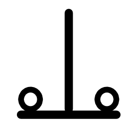
**Exam Format**: The exam will be "**CLOSED BOOK**".

**Problem #1)** Which type of device is depicted by the symbol shown to the right?

**a)** Normally Open (NO) Pushbutton
**b)** Normally Closed (NC) Pushbutton
**c)** Normally Open (NO) Switch
**d)** Normally Closed (NC) Switch



**Problem #2)** What is the **primary difference** between a "***contactor***" and a "***relay***"?

**Problem #3) Draw** the symbol typically used to depict a "***Normally Closed Contact***".

**Problem #4)** Are the following statements relating to "Overload Relays" ***True*** or ***False***?

__________ Overload relays are designed to protect motors from line currents that are larger in magnitude than the motor's starting current.

__________ Overload relays operate on a time curve such that their trip time decreases as the line current magnitude increases.

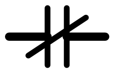
__________ A basic mechanical overload relay utilizes a set of "heaters" and normally open contacts.

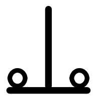
__________ An overload relay's heaters are placed in series with the lines supplying the motor such that the entire line currents flow through the heaters.

**Problem #5)** What are the **primary disadvantages** of using an "***Across the Line***" motor starter?

**Problem #6) List the functional steps** that a "***Series Resistance Reduced Voltage Starter***" utilizes to start a three phase induction motor.

**Problem #7**) Match the symbols shown in the left-hand column with the devices listed in the right-hand column by writing the letter associated with the correct device next to the appropriate symbol.

____ 

____ 

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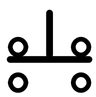
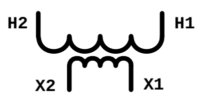
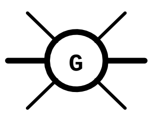
____ 

____ 


____ 


**A)** Main Contactor's Field Coil

**B)** Transformer

**C)** Circuit Breaker

**D)** Two Position Switch

**E)** Control Relay's Field Coil

**F)** Indicator Lamp

**G)** Normally Closed Pushbutton

**H)** Normally Closed Contact

**I)** Overload Relay's Heater

**J)** Fuse

**K)** Pressure Switch

**L)** Normally Open Pushbutton

**M)** Normally Open Contact

**N)** None of the above

**Problem #8**) Describe how a "series-resistance" motor starter limits the starting current of an induction motor.

**Problem #9)** Specify whether each of the following statements are true or false by **printing** either "TRUE" or "FALSE" in the blank answer space preceding each statement.

***Note – answer spaces containing only a "T" or an "F" will be graded as "incorrect".***

__________ A Normally Open (NO) Pushbutton contains one or more sets of contacts that "close" while the button is pressed and then return back to an "open" state when the button is released.

__________ A Normally Closed (NC) Auxiliary Contact is often used to "hold-in" a contactor after the "start" pushbutton in a motor control system is pressed and then released.

__________ A contactor's Auxiliary Contacts function in the exact same manner as its Main Contacts, although the auxiliary contacts typically have a much lower current rating than that of the main contacts.

__________ An Overload Relay is designed to protect a motor from an overload due to a high supply voltage magnitude while the machine is driving up to its rated mechanical load.

__________ An Across-the-Line Motor Starter starts the motor by applying full rated voltage to the motor's terminals.

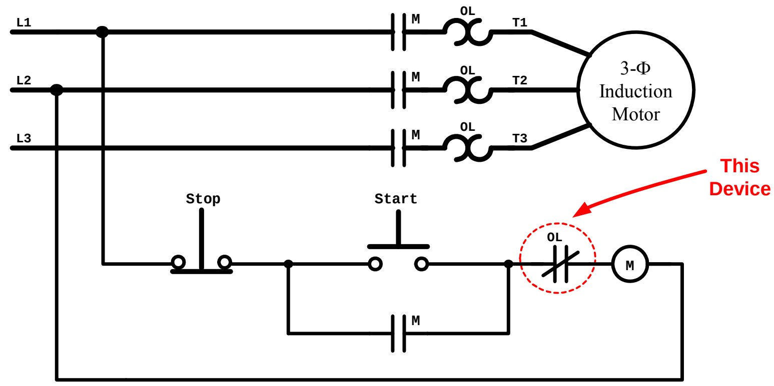
__________ Although an Overload Relay uses an Off-Delay Timer to delay shutting-down a motor during "start-up", it is able to bypass the timer and immediately shut-down the motor if it detects an overload condition while the motor is operating near rated speed.

__________ Although contactors are designed to be able to disconnect an energized motor from its supply lines (i.e. – shut-down the motor) even during overload conditions, contactor's are not designed to interrupt short-circuit or other similarly large currents.

__________ While a motor is driving its rated load, a moderate increase in the supply voltage magnitude will likely result in an overload condition where as a moderate decrease in the supply voltage magnitude may slow-down the motor but will not result in an overload.

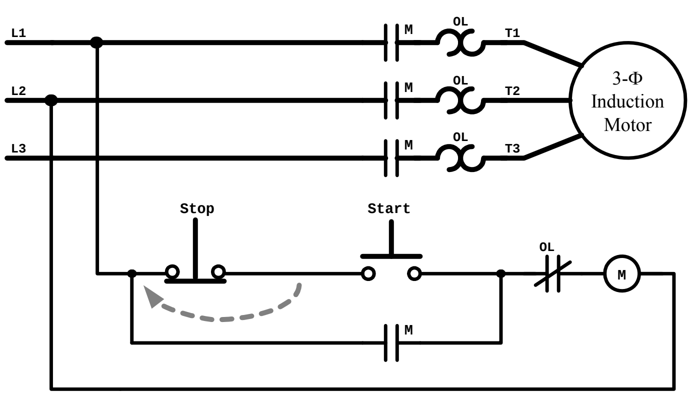
__________ Starting a large induction motor by applying full rated voltage to its terminals will result in large inrush currents and an associated developed torque surge during start-up, with both the line currents and the developed torque typically reaching magnitudes that are four to ten times larger than their rated values.

