ECET 4530 – Summer 2019 ↱ **(in space to the right)**↘

Industrial Motor Control – Exam I pt. A **Print Name (Last Name First):_____ ANSWERS_____**

Instructions: Part A of this exam is closed-book. All final answers must be placed in the spaces provided.

Problem #1) 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.

Do **NOT** write only "T" or "F" in the blanks. Instead, **PRINT** either the word "**True**" or "**False**".

FALSE Given a contactor that contains both normally-open (NO) and normally-closed (NC) **auxiliary contacts**, the contactor can be utilized as a directional (D) contactor that can supply an Induction Motor with either a positive or a negative sequence set of voltages.

TRUE A **Variable Frequency Drive** (VFD) can be utilized to control the speed of an Induction Motor because the motor will normally operate at a speed that is less than, but within 5% of, its synchronous speed which is directly proportional to the source frequency.

FALSE Although a normally-open (NO) "M" contact is typically wired in parallel with a "start" button as a "hold-in contact", an additional NO "M" contact wired **in parallel with the "stop" button** would require the operator to "press-and-hold" "stop" to stop the motor.

TRUE When **pressing** one of the **combination pushbuttons** in the Q-215 lab that contain both a NO contact and a NC contact, the NC contact is actuated open slightly before the NO contact is actuated closed.

TRUE Since a motor naturally draws currents at startup that are larger than rated current, the operation of an **overload relay** is based on an inverse time-curve to prevent the relay from immediately shutting-down the motor if it is initially energized with full-voltage.

TRUE Since the **direction** that a 3Φ Induction Motor rotates is determined by the phase-sequence of its supply voltages, the motor can be reversed by swapping any two of the three supply lines that connect to the motor terminals.

FALSE While an induction motor is driving a mechanical load, a **increase in the load torque** provided by the mechanical load will result in an **increase** in the magnitude of the line currents drawn by the motor and an **increase** in the speed of the motor.

TRUE A **Series-Resistance** starter attempts to start a motor by initially supplying the motor through a set of series-connected resistors and then bypassing the resistors once the motor has accelerated to the point where it no longer draws excessively large currents.

FALSE A typical 3Φ **contactor** used for a motor-started contains three normally-open (NO) main contacts and at least one normally-closed (NC) auxiliary contact.

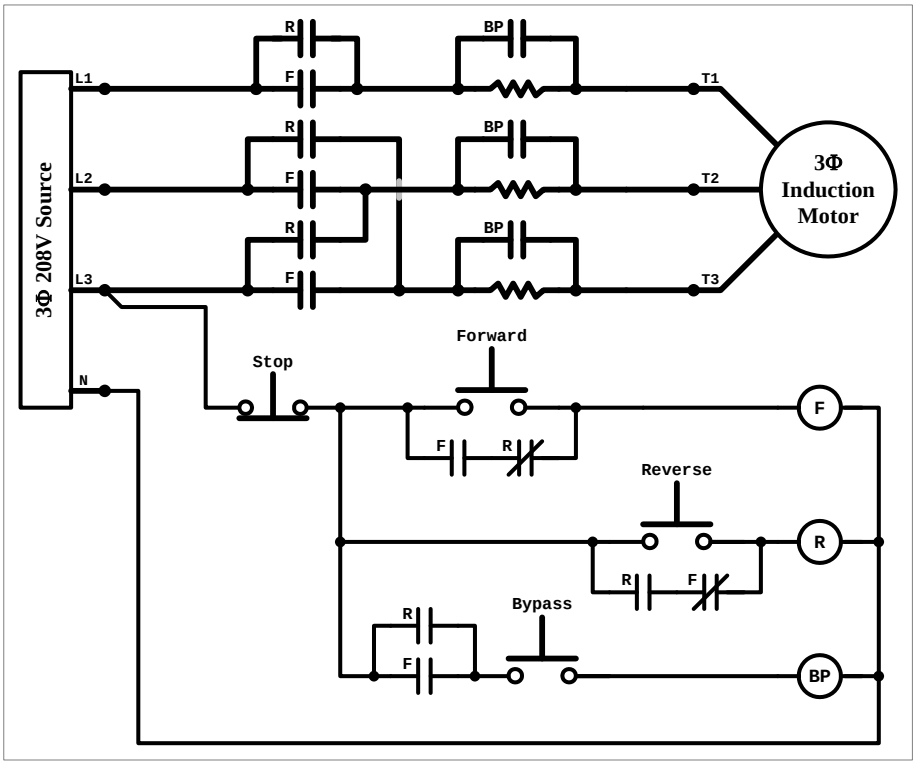
FALSE The resistors utilized within a **series-resistance, reduced-voltage, motor starter** can theoretically be replaced by either a set of inductors or a set of capacitors and the starter will still limit the amount of current drawn by the motor at startup.

TRUE **Contactors** are only designed to energize and de-energize motors or other high-current loads during both times of normal operation and times of abnormal operation such as a locked-rotor, but not during the occurrence of a fault (short-circuit) in the supply circuit.

