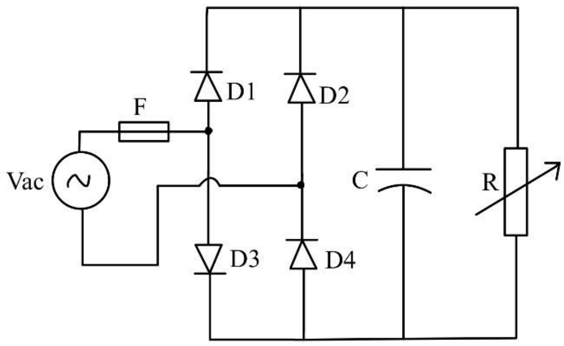
Question 1:

While connecting the diodes of a full bridge rectifier, the Power electronics engineer made a mistake and connected one of the diodes with wrong polarity as shown in the figure below. The circuit was then connected to 230V AC supply, through a semiconductor fuse. Which of the following statements are FALSE?

(Assume the forward drop of diode is 0 V)



1. *Circuit will work properly during positive half cycle and no current will flow during negative half cycle.*
2. *The Semiconductor fuse used in the circuit would blow up immediately.*
3. *The capacitor will blow up if fuse is not used.*
4. *The load resistor will blow up if fuse is not used.*
5. *Diode D1 and D4 will be damaged if fuse is not used.*
6. *Diode D2 will not be damaged.*
7. *Diode D3 and D4 will be damaged if fuse is not used.*

a) *1,3,4,6*
b) *2,3,5,6*
c) *1,3,4,5*
d) *1,2,6,7*

Solution: Correct option is (c)

Due to the wrong connection made, during positive half cycle, D3 and D4 will be forward biased and thus the AC supply is shorted and huge currents will flow and the semiconductor fuse will blow up. Semiconductor fuses are extremely fast and can act in few milliseconds or even less than a millisecond. So, if the fuse is used, the diodes D3 and D4 will be protected. Otherwise, they will blow up. In the negative half cycle, there is no path for current to flow. Hence D2, Output Capacitor C and Load Resistor R will not blow up whether fuse is used or not.

D1 is forward biased during positive half cycle, but no current will flow through D1 and through R||C, because the supply has a dead short through D3 and D4 and all the currents will flow through D3 and D4. Therefore, D1 will not be damaged.

Question 2:

In a particular rectifier circuit, the AC supply (230V , 50Hz) is turned ON exactly at the zero crossing (using a Zero Crossing Detection Circuit). Based on the load conditions, the Power Electronics Engineer calculated the amplitude of the inrush current during the first cycle when the supply is turned ON. The amplitude came out to be 75A. Also, his circuit will be operating in an ambient temperature of 37.5°C. The engineer checks through the datasheet of 1N4007 to see whether it can handle 75A of surge current at the starting. He finds out that the maximum tolerable surge current of 1N4007 diode at 37.5°C is________________.

(The datasheet is attached. The student is advised to go through the data sheet thoroughly and find the value of surge current. Assume for simplicity that the inrush current pulse is square pulse)

(https://www.vishay.com/docs/88503/1n4001.pdf)

Solution: Range (28-30)

Since the source is turned at zero crossing, for the source to reach the peak, it will take 5ms for the source to reach the peak value. So, the inrush current pulse will flow for 5ms. Even though it is not exactly a square, as allowed in the question, we will take it as a square.

This inrush current happens only in the first cycle when the supply is turned ON. It doesn't repeat for the consecutive cycles and therefore we have to look at the **non-repetitive peak forward surge current** value mentioned in the datasheet. Looking at the tables, we get

