LARC BASIC AMATEUR RADIO COURSE - 2019

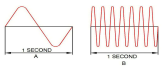
CAPACITANCE and INDUCTANCE (Chapter 4)

Mike Cook© VE3ZMC

1

Capacitance and Inductance are very important properties affecting AC currents.

They are both frequency-dependent properties.



We will also look at the phenomenon of resonance which is very important for radio and involves both capacitance and inductance.

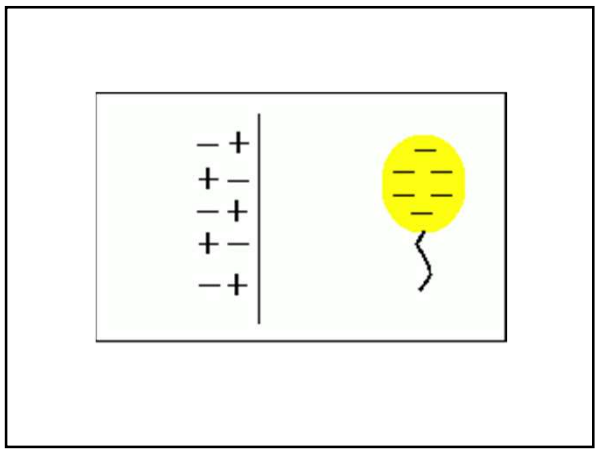
There are two kinds of induction, electrostatic and electromagnetic.

Electrostatic induction is involved in the way capacitors work so we will start with capacitance.

