SHORT QUESTIONS

16.1 A sinusoidal current has rms (effective) value of 10 A. What is the maximum or peak value?

Ans. Root mean square value of sinusoidal current

$$I_{rms} = 10A$$

Using

$$\boxed{I_{rms} = \frac{I_o}{\sqrt{2}}}$$

$$I_o = I_{rms} \times \sqrt{2}$$
$$= 10 \times \sqrt{2}$$
$$= 10 \times 1.414 = 14.14 \text{ A}$$

So peak value of current $= I_o = 14.14$ A

16.2 Name the device that will (a) permit flow of direct current but oppose the flow of alternating current (b) permit flow of alternating current but not the direct current.

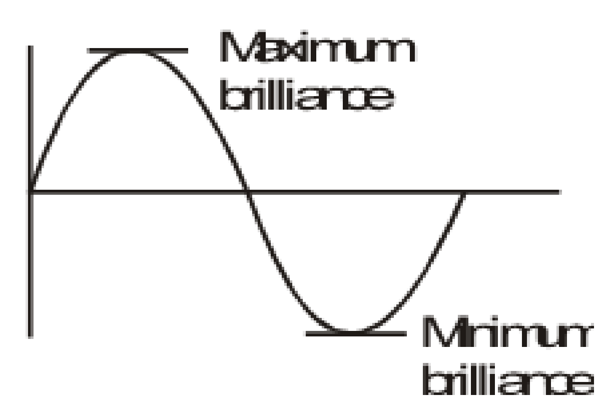
Ans. (a) A device that will permit flow of direct current but opposes the flow of alternating current is called an inductor.

(b) A device that will permit the flow of alternating current (A.C) and not the direct current is called a capacitor.

16.3 How many times per second will an incandescent lamp reach maximum brilliance when connected to a 50 Hz source?

Ans. The lamp will reach maximum brilliance 100 times per second, because current becomes maximum twice in a cycle. As frequency of A.C is 50 Hz. i.e., 50 Cps.

Maximum brilliance = 2 × 50 = 100 times per second



16.4 A circuit contains an iron-cored inductor, a switch and a D.C. source arranged in series. The switch is closed and after an interval reopened. Explain why a spark jumps across the switch contacts?

Ans. Consider a circuit contains an iron-cored inductor, a switch and a D.C source connected in series. When switch is closed, then current flows through the inductor and energy is stored in it in the form of magnetic field. When a switch is reopened then energy stored flows as a high current through the switch and a spark jumps across the switch contacts.

16.5 How does doubling the frequency affect the reactance of (a) an inductor (b) a capacitor?

Ans. (a) **For an Inductor:** The formula for the reactance of an inductor is given by

$$X_L = \omega L \quad \text{But} \quad \omega = 2\pi f$$

So $$X_L = 2\pi f L$$

Let X_L' be the reactance of an inductor when frequency becomes double i.e., 2f.

$$X_L' = 2\pi(2f)L$$

$$X_L' = 2(2\pi fL)$$

$$X_L' = 2X_L$$

Hence by doubling the frequency, the inductor's reactance will become double.

(b) For capacitor, the formula for reactance of the capacitor is given by

$$X_C = \frac{1}{\omega C} \quad \text{But} \quad \omega = 2\pi f$$

$$X_C = \frac{1}{2\pi fC}$$

Let X_C' be the reactance of the capacitor when frequency becomes double i.e., 2f.

So $$X_C' = \frac{1}{2\pi(2f)C}$$

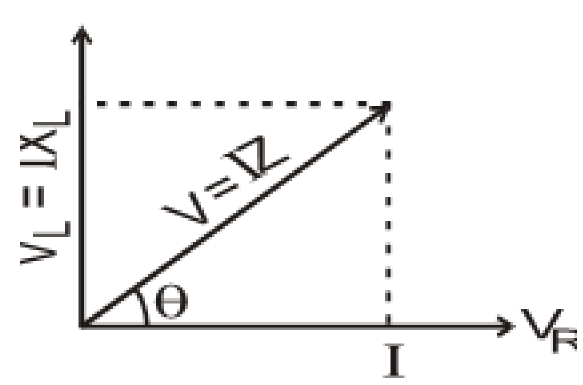
$$X_C' = \frac{1}{2(2\pi fC)}$$

$$X_C' = \frac{X_C}{2}$$

Hence by doubling the frequency, reactance of a capacitor becomes half.