**Problem #10)** Parts "**a**" and "**b**" of this problem are related only to the motor starter shown in the upper right corner of this page. Part "**c**" of this problem requires a comparison of the first starter's operation to that of the starter shown in the bottom left corner of this page.




**a)** Describe the function of the "circled" device in terms of its purpose as part of the entire motor control system. Be specific in terms of when it should activate and how its activation affects the other parts of the system.

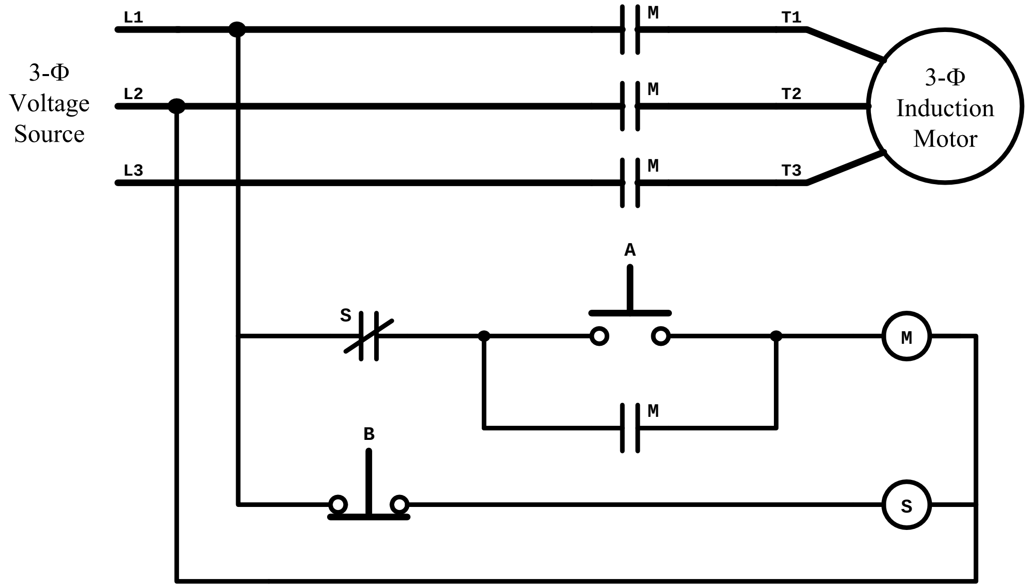
**b)** If the "circled" device was removed and replaced with an ideal wire, describe the effect this would have on the operation of the starter? (I.e. – could the system still start the motor and/or stop the motor, and would there be other changes to the starter's functions?)




c) Compared to the original starter shown above, how would it affect the operation of the starter if the auxiliary contact was mistakenly wired as shown in the diagram to the left?

***Write your answer to part "c" on the back of the previous page (page 2) of the exam booklet.***

**Problem #11)** The motor control system shown below was designed to operate as a across-the-line (full voltage) "Start/Stop" system. Pushbutton "A" is used to "Start" the motor and pushbutton "B" is used to "Stop" the motor. The system does not work properly.




Describe the manner in which the system does not work properly as shown above:

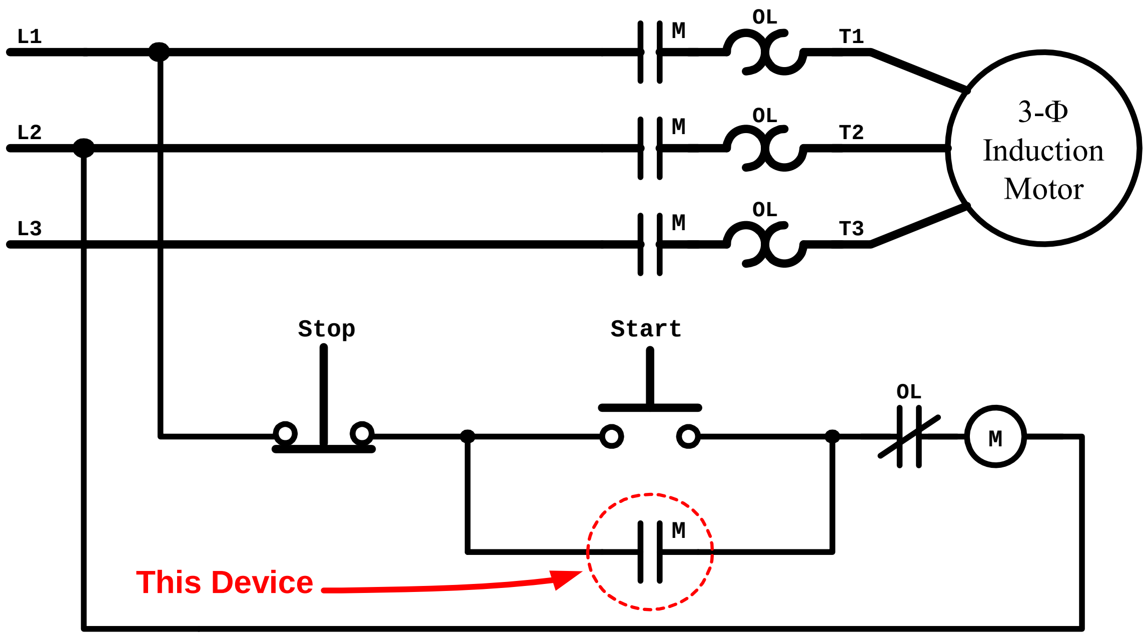
There are two "**single**" changes that could be made to the system such that if either change is made the system would function properly. Determine both of these changes.

