27

Alternating Current

BRIEF REVIEW

A time dependent current $i(t)$ is termed as AC or alternating current. It is of four types:

(a) sinusoidal (b) complex periodic

(c) aperiodic (d) random.

Sinusoidal AC If the current or voltage varies in accordance with sine or cosine function or their combination, then such a current or voltage is termed as sinusoidal. For example,

$I = I_p \sin \omega t$, $I = I_p \sin(\omega t \pm \phi)$, $I = I_p \cos(\omega t \pm \phi)$ and $I = I_{p1} \sin \omega t + I_{p2} \cos \omega t$ etc. are sinusoidal AC currents. Note that in $I = I_p \sin(\omega t \pm \phi)$ where I is instantaneous value of current, I_p is its peak value, ω is angular frequency and ϕ is initial phase angle or epoch or angle of repose. $\omega = 2\pi f = \frac{2\pi}{T}$ or $f = \frac{1}{T}$ is linear frequency. T is time period Fig. 27.1 shows sinusoidal variation of AC current.

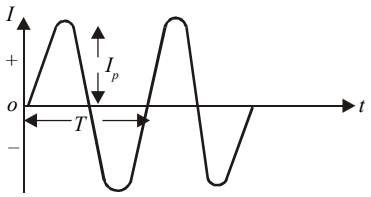


Fig. 27.1 Sinusoidal *AC* current

Complex periodic *AC* If voltage or current wave forms are periodic but different from sine or cosine function such as rectangular, square wave, sawtooth, triangular wave form etc are complex periodic. These can be simplified using Fourier analysis. Thus the ***dc* value (or average value)**, **rms** value or peak value may be known using **Fourier analysis**.

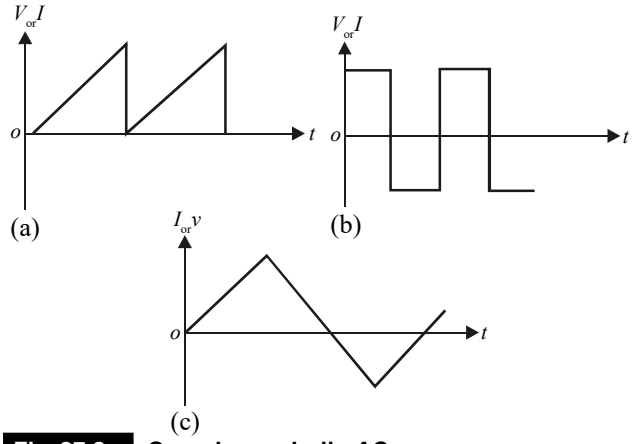


Fig. 27.2 Complex periodic *AC*

Fig. 27.2 shows examples of complex periodic wave.

Aperiodic *AC* The voltage or current wave form which is periodic but remains only positive or only negative and normally occurs for a short interval is called aperiodic wave. Pulse waveform is aperiodic as illustrated in Fig. 27.3.

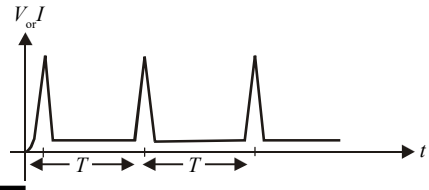


Fig. 27.3 Aperiodic *AC*

Random *AC* The voltage or current whose magnitude or time of occurrence is not well defined as shown in Fig. 27.4.

Four values of *AC* voltage or current may be defined as follows:

Fig. 27.4 **Random *AC***

(a) peak voltage or peak current (V_p or I_p)

(b) mean or average voltage / current (V_{av} or I_{av})

(c) RMS voltage / current (V_{rms} or I_{rms})

(d) Peak-to-peak voltage / current (V_{pp} or I_{pp})

Look carefully into Fig. 27.5 The maximum voltage which one can have is called peak voltage V_p.

Note that $V_{pp} = 2\ V_p$

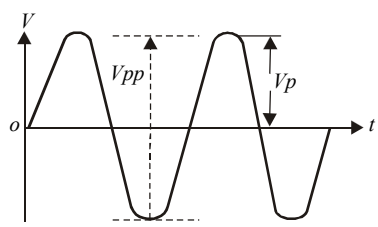


Fig. 27.5 **Peak and peak to peak value illustration**

AC can be measured using *AC* voltmeter / *AC* ammeter. *DC* meters cannot record *AC*. Moreover, *AC* meters measure RMS value of current or voltage. Two types of *AC* voltmeters are available: One which employs a rectifier which converts *AC* to *DC* and then *DC* meter records the voltage/current. The other type is based on heat produced is $\propto V^2$ or I^2 special type of meters are available which record peak voltage or mean voltage.

Mean or average voltage (V_{av}) Since the mean or average voltage over a complete cycle is zero, we define it for half the cycle.

$$\text{Thus } V_{av} = \frac{2}{T}\int_0^{T/2} V_p \sin \omega t\, dt$$

$$\text{Similarly } I_{av} = \frac{2}{T}\int_0^{T/2} I_p \sin \omega t\, dt$$

For sinusoidal voltage $V_{av} = 0.63\ V_p$, similarly $I_{av} = 0.63\ I_p$.

RMS or Root Mean Square Voltage Also known as virtual or effective voltage, it is that value of *AC* voltage which will produce same amount of heat in a given resistance in a given time as is produced by *DC* voltage in the same resistance for the same time.

$$V_{rms}^2 = \frac{1}{T}\int_0^T V^2\, dt = \frac{1}{T}\int_0^T V_p^2 \sin^2 \omega t\, dt = \frac{V_p^2}{2}$$

$$\text{or } V_{rms} = \frac{V_p}{\sqrt{2}} = 0.707\ V_p \text{ similarly}$$

$$I_{rms} = \frac{I_p}{\sqrt{2}} = 0.707\ I_p.$$

Reactance The resistance offered by an *AC* or reactive component (capacitor or inductor) when *AC* is applied is called reactance. It also introduces a phase shift of $\pi/2$ in voltage or current. Unit of Reactance is **Ohm.**

Capacitive reactance $X_c = \dfrac{1}{C\omega}$. When ac is applied across a capacitor the current leads the voltage wave form by $\pi/2$ radian or 90^0. Fig. 27.6 shows the *V* and *I* phasor diagram in case of capacitor.

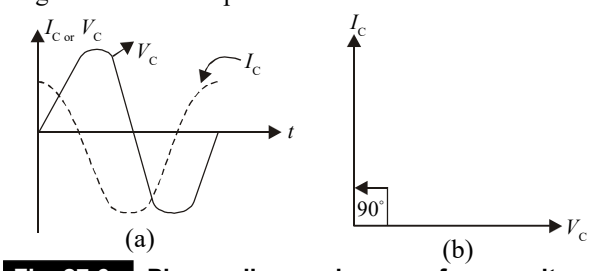


Fig. 27.6 **Phasor diagram in case of a capacitor**

Inductive reactance $X_L = L\omega$. Current lags the voltage waveform by 90º or $\pi/2$ radian when ac is applied across a pure Inductor. Fig. 27.7 illustrates the phasor diagram in case of inductor's *V* and *I*.

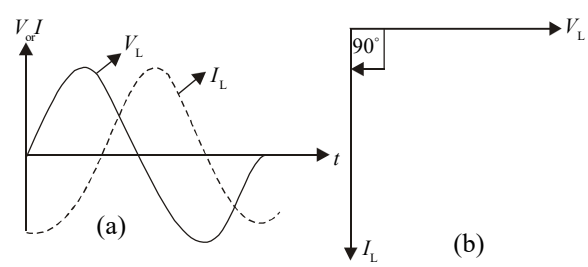


Fig. 27.7 **Phasor diagram in case of an inductor**

Note that capacitor and inductor act like filter capacitor.

Blocks *DC* and allows *AC* to pass $\because$ $X_C = \dfrac{1}{C\omega}$ when $\omega \to 0$,

$X_C \to \infty$ and when $\omega \to \infty, X_C \to 0$

Inductor allows *DC* to pass and attenuates *AC*. $X_L = L$, when $\omega \to 0, X_L \to 0$ and when $\omega \to \infty, X_L \to \infty$

Reciprocal of reactance is called susceptance.

***AC* components** offer phase shift between *V* and *I* along with reactance when *AC* is applied. *L* and *C* are *AC*

components. AC components are also called reactive components.

DC components The circuit elements which do not offer any phase shift between V and I when AC is applied. Such elements behave alike in AC or DC. Resistor (R) is common example.

Impedance (Z) The net resistance offered in an AC circuit when both AC and DC circuit elements are present is called impedance. Unit is Ohm. There will be a phase shift between V and I such that $0 < \phi < 90^0$.

Admittance (Y) Reciprocal of impedance is called admittance. $Y = \frac{1}{Z}$ unit is ohm^{-1} or siemen (S).

Series RC circuit In series RC circuit, impedance

$$|Z| = \sqrt{R^2 + X_c^2} = \sqrt{R^2 + \frac{1}{C^2\omega^2}} \quad \tan\phi = \frac{1}{RC\omega}$$

and $$i = \frac{V_p}{\sqrt{R^2 + \frac{1}{C^2\omega^2}}} \sin\left(\omega t + \tan^{-1}\frac{1}{RC\omega}\right)$$

Note that current leads the voltage wave form by

$$\phi = \tan^{-1}\left(\frac{1}{RC\omega}\right)$$ as illustrated in Fig. 27.8.

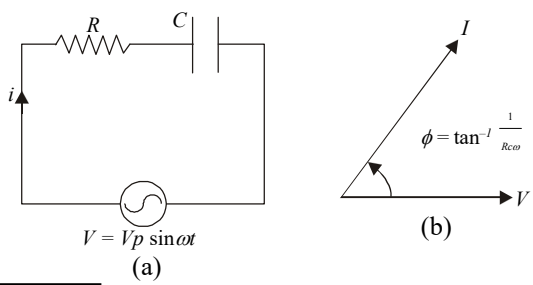


Fig. 27.8

Series RL circuit In series RL circuit current lags the voltage wave form by $\tan^{-1}\left(\frac{L\omega}{R}\right)$ as illustrated in Fig. 27.9

(b) Impedance Z of the circuit is

$$|Z| = \sqrt{R^2 + X_L^2} = \sqrt{R^2 + L^2\omega^2}\ ;$$

$$\tan\phi = \frac{L\omega}{R}$$

$$i = \frac{V_p}{\sqrt{R^2 + L^2\omega^2}} \sin\left(\omega t - \tan^{-1}\frac{L\omega}{R}\right)$$

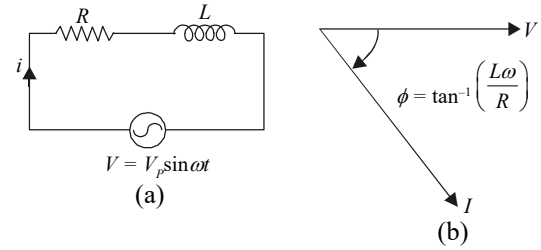


Fig. 27.9

Series RLC circuit It is also called resonant circuit.

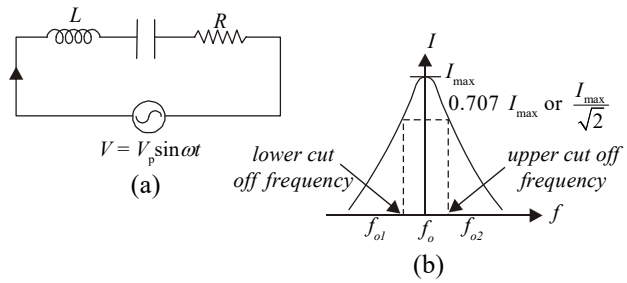


Fig. 27.10

$$|Z| = \sqrt{R^2 + (X_L - X_c)^2} = \sqrt{R^2 + \left(L\omega - \frac{1}{C\omega}\right)^2}$$

$$\tan\phi = \frac{X_L - X_c}{R} = \frac{X_c - X_L}{R}$$

$$i = \frac{V_p}{|Z|} \sin(\omega t + \phi)$$

Three carses arise

(i) when at a particular frequency ω_0, $X_L = X_c$

$$\text{or } L\omega_0 = \frac{1}{Cw_0},\ i.e.,\ \omega_0 = \frac{1}{\sqrt{LC}} \text{ or } f_0 = \frac{1}{2\pi\sqrt{LC}}$$

This frequency is called resonant frequency. At resonant frequency $Z = R$ *i.e.* impedance is pure resistance. No phase shift exists between V and I. Note that impedance is minimum at $f = f_0$ and hence current is maximum at f_0 as shown in Fig. 27.10 (b)

(ii) If $\omega < \omega_0$ or $f < f_0$, the impedance is capacitive as $X_c > X_L$ and hence current leads the voltage waveform.

(iii) If $\omega > \omega_0$ or $f > f_0$, the impedance is inductive as $X_L > X_c$ and hence current lags the voltage wave form.

***Q*-factor or quality factor** ($Q = \frac{L\omega}{r}$) where r is internal resistance of the coil $Q = \frac{L\omega}{r} = \frac{\omega}{\omega_{02} - \omega_{01}}$. If Q factor is large, resonance is sharp. It is clear from Fig. 27.11that if Q is low, resonance is poor, however band width is small.

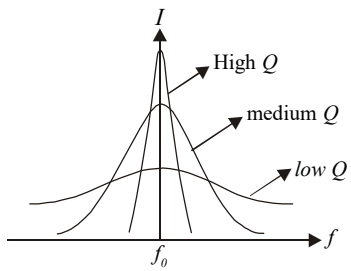


Fig. 27.11

Bandwidth The band of allowed frequencies is called bandwidth. It is the difference between upper and lower cut off frequencies *i.e.* bandwidth $BW = \Delta f = f_{02} - f_{01}$ as shown in Fig 27.10 (b)

Note that a series LCR circuit may be used as a band pass filter.

Cut off frequencies or – 3 dB frequencies These represent the frequencies at which power becomes half of the maximum or current becomes $\frac{I_{max}}{\sqrt{2}}$.

