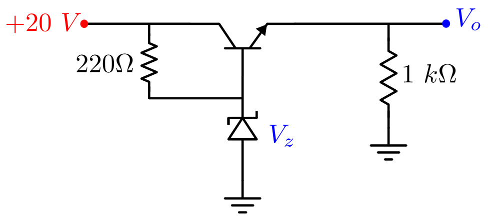
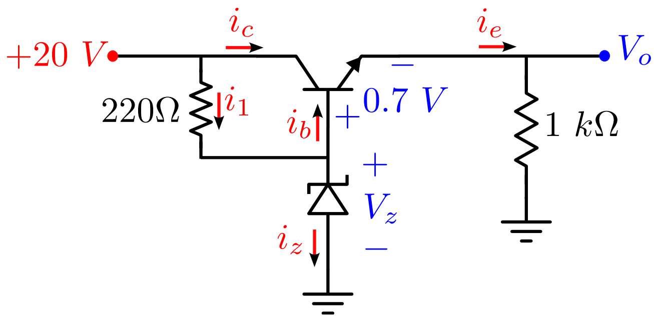
Question 1: Numerical type

In the regulator circuit shown below $V_Z = 12\ V$, $\beta = 50$, $V_{BE} = 0.7\ V$. The Zener current (in mA) is_________.



Solution: Answer range (36.0 - 36.2)



Applying KVL we can obtain the value of the output voltage as

$$V_o = V_z - 0.7 = 11.3\ V$$

Now, the emitter current can be calculated as

$$i_e = \frac{V_o}{1k} = 11.3\ mA$$

As the BJT is operating in linear region and hence the base current can be calculated as

$$i_b = \frac{i_e}{1+\beta} = 0.22\ mA$$

We can calculate i_1 as

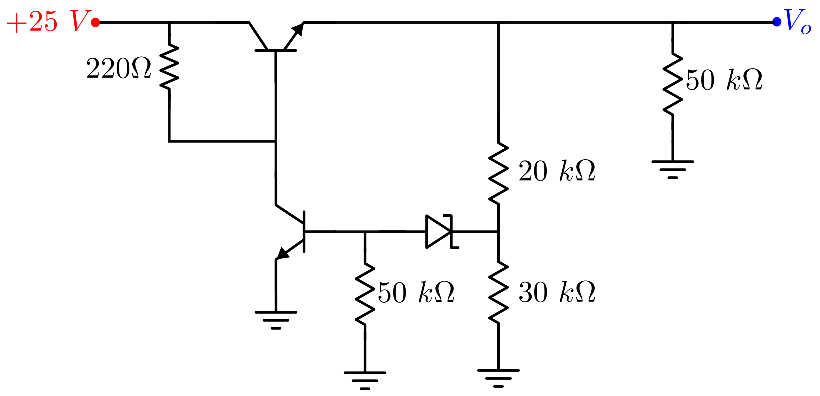
$$i_1 = \frac{20 - V_Z}{0.22k} = \frac{20-12}{0.22} = 36.36\ mA$$

Now applying KCL we can write

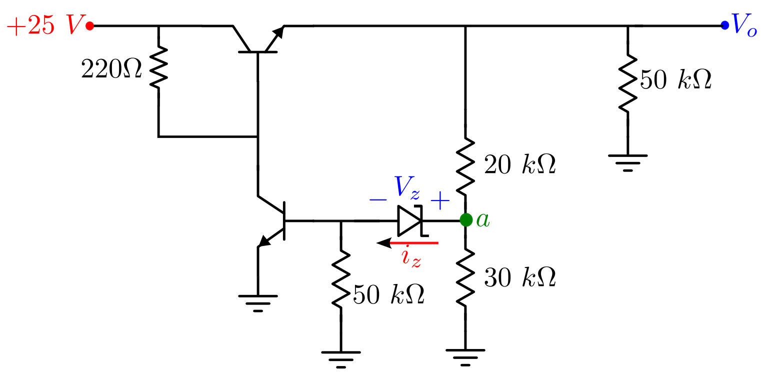
$$i_z = i_1 - i_b = 36.14\ mA$$

Question 2: Numerical type

In the series voltage regulator circuit shown below assume the Zener diode to be ideal. Given that: $V_Z = 8.3\ V$, $\beta = 50$, $V_{BE} = 0.7\ V$, *What would be the output voltage,* V_o, *(in Volts)* ___________.