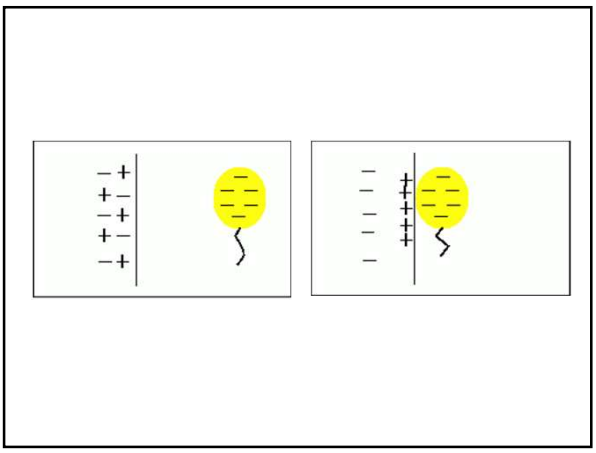
2

3

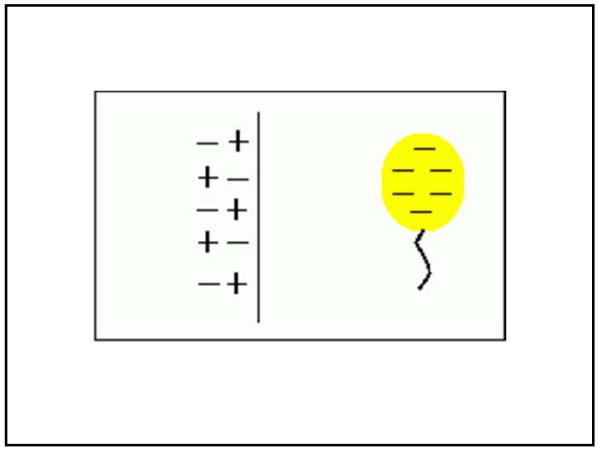
4



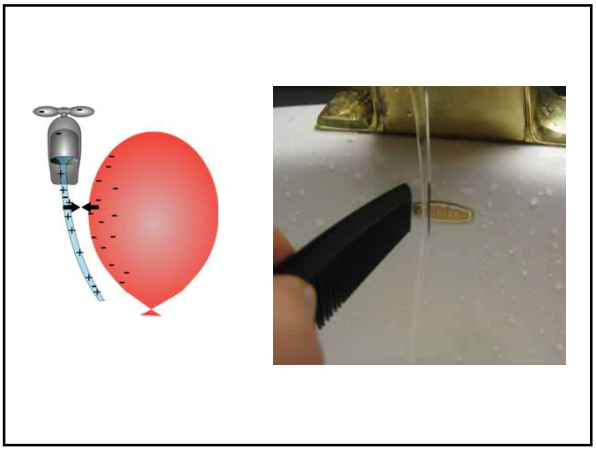
5



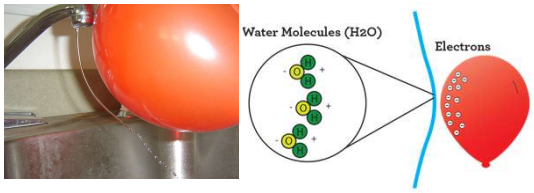
7



6



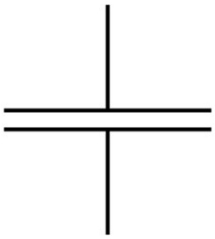
8

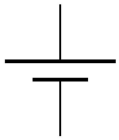


Electrostatic induction

9

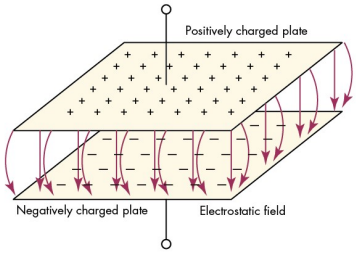
Capacitance



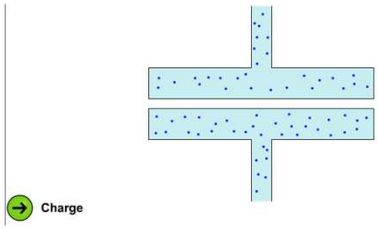


The symbol for capacitance is C and the units are Farads (F)