Filters may be divided into three categories

(a) Low-pass filter (b) High pass filter, and (c) Band-pass filters. An Ideal **low-pass filter** allows all frequencies less than a certain maximum *i.e.* $f < f_{02}$ are allowed as shown in Fig. 27.12 (*a*). A practical low pass-filter is shown in Fig. 27.13 (*b*). An ideal high pass filter allows all frequencies

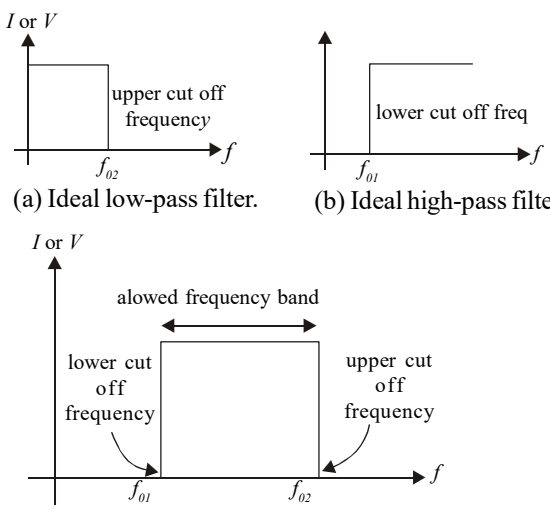
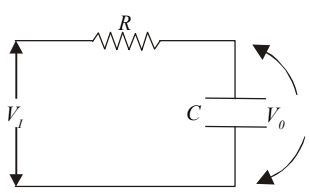
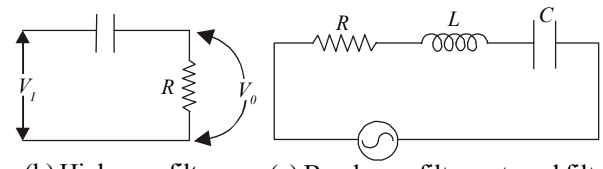


Fig. 27.12

greater than a minimum called lower cut off frequency to pass without attenuation as shown in Fig. 27.12 (*b*). Fig. 27.13 (a) shows implementation of low pass filter using *R* and C.



(a) Low-pass filter



(b) High-pass filter (c) Band-pass filter or tuned filter

Fig. 27.13

An ideal **band pass filter** allows all frequencies lying between f_{01} and f_{02} to pass without attenuation. [Fig 27.13(*c*)]. A series LCR [Fig. 27.13 (c)] is a practical band pass filter implementation.

A parallel LC circuit acts as a band reject filter.

Power (*P*) $P = V_{rms} I_{rms} \cos\phi$; $\cos\phi$ is called power factor. Power companies try to supply at highest power factor ($\phi = 0$). ϕ is the phase shift between *V* and *I*.

$$P = V_{rms} I_{rms} \cos\phi = \frac{V_{rms}^2}{|Z|}$$

$$\cos\phi = \frac{V_p^2}{2|Z|} \cos\phi.$$

If $\phi = 90^0$, $P = 0$, such a power is called wattless power and energy meters cannot record it There could be two types of power active and reactive power. Only active power is read by energy meters. $P_{active} = V_{rms} I_{rms} \cos\phi$. Reactive power is not read by energy meters $P_{reactive} = V_{rms} I_{rms} \sin\phi$.

Transformer An ideal transformer is a loss-less element. The principle is mutual induction. It is used to transform the voltage and current levels in an ac circuit.

In an ideal transformer $V_1 I_1 = -V_2 I_2$, *i.e.*, $P_1 + P_2 = 0$

$$\frac{V_1}{V_2} = \frac{I_2}{I_1} = \frac{N_1}{N_2}$$

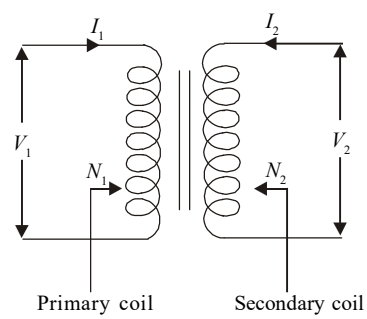


Fig. 27.14 **Transformer**

where N_1 and N_2 are number of turns in primary and secondary coils respectively.

Power transformers are of two types: step up transformer and step down transformer.

In step up transformers, $N_2 > N_1$

and hence $V_2 > V_1$ Thus $I_2 < I_1$.

In a step down transformer $V_2 < V_1$, $N_2 < N_1$ but $I_2 > I_1$.

Step up transformers are used at the generator end in a power distribution system so that $I \to 0$, and hence power loss in transmission line $P = I^2R \to 0$ (due to heating produced in the transmission line). Step down transformer is used as the distribution end near a locality.

Efficiency of the transformer $\eta = \frac{P_{output}}{P_{input}} = \frac{V_{output}}{V_{input}}$

$$= \frac{V_2 - I_2 r}{V_2} \text{ see Fig 27.15}$$

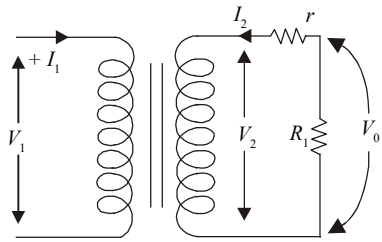


Fig. 27.15

Losses in transformers may be divided into two categories:

(a) Copper loss (due to resistance of Cu winding) [See Fig. 27.15]

(b) Magnetic losses (eddy current loss, flux linkage loss and hysteresis loss)

Eddy current loss is minimised using laminated core in form of E and I or Square Core. Flux linkage loss is prevented by winding one coil over the other. Hysteresis loss is minimised using soft iron core with 4% Si.

Generator Generators are of two types: *AC* generator and *DC* generator. The basic difference in construction is that in *AC* generators slip rings are used and in *DC* generators split rings are employed so that after each half cycle direction changes and same polarity is maintained.

To generate emf a coil is moved in a magnetic field and emf is generated $V = BA_0\omega N \sin \omega t$ where N is number of turns, B is uniform magnetic field. $A = A_0 \cos \omega t$ is area at any instant. And ω is angular frequency.

Tuned circuits or **Tank circuit** or **Oscillation circuits** Fig. 27.16 (*a*) is called tank circuit.

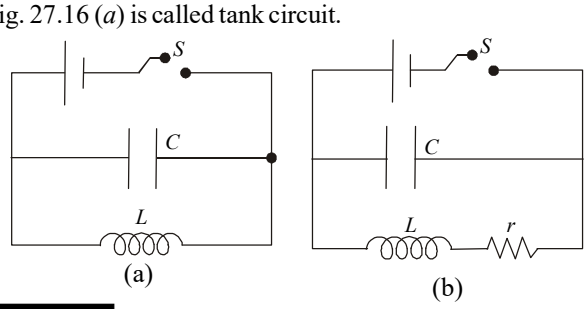


Fig. 27.16

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

Resonant frequency or frequency of oscillation In Fig. 27.16 (*b*) damped oscillations are produced and damped frequency $\omega' = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$. These circuits in *AC* behave as band reject circuits. The current-frequency curve is shown in Fig. 27.17

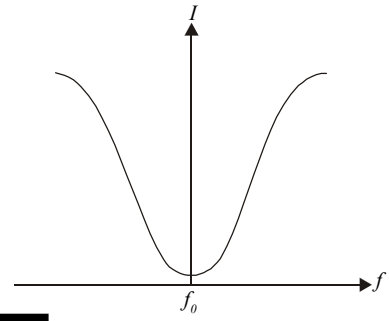


Fig. 27.17

SHORT CUTS AND POINTS TO NOTE

1. $I_{av} = \frac{\int_0^T I dt}{\int_0^T dt} = \frac{1}{T}\int_0^T I dt$. If wave is sinusoidal or complex periodic, integrate for half cycle *i.e.* $I_{av} = \frac{2}{T}\int_0^{T/2} I dt$.

   For sinusoidal current $I_{av} = \frac{2I_p}{\pi} = 0.636\, I_p$

2. $I_{rms} = \sqrt{\frac{1}{T}\int_0^T I^2 dt}$ I_{rms} is also called apparent or virtual or effective current.

   For sinusoidal waves $I_{rms} = \frac{I_p}{\sqrt{2}} = 0.707\, I_p$.

3. Peak-to-peak voltage $V_{pp} = 2V_p$ where V_p is peak voltage.

4. Form factor of *AC* $F = \frac{I_{rms}}{I_{av}}$ $\left(= \frac{\pi}{2\sqrt{2}}\right.$ for sinusoidal *AC*)

5. Capacitive reactance $X_C = \frac{1}{C\omega}$. Note that $X_C \propto \frac{1}{\omega}$ or $\frac{1}{f}$ *i.e.* capacitive reactance falls as frequency increases.

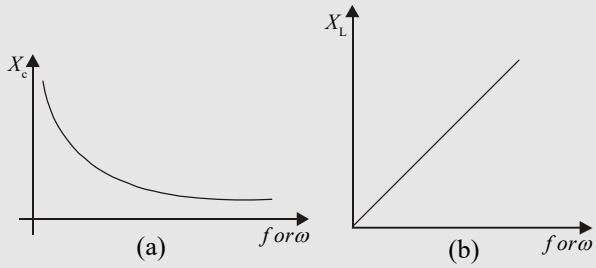


Fig. 27.18

Capacitor acts as a short circuit for very high frequencies $X_C \to 0$ if $\omega \to \infty$. Current leads the voltage by $\frac{\pi}{2}$ radian or 90^0 when AC is applied across a capacitor. Inductive reactance $X_L = L\omega$. Note that $X_L \propto \omega$ or f. Inductive reactance attenuates AC and allows DC to pass without attenuation. Current lags the voltage by 90^0 when AC is applied across pure inductor.

6. In series RC circuit $|Z| = \sqrt{R^2 + X_C^2}$

$= \sqrt{R^2 + \frac{1}{C^2\omega^2}}$; $\tan\phi = \frac{X_c}{R} = \frac{1}{RC\omega}$ current leads the voltage wave form by ϕ.

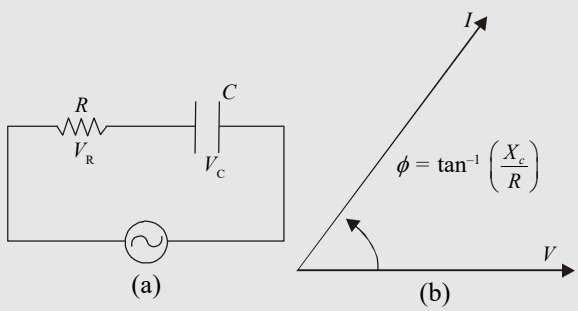


Fig. 27.19

$$V_c = IX_c;\ V_{rms} = \sqrt{V_R^2 + V_C^2}$$

or $$\frac{V_p^2}{2} = V_R^2 + V_C^2$$

$$I = \frac{V_P}{|Z|}\sin(\omega t + \phi)\ ;\ \text{Power } P = \frac{V_{RMS}^2}{|Z|}$$

$$\cos\phi = \frac{V_p^2 R}{2|Z|^2} \quad \because \cos\phi = \frac{R}{|Z|}$$

7. In series RL circuit $|Z| = \sqrt{R^2 + X_L^2}$

$$= \sqrt{R^2 + L^2\omega^2}$$

$$\tan\phi = \frac{XL}{R} = \frac{L\omega}{R}.$$

Current lags the voltage wave form by ϕ.

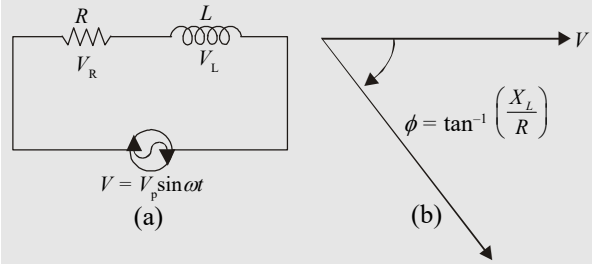


Fig. 27.20

$$V_L = IX_L\ ;\ V_{app}(\text{rms}) = \sqrt{V_R^2 + V_L^2}$$

or $$\frac{V_P^2}{2} = V_R^2 + V_L^2$$

$$I = \frac{V_P}{|Z|}\sin(\omega t - \phi)$$

Power $$P = \frac{V_{rms}^2\cos\phi}{|Z|} = \frac{V_P^2 R}{2|Z|^2}$$

8. In series RLC circuit $|Z| = \sqrt{R^2 + (X_L - X_c)^2}$

$$= \sqrt{R^2 + \left(L\omega - \frac{1}{C\omega}\right)^2}$$

$$\tan\phi = \left(\frac{\frac{1}{C\omega} - L\omega}{R}\right).$$

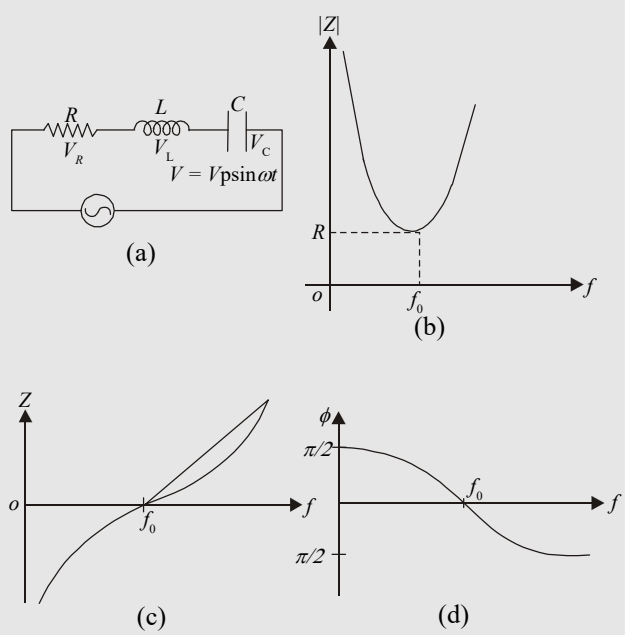


Fig. 27.21

If ϕ is positive impedance is capacitive and current leads the voltage wave form *i.e.* for $\omega < \omega_0$ impedance is capacitive. If $f = f_0$ or $\omega < \omega_0 = \frac{1}{\sqrt{LC}}$ then $\phi = 0$, impedance is pure resistive and is minimum. Current is maximum. These is no phase shift between V and I at resonance.

If $f > f_0$ or $\omega < \omega_0$, the impedance is inductive, ϕ is negative *i.e.* current lags the voltage wave form. Fig. 27.21 (*d*) shows variation of phase shift with frequency. Fig. 27.21 (*b*) and (*c*) represent variation of impedance with frequency.

$$\text{Power } P = \frac{V_P^2 R}{2|Z|^2} = \frac{V_P^2 R}{2\left[R^2\left(X_L - X_c\right)^2\right]}$$

$$P_{(\text{resonance})} = \frac{V_P^2}{2R} \text{ is maximum.}$$

$$\text{Power at cut off frequencies} = \frac{V_P^2}{4R}$$

9. At cut off frequencies $Z = \sqrt{2}R$

$R^2 + (X_L - X_C)^2 = 2R^2$ or $L\omega - \frac{1}{C\omega} = R$

or $LC\omega^2 - RC\omega - 1 = 0$

or $\omega = \frac{RC \pm \sqrt{R^2C^2 + 4LC}}{2LC}$ represent cut off frequencies. Band width $\omega_{02} - \omega_{01} = \frac{\sqrt{R^2C^2 + 4LC}}{LC}$

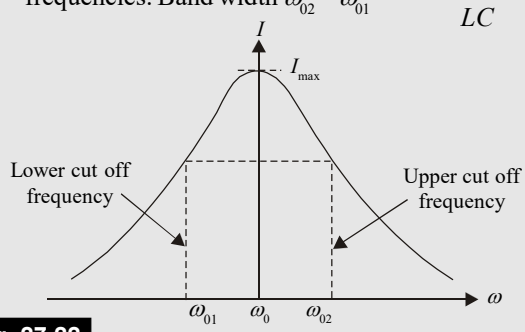


Fig. 27.22

Note that cut off frequencies are also called half power frequencies or $-3dB$ frequencies.

