**Electrical Science and Principles - Workbook 3**

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| **Name:** |  | **Group:** |  |

The purpose of the last block of learning [**BLOCK 2**: **Steps 1 -** **6**], was to get you to demonstrate an understanding of REACTANCE and IMPEDANCE, and to be able to explain these electrical properties.

The purpose of this block of learning [**BLOCK 3**: **Steps 1 -** **6]** is to try to get you to demonstrate an understanding of CAPACITANCE, and that when combined with RESISTANCE AND INDUCTANCE, to be able to explain the resulting effects.

This sheet contains a study plan with **Step**s that must be followed in the order laid out; skipping steps or undertaking them in the wrong order **will not help at all**.

References for study including **Text** and YouTube video links, are shown below each answer box.

**Step 1**

With the aid of a simple diagram(s) describe the construction of a capacitor.

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| **Diagram(s)** |
| **Description** |
| **References:**   * **Text Book B Chapter ELTK 08 page 450** * **YouTube videos:** [Capacitor construction](https://www.youtube.com/watch?v=GveI9gXIsHw) |

**Step 2**

The following four questions relate to **the construction** of capacitors:

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| 1. What is the **S.I. Unit** for Capacitance ? |
| 1. Because of the very large size of the S.I. Unit of Capacitance what other **three** sub-multiples based on 10-6, 10-9, and 10-12 are used? |
| 1. What is the difference between **1nF** and **1pF** value capacitors? |
| 1. What **three things** affect the value of a capacitor? |
| **References:**   * **Text Book B Chapter ELTK 08 pages 445 and 459** * **YouTube videos:** [Capacitor construction](https://www.youtube.com/watch?v=GveI9gXIsHw) |

**Step 3**

Like Inductors, Capacitors have a different effect when connected to **d.c.** or **a.c.** supplies.

a) Explain how charge builds up across the terminals of a capacitor when it is connected to a **d.c.** supply.

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| **References:**   * **Text Book B Chapter ELTK 08 pages 461 - 463** * **YouTube videos:** [How Capacitors work](https://www.youtube.com/watch?v=X4EUwTwZ110) |

**Step 3 (continued)**

b) Once the Capacitor is disconnected from the supply, explain how is it possible **to test** to see if the

capacitor remains ‘charged’

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| **References:**   * **Text Book B Chapter ELTK 08 page 461** * **YouTube videos:** [How Capacitors work](https://www.youtube.com/watch?v=X4EUwTwZ110) |

c) Give **three examples** of where large capacitors are found in commercial and industrial equipment.

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| **References:**   * **Text Book B Chapter ELTK 08 page 476** * **YouTube videos:** [How Capacitors work](https://www.youtube.com/watch?v=X4EUwTwZ110) |

d) What is the purpose of fitting Capacitor ‘**Banks**’ in large industrial premises?

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| **References:**   * **Text Book B Chapter ELTK 08 page 346** * **YouTube videos:** [How Capacitors work](https://www.youtube.com/watch?v=X4EUwTwZ110) |

**Step 4**

As was stated earlier, capacitors have a different effect when connected to an **a.c.** supply. Like inductors, capacitors react to the alternating supply and produce Capacitive Reactance (Ohms).

1. Show the formula that allows you to calculate the extra OHMs that a capacitor will produce when connected to an a.c. supply, and provide details of all the units in the formula.

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| **References:**   * **Text Book B Chapter ELTK 08 page 320** * **YouTube videos:** [Calculating Capacitive Reactance](https://www.youtube.com/watch?v=mqECFI_dCvg) |

1. A 0.05 microfarad capacitor is connected across a 100 kHz supply. Calculate the capacitive reactance produced by the capacitor

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| **Show all your working out**. |
| **References:**   * **Text Book B Chapter ELTK 08 page 326** * **YouTube videos:** [Calculating Capacitive Reactance](https://www.youtube.com/watch?v=mqECFI_dCvg) [Capacitive Reactance & Frequency](https://www.youtube.com/watch?v=t5PyB5yuugE) |

1. For the question above, which of the following electrical quantities **DO NOT** make any difference whatsoever to the capacitive reactance produced by the capacitor?