16.6 In a R-L circuit, will the current lag or lead the voltage? Illustrate your answer by a vector diagram.

Ans. In R-L series circuit the current will lag the voltage by an angle θ

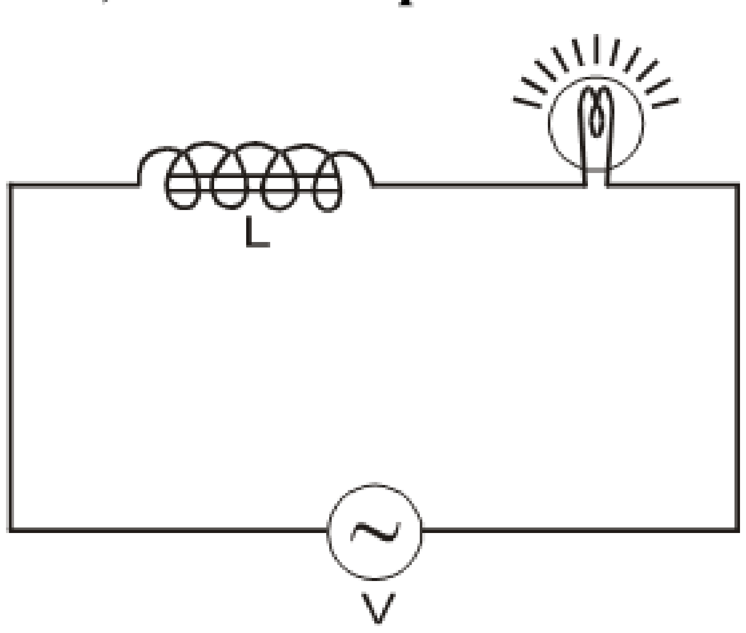


$$\theta = \tan^{-1}\left(\frac{\omega L}{R}\right)$$

$$\theta = \tan^{-1}\left(\frac{X_L}{R}\right)$$

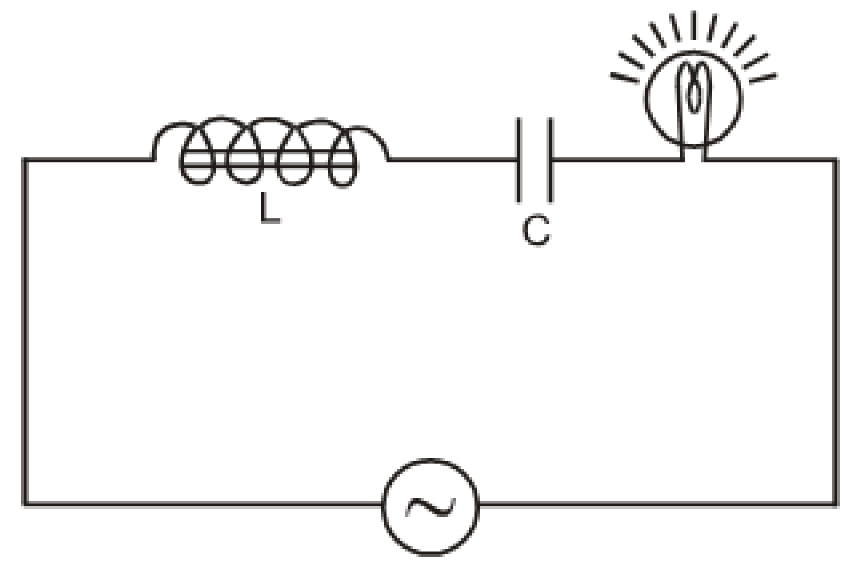
16.7 A chock coil placed in series with an electric lamp in an A.C. circuit causes the lamp to become dim. Why is it so? A variable capacitor added in series in this circuit may be adjusted until the lamp glows with normal brilliance. Explain, how this is possible?