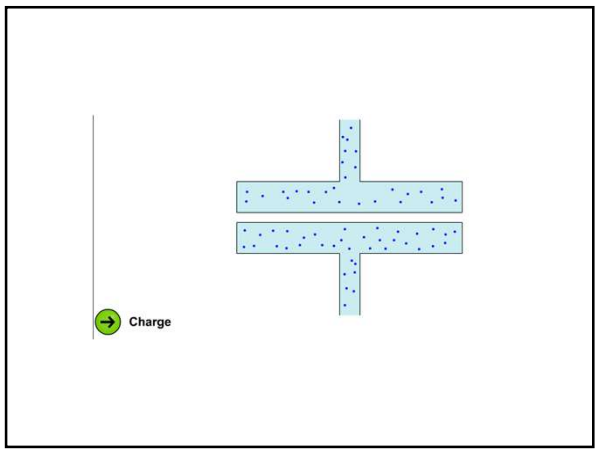
10



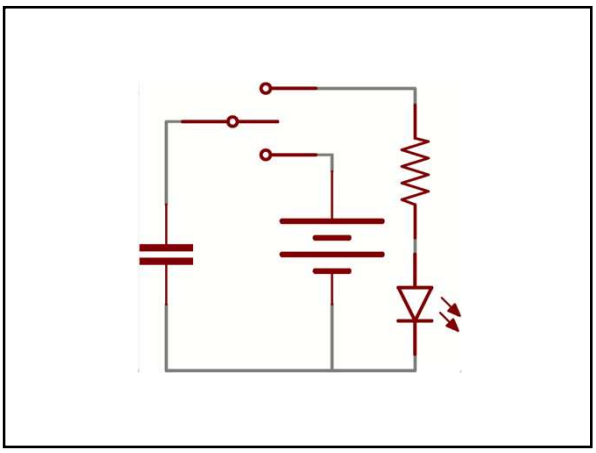
11



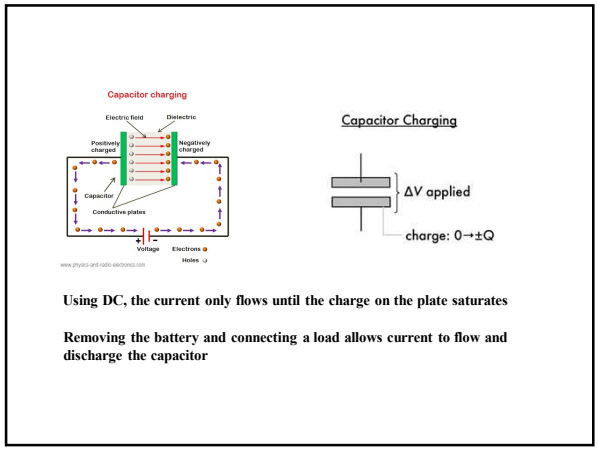
12


Charge

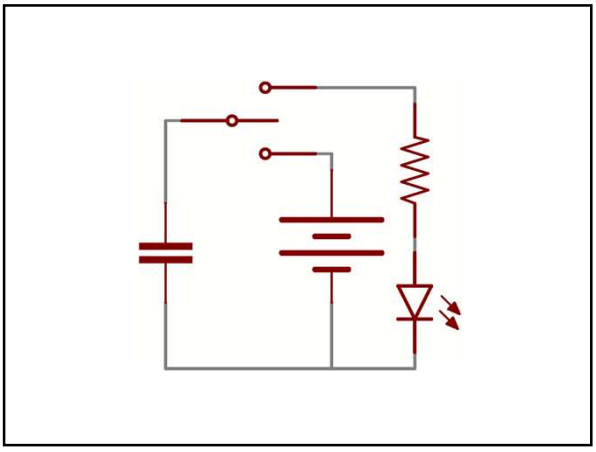
13



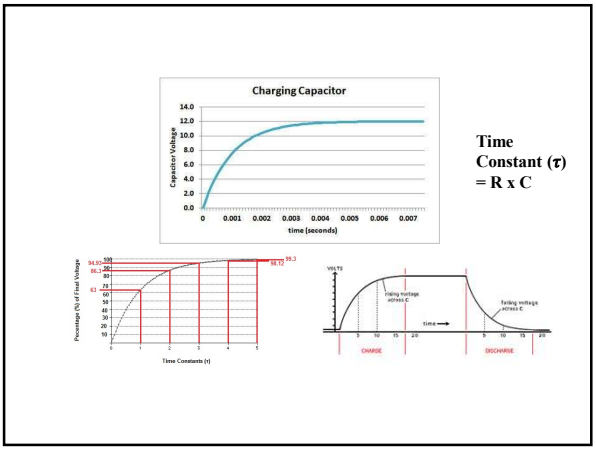
15


Capacitor charging
Electric field
Dielectric
Positively charged
Negatively charged
Capacitor
Conductive plates
Voltage
Electrons
Holes
Capacitor Charging
ΔV applied
charge: 0→±Q
Using DC, the current only flows until the charge on the plate saturates
Removing the battery and connecting a load allows current to flow and discharge the capacitor

14

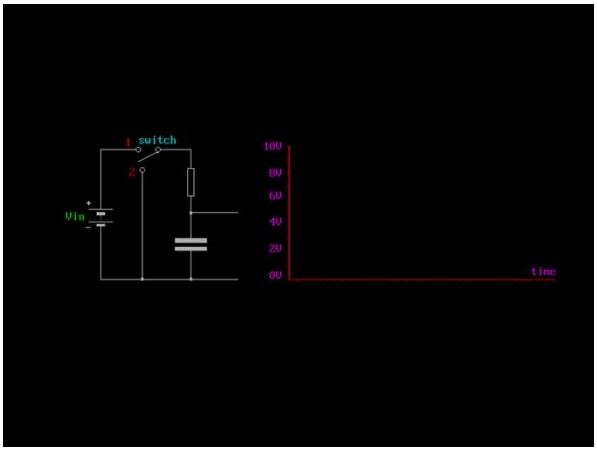


16



Time Constant (τ) = R x C

17

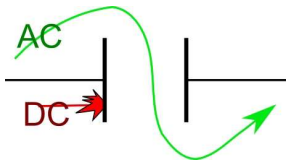


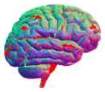
18

A very brief flow of current occurs and then it stops.

The charge is stored. ***So capacitors block DC current***

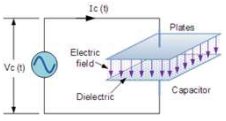
But what happens if AC current is used?