MAXIMUM RATINGS (T_A = 25 °C unless otherwise noted)										
PARAMETER		**SYMBOL**	**1N4001**	**1N4002**	**1N4003**	**1N4004**	**1N4005**	**1N4006**	**1N4007**	**UNIT**
Maximum repetitive peak reverse voltage		V_{RRM}	50	100	200	400	600	800	1000	V
Maximum RMS voltage		V_{RMS}	35	70	140	280	420	560	700	V
Maximum DC blocking voltage		V_{DC}	50	100	200	400	600	800	1000	V
Maximum average forward rectified current 0.375" (9.5 mm) lead length at T_A = 75 °C		$I_{F(AV)}$	1.0							A
Peak forward surge current 8.3 ms single half sine-wave superimposed on rated load		I_{FSM}	30							A
Non-repetitive peak forward surge current square waveform T_A = 25 °C (fig. 3)	t_p = 1 ms	I_{FSM}	45							A
	t_p = 2 ms		35							
	t_p = 5 ms		30							
Maximum full load reverse current, full cycle average 0.375" (9.5 mm) lead length T_L = 75 °C		$I_{R(AV)}$	30							μA
Rating for fusing (t < 8.3 ms)		I^2t (1)	3.7							A^2s
Operating junction and storage temperature range		T_J, T_{STG}	-50 to +150							°C

The tables provide the value at 25°C. In order to get the exact value at 37.5°C, we need to look at the characteristics.We can see from the characteristics, that the value of surge current is nearly 29 A at 37.5°C (marked in RED).

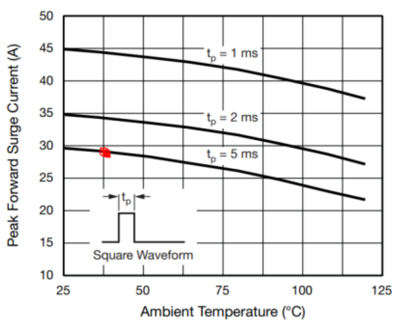
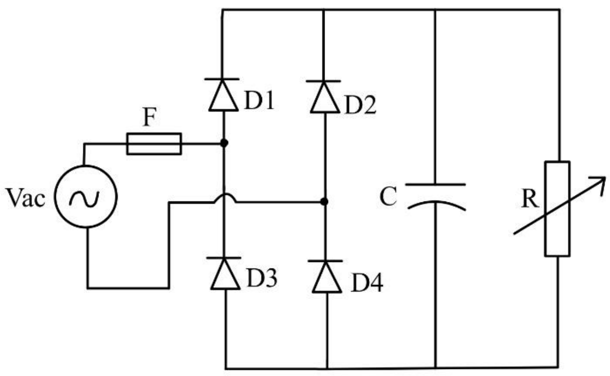


Fig. 3 - Non-Repetitive Peak Forward Surge Current

Question 3:

In the diode bridge rectifier circuit given below, which of the following statements are true, if diode D2 is damaged and acts as OPEN for the entire time of operation.

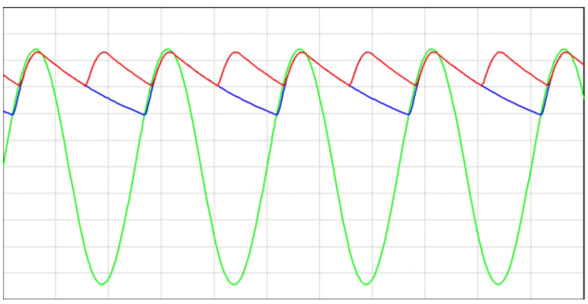


1. The Capacitor voltage ripple for a given load current will be lesser than the circuit in which D2 is working properly.
2. If the load current is extremely small, the output voltage will appear to be approximately the same whether D2 is working properly or not.
3. If the load current is very large, the output voltage can also come down to zero, before the positive half of the next cycle.

a) 1,2,3
b) 2,3
c) 1,3
d) None are correct

Solution: (b)

When D2 is open, no current will flow during the negative half cycle and therefore the capacitor will discharge for a longer time and thus the capacitor voltage ripple will be larger.



The green waveform is the input voltage. The red waveform is the output voltage when D2 is working properly. The blue waveform is the output voltage when D2 is OPEN.

When the load current is very large, the capacitor will discharge quickly and be at 0V.