10. ***Q* factor of a coil** $Q = \frac{L\omega}{r} = \frac{\omega_0}{\omega_{02} - \omega_{01}}$ Larger the value of Q, sharper is the resonance.

If $r \to 0$, $Q \to \infty$, $I \to \infty$ *i.e.* resonance catastrophe occurs and bandwidth $\to 0$.

11. Series RLC circuit acts as a band pass filter or tuned filter.

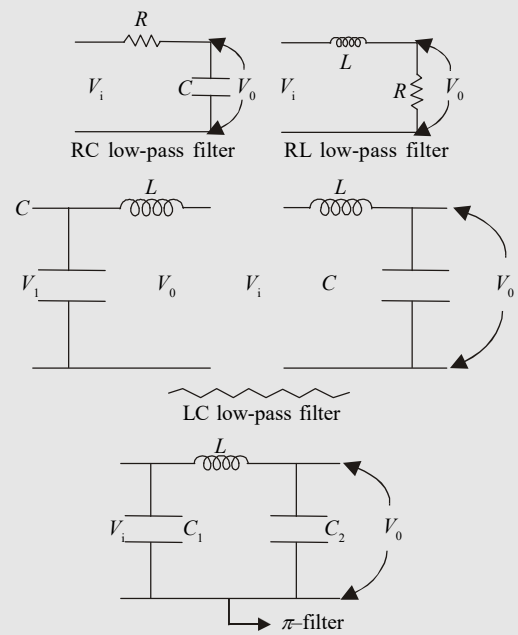


Fig. 27.23 **Low-pass filter circuits**

RC, *LC* or π low-pass filters are preferred.

RC high-pass filter is very commonly employed.

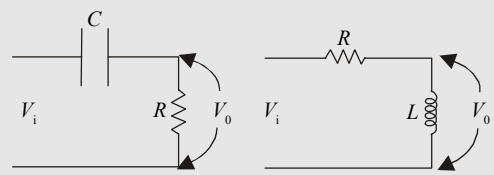


Fig. 27.24 **High-pass filters**

12. Active power $P = V_{rms} I_{rms} \cos\phi = \frac{V_p^2 R}{2|Z|^2}$ It is recorded by energy meters. Reactive power $P_{(\text{Reactive})} = V_{rms} I_{rms} \sin\phi$ is not recorded by energy meters.

13. $\angle i = -\angle Z$, *i.e.* –ve phase angle of impedance is the phase shift between V and I.

14. Kirchoff's Laws can be applied to *AC* as well if stated as follows:

KCL or Junction Law: The algebraic sum of all the currents entering a node at any instant is zero.

KVL or Loop law: The algebraic sum of all the potential drops in a loop at any instant is zero.

15. *AC* voltage and currents are phasors, So are impedance and reactances. Apply vector laws for analytical treatment.

16. In a transformer $\frac{V_1}{V_2} = -\frac{I_2}{I_1} = \frac{N_1}{N_2}$ Note: –ve sign shows phase reversal of current in secondary coil. Dot (.) on the coils of a transformer represents that

their winding are made in the same direction *i.e.* either both clockwise or both anti-clockwise so that a phase shift of 180^0 is developed between primary and secondary currents.

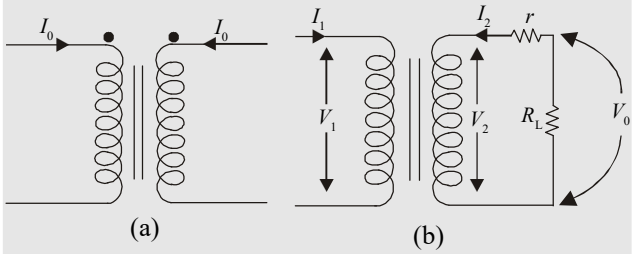


Fig. 27.25 **Transformer**

$$I_1 = \frac{V_1}{\left(\frac{N_1}{N_2}\right)R_L}.$$

$$\text{Efficiency } \eta\% = \frac{P_{\text{output}}}{P_{\text{input}}} \times 100$$

From Fig. 27.25 (b) $\eta\% = \frac{V_{\text{out put}}}{V_2} \times 100 = \frac{V_2 - I_2 r}{V_2} \times 100$

17. In parallel LCR circuit as shown in Fig.27. 26

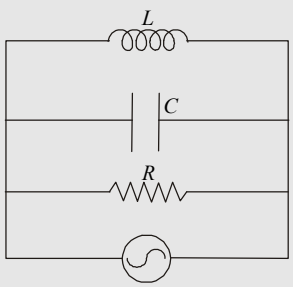


Fig. 27.26 **Paralll RLC Circuit**

$$|Y| = \frac{1}{|Z|} = \sqrt{\frac{1}{R^2} + \left(\frac{1}{X_C} - \frac{1}{X_L}\right)^2}$$

$$= \sqrt{\frac{1}{R^2} + \left(C\omega - \frac{1}{L\omega}\right)^2}$$

Parallel LCR circuit is called anti-resonant circuit or band reject circuit. Current is minimum at resonance.

18. In our country *AC* mains has frequency 50 Hz.

19. Fourier analysis can be used to find V_{av} or amplitude of fundamental frequency or other harmonics.

20. Maximum Power from an *AC* source is transferred to a load (ac) if $Z_L = Z_S$

or $R_L + jX_L = R_S - jX_S$ OR $R_L = R_S$

and $X_L = -X_S$, i.e., if source is inductive then load is capacitive and equivalent (so that X_L and X_S cancel out) or vice versa.

21. Current when $\phi = 90^o$ is called wattless current. It is possible if pure capacitor or pure inductor is applied.

CAUTION

1. Considering that impedances/reactances are added like resistors.

⇒ These quantities are phasors and vector algebra should be applied.

2. Considering $V_{\text{app}}(rms) = V_R + V_C$ in Fig 27.27 (a)

or $V_{\text{app}}(rms) = V_R + V_L$ in Fig. 27.27 (b)

or $V_{\text{app}}(rms) = V_R + V_L + V_C$ in Fig. 27.27 (c)

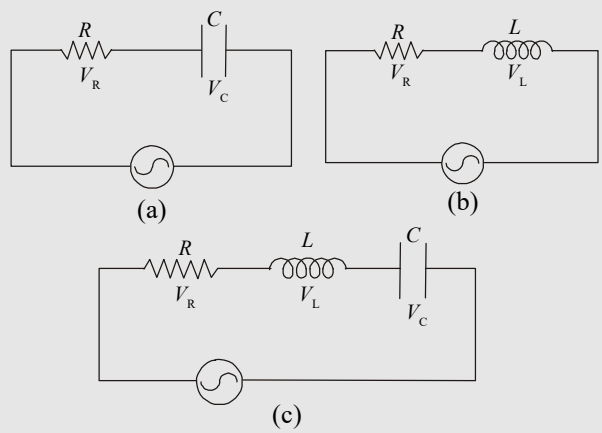


Fig. 27.27

⇒ Apply $V_{\text{app}}(rms) = \sqrt{V_R^2 + V_C^2}$ in Fig. 27.26 (a)

$V_{\text{app}}(rms) = \sqrt{V_R^2 + V_L^2}$ in Fig. 27.26 (b)

and $V_{\text{app}}(rms) = \sqrt{V_R^2 + (V_C - V_L)^2}$ in Fig. 27.26 (c)

3. Considering transformers can step up or step down *DC* also.

⇒ Transformers can step up or step down only *AC* or time varying voltage/currents, as they are based on principles of mutual induction.

To step up or step down *DC* potential divider circuit or Rheostat can be used.

4. Considering $V_{\text{rms}} = \frac{V_P}{\sqrt{2}} = 0.707\ V_P$ for all types of *ACs*.

⇒ $V_{\text{rms}} = \frac{V_P}{\sqrt{2}}$ for sinusoidal *AC*.

For all others apply $V_{\text{rms}} = \sqrt{\frac{1}{T}\int_0^T V^2 dt}$

Similarly $V_{av} = \frac{2V_P}{\pi}$ or 0.636 V_P for sinusoidal AC.

For all other types use $V_{av} = \frac{1}{T}\int_0^T V dt$

or $\frac{2}{T}\int_0^{T/2} V dt$ depending upon whether they remain on one side of zero line or two sides of zero line.

5. Not remembering frequency of AC mains.

⇒ Frequency of AC mains is 50 Hz.

6. Considering $V = IX_L$ or $V = IX_C$ completely represents voltage across inductor or capacitor.

⇒ $V = IX_L$ or $V = IX_C$ only gives the magnitude (amplitude) of voltage and not instantaneous values.

7. Considering current cannot pass through capacitor as its plates are insulated.

⇒ AC current can pass as capacitor charges and discharges. There is an equal current i entering one plate and i leaving other plate and an equal displacement current between the plates.

Mathematically $Q = CV$ $\quad \frac{dQ}{dt} = i = C\frac{dV}{dt}$

i.e. if V is varying with time, current can flow.

OR $X_C = \frac{1}{C\omega}$ if $\omega = 0, X_C \to \infty$ i.e. DC current cannot pass through capacitor but AC current can pass.

8. Considering in AC power consumed is same as in DC i.e. $P = V_{rms} I_{rms}$

⇒ Power consumed is $P = V_{rms} I_{rms} \cos\phi$. Power may be wattless if $\phi = 90^o$

9. considering net impedance of circuit shown in Fig. 27.28

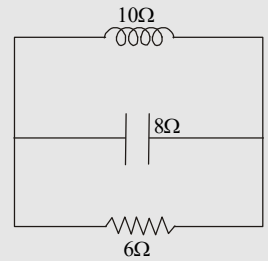


Fig. 27.28

$$\frac{1}{|Z|} = \frac{1}{10} + \frac{1}{8} + \frac{1}{6}$$

⇒ Apply $= \frac{1}{|Z|} = \sqrt{\frac{1}{6^2} + \left(\frac{1}{10} - \frac{1}{8}\right)^2}$

10. Considering phase shift is fixed in series RLC circuit.

⇒ Phase shift varies with frequency as shown in Fig 27.28. It is $+ve$ if $f < f_0$ and 0° at $f = f_0$. Phase shift is negative when $f > f_0$

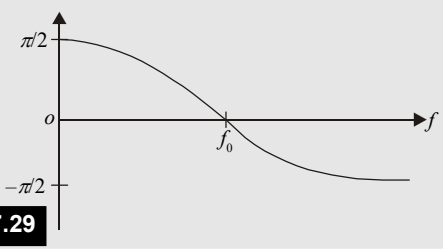


Fig. 27.29

SOLVED PROBLEMS

1. In a circuit L, C, R connected in series with an alternating voltage source of frequency f. The current leads the voltage by 45°. The value of C is

[CBSE PMT 2005]

(a) $\frac{1}{\pi f(2\pi fL - R)}$ (b) $\frac{1}{2\pi f(2\pi fL - R)}$

(c) $\frac{1}{\pi f(2\pi fL + R)}$ (d) $\frac{1}{2\pi f(2\pi fL + R)}$

Solution (d) $\tan 45 = \frac{\frac{1}{2\pi fC} - 2\pi fL}{R}$ or

$$C = \frac{1}{2\pi f(2\pi fL + R)}$$

2. The self inductance of a motor of an electric fan is 10 H. In order to impart maximum power at 50 Hz, it should be connected to a capacitance of

[AIEEE 2005]

(a) 4 μF (b) 8 μF

(c) 1 μF (d) 2 μF

Solution (c) Maximum power is transferred at resonance.

$$\therefore f_0 = \frac{1}{2\pi\sqrt{LC}}$$

or $C = \frac{1}{4\pi^2 f_0^2 L} = \frac{1}{4\times10\times(50)^2\times10}$

$= 10^{-6}\,\text{F} = 1\mu\text{F}$

3. A circuit has resistance of 12 Ω and an impedance of 15 Ω. The power factor of the circuit will be

[AIEEE 2005]

(a) 0.8 (b) 0.4

(c) 1.25 (d) 0.125

Solution (a) $\cos\phi = \frac{R}{|Z|} = \frac{12}{15} = 0.8$

4. The phase difference between alternating current and emf is $\frac{\pi}{2}$. Which one of the following cannot be the constituent of the circuit?

[AIEEE 2005]

(a) C alone (b) R, L

(c) L, C (d) L alone

Solution (b) $0 < \phi < 90^\circ$ for a series RL circuit.

5. The circuit shown in Fig. 27.30 acts as a

[AIIMS 2005]

(a) tuned filter (b) low pass filter

(c) high pass filter (d) rectifier

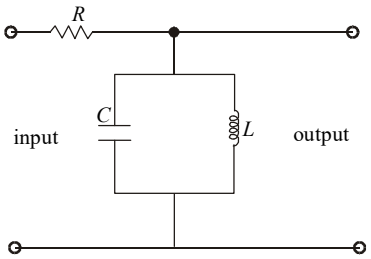


Fig. 27.30

Solution (a)

6. A 50 Hz, 20 V AC source is connected across R C series circuit as shown in Fig. 27.31 If the voltage across R is 12 V then voltage across capacitor is

[AIIMS 2005]

(a) 8 V (b) 16 V

(c) 10 V

(d) cannot be predicted as values of R and C are not given.

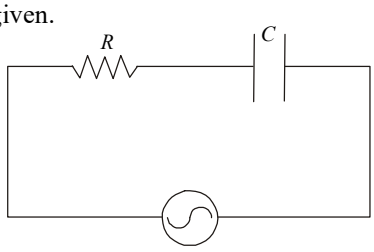


Fig. 27.31

Solution (b) $20^2 = 12^2 + V_C^2$ or $V_C = 16$ V

7. In an LCR circuit the capacitance is made $\frac{1}{4}$ th then what should be the change in inductance that the circuit remains in resonance again?

[BHU 2005]

(a) 8 times (b) $\frac{1}{4}$ times

(c) 2 times (d) 4 times

Solution (d) $f_0 = \frac{1}{2\pi\sqrt{LC}}$ To keep frequency unchanged L be made 4 times.

