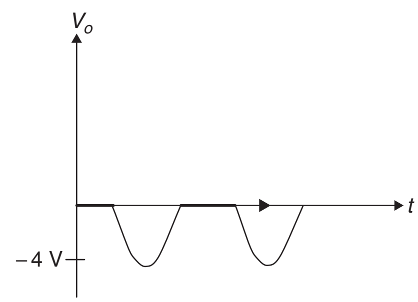



(A) $R \leq 5$ kΩ (B) $R > 8.75$ kΩ
(C) 5 kΩ < $R$ < 8.75 kΩ (D) None of these

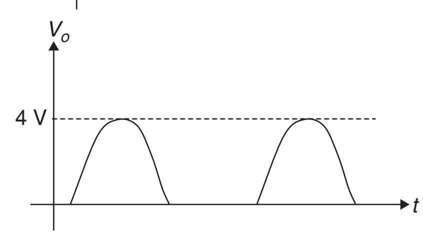
**21.** Draw the output $V_o$ of the figure given below (assume diode is ideal)



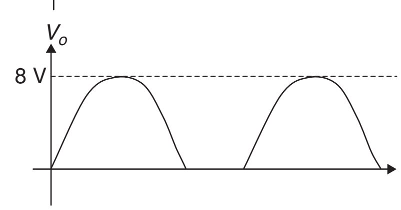

(A)



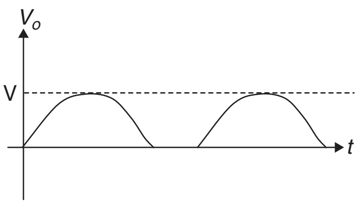

(B)



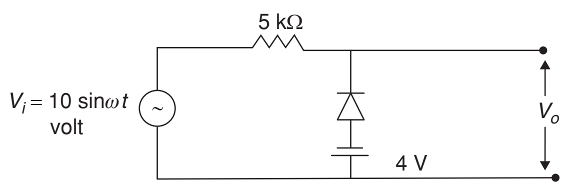

(C)



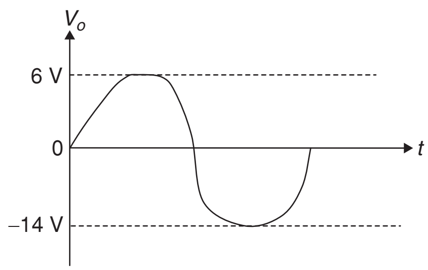
(D)



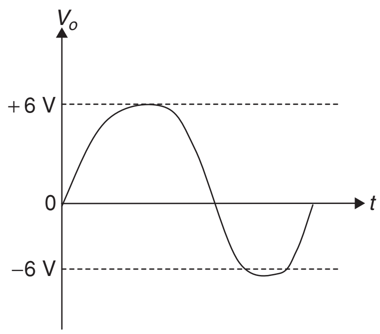

**22.** Draw the output $V_o$ assume diode FB voltage drop is 0.6 V.



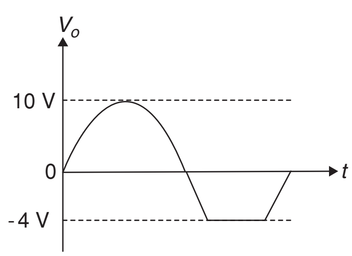

(A)



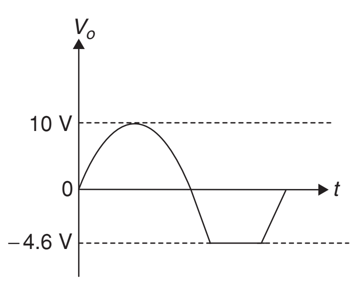

(B)



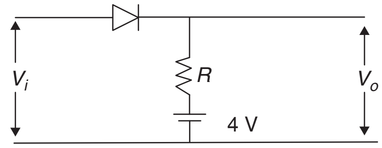

(C)



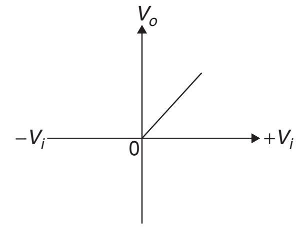

(D)



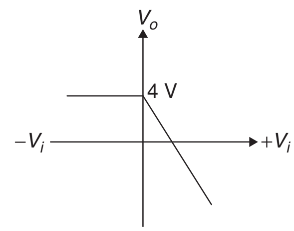

**23.** Draw the transfer characteristic of the figure given below (assume diode is ideal)



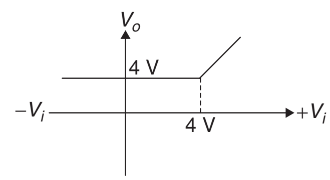

(A)



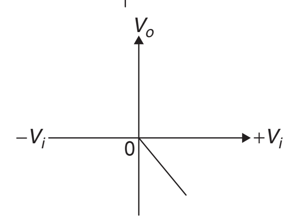

(B)



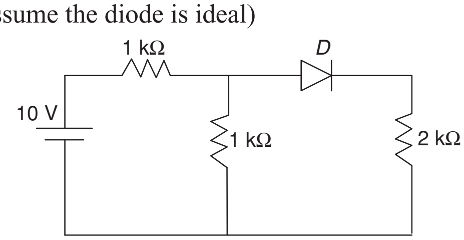

(C)




(D)