Change #1:

Change #2:

Which of the above changes is the preferred "fix" to the system? Explain why.

**Problem #12)** Specify the function of the device that is highlighted in the figure below that shows a motor control system. Do not discuss the device's theoretical operation, but instead discuss its purpose or ***function within the motor control system***.

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Note – you should be able to specify the function of every device used in the motor-starting control system shown for problem #12 at the top of this page. For example, if I asked for the function of the "Stop" button (instead of the auxiliary contact that problem #12 is addressing), an appropriate answer would be:

> "***The Stop button provides the means for stopping the motor by interrupting or breaking the current path to the field coil of the main contactor whenever it is pressed. When the field coil is de-energized, both the main power contacts and the auxiliary contact will drop-out, removing power from the motor and preventing it from starting back up when the Stop button is released until the Start button is pressed again.***"

---

As a final thought… the test will cover the fundamentals of motor control systems including the terminology, concepts, theory, devices, control systems and control logic as discussed and investigated during both the lecture and the laboratory sessions.

***Review your notes and the PowerPoint slides, and read the appropriate sections in the <u>Fundamentals of Motor Control</u> reference book available on my faculty webpage.***

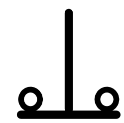
The relevant sections in the Fundamentals of Motor Control handbook for this exam are:

| | | |
|---|---|---|
| Chapter 1 | – Introduction | pages 1 – 6 |
| Chapter 3 | – Overcurrent and Overload | pages 11 – 14 (top), 16 (bottom) – 17 |
| Chapter 4 | – Starters | pages 21(Magnetic Control) – 23, 27, 29 – 31 |
| Chapter 5 | – Diagrams and Wire Control | page 35 (Three Wire Control) |
| Chapter 6 | – Power Devices | pages 37 – 40 |
| Chapter 7 | – Relays, Timers, Starters… | (all devices discussed during the lectures) |

**ECET 4530 – Industrial Motor Control** **Sample Exam I – Old Part A – Solutions**

**Exam Format**: The exam will be "**CLOSED BOOK**".

**Problem #1)** Which type of device is depicted by the symbol shown to the right?

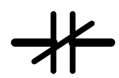


- **a)** Normally Open (NO) Pushbutton
- **b)** **Normally Closed (NC) Pushbutton ←**
- **c)** Normally Open (NO) Switch
- **d)** Normally Closed (NC) Switch

**Problem #2)** What is the **primary difference** between a "***contactor***" and a "***relay***"?

**A contactor is designed to handle large currents compared to a relay**

**Problem #3) Draw** the symbol typically used to depict a "***Normally Closed Contact***".



**Problem #4)** Are the following statements relating to "Overload Relays" ***True*** or ***False***?

**___False____** Overload relays are designed to protect motors from line currents that are larger in magnitude than the motor's starting current.

**___True____** Overload relays operate on a time curve such that their trip time decreases as the line current magnitude increases.

**___False____** A basic mechanical overload relay utilizes a set of "heaters" and normally open contacts.

**___True____** An overload relay's heaters are placed in series with the lines supplying the motor such that the entire line currents flow through the heaters.

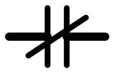
**Problem #5)** What are the **primary disadvantages** of using an "***Across the Line***" motor starter?

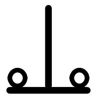
**Large starting currents and associated large torques cause electrical, mechanical and thermal stress on the motor, electrical stress and voltage drops on the electric distribution system, and mechanical stress on the load that the motor is driving**

**Problem #6) List the functional steps** that a "***Series Resistance Reduced Voltage Starter***" utilizes to start a three phase induction motor.

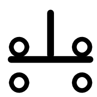
- **"start" contactor is energized**
- **"start" contacts close, supplying power to motor through resistors and starting timer**
- **when timer finishes counting, timer contact closes, energizing "run" contactor**
- **"run" contacts close, providing short-circuit current path around resistors**

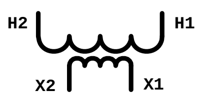
**Problem #7**) Match the symbols shown in the left-hand column with the devices listed in the right-hand column by writing the letter associated with the correct device next to the appropriate symbol.

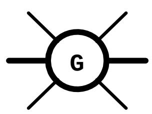
H 

G 

I 

N 

B 


F 


**A)** Main Contactor's Field Coil

**B)** Transformer

**C)** Circuit Breaker

**D)** Two Position Switch

**E)** Control Relay's Field Coil

**F)** Indicator Lamp

**G)** Normally Closed Pushbutton

**H)** Normally Closed Contact

**I)** Overload Relay's Heater

**J)** Fuse

**K)** Pressure Switch

**L)** Normally Open Pushbutton

**M)** Normally Open Contact

**N)** None of the above

**Problem #8**) Describe how a "series-resistance" motor starter limits the starting current of an induction motor.

**Initially starts the motor with a set of resistors connected in series with each phase of the motor, causing a voltage-drop as the starting-current flows through them, thus decreasing the actual voltage magnitude seen at the terminals of the motor.**

**Problem #9)** Specify whether each of the following statements are true or false by **printing** either "TRUE" or "FALSE" in the blank answer space preceding each statement.