Ans. Consider a circuit in which a choke coil is placed in series with an electric lamp in an A.C circuit as shown in figure. We know that reactance of an inductor is $X_L = 2\pi fL$ and in this case total impedance of circuit will be



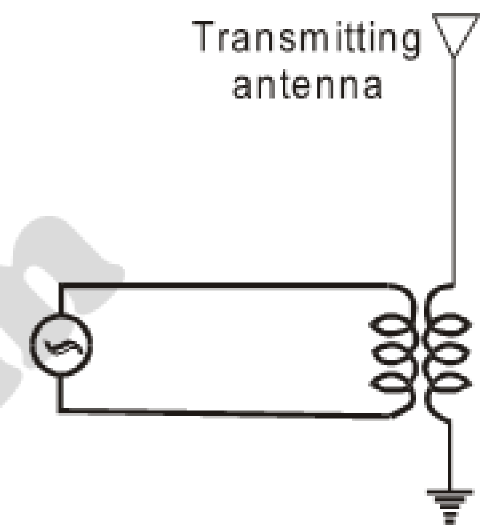
$$Z = \sqrt{X_L^2 + R^2}$$

As choke coil has very large reactance therefore current in circuit will be very small and lamp will become dim but when a variable capacitor is added in series with this circuit as shown in figure then at resonance frequency reactance of capacitor will become equal to the reactance of an inductor and total impedance of circuit will become minimum that is equal to 'R' therefore current will become maximum. So bulb will glow with normal brilliance.



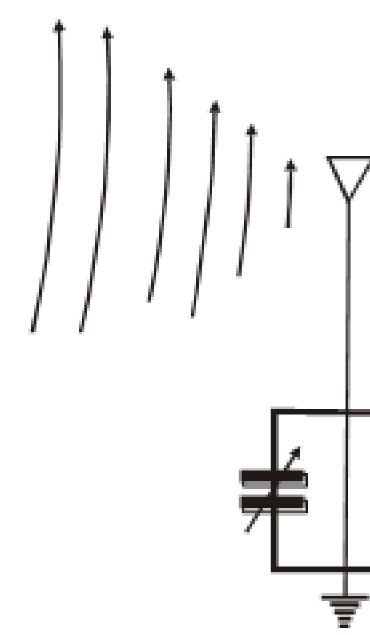
16.8 Explain the conditions under which electromagnetic waves are produced from a source?

Ans. Electromagnetic waves can be produced by changing electric or magnetic field or by accelerating the charge particles or oscillating the charge particles by connecting it to an alternating voltage source. Radio transmitting antenna provides a good example of generating electromagnetic waves by acceleration of charges. It is charged by an alternating source of potential of frequency f and time period T. As the changing potential alternates the charges will be changes from +q to −q after regular time intervals this will change electric flux and it will sets up electromagnetic waves.



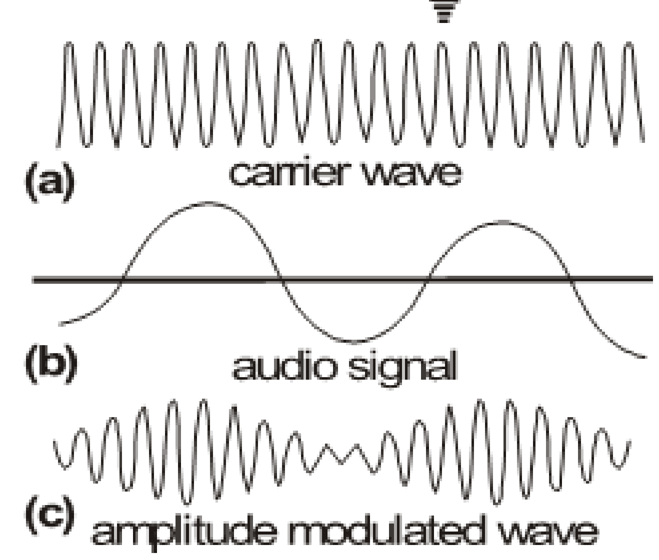
16.9 How the reception of a particular radio station is selected on your radio set?