Solution: Answer range (14.8-15.2)



In this problem, we must assume first whether the transistors are ON or OFF and whether the Zener is in reverse breakdown region or not. Based on the assumption, we solve the circuit to see whether our assumptions are right or wrong. Based on this method, we have found out that both the transistors are ON, and the Zener is in reverse breakdown. **Please note that "ON" here doesn't mean it is in saturation. It means that the transistors are in linear region, and it basically behaves like a resistor. For series regulator circuits, normally the transistors operate in linear region.**

The potential at the point 'α' can be calculated as

$$V_a = V_{BE} + V_Z = 9\ V$$

As Zener diode is assumed to ideal, then we have

$$i_z \approx 0\ A$$

Now, applying potential division we have

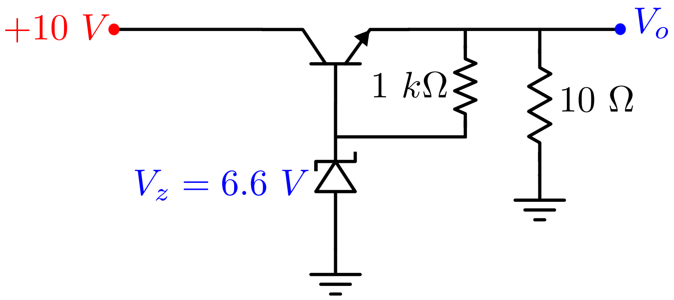
$$V_a = \frac{30}{30 + 20} V_o = \frac{3}{5} V_o$$

Thus, the output voltage V_o can be calculated as

$$V_o = \frac{5}{3} V_a = 15\ V$$

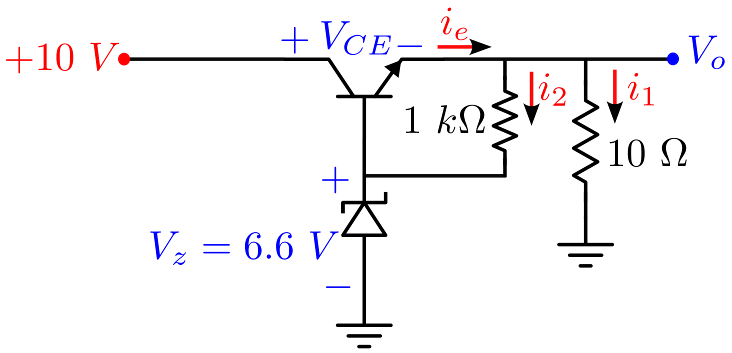
Question 3:

The three terminal linear voltage regulator is connected to a $10\ \Omega$ *load resistor as shown in the figure below. If* V_{in} *is* $10\ V$*, what is the power dissipated in the transistor. (Assume* $V_{BE} = 0.6\ V$*)*



(a) 0.6 W
(b) 4.2 W
(c) 2.4 W
(d) 5.4 W

Solution: Correct option is (c)



The output voltage of the linear voltage regulator can be calculated as

$$V_o = V_Z - V_{BE} = 6.6 - 0.6 = 6\ V$$

i_1 can be calculated as follows

$$i_1 = \frac{V_o}{10} = 0.6\ A$$

i_2 can be calculated as follows

$$i_2 = \frac{V_o - V_z}{1k} = -0.6\ mA$$

Applying KCL we get the value of emitter current, i_e, as

$$i_e = i_1 + i_2 = 0.599\ A$$

Now, the emitter-collector voltage can be calculated as

$$V_{CE} = 10 - V_o = 10 - 6 = 4\ V$$

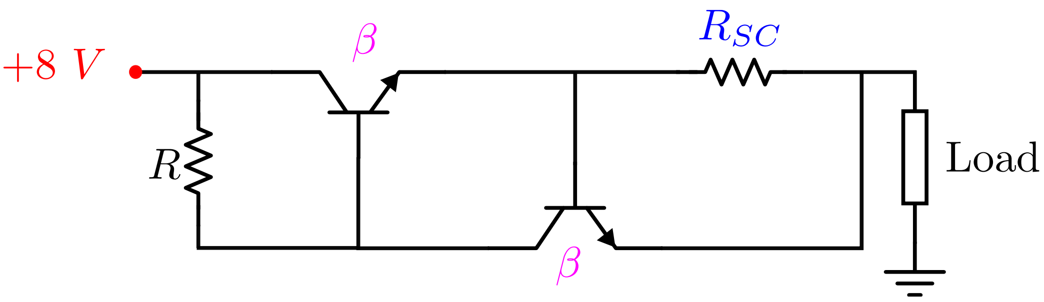
Thus, the power dissipated in the transistor can now be calculated as

$$P = V_{CE} \times i_e = 2.39\ W$$

Question 4:

A 5V regulator uses a 12 W series pass transistor. Find R_{sc} for output short circuit protection.