***<u>Note – answer spaces containing only a "T" or an "F" will be graded as "incorrect"</u>.***

**___True____** A Normally Open (NO) Pushbutton contains one or more sets of contacts that "close" while the button is pressed and then return back to an "open" state when the button is released.

**___False____** A Normally Closed (NC) Auxiliary Contact is often used to "hold-in" a contactor after the "start" pushbutton in a motor control system is pressed and then released.

**___True____** A contactor's Auxiliary Contacts function in the exact same manner as its Main Contacts, although the auxiliary contacts typically have a much lower current rating than that of the main contacts.

**___False____** An Overload Relay is designed to protect a motor from an overload due to a high supply voltage magnitude while the machine is driving up to its rated mechanical load.

**___True____** An Across-the-Line Motor Starter starts the motor by applying full rated voltage to the motor's terminals.

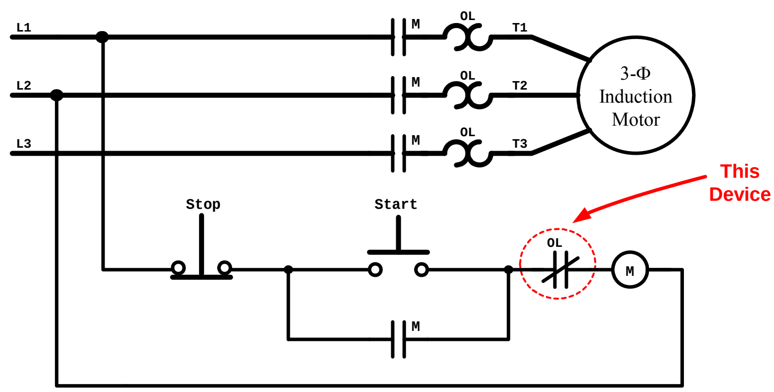
**___False____** Although an Overload Relay uses an Off-Delay Timer to delay shutting-down a motor during "start-up", it is able to bypass the timer and immediately shut-down the motor if it detects an overload condition while the motor is operating near rated speed.

**___True____** Although contactors are designed to be able to disconnect an energized motor from its supply lines (i.e. – shut-down the motor) even during overload conditions, contactor's are not designed to interrupt short-circuit or other similarly large currents.

**___False____** While a motor is driving its rated load, a moderate increase in the supply voltage magnitude will likely result in an overload condition where as a moderate decrease in the supply voltage magnitude may slow-down the motor but will not result in an overload.

**___False____** Starting a large induction motor by applying full rated voltage to its terminals will result in large inrush currents and an associated developed torque surge during start-up, with both the line currents and the developed torque typically reaching magnitudes that are four to ten times larger than their rated values.

**Problem #10)** Parts "**a**" and "**b**" of this problem are related only to the motor starter shown in the upper right corner of this page. Part "**c**" of this problem requires a comparison of the first starter's operation to that of the starter shown in the bottom left corner of this page.

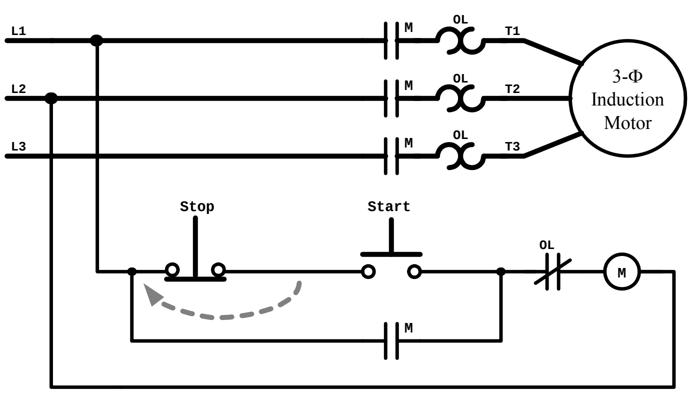



**a)** Describe the function of the "circled" device in terms of its purpose as part of the entire motor control system. Be specific in terms of when it should activate and how its activation affects the other parts of the system.

**NC contact associated with Overload Relay. When an overload causes the Overload Relay to activate, this NC contact will open and de-energize the main contactor, the contacts of which will open, thus shutting-down the motor**

**b)** If the "circled" device was removed and replaced with an ideal wire, describe the effect this would have on the operation of the starter? (I.e. – could the system still start the motor and/or stop the motor, and would there be other changes to the starter's functions?)

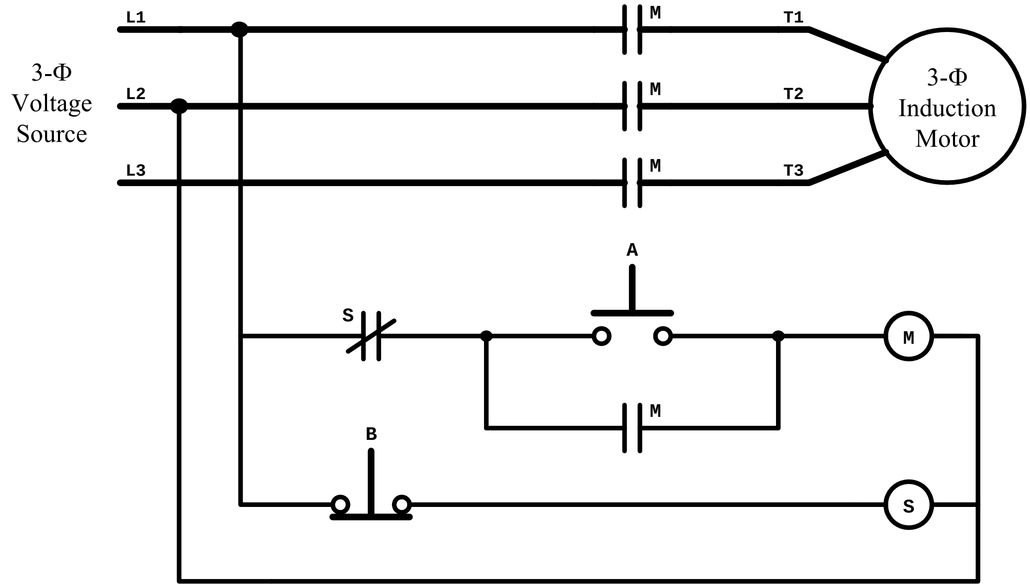
**It would have no effect during normal operation, but the motor would no longer be protected from overloads because the OL Relay would not be able to de-energize the contactor.**