Ans. The receiving antenna is used for reception of a particular radio station is selected in our radio set. Receiving antenna consist of inductor and a variable capacitor connected parallel which is called L − C circuit and its frequency is given by $f = \dfrac{1}{2\pi\sqrt{LC}}$ when frequency of electromagnetic waves match with the frequency of L − C circuit then due to resonance circuit will be tuned.

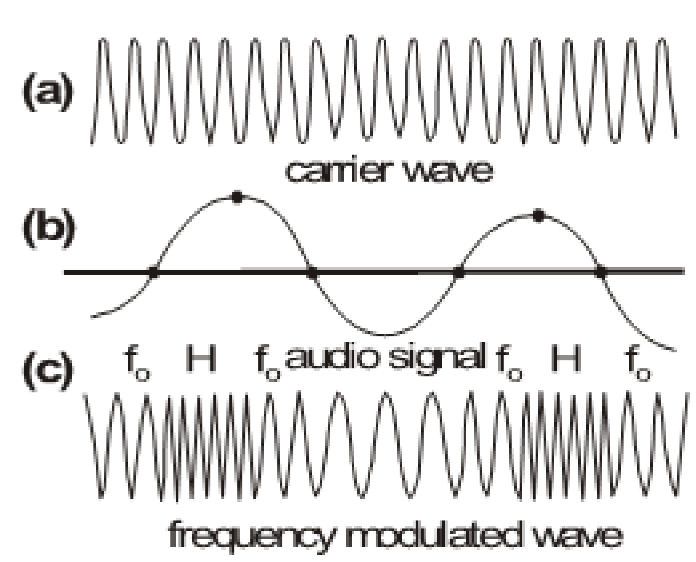


16.10 What is meant by A.M. and F.M.?

Ans. **(i) A.M:** The term A.M stands for amplitude modulation. A type of modulation in which amplitude of the carrier wave is increased or decreased as the amplitude of the superposing modulating signal increases or decreases. The A.M transmission frequencies range from 540 KH to 1600 KHz. The sound quality of A.M is not good.



(ii) F.M: The term F.M stands for frequency modulation. A type of modulation in which frequency of carrier waves have increased or decreased as the modulating signal amplitude increases or decreases but the carrier wave amplitude remains constant. The F.M transmission frequencies range from 88 MHz to 108 MHz. F.M radio waves are less affected by electrical interference therefore they provide high quality transmission of sound.



PROBLEMS WITH SOLUTIONS

PROBLEM 16.1

An alternating current is represented by the equation I = 20 sin 100 πt. Compute its frequency and the maximum and rms values of current.

Data

As $I = 20 \sin 100\pi t$

To Find

Frequency $= f = ?$

Maximum value of current $= I_o = ?$

rms value of current $= I_{rms} = ?$

SOLUTION

As, $\boxed{I = 20 \sin 100\pi t}$

But the value of alternating current is

$$\boxed{I = I_o \sin 2\pi ft}$$

Comparing the above two equation

$$I_o = 20A$$

$$\sin 2\pi ft = \sin 100\,\pi t$$

$$2f = 100$$

$$f = \frac{100}{2}$$

$$f = 50\text{ Hz}$$

For rms value of current

As we know that

$$\boxed{I_{rms} = 0.7\,I_o}$$

$$= 0.7 \times 20$$

$$I_{rms} = 14\text{ Amp}$$

Result

Frequency of alternating current $= f = 50\text{Hz}$

Maximum value of current $= I_o = 20\text{ Amp}$

The rms value of current $= I_{rms} = 14\text{ Amp}$

PROBLEM 16.2

A sinusoidal A.C. has a maximum value of 15 A. What are its rms values? If the time is recorded from the instant the current is zero and is becoming positive, what is the instantaneous value of the current after 1/300 s, given frequency is 50 Hz.