Capacitance (0.05 μF) Voltage (230 V) Frequency (100 kHz)

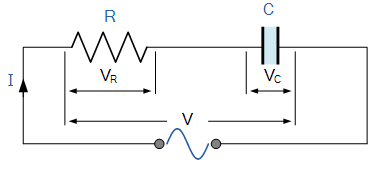
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**Step 4 (continued)**

1. Explain what it means when the Capacitive Reactance (XC) is being described as being **inversely proportional** to the frequency.

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| **References:**   * **Text Book B Chapter ELTK 08 page 326** * **YouTube videos:** [Calculating Capacitive Reactance](https://www.youtube.com/watch?v=mqECFI_dCvg) |

Below is a **RESISTOR** in series with a **CAPACITOR,** this is usually referred to as a RC circuit.



1. In a similar way to how RESISTANCE (Ohms) and INDUCTIVE REACTANCE (Ohms) was combined to produce the total circuit IMPEDANCE (Ohms), show the formula that allows the RESISTANCE (Ohms) and CAPACITIVE REACTANCE (Ohms) to be combined to produce the total IMPEDANCE.

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| **References:**   * **Text Book B Chapter ELTK 08 page 326** |

1. A 50 microfarad capacitor is connected in series with a 40 Ohm resistor which is connected to a 12V 60Hz a.c. supply. Calculate:
2. the capacitive reactance produced by the capacitor (**XC**)
3. the total circuit impedance (**Z**)
4. The circuit current (**I**)
5. The voltage across the resistor (**VR**)
6. The voltage across the capacitor (**VC**)

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| **Capacitive Reactance (XC)**  **Show all your working out**. |
| **Circuit Impedance (Z)**  **Show all your working out**. |
| **Circuit Current (I)**  **Show all your working out**. |
| **Voltage across the resistor (VR) Show all your working out**. |
| **Voltage across the capacitor (VC) Show all your working out**. |
| **References:**   * **Text Book B Chapter ELTK 08 page 326** * **YouTube videos:** [RC calculation](https://www.youtube.com/watch?v=ZOn0L42cyFE) |

1. A 160 microfarad capacitor is connected in series with a 15 Ohm resistor which is connected to a 250V 50Hz supply. Calculate:
2. the capacitive reactance produced by the capacitor (**XC**)
3. the total circuit impedance (**Z**)
4. the circuit current (**I**)
5. the voltage across the resistor (**VR**)
6. the voltage across the capacitor (**VC**)

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| **Capacitive Reactance (XC)**  **Show all your working out**. |
| **Circuit Impedance (Z)**  **Show all your working out**. |
| **Circuit Current (I)**  **Show all your working out**. |
| **Voltage across the resistor (VR) Show all your working out**. |
| **Voltage across the capacitor (VC) Show all your working out**. |
| **References:**   * **Text Book B Chapter ELTK 08 page 326** * **YouTube videos:** [RC calculation](https://www.youtube.com/watch?v=ZOn0L42cyFE) |

1. Explain what happens to the relationship between the **Voltage** ‘across’ and the **Current** ‘through’ the Capacitor when it is connected to an **a.c. supply**

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| **References:**   * **Text Book B Chapter ELTK 08 page 320** * **YouTube videos:** [Phase shift](https://www.youtube.com/watch?v=SGel5QNSkIQ) |

1. With the aid of diagrams, show the relationship between the **Voltage** ‘across’ and the **Current** ‘through’ a Capacitor when it is connected to an **a.c. supply**

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| **Wave diagram** | **Phasor diagram** |
| **References:**   * **Text Book B Chapter ELTK 08 page 320** * **YouTube videos:** [Phase shift](https://www.youtube.com/watch?v=SGel5QNSkIQ) [Wave diagrams](https://www.youtube.com/watch?v=_XNvQ44feqA) | |

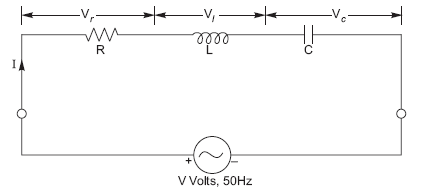
1. Explain what happens when BOTH Inductive Reactance (**XL**) OHMs and Capacitive Reactance (**XC**) OHMs are in the same a.c. circuit.

