LAB # 3

CSE-203L Circuit & Systems-II Lab

Fall 2022

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Class Section: **C**

"On my honor, as student of University of Engineering and Technology, I have neither given nor received unauthorized assistance on this academic work."

Student Signature: ______________

Submitted to:

Engr. Faiz Ullah

1st November, 2022

Department of Computer Systems Engineering

TITLE:

Inductive Reactance

OBJECTIVES:

- To learn the basic concept of inductive reactance of an inductor.
- To investigate the relationship between inductance and frequency.
- To plot a graph of inductive reactance versus frequency.

APPARATUS:

- Oscilloscope
- AC Function Generator

COMPONENTS:

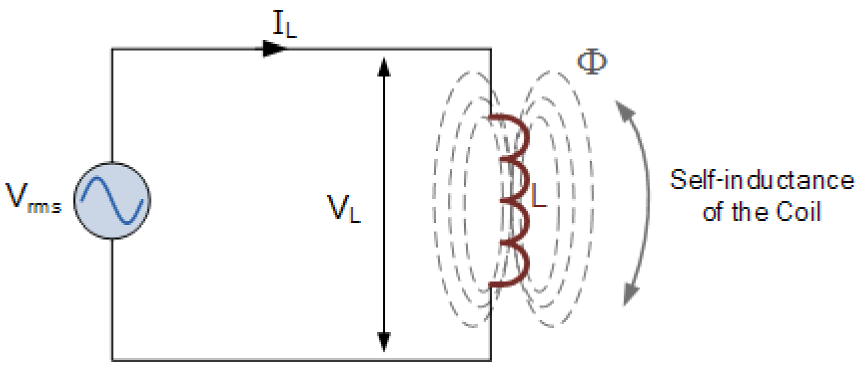
- 1 mH Inductor
- 10 mH Inductor
- 10k Ω Resistor

INDUCTIVE REACTANCE:

As the component we are interested in is an inductor, the reactance of an inductor is therefore called “Inductive Reactance”. In other words, an inductors electrical resistance when used in an AC circuit is called Inductive Reactance.

Inductive Reactance which is given the symbol XL, is the property in an AC circuit which opposes the change in the current. In Capacitors in AC Circuits, we see that in a purely capacitive circuit, the current IC “LEADS” the voltage by 90o. In a purely inductive AC circuit the exact opposite is true, the current IL “LAGS” the applied voltage by 90o, or (π/2 rads).

AC INDUCTOR CIRCUIT

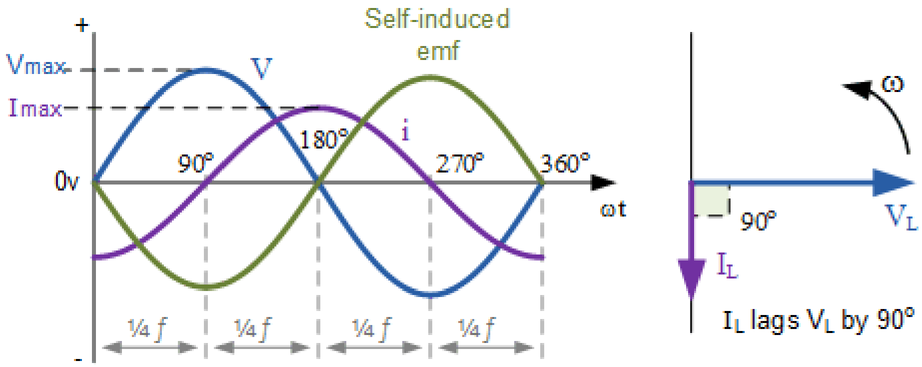


In the purely inductive circuit above, the inductor is connected directly across the AC supply voltage. As the supply voltage increases and decreases with the frequency, the self-induced back emf also increases and decreases in the coil with respect to this change.

We know that this self-induced emf is directly proportional to the rate of change of the current through the coil and is at its greatest as the supply voltage crosses over from its positive half cycle to its negative half cycle or vice versa at points, 0o and 180o along the sine wave.

Consequently, the minimum rate of change of the voltage occurs when the AC sine wave crosses over at its maximum or minimum peak voltage level. At these positions in the cycle the maximum or minimum currents are flowing through the inductor circuit and this is shown below.

AC INDUCTOR PHASOR DIAGRAM



These voltage and current waveforms show that for a purely inductive circuit the current lags the voltage by 90o. Likewise, we can also say that the voltage leads the current by 90o. Either way the general expression is that the current lags as shown in the vector diagram. Here the current vector and the voltage vector are shown displaced by 90o. The current lags the voltage.

We can also write this statement as, VL = 0o and IL = -90o with respect to the voltage, VL. If the voltage waveform is classed as a sine wave then the current, IL can be classed as a negative cosine and we can define the value of the current at any point in time as being:

$$I_L = I_{max} \sin(\omega t - 90^o)$$

Where: ω is in radians per second and t is in seconds.

Since the current always lags the voltage by 90o in a purely inductive circuit, we can find the phase of the current by knowing the phase of the voltage or vice versa. So if we know the value of VL, then IL must lag by 90o. Likewise, if we know the value of IL then VL must therefore lead by 90o. Then this ratio of voltage to current in an inductive circuit will produce an equation that defines the Inductive Reactance, XL of the coil.

INDUCTIVE REACTANCE

$$X_L = \frac{V_L}{I_L} = \omega L \ \ (\Omega)$$

We can rewrite the above equation for inductive reactance into a more familiar form that uses the ordinary frequency of the supply instead of the angular frequency in radians, ω and this is given as:

$$X_L = 2\pi f L$$

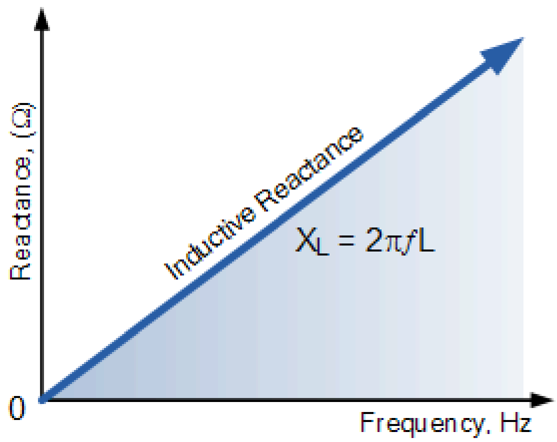
Where: *ƒ* is the Frequency and L is the Inductance of the Coil and 2π*ƒ* = ω.

From the above equation for inductive reactance, it can be seen that if either of the Frequency or Inductance was increased the overall inductive reactance value would also increase. As the frequency approaches infinity the inductors reactance would also increase to infinity acting like an open circuit.

However, as the frequency approaches zero or DC, the inductors reactance would decrease to zero, acting like a short circuit. This means then that inductive reactance is “proportional” to frequency.

In other words, inductive reactance increases with frequency resulting in XL being small at low frequencies and XL being high at high frequencies and this demonstrated in the following graph:

INDUCTIVE REACTANCE AGAINST FREQUENCY

	The slope shows that the "Inductive Reactance" of an inductor increases as the supply frequency across it increases. Therefore Inductive Reactance is proportional to frequency giving: (XL α *ƒ*)

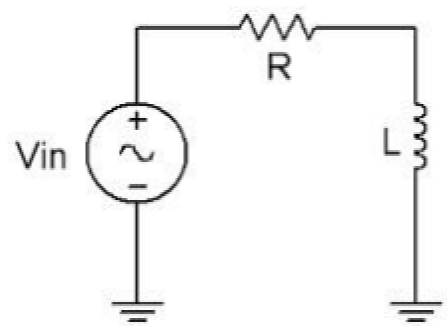
Then we can see that at DC an inductor has zero reactance (short-circuit), at high frequencies an inductor has infinite reactance (open-circuit).

EXPERIMENT:

The magnitude of inductive reactance may be determined experimentally by feeding an inductor a known current, measuring the resulting voltage, and dividing the two, following Ohm's Law. This process may be repeated across a range of frequencies in order to obtain a plot of inductive reactance versus frequency.

An AC current source may be approximated by placing a large resistance in series with an AC voltage, the resistance being considerably larger than the maximum reactance expected.

CIRCUIT DIAGRAM:



PROCEDURE:

1. CURRENT SOURCE

Using Figure 1 with Vin=10 Vp-p and R=10 kΩ, and assuming that the reactance of the inductor is much smaller than 10k and can be ignored, determine the circulating current using measured component values and record in Table 1.

2. MEASURING REACTANCE

Build the circuit of Figure 1 using R=10 kΩ, and L=10 mH. Place one probe across the generator and another across the inductor. Set the generator to a 1000 Hz sine wave and 10Vp-p. Make sure that the Bandwidth Limit of the oscilloscope is engaged for both channels. This will reduce the signal noise and make for more accurate readings.

3. Calculate the theoretical value of XL using the measured inductor value and record in Table2.

4. Record the peak-to-peak inductor voltage and record in Table 2.

5. Using the source current from Table 1 and the measured inductor voltage, determine the experimental reactance and record it in Table 2. Also compute and record the deviation.