8. Two inductors each equal to L are joined in parallel. The equivalent inductance is

[BHU 2005]

(a) zero (b) 2 L

(c) L (d) $\frac{L}{2}$

Solution (d) Inductances are added like resistors.

$$\frac{1}{L_{er}} = \frac{1}{L_1} + \frac{1}{L_2}$$

$$\therefore L_{er} = \frac{L}{2}$$

9. The turn ratio of a transformer is 2:3. If the current through primary is 3A, then current through load resistance is

[BHU 2005]

(a) 1A (b) 4.5 A

(c) 2 A (d) 1.5 A

Solution (b) $\frac{I_P}{I_S} = \frac{N_S}{N_P}$ or $\frac{3}{I_S} = \frac{2}{3}$

or $I_S = 4.5$ A

10. The square root of the product of inductance and capacitance has dimensions of

(a) length (b) mass

(c) time (d) dimensionless

[CET Karnataka 2005]

Solution (c) $f = \frac{1}{\sqrt{LC}}$ or $\sqrt{LC} = T$

11. In a series RLC circuit R = 300 Ω, L = 60 mH, $C = 0.5\ \mu$F, V = 50 V, $\omega = 10^4$ rad s^{-1}. Find the voltage across capacitor.

(a) 30 V (b) 20 V

(c) 60 V (d) 50 V

Solution (b) $I = \dfrac{V}{|Z|}$

$$= \frac{50}{\sqrt{300^2 + \left(60\times10^{-3}\times10^4 - \dfrac{1}{.5\times10^4\times10^{-6}}\right)^2}}$$

$$= \frac{50}{\sqrt{300^2+400^2}} = \frac{1}{10}\text{A}$$

$$V_C = IX_C = \frac{1}{10}\times200 = 20\text{ V}$$

12. In series CR circuit excited by ac mains, $C = 10\ \mu$F, $R = 300\ \Omega$. Find power factor.

(a) $\dfrac{3}{\sqrt{17}}$ (b) $\dfrac{3}{\sqrt{16}}$

(c) $\dfrac{3}{\sqrt{18}}$ (d) $\dfrac{3}{\sqrt{19}}$

Solution (d) $\cos\phi = \dfrac{R}{|Z|} = \dfrac{R}{\sqrt{R^2 + \dfrac{1}{C^2\omega^2}}}$

$$= \frac{300}{\sqrt{300^2 + \left(\dfrac{1}{100\pi\times10^{-5}}\right)^2}}$$

$$= \frac{300}{100\sqrt{9+10}} = \frac{3}{\sqrt{19}}$$

13. In the given circuit what is the potential drop across resistance?

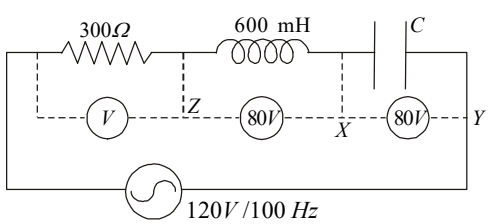


Fig. 27.32

(a) 40 V (b) 80 V

(c) 120 V (d) zero

Solution (c) $\because |V_L| = |V_C|$ It is possible at resonance.

Therefore $V_R = V_{app} = 120$ V

14. In Q.13 what is the potential drop across ZY?

(a) 160 V (b) $80\sqrt{2}$

(c) 80 V (d) zero

Solution (d) $V_{ZY} = V_C - V_L = 0$

15. In the circuit shown in Fig 27.33, for output voltage V_{AB} acts as

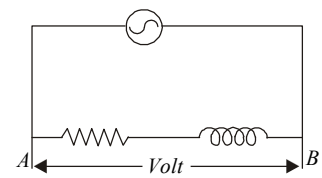


Fig. 27.33

(a) band-pass filter (b) low-pass filter

(c) high-pass filter (d) band reject filter

Solution (c)

16. For the circuit shown in Fig. 27.34 the rms current is

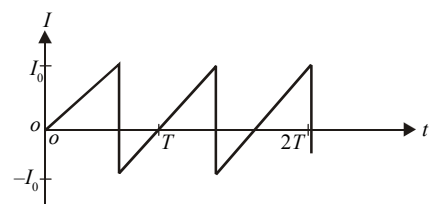


Fig. 27.34

(a) I_0 (b) $I_0/\sqrt{2}$

(c) $I_0/\sqrt{3}$ (d) $I_0/2$

Solution (c) $I = \dfrac{2I_0 t}{T}$ when $0 < t < T/2$

$$I = 2I_0(t-T)/T \text{ when } T/2 < t < T$$

$$I_{rms}^2 = \frac{1}{T}\left[\int_0^{T/2} I^2 dt + \int_{T/2}^{T} I^2 dt\right]$$

$$= \frac{1}{T}\int_0^{T/2}\left(\frac{2I_0 t}{T}\right)^2 dt$$

$$+ \frac{1}{T}\int_{T/2}^{T}\left(\frac{2I_0 D}{T}(t-T)\right)^2 dt$$

$$I_{rms} = I_0/\sqrt{3}$$

17. The reactance of capacitor is 350 Ω, R = 180 Ω. Find X_L if in a series LCR circuit current leads the voltage by 53°.

(a) 120 Ω (b) 140 Ω
(c) 210 Ω (d) 110 Ω

Solution (d) $\tan 53 = \frac{X_C - X_L}{R} \Rightarrow \frac{4}{3} = \frac{350 - X_L}{180}$

or $X_L = 110\,\Omega$

18. A 400 Ω resistor and 6 μF capacitor are connected in parallel to a source of V_{rms} = 220 V and angular frequency 360 *rad/s*. Find the current in the resistor and capacitor.

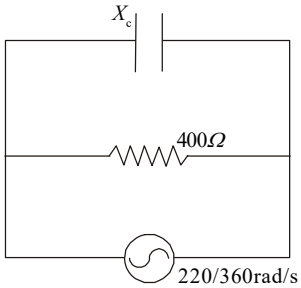


Fig. 27.35

(a) 0.55 A, 0.475 A (b) 0.55 A, 0.726 A
(c) 0.55 A, 0.176 A (d) none of these

Solution (a) $\frac{1}{X_C} = C\omega = 6 \times 10^{-6} \times 360 = 2.16 \times 10^{-3}$

$$\frac{1}{Z} = \sqrt{\frac{1}{R^2} + (C\omega)^2}$$

$$= \sqrt{\left(\frac{1}{400}\right)^2 + \left(2.16 \times 10^{-3}\right)^2}$$

$$I_{net} = 220 \times \frac{1}{Z} = 220 \times 10^{-3} \times 3.3 = 0.726;$$

$$I_R = \frac{220}{400} = 0.55 \text{ A}$$

$$I_C = \sqrt{I_{net}^2 - I_R^2} = \sqrt{(.726)^2 - (.55)^2} = 0.475 \text{ A}$$

Short cut $I_C = 220 \times \frac{1}{X_C} = 220 \times 2.16 \times 10^{-3} = 0.475$ A

$I_R = 220 \times 2.5 \times 10^{-3} = 0.55$ A

19. A 120 V *AC* line transformer is to supply 13000 V for a neon sign. To reduce shock hazard a 8.5 mA fuse is inserted. Find the maximum input power to the transformer.

(a) 120 W (b) 121 W
(c) 110 W (d) 104 W

Solution (c)

$$P_{input} = P_{output} = 13000 \times 8.5 \times 10^{-3} = 110.5 \text{ W}$$

20. An LC circuit has L = 5 mH and C = 20 μF.

$V = 5 \times 10^{-3} \cos \omega t$ is supplied. ω is twice the resonant frequency. Find the maximum charge stored in the capacitor.

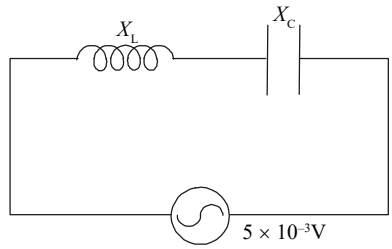


Fig. 27.36

(a) 66.6 nC (b) 11.3 nC
(c) 23.2 nC (d) 33.3 nC

Solution (d)

$$\omega = 2\,\omega_0 = 2 \times \frac{1}{\sqrt{LC}} = \frac{2 \times 10^4}{\sqrt{10}}$$

$$I = \frac{5 \times 10^{-3}}{\sqrt{(X_L - X_C)^2}} = \frac{5 \times 10^{-3}}{\sqrt{\left(10\sqrt{10} - 2.5\sqrt{10}\right)^2}}$$

$$= \frac{5 \times 10^{-3}}{7.5\sqrt{10}} = 2.1 \times 10^{-4} \text{ A}$$

$$V_C = IX_C \text{ and } Q = CV_C = I \times \frac{I}{C\omega} \times C$$

$$= \frac{I}{\omega} = \frac{2.1 \times 10^{-4} \times \sqrt{10}}{2 \times 10^4} = 33.3 \text{ nC}$$

21. An AM radio operates at 550 kHz to 1650 kHz. If L is fixed and C is varied for tuning then minimum and maximum value of C is

(a) C, 3 C (b) C, 6 C
(c) C, 9 C (d) C, 12 C

Solution (c) $\frac{f_{max}}{f_{min}} = 3 \therefore \frac{\sqrt{LC_{max}}}{\sqrt{LC_{min}}} = 3$ or $\frac{C_{max}}{C_{min}} = 9$

22. In an ideal transformer turn ratio is 2 : 3. If input voltage is 100 V/60 Hz, then output voltage is

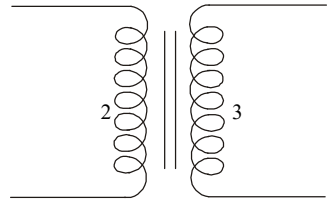


Fig. 27.37

(a) 150 V/90 Hz (b) 150 V/40 Hz
(c) 150 V/60 Hz (d) 66.6 V/60 Hz

Solution (c)

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} \Rightarrow \frac{100}{V_2} = \frac{2}{3} \text{ and}$$

frequency does not change.

23. A centre tapped transformer is rated 12 – 0 – 12 V. The peak voltage obtained is

(a) 12 V (b) $\frac{12}{\sqrt{2}}$ V
(c) $12\sqrt{2}$ V (d) 24 V
(e) $24\sqrt{2}$ V

Solution (c)

$$V_{rms} = 12 \text{ V } V_P = V_{rms}\sqrt{2} = 12\sqrt{2} \text{ V}$$

24. $I = 6 \cos wt + 8 \sin wt$ is applied across a resistor of 40Ω. Find the potential difference across the resistor.

(a) 660 V (b) 80 V
(c) 330 V (d) 400 V

Solution (d) $I_{rms} = \sqrt{6^2 + 8^2} = 10$ A

$$V_R = I_{rms} \times R = 10 \times 40 = 400 \text{ V}$$

25. If the output is taken across a capacitor in a series RLC circuit then it acts as

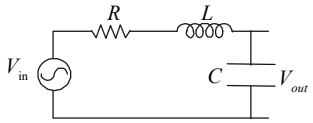


Fig. 27.38

(a) band-pass filter (b) high-pass filter
(c) low-pass filter (d) band reject filter

Solution (c)

26. Plot the output voltage V_0 across the capacitor in a series RC circuit if square wave is inputted.

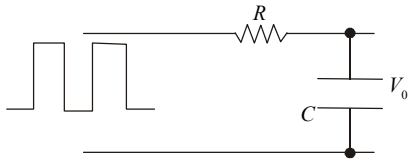


Fig. 27.39

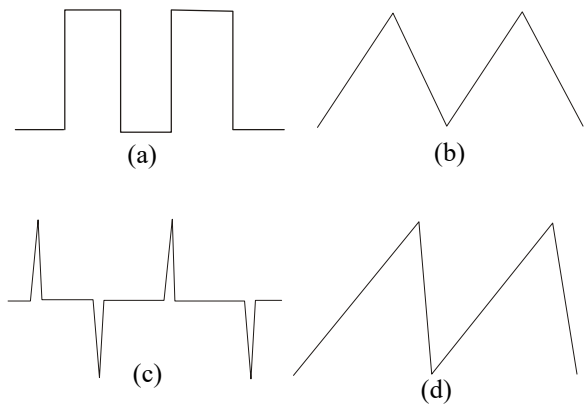


Fig. 27.40

Solution (b) $V_C = \frac{1}{C}\int i dt = \frac{V}{RC}\int dt$

∴ Choice is (b).

TYPICAL PROBLEMS

27. If 10 mV/ 1kHz input is given to a series RC circuit then output voltage across the capacitor is

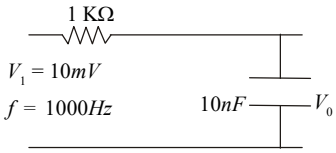


Fig. 27.41

(a) 8.5 mV (b) 10 mV (c) 7.5 mV
(d) 6.5 mV (e) none of these

Solution (a) $V_C = IX_C = \frac{V_{in}}{|Z|} X_C$

$$= \frac{10 \times 10^{-3}}{\sqrt{(10^3)^2 + \left(\frac{10^4}{2\pi}\right)^2}} \times \frac{1}{10^{-8} \times 10^4 \times 2\pi}$$

$$= \frac{100}{10^3 \times 1.8} \times \frac{1}{2\pi} = 8.5 \text{ mV}$$

28. A 100 W/200 V bulb and an inductor are connected in series to a 220 V/50 Hz supply. Find the power consumed by the bulb.

(a) 100 W (b) 92 W
(c) 84 W (d) 74 W

Solution (d) $P = I^2R = \left(\frac{V}{|Z|}\right)^2 R$

$$= \left(\frac{220}{\sqrt{(400)^2 + (100\pi)^2}}\right)^2 \times 400;$$

$$R = \frac{200^2}{100} = 400\,\Omega$$

$$= \frac{484 \times 10^2 \times 400}{16 \times 10^4 \times 10 \times 10^4} = \frac{1936}{26} = 74.46 \text{ W}$$

29. A parallel plate capacitor has area 20 cm^2 and separation between the plates is 0.1 mm. The dielectric break down strength is 3×10^6 V/m. The maximum rms voltage which can be safely applied is

(a) 210 V (b) 300 V

(c) 100 V < V < 300 V (d) < 200 V

Solution (a) $E = 3 \times 10^6 = \frac{V\sqrt{2}}{d}$

$$\text{or } V = \frac{3 \times 10^6 \times 10^{-4}}{\sqrt{2}} = 210 \text{ V}$$

30. A telegraph wire 200 km long has capacity 0.014 μF per km and resistance 2 Ω/km. If it carries an AC of frequency 5 kHz then what should be the inductance so that maximum power is delivered at the other end?

(a) 0.014 H (b) 140 mH

(c) 1.4 mH (d) none of these

Solution (a) $X_L = X_C$

$$\text{or } L = \frac{1}{C\omega^2} = \frac{1}{2.8 \times 10^{-6} \times (5 \times 10^3)^2}$$

$$= \frac{1}{2.8 \times 25} = \frac{1}{70} H.$$

31. When 4 V DC is connected across an inductor current is 0.2 A. When AC of 4 V is applied the current is 0.1A. Then self inductance of the coil is ..... $\omega = 1000$ $rads^{-1}$

(a) 20 mH (b) 40 mH

(c) $20\sqrt{3}$ mH (d) none of these

Solution (c) $Z = \frac{4}{0.1} = 40\,\Omega = \sqrt{R^2 + (L\omega)^2}$

$$\text{and } R = \frac{4}{0.2} = 20\,\Omega$$

$$\therefore L\omega = 20\sqrt{3}\,\Omega \quad \text{or } L = 20\sqrt{3} \text{ mH}$$

32. A capacitor has capacitance 0.5 nF. A choke of 5 μH is connected in series. An em wave of wave length λ is found to resonate with it. Find λ.

