Question 1: Numerical type

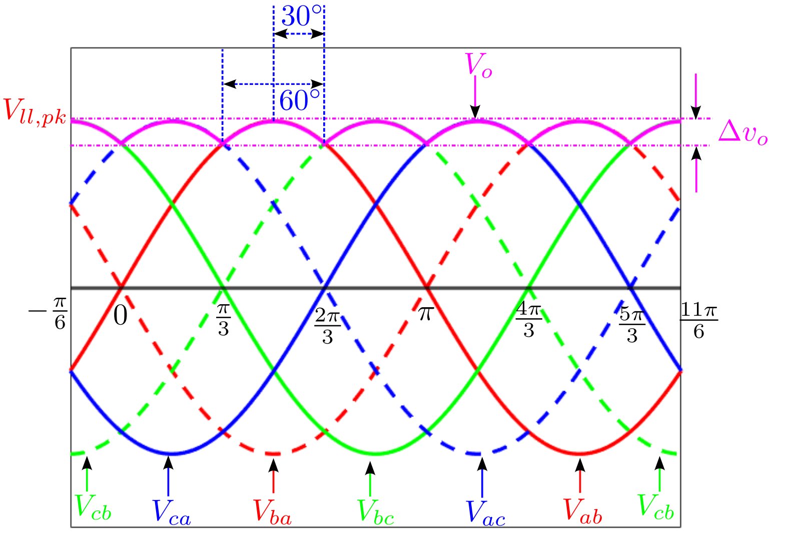
A three-phase bridge rectifier is supplied by 400V (line-line rms), 50Hz, three phase grid. The full bridge rectifier is connected to a resistive load of 1000Watt. If the maximum output voltage ripple requirement is 15% of the peak line-to-line input voltage, what is the minimum possible capacitor (in µF) ______.

Solution: Answer range (0-0)

The peak value of line-to-line input voltage ($V_{ll,pk}$) = $400\sqrt{2}\ V$

Therefore, the permissible value of the output ripple is = $0.15 \times V_{ll,pk} = 84.85\ V$

Let us now calculate the ripple voltage of the output of the three-phase rectifier under consideration. The waveforms of the line-to-line voltages and the corresponding output voltage (V_o) of a rectifier are shown in the figure below:



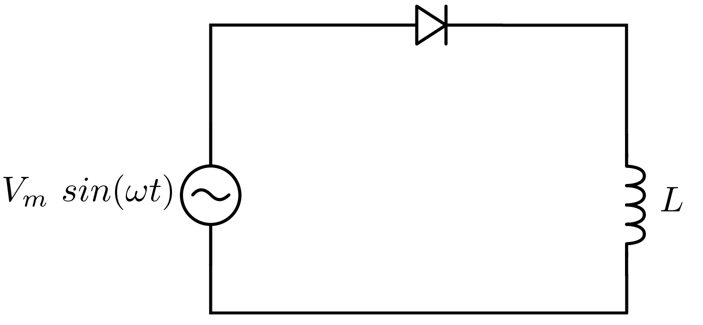
The ripple in the output voltage of the rectifier can be calculated as follows:

$$\Delta v_o = V_{ll,pk} - V_{ll,pk}\cos 30^o = 400\sqrt{2}\left(1 - \frac{\sqrt{3}}{2}\right) = 75.78\ V$$

As the ripple of the output voltage, Δv_o, is itself lower than the permissible value of the ripple voltage, therefore there is no requirement of extra capacitor filter.

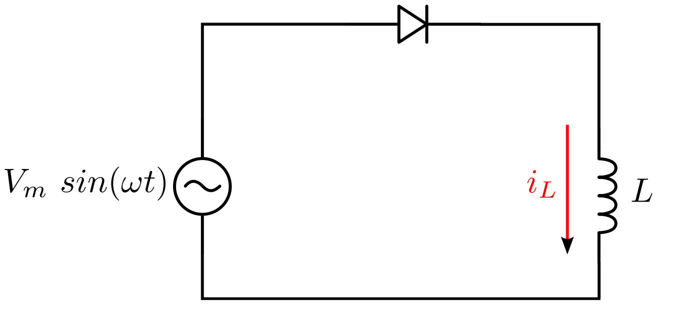
Question 2:

In the circuit shown below an ideal diode connects the ac source with a pure inductance L. The circuit is initially relaxed. The diode conducts for



(a) 90^0
(b) 180^0
(c) 270^0
(d) 360^0

Solution: Correct option is (d)



The expression for the inductor current is given by

$$i_L(t) = \frac{1}{L} \int V_m \ \sin \omega t \ dt = -\frac{V_m}{L} \cos \omega t + K$$

Where K is the integral constant.