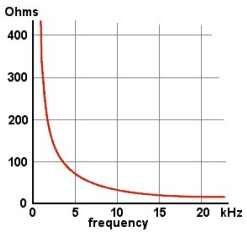


AC can pass depending on frequency (f) (or wavelength (λ))

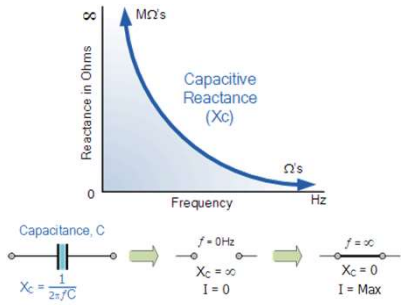
19



For "resistance" to AC current we use the term "reactance" symbol X and units Ω

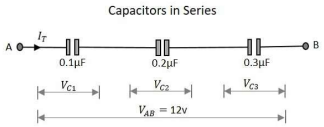


20



21

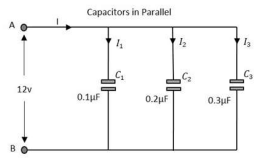
Series and Parallel calculations



$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \qquad C_T = \frac{C_1 \times C_2}{C_1 + C_2}$$

$V_T = V_{C1} + V_{C2} + V_{C3}$ $\qquad I = I_1 = I_2 = I_3$

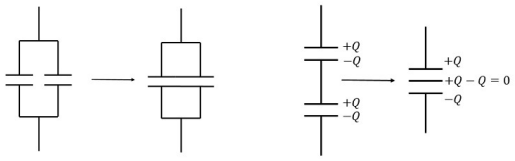
22



$$C_T = C_1 + C_2 + C_3$$

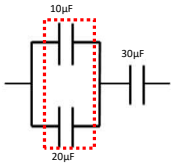
$V_T = V_1 = V_2 = V_3$ $\qquad I_T = I_1 + I_2 + I_3$

23



$C_{total} = C_1 + C_2$ $\qquad 1/C_{total} = 1/C_1 + 1/C_2$

24



Parallel first:
$C_1 = 10\mu F + 20\mu F = 30\mu F$

Then series:
$1/C_{total} = 1/C_1 + 1/C_2 = 1/30\mu F + 1/30\mu F = 2/30\mu F$

$C_{total} = 30\mu F/2 = 15\mu F$

Or 30x30/30+30 = 900/60 = 15

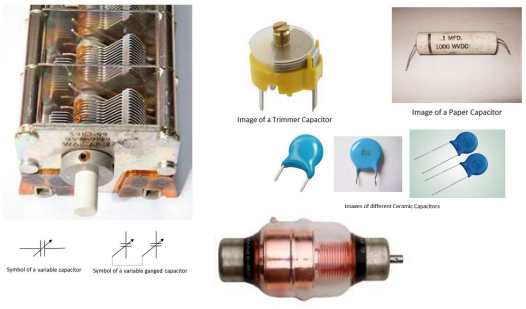
25

There are many types of capacitors


Images of Glass Capacitors

26

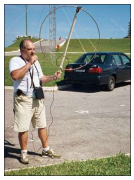
27



28

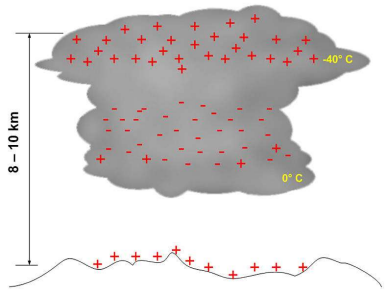
Capacitance depends on the area of the plates, the distance between the plates, and the dielectric in between them. The dielectric can include air, glass, polyethylene, mica, Teflon® etc.

Vacuum capacitors (fixed or variable) are designed to overcome high voltage breakdown. You will see them used in loop antennas.



29

31



30

Can you see the positive upstroke?

Luminosity is very low because the current is very low

Photographs like this are very rare

32

33

B-005-9-6 What determines the capacitance of a capacitor?
1. The material between the plates, the area of one side of one plate, the number of plates and the spacing between the plates
2. The material between the plates, the number of plates and the size of the wires connected to the plates
3. The number of plates, the spacing between the plates and whether the dielectric material is N type or P type
4. The material between the plates, the area of one plate, the number of plates and the material used for the protective coating

34

B-005-9-3 If two equal-value capacitors are connected in series, what is their total capacitance?
1. Twice the value of one capacitor
2. The same as the value of either capacitor
3. The value of one capacitor times the value of the other
4. Half the value of either capacitor

35

B-005-9-9 Three 15 microfarad capacitors are wired in series. The total capacitance of this arrangement is:
1. 45 microfarads
2. 12 microfarads
3. 5 microfarads
4. 18 microfarads