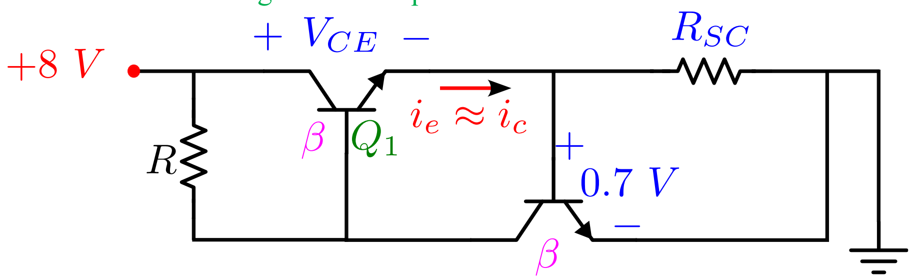
(Assume $V_{BE} = 0.7\ V$, $\beta \to \infty$)



(a) 0.13 Ω
(b) 0. 23 Ω
(c) 0. 33 Ω
(d) 0.43 Ω

Solution: Correct option is (d)

If the load gets shorted the circuit given in the question becomes as shown below



The transistor is rated for 12 W. Thus, R_{sc} should be chosen such that the current flowing through the transistor Q_1 during short circuit conditions does not cause a power dissipation more than the rated power of Q_1.

The collector to emitter voltage can be calculated as

$$V_{CE} = 8 - 0.7 = 7.3\ V$$

The rated power of transistor Q_1 is 12 W. Thus, the maximum permissible current through Q_1 can be calculated as

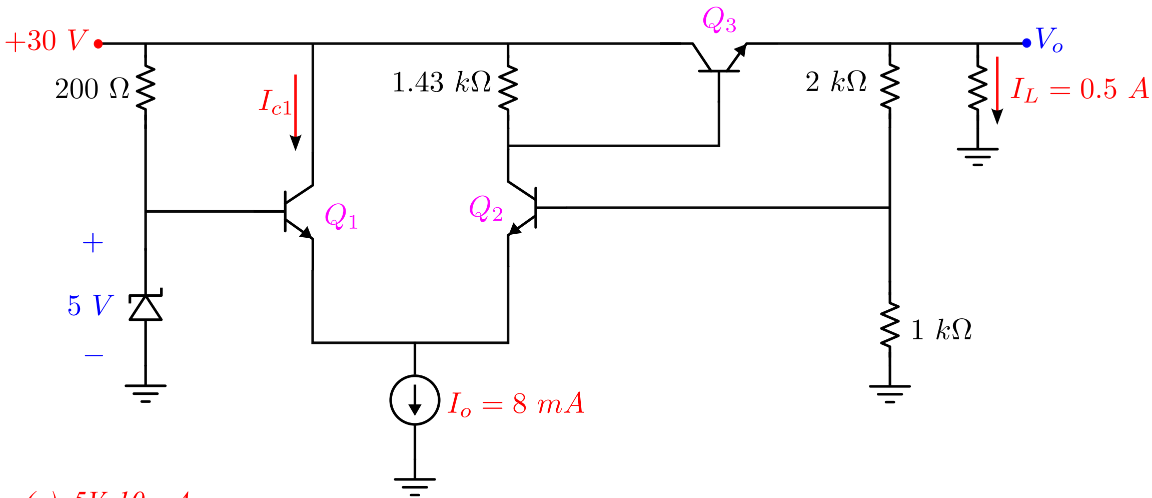
$$i_{c,max} \approx i_{e,max} = \frac{12}{V_{CE}} = 1.64\ A$$