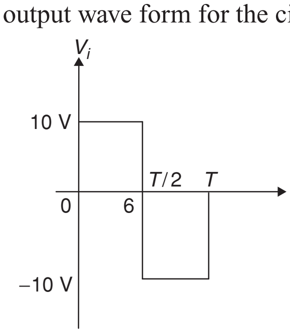


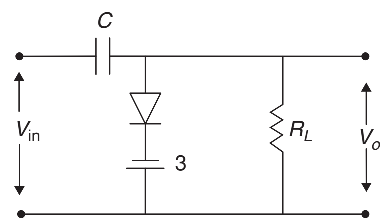

**24.** Calculate the voltage drop across 2 kΩ of the figure (assume the diode is ideal)



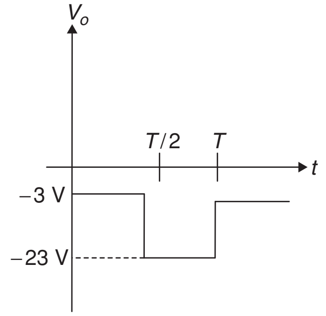

(A) 10 V
(B) 2 V
(C) 4 V
(D) 0 V

**25.** Sketch the output wave form for the circuit given.

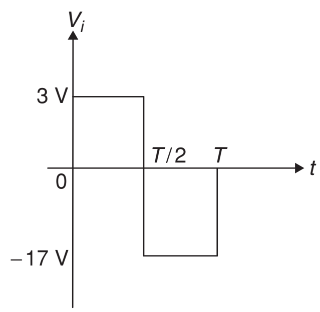




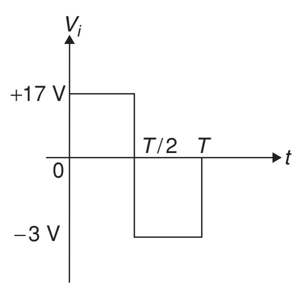

(A)



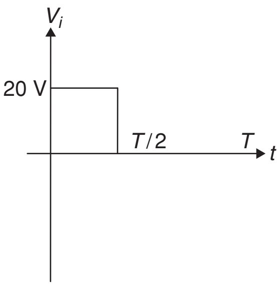

(B)




(C)



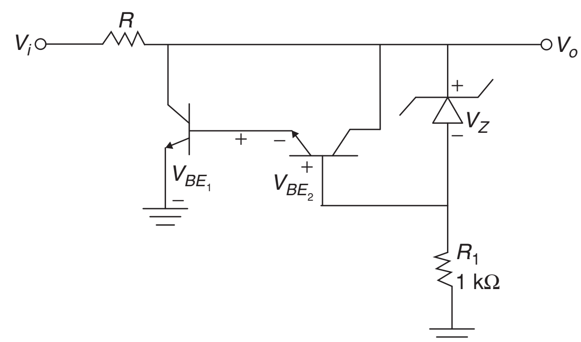

(D)




**26.** A HWR uses a transformer of turn ratio 2:1 and a load resistance of 500 Ω. If the rms primary voltage is 240 V. The DC output voltage is
(A) 54 V (B) 38 V
(C) 76 V (D) None of these

**27.** The PIV of diode is
(A) 120 V (B) 240 V
(C) 360 V (D) 170 V

**28.** Find the output voltage of a shunt regulator given below with following specifications.
$V_{BE_1} = V_{BE_2} = 0.6$ V and $V_Z = 10$ V




(A) 10.6 V (B) 8.8 V
(C) 10 V (D) 11.2 V

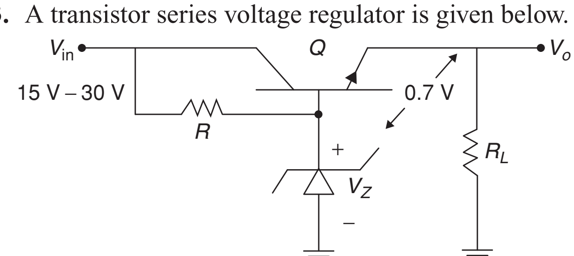
## Practice Problems 2

***Directions for questions 1 to 26:*** Select the correct alternative from the given choices.

**1.** The DC output voltage is 45 V at full load and 47 V at no-load. The % regulation factor is
(A) 2.5% (B) 1%
(C) 4.25% (D) 4.44%

**2.** In a FWR, the rms output is 10 V. What is its DC output voltage.
(A) 10 V (B) 9 V
(C) 5 V (D) 6 V

**3.** A transistor series voltage regulator is given below.



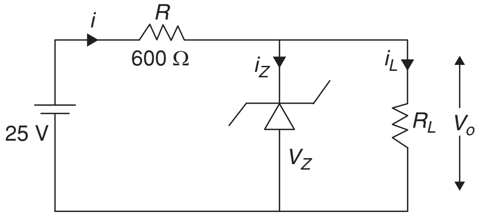

What break down voltage $V_Z$, should the Zener diode have if the load voltage is to be maintained at 12 V?
(A) 11.3 V (B) 12.7 V
(C) 12 V (D) None of these

**4.** If the Zener diode must conduct 12 mA to remain in the breakdown region, what minimum value should $R$ have (in above problem)?

