**Continuity of Learning - Part 7**

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

The purpose of the last block of learning [[**BLOCK 6**: **Steps 1 -** **6]** was to try to get you to demonstrate an understanding of TRANSFORMERS.

The purpose of this block of learning [**BLOCK 7**: **Steps 1 -** **12]** is to try to get you to demonstrate an understanding of the operating principles and applications of **DIRECT CURRENT (d.c.) MACHINES & ALTERNATING CURRENT (a.c.) MOTORS**, alongside the starting and control methods.

The **MOTOR** is the most widely used item of electrical equipment and can be found in many situations such as, domestic appliances, plant & machinery, HVAC systems, and much more.

This sheet contains a study plan with **Steps** 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**

By now you should have come across the practical use of motors and know that they convert electricity in to mechanical rotary energy referred to as **Torque**. The simplest d.c. motor can be made by just placing a coil in a magnetic field and passing current from a battery through it.

1. Using a sketch, show how a single loop of wire can be made to rotate in a magnetic field.

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 365 Fig. 8.101** * **YouTube videos:**  [DC Motor explained](https://www.youtube.com/watch?v=GQatiB-JHdI) [How D.C. Motors Work For Beginners](https://www.youtube.com/watch?v=onjFFoOC_yk) |

1. Using an arrow, show the direction of the following current-carrying conductors:

|  |  |
| --- | --- |
|  |  |
|  |  |
| **References:**   * **Text Book B Chapter ELTK 08 page 365 Fig. 8.100** * **YouTube videos:**  [DC Motor explained](https://www.youtube.com/watch?v=GQatiB-JHdI) 10:02 | |

**Step 1 continued**

1. What is the name given to the arrangement that allows current flow in to the rotor windings?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 366 Fig. 8.102** |

1. What is the material made of that conducts current in to and rubs against the rotor?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 366 Fig. 8.102** |

1. State **two** ways in which you can reverse the direction of a simple battery operated d.c. motor.

|  |
| --- |
| **Method 1**: |
| **Method 2**: |
| **References:**   * **Text Book B Chapter ELTK 08 page 348** * **YouTube videos:**  [DC Motor explained](https://www.youtube.com/watch?v=GQatiB-JHdI) 15:05 [How D.C. Motors Work For Beginners](https://www.youtube.com/watch?v=onjFFoOC_yk) 9:00 |

1. In commercial d.c. motors the permanent magnet found in simple d.c. motors is replaced with electromagnetic coils fixed to the inside of the motor body. What name is given to them?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 367**   **YouTube videos:**  [Working Principle of DC Motor](https://www.youtube.com/watch?v=j_F4limaHYI) 0:52 |

1. Give the **name** of the rule that allows you to work out the **direction of rotation** of a d.c. motor

if you know the **direction of the magnetic field** and the **direction of the current**.

|  |
| --- |
| - - - - - - - - ‘ - - - - - - - - - - - - - |
| **References:**   * **Text Book B Chapter ELTK 08 page 367**   **YouTube videos:**  [Working Principle of DC Motor](https://www.youtube.com/watch?v=j_F4limaHYI) 0:52 |

**Step 1 continued**

Other than for very small motors which have permanent field magnets, there are three basic forms of d.c. motor based on the way the field coils and the rotor coils are connected.

1. For each of the three arrangement types, state the **name (Form)**, give at least one positive **characteristic**, where they might be **used**, and produce a simple **circuit diagram**:

|  |  |
| --- | --- |
| **Form 1**: …………………………….. | Circuit diagram: |
| Characteristic (s): |
| Application (s): |
| **Form 1**: …………………………….. | Circuit diagram: |
| Characteristic (s): |
| Application (s): |
| **Form 1**: …………………………….. | Circuit diagram: |
| Characteristic (s): |
| Application (s): |
| **References:**   * **Text Book B Chapter ELTK 08 pages 368 - 369** * **YouTube videos:**  [Electromagnetic Induction Explained](https://www.youtube.com/watch?v=1OfduAzKdyk) 7:00 | |

**Step 2**

The basic construction of a **D.C.** **Generato**r is very similar to that of a d.c. motor.