6. Repeat steps three through five for the remaining frequencies of Table 2.

7. Replace the 10 mH inductor with the 1mH unit and repeat steps two through six, recording results in Table 3.

8. Using the data of Tables 2 and 3, create plots of inductive reactance versus frequency.

OBSERVATIONS:

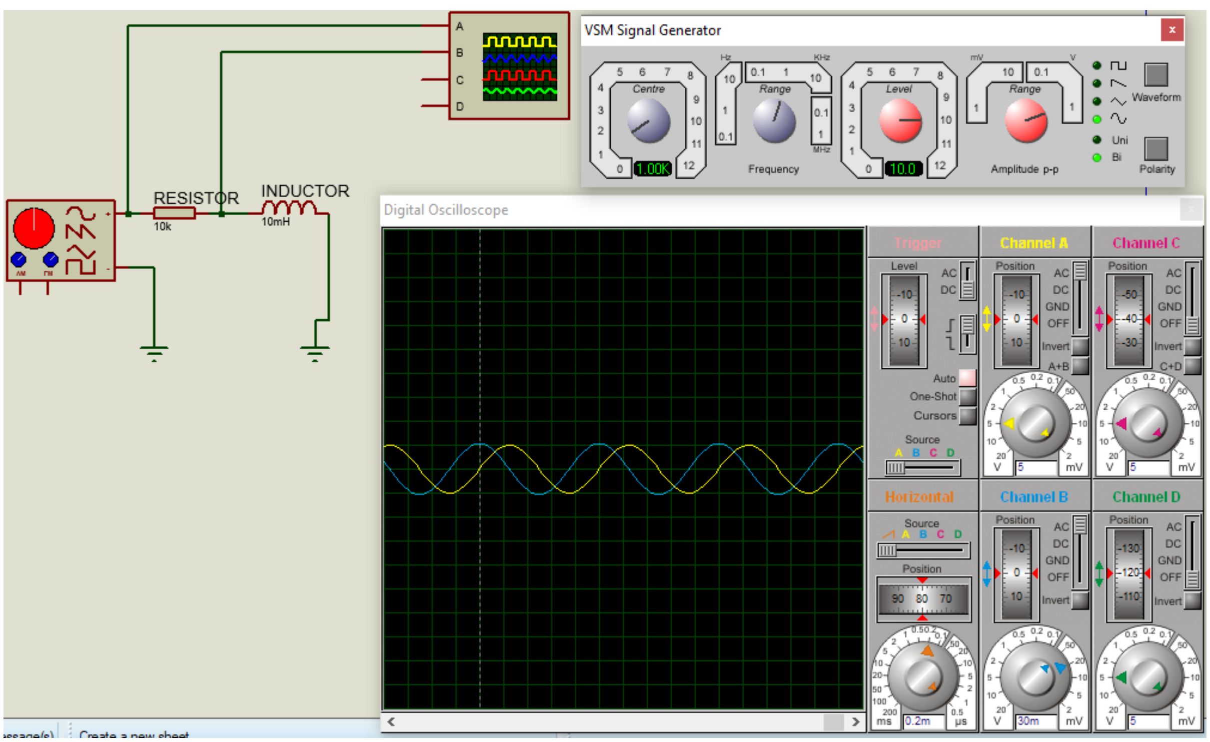
$V_{(p-p)}$ = 10V

For 10mH

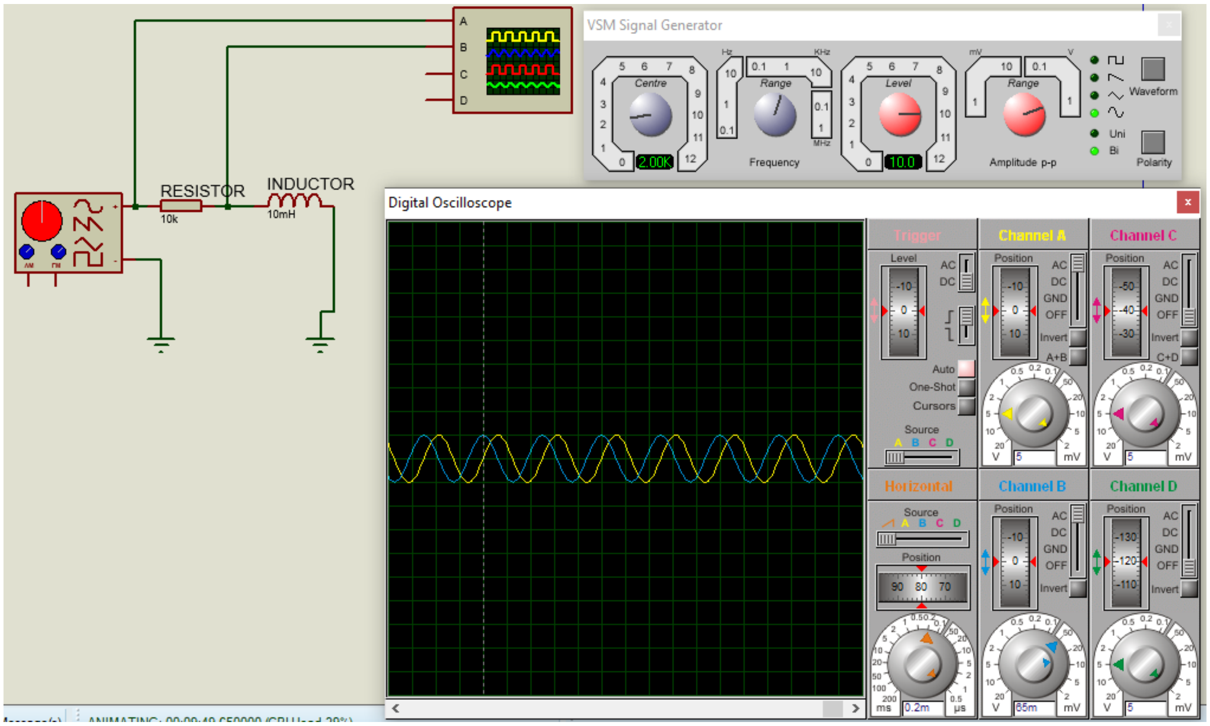
$Is_{(p-p)}$	1 mA

Frequency	$X_{L(TH)}$	$V_{L(p-p)}$	$X_{L(EXP)}$	%DIFF
1k	62.8 H	60 mV	60 H	4.45%
2k	125.6 H	130 mV	130 H	3.50%
3k	188.4 H	200 mV	200 H	6.17%
4k	251.2 H	260 mV	260 H	3.58%
5k	314 H	320 mV	320 H	1.91%
6k	376.8 H	380 mV	380 H	1.06%
8k	502.4 H	520 mV	520 H	3.51%
10k	628 H	640 mV	640 H	1.9%