As $\beta \to \infty$, the base current of the transistors can be neglected, and we can assume that $i_{e,max}$ is flowing through R_{sc}. Thus, R_{sc} can be calculated as

$$R_{sc} = \frac{0.7}{1.64} \approx 0.43\ \Omega$$

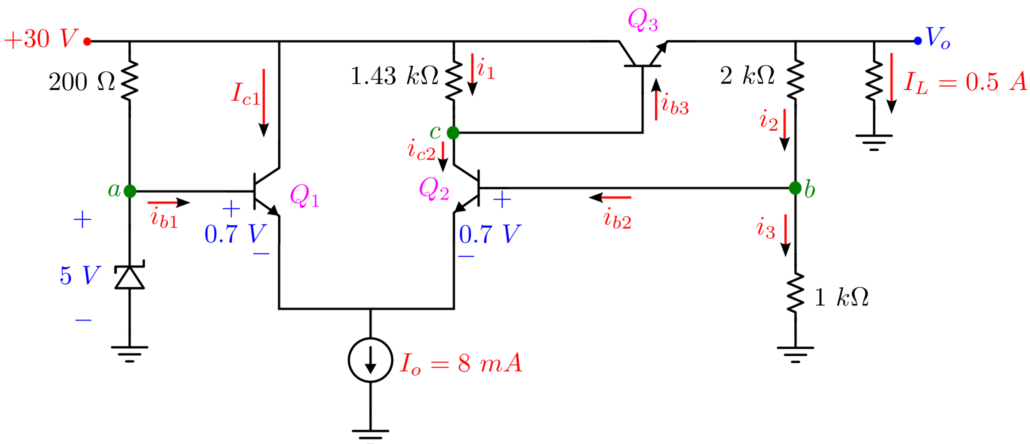
Question 5:

In the circuit diagram given below assume that Q_1 and Q_2 has infinite current gain (i.e. $\beta_1 \approx \beta_2 \rightarrow \infty$) The current gain of transistor Q_3, $\beta_3 = 99$. Calculate V_o (in V), I_{c1} (in mA) if $I_L = 0.5\ A$. (Assume $V_{BE} = 0.7\ V$)



(a) 5V, 10 mA
(b) 5V, 4.95 mA
(c) 15V, 4.95 mA
(d) 15V, 3.05 mA

Solution: Correct option is (d)



From the above circuit diagram, we can conclude that

$$V_a = V_b = 5\ V$$

As $\beta_2 \rightarrow \infty$ and $\beta_1 \rightarrow \infty$, we have

$$i_{b1} = i_{b2} = 0$$

Thus, applying potential divider we can write

$$V_b = \frac{1}{3} V_o$$

Thus, the output voltage, V_o, can be calculated as

$$V_o = 3 \times V_b = 15\, V$$

The potential at point ‘c’ can be calculated as

$$V_c = V_o + 0.7 = 15.7\, V$$

Thus, i_1 can be calculated as

$$i_1 = \frac{30 - V_c}{1.43}\, mA = 10\, mA$$

Since $i_{b2} = 0$, the current flowing through $2\, k\Omega$ can be calculated as

$$i_2 = \frac{V_o}{3} = 5\, mA$$

Applying KCL, the emitter current of Q_3 can be calculated as

$$i_{e3} = I_L + i_2 = 505\, mA$$

Thus, the base current of Q_3 is

$$i_{b3} = \frac{i_{e3}}{1 + \beta_3} = 5.05\, mA$$

Thus, the collector current of Q_2 is

$$i_{c2} = i_1 - i_{b3} = 4.95\, mA$$

Since $i_{b2} = 0$, we can write

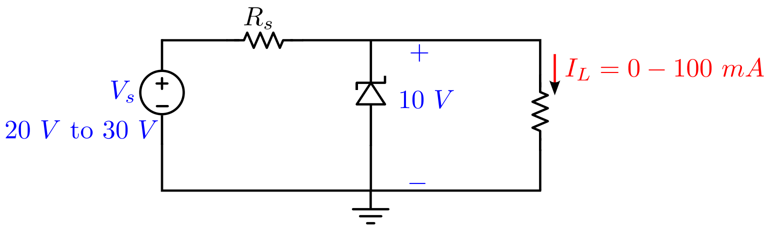
$$i_{c2} = i_{e2} = 4.95\, mA$$

Thus, the collector current of Q_1 is

$$I_{C1} = I_0 - i_{e2} = 8 - 4.95 = 3.05\, mA$$

Question 6: Numerical type

Find the value of R_s (in Ω) as a worst-case design, if V_s ranges from 20 V to 30 V and I_L ranges from 0 to 100 mA and $I_{Z(knee)} = 1\ mA$.



Solution: Answer range (98.5-99.5)

$I_{Z(knee)}$ is the minimum current that must flow through the Zener diode so that it can maintain a voltage of $V_Z = 10\ V$.