1. Using a sketch, show how a single loop of wire can be made to generate electricity when rotated in a magnetic field.

|  |
| --- |
|  |
| **References:**   * **YouTube videos:**  [Working Principle of DC Generator](https://www.youtube.com/watch?v=mq2zjmS8UMI) |

1. Using a **+** and **-**  indicate the direction of current flow in the following rotating conductor loop:

|  |  |
| --- | --- |
|  |  |
|  |  |
| **References:**  **YouTube videos:**  [Working Principle of DC Generator](https://www.youtube.com/watch?v=mq2zjmS8UMI) | |

1. Give the **name** of the rule that allows you to work out the **direction of current** of a d.c. generator

if you know the **direction of the magnetic field** and the **direction of the rotation** (movement).

|  |
| --- |
| - - - - - - - - ‘ - - - - - - - - - - - - - - |
| **References:**  **YouTube videos:**  [Working Principle of DC Generator](https://www.youtube.com/watch?v=mq2zjmS8UMI) |

**Step 3**

The majority of industrial motors are of the a.c. type and are basically either single or three-phase.

We will start by looking at the **three-phase a.c. induction motor**.

1. What is the name of the arrangement that is wrapped around the circumference of the motor?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 373** * **YouTube videos:**  [How does an Induction Motor work](https://www.youtube.com/watch?v=N7TZ4gm3aUg) 2:25 |

1. What is the name of the arrangement that is wrapped around the shaft of the motor?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 373** * **YouTube videos:**  [How does an Induction Motor work](https://www.youtube.com/watch?v=N7TZ4gm3aUg) 2:35 |

1. What is the name used to describe the rotor assembly?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 373** * **YouTube videos:**  [How does an Induction Motor work](https://www.youtube.com/watch?v=N7TZ4gm3aUg) 5:25 |

1. Other than copper, what are the end ring connecting bars usually made from?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 373** * **YouTube videos:**  [How does an Induction Motor work](https://www.youtube.com/watch?v=N7TZ4gm3aUg) 5:45 |

1. Describe the two main functions of the laminated rings that make up the bulk of the rotor?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 373** * **YouTube videos:**  [How does an Induction Motor work](https://www.youtube.com/watch?v=N7TZ4gm3aUg) 6:30 |

**Step 3 continued**

1. What is the name given to the amount of times the a.c. current changes direction every second and what are the units?

|  |  |
| --- | --- |
| Quantity: | Unit: |
| **References:**   * **Text Book B Chapter ELTK 08 page 315** * **YouTube videos:**  [How does an Induction Motor work](https://www.youtube.com/watch?v=N7TZ4gm3aUg) 9:15 | |

1. Using a sketch, show the stator winding arrangement of a three-phase induction motor with a pole pair per phase.

|  |
| --- |
|  |
| **References:**   * **YouTube videos:**  [Working Principle of DC Generator](https://www.youtube.com/watch?v=mq2zjmS8UMI) |

1. What is the name of the phenomenon that is produced in the stator windings by the application of a three-phase a.c. supply?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 373 - 375** * **YouTube videos:**  [How does an Induction Motor work](https://www.youtube.com/watch?v=N7TZ4gm3aUg) 9:25 |

1. What causes the rotor to rotate in a three-phase squirrel cage induction motor

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 372** * **YouTube videos:**  [How does an Induction Motor work](https://www.youtube.com/watch?v=N7TZ4gm3aUg) 9:30 |

**Step 4**

Although the majority of three-phase motors are of the squirrel cage construction, other construction types are sometimes needed.

We will now look at the **three-phase wound rotor** (or slip-ring) induction motor.

1. Describe the main difference in the rotor construction between a squirrel caged motor and a wound rotor motor.

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 375** * **YouTube videos:**  [Slip ring Induction Motor](https://www.youtube.com/watch?v=JPn5Ou-N0b0) 4:05 |

1. Describe the main advantage of being able to introduce different resistance values in to the rotor of a wound induction motor.

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 376** * **YouTube videos:**  [Slip ring Induction Motor](https://www.youtube.com/watch?v=JPn5Ou-N0b0) 5:35 |

1. Describe how the external resistor bank is connected to the rotor of a wound induction motor.

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 375** * **YouTube videos:**  [Slip ring Induction Motor](https://www.youtube.com/watch?v=JPn5Ou-N0b0) 5:15 |

1. Give two common applications for the wound rotor induction (slip-ring) motor.

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 375** * **YouTube videos:**  [Slip ring Induction Motor](https://www.youtube.com/watch?v=JPn5Ou-N0b0) 6:00 |

**Step 5**

Where there is no three-phase supply available the alternative is a single-phase induction motor.