(A) 500 Ω (B) 1.4 kΩ
(C) 2 kΩ (D) 192 Ω

**5.** A Zener diode voltage regulator is given below with following specifications.

$V_Z = 4.1$ V, $I_{ZK} = 3$ mA, $I_{Z_{\max}} = 28$ mA and $r_z = 0$



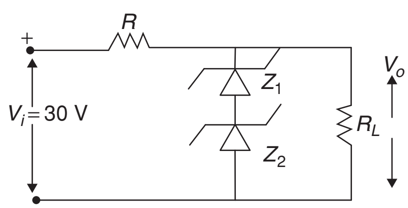

Calculate minimum and maximum load currents for which Zener diode will maintain regulation.

(A) 3 mA and 31.83 mA (B) 6.83 mA and 31.83 mA
(C) 6.83 mA and 28 mA (D) 3 mA and 28 mA

**6.** For above problem calculate the minimum value of $R_L$ used

(A) 128 Ω (B) 85 Ω
(C) 600 Ω (D) 117 Ω

**7.** The circuit given below uses two Zener diodes, each is rated at 12 V, 100 mA and assume that load current is negligible.



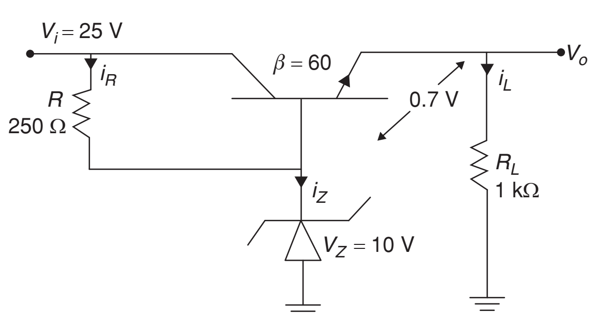

The regulated output $V_o$ is

(A) 24 V (B) 12 V
(C) 6 V (D) 0 V

**8.** For above problem the value of series resistance $R$ is

(A) 180 Ω (B) 15 Ω
(C) 60 Ω (D) None of these

**9.** A transistor series voltage regulator is given below



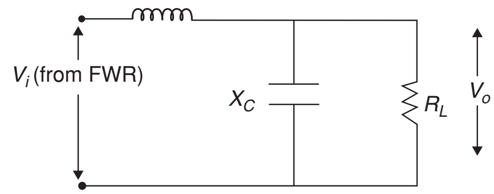

The output voltage $V_o$ is

(A) 9.3 V (B) 10.7 V
(C) 10 V (D) 0.7 V

**10.** For above problem Zener current $i_z$ is

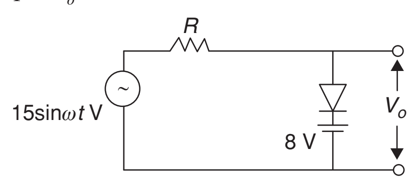
(A) 60 mA (B) 0.15 mA
(C) 59.84 mA (D) 10 mA

**11.** Calculate the ripple factor ($\gamma$) of L-section filter given below with $X_C = 10$ Ω, $X_L = 100$ Ω and $R_L = 1$ kΩ.

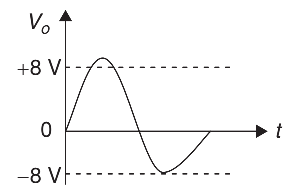



(A) 0.14 (B) 0.047
(C) 0.482 (D) 0.52

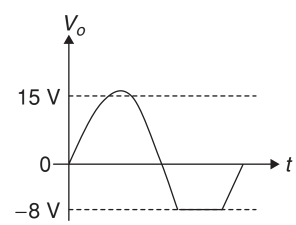
**12.** For the circuits given assume the diode is ideal sketch the output $V_o$.



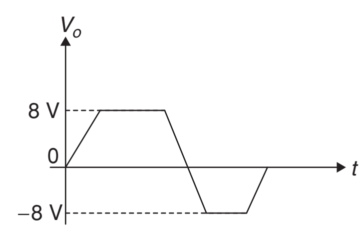

(A)



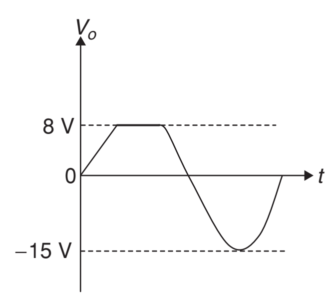

(B)



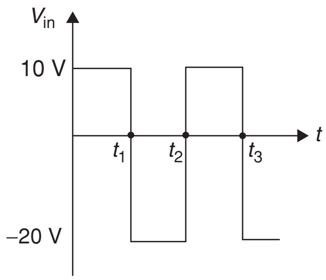

(C)

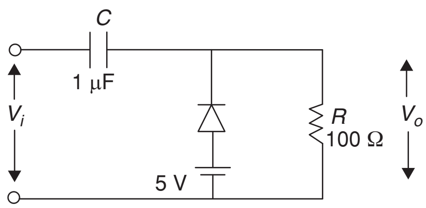



(D)

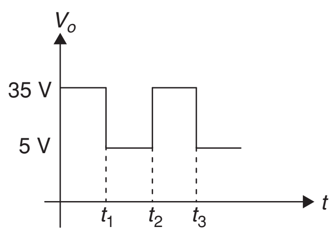


**13.** A DC restorer is shown below. Sketch the output $V_o$.

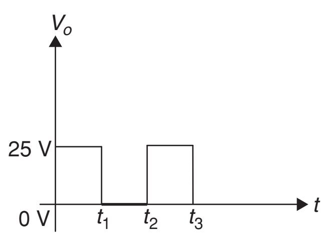


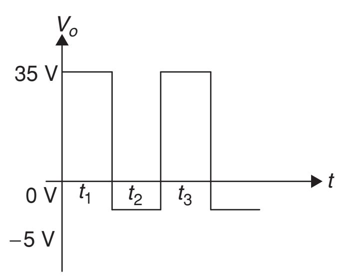

(A)