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| **References:**   * **Text Book B Chapter ELTK 08 page 327** * **YouTube videos:** [Impedance in RLC circuit](https://www.youtube.com/watch?v=1bIRwZtSurg) |

**Step 5**

By now you should have become aware that, individually, a **RESISTOR (R)**, a **CAPACITOR (C)**, or an **INDUCTOR** (**L**) each affect the Voltage/ Current relationship in different ways.

Remember, the Current is the constant through the series connected components (**RLC**)



**For the following 3 questions you may want to remember this useful memory aid:**  **C I V I L**

1. For a **purely resistive** circuit, which one of the following statements is **TRUE**?

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| The Voltage (**VR**) across the resistor lags the current (**I**) through the resistor | |  |
| The Voltage (**VR**) across the resistor is in phase with the current (**I**) through the resistor | |  |
| The Voltage (**VR**) across the resistor leads the current (**I**) through the resistor | |  |
| **References:**   * **Text Book B Chapter ELTK 08 page 316** | * **YouTube videos:** [Phasor diagrams and CIVIL](https://www.youtube.com/watch?v=_F1jzaGgtXw) | |

1. For a **purely inductive** circuit, which one of the following statements is **TRUE**?

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| The Voltage (**VL**) across the inductor lags the current (**I**) through the inductor | |  |
| The Voltage (**VL**) across the inductor is in phase with the current (**I**) through the inductor | |  |
| The Voltage (**VL**) across the inductor leads the current (**I**) through the inductor | |  |
| **References:**   * **Text Book B Chapter ELTK 08 page 317** | * **YouTube videos:** [Phasor diagrams and CIVIL](https://www.youtube.com/watch?v=_F1jzaGgtXw) | |

1. For a **purely capacitive** circuit, which one of the following statements is **TRUE**?

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|  | | **Tick 🗸** |
| The Voltage (**VC**) across the capacitor lags the current (**I**) through the capacitor | |  |
| The Voltage (**VC**) across the capacitor is in phase with the current (**I**) through the capacitor | |  |
| The Voltage (**VC**) across the capacitor leads the current (**I**) through the capacitor | |  |
| **References:**   * **Text Book B Chapter ELTK 08 page 320** | * **YouTube videos:** [Phasor diagrams and CIVIL](https://www.youtube.com/watch?v=_F1jzaGgtXw) | |

**Step 5 (continued)**

1. A 15 microfarad capacitor is connected in series with a 150 Ohm resistor and a 750 milliHenry inductor, which are all connected to a 230 V 55 Hz supply.

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| Calculate:   1. (i) the capacitive reactance (**XC**) 2. (ii) the inductive reactance (**XL**) 3. (iii) the total circuit impedance (**Z**) | | 1. (iv) the circuit current (**I**) 2. (v) the voltage across the resistor (**VR**) 3. (vi) the voltage across the capacitor (**VC**)   (vii) the voltage across the inductor (**VL**) | |
| **Capacitive Reactance (XC)**  **Show all your working out**. | | | |
| **Inductive Reactance (XL)**  **Show all your working out**. | | | |
| **Circuit Impedance (Z)**  **Show all your working out**. | | | |
| **Circuit Current (I)**  **Show all your working out**. | | | |
| **Voltage across the resistor (VR) Show all your workin g out**. | | | |
| **Voltage across the capacitor (VC) Show all your working out**. | | | |
| **Voltage across the inductor (VL) Show all your working out**. | | | |
| **References:**   * **Text Book B Chapter ELTK 08 page 328** | | * **YouTube videos:** [RLC calculation](https://www.youtube.com/watch?v=1bIRwZtSurg) | |

**Step 6**

A 150 microfarad capacitor is connected in series with a 5 Ohm resistor and a 20 milli-Henry inductor, which are all connected to a 230 V 50 Hz supply.

Calculate:

1. the total circuit impedance (Z)
2. the circuit current (I)
3. the power factor

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| **Show all your working out**. |