We will now look at the **single-phase** induction motor.

As we have seen, a three-phase induction motor is ‘self-starting’ in that all it requires is three phases to create a rotating magnetic field in the stator which causes the rotor to rotate.

1. Why would a single winding (1 pole pair) connected to a single-phase supply not cause the motor to self-start and the rotor to rotate?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 376** * **YouTube videos:** [How a single phase a.c. induction motor works](https://www.youtube.com/watch?v=2XYdTogWcIA) 1:20 |

1. With the aid of a diagram, show how a single-phase 2-pole induction motor can be made to self-start and the rotor to rotate?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 377** * **YouTube videos:** [How a single phase a.c. induction motor works](https://www.youtube.com/watch?v=2XYdTogWcIA) 2:40 |

1. Describe the purpose of the centrifugal switch in a capacitor start single-phase induction motor?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 380** * **YouTube videos:** [How a single phase a.c. induction motor works](https://www.youtube.com/watch?v=2XYdTogWcIA) 6:30 |

**Step 5 continued**

1. Draw a labelled circuit diagram of a capacitor start/ capacitor run single phase induction motor.

Include: Run winding (U1 U2), Start winding (Z1 Z2), centrifugal switch, start capacitor, run capacitor, and Line & Neutral of a.c. supply.

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 382** * **YouTube videos:** [How to Connect a Single Phase Motor](https://www.youtube.com/watch?v=UVjJvJMHzyI) |

1. Which of the two capacitors remains in the circuit once the motor is up to full speed?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 382** * **YouTube videos:** [How to Connect a Single Phase Motor](https://www.youtube.com/watch?v=UVjJvJMHzyI) 4:35 |

1. What is an advantage(s) of a capacitor start/ capacitor run single phase induction motor?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 382** |

1. Give typical applications for capacitor start/ capacitor run single phase induction motors?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 382** |

**Step 6**

One final type of single-phase induction motor is the shaded pole type.

1. Using a sketch, show the construction of a single-phase shaded pole induction motor.

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 383 Fig. 8.127** * **YouTube videos:**  [How a single phase a.c. induction motor works](https://www.youtube.com/watch?v=2XYdTogWcIA) 8:20 |

1. Why is the core of the shaded pole induction motor made of iron?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 383** * **YouTube videos:**  [How a single phase a.c. induction motor works](https://www.youtube.com/watch?v=2XYdTogWcIA) 9:05 |

1. Give typical applications for single-phase shaded pole induction motors?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 383** * **YouTube videos:**  [How a single phase a.c. induction motor works](https://www.youtube.com/watch?v=2XYdTogWcIA) 9:05 |

1. What is the purpose of the copper ring shades found in shaded pole induction motors?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 383** * **YouTube videos:**  [How a single phase a.c. induction motor works](https://www.youtube.com/watch?v=2XYdTogWcIA) 10:30 |

**Step 7**

We have now looked at the most common motors that an electrician might encounter in the workplace.

We will now consider the relevant methods of starting and controlling these motors.

The **D**irect **O**n **L**ine (**DOL** **for short**) is the cheapest and simplest method of connecting a squirrel cage induction motor to a single-phase or three-phase a.c. supply.

1. What would be the issue with just using an isolating switch to directly operate all motors?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 391 - 395** * **YouTube videos:**  [Principles of Motor Control](https://www.youtube.com/watch?v=aml0VGzNXEo) 1:15 |

1. What is the name of the device which connects the electrical supply to the motor?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 391 - 395** * **YouTube videos:**  [Principles of Motor Control](https://www.youtube.com/watch?v=aml0VGzNXEo) 1:35 |

1. What is the name of the arrangement that contains the contacts that bridge between the electrical supply and the motor?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 391 - 395** * **YouTube videos:**  [Principles of Motor Control](https://www.youtube.com/watch?v=aml0VGzNXEo) 1:55 |

1. Explain how the coil causes the contacts to make between the electrical supply and the motor?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 391 - 395** * **YouTube videos:**  [Principles of Motor Control](https://www.youtube.com/watch?v=aml0VGzNXEo) 1:55 |

**Step 7 continued**

1. Describe what happens when the coil is de-energised.

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 391 - 395** * **YouTube videos:**  [Principles of Motor Control](https://www.youtube.com/watch?v=aml0VGzNXEo) 2:45 |