c) Compared to the original starter shown above, how would it affect the operation of the starter if the auxiliary contact was mistakenly wired as shown in the diagram to the left?

**Once the motor was started, pressing the "Stop" button would not cause the motor to stop because the (now closed) NO auxiliary contact would continue to provide a current-path to the field coil of the contactor**.

**Problem #11)** The motor control system shown below was designed to operate as a across-the-line (full voltage) "Start/Stop" system. Pushbutton "A" is used to "Start" the motor and pushbutton "B" is used to "Stop" the motor. The system does not work properly.




Describe the manner in which the system does not work properly as shown above:

**The motor will not be able to start unless pushbutton "B" is pressed and held in.**

**If "B" is not pressed, then field-coil "S" will be energized, and its NC contact will become open, in-turn preventing the contactor "M" field-coil from being energized.**

There are two "**single**" changes that could be made to the system such that if either change is made the system would function properly. Determine both of these changes.

Change #1:

**Change the NC "S" contact to a NO contact**

Change #2:

**Change the NC pushbutton "B" to a NO pushbutton**

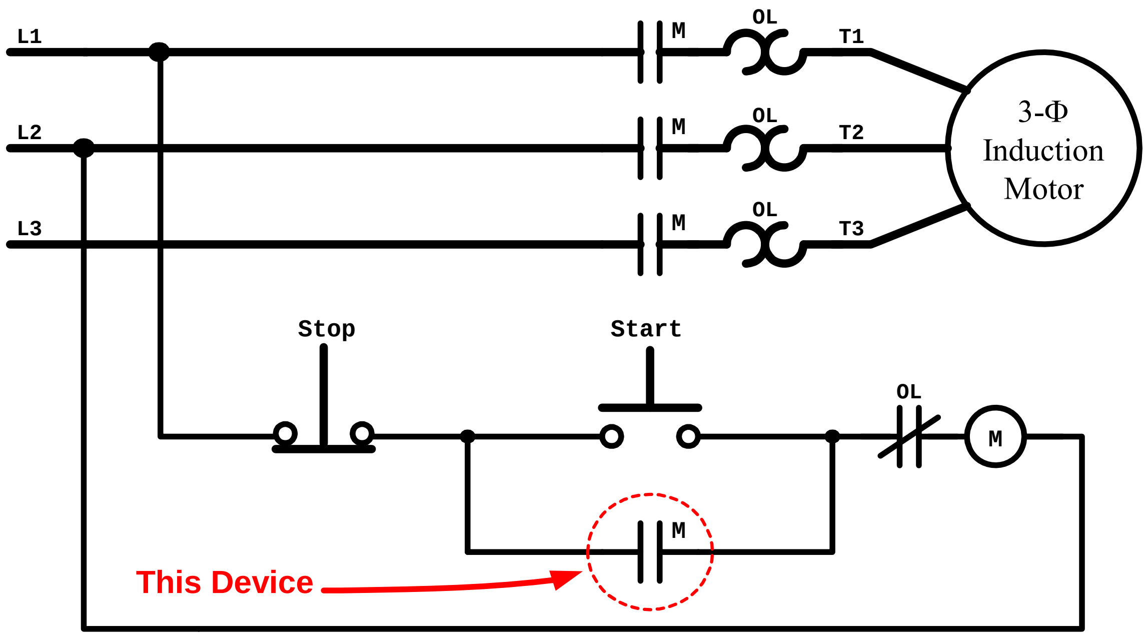
Which of the above changes is the <u>preferred</u> "fix" to the system? Explain why.

**<u>Change #1</u>. With change #2, if relay "S" fails, the system will continue to without any sign of a problem until "B" is pressed, at which time the failure would become evident because pressing "B" will not stop the machine is relay "S" does not function. Not being able to stop the machine could be quite hazardous.**

**Which change #1, is relay "S" fails, the motor will stop unexpectedly and would not be able to start again until the relay was fixed.**