36

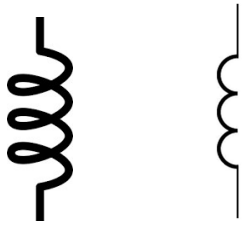
B-005-9-7 If two equal-value capacitors are connected in parallel, what is their capacitance?
1. The same value of either capacitor
2. The value of one capacitor times the value of the other
3. Half the value of either capacitor
4. Twice the value of either capacitor

37

B-005-10-2 How does a capacitor react to AC?
1. As the frequency of the applied AC increases, the reactance decreases
2. As the frequency of the applied AC increases, the reactance increases
3. As the amplitude of the applied AC increases, the reactance increases
4. As the amplitude of the applied AC increases, the reactance decreases

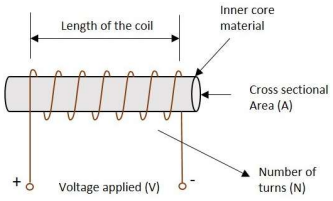
38

Inductance



The symbol for inductance is L and the units are Henrys (H)

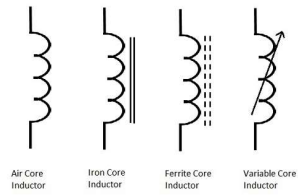
39



40

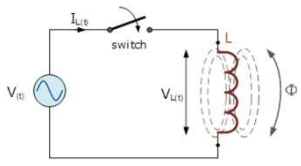
41

42



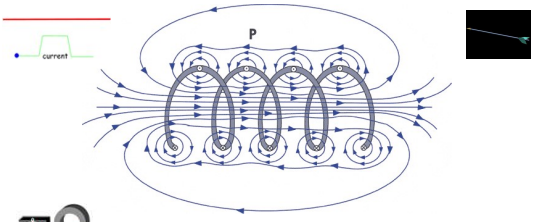
43

The inductor is the other frequency-dependent device which we need to learn about.



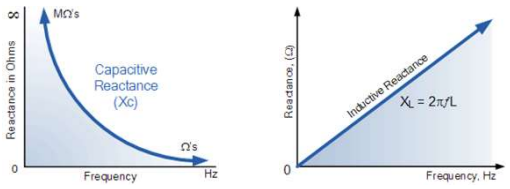
Coiled inductors work by electromagnetic induction

44



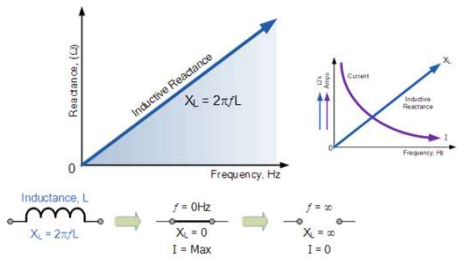
The changing magnetic field causes (induces) a current which is in the opposite direction. It therefore opposes current flow.
It is called the self-inductance (or just inductance) of a coil.

45

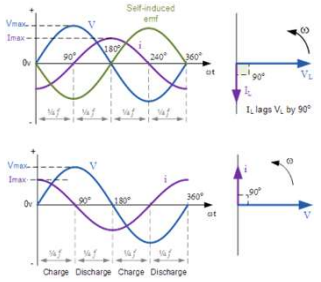


Inductors "block" AC and pass DC. Capacitors "block" DC and pass AC
A better word is impede

47



46



ELI

the

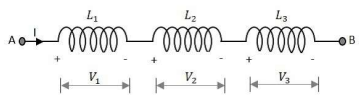
ICE

man

48

Series and Parallel calculations *similar to resistance*

Inductors in Series

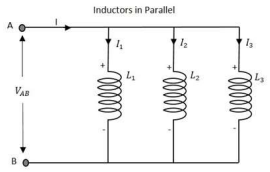


$$L_T = L_1 + L_2 + L_3$$

$V = V_1 + V_2 + V_3$ $I = I_1 = I_2 = I_3$

49

Inductors in Parallel



$$L_T = \frac{L_1 \times L_2}{L_1 + L_2}$$

$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}$$

$V = V_1 = V_2 = V_3$ $I = I_1 + I_2 + I_3$

50

B-005-9-1 If two equal-value inductors are connected in series, what is their total inductance?
1. Half the value of one inductor
2. The same as the value of either inductor
3. The value of one inductor times the value of the other
4. Twice the value of one inductor