Data

Maximum value of current $= I_o = 15$ Amp

Given time $= t = \frac{1}{300}$ sec.

Frequency of A.C supply $= f = 50$ Hz

To Find

The rms value of current $= I_{rms} = ?$

Instantaneous current $= I = ?$

SOLUTION

As we know that

$$\boxed{I_{rms} = 0.7\, I_o}$$

$$= 0.7 \times 15$$

$$I_{rms} = 10.5 \text{ Amp}$$

For instantaneous current

$$\boxed{I = I_o \sin 2\pi ft}$$

$$I = 15 \sin\left(2\pi \times 50 \times \frac{1}{300}\right)$$

$$I = 15 \sin\left(2 \times \frac{180}{6}\right)$$

$$= 15 \sin 60°$$

$$= 15 \times 0.866$$

$$I = 12.99 \text{ Amp}$$

$$I = 13 \text{ Amp}$$

Result

The rms value of current $= I_{rms} = 10.5$ Amp

Instantaneous current $= I = 13$ Amp

PROBLEM 16.3

Find the value of the current and inductive reactance when A.C. voltage of 220 V at 50 Hz is passed through an inductor of 10H.

Data

A.C voltage = V = 220 volt

Frequency = f = 50 Hz

Inductance = L = 10 H

To Find

Inductive reactance = X_L = ?

Value of current = I = ?

SOLUTION

By formula for the inductive reactance

$$\boxed{X_L = 2\pi fL}$$

$$= 2 \times 3.14 \times 50 \times 10$$

$$X_L = 3140\Omega$$

And for the value of current

$$V = IX_L$$

$$\boxed{I = \frac{V}{X_L}}$$

$$I = \frac{220}{3140}$$

$$= 0.07 \text{ Amp}$$

Result

Inductive reactance = X_L = 3140Ω

Value of current = I = 0.07 Amp

PROBLEM 16.4

A circuit has an inductance of $1/\pi$ H and resistance of 2000 Ω. A 50 Hz A.C. is supplied to it. Calculate the reactance and impedance offered by the circuit.

Data

Inductance = $L = \frac{1}{\pi}$ H

Resistance = R = 2000Ω

Frequency = f = 50Hz

To Find

Reactance offered by the circuit $= X_L = ?$

Impedance offered by the circuit $= Z = ?$

SOLUTION

For the reactance of the circuit

$$\boxed{X_L = 2\pi fL}$$

$$X_L = 2 \times 3.14 \times 50 \times \frac{1}{\pi}$$

$$X_L = 100\,\Omega$$

For the impedance of the circuit is

$$Z = \sqrt{(2\pi fL)^2 + R^2}$$

$$= \sqrt{(100)^2 + (2000)^2}$$

$$= \sqrt{10000 + 4000000}$$

$$= \sqrt{4010000}$$

$$Z = 2002.49\,\Omega = 2002.5\,\Omega$$

Result

Reactance offered by the circuit $= X_L = 100\Omega$

Impedance offered by the circuit $= Z = 2002.5\Omega$

PROBLEM 16.5

An inductor of pure inductance $3/\pi$ H is connected in series with a resistance of 40Ω. Find (i) the peak value of the current (ii) the rms value, and (iii) the phase difference between the current and the applied voltage $V = 350 \sin(100\,\pi t)$

Data

Pure inductance $= L = \frac{3}{\pi}$ H

Resistance $= R = 40\,\Omega$

Voltage $= V = 350 \sin(100\,\pi t)$

To Find

(i) Peak value of current $= I_o = ?$

(ii) The rms value of current $= I_{rms} = ?$

(iii) Phase difference b/w current and voltage $= \theta = ?$

SOLUTION

(i) For peak value of current

$$\boxed{I_o = \frac{V_o}{Z}}$$

But
$$Z = \sqrt{(2\pi fL)^2 + R^2}$$
$$= \sqrt{\left(2 \times \pi \times 50 \times \frac{3}{\pi}\right)^2 + (40)^2}$$
$$= \sqrt{(300)^2 + (40)^2}$$
$$= \sqrt{91600}$$
$$Z = 302.65\ \Omega$$