**Note – either way, this is not an "ideal" start/stop controller.**

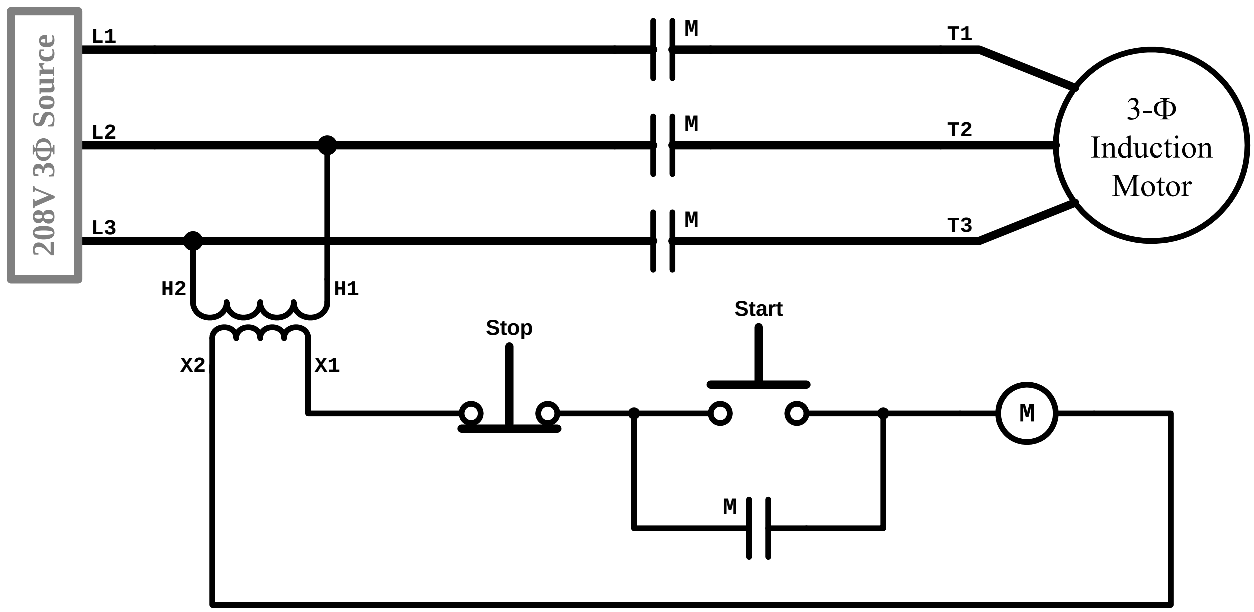
**Problem #12)** Specify the function of the device that is highlighted in the figure below that shows a motor control system. Do not discuss the device's theoretical operation, but instead discuss its purpose or ***function within the motor control system***.




**The circled NO contact is used to keep the motor running after the "Start" pushbutton is pressed and released.**

**When "Start" is pressed, contactor "M" will be energized, causing all of its contacts to actuate, one of which is the circled NO contact. When that contact closes, it provides a short-circuit current path around the "Start" button, allowing field-coil "M" to remain energized until the "Stop" button is pressed.**

**Problem A)** The following figure shows a 208V, 3Φ Induction motor that is being controlled by a simple start/stop motor controller.




You are expected to **redesign the system** such that it includes overload protection for the motor along with several other required features as described below…

**To receive complete credit for this problem:**

Redesign the system such that it includes:

- **i)** **Overload Protection** that will stop the motor if the motor is overloaded for too long, and
- **ii)** An **Indicator Lamp** to illuminates when the motor is energized, and
- **iii)** An **Indicator Lamp** that illuminates whenever the overload relay is in a "tripped" state.
- **iv)** A **"Reset" Push-Button** that must be pressed **after** the overload relay has had a chance to cool-down but **before** the motor can be restarted after the occurrence of an overload,.
  (I.e. – Pressing the "Start" button will not cause the motor to be re-energized unless the "Reset" button has been pressed after the relay has cooled-down and the relay's contacts have reverted back to their normal states)
- **v)** An additional **Indicator Lamp** that illuminates when the overload relay trips and remains illuminated until the "Reset" button has been pressed after the relay's contacts have reverted back to their normal states.

Additional Notes:

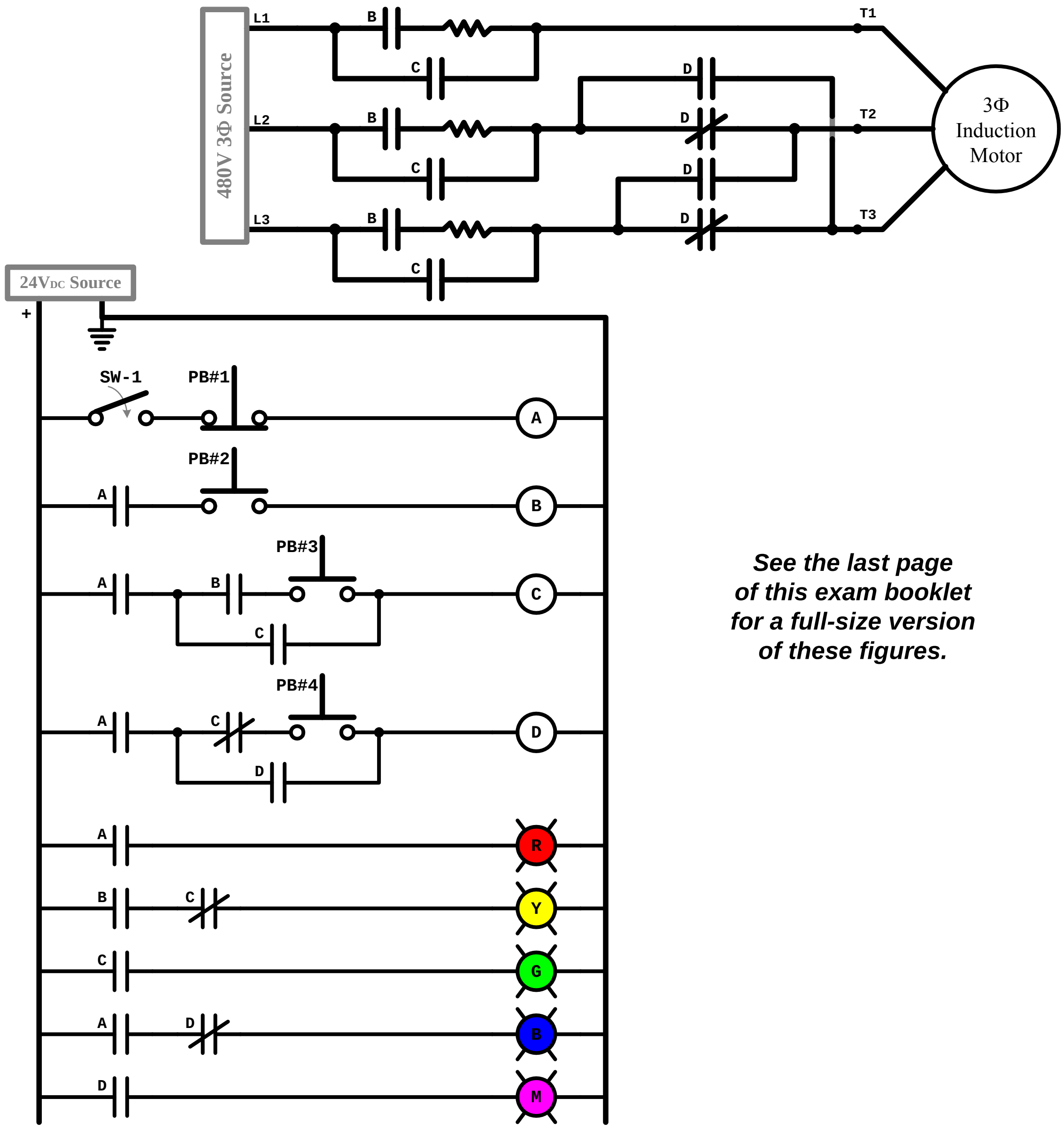
The overload relay utilized for this problem operates by means of a heated bi-metal strip such that, once the relay trips due to an overload, the relay's contacts will automatically revert back to their "normal" states once the bi-metal strip has had a chance to cool-down.