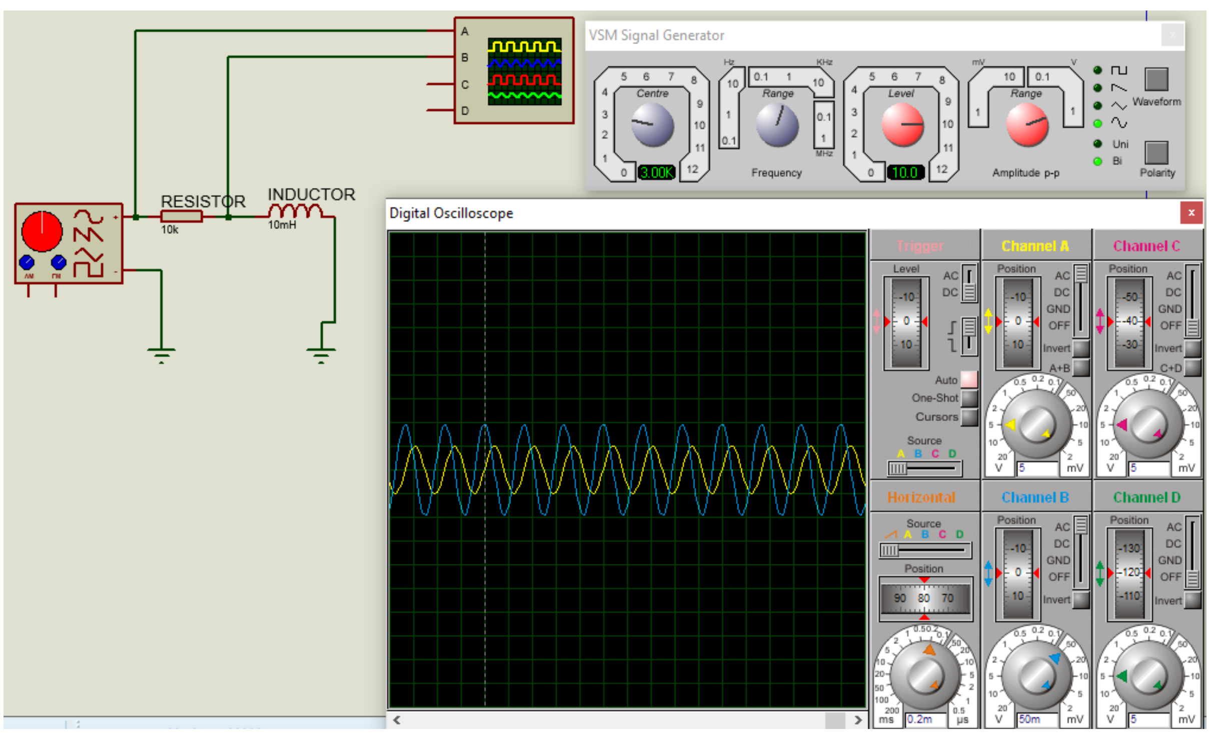
For 1k Hz,10mH



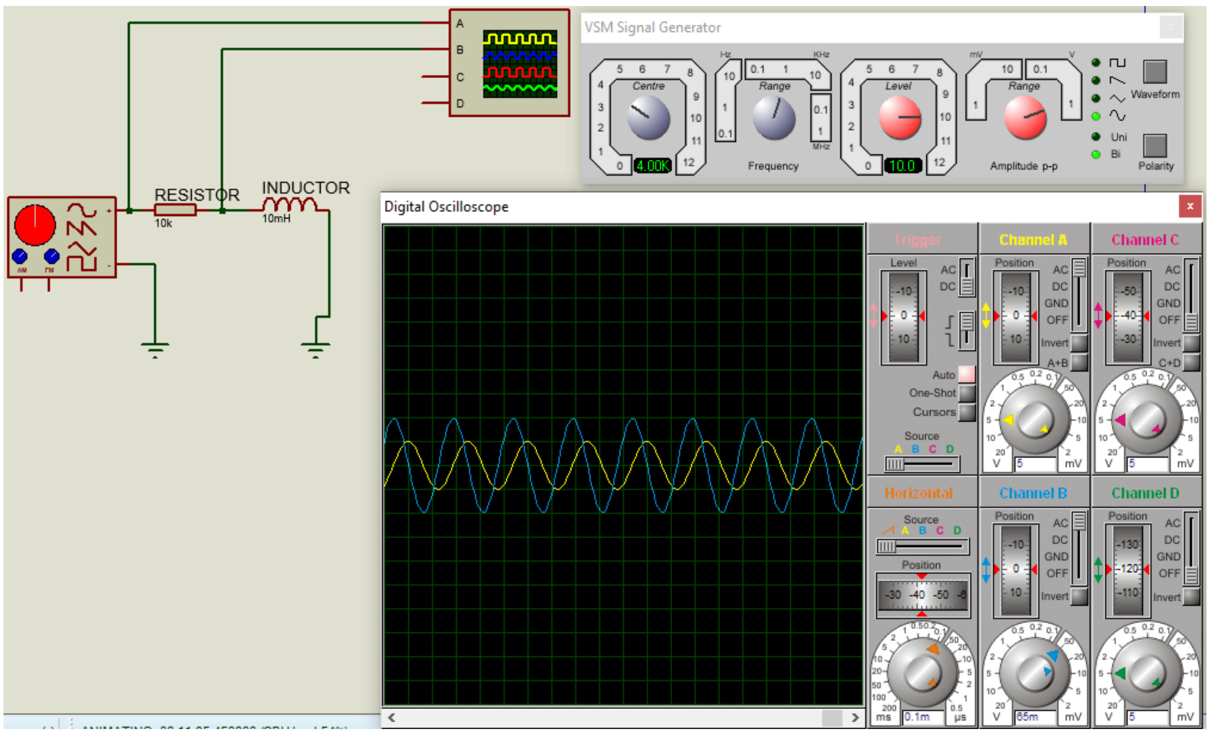
For 2k Hz,10mH



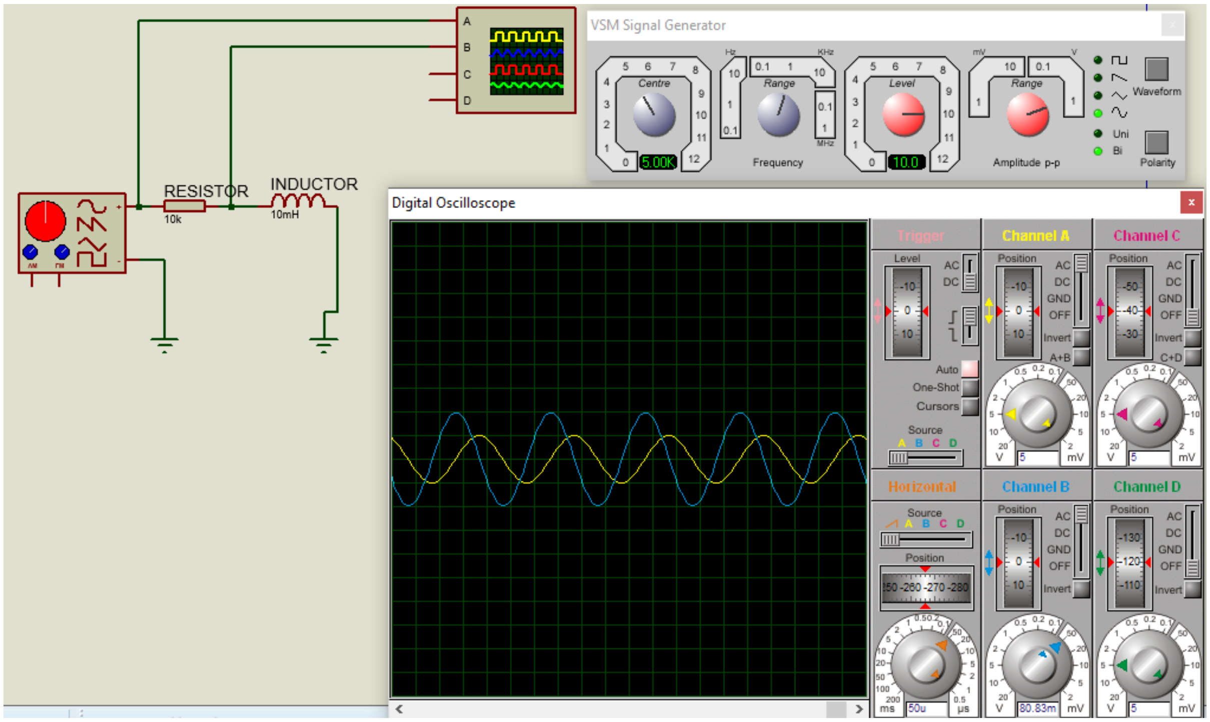
For 3k Hz,10mH



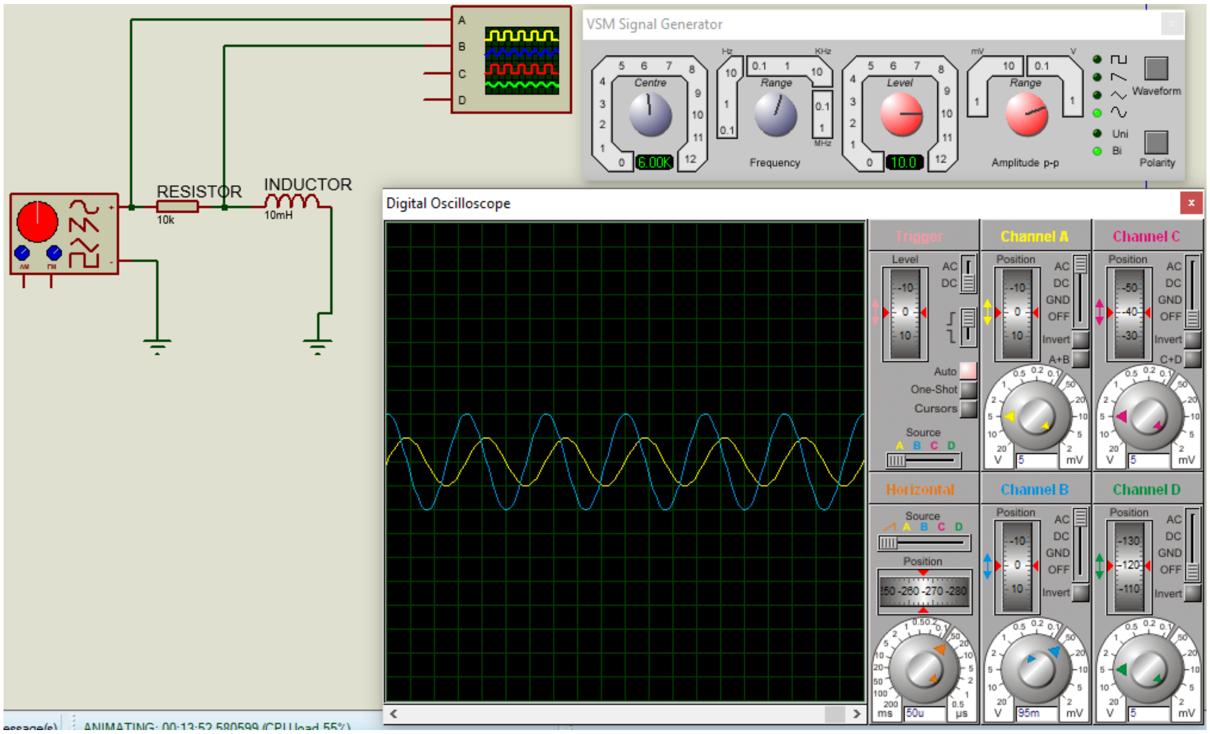
For 4k Hz,10mH



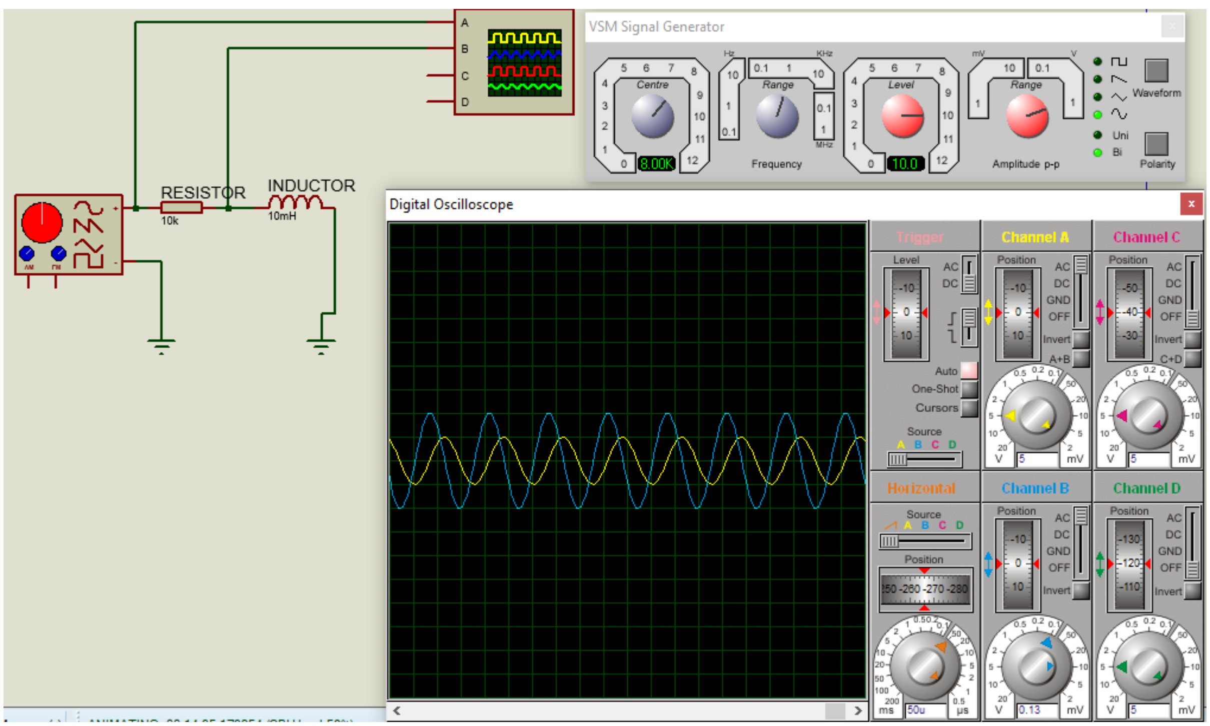
For 5k Hz,10mH