To obtain the value of K we need to apply the initial conditions. We know that the circuit was initially relaxed. Thus, we can write

$$i_L(t = 0) = 0 = -\frac{V_m}{L} + K$$

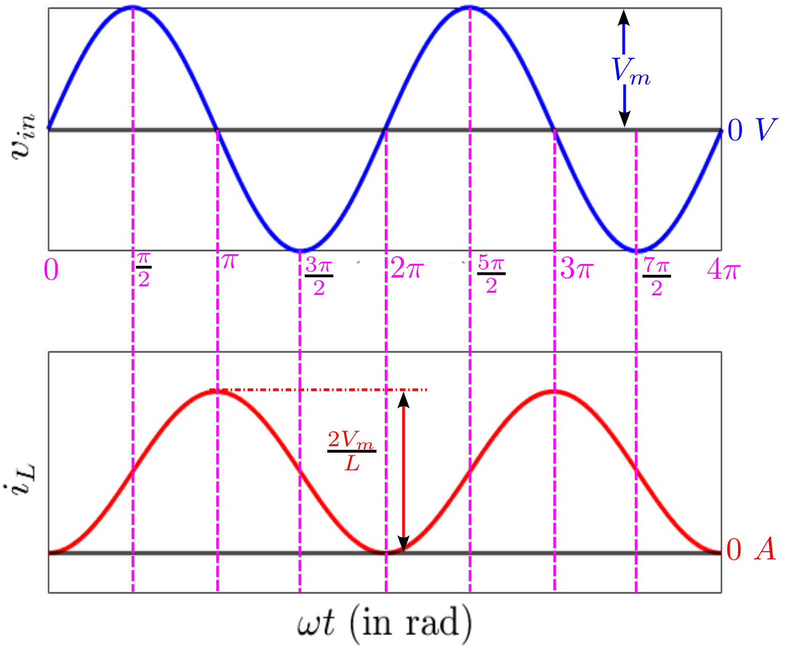
Thus, the value of K can be obtained as

$$K = \frac{V_m}{L}$$

The equation of the inductor current can therefore be written as:

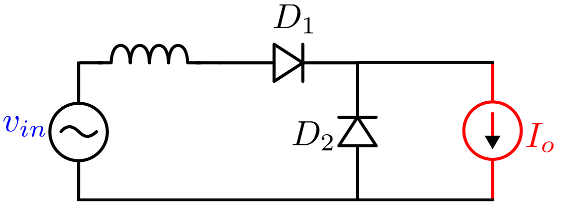
$$i_L(t) = \frac{V_m}{L} (1 - \cos \omega t)$$

For any value of 't', the above expression is always positive and hence the diode will always conduct as it is never reverse biased. The waveform of the inductor current, $i_L(t)$, is shown in the figure below.



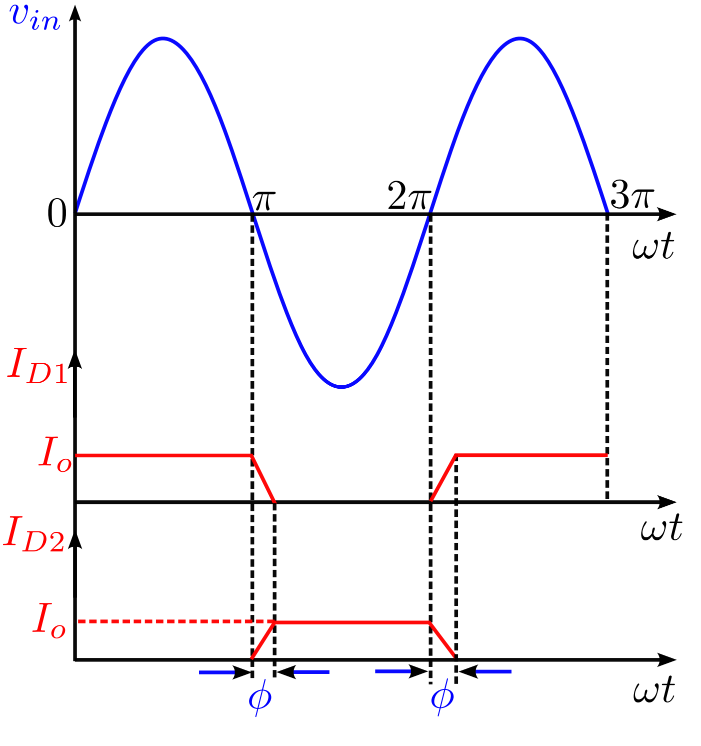
Question 3:

In the circuit shown below, the diodes are ideal, the inductance is small, and $I_o \neq 0$. Which of the following statements is true.



(a) D_1 *conducts for greater than* 180^o *and* D_2 *conducts for greater than* 180^o
(b) D_2 *conducts for greater than* 180^o *and* D_1 *conducts for* 180^o
(c) D_1 *conducts for* 180^o *and* D_2 *conducts for* 180^o
(d) D_1 *conducts for greater than* 180^o *and* D_2 *conducts for* 180^o

Solution: Correct option is (a)



The diode D_1 does not get reverse biased immediately when v_{in} becomes negative because of the energy stored in the source inductance. Thus, the current I_{D1} flowing through D_1 gradually goes to zero as shown in the figure above. However, the load demands a constant current I_o. To maintain the load current at I_o, D_2 starts conducting at $\omega t = \pi$. At $\omega t = \pi + \Phi$, the current I_{D1} goes to zero and I_{D2}, flowing through the diode D_2, free wheels and carries the current I_o.

From the figure it is evident that option (a) is correct.

Question 4: Numerical type

The input voltage of a converter is:

$$V_{in} = 100\sqrt{2}\ \sin(100\pi t)\ V$$

The current drawn by the converter is:

$$i_{in} = 10\sqrt{2}\ \sin(100\pi t - \frac{\pi}{3}) + 5\sqrt{2}\ \sin(300\pi t + \frac{\pi}{4}) + 2\sqrt{2}\ \sin(500\pi t - \frac{\pi}{6})\ A$$

The input power factor of the converter is ____________________.

Solution: Answer range (0.4 - 0.47)

The active power consumed can be calculated as

$$P = \frac{100\sqrt{2} \times 10\sqrt{2}}{2} \cos\frac{\pi}{3} = 500\ W$$

The rms value of the current drawn by the converter can be calculated as

$$i_{rms} = \sqrt{10^2 + 5^2 + 2^2} = 11.35$$

Total input VA can be calculated as

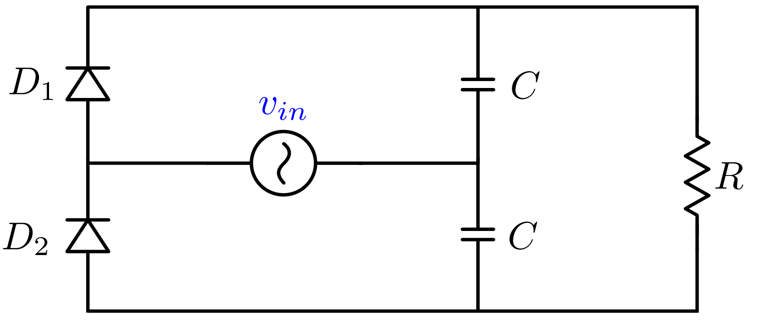
$$VA_{in} = i_{rms} \times v_{in,rms} = 11.3578 \times 100 = 1135.78$$

Power factor of the converter can then be calculated as

$$p.f. = \frac{P}{VA_{in}} = \frac{500}{1135.78} = 0.44$$

Question 5:

In the circuit given below, the input voltage $v_{in} = 100\ \sin(100\pi t)$. *For* $100\pi RC = 50$, *the average voltage across R (in volts) under steady state is nearest to*