When the load current is very small, the capacitor will discharge very slowly and thus the output voltage ripple will be less and the voltage waveform will look alike in both the cases.

Question 4:

While selecting the capacitor for the diode full bridge rectifier, the Power Electronics Engineer must look into several parameters to decide the capacitor and one of them is the ***maximum voltage across the capacitor.*** *The engineer must design this rectifier for a particular country where the standard AC voltage is 110Vrms ,60Hz. There can be a fluctuation of 40% around the standard value. Considering the fluctuation in supply voltage, and giving a margin of 20% on top of the fluctuations, what is the nearest voltage rating of the capacitor that the engineer arrives at:*

a) 218 V
b) 154 V
c) 282V
d) 262 V

Solution: (D)

$$Standard\ average\ RMS\ voltage = 110\ Vrms$$

$$Maximum\ RMS\ voltage\ of\ the\ supply = 110 + 110 \times \frac{40}{100} = 154\ Vrms$$

$$The\ peak\ voltage\ for\ the\ maximum\ condition = Vrms \times \sqrt{2} = 154 \times 1.414 = 217.756\ \mathrm{V}$$

$$Adding\ 20\%\ margin\ to\ this\ we\ get\ Vm = 217.756 \times 1.2 = 261.307 \approx 262V$$

The engineer will obviously not find a capacitor of this exact voltage rating, but he must choose a voltage rating for the capacitor very near to 262 V that is available in the market.

Question 5:

For a particular application, after the circuit designer did all the necessary circuit analysis he came up with the following values for the capacitor

C= 215 uF ; V_c=320V ; I_{CRMS}=1.5A

A datasheet of a series of capacitors were handed to him. All the capacitors in this datasheet are rated at 500V. So the voltage aspect is taken care of. ***He has to make sure that at all times, the capacitance should be 215uF.*** *The designer goes through the datasheet and write the code for the capacitor that he will choose finally is________________.*

(The datasheet of the Electrolytic capacitor is attached. The student is advised to go through the datasheet thoroughly and find the code of the capacitor required for the above application.

(https://www.nichicon.co.jp/english/series_items/catalog_pdf/e-lgc.pdf *)*

Solution: LGC2H271MELA50

Voltage is 500V for all the capacitors. Therefore, we need not worry about voltage as it is way beyond 320V.

Now the capacitance designed is 215uF. We will be tempted to choose from the 220uF category. But the datasheet states that the capacitance has a tolerance of 20%.

Capacitance Tolerance	±20% at 120Hz, 20°C

This implies that in the worst-case scenario, the capacitance will be

$$220 - 220 * \frac{20}{100} = 176\ \mu F$$

Therefore, the designer will choose the 270uF category. Considering the tolerance, the minimum capacitance will be:

$$270 - 270 * \frac{20}{100} = 216\ \mu F$$

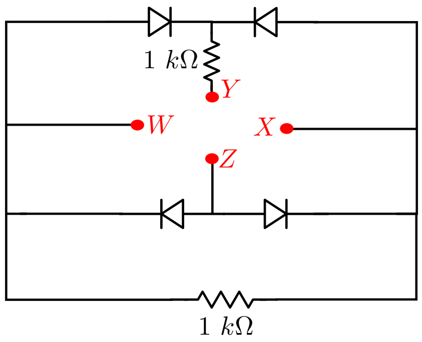
Now within this section, there are 4 available capacitors, and they differ mainly in the maximum RMS value permissible.

270	22 × 60	1620	1.10	LGC2H271MELZ60
	25 × 50	1600	1.10	LGC2H271MELA50
	30 × 35	1480	1.10	LGC2H271MELB35
	35 × 30	1430	1.10	LGC2H271MELC30

For our application, the maximum RMS value is 1.5 A. Therefore, the designer will choose the capacitor with rms current higher than that which is 1.6 A which corresponds to LGC2H271MELA50.