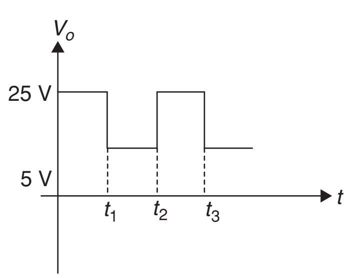

(B)



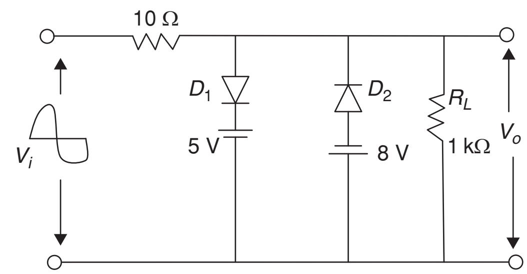

(C)



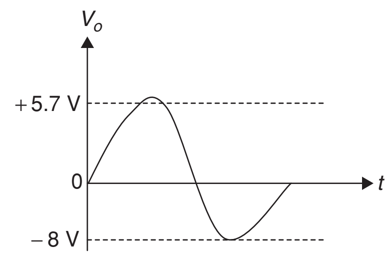

(D)



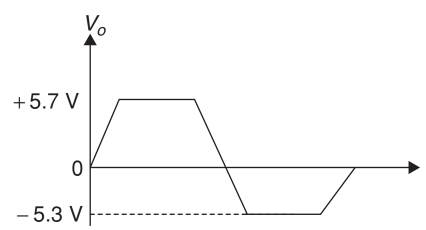

**14.** Draw the output $V_o$ of the figure given. Assume forward voltage drop of each diode is 0.7 V.



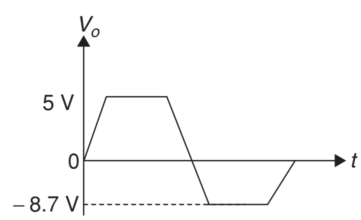

(A)



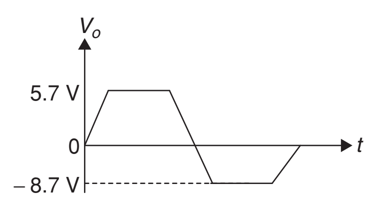

(B)



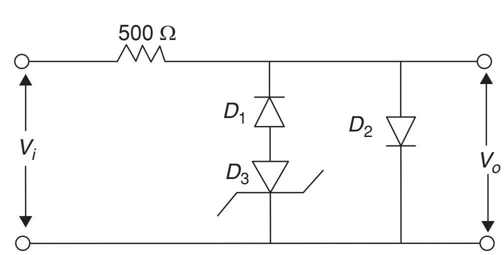

(C)




(D)

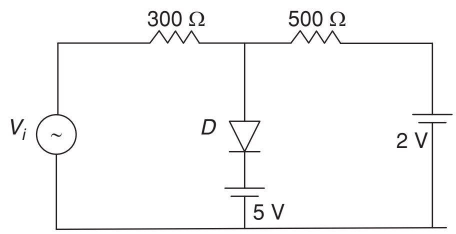



**15.** In the following limiter circuit, an input voltage $V_i = 12 \sin 100\pi t$ V is applied. Assume that the diode forward voltage drop is 0.6 V and Zener breakdown voltage is 4.2 V. What is the minimum and maximum value of output voltage?



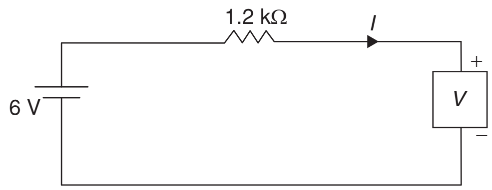

(A) –0.6 V and 4.8 V
(B) –4.8 V and 0.6 V
(C) 0.6 V and 4.2 V
(D) –4.2 V and –0.6 V

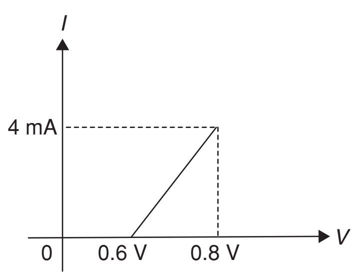
**16.** Find input $V_i$ for the diode to be FB




(A) 7 V (B) 6.8 V
(C) 3 V (D) 5 V

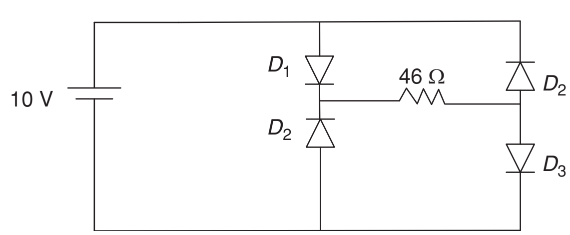
**17.** Find current $I$ for the given characteristic