(a) 10πm (b) 20πm

(c) 30πm (d) 5πm

(e) none of these

Solution (c) $f = \frac{1}{2\pi\sqrt{LC}}$ and

$$\lambda = \frac{C}{f} = 3 \times 10^8 \times 2\pi\sqrt{LC}$$

$$= 3 \times 10^8 \times 2\pi\sqrt{5 \times 10^{-6} 5 \times 10^{-10}} = 30\pi m$$

33. The frequency of generator (AC) is measured using

(a) multimeter (b) AVO meter

(c) tachometer (d) speedometer

Solution (c)

34. An AC source of 100 V (rms) supplies a current of 10 A (rms) to a circuit. Then power consumed is

(a) = 1000 W (b) $\le$ 1000 W

(c) $\ge$ 1000 W (d) < 1000 W only

Solution (b) $P = V_{rms} I_{rms} \cos\phi$ since $0 \le \cos\phi \le 1$

$\therefore p \le 1000$ W.

35. An inductor having some resistance is connected to an AC source. Which of the following quantities has zero average value over a complete cycle?

(a) current (b) induced emf

(c) Joule heat

(d) magnetic energy stored in the inductor

Solution (a) and (b)

36. A 60 W/120 V bulb is connected to a 240/60 Hz supply with an inductance in series. Find the value of inductance so that bulb gets correct voltage.

(a) $\frac{2.3}{\pi}$ H (b) $2\sqrt{3}$ H

(c) π H (d) $\frac{2\sqrt{3}}{\pi}$ H

Solution (d) $R = \frac{(120)^2}{60} = 240\,\Omega$ we require $i = 0.5$ A

$$\text{or } |Z| = 480\,\Omega$$

$$X_L = \sqrt{480^2 - 240^2} = 240\sqrt{3}\,\Omega$$

$$L = \frac{240\sqrt{3}}{60 \times 2\pi} = \frac{2\sqrt{3}}{\pi} H$$

37. The current in a series RL circuit decays as $I = I_0 e^{-t/\tau}$. Obtain the *rms* current in the interval $0 \le t \le \tau$

(a) $\frac{I_0}{2}$ (b) $\frac{I_0}{e}$

(c) $\frac{I_0}{\sqrt{2}e}$ (d) $\frac{I_0}{e}\sqrt{\frac{e^2-1}{2}}$

Solution (d) $i_{rms}^2 = \frac{1}{\tau}\int_0^\tau I^2 dt = \frac{1}{\tau}\int_0^\tau I_0^2 e^{-2t/\tau} dt$

$$= \frac{-I_0^2}{\tau}\left.\frac{e^{-2t/\tau}}{2/\tau}\right|_0^\tau \quad \text{or } i_{rms} = \frac{I_0}{e}\sqrt{\frac{e^2-1}{2}}$$

38. A storage battery takes t_o time when *DC* current I_0 is used to charge it. Find the time taken if a half wave rectifier is used with *AC* mains and effective current is I_0.

(a) $t_0\pi$ (b) $\frac{2t_0}{\pi}$

(c) $\frac{\pi t_0}{2}$ (d) t_0

Solution (c) $I_{dc} = \frac{I_P}{\pi}$; $I_{eff} = I_{rms} = \frac{I_P}{2} = I_0$

Therefore $I_P = 2I_0$

Hence dc current supplied by the rectifier is $\frac{2I_0}{\pi}$

Time require is calculated using $I_1 t_1 = I_2 t_2$

$$\text{or } t_2 = \frac{I_0 t_0}{2\frac{I_0}{\pi}} = \frac{\pi t_0}{2}$$

39. A leaky capacitor 10 Ω/60º is connected in series with a 10 Ω resistance. Find the overall impedance.

(a) 10 Ω (b) $10\sqrt{2}$ Ω

(c) 15 Ω (d) $10\sqrt{3}$ Ω

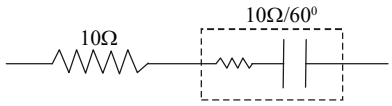


Fig. 27.42

Solution (d) $\sqrt{r^2 + X_C^2} = 10$ and $\frac{X_C}{r} = \tan 60$

$$\therefore \sqrt{r^2 + \left(\sqrt{3}r\right)^2} = 10 \text{ or } r = 5\,\Omega,\ X_C = 5\sqrt{3}\,\Omega$$

$$|Z| = \sqrt{(10+5)^2 + 5\sqrt{3}} = 10\sqrt{3}\,\Omega;$$

$$\phi = \tan^{-1}\frac{X_C}{R} = \tan^{-1}\left(\frac{5\sqrt{3}}{15}\right)$$

$$= \tan^{-1}\left(\frac{1}{\sqrt{3}}\right) \quad \text{or } \phi = 30^\circ$$

40. An inductor 10 Ω/60º is connected to a 5 Ω resistance in series. Find net impedance

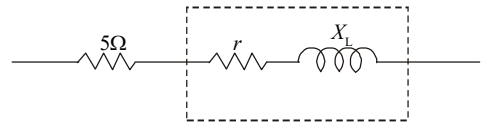


Fig. 27.43

(a) 15 Ω (b) 12 Ω

(c) 13.2 Ω (d) 18 Ω

Solution (c) $10 = \sqrt{r^2 + X_L^2}$ and $\frac{X_L}{r} = \tan 60$

$$10 = \sqrt{r^2 + \left(r\sqrt{3}\right)^2} \text{ or } r = 5\,\Omega, X_L = 5\sqrt{3}\,\Omega$$

$$Z = \sqrt{(5+5)^2 + \left(5\sqrt{3}\right)^2} = \sqrt{175} = 13.2\,\Omega$$

$$\tan\phi = \frac{X_L}{R+r} = \frac{5\sqrt{3}}{10}$$

$$\text{or } \phi = \tan^{-1}\left(\frac{\sqrt{3}}{2}\right).$$

PASSAGE 1

Read the following passage and answer the questions given at the end.

In principle, the transformer consists of two coils electrically insulated from each other and wound on the same iron core. An alternating current in one winding sets up an alternating flux in the core, and the induced electric field produced by this varying flux induces an emf in the other winding. Energy is thus transferred from one winding to another via the core flux and its associated induced electric field. The winding to which power is supplied is called the primary; that from which power is delivered is called the secondary. The circuit symbol for an iron core transformer is shown in Fig 27.44.

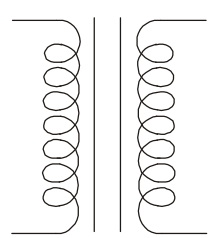


Fig. 27.44

The power output of a transformer is necessarily less than the power input because of unavoidable losses. These losses consist of $I^2 R$ losses in the primary and secondary windings, and hysteresis and eddy-current losses in core.

Hysteresis losses are minimized by the use of iron having a narrow hysteresis loop; and eddy currents are minimized by laminating the core. Inspite of these losses, transformer efficiencies are usually well over 90% and in large installation may reach 99%

1. Eddy current is the current generated in

(a) random direction (b) in a fixed direction

(c) random or fixed direction depending upon the shape of the body

(d) none of these

2. The efficiency of a transformer is 90%. The maximum loss has occured in

(a) resistance of primary and secondary coils

(b) eddy current

(c) hysteresis loss

(d) magnetostriction loss.

3. Hysteresis loss is minimized using

(a) soft iron core

(b) soft iron core with 4% *Si*

(c) cobalt core

(d) ferrite core (e) radiometal

Solution **1.** (a)

Solution **2.** (a)

Solution **3.** (b)

PASSAGE 2

Read the following passage and answer the questions given at the end.

When you join your new assignment, on the very first day your boss gives you an inductor and asks you to find its inductance. You are provided an *AC* voltmeter of high impedance, a resistor, a capacitor and an *AC* source of variable frequency. You recall from your physics class that if *R*, *L* and *C* are connected in series current is maximum at resonance. Since you are not provided an ammeter you drop this idea. To measure inductance, however, on the advice of an experienced colleague you connect *L*, *R* and *C* in series with the *AC* source of variable frequency.

1. To measure *L*

(a) you will measure the potential drop across resistor till it is minimum on varying frequency

(b) you will measure voltage across resistor till it is maximum on varying frequency

(c) you will measure voltage across *L* and *C* at various frequencies until $V_L = V_C$

(d) you will measure voltage across *L* until it is minimum at a particular frequency.

2. You apply $f = \dfrac{1}{2\pi\sqrt{LC}}$ to find *L*. Which frequency will you select?

(a) when V_R is minimum (b) when V_R is maximum

(c) when V_C is maximum (d) when V_C is minimum.

Solution **1.** (b) or (c) when *I* is maximum potential drop *IR* is maximum. At resonance $|X_L| = |X_C|$ $\therefore$ $V_L = V_C$ but opposite in phase.

Solution **2.** (b)

PASSAGE 3

Read the following passage and answer the questions given at the end.

To impress your friend you tell him that you have developed a machine which can act as a high-pass as well as low pass filter. You further impress him, hey even it acts as a band pass filter. Your friend is thrilled.

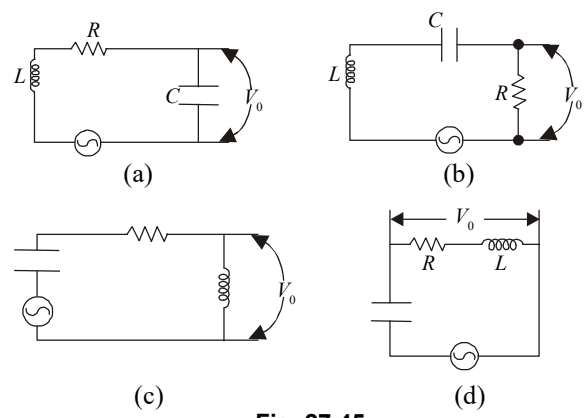


Fig. 27.45

You show him four designs: Figure 27.45 (a), (b), (c) and (d) of a series LCR circuit and explain him that by taking output at different positions you can get low pass, high pass and band pass filter.

1. Band pass filter is the one shown in Fig. 27.45.

(a) (b)

(c) (d)

2. Low-pass filter is the one shown in Fig. 27.45.

(a) (b)

(c) (d)

3. High-pass filter is the one shown in Fig. 27.45.

(a) (b)

(c) (d)

Solution **1.** (b) at resonance

Solution **2.** (a)

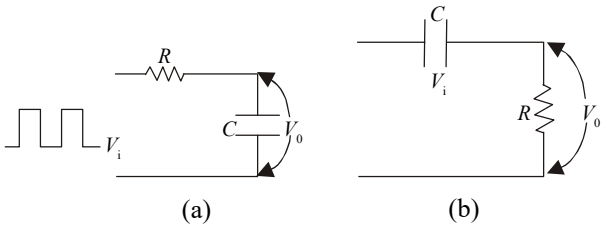
Solution **3.** (c) and (d).

PASSAGE 4

Read the following passage and answer the questions given at the end.

You were designing a project in which you required triangular wave. The function generator available to you gives only sine and square wave. You had listened to your physics teacher very carefully in the previous lecture. He stressed how series RC circuit can be used as an integrater and differentiator. You wish to apply the same idea to convert square wave into triangular wave. Your project demands amplitude of triangular wave ≥ 3.6 V at 2 kHz.

1. Which of the simplest RC circuit will you use?



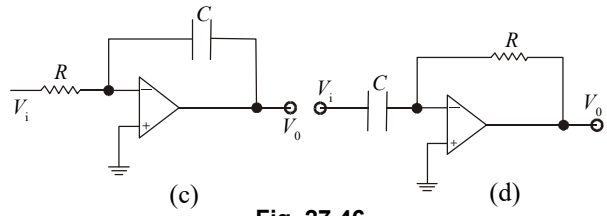


Fig. 27.46

2. What should be the values of R and C?

(a) $R = X_C$ (b) $X_C = 3/4\ R$

(c) $X_C = 4/3\ R$ (d) none of these

Solution **1.** (a) or (c)

Solution **2.** (c) $\dfrac{X_c}{\sqrt{R^2 + X_c^2}} = \dfrac{4}{5}$ for the safe side we take 4V out put.

or $R = 3/4\ X_C$

QUESTIONS FOR PRACTICE

1. A capacitor acts as an infinite resistance for

(a) DC (b) AC

(c) DC as well as AC (d) neither AC nor DC.

2. An inductor, a resistor and a capacitor are joined in series with an AC source. As the frequency of the source is slightly increased from a very low value, the reactance

(a) of the inductor increases

(b) of the resistor increases

(c) of the capacitor increases

(d) of the circuit increases

3. The reactance of a circuit is zero. It is possible that the circuit contains

(a) an inductor and a capacitor

(b) an inductor but no capacitor

(c) a capacitor but no inductor

(d) neither an inductor nor a capacitor

4. Which of the following plots may represent the reactance of a series LC combination?

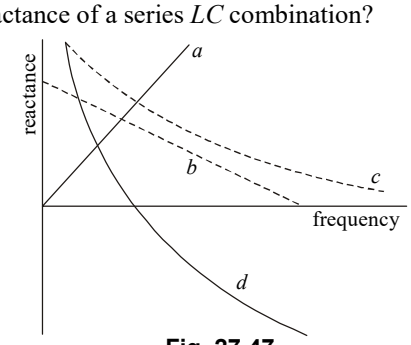


Fig. 27.47

5. The peak voltage in a 220 V, 50 Hz AC source is

(a) 220 V (b) about 160 V

(c) about 310 V (d) 440 V

6. An alternating current having peak value 14 A is used to heat a metal wire. To produce the same heating effect, a constant current i can be used where i is

(a) 14 A (b) about 20 A

(c) 7 A (d) about 10 A.

7. An AC source producing emf

$$E = E_0\,[\cos(100\,\pi s^{-1})\,t + \varphi_1] + i_2 \cos[(500\,\pi s^{-1})t + \varphi_2]$$

is connected in series with a capacitor and a resistance, the steady state current in the circuit is found to be

(a) $i_1 > i_2$ (b) $i_1 = i_2$

(c) $i_1 < i_2$ (d) Insufficient information

8. A constant current of 2.8 A exists in a resistor. The *rms* current is

(a) 2.8 A (b) about 2 A

(c) 1.4 A

(d) undefined for a direct current

9. A series AC circuit has a resistance of 4 Ω and a reactance of 3 Ω. The impedance of the circuit is

(a) 5 Ω (b) 7 Ω

(c) 12/7 Ω (d) 7/12 Ω.