1. What is the main purpose of a starter?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 391 - 395** * **YouTube videos:**  [Principles of Motor Control](https://www.youtube.com/watch?v=aml0VGzNXEo) 3:00 |

1. What colour is associated with a start button?

|  |
| --- |
|  |
| **References:**   * **YouTube videos:**  [Principles of Motor Control](https://www.youtube.com/watch?v=aml0VGzNXEo) 4:30 |

1. What does the abbreviation **N.O.** mean when associated with a start button?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 391 - 395** |

1. What is the term used to describe a contact that can be added to the top or side of a contactor?

|  |
| --- |
|  |
| **References:**   * **YouTube videos:**  [Principles of Motor Control](https://www.youtube.com/watch?v=aml0VGzNXEo) 4:50 |

**Step 7 continued**

1. What terms are used to describe the current that a motor takes when at **full speed**?

|  |  |
| --- | --- |
|  | |
| **References:**   * **Text Book B Chapter ELTK 08 pages 391-395** | * **YouTube videos:** [Principles of Motor Control](https://www.youtube.com/watch?v=aml0VGzNXEo) 11:30 |

1. When a motor is first switched on what is the **inrush current** compared the current that a motor takes when at full speed?

|  |  |
| --- | --- |
|  | |
| **References:**   * **Text Book B Chapter ELTK 08 pages 391-395** | * **YouTube videos:** [Principles of Motor Control](https://www.youtube.com/watch?v=aml0VGzNXEo) 11:50 |

1. What part of a protective device protects against **Short Circuit** overcurrent?

|  |  |
| --- | --- |
|  | |
| **References:**   * **Text Book B Chapter ELTK 08 pages 391-395** | * **YouTube videos:** [Principles of Motor Control](https://www.youtube.com/watch?v=aml0VGzNXEo) 12:30 |

1. What part of a protective device protects against **Overload** overcurrent?

|  |  |
| --- | --- |
|  | |
| **References:**   * **Text Book B Chapter ELTK 08 pages 391-395** | * **YouTube videos:** [Principles of Motor Control](https://www.youtube.com/watch?v=aml0VGzNXEo) 12:30 |

1. What is the name of the separate component that can be inserted at the outgoing terminals of a contactor to provide only **Overload Protection**?

|  |  |
| --- | --- |
|  | |
| **References:**   * **Text Book B Chapter ELTK 08 pages 391-395** | * **YouTube videos:** [Principles of Motor Control](https://www.youtube.com/watch?v=aml0VGzNXEo) 14:10 |

1. What is the purpose of the three **bi-metals** inside the overload device?

|  |  |
| --- | --- |
|  | |
| **References:**   * **Text Book B Chapter ELTK 08 pages 391-395** | * **YouTube videos:** [Principles of Motor Control](https://www.youtube.com/watch?v=aml0VGzNXEo) 14:15 |

**Step 7 continued**

We will now look at DOL circuit diagram based on IEC **symbols** to BSEN IEC 60617.

1. Insert the symbol described and its purpose.

|  |  |  |  |
| --- | --- | --- | --- |
| **Description** | **Symbol** | | **Purpose** |
| Contactor coil |  | |  |
| Start button |  | |  |
| Stop button |  | |  |
| Overload normally closed contact |  | |  |
| Contactor auxiliary contact |  | |  |
| Overload normally open contact |  | |  |
| Yellow LED indicator |  | |  |
| **References:**  **YouTube videos:** [DOL Starter Diagram](https://www.youtube.com/watch?v=J1fDMAdbqvU) | | * **YouTube videos:** [DOL Starter Diagram](https://www.youtube.com/watch?v=J1fDMAdbqvU) | |

|  |
| --- |
| **Other YouTube videos:** [How to Connect a 400v DOL Starter](https://www.youtube.com/watch?v=W5rbyNhuJwI)  [3-phase dol starter Control & Power Wiring diagram](https://www.youtube.com/watch?v=bBxZnW6szgU)  [Single Phase DOL Starter Wiring Diagram](https://www.youtube.com/watch?v=53WGVgbQ86w) |

**Step 8**

The DOL starter is more often only suitable for starting small loads i.e. those powered by motors up to about **4** - **5 kW**, depending on the load characteristics.

Starting motors much bigger than this could exert an unacceptable strain on the protective devices, the associated switchgear and the cables.

We will now consider the relevant methods of controlling large three-phase motors using a method known as **Star**-**Delta** starting.