Question 6:

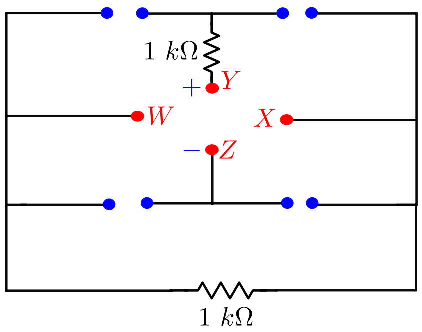
A voltage $100\ \sin(\omega t)$ *is applied across* YZ. *Assuming diodes to be ideal, the voltages measured across WX (in volts) is*



(a) $\sin(\omega t)$
(b) $(\sin(\omega t) + |\sin(\omega t)|)/2$
(c) $(\sin(\omega t) - |\sin(\omega t)|)/2$
(d) $0\ for\ all\ t$

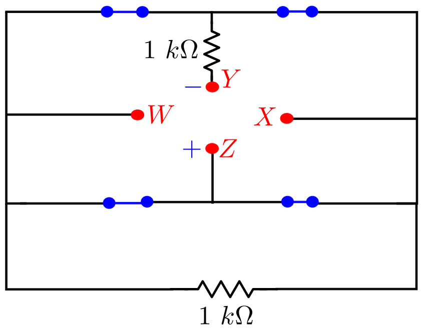
Solution: Correct option is (d)

During the positive half cycle the circuit becomes:



Thus, the voltage across 'WX' during the positive half cycle is 0 V.

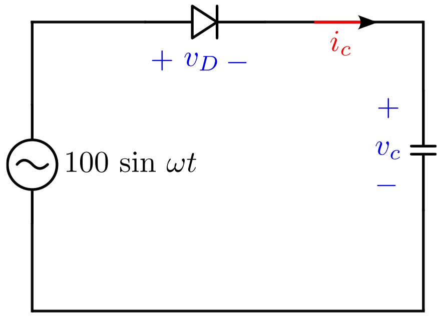
During the negative half cycle the circuit becomes:



Thus, the voltage across 'WX' during the negative half cycle is 0 V.

Question 7: Numerical type

In the circuit shown below find the rms value of the voltage (in volts) across the diode in steady state.



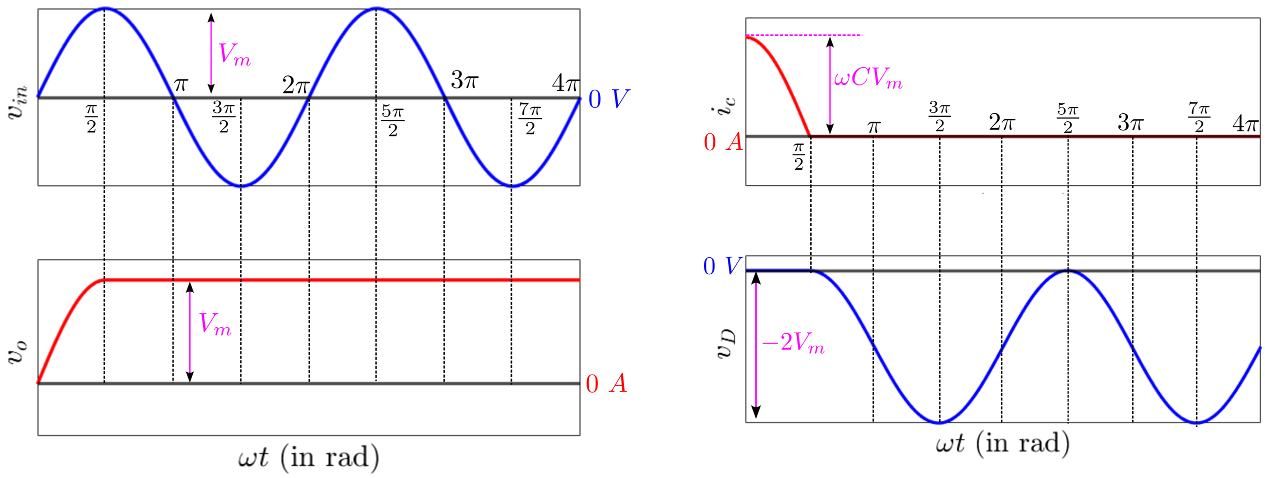
Solution: Answer range (121-123)