10. The magnetic field energy in an inductor changes from maximum value to minimum value in 5.0 ms when connected to an *AC* source. The frequency of the source is

(a) 20 Hz (b) 50 Hz
(c) 200 Hz (d) 500 Hz.

11. Transformers are used

(a) in *DC* circuits only (b) in *AC* circuits only
(c) in both *DC* and *AC* circuits
(d) neither in *DC* nor in *AC* circuits.

12. An *AC* source is rated 220 V, 50 Hz. The average voltge is calculated in a time interval of 0.01 s. It

(a) must be zero (b) may be zero
(c) is never zero (d) is $(220/\sqrt{2})$ V

13. An alternating current is given by

$i = i_1 \cos \omega t + i_2 \sin \omega t$.

The *rms* current is given by

(a) $\frac{i_1 + i_2}{\sqrt{2}}$ (b) $\frac{|i_1 + i_2|}{\sqrt{2}}$

(c) $\sqrt{\frac{i_1^2 + i_2^2}{2}}$ (d) $\sqrt{\frac{i_1^2 + i_2^2}{\sqrt{2}}}$

14. In an *AC* series circuit, the instantaneous current is zero when the instantaneous voltage is maximum. Connected to the source may be a.

(a) Pure inductor (b) Pure capacitor
(c) Pure resistor
(d) cobination of a capacitor and an inductor

15. The *AC* voltage across a resistance can be measured using

(a) a potentiometer (b) a hot wire voltmeter
(c) A moving-coil galvanometer
(d) a moving-magnet galvanometer.

16. An inductor-coil having some resistance is connected to an *AC* source. Which of the following quantities have zero average value over a cycle?

(a) current
(b) induced emf in the inductor
(c) Joule heat
(d) magnetic energy stored in the inductor

17. To convert mechanical energy into electrical energy, one can use

(a) *DC* dynamo (b) *AC* dynomo
(c) motor (d) transformer.

18. An *AC* source rated 100 V (*rms*) supplies a current of 10 A (rms) to a circiut. The average power delivered by the source.

(a) must be 1000 W (b) may be 1000 W
(c) may be greater than 1000 W
(d) may be less than 1000 W

19.

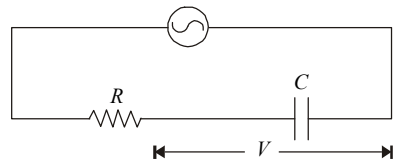


Fig. 27.48

A resistance *R* and a capacitor *C* are joined to a source of *AC* of constant emf and variable frequency. The potential difference across *C* is *V*. If the frequency of *AC* is gradually increased, *V* will

(a) increase (b) decrease
(c) remain constant
(d) first increase and then decrease

20. In an *AC* circuit, the reactance is equal to the resistance. The power factor of the circuit will be

(a) 1 (b) $\frac{1}{2}$

(c) $\frac{1}{\sqrt{2}}$ (d) zero

21. An inductance *L*, a capacitance *C* and a resistance *R* may be connected to an *AC* source of angular frequency ω, in three different combinations of *RC*, *RL* and *LC* in series. Assume that $\omega L = \frac{1}{\omega C}$. The power drawn by the three combinations are P_1, P_2, P_3 respectively. Then,

(a) $P_1 > P_2 > P_3$ (b) $P_1 = P_2 < P_1$
(c) $P_1 = P_2 > P_1$ (d) $P_1 = P_2 = P_3$.

22. An electrical heater and a capacitor are joined in series across a 220 V, 50 Hz *AC* supply. The potential difference across the heater is 90 V. The potential difference across the capacitor will be about

(a) 200 V (b) 130 V
(c) 110 V (d) 90 V

23. If the value of virtual voltages across *L*, *C* and *R* in an *L-C-R* circuit are V_L, V_c and V_R respectively then the source voltage will be

(a) $V = \sqrt{V_R^2 + (V_L - V_C)^2}$ (b) $V = V_L + V_C + V_R$

(c) $V = \sqrt{V_R^2 + (V_L^2 - V_C^2)}$ (d) $V = V_L - V_C + V_R$

24. The resultant reactance in an *L-C-R* circuit is

(a) $X_L + X_C$ (b) $X_L - X_C$

(c) $\sqrt{x_L^2 + x_C^2}$ (d) $\sqrt{x_L^2 - x_C^2}$

25. The unit of *RC* is

(a) second^{-1} (b) second^2

(c) second (d) second^3

26. The natural frequency of an *L-C* circuit is

(a) $\frac{1}{2\pi\sqrt{LC}}$ (b) $\frac{1}{2\pi}\sqrt{\frac{C}{L}}$

(c) $\frac{1}{2\pi}\sqrt{\frac{L}{C}}$ (d) $\sqrt{LC}$

27. The angular frequency of an AC source is 10 radian/sec. The reactance of $1\mu F$ capacitor will be—

(a) $10^4\Omega$ (b) $10^2\Omega$

(c) $10^1\Omega$ (d) $10^5\Omega$

28. If the values of inductance and frequency in an AC circuit are 2 henry and $10^3/2\pi Hz$ respectively then the value of inductive reactance will be

(a) $2 \times 10^3/\pi\ \Omega$ (b) $2 \times 10^2\ \Omega$

(3) $10^3\ \Omega$ (d) $2 \times 10^3\ \Omega$

29. If the reactance of a choke coil is X_L and its resistance is *R*, then

(a) $X_L = R$ (b) $X_L >> R$

(c) $X_L << R$ (d) $X_L = \propto$

30. If the phase difference between the emf and the current in an AC circuit is *f* then the *RMS* value of wattless current will be

(a) $I_{rms}\cos f$ (b) $I_{rms}\sin f$

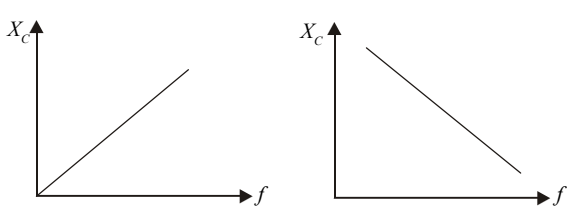
(c) $I_{rms}\tan f/2$ (d) 0

31. An electric bulb of resistance 280 Ω is connected to 200 Volt supply line. The peak value of current flowing in the circuit will be

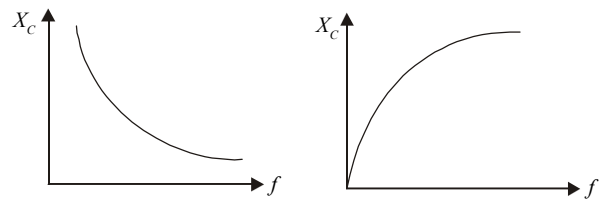
(a) nearly 1 amp (b) zero

(c) nearly 2 amp (d) nearly 4 amp

32. The correct curve representing the variation of capacitive reactance X_c with frequency *f* is



(a) (b)



(c) (d)

Fig. 27.49

33. If the equation of AC in an *AC* circuit is $I = 200 \cos(\omega t + \theta)$ ampere, then the effective value of current will be—

(a) $\frac{200}{\sqrt{2}}\ A$ (b) $200\sqrt{2}\ A$

(c) $200\ A$ (d) 0

34. The time constant of an *L-R* circuit is—

(a) LR (b) $\frac{L}{R}$

(c) $\frac{R}{L}$ (d) $\frac{L^2}{R}$

35. Time constant of an *R-C* circuit is that time, in which on closing the circuit the value of charge q on condenser plates becomes—

(a) $0.37\ q_0$ (b) $0.636\ q_0$

(c) $0.5 q_0$ (d) q_0

36. The unit of $\sqrt{LC}$ is—

(a) Henry (b) Farad

(c) Second (d) Ampere

37. In an *L-C-R* circuit the values of X_L, X_C and *R* are 300 Ω, 200 Ω and 100 Ω respectively. The total impedance of the circuit will be—

(a) 600 Ω (b) 200 Ω

(c) 141 Ω (d) 310 Ω

38. When the frequency of applied emf in an *L-C-R* series circuit is less than the resonant frequency, then the nature of the circuit will be—

(a) capacitive (b) resistive

(c) inductive (d) all of the above

39. The resonant frequency in an antiresonant circuit is—

(a) $\frac{1}{2\pi\sqrt{LC}}$ (b) $\frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$

(c) $\frac{1}{2\pi}\sqrt{LC}$ (d) $\frac{1}{2\pi}\sqrt{\frac{C}{L}}$

40. The range of values of power factor is

(a) 0 to + 1 (b) 0 to – 1

(c) 0 to 8 (d) 2 to 8

41. How are the small bulbs, used for decoration purpose, connected ?

(a) in parallel (b) in series

(c) in mixed order (d) all of the above

42. To protect the electrical appliances the fuse wire in electric supply line is connected in

(a) series (b) parallel

(c) mixed order (d) none of the above

43. The unit of susceptance is

(a) ohm (b) ohm^{-1}

(c) ohm/cm (d) ohm/m

44. The frequency of *AC* supply line in houses in England is

(a) 40 Hz (b) 50 Hz

(c) 100 Hz (d) 200 Hz

45. The *I-f* curve for anti-resonant circuit is

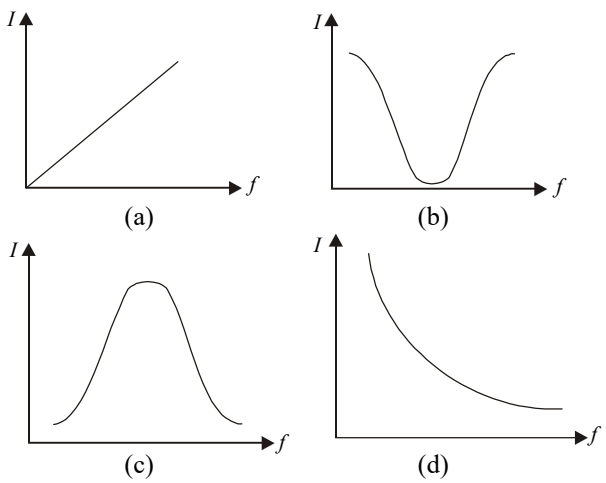


Fig. 27.50

46. The *RMS* value of effective current is

(a) $I_{rms}\cos\theta$ (b) $I_{rms}\sin\theta$

(c) $I_0\cos\theta$ (d) $I_0\sin\theta$

47. If *N* similar bulbs of *P* watt are connected in series then the power of combination will be

(a) PN (b) $\frac{P}{N^2}$

(c) $\frac{N}{P}$ (d) $\frac{P}{N}$

48. If the values of *L*, *C* and *R* in a series *L-C-R* circuit are 10 mH, 100 μF and 100 Ω respectively then the value of resonant frequency will be

(a) $\frac{10^3}{2\pi}$ Hz (b) 2×10^3 Hz

(c) $2\times\frac{10^3}{\pi}$ Hz (d) 10^3 Hz

49. If the current flowing in a choke coil of 2 H is decreasing at the rate of 5 amp/s, then induced emf across the ends of the coil will be

(a) 10^3 volt (b) 2.5 volt

(c) 10 volt (d) – 2.5 volt

50. The values of *XL*, *XC* and *R* in an AC circuit are 8 Ω, 6 Ω and 10 Ω respectively. The total impedance of the circuit will be

(a) 10.2 Ω (b) 12.2 Ω

(c) 10 Ω (d) 24.4 Ω

51. The electric supply line in houses works at 220 volt. The amplitude of emf will be

(a) 220 volt (b) 331 volt

(c) 110 volt (d) 440 volt

52. In the following circuit the values of *L*, *C*, *R* and E_0 are 0.01H, 10^{-5} *F*, 25 Ω and 220 volt respectively. The value of current flowing in the circuit at $f = 0$ and $f = \infty$ will respectively be

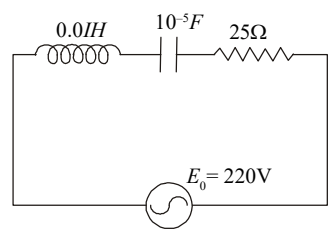


Fig. 27.51

(a) 8 *A* and 0 *A* (b) 0 *A* and 0 *A*

(c) 8 *A* and 8 *A* (d) 0 *A* and 8 *A*

53. If in an AC circuit $XL = XC$ then the value of power factor will be

(a) 1 (b) 0

(c) infinity (d) $\frac{1}{2}$

54. An inductance coil of 1H and a condenser of capacity 1*pF* produce resonance. The resonant frequency will be

(a) $\frac{10^6}{\pi}$ Hz (b) $27\pi\times10^6$ Hz

(c) $\frac{2\pi}{10^6}$ Hz (d) $\frac{10^6}{2\pi}$ Hz

55. An alternating emf $E = 200\sqrt{2}\ \sin(100t)$ volt is connected to a condenser of capacity 0.1 μF through an AC ammeter. The reading of the ammeter will be

(a) 10 mA (b) 80 mA

(c) 40 mA (d) 2 mA

56. A pure capacitor is connected in an AC circuit. The power factor of the circuit will be

(a) 1 (b) infinity

(c) zero (d) 0.5

57. If the equations of alternating voltage and alternating current in an A.C. circuit are $E = E_0 \sin\omega t$ volt and $I = I_0 \sin(\omega t - \pi/2)$ ampere respectively. The power loss in the circuit will be

(a) zero (b) $\frac{E_0 I_0}{\sqrt{2}}$

(c) $\frac{E_0 I_0}{2}$ (d) $\frac{EI}{\sqrt{2}}$

58. The values of L, C and R in an L-C-R series circuit are 4 mH, 40 pF and 100 Ω respectively. The quality factor of the current is

(a) 10 (b) 100

(c) 1000 (d) 10,000

59. The phase difference between alternating emf and current in a purely capacitive circuit will be

(a) zero (b) π

(d) $-\frac{\pi}{2}$ (c) $\frac{\pi}{2}$

60. The power factor of wattless current is

(a) infinity (b) 1

(c) zero (d) $\frac{1}{2}$

61. A coil of self-inductance L and resistance R is connected to a cell of emf E volt. The value of current flowing in the circuit will be

(a) $\sqrt{\frac{EL}{R^2 + L^2}}$ (b) $\sqrt{\frac{E}{R^2 + L^2}}$

(c) $\frac{E}{L}$ (d) $\frac{E}{R}$

62. A bulb of 25 W, 220 V and another bulb of 100 W, 220 V are connected in series with a supply line of 220 V. Then

(a) both bulbs will glow with same brightness

(b) both bulbs will get fused

(c) 25 W bulb will glow more brightly

(d) 100 W bulb will glow more brightly

63. The readings of ammeter and voltmeter in an AC circuit are 10 A and 25 volt respectively. The power loss in the circuit will be