1. Give a reason why a star delta starter would be needed over a simple DOL starter.

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 396 - 397** * **YouTube videos:**  [Understanding the STAR-DELTA Starter](https://www.youtube.com/watch?v=km8MSWm39Z0) 2:40 |

1. Produce a diagram showing the two methods the stator windings (U1-U2, V1-V2, and W1-W2) can be connected to a three-phase supply to create star and delta configurations.

|  |  |
| --- | --- |
| Star: | Delta: |
| **References:**   * **Text Book B Chapter ELTK 08 pages 396 - 397** * **YouTube videos:**  [Understanding the STAR-DELTA Starter](https://www.youtube.com/watch?v=km8MSWm39Z0) 3:30 | |

1. State the nominal phase voltage in Star and Delta

|  |  |
| --- | --- |
| Star: | Delta: |
| **References:**   * **Text Book B Chapter ELTK 08 pages 396 - 397** * **YouTube videos:**  [Understanding the STAR-DELTA Starter](https://www.youtube.com/watch?v=km8MSWm39Z0) 3:50 | |

**Step 8 continued**

1. Explain how starting the motor in star and then changing to delta reduces the **start-up current**.

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 396 - 397** * **YouTube videos:**  [Understanding the STAR-DELTA Starter](https://www.youtube.com/watch?v=km8MSWm39Z0) 4:10 |

1. Using two links and the winding abbreviations U1-U2, V1-V2, W1-W2, show how a three-phase supply L1, L2, L3, would connect to a six terminal junction box if the motor was set up for **Star**, then if the motor was set up for **Delta**.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Star:   |  |  |  | | --- | --- | --- | |  |  |  | |  |  |  | | Delta:   |  |  |  | | --- | --- | --- | |  |  |  | |  |  |  | |
| **References:**   * **Text Book B Chapter ELTK 08 pages 396 - 397** * **YouTube videos:**  [Understanding the STAR-DELTA Starter](https://www.youtube.com/watch?v=km8MSWm39Z0) 4:10 | |

1. By removing the terminal housing cover how is it possible to instantly recognise if a motor is manually fixed for star or delta.

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 396 - 397** * **YouTube videos:**  [Star Delta Starter Explained](https://www.youtube.com/watch?v=h89TTwlNnpY&list=TLPQMTgxMDIwMjCIiMDPIf6yqg&index=2) 3:45 |

**Step 8 continued**

1. Explain how starting the motor in star and then changing to delta can be automated.

|  |  |
| --- | --- |
|  | |
| **References:**   * **Text Book B Chapter ELTK 08 pages 396 - 397** | * **YouTube videos:**  [The STAR-DELTA Starter](https://www.youtube.com/watch?v=km8MSWm39Z0) 4:30 |

1. Which contactors must be switched in so that the motor is configured for Star at Start-up?

|  |  |
| --- | --- |
|  | |
| **References:**   * **Text Book B Chapter ELTK 08 pages 396 - 397** | * **YouTube videos:**  [The STAR-DELTA Starter](https://www.youtube.com/watch?v=km8MSWm39Z0) 5:20 |

1. Which contactors must be switched in so that the motor is configured for Delta for running?

|  |  |
| --- | --- |
|  | |
| **References:**   * **Text Book B Chapter ELTK 08 pages 396 - 397** | * **YouTube videos:**  [The STAR-DELTA Starter](https://www.youtube.com/watch?v=km8MSWm39Z0) 5:45 |

1. Which component automatically controls the changeover from star to delta?

|  |  |
| --- | --- |
|  | |
| **References:**   * **Text Book B Chapter ELTK 08 pages 396 - 397** | * **YouTube videos:**  [The STAR-DELTA Starter](https://www.youtube.com/watch?v=km8MSWm39Z0) 6:15 |

1. Why do we use star/ delta starters?

|  |  |
| --- | --- |
|  | |
| **References:**   * **Text Book B Chapter ELTK 08 pages 396 - 397** | * **YouTube videos:**  [The STAR-DELTA Starter](https://www.youtube.com/watch?v=km8MSWm39Z0) 7:15 |

1. As a **percentage** what is the phase voltage(V), current (I) and torque (Τ) in star compared to the phase voltage/ current/ torque in delta.

|  |  |  |  |
| --- | --- | --- | --- |
| V**P** **Star** / V**P** **Delta** | I**P** **Star** / I**P** **Delta** | | Τ **Star** / Τ **Delta** |
| **References:**   * **Text Book B Chapter ELTK 08 pages 396 - 397** | | * **YouTube videos:**  [The STAR-DELTA Starter](https://www.youtube.com/watch?v=km8MSWm39Z0) 7:30 | |

**Step 9**

The other three-phase motor encountered earlier is the Wound Rotor induction motor and these motors are controlled using a **Rotor Resistance Starter**.