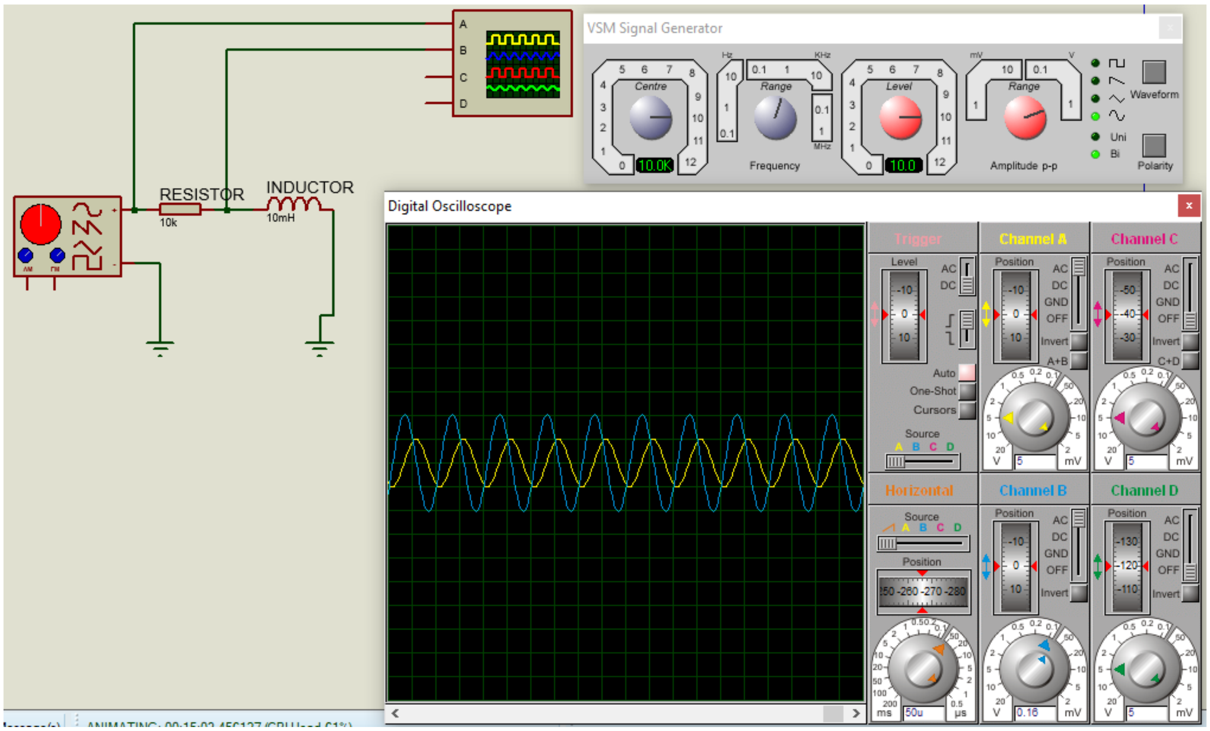
For 6k Hz,10mH

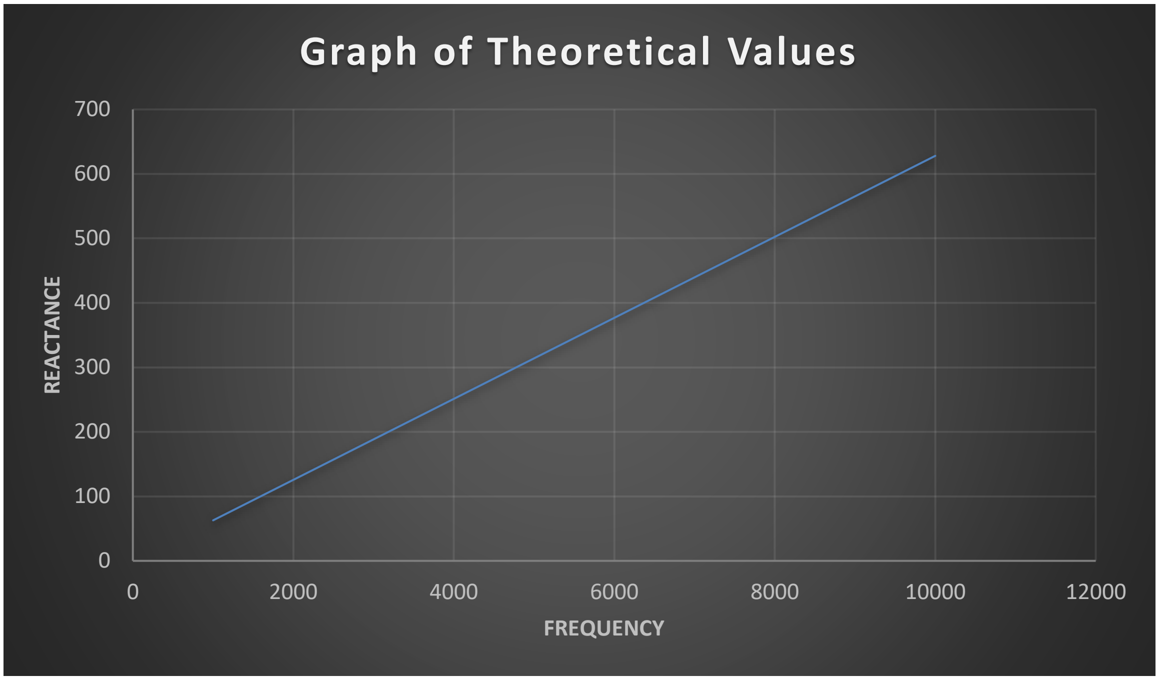


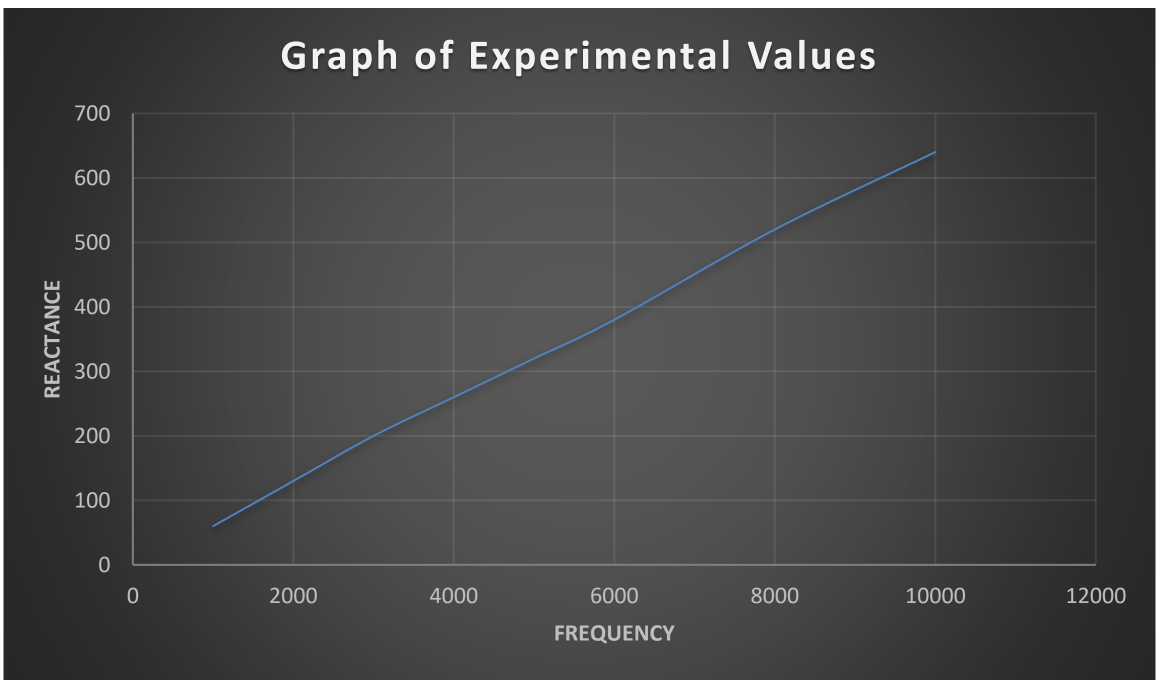
For 8k Hz,10mH



For 10k Hz,10mH







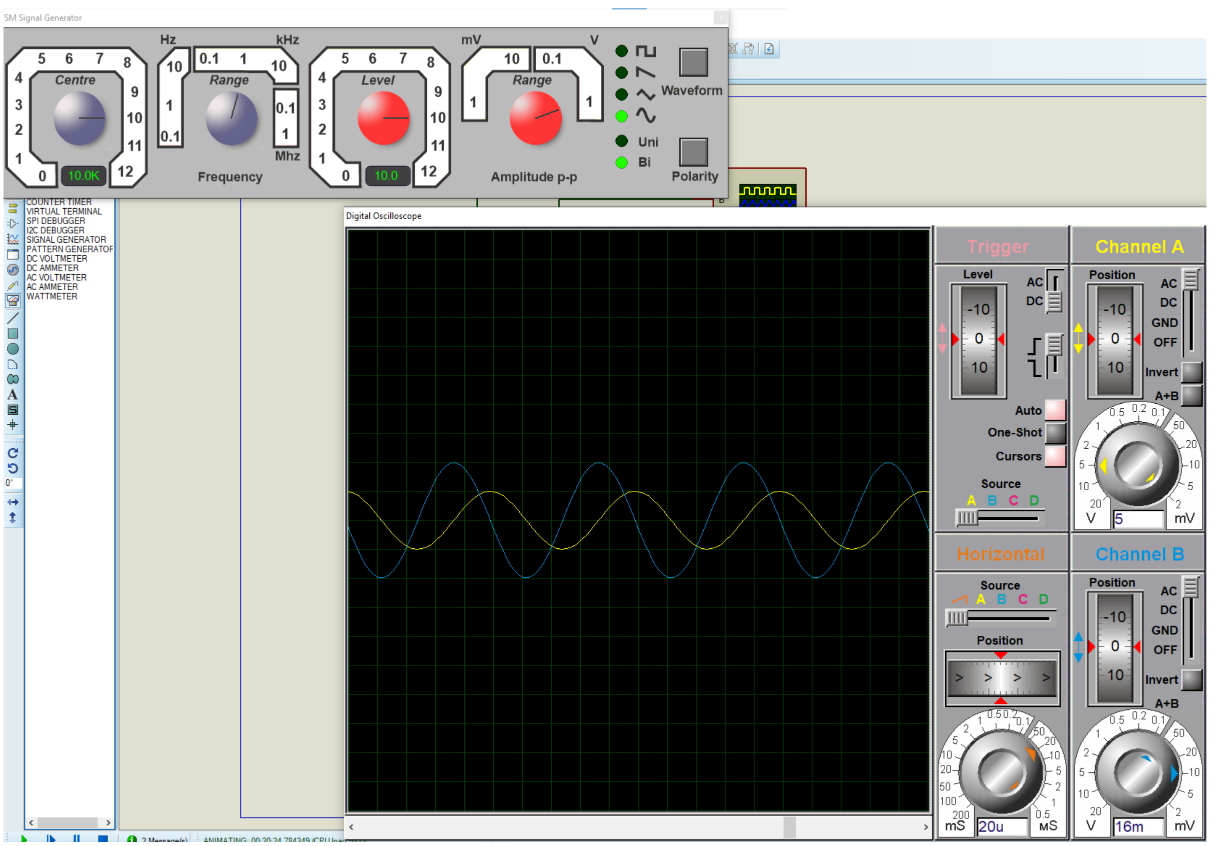
For 1mH

$Is_{(p-p)}$	1 mA

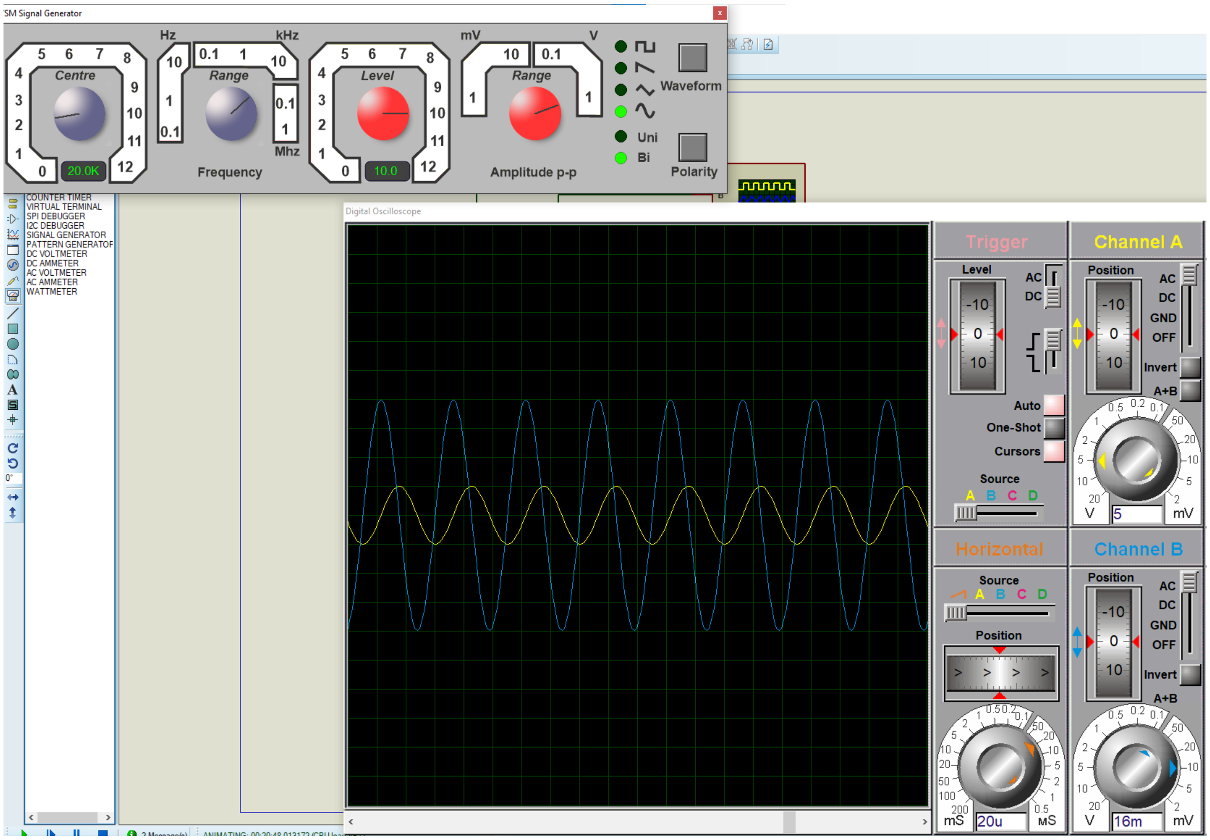
Frequency	**$X_{L(TH)}$**	**$V_{L(p-p)}$**	**$X_{L(EXP)}$**	**%DIFF**

10k	62.8	64 mV	64H	1.91%
20k	125.6	128 mV	128H	1.91%
30k	188.4	192 mV	192H	1.91%
40k	251.2	255 mV	255H	1.51%
50k	314	320 mV	320H	1.91%
60k	376.8	380 mV	380H	0.84%
80k	502.4	504 mV	504H	0.31%
100k	628	640 mV	640H	1.91%