So,
$$I_o = \frac{350}{302.56}$$
$$I_o = 1.16 \text{ Amp}$$

(ii) As we know that

$$\boxed{I_{rms} = 0.7\ I_o}$$
$$I_{rms} = 0.7 \times 1.16$$
$$I_{rms} = 0.81 \text{ Amp}$$

(iii) For phase difference

$$\tan\theta = \frac{\omega L}{R}$$
$$\tan\theta = \frac{2\pi fL}{R}$$

But
$$2\pi fL = 300$$
$$\tan\theta = \frac{300}{40}$$
$$\tan\theta = 7.5$$
$$\theta = \tan^{-1}(7.5)$$
$$\theta = 82.4^\circ$$

Result

(i) Peak value of current = I_o = 1.16 Amp

(ii) The rms value of current = I_{rms} = 0.81 Amp

(iii) Phase difference = θ = 82.4°

PROBLEM 16.6

A 10 mH, 20Ω coil is connected across 240 V and 180 /π Hz source. How much power does it dissipate?

Data

Inductance of the coil = L = 10 mH

$= 10 \times 10^{-3}$ H

Resistance = R = 20 Ω

Voltage = V = 240 V

Frequency = f = $\frac{180}{\pi}$ Hz

To Find

Power dissipate = P = ?

SOLUTION

By formula

$$\boxed{P = VI\cos\theta} \quad \ldots\ldots \text{(i)}$$

But $I_{rms} = \frac{V}{Z}$

And $Z = \sqrt{(2\pi fL)^2 + R^2}$

$$= \sqrt{\left(2 \times \pi \times \frac{180}{\pi} \times 10 \times 10^{-3}\right)^2 + (20)^2}$$

$$= \sqrt{(3.6)^2 + 400}$$

$$Z = 20.32\ \Omega$$

So, $I_{rms} = \frac{240}{20.32}$

$= 11.81$ Amp

Now using

$$\theta = \tan^{-1}\frac{\omega L}{R}$$

$$= \tan^{-1}\frac{2\pi fL}{R}$$

$$= \tan^{-1}\frac{\left(2\pi\frac{180}{\pi}10^{-2}\right)}{20}$$

$$= \tan^{-1}\left(\frac{36}{20}\right)$$

$$= \tan^{-1}(0.18)$$

$$\theta = 10.20°$$

Now putting values in eq. (i)

$$\therefore \quad P = 240 \times 11.81 \cos 10.20°$$

$$= 240 \times 11.81\ 0.984$$

$$P = 2789.6\ W$$

Result

Power dissipation = P = 2789.6 Watt

PROBLEM 16.7

Find the value of the current flowing through a capacitance 0.5 μF when connected to a source of 150 V at 50 Hz.

Data

Capacitance of the capacitor = C = 0.5 μF

= 0.5×10^{-6} F

Voltage = V = 150 volt

Frequency = f = 50 Hz

To Find

Value of the current = I = ?

SOLUTION

As we know that

$$V = IX_C$$

$$\boxed{I = \frac{V}{X_C}} \quad \ldots\ldots (i)$$

But

$$X_C = \frac{1}{2\pi fC}$$

$$= \frac{1}{2 \times 3.14 \times 50 \times 0.5 \times 10^{-6}}$$

$$= \frac{1}{157 \times 10^{-6}}$$

$$= 6.369 \times 10^{6-3}$$

$$= 6.369 \times 10^{3}$$

$$X_C = 6369\ \Omega$$

Putting in eq. (i)

Therefore,

$$I = \frac{150}{6369}$$

$$= 0.024\ Amp$$

Result

Value of current = I = 0.024 Amp

PROBLEM 16.8

An alternating source of emf 12 V and frequency 50 Hz is applied to a capacitor of capacitance 3 μF in series with a resistor of resistance 1 KΩ. Calculate the phase angle.