(a) more than 250 W (b) less than 150 W

(c) 250 W (d) 250 W or less than 250 W

64. The value of power factor in an AC circuit will be less if the value of R is

(a) more (b) less

(c) medium (d) infinity

65. The power factor of an L-R circuit is

(a) 1 (b) zero

(c) between 0 and 1 (d) infinity

66. The phase difference between the applied emf and the line current in an anti resonant circuit at resonance is

(a) $\frac{\pi}{2}$ radian (b) π radian

(c) $\frac{3\pi}{2}$ radian (c) zero

67. The value of R/Z is equal to

(a) $\cos\theta$ (b) $\sin\theta$

(c) $\tan\theta$ (d) θ

68. The ratio of apparent power to average power in an AC circuit is equal to

(a) $\cos\theta$ (b) $\frac{1}{\cos\theta}$

(c) form factor (d) $\frac{1}{\cos\theta}$

69. The correct curve between the uniform direct current and time is

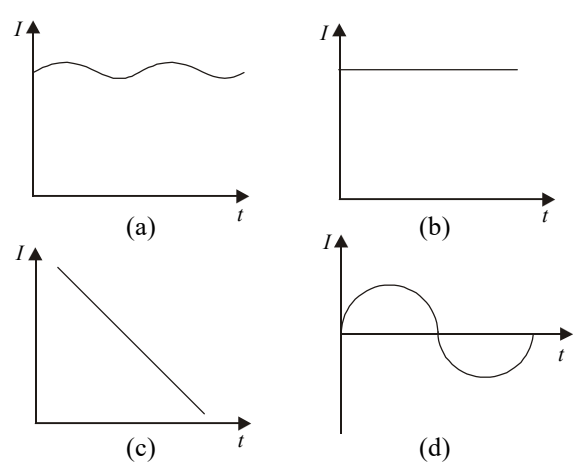


Fig. 27.52

70. In *P-f* curve the half power frequencies are those at which

(a) $P = \frac{P_{max}}{\sqrt{2}}$ (b) $P = \frac{P_{max}}{2}$

(c) $P = \frac{P_{max}}{4}$ (d) $P = P_{max}$

71. The correct phase diagram representing the relation between *IL*, *IC* and *E* in an anti-resonant *L-C* circuit is

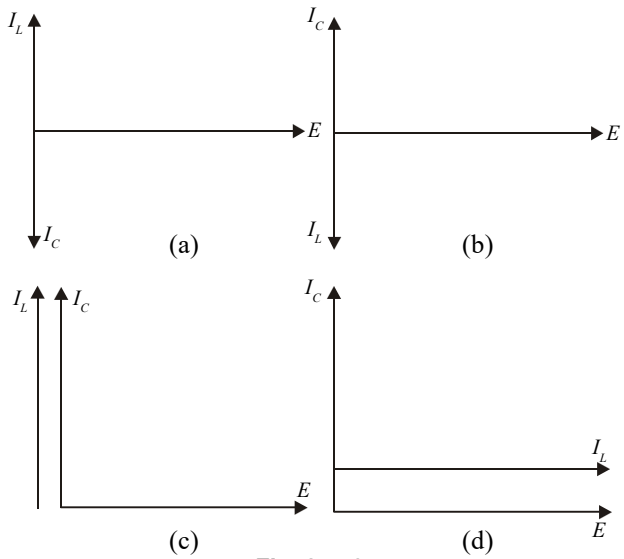


Fig. 27.53

72. The resonance point in $X_L - f$ and $X_C - f$ curves is

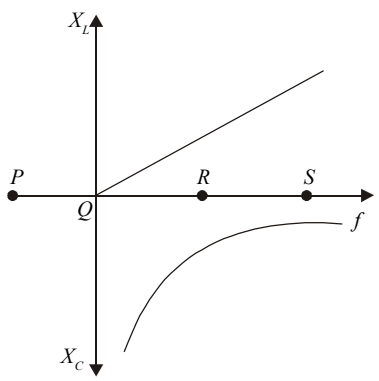


Fig. 27.54

(a) *P* (b) *Q*

(c) *R* (d) *S*

73. The unit of *RC* is

(a) second^{-1} (b) second^2

(c) second (d) second^3

74. On connecting a condenser in parallel to an electric fan connected to an *AC* circuit, the phase angle

(a) decreases (b) increases

(c) remains constant

(d) keeps on increasing and decreasing

75. The correct curve between X_L and $\log f$ is

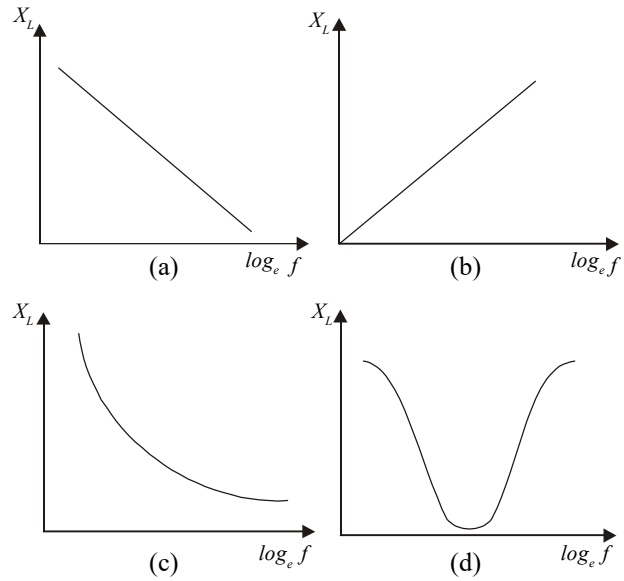


Fig. 27.55

76. The amplitude of effective current in an A.C. circuit is

(a) $I_0 \sin\theta$ (b) $I_0 \cos\theta$

(c) $I_{rms} \sin\theta$ (d) $I_{rms} \cos\theta$

77. The quality factor of an *AC* circuit is related to band width as

(a) inversely proportional

(b) directly proportional

(c) directly proportional to log

(d) inversely proportional to log

78. The impedance of a pure anti-resonant circuit at resonance is

(a) zero (b) infinity

(c) 1 (d) $\frac{1}{2}$

79. The sharpness of resonance in a series *L-C-R* resonant circuit, as the resistance of the circuit is increased, goes on

(a) increasing (b) decreasing

(c) tends from zero to infinity

(d) tends from infinity to zero

80. In the transmission and receiving circuits for radio waves, the series resonant circuits are used as

(a) selector circuits (b) rejecter circuits

(c) rectifiers (d) oscillators

81. The value of admittance at resonance in antiresonant circuit

(a) $\sqrt{G^2 - S^2}$ (b) $G^2 + S^2$

(c) $\sqrt{G^2 + S^2}$ (d) $\frac{G^2}{S^2}$

82. The correct curve between the resistance of a conductor (R) and frequency (f) is

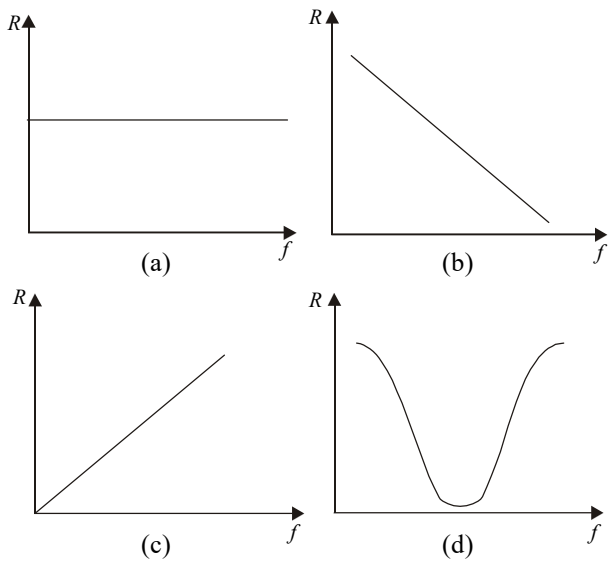


Fig. 27.56

83. Choke coil in an A-C circuit is used for

(a) decreasing AC (b) decreasing AV

(c) increasing AC (d) increasing AV

84. The inductive reactance of a coil is 2500 Ω. On increasing its self-inductance three times, the new inductive reactance will be

(a) 7500 Ω (b) 2500 Ω

(c) 1225 Ω (d) zero

85. In series L-C-R resonant circuit, to increase the resonant frequency

(a) L will have to be increased

(b) C will have to be increased

(c) LC will have to be decreased

(d) LC will have to be increased

86. An electric bulb is marked $100W$, $220V$. Its resistance is

(a) 484 Ω (b) 100 Ω

(c) 220 Ω (d) 48 Ω

87. The correct curve between inductive reactance (XL) and frequency (f) is

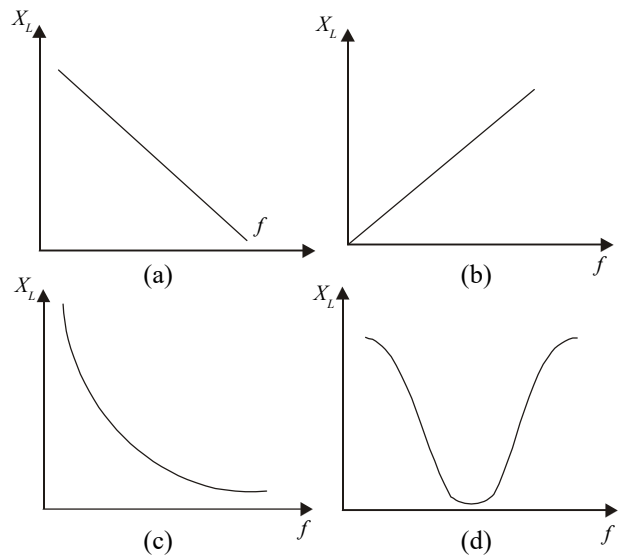


Fig. 27.57

88. An alternating current can be produced by

(a) transformer (b) generator

(c) turbine (d) electric motor

89. The capacitive reactance at 1600 Hz is 81 Ω. When the frequency is doubled then capacitive reactance will be

(a) 40.5 Ω (b) 81 Ω

(c) 162 Ω (d) zero

90. Energy in an inductance coil is stored in the form of

(a) magnetic energy (b) electrical energy

(c) heat energy (d) light energy

91. The incorrect statement about power factor is

(a) it is unit-less

(b) it depends on the nature of the components used

(c) its value can be anything between zero and 1

(d) $\cos\theta = \frac{Z}{R}$

92. If two bulbs of 60 watt and 40 watt are connected in parallel, then

(a) both bulbs with shine equally

(b) both bulbs will get fused

(c) 60 watt bulb will shine more brightly

(d) 40 watt bulb will shine more brightly

93. An alternating voltage source is connected in an AC circuit whose maximum value is 170 volt. The value of potential at a phase angle of 45° will be

(a) 120.56 Volt (b) 110.12 Volt

(c) 240 Volt (d) zero

94. The peak value of AC is $2\sqrt{2}$ ampere. Its apparent value will be

(a) 1 ampere (b) 2 ampere

(c) 4 ampere (d) zero

95. The correct curve between admittance (Y) and frequency (f) in an antiresonant circuit will be

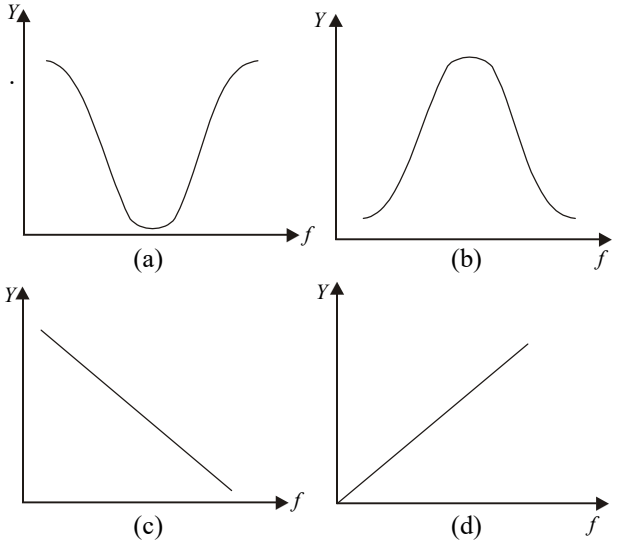


Fig. 27.58

96. The reactance of a condenser of capacity $50\mu F$ for an AC of frequency 2×10^3 Hertz will be

(a) 5 ohm (b) $\frac{2}{\pi}$ ohm

(c) $\frac{3}{\pi}$ ohm (d) – ohm

97. A voltmeter connected in an AC circuit reads 220 volt. IE represents

(a) Peak voltage (b) $R.M.S.$ voltage

(c) Average voltage (d) Mean square voltage

98. In the equation of AC $I = I_0 \sin\omega t$, the current amplitude and frequency will respectively be

(a) $I_0, \frac{\omega}{2\pi}$ (b) $\frac{I_0}{2}, \frac{\omega}{2\pi}$

(c) $I_{rms}, \frac{\omega}{2\pi}$ (d) I_0, ω

99. The inductive reactance of a choke coil of $1/4\pi$ mH in an AC circuit of 50 Hz, will be

(a) 25 ohm (b) 0.25 ohm

(c) 0.025 ohm (d) 2.5 ohm

100. A pure resistance is connected as shown in the figure. The phase difference between the voltage applied and the current flowing in it will be

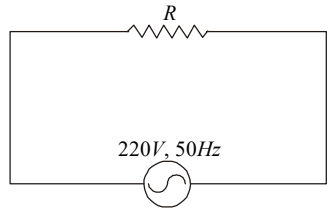


Fig. 27.59

(a) zero (b) $\frac{\pi}{2}$

(c) $-\frac{\pi}{2}$ (d) $\frac{\pi}{4}$

101. What will be the equation of alternating current of frequency 75 Hz if its RMS value is 20 ampere?

(a) $I = 20 \sin 150\pi t$. (b) $I = 20\sqrt{2}\sin(150\pi t)$

(c) $I = \frac{20}{\sqrt{2}}\sin(150\pi t)$ (d) $I = 20\sqrt{2}\sin(75\pi t)$

102. The time taken by an AC of frequency 50 Hz to complete one cycle will be

(a) 2 second (b) 0.2 second

(c) 0.02 second (d) 0.002 second

103. An R-C circuit is as shown in the following diagram. The capacity reactance and impedance will be

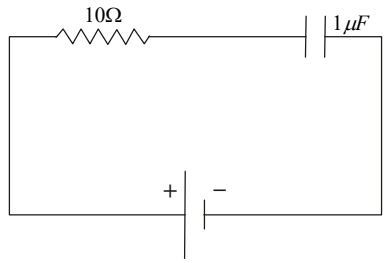


Fig. 27.60

(a) zero (b) infinity

(c) $\frac{1}{\omega c}$ (d) ωc

104. The value of alternating emf in the following circuit will be

(a) 220 volt (b) 140 volt

(c) 20 volt (d) 100 volt

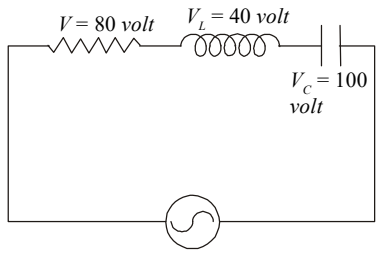


Fig. 27.61

105. The alternating emf applied and the current flowing in an AC circuit are represented by $E = E_0 \sin\omega t$ and $I = I_o \sin(\omega t + \pi/2)$ respectively. The power loss in the circuit will be