51

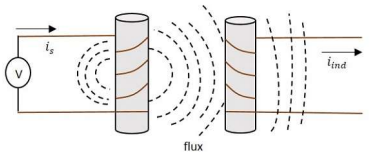
B-005-9-5 What determines the inductance of a coil?
1. The core material, the number of turns used to wind the core and the frequency of the current through the coil
2. The core diameter, the number of turns of wire used to wind the coil and the type of metal used for the wire
3. The core material, the core diameter, the length of the coil and the number of turns of wire used to wind the coil
4. The core material, the core diameter, the length of the coil and whether the coil is mounted horizontally or vertically

52

B-005-10-10 What is the approximate inductive reactance of a 1.0 Henry choke coil used in a 60 hertz circuit?
1. 376 ohms
2. 3760 ohms
3. 188 ohms
4. 1888 ohms

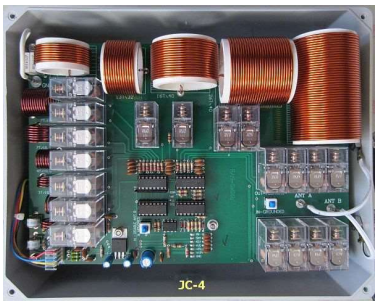
53

Mutual Inductance

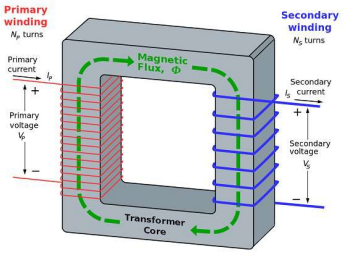


This is magnetic coupling

54

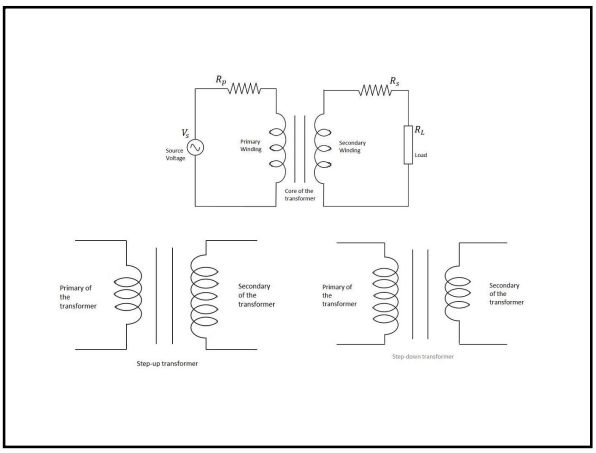


55



Current is induced in the secondary coil

56



57

$$\frac{E_S}{E_P} = \frac{N_S}{N_P} \qquad Eqn\,4-3$$

$E_P = 150$ VAC

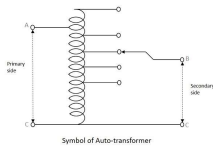
$N_P = 120$ turns

$\frac{N_S}{N_P} = 5:2$

$N_S = \frac{5 \times 120}{2} = 300$ turns

$E_S = \frac{300 \times 150}{120} = 375\,\text{V}$

58



Auto-transformers do not isolate

59

60

B-005-11-4 In a mains power transformer, the primary winding has 250 turns, and the secondary has 500. If the input voltage is 110 volts, the likely secondary voltage is:
1. 440 V
2. 220 V
3. 560 V
4. 24 V

61

B-005-11-2 A transformer operates a 6.3 volt 2 ampere light bulb from its secondary winding. The power consumed by the primary winding is approximately:
1. 13 watts
2. 6 watts
3. 8 watts
4. 3 watts

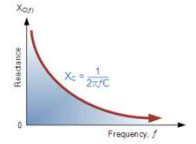
62

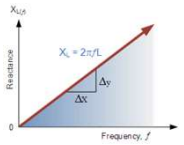
B-005-10-1 How does a coil react to AC?
1. As the amplitude of the applied AC increases, the reactance decreases
2. As the amplitude of the applied AC increases, the reactance increases
3. As the frequency of the applied AC increases, the reactance increases
4. As the frequency of the applied AC increases, the reactance decreases

63

Impedance

We know about reactance now. Circuits can have reactance and resistance





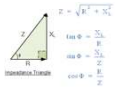
$$X_C = \frac{1}{2\pi fC} \quad \text{Eqn 4-7}$$

$$X_L = 2\pi fL \quad Eqn\,4-6$$

64

Impedance Z (*measured in* Ω) is the sum of reactance and resistance

$$Z = \sqrt{R^2 + X^2} \quad \text{Eqn 4-8}$$



Matching impedances is an important concept in radio. The output of a transmitter should have the same impedance as the feed line and antenna it is connected to.