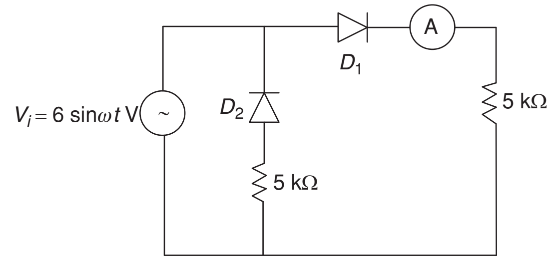

(A) 4.32 mA (B) 5 mA
(C) 4 mA (D) 0

**18.** If the cut-in voltage and forward resistance of each diode are 0.6 V and 2 Ω respectively. The current passing through 46 Ω is



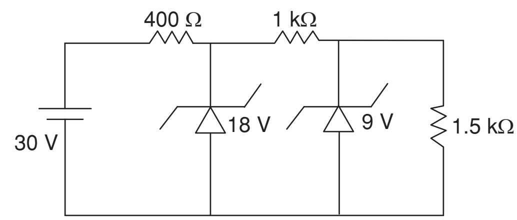

(A) 0.176 A (B) 0.16 A
(C) 0 A (D) 0.2 A

**19.** In the circuit shown, assume that diodes are ideal an ammeter is rms value indicating meter with zero internal resistance. The ammeter reading is




(A) 0.3 mA (B) 1.2 mA
(C) 0.6 mA (D) $\frac{1.2}{\pi}$ mA

**20.** What is the output voltage across 1.5 kΩ load in the circuit given below.




(A) 18 V (B) 10.8 V
(C) 9 V (D) 5.4 V

**21.** An AC supply of 200 V, 50 Hz is applied to bridge rectifier through a transformer turn ratio 4:1. The diode forward resistance is 200 Ω and load $R_L$ = 1 kΩ. What is the DC output current?
(A) 31.8 mA (B) 26.54 mA
(C) 106 mA (D) None of these

**22.** What is the peak inverse voltage of diode?
(A) 50 V (B) 100 V
(C) 200 V (D) 400 V

**23.** Output ripple frequency is
(A) 100 Hz (B) 50 Hz
(C) 25 Hz (D) 0 Hz

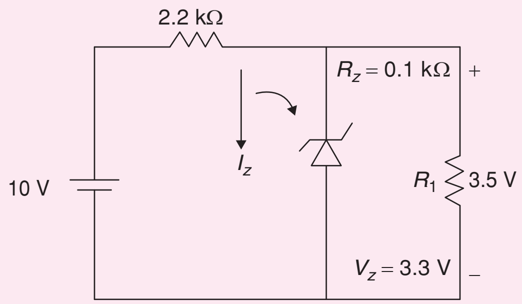
**24.** A power supply is delivering 100 W to a load of 10 kΩ. What is the AC (ripple) voltage across the load if the ripple factor is 0.1%.
(A) 100 V (B) 10 V
(C) 1 V (D) 0.1 V

**25.** A full wave rectifier uses a centre tapped transformer. The AC voltage from its centre tap to either end is $20\sin 314t$ V. The load resistance of the circuit is 80 Ω and diode resistance is 20 Ω. What is rms value of output current ($I_{rms}$)?
(A) 0.2 A (B) 2 mA
(C) 20 mA (D) 0.14 A

**26.** Rectifier efficiency is
(A) 81.2% (B) 64.96%
(C) 58.7% (D) 40.6%

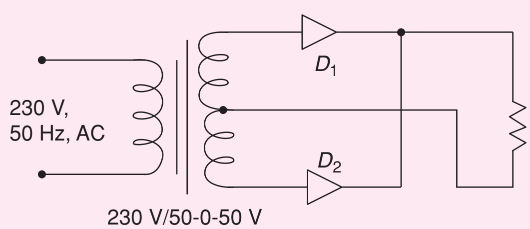
## PREVIOUS YEARS' QUESTIONS

**1.** The current through the Zener diode in the figure is **[2004]**



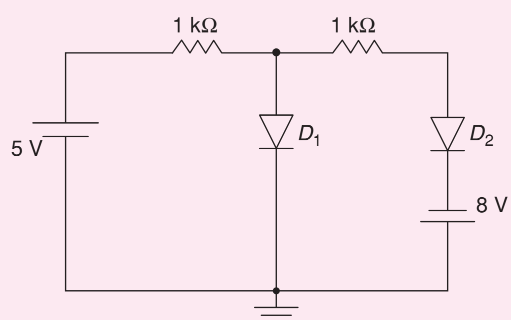

(A) 33 mA (B) 3.3 mA
(C) 2 mA (D) 0 mA

**2.** The circuit in figure shows a full wave rectifier. The input voltage is 230 V (rms) single-phase AC. The peak reverse voltage across the diodes $D_1$ and $D_2$ is **[2004]**



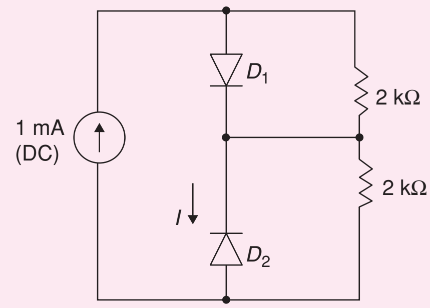

(A) $100\sqrt{2}$ V (B) 100 V
(C) $50\sqrt{2}$ V (D) 50 V

**3.** Assuming that the diodes are ideal in figure, the current in $D_1$ is **[2004]**




(A) 8 mA (B) 5 mA
(C) 0 mA (D) –3 mA

**4.** Assume that $D_1$ and $D_2$ in the figure are ideal diodes. The value of current $I$ is: **[2005]**



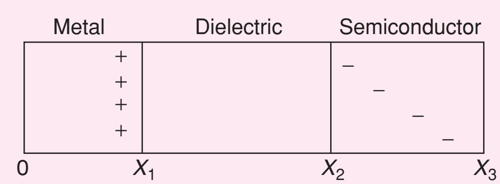

(A) 0 mA (B) 0.5 mA
(C) 1 mA (D) 2 mA

**5.** A three-phase diode bridge rectifier is fed from a 400 V rms, 50 Hz, three-phase AC source. If the load is purely resistive, the peak instantaneous output voltage is equal to **[2005]**