(a) 100
(b) 31.8
(c) 63.6
(d) 200

Solution: Correct option is (d)

The time constant of the circuit can be calculated as

$$RC = \frac{50}{100\pi} \approx 0.16\ s$$

As the frequency of the source voltage, $v_{in}(t)$, is 50 Hz, the frequency of the fully rectified sine wave would be 100 Hz. Thus, the time period of the fully rectified sine wave is 0.01 s. The time constant is exceeding the time period by more than a factor of 10. Thus, we can assume that the load resistance, R, is large enough to maintain the voltage across the capacitors. We can now redraw the circuit as shown below:

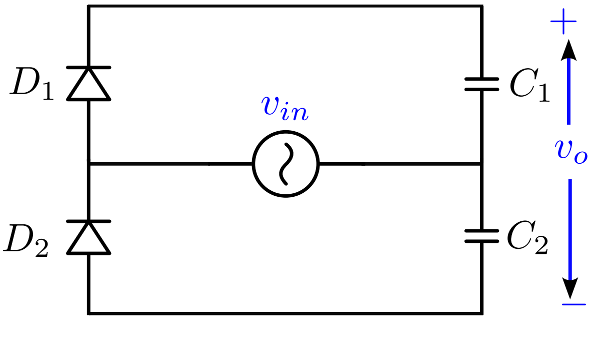


Fig. (a)

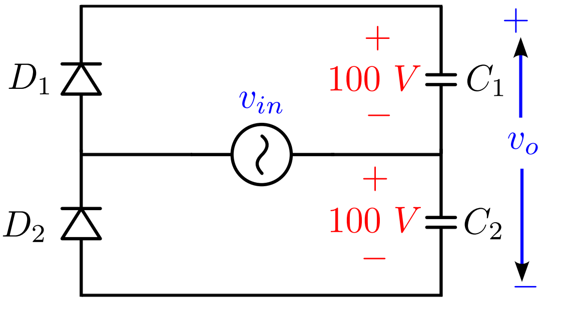


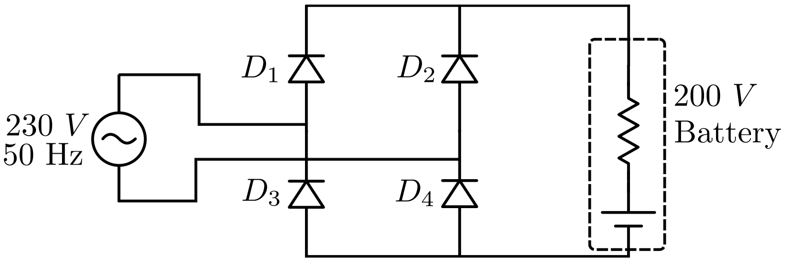
Fig. (b)

During the positive half cycle D_1 will be conducting till the voltage across the capacitor, C_1, reaches the peak value of the input voltage v_{in} after which the diode D_1 gets reverse biased.

In the negative half cycle D_2 will be conducting till the voltage across the capacitor, C_2, reaches the peak value of the input voltage v_{in} after which the diode D_2 gets reverse biased. Thus, at steady state the voltage across the capacitors will be as shown in the Fig. (b).

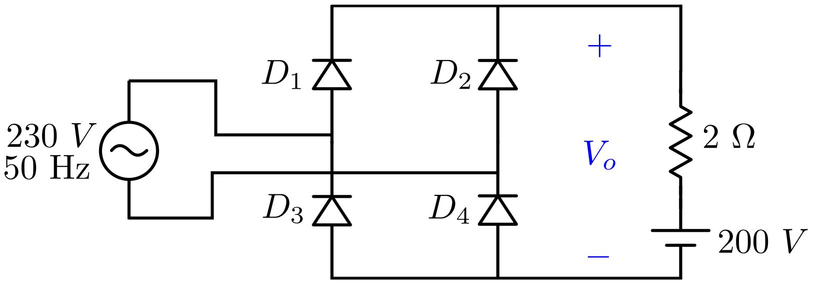
Question 6:

A single-phase full bridge rectifier is used to charge a battery of 200 V having an internal resistance of 2Ω. If the diode D_2 gets open circuited due to some fault, what would be the average charging current.