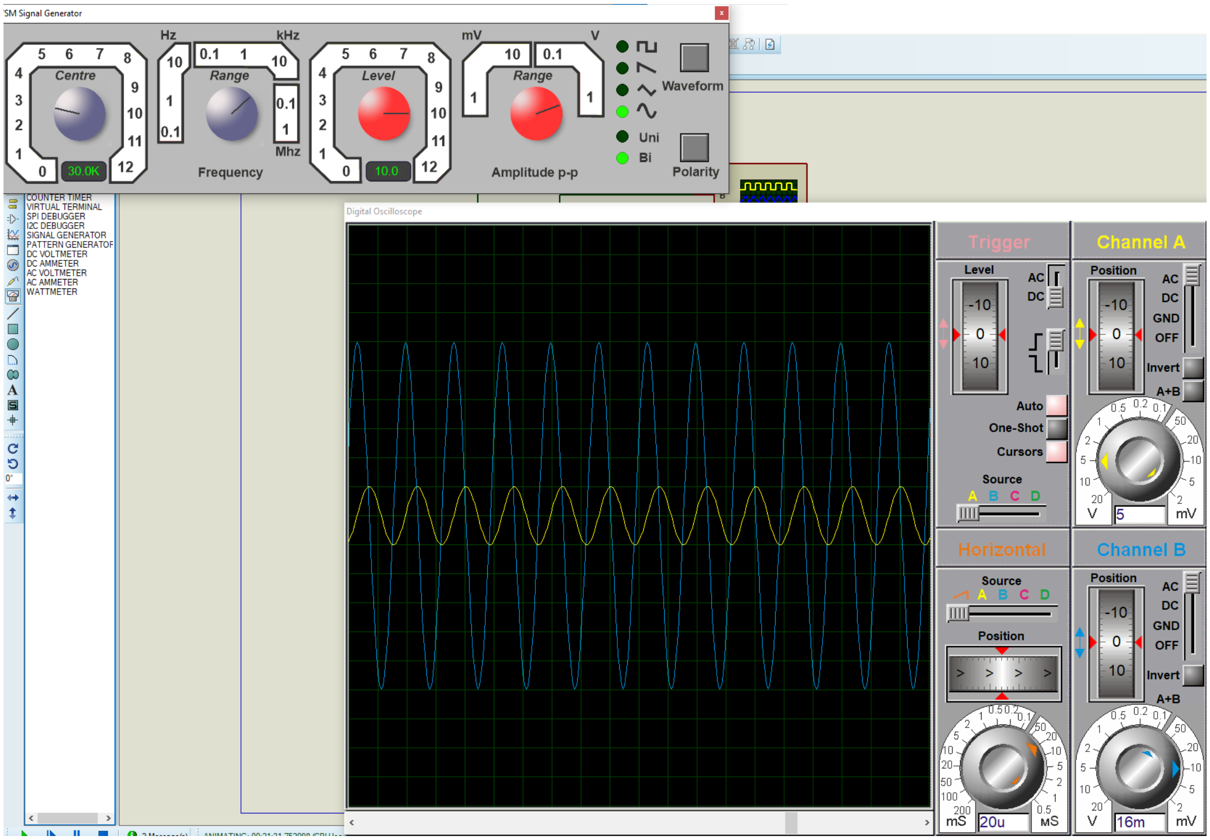
For 10k Hz, 1mH



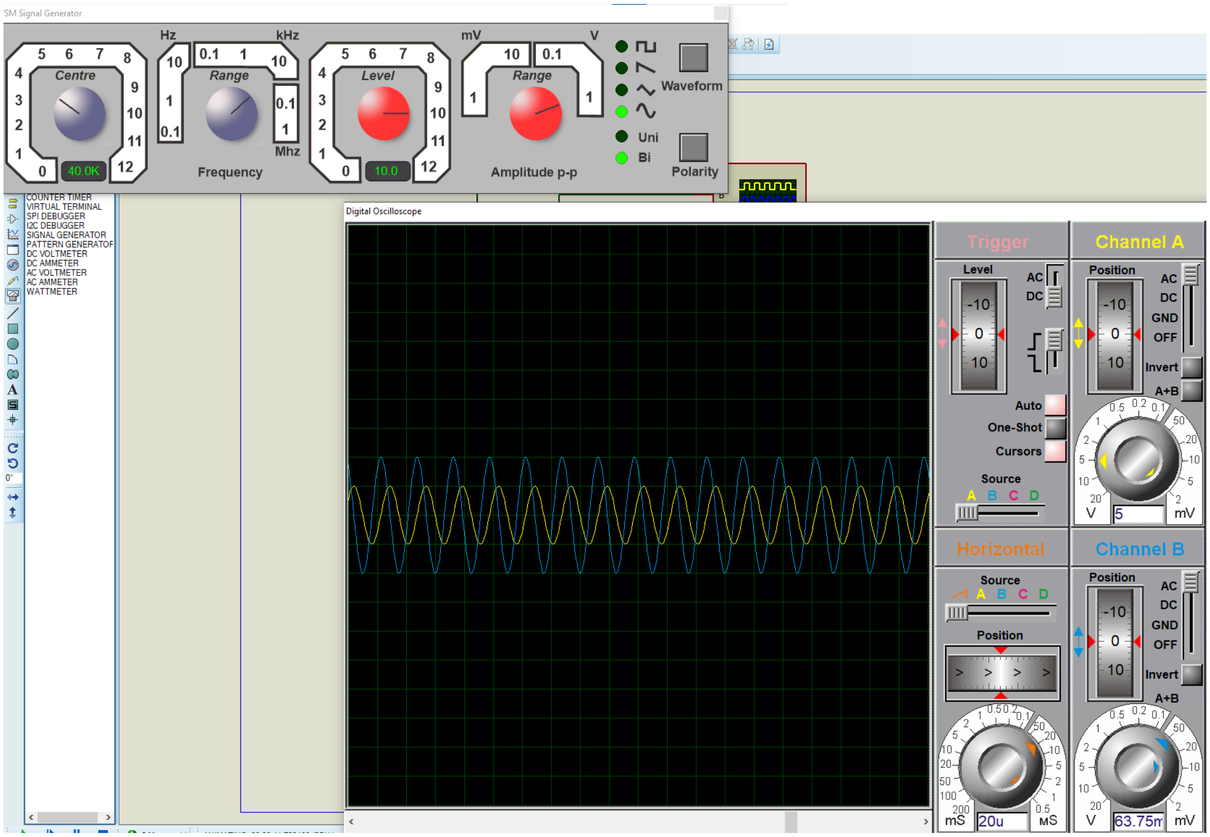
For 20k Hz, 1mH



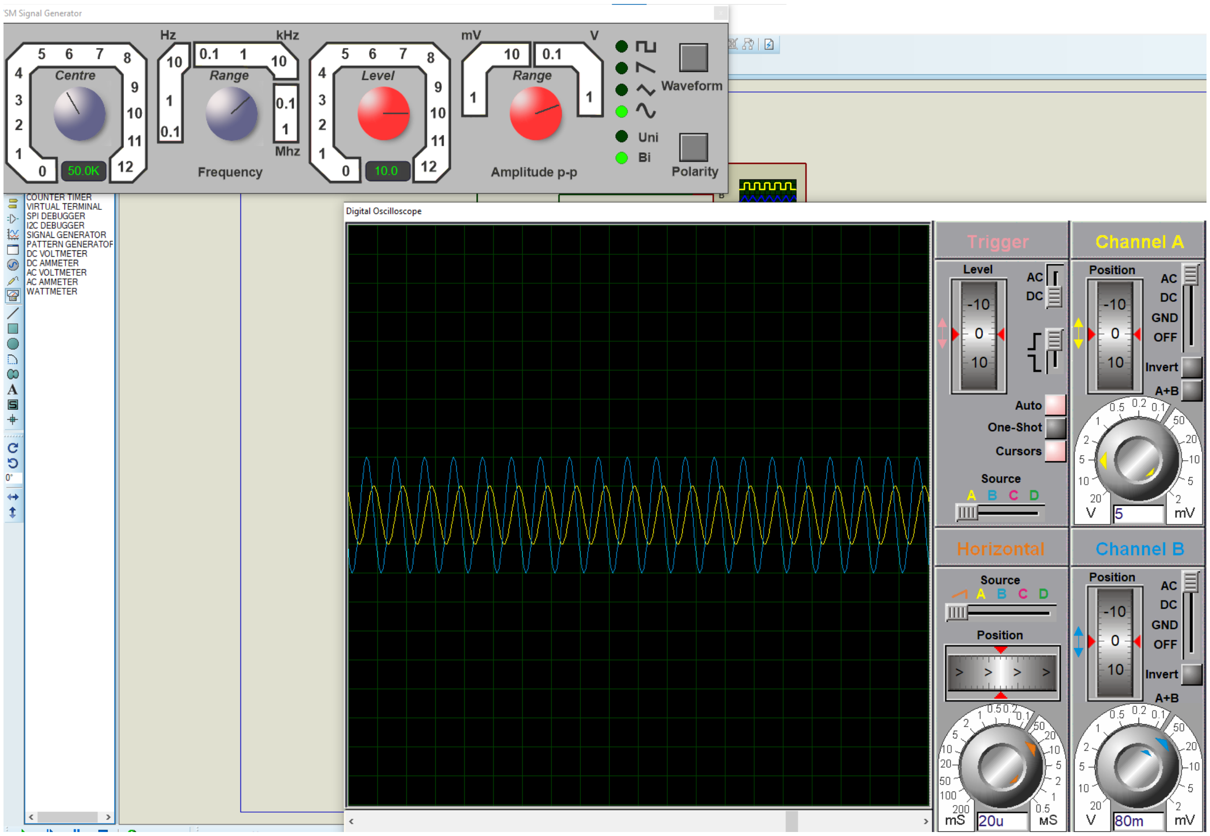
For 30k Hz, 1mH



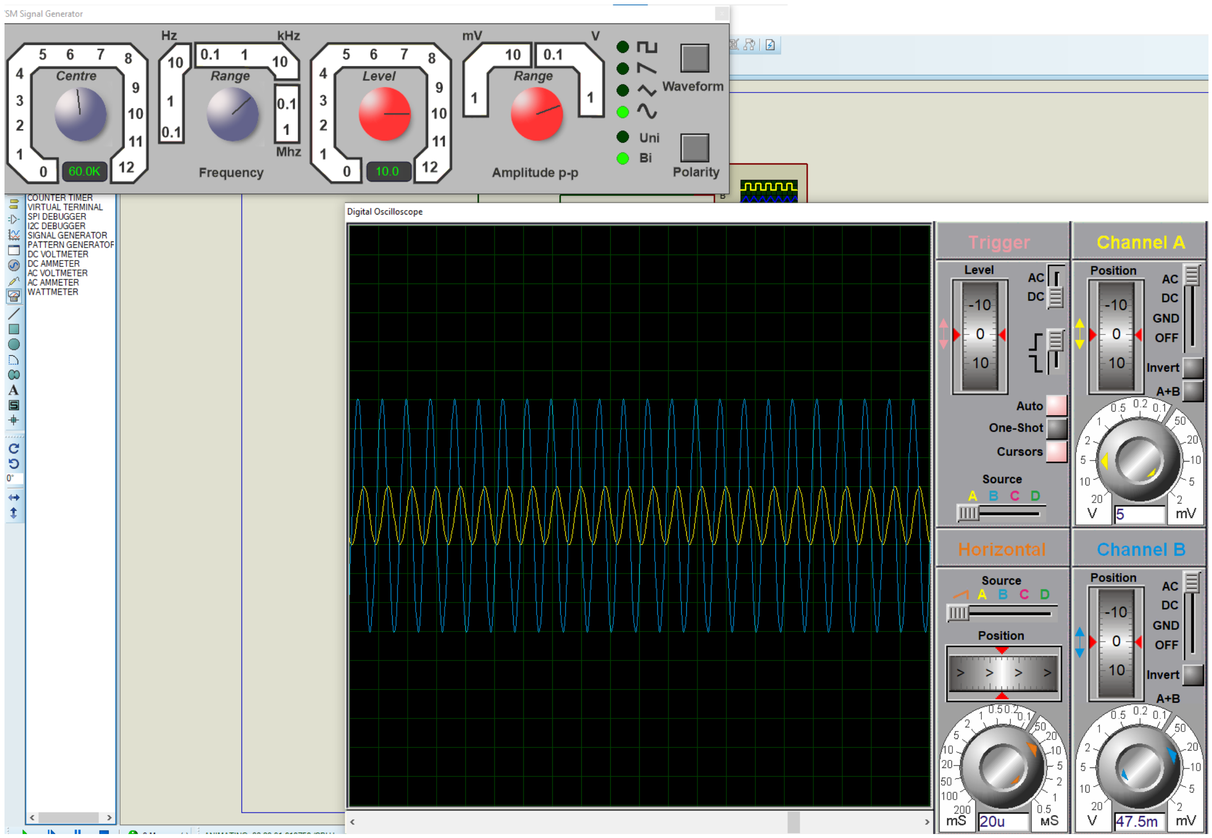
For 40k Hz, 1mH



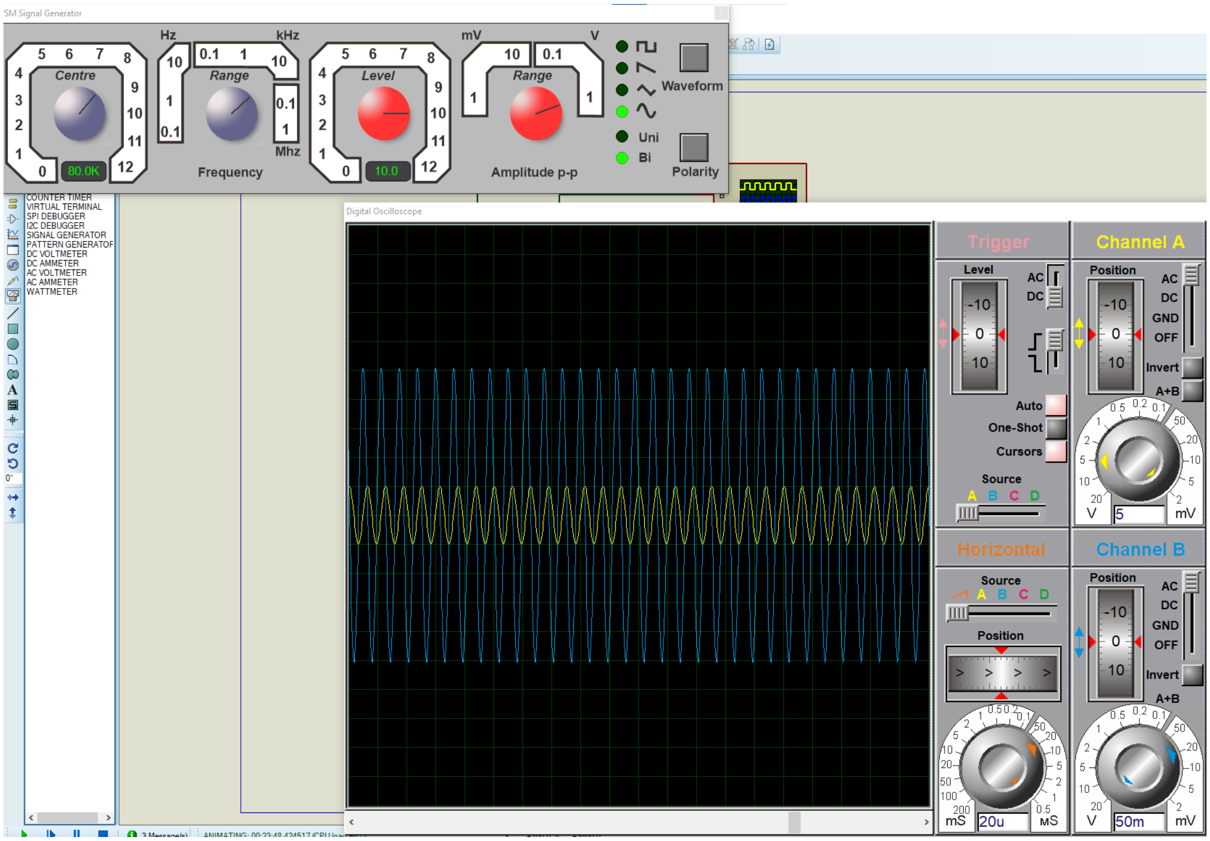
For 50k Hz, 1mH



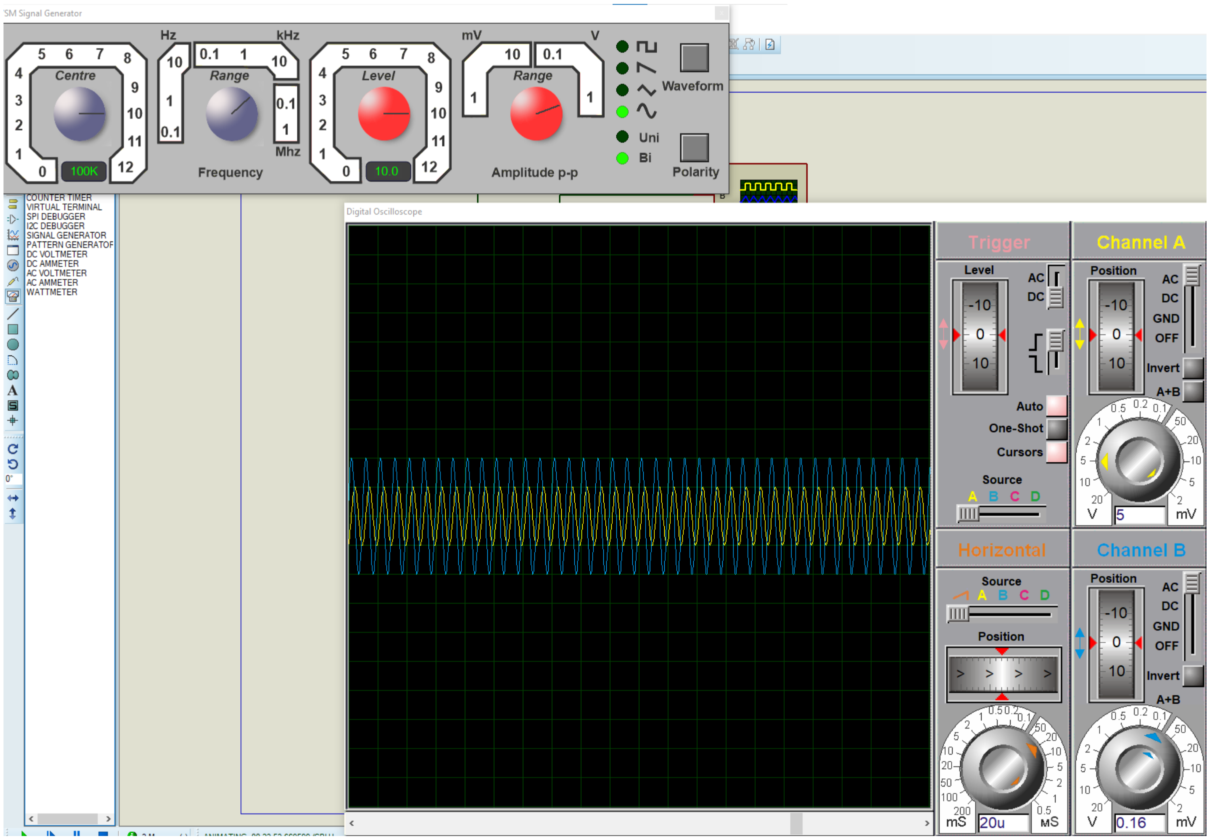
For 60k Hz, 1mH



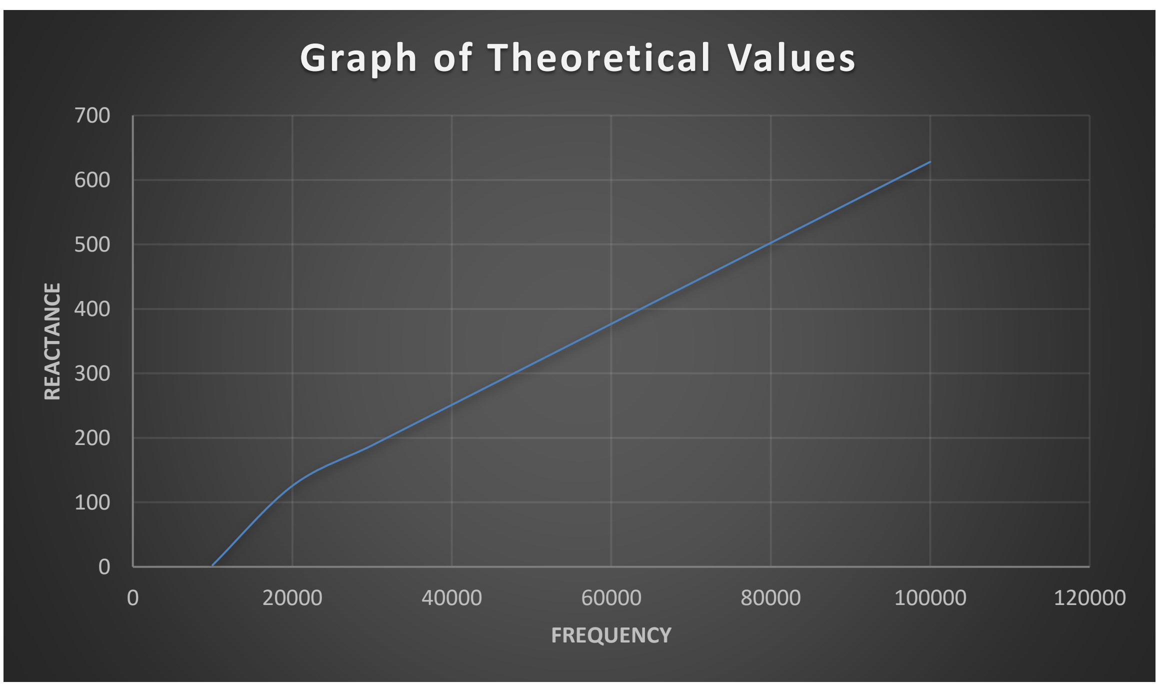
For 80k Hz, 1mH



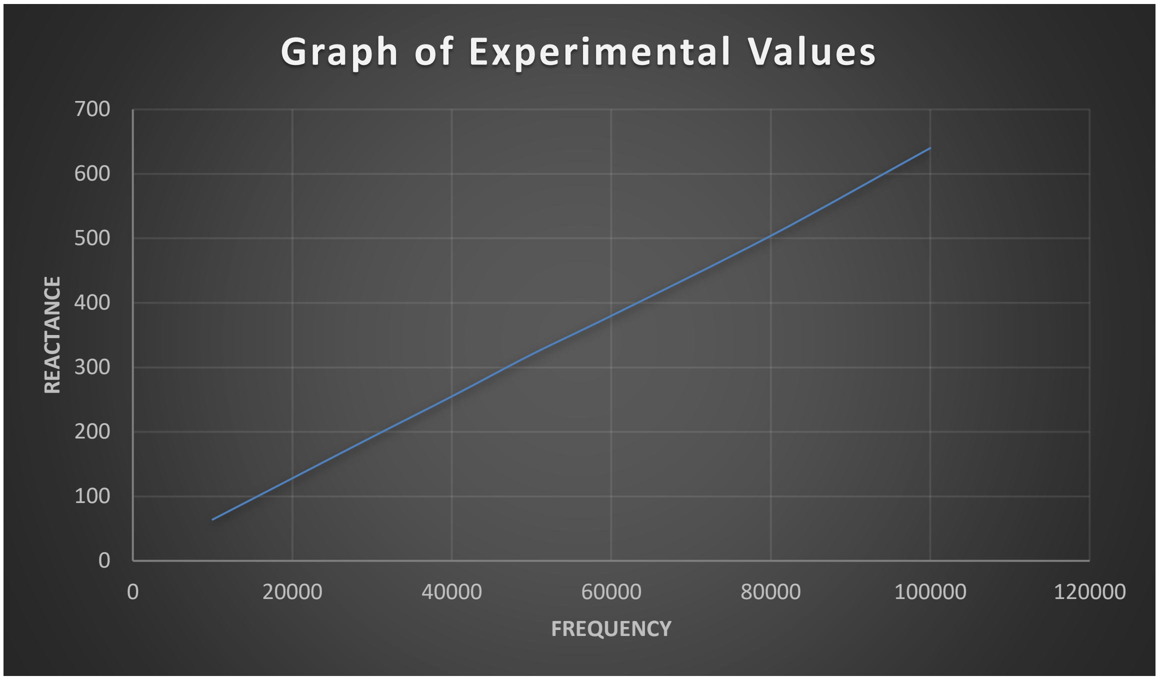
For 100k Hz, 1mH



SM Signal Generator
Centre
Range
Frequency
Level
Amplitude p-p
Waveform
Polarity
Uni
Bi
Hz
kHz
Mhz
mV
V
100K
10.0
COUNTER TIMER
VIRTUAL TERMINAL
SPI DEBUGGER
I2C DEBUGGER
SIGNAL GENERATOR
PATTERN GENERATOR
DC VOLTMETER
DC AMMETER
AC VOLTMETER
AC AMMETER
WATTMETER
Digital Oscilloscope
Trigger
Channel A
Horizontal
Channel B
Level
Position
Source
Auto
One-Shot
Cursors
Invert
A+B
AC
DC
GND
OFF
20u
5
0.16



Graph of Theoretical Values
REACTANCE
FREQUENCY
700
600
500
400
300
200
100
0
0
20000
40000
60000
80000
100000
120000



QUESTIONS:

1. What is the relationship between inductive reactance and frequency?
2. What is the relationship between inductive reactance and inductance?
3. If the 10mH trial had been repeated with frequencies 10 times higher than those in Table 2, what effect would that have on the experiment?
4. Do the coil resistances have any effect on the plots?

ANSWER#1

As we know that,

$$X_L = \frac{V_L}{I_L} = \omega L \ (\Omega)$$

We can rewrite the above equation for inductive reactance into a more familiar form that uses the ordinary frequency of the supply instead of the angular frequency in radians, ω and this is given as:

$$X_L = 2\pi f L$$

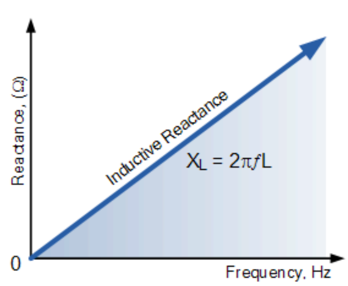
Where: f is the Frequency and L is the Inductance of the Coil and $2\pi f = \omega$.

From the above equation for inductive reactance, it can be seen that if either of the Frequency or Inductance was increased the overall inductive reactance value would also increase. As the frequency approaches infinity, the inductors reactance would also increase to infinity acting like an open circuit.

However, as the frequency approaches zero or DC, the inductors reactance would decrease to zero, acting like a short circuit. This means then that inductive reactance is "proportional" to frequency.

In other words, inductive reactance increases with frequency resulting in XL being small at low frequencies and XL being high at high frequencies and this demonstrated in the following graph:

INDUCTIVE REACTANCE AGAINST FREQUENCY

	The slope shows that the "Inductive Reactance" of an inductor increases as the supply frequency across it increases. Therefore Inductive Reactance is proportional to frequency giving: (XL α ƒ)

ANSWER#2

INDUCTANCE:

Inductance is the ability to create a voltage within a conductor or a nearby conductor by changing the current flow in that first conductor.

The larger the inductance the greater the voltage induced per change in current. Inductive reactance is an opposit. The higher the inductive reactance, the larger the resistance to a change in current is.ion to a change in current

The two terms are related closely, but are not the same.

Generally,

the larger the inductance the more inductive reactance a circuit element has.

This makes sense since a larger induced voltage per change in current (larger inductance) opposes that change in current (inductive reactance) more than a smaller induced voltage per change in current. In other words, a smaller change in the current will induce equal voltage to a larger change in current if inductance is larger. With greater inductance the change in current required to induce a particular voltage is smaller.

ANSWER#3

As we know that inductive reactance is directly proportional to the frequency.

The greater the frequency, the greater the inductive reactance.

So, if we increase the frequency 10 times, the reactance will increase proportionally by ten times.

Same is the case for 10mH inductor, if we increase the frequency 10 times, the reactance will increase by 10 times. The trend in graph plot will remain the same as that of lower frequencies.

ANSWER#4

The four factors that affect the inductance of a coil are;

1. Coil Area
2. Coil length
3. Coil material
4. Coil turns

In real life an inductor consists of a coil of wire (with or without a laminated iron core). So a real inductor has both resistance and inductance. If you double the inductance by increasing the length of wire on the coil, then the resistance will increase . And the inductance is doubled by adding more turns to the coil. However, the case may be different for pure and real-life inductors.

So, plot doesn't change.