(a) zero (b) $\frac{E_o I_o}{2}$

(c) $\frac{E_o I_o}{\sqrt{2}}$ (d) $\frac{E_o I_o}{4}$

106. A resistance of 10 Ω and an inductance of 100 mH are connected in series with an AC source of voltage $V = 100 \cos(100t)$ volt. The phase difference between the voltage applied and the current flowing in the circuit will be

(a) zero (b) $\frac{\pi}{2}$

(c) $\frac{\pi}{2}$ (d) π

107. When the values of inductance and capacitance in an L-C circuit are 0.5 H and 8μF respectively then current in the circuit is maximum. The angular frequency of alternating e.m.f. applied in the circuit will be

(a) 5×10^3 Radian/sec (b) 50 Radian/sec

(c) 5×10^2 Radian/sec (d) 5 Radian/sec

108. The frequency of applied A.V. is 2 KHz. Its time period will be

(a) 0.5×10^{-3} second (b) 5 second

(c) 0.5 second (d) 2 second

109. The value of induced e.m.f. in an R-L circuit at break, as compared to its value at make, will be

(a) less (b) more

(c) sometimes less and sometimes more

(d) nothing can be said

110. The time constant of an R-C circuit during discharge is that time in which charge on condenser plates, as compared to maximum charge (q_0), becomes

(a) 63.3% (b) 36.6%

(c) 50% (d) 25%

111. The unit of I/Z/q is

(a) Newton (b) Dyne

(c) Joule (d) Joule/s

112. An AC voltmeter in an L-C-R circuit reads 30 volt across resistance, 80 volt across inductance and 40 volt across capacitance. The value of applied voltage will be

(a) 50 volt (b) 25 volt

(c) 150 volt (d) 70 volt

113. An experimentalist has a coil of 3 mH. He wants to make a circuit whose frequency is 106 Hz. The capacity of condenser used will be

(a) 0.44 pf (b) 8.44 pf

(c) 4.44 pf (d) zero

114. A coil of 10 mH and 10 Ω resistance is connected in parallel to a capacitance of 0.1μF. The impedance of the circuit at resonance will be

(a) $10^2\ \Omega$ (b) $10^4\ \Omega$

(c) $10^6\ \Omega$ (d) $10^8\ \Omega$

115. The self inductance of a coil is 1/2 henry. At what frequency will its inductive reactance be 3140 Ω

(a) 100 Hz (b) 10 Hz

(c) 1000 Hz (d) 10000 Hz

116. The capacitive reactance of a condenser of capacity 25μF for an AC of frequency 4000 Hz will be

(a) $\frac{5}{\pi}\ \Omega$ (b) $\frac{10}{\pi}\ \Omega$

(c) $5\pi\ \Omega$ (d) $\frac{\pi}{5}\ \Omega$

117. The peak value of an AC is $2\sqrt{2}$ ampere. Its RMS value will be

(a) $\sqrt{2}\,A$ (b) $2\sqrt{2}\,A$

(c) $2\,A$ (d) zero

118. If the inductance of a coil is 1 henry then its effective resistance in a $D.C.$ circuit will be

(a) ∞ (b) zero

(c) 1 Ω (d) 2 Ω

119. An $A.C.$ ammeter can be used in

(a) only in DC circuit

(b) only in AC circuit

(c) both in AC and DC circuits

(d) neither in AC nor in DC circuits

120. The value of power factor, in an AC circuit, is zero in

(a) only inductive circuit (b) only resistive circuit

(c) an L-R circuit (d) an R-C circuit

121. The power loss in an AC circuit is ErmsIrms, when in the circuit there is only

(a) C (b) L

(c) R (d) L, C and R

122. In the following circuit diagram, if the frequency of the source is doubled then the value of current flowing in R will become

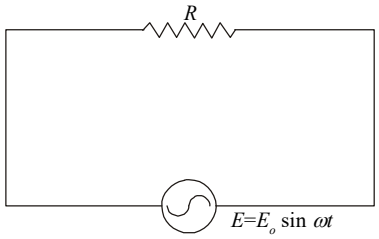


Fig. 27.62

(a) double (b) half

(c) remain unchanged (d) four times

123. The correct formula for the angular frequency ω_0 of an L-C resonant circuit is

(a) $\frac{1}{\sqrt{LC}}$ (b) $\sqrt{LC}$

(c) $\frac{1}{2\pi\sqrt{LC}}$ (d) $\frac{1}{2\pi LC}$

124. The specific resistance of fuse wire is

(a) high (b) low

(c) zero (d) infinity

125. The energy expended in 1 kW electric heater in 30 seconds will be

(a) $3 \times I0^4$ joule (b) $3 \times I0^4$ erg

(c) $3 \times I0^4$ eV (d) zero

PASSAGE 1

Read the following passage and answer the questions given at the end.

A captain is shipwrecked on a deserted tropical island. He possesses some electrical devices that could be operated using a generator but he does not have magnets. The earth's magnetic field at that location is horizontal and is equal to 8×10^{-5} T. He decides to use this magnetic field for a generator by rotating a large circular coil of wire at a high rate. His requirement is 9 V and he thinks he can rotate the coil at a speed 30 rpm by turning a crank handle. The number of turns in the coil are 2000.

1. The area of the coil must be ____.

(a) 1.8 m^2 (b) 18 m^2

(c) 8 m^2 (d) none of these

2. Is this device feasible?

(a) Yes (b) no

(c) depends on the availability of material

3. What is the translational speed of a point on the coil?

(a) 2.8 ms^{-1} (b) 3.0 ms^{-1}

(c) 3.5 ms^{-1} (d) 5.7 ms^{-1}

(e) none of these

Solution **1.** (b) $\varepsilon = \frac{-d\phi}{dt} \Rightarrow 9 = NBA\omega \sin \omega t$

or $$9 = \frac{8\times10^{-5}\times A\times30\times2\pi\times2000}{60}$$

$$A = \frac{9\times10^5}{50\times10^3} = 18\text{ m}^2$$

Solution **2.** (b)

Solution **3.** (c)

$v = R\omega$ and $\pi R^2 = 18$

or $R = 2.3$ m

$v = 2.3\,(\pi/2)$,

$= 3.51$ ms^{-1}

PASSAGE 2

Read the following passage and answer the questions given at the end.

Fig. 27.63 shows a cross-over network in a loud speaker system. One branch consists of a capacitor C and a resistor R in series (the tweeter). This branch is in parallel with a second branch (The woofer) that consists of an inductor L and a resistor R in series. The same source voltage with angular frequency ω (from an amplifier) is applied across each parallel branch.

1. The impedance of the tweeter and woofer branches are respectively.

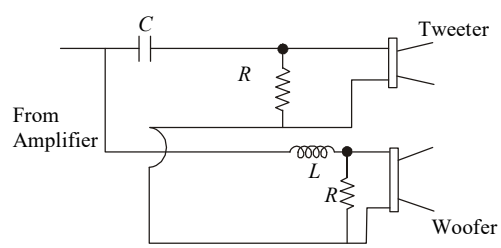


Fig. 27.63

(a) $\sqrt{R^2+X_c^2}$, $\sqrt{R^2+X_L^2}$

(b) $\sqrt{R^2+X_L^2}$, $\sqrt{R^2+X_c^2}$

(c) $\sqrt{R^2+(X_L-X_C)^2}$ each

(d) $\sqrt{\left(\frac{1}{R^2}+\left(\frac{1}{X_C}-\frac{1}{X_L}\right)^2\right)^{-1}}$ each

2. The response 2 in Fig. 27.64 is for

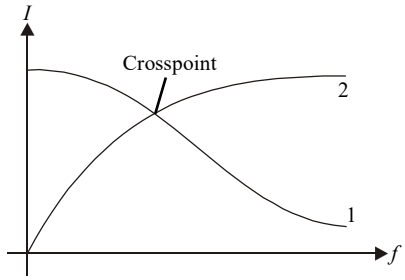


Fig. 27.64

(a) tweeter (b) woofer
(c) both woofer and tweeter.

3. The cross-over frequency f_c is

(a) $\frac{1}{2\pi\sqrt{LC}}$ (b) $\frac{1}{2\pi RC}$

(c) $\frac{R}{2\pi L}$ (d) none

4. For frequency $f < f_c$ the out-put of —— is predominant.

(a) tweeter (b) woofer
(c) equal for both
(d) insufficient data to reply

Solution **1.** (a)

Solution **2.** (a)

Solution **3.** (a) resonance $f = \frac{1}{2\pi\sqrt{LC}}$

Solution **4.** (b)

PASSAGE 3

Read the following passage and answer the questions given at the end.

Generators at most of the power stations produce electricity at 2200 volts. Huge losses would result if electricity were transmitted at this voltage over long distances. Transformers are used to step up this voltage nearly 100 times before transmission to the cities. Near the cities this voltage is stepped down at sub-station back to about 2200 V and then further stepped down in the cities before it is supplied to the consumers at 220 V.

1. The process of stepping up or stepping down of voltage can be done with

(a) alternating voltage
(b) direct voltage only
(c) both alternating and direct voltage

Solution (a)

2. Stepping up of voltage by a factor of 100, reduces the current by a factor of

(a) 10 (b) 100
(c) leaves the current unchanged
(d) increases the current by a factor of 100

Solution (b)

3. At present, electricity production is not taking place using

(a) nuclear fission
(b) nuclear fusion
(c) burning of coil
(d) it is being produced using all the above methods

Solution (b)

PASSAGE 4

Read the following passage and answer the questions given at the end.

The current in an *L-C-R* series circuit fed by an alternating voltage source $V = V_0 \sin \omega t$ is given by

$$i = \frac{V_0 \sin(\omega t - \phi)}{\sqrt{R^2 + \left(L\omega - \frac{1}{C\omega}\right)^2}} \quad .....(1)$$

$$\text{where } \tan\phi = \frac{\omega L - \frac{1}{\omega C}}{R} \quad .....(2)$$

ϕ is the phase difference between the current and the voltage. The average power delivered by the source to the circuit is given by the equation

$$P = \frac{1}{2}\frac{V_0^2 \cos\phi}{|Z|} \quad .....(3)$$

where $|Z|$ is the impedance of the circuit given by the denominator of equation (1).

1. At resonance, the angle ϕ is

(a) $\frac{\pi}{4}$ (b) $\frac{\pi}{2}$

(c) $\frac{\pi}{2}$ (d) zero

Solution (d)

2. If $R = 100\ \Omega$, $L = 10\ mH$ and $C = 10^{-4}\ F$. the value of resonant frequency will be nearly

(a) 50 cps (b) 160 cps
(c) 100 cps (d) 960 cps

Solution (b)

3. The current in the *L-C-R* series circuit

(a) lags behind the voltage

(b) leads the voltage

(c) is in phase with the voltage

(d) At a given instant (a), (b) or (c)

Solution (d)

4. In an *AC* circuit, the voltage is given by $V = 110 \sin 2\pi (60)\, t$. The voltage across the inductor, capacitor as well as resistor

(a) must be less than 110 *V*

(b) must be less than 220 *V*

(c) many be more or less than 110 *V*

(d) may be more than 110 *V* across *L* or *C* but must be less than 110 *V* cross *R*.

Solution (d)

Answers to Questions for Practice

1.	(a)	**2.**	(a)	**3.**	(a, d)	**4.**	(d)	**5.**	(c)	**6.**	(d)	**7.**	(c)
8.	(a)	**9.**	(a)	**10.**	(b)	**11.**	(b)	**12.**	(c)	**13.**	(c)	**14.**	(b)
15.	(b)	**16.**	(a,b)	**17.**	(a,b)	**18.**	(b,d)	**19.**	(b)	**20.**	(c)	**21.**	(b)
22.	(a)	**23.**	(a)	**24.**	(b)	**25.**	(c)	**26.**	(a)	**27.**	(d)	**28.**	(d)
29.	(b)	**30.**	(a)	**31.**	(a)	**32.**	(c)	**33.**	(a)	**34.**	(b)	**35.**	(b)
36.	(c)	**37.**	(c)	**38.**	(a)	**39.**	(a)	**40.**	(a)	**41.**	(b)	**42.**	(a)
43.	(b)	**44.**	(b)	**45.**	(b)	**46.**	(a)	**47.**	(d)	**48.**	(a)	**49.**	(c)
50.	(a)	**51.**	(b)	**52.**	(b)	**53.**	(a)	**54.**	(d)	**55.**	(d)	**56.**	(c)
57.	(a)	**58.**	(b)	**59.**	(c)	**60.**	(c)	**61.**	(d)	**62.**	(c)	**63.**	(d)
64.	(b)	**65.**	(c)	**66.**	(d)	**67.**	(a)	**68.**	(b)	**69.**	(b)	**70.**	(b)
71.	(b)	**72.**	(c)	**73.**	(c)	**74.**	(a)	**75.**	(b)	**76.**	(b)	**77.**	(a)
78.	(b)	**79.**	(b)	**80.**	(a)	**81.**	(c)	**82.**	(a)	**83.**	(a)	**84.**	(a)
85.	(c)	**86.**	(a)	**87.**	(b)	**88.**	(b)	**89.**	(a)	**90.**	(a)	**91.**	(d)
92.	(c)	**93.**	(a)	**94.**	(b)	**95.**	(a)	**96.**	(d)	**97.**	(b)	**98.**	(a)
99.	(c)	**100.**	(a)	**101.**	(b)	**102.**	(c)	**103.**	(b)	**104.**	(d)	**105.**	(a)
106.	(c)	**107.**	(c)	**108.**	(a)	**109.**	(b)	**110.**	(b)	**111.**	(c)	**112.**	(a)
113.	(b)	**114.**	(b)	**115.**	(c)	**116.**	(a)	**117.**	(c)	**118.**	(b)	**119.**	(c)
120.	(a)	**121.**	(c)	**122.**	(c)	**123.**	(a)	**124.**	(a)	**125.**	(a)		

EXPLANATION

20 (c) $\tan \varphi = \frac{X}{R} = 1$. Power factor $= \cos \varphi = \frac{1}{\sqrt{2}}$.

21 (b)The *LC* circuit draws no power. When $\omega L = \frac{1}{\omega C}$, the impedances of the *RC* and *LR* circuits are equal, and they draw the same power.

22 (a) The supply voltage *E*, the potential difference (V_R) across the resistance, and the potential difference (V_C) across the capacitor are related as

$$E^2 = V_R^2 + V_C^2 \;\therefore\; V_C = \sqrt{220^2 - (90)^2} = 10^2 \sqrt{4.03}$$