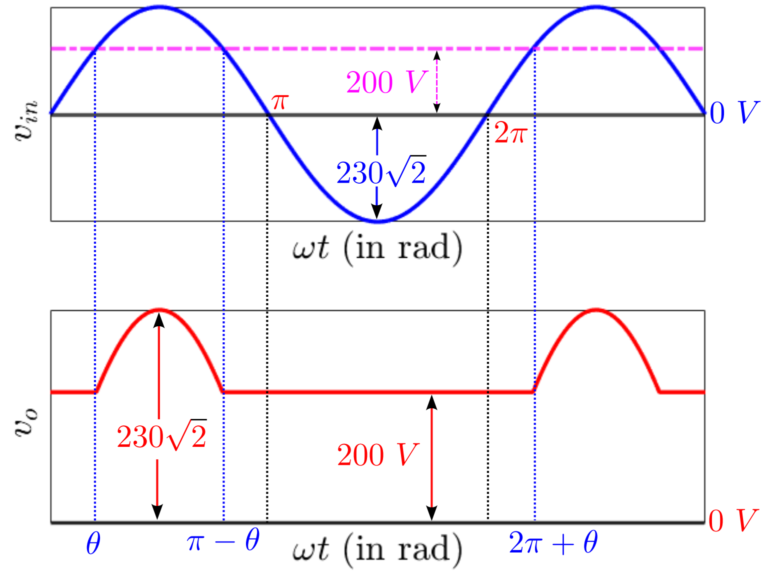


(a) 11.9 A
(b) 15 A
(c) 23.8 A
(d) 3.54 A

Solution: Correct option is (a)



If one of the diodes gets open circuited, the diode bridge starts acting as a half bridge rectifier. In order to determine the average current, we need to find the average value of output voltage, V_o. The waveform of the V_o is shown in the figure below.



The diodes D_1 and D_4 gets forward biased only when $v_{in}(t)$ exceeds $200\ V$.

The value of θ can be calculated as below:

$$\theta = \sin^{-1}\left(\frac{200}{230\sqrt{2}}\right) = 37.94^o = 0.662\ radians$$

The average value of the output voltage can be calculated as:

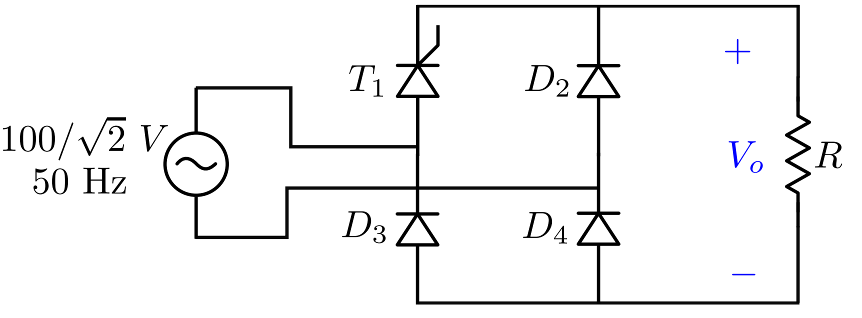
$$V_o = \frac{1}{2\pi}\left(\int_0^{\theta} 200\ .d(\omega t) + \int_{\theta}^{\pi-\theta} 230\sqrt{2}\ \sin(\omega t)\ .d(\omega t) + \int_{\pi-\theta}^{2\pi} 200\ .d(\omega t)\right) = 223.8\ V$$