You may assume that the overload relay has both normally-open and normally-closed contacts available for use in your control circuit.

You may utilize as many additional relays and push-buttons as needed in order to complete the tasks.

**Neatly redraw the entire system** such that it includes all of the additional components required to complete the tasks specified above. Be sure all of the components are accurately labeled.

**Problem B)** Refer to the following motor starter and control circuit when completing parts (a)→(e):




***See the last page of this exam booklet for a full-size version of these figures.***

**a)** Specify a logical (<u>one</u> or <u>two</u> word) **name** or **label** for each of the push-buttons and indicator lamps that could be printed next to each of those devices on the system's control panel in order to provide the operator with information relating to the function or purpose of each specific device.

**b)** Assuming that SW-1 has been switched "**ON**" and that no push-buttons have been pressed, specify the exact **set of steps** that an operator should follow in order **to start the motor** in the forward direction. Additionally, specify which indicator lamps will be "**ON**" and "**OFF**" after each step is completed.

**c)** Specify the **procedure** that is required in order to change the motor's direction of rotation from **Forward to Reverse**. Include details that cover the following cases:

i) The motor is currently stopped and set for "Forward" operation,

ii) The motor is currently running in the "Forward" direction.

**d)** Specify the **procedure** that is required in order to change the motor's direction of rotation from **Reverse to Forward**. Include details that cover the following cases:

i) The motor is currently stopped and set for "Reverse" operation, and

ii) The motor is currently running in the "Reverse" direction.

**e)** **State** whether or not it is possible to change the direction of the motor while the motor is energized. **Justify** your answer.

**Answers to Problem B parts (a) and (b):**

a) **Device Names/Labels:** SW-1: **_Main Power_**     Red (R) Indicator: **______Power______**

PB#1: ________________     Yellow (Y) Indicator: ________________

PB#2: ________________     Green (G) Indicator: ________________

PB#3: ________________     Blue (B) Indicator: ________________

PB#4: ________________     Magenta (M) Indicator: ________________

b) **Instructions for Starting the Motor in the Forward Direction:**
(Note – you may not require all six steps. Leave any unused steps blank)

Step 1 – **______Flip the "Power" switch to the "ON" position in order to energize________ _________the control system.___________________________________________**

Indicator Lamps: **R_ON_ Y_OFF_ G_OFF_ B_ON_ M_OFF_** **(after step 1 is complete)**

Step 2 – ____________________________________________

____________________________________________

Indicator Lamps: **R_____ Y_____ G_____ B_____ M_____** **(after step 2 is complete)**

Step 3 – ____________________________________________

____________________________________________

Indicator Lamps: **R_____ Y_____ G_____ B_____ M_____** **(after step 3 is complete)**

Step 4 – ____________________________________________

____________________________________________

Indicator Lamps: **R_____ Y_____ G_____ B_____ M_____** **(after step 4 is complete)**

Step 5 – ____________________________________________

____________________________________________

Indicator Lamps: **R_____ Y_____ G_____ B_____ M_____** **(after step 5 is complete)**

Step 6 – ____________________________________________

____________________________________________

Indicator Lamps: **R_____ Y_____ G_____ B_____ M_____** **(after step 6 is complete)**

**Answers to Problem B parts (c), (d) and (e):**

c) **Instructions for Changing the Motor's Direction of Rotation from Reverse to Forward:**