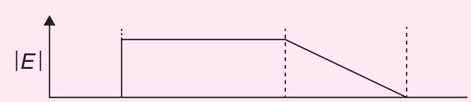
(A) 400 V (B) $400\sqrt{2}$ V

(C) $400\sqrt{\frac{2}{3}}$ V (D) $\frac{400}{\sqrt{3}}$ V

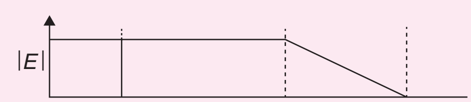
**6.** The charge distribution in a metal-dielectric-semiconductor specimen is shown in the figure. The negative charge density decreases linearly in the semiconductor as shown. The electric field distribution is as shown in **[2005]**



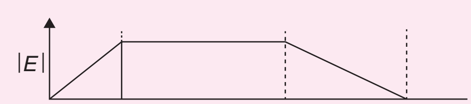

(A)



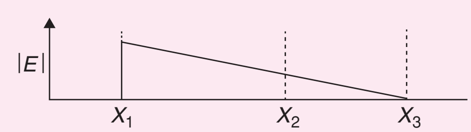

(B)



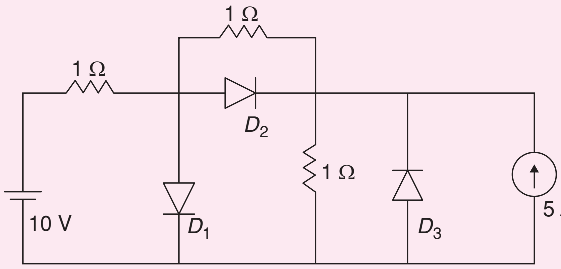

(C)




(D)

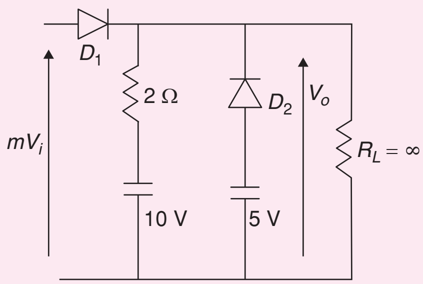


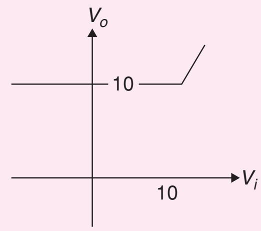

**7.** What are the states of the three ideal diodes of the circuit shown in figure? **[2006]**

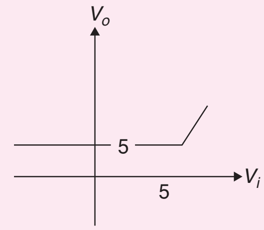


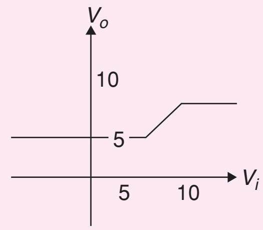

(A) $D_1$ ON, $D_2$ OFF and $D_3$ OFF
(B) $D_1$ OFF, $D_2$ ON and $D_3$ OFF
(C) $D_1$ ON, $D_2$ OFF and $D_3$ ON
(D) $D_1$ OFF, $D_2$ ON and $D_3$ ON

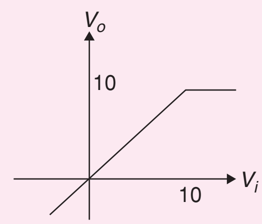
**8.** Assuming the diodes $D_1$ and $D_2$ of the circuit shown in the figure to be ideal ones, the transfer characteristics of the circuit will be **[2006]**



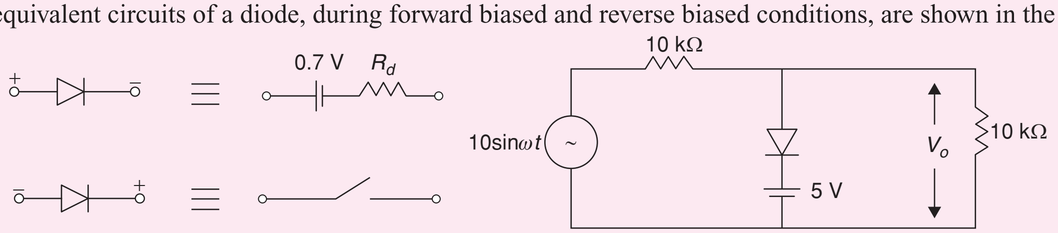

(A)



(B)