In the positive half cycle, the diode gets forward biased and starts conducting for the period

$0 \le \omega t \le \frac{\pi}{2}$. Thus, during this period

$$v_c = 100\ \sin(\omega t)$$

At $\omega t = \frac{\pi}{2}$, the voltage across the capacitors reaches its maximum value $V_m = 100\ V$. Thus, the diode gets reverse biased for $\omega t > \frac{\pi}{2}$ and the current through the diode, i_c stays put at 0 A. The corresponding waveforms are illustrated in the figures below:



Therefore, at steady state i.e. for $\omega t > \frac{\pi}{2}$, the expression for the diode voltage can be written as

$$v_D = V_m(\sin(\omega t) - 1)$$

Thus, from the expression we can conclude that the average value of the v_D is

$$V_{D,avg} = \langle v_D \rangle_T = \frac{V_m}{2\pi}\int_0^{2\pi} (\sin(\omega t) - 1)\ d(\omega t) = V_m$$

Rms value of the fundamental component of v_D is

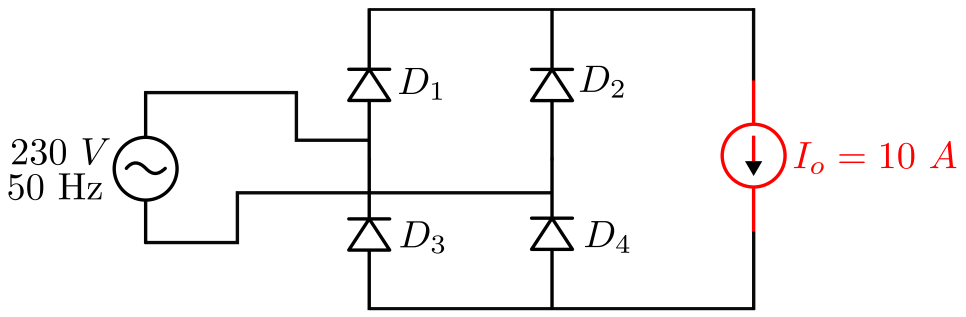
$$V_{1,rms} = \frac{V_m}{\sqrt{2}}$$

The rms value of the voltage across diode is thus given by

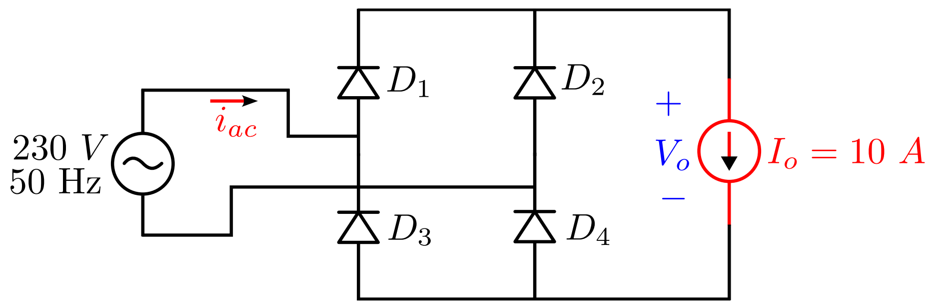
$$V_{D,rms} = \sqrt{{V_{D,avg}}^2 + {V_{1,rms}}^2} = \sqrt{\frac{3}{2}}V_m = 122.47\ V$$

Question 8:

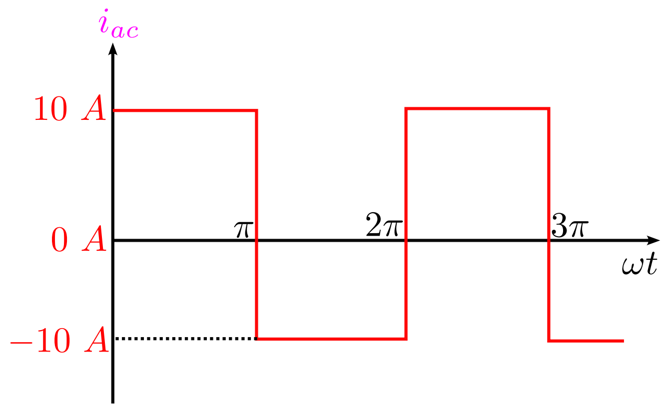
The figure shows the circuit of a rectifier fed from a 230 V (rms), 50 Hz sinusoidal voltage source. If we want to replace the current source with a resistor so that the rms value of the current supplied by the voltage source remains unchanged, the value of resistance (in Ω) is ____________ (Assume diodes to be ideal).



Solution: Answer range (22.99-23)



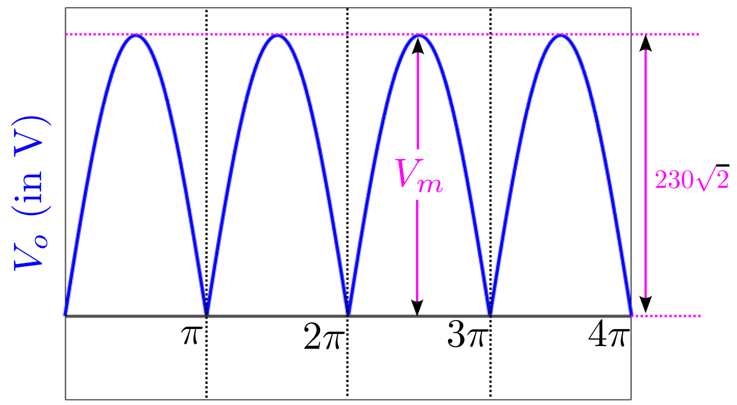
With the current source in the circuit, the waveform of i_{ac} is illustrated in the figure below



Thus, the rms value of the current, i_{ac}, supplied by the voltage source is

$$i_{ac,rms} = 10\ A$$

The waveform of the output voltage, V_o, is illustrated in the figure below



The rms value of the output voltage, V_o, is given by

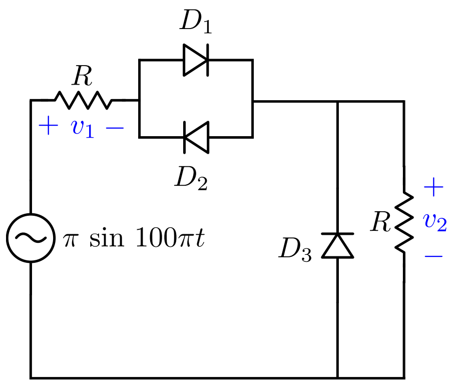
$$V_{o,rms} = \frac{V_m}{\sqrt{2}} = 230\ V$$

Now, if we want to replace the current source with a resistive load such that the rms current remains same as $i_{ac,rms}$, then the value of the resistive load can be obtained as

$$R_L = \frac{V_{o,rms}}{i_{ac,rms}} = 23\ \Omega$$

Question 9:

For the circuit shown below assume the diodes D_1, D_2 and D_3 to be ideal.



The dc components of voltages v_1, and v_2 respectively are

(a) 0 V and 1 V
(b) -0.5 V and 0.5 V
(c) 1 V and 0.5 V
(d) 1 V and 1 V

Solution: Correct option is (b)