1. Explain the main difference between the construction of a three-phase squirrel cage induction motors and **wound rotor** induction motors.

|  |  |
| --- | --- |
|  | |
| **References:**   * **Text Book B Chapter ELTK 08 pages 399 - 400** | * **YouTube videos:**  [SLIP RING MOTOR](https://www.youtube.com/watch?v=W1mee2uNFiE) 2:10 |

1. What is the name of the arrangement which connects the rotor winding back to the control cabinet in wound rotor induction motors?

|  |  |
| --- | --- |
|  | |
| **References:**   * **Text Book B Chapter ELTK 08 pages 399 - 400** | * **YouTube videos:**  [SLIP RING MOTOR](https://www.youtube.com/watch?v=W1mee2uNFiE) 3:30 |

1. Explain the function of the three contactors seen in the **Resistance Control Cabinet** that is used for starting the lift wound rotor induction motor.

|  |  |  |
| --- | --- | --- |
| **Contactor** | **Function** | |
| **M.C.** |  | |
| **R.C.** |  | |
| **R.C.1.** |  | |
| **References:**   * **Text Book B Chapter ELTK 08 pages 399 - 400** | | * **YouTube videos:**  [SLIP RING MOTOR](https://www.youtube.com/watch?v=W1mee2uNFiE) 5:30 |

**Step 10**

Electronic devices have found their way in to motor control both for **starting** and for **speed regulation**. We will now consider **Soft Starters** and **Variable Frequency Drives** (VFDs).

1. Give a reason why a soft starter would be selected over a simple DOL starter.

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 398** * **YouTube videos:**  [What is a Soft Starter](https://www.youtube.com/watch?v=6X71RZWvOvc) 1:10 |

1. Give two applications where soft starters might be used in industrial applications.

|  |
| --- |
|  |
| **References:**   * **YouTube videos:**  [What is a Soft Starter](https://www.youtube.com/watch?v=6X71RZWvOvc) 2:00 |

1. What is the main electronic component used in soft starters to control the voltage to the motor?

|  |
| --- |
|  |
| **References:**   * **YouTube videos:**  [What is a Soft Starter](https://www.youtube.com/watch?v=6X71RZWvOvc) 3:50 |

1. Give a reason why a Variable Frequency Drive (VFD) would be selected.

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 402** * **YouTube videos:**  [What is a VFD? (Variable Frequency Drive)](https://www.youtube.com/watch?v=g7jFGOn6xfU) 1:10 |

1. Explain the main difference between VFD and Soft Starter applications.

|  |
| --- |
|  |
| **References:**  **YouTube videos:**  [The Difference between VFD and Soft Starter](https://www.youtube.com/watch?v=_ZztDN5XX5o) 1:15 3:20 |

**Step 11**

For many applications there is a need to have more than one start or stop button, the additional ones often being wired **remote** from the **local** buttons found on the starter itself.

1. How are multiple stop buttons wired in to a motor control circuit.

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 396** * **YouTube videos:**  [3 Wire Start Stop Circuit](https://www.youtube.com/watch?v=kHbXbK7S188) 2:35 |

1. How are multiple start buttons wired in to a motor control circuit.

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 396** * **YouTube videos:**  [3 Wire Start Stop Circuit](https://www.youtube.com/watch?v=kHbXbK7S188) 3:00 |

1. Produce a circuit diagram showing how **ONLY** three stop buttons, two start buttons and the auxiliary hold on contact would be wired together as part of a motor control circuit.

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 396** * **YouTube videos:**  [3 Wire Start Stop Circuit](https://www.youtube.com/watch?v=kHbXbK7S188) 3:00 |

**Step 12**

We will now consider the calculations involved in determining the **Input Power**, the **Output Power**, and the **Efficiency** associated with a.c. induction motors.