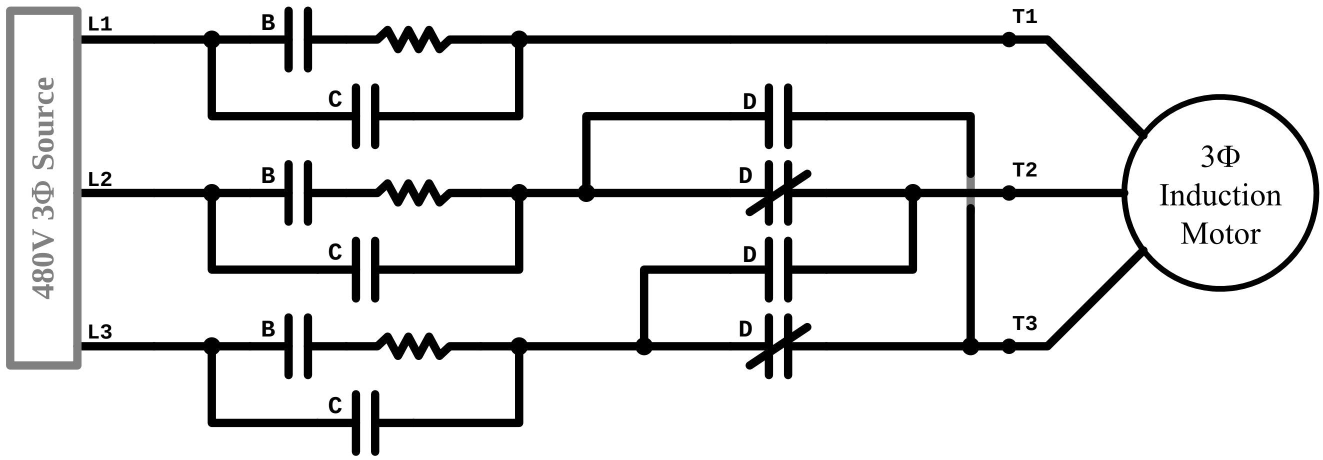
Instructions: ____________________

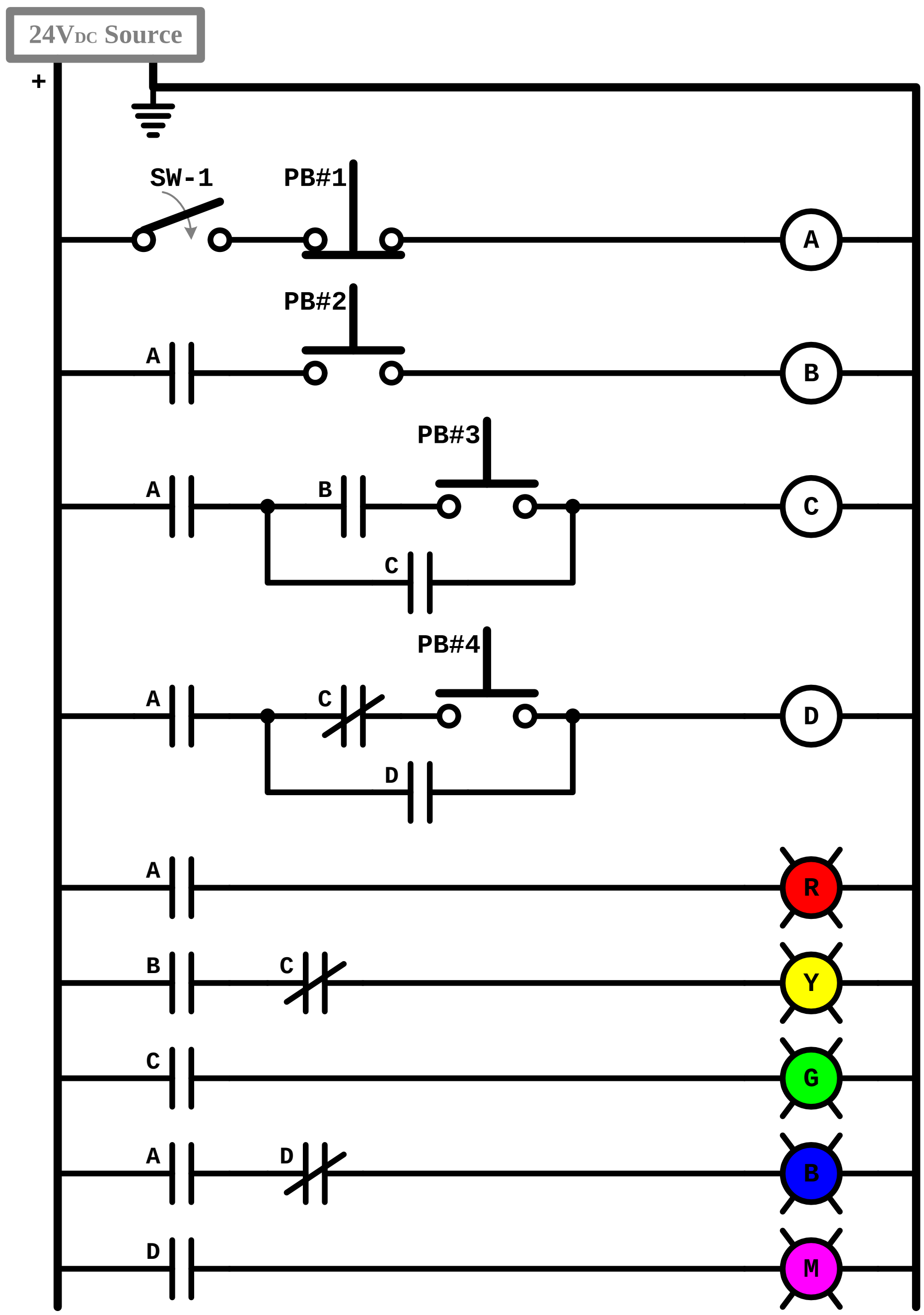
d) **Instructions for Changing the Motor's Direction of Rotation from Forward to Reverse:**

Instructions: ____________________

e) **Is possible to change the direction while the motor is energized?** ________ (YES or NO)

Justify your answer: ____________________




**Full-Size Version of Figures for Problem #3**