Hams spend a lot of time adjusting the impedance of their antennas so that the maximum power transfer from the transmitter can happen.

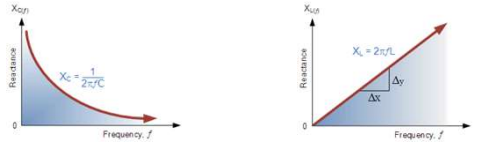
65

Resonance

66

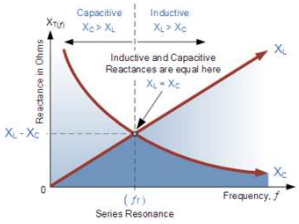
67

68



At some frequency X_C will equal X_L

69

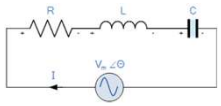


When $X_c = X_L$ the reactances cancel leaving only resistance

70

This is an example of a series resonant circuit ***aka a tuned circuit***

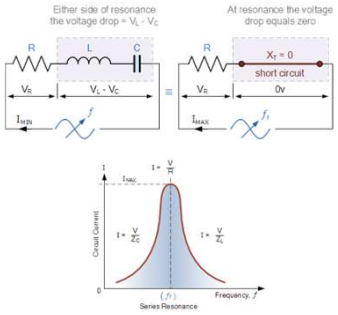
Acceptor circuit



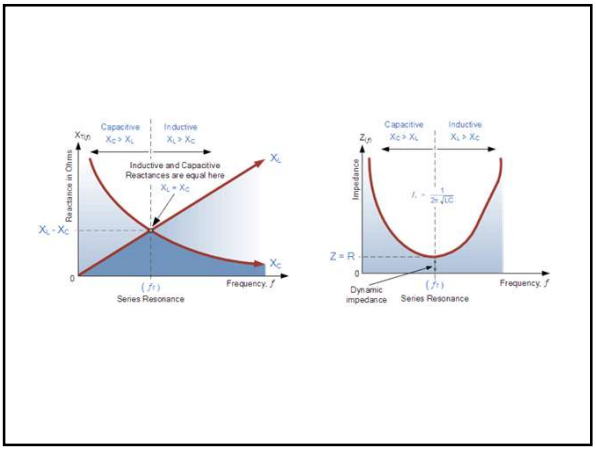
Frequency selection
Band pass filter

$$f_r = \frac{1}{2\pi\sqrt{LC}} \quad Eqn\ 4-11$$

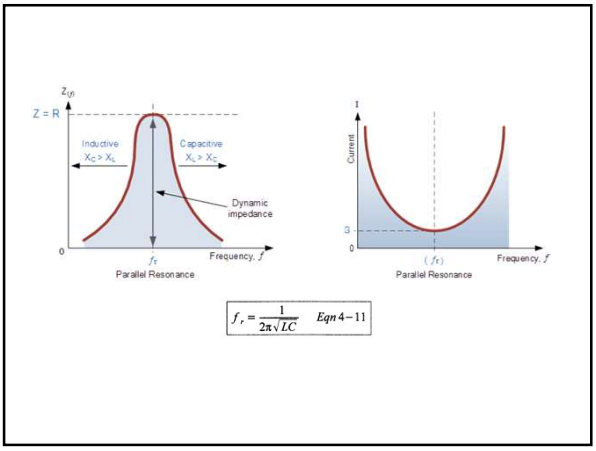
71



72



73

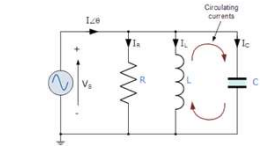


$$f_r = \frac{1}{2\pi\sqrt{LC}} \quad Eqn\ 4-11$$

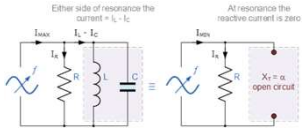
75

This is an example of a parallel resonant circuit ***also a tuned circuit***

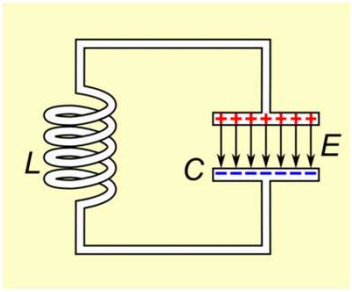
Rejector circuit



Band stop filter
IF trap
"Tank" circuit in an oscillator

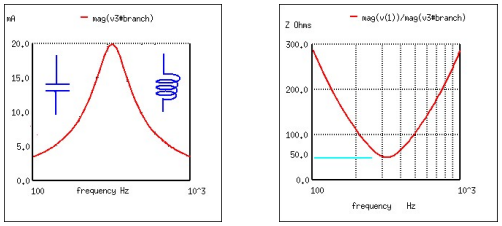


74



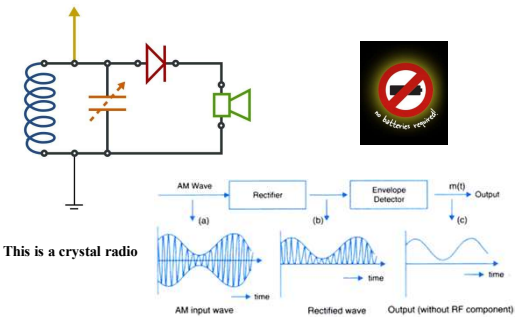
Tank circuit

76



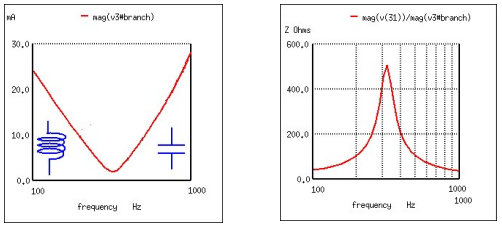