Worst case condition would be:

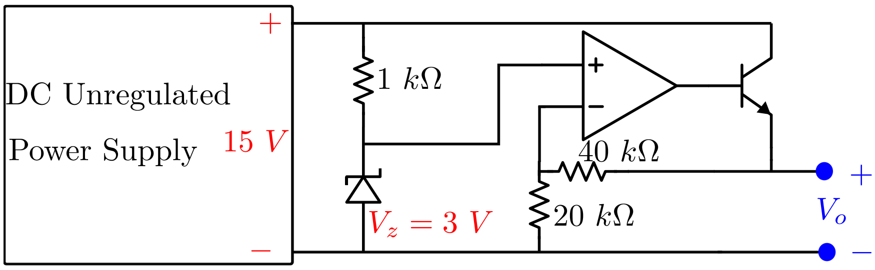
$$V_s = 20\ V \quad and \quad I_L = 100\ mA$$

Because it would be the case when the voltage drop across R_s would be maximum. The value of R_s can then be calculated as

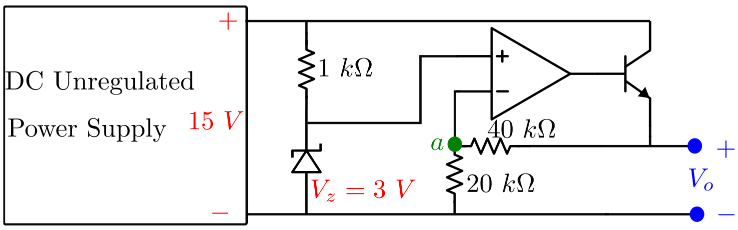
$$R_s = \frac{20 - 10}{I_{Z(knee)} + I_L} = \frac{10}{101} \times 10^3 \Omega = 99\ \Omega$$

Question 7: Numerical type

Find the output voltage, V_o (in volts), of the regulated power supply shown in the figure. Assume the op-amp to be ideal.



Solution: Answer range (8.9-9)



As the op-Amp is ideal, the gain of op-Amp is infinite. And hence due to virtual grounding

$$V_a = V_z = 3\ V$$

Again, we have

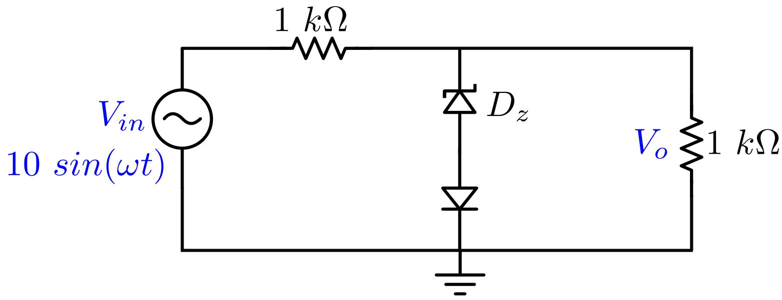
$$V_a = \frac{20}{20+40} V_o = \frac{1}{3} V_o$$

The output voltage of regulated power supply is

$$V_o = 3V_a = 9\ V$$

Question 8:

The cut in voltage of both Zener diode D_z and D shown in the figure below is 0.7 V while breakdown voltage of the Zener is 3.3 V and reverse break down of D is 50 V. The other parameters can be assumed to be the same as those of an ideal diode. The values of the peak output voltage (V_o) are



(a) 3.3 V in the positive half cycle and 1.4 V in the negative half cycle
(b) 4 V in the positive half cycle and 5 V in the negative half cycle
(c) 3.3 V in both positive and negative half cycle
(d) 5 V in both positive and negative half cycle

Solution: Correct option is (b)

In the positive half cycle,

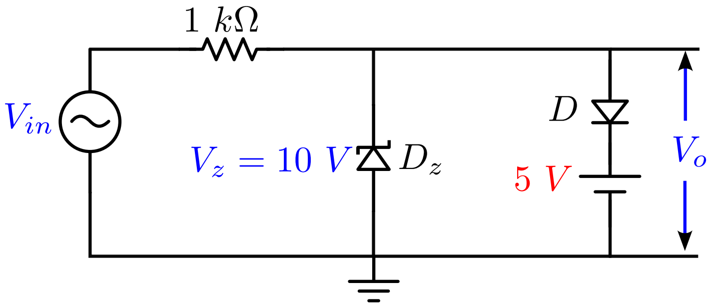
When V_o exceeds ($V_z + 0.7\ V = 4\ V$), it gets clamped to $4\ V$

In the negative half cycle,

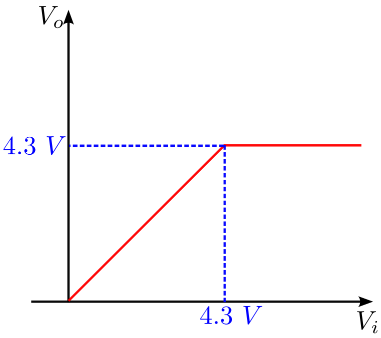
The diode D remains reverse biased and hence $V_o = \frac{V_{in}}{2}$. Hence, the peak value of V_o in the negative half cycle is 5 V.