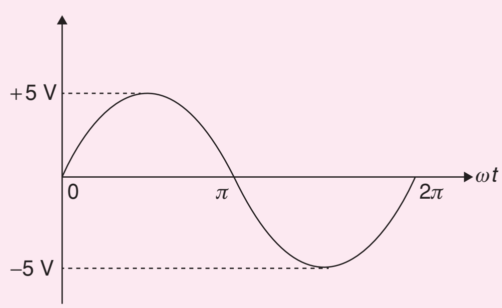

(C)


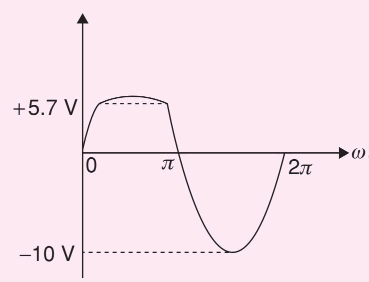

(D)


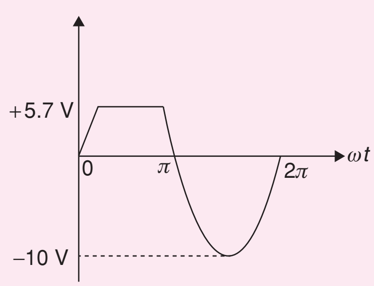

**9.** The equivalent circuits of a diode, during forward biased and reverse biased conditions, are shown in the figure.

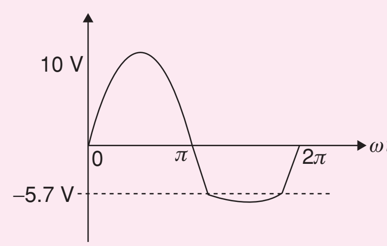



If such a diode is used in clipper circuit of figure given above, the output voltage ($V_o$) of the circuit will be **[2008]**

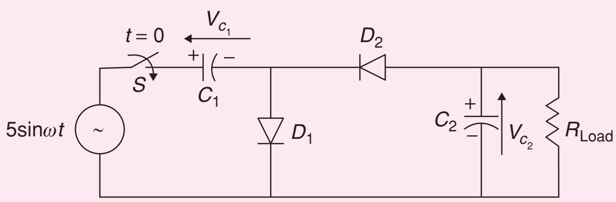
(A)



(B)



(C)


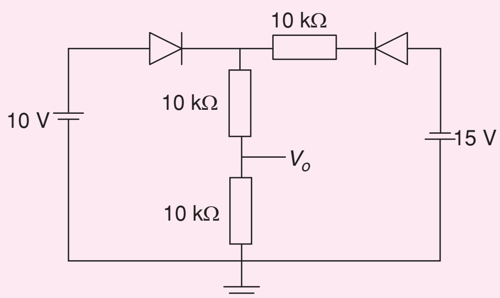

(D)


**10.** In the voltage doubler circuit shown in the figure, the switch '$S$' is closed at $t = 0$. Assuming diodes $D_1$ and $D_2$ to be ideal, load resistance to be infinite and initial capacitor voltages to be zero, the steady state voltage across capacitors $C_1$ and $C_2$ will be **[2008]**



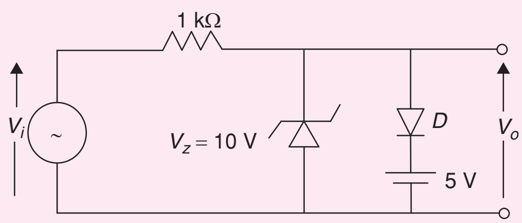

(A) $V_{c_1} = 10$ V, $V_{c_2} = 5$ V (B) $V_{c_1} = 10$ V, $V_{c_2} = -5$ V
(C) $V_{c_1} = 5$ V, $V_{c_2} = 10$ V (D) $V_{c_1} = 5$ V, $V_{c_2} = -10$ V

**11.** Assuming that the diodes in the given circuit are ideal, the voltage $V_o$ is **[2010]**



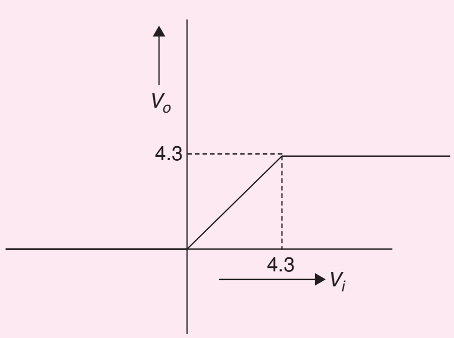

(A) 4 V (B) 5 V
(C) 7.5 V (D) 12.12 V

**12.** A clipper circuit is shown below.

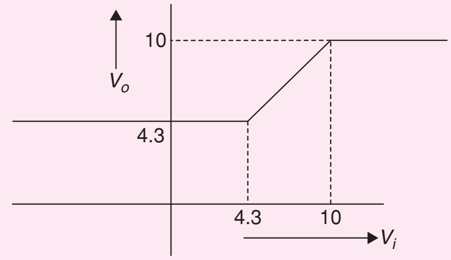



Assuming forward voltage drops of the diodes to be 0.7 V, the input-output transfer characteristic of the circuit is. **[2011]**

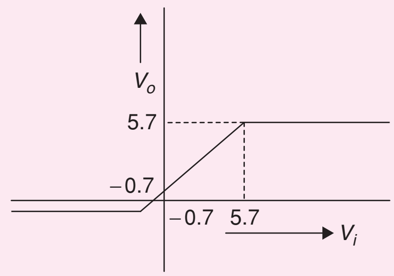
(A)