The average value of current can be calculated as

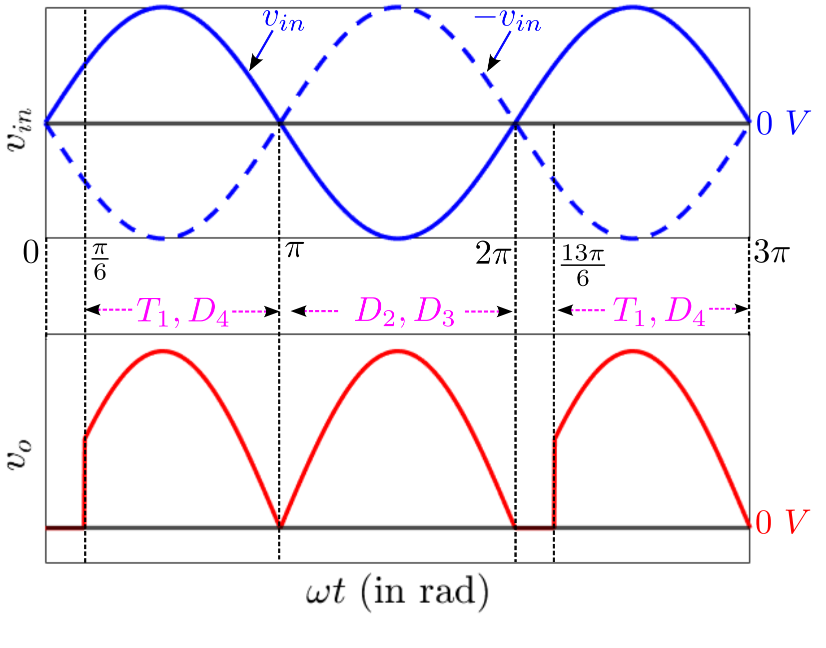
$$I_{o,avg} = \frac{223.8 - 200}{2} = 11.9\ A$$

Question 7: Numerical type

In the given rectifier, the firing angle of thyristor (SCR) T_1 measured from the positive going zero crossing of V_s is 30^o. If the input voltage, v_{in}, is $100\ \sin(100\pi t)$ V, the average voltage across R (in Volts) under steady-state is ___________________ .



Solution: Answer range (61-62)



During the period $0 \leq \omega t \leq \frac{\pi}{6}$, none of the switches will be conducting as T_1 is not fired and D_2 and D_3 are reverse biased.

For $\frac{\pi}{6} \leq \omega t \leq \pi$, T_1 and D_4 starts conducting as T_1 is fired at $\omega t = \frac{\pi}{6}$.

For $\pi \leq \omega t \leq 2\pi$, D_2 and D_3 starts conducting as these diodes are forward biased.

The waveform of the output voltage, $v_{o,}$ is shown in the figure above. Thus, the average value of the output voltage can be calculated as

$$V_o = \frac{1}{2\pi}\left(\int_{\frac{\pi}{6}}^{\pi} 100\ \sin(\omega t).\,d(\omega t) + \int_{\pi}^{2\pi} 100\ \sin(\omega t).\,d(\omega t)\right) = 61.53\ V$$

Question 8:

In the circuit shown below, three signals of the Fig. (b) are impressed on the input terminals of Fig. (a)

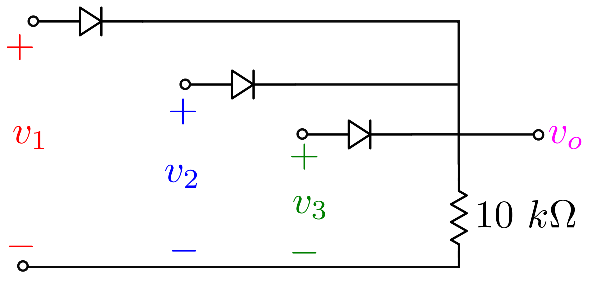


Fig. (a)

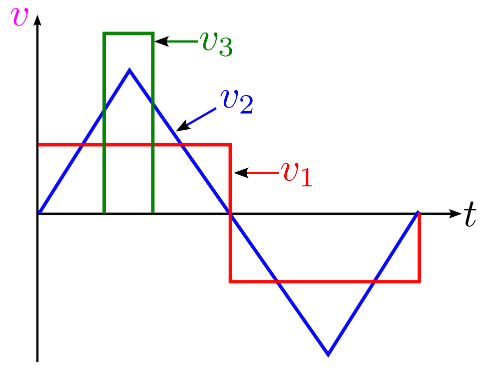
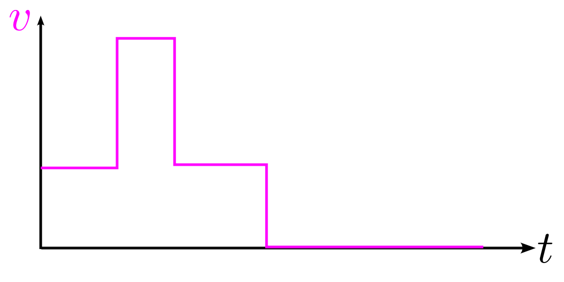