Question 9:

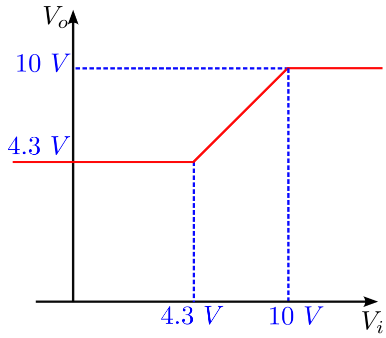
Assuming forward voltage drop of the diodes to be 0.7 V, the input-output transfer characteristics of the circuit is



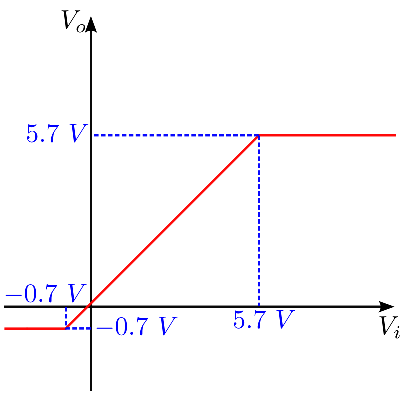
(a)



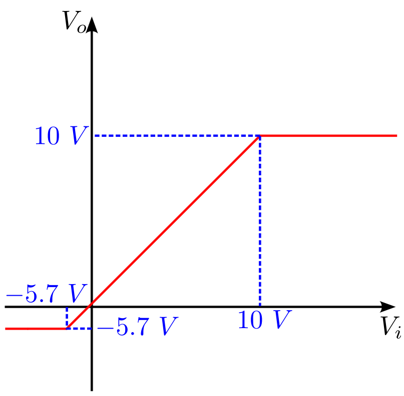
(b)



(c)



(d)



Solution: Correct option is (c)

When $-0.7\ V \leq V_{in} \leq 5.7\ V$,

Diode D remains reverse biased. The Zener diode acts as open circuit as V_{in} has not exceeded its breakdown voltage ($V_z = 10\ V$). Thus. During this period $\boldsymbol{V_o = V_{in}}$

When $V_{in} > 5.7\ V$,

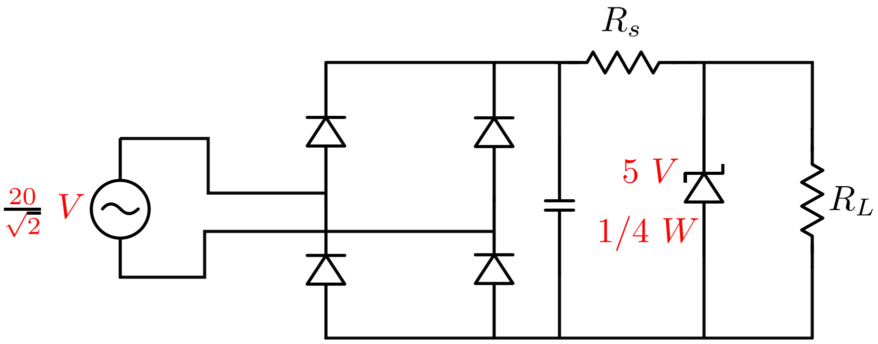
The output voltage gets clamped at 5.7 V.

When $V_{in} \leq -0.7\ V$,

The Zener diode starts acting as a forward biased diode and hence the output voltage gets clamped at $-0.7\ V$.

Question 10: Numerical Type

The sinusoidal ac source in the figure has 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 ___________.



Solution: Answer range (299-300)

If $R_L \to \infty$ (i.e. open circuit condition),

The load current would flow through the Zener diode. Thus, we should ensure that the power dissipation during this condition does not exceed the rated value of 0.25 W. Therefore,

$$i_{Z,max} = \frac{0.25}{5} = 0.05\ A$$

Considering the worst-case condition, the voltage across the capacitor will be almost close to the peak value of the source voltage. Thus, the value of resistance R_s should be

$$R_s = \frac{20 - 5}{0.05} = 300\ \Omega$$