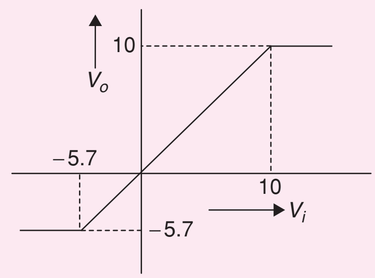

(B)




(C)



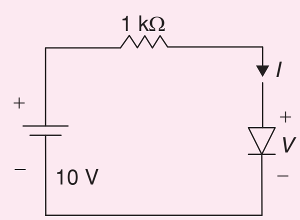

(D)




**13.** The I–V characteristics of the diode in the circuit given below are **[2012]**

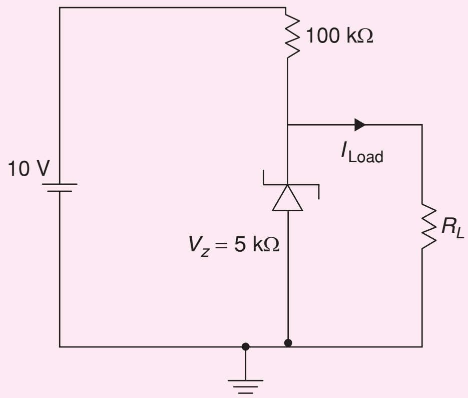
$$I = \begin{cases} \dfrac{V - 0.7}{500} \text{A}, V > 0.7 \text{ V} \\ 0 \text{A}, V < 0 \cdot 7 \text{ V} \end{cases}$$

The current in the circuit is



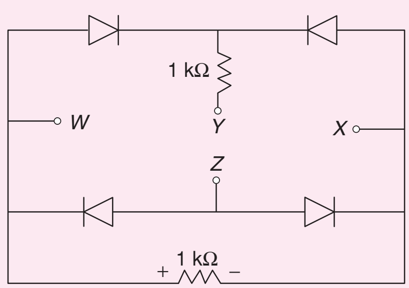

(A) 10 mA (B) 9.3 mA
(C) 6.67 mA (D) 6.2 mA

**14.** In the circuit shown below, the knee current of the ideal Zener diode is 10 mA. To maintain 5 V across $R_L$, the minimum value of $R_L$ in Ω and the minimum power rating of the Zener diode in mW respectively are **[2013]**



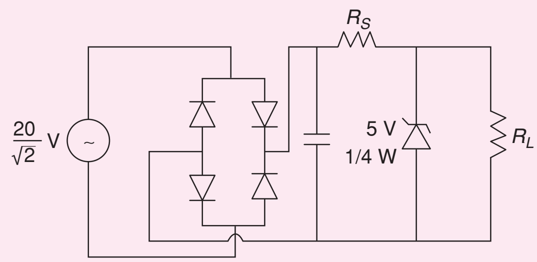

(A) 125 and 125 (B) 125 and 250
(C) 250 and 125 (D) 250 and 250

**15.** A voltage $1000\sin\omega t$ V is applied across $YZ$. Assuming ideal diodes, the voltage measured across $WX$ in V is **[2013]**

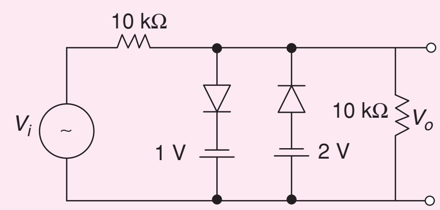



(A) $\sin\omega t$ (B) $(\sin\omega t + |\sin\omega t|)/2$
(C) $(\sin \omega t - |\sin \omega t|)/2$ (D) 0 for all $t$

**16.** A sinusoidal AC source in the figure has an rms value of $\frac{20}{\sqrt{2}}$ V. Considering all possible values of $R_L$, the minimum value of $R_s$ in Ω to avoid burnout of the Zener diode is ________. **[2014]**




**17.** Assuming the diodes to be ideal in the figure, for the output to be clipped, the input voltage $V_i$ must be outside the range **[2014]**




(A) −1 V to −2 V (B) −2 V to −4 V
(C) +1 V to −2 V (D) +2 V to −4 V

## Answer Keys

## Exercises

### Practice Problems 1

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **1.** B | **2.** C | **3.** A | **4.** A | **5.** D | **6.** A | **7.** D | **8.** C | **9.** A | **10.** B |
| **11.** A | **12.** C | **13.** C | **14.** C | **15.** B | **16.** C | **17.** C | **18.** B | **19.** C | **20.** A |
| **21.** B | **22.** D | **23.** C | **24.** C | **25.** A | **26.** A | **27.** D | **28.** D | | |

### Practice Problems 2

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **1.** D | **2.** B | **3.** B | **4.** D | **5.** B | **6.** A | **7.** A | **8.** C | **9.** A | **10.** C |
| **11.** B | **12.** D | **13.** A | **14.** D | **15.** B | **16.** B | **17.** A | **18.** A | **19.** C | **20.** C |
| **21.** B | **22.** A | **23.** A | **24.** C | **25.** D | **26.** B | | | | |

### Previous Years' Questions

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **1.** C | **2.** A | **3.** C | **4.** A | **5.** B | **6.** A | **7.** A | **8.** A | **9.** A | **10.** D |
| **11.** B | **12.** C | **13.** D | **14.** B | **15.** D | **16.** 300 | **17.** B | | | |