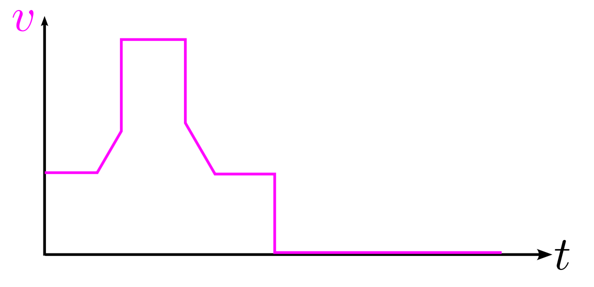
Fig. (b)

If the diodes are ideal then the voltage, v_o, is

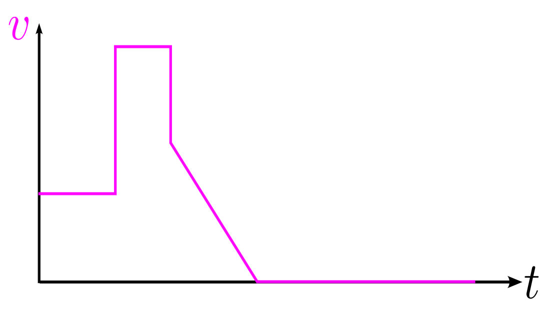
(a)



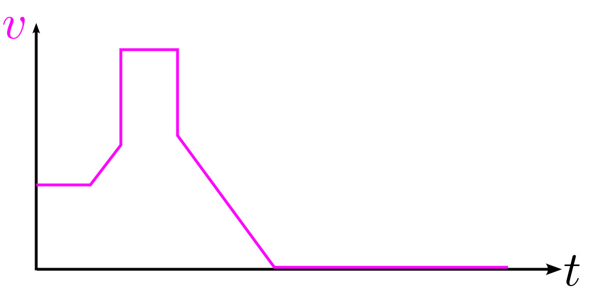
(b)



(c)



(d)

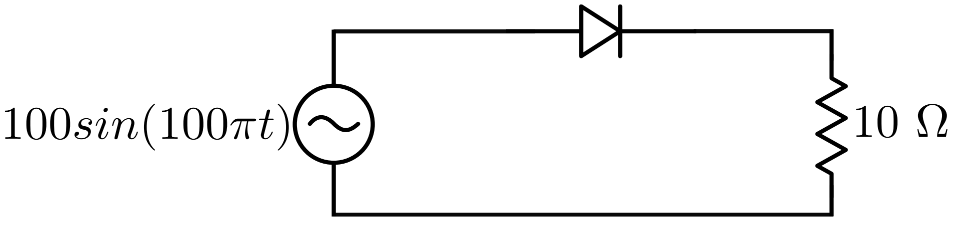


Solution: Correct option is (b)

The output voltage would be maximum of $(v_1(t), v_2(t), v_3(t))$ at any instant in time.

Question 9: Numerical type

In the circuit shown below the diode used is ideal. The input power factor is _______ (Give answer upto two decimal places).



Solution: Answer range (0.65 - 0.75)

The rms value of the voltage across the 10 Ω resistor is

$$V_{o,rms} = \frac{V_m}{2} = 50\ V$$

Where, V_m is the peak value of sinusoidal supply voltage.