Data

Source of emf = V = 12 volt

Frequency = f = 50 Hz

Capacitance of the capacitor = C = 3 μF

= 3×10^{-6} F

Resistance = R = 1 KΩ

= 1000 Ω

To Find

Phase Angle = θ = ?

SOLUTION

The formula for the phase angle is

$$\boxed{\theta = \tan^{-1}\left(\frac{X_C}{R}\right)} \qquad \text{...... (i)}$$

But

$$X_C = \frac{1}{2\pi fC}$$

$$= \frac{1}{2 \times 3.14 \times 50 \times 3 \times 10^{-6}}$$

$$= \frac{1}{942 \times 10^{-6}}$$

$$= 1.061 \times 10^{-3+6}$$

$$= 1.061 \times 10^{3}$$

$$X_C = 1061\Omega$$

Putting in eq (i)

$$\theta = \tan^{-1}\left(\frac{1061}{1000}\right)$$

$$= \tan^{-1}(1.061)$$

$$\theta = 46.7^\circ$$

Result

Phase angle = θ = 46.7°

PROBLEM 16.9

What is the resonant frequency of a circuit which includes a coil of inductance 2.5 H and a capacitance 40 μF?

Data

Inductance of coil $= L = 2.5H$

Capacitance of the capacitor $= C = 40\mu F$

$= 40 \times 10^{-6}$ F

To Find

Resonant frequency $= f_r = ?$

SOLUTION

By formula

$$\boxed{f_r = \frac{1}{2\pi\sqrt{LC}}}$$

$$= \frac{1}{2(3.14)\sqrt{2.5 \times 40 \times 10^{-6}}}$$

$$= \frac{1}{6.28\sqrt{100 \times 10^{-6}}}$$

$$= \frac{1}{6.28\,(10 \times 10^{-3})}$$

$$= \frac{1}{62.8 \times 10^{-3}}$$

$$= 0.0159 \times 10^{3}$$

$$f_r = 15.9 \text{ Hz}$$

Result

Resonant frequency $= f_r = 15.9$Hz

PROBLEM 16.10

An inductor of inductance 150 μH is connected in parallel with a variable capacitor whose capacitance can be changed from 500 pF to 20 pF. Calculate the maximum frequency and minimum frequency for which the circuit can be turned.

Data

Inductance of inductor $= L = 150\ \mu H$

$= 150 \times 10^{-6}$ H

Maximum capacitance of the capacitor $= C_{max} = 500$ pF

$= 500 \times 10^{-12}$ F

Minimum capacitance $= C_{min} = 20$ pF

$= 20 \times 10^{-12}$F

To Find

Maximum frequency = f_{max} = ?

Minimum frequency = f_{min} = ?

SOLUTION

As we know that frequency is

$$f = \frac{1}{2\pi\sqrt{LC}}$$

For maximum frequency

$$f_{max} = \frac{1}{2\pi\sqrt{LC_{min}}}$$

$$= \frac{1}{2(3.14)\sqrt{150\times10^{-6}\times20\times10^{-12}}}$$

$$= \frac{1}{6.24\sqrt{3000\times10^{-18}}}$$

$$f_{max} = \frac{1}{6.24\,(54.77\times10^{-9})}$$

$$= 2.92\times10^{9-3}$$

$$= 2.92\times10^{6}\text{ Hz}$$

$$= 2.92\text{ MHz}$$

For minimum frequency

$$f_{min} = \frac{1}{2\pi\sqrt{LC_{max}}}$$

$$= \frac{1}{2(3.14)\sqrt{150\times10^{-6}\times500\times10^{-12}}}$$

$$= \frac{1}{6.24\sqrt{75000\times10^{-18}}}$$

$$= \frac{1}{6.24\,(273.8\times10^{-9})}$$

$$= 5.85\times10^{9-4}$$

$$= 5.85\times10^{5}\text{ Hz}$$

$$= 0.585\times10^{6}\text{ Hz}$$

$$f_{min} = 0.585\text{ MHz}$$

Result

Maximum frequency = f_{max} = 2.92 MHz

Minimum frequency = f_{min} = 0.585 MHz