1. Determine the **efficiency** (%) of a 8.32 kW motor that takes 34 Amps from a 250 Volt supply.

|  |  |
| --- | --- |
|  | |
| **References:**   * **Text Book B Chapter ELTK 08 pages 256** | * **YouTube videos:**  [Calculating motor efficiency](https://www.youtube.com/watch?v=U8IOOdwEGbM) 0:30 |

1. Determine the efficiency (%) of a 2 kW motor that takes 5 Amps from a 440 Volt supply.

|  |
| --- |
|  |

1. Determine the efficiency of a 0.75 kW motor that takes 5 A at p.f. 0.8, from a 230 Volt supply.

|  |
| --- |
|  |

**Step 12 continued**

We will now consider the calculations involved in determining the **Synchronous Speed**, the **Rotor Speed**, and the **Slip** associated with a.c. induction motors.

1. What is the speed of the rotating magnetic field in a 3-phase induction motor known as?

|  |  |
| --- | --- |
|  | |
| **References:**   * **Text Book B Chapter ELTK 08 pages 385** | * **YouTube videos:**  [Rotating Magnetic Field](https://www.youtube.com/watch?v=8XF-11MQGQ0) 1:00 |

1. Calculate the **Synchronous speed** (**NS**) of three-phase 8 pole 50Hz induction motor.

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 387** * **YouTube videos:** [Poles vs the generator speed](https://www.youtube.com/watch?v=iZzK7bPfvUs)  [Find the synchronous speed of a motor](https://www.youtube.com/watch?v=qV8X1rhDuGQ) |

1. Calculate the **Synchronous speed** (**NS**) of following motors induction motor.

|  |  |  |
| --- | --- | --- |
| **No. of poles** | **Frequency** (Hz) | **NS** (RPM) |
| **2** | **50** |  |
| **4** | **50** |  |
| **8** | **50** |  |
| **12** | **50** |  |
| **2** | **60** |  |
| **4** | **60** |  |
| **8** | **60** |  |
| **12** | **60** |  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 387** * **YouTube videos:** [Poles vs the generator speed](https://www.youtube.com/watch?v=iZzK7bPfvUs)  [Find the synchronous speed of a motor](https://www.youtube.com/watch?v=qV8X1rhDuGQ) | | |

**Step 12 continued**

1. What is the definition of slip in a 3-phase induction motor?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 386 - 387** * **YouTube videos:**  [What is slip in an induction motor](https://www.youtube.com/watch?v=fn4e1N2Vs4I) 0:08 |

1. State the meaning of the following symbols found in the formula used to calculate Slip.

|  |  |
| --- | --- |
| **Symbol** | **Description** |
| **S** |  |
| **S (per cent)** |  |
| **NS** |  |
| **NR** |  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 387 - 388** * **YouTube videos:**  [What is slip in an induction motor](https://www.youtube.com/watch?v=fn4e1N2Vs4I) 0:08 | |

1. Calculate the percentage slip for the following situations:

|  |  |
| --- | --- |
| **Situation** | **S %** |
| A 12 pole, 50Hz induction motor runs at 475 revs/minute. |  |
| A 8 pole, 50Hz induction motor runs at 12 revs/second. |  |
| A 4 pole, 50Hz induction motor runs at 25 revs/second. |  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 387 - 388** * **YouTube videos:**  [What is slip in an induction motor](https://www.youtube.com/watch?v=fn4e1N2Vs4I) 0:08 | |

**Step 12 continued**

We finally need to consider how we change the direction of rotation of a.c. induction motors.

1. Explain how to permanently change the direction of rotation of a three-phase induction motor?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 386 - 387** * **YouTube videos:**  [Reverse the Direction of a 3 Phase Motor](https://www.youtube.com/watch?v=VqgXVIi0jw8) 0:05 |

1. With the aid of a circuit diagram shown how to remotely change the direction of rotation of a three-phase induction motor using contactors?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 pages 386 - 387** * **YouTube videos:**  [Reverse the Direction of a 3 Phase Motor](https://www.youtube.com/watch?v=VqgXVIi0jw8) [Forward Reversing Starter](https://www.youtube.com/watch?v=fMTvZ60y0z0) |

1. Explain how to change the direction of rotation of a single-phase induction motor?

|  |
| --- |
|  |
| **References:**   * **Text Book B Chapter ELTK 08 page 379** * **YouTube videos:**  [Reversing the Direction of single phase motor](https://www.youtube.com/watch?v=qmQV0gDiQVo) 0:40 |