The power consumed by the resistor is therefore

$$P = \frac{50^2}{10} = 250\ W$$

The rms value of the source current is given as

$$I_{s,rms} = \frac{V_{o,rms}}{10} = 5A$$

Thus, total VA supplied to the load is

$$VA = V_{s,rms} \times I_{s,rms} = \frac{100}{\sqrt{2}} \times 5$$

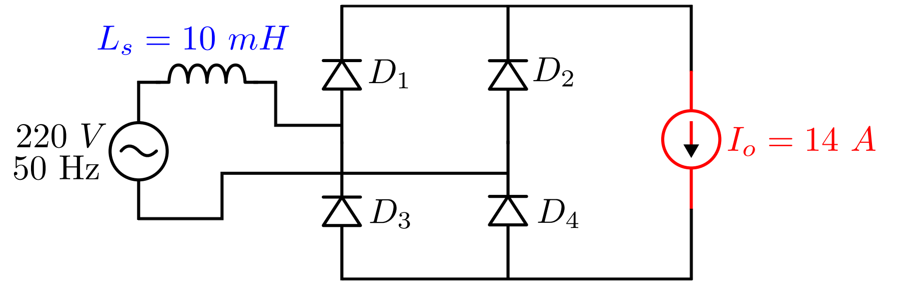
Where, $V_{s,rms}$ is the rms value of the source voltage.

Thus, the input power factor can be calculated as

$$p.f. = \frac{P}{VA} = 0.707$$

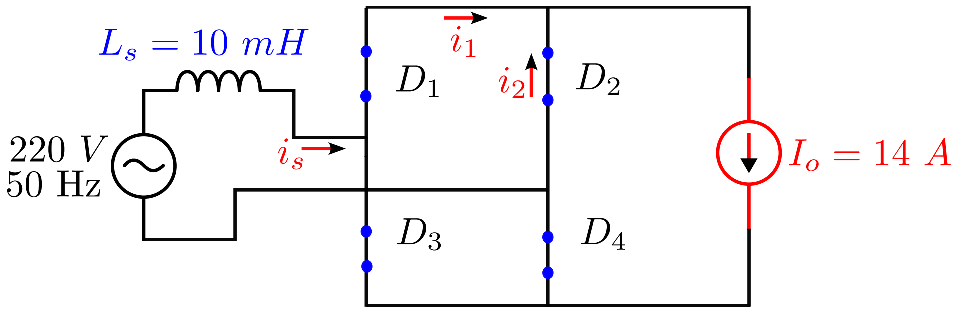
Question 10: Numerical type

The figure shows an uncontrolled full bridge rectifier suppled from a 220 V, 50 Hz single phase ac source. The load draws a constant current of $I_o = 14\ A$. The conduction angle of the diodes in degrees (rounded off to two decimal places) is _____________.



Solution: Answer range (220-230)

In an uncontrolled full bridge rectifier without a source inductance, L_s, the load current immediately shifts from (D_1, D_4) to (D_2, D_3) and vice-versa as the polarity of the source voltage changes. But any practical voltage source comes with a source inductance which cannot be avoided. In such a case the current does not immediately shift from (D_1, D_4) to (D_2, D_3), rather the current through the diodes (D_1, D_4) gradually reduces and current through the diodes (D_2, D_3) gradually increases as the polarity of the source voltage goes from positive to negative. During this small period of time, called the overlapping period, all the four diodes will be conducting and the voltage across the current source will be $0\ V$ during this overlapping period.



Applying KCL we have,

$$i_1 + i_2 = I_o$$

As $I_o = constant$, we can write

$$\frac{di_1}{dt} + \frac{di_2}{dt} = 0 \rightarrow \frac{di_1}{dt} = -\frac{di_2}{dt}$$

Again, applying KCL at the input node we have

$$i_s = i_1 - i_2$$

Taking derivate w.r.t 't' on both sides we get

$$\frac{di_s}{dt} = \frac{di_1}{dt} - \frac{di_2}{dt} = 2\frac{di_1}{dt}$$

As all the diodes are conducting, the entire supply voltage appears across the source inductance. Therefore, we can write:

$$v_{in} = L_s \frac{di_s}{dt} = 2L_s \frac{di_1}{dt}$$

Say the current i_1 is increasing from 0 to I_o during this period 'μ'. Therefore, integrating the above equation, we get

$$\int_o^{\mu} 220\sqrt{2} \sin(\omega t).\, d(\omega t) = 2\omega L_s \int_0^{I_o} di_1$$

Therefore, we have

$$220\sqrt{2}\,(1 - \cos\mu) = 2\omega L_s I_o$$

Thus, the overlapping period 'μ' can be calculated as

$$\mu = \cos^{-1}\left(1 - \frac{2\omega L_s I_o}{220\sqrt{2}}\right) = 44.17^o$$

The conduction angle of the diode is therefore = $180^0 + 44.17^o = 224.17^o$