Series resonance

77



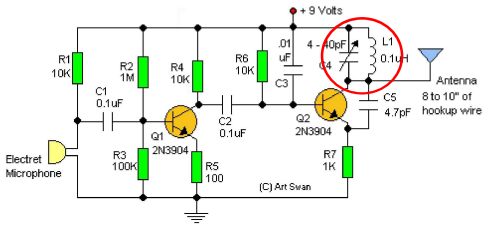
This is a crystal radio

79



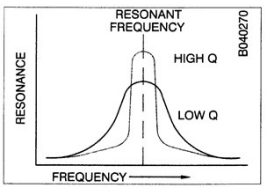
Parallel resonance

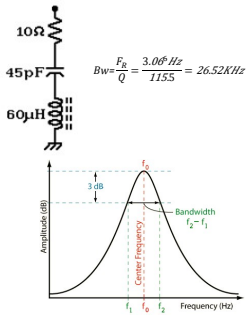
78



80

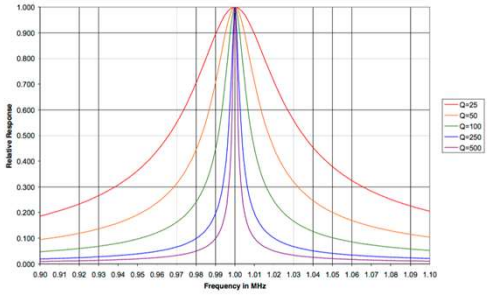
Q



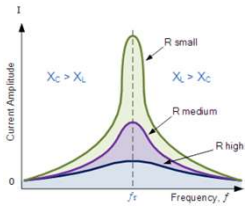


$$Bw = \frac{F_R}{Q} = \frac{3.06^6 Hz}{1155} = 26.52KHz$$

81



83



82

B-005-12-1 Resonance is the condition that exists when:
1. inductive reactance and capacitive reactance are equal
2. inductive reactance is the only opposition in the circuit
3. the circuit contains no resistance
4. resistance is equal to the reactance

84

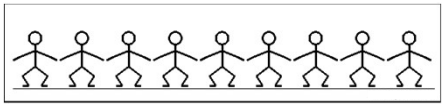
B-005-12-7 In a series resonant circuit at resonance, the circuit has:
1. low impedance
2. high impedance
3. low mutual inductance
4. high mutual inductance

85

B-006-6-5 What happens when the impedance of an electrical load is equal to the internal impedance of the power source?
1. The electrical load is shorted
2. The source delivers maximum power to the load
3. No current can flow through the circuit
4. The source delivers minimum power to the load

86

Next time: Waves and Propagation



87