During the positive half cycle, D_1 is forward biased and D_2 *and* D_3 are reverse biased. Thus, during this period

$$v_1 = v_2 = \frac{\pi}{2}\ \sin(100\pi t)$$

During the negative half cycle, D_1 is reverse biased and D_2 *and* D_3 are forward biased. Thus, during this period

$$v_1 = \pi\ \sin(100\pi t) \quad and \quad v_2 = 0\,V$$

Now, we can calculate the average value of v_1 as

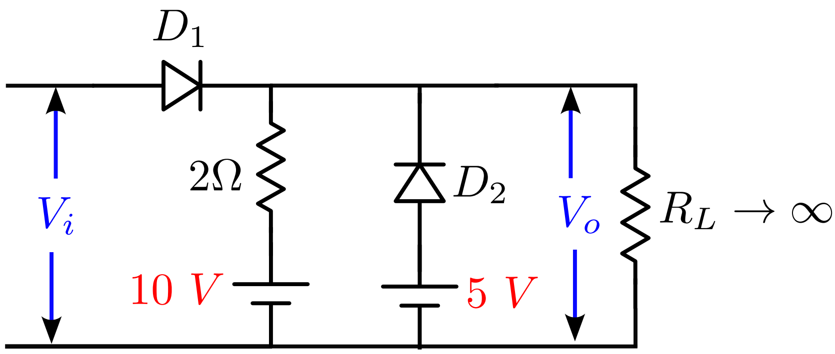
$$\langle v_1 \rangle_T = \frac{1}{2\pi}\left[\int_o^{\pi} \frac{\pi}{2}\ \sin(\omega t)\ d(\omega t) + \int_{\pi}^{2\pi} \pi\ \sin(\omega t)\ d(\omega t)\right] = -\frac{1}{2}$$

Similarly, we can calculate the average value of v_2 as

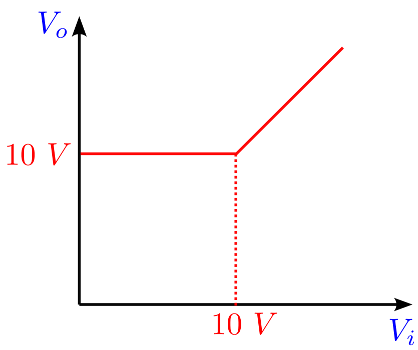
$$\langle v_2 \rangle_T = \frac{1}{2\pi}\left[\int_o^{\pi} \frac{\pi}{2}\ \sin(\omega t)\ d(\omega t)\right] = \frac{1}{2}$$

Question 10:

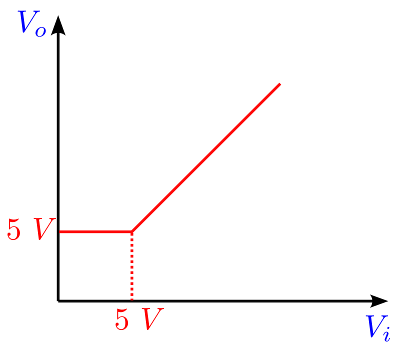
Assuming the diodes to be ideal, the transfer characteristics of the circuit will be



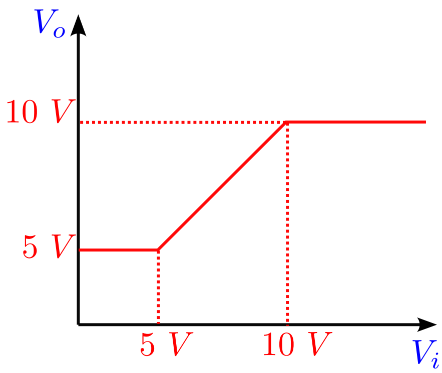
(a)



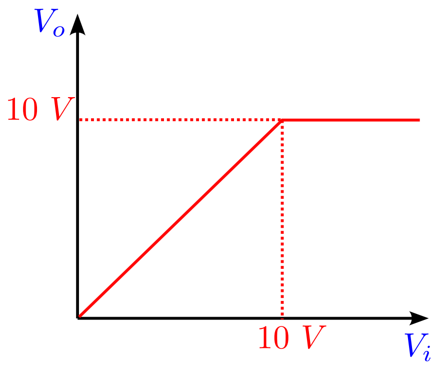
(b)



(c)



(d)



Solution: Correct option is (a)

The output voltage V_o becomes equal to V_i only when $V_i > 10\ V$. Else, $V_o = 10\ V$, as there is no path for the current to flow and hence no voltage drop across 2Ω resistor.