Problem #2) Given the following **manually-controlled**, **series-resistance** (reduced-voltage), **reversible** motor control system:

The system is designed such that the operator **must**:

- First **press** either "Forward" or "Reverse" to initially energize the motor in the chosen direction with reduced-voltage, and then **press** "Bypass" to bypass the resistors and operate at full voltage,
- **Press** "Stop" to stop the motor (such that it must be restarted as previously described).



Additionally, the system is designed such that:

- The motor **cannot** be initially energized with full voltage applied to its terminals, and
- The direction of the motor **cannot** be changed after the motor is energized without first pressing "Stop".

Does the motor controller function properly? (I.e. – Can the motor be initially started with full voltage applied to its terminals? Can the direction of the motor be changed while the motor is energized? Are there any other problems with the designed system?) **State** and **justify** your answer:

Forward or Reverse must be pressed first to energize and actuate either the F or R contactor before Bypass can be pressed to operate the motor at full voltage (i.e. – the motor cannot be initially energized with full voltage applied to its terminals), and

Stop works correctly.

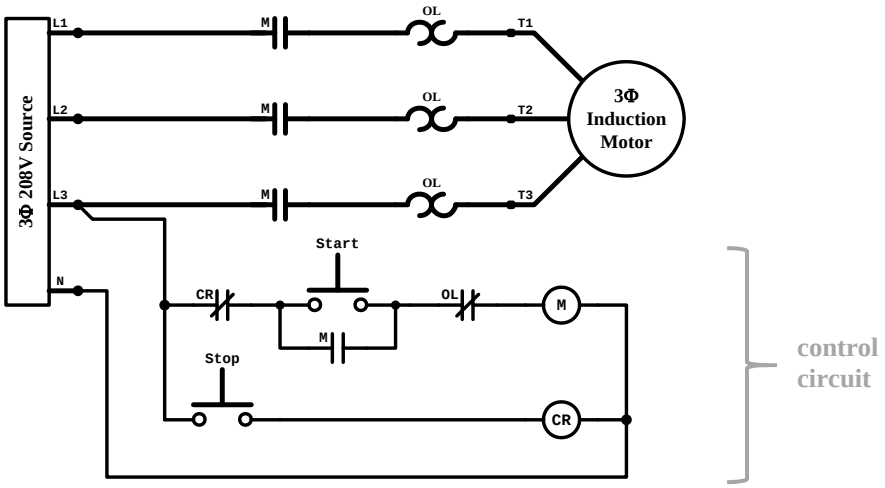
But there are several problems with the operation of the system:

1) Bypass must be held-in to keep the motor operating at full-voltage due to a **missing hold-in contact**.

2) Pressing Forward or Reverse while the motor is already running in the opposite direction will cause the motor to try to **instantly change direction without pressing Stop**.
Note – will actually Short Circuit the supply as original contactor drops-out.

3) Pressing Forward and Reverse simultaneously will energize both F and R, **Short Circuiting** the supply.

Problem #3) A technician proposes the following **start-stop** motor control system with **overload protection** when it was discovered that there were no normally-closed pushbuttons immediately available for use as a "Stop" button:



a) Does the system function correctly as a **start-stop** motor controller with **overload protection**? (I.e. – does the system "Start" and "Stop" correctly and does it provide overload protection?) **State** and **justify** your answer:

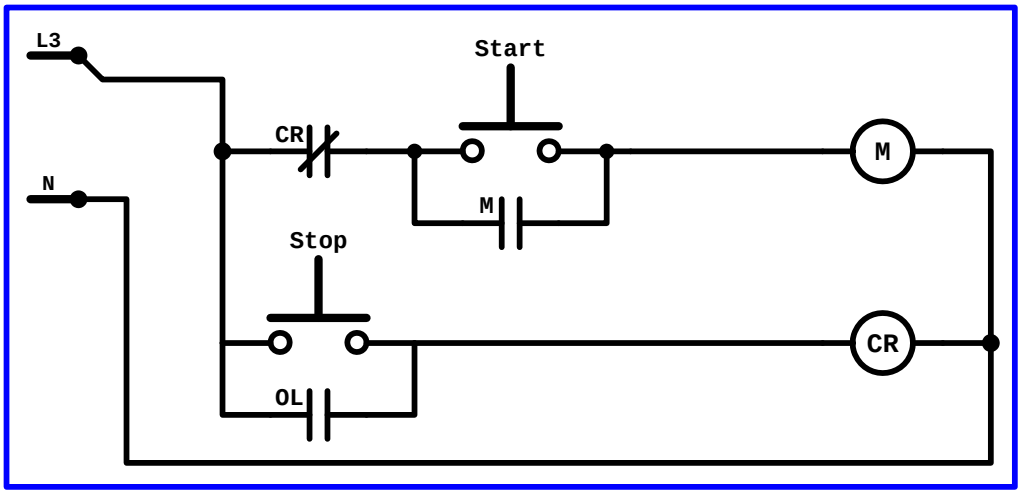
Yes. The NC CR contact in place of the NC Stop still allows the motor to start properly,

An OL will still cause M coil to be de-energized, shutting down the motor, and

Even though Stop is now a NO pushbutton, pressing Stop will energize CR coil, opening CR NC contact, de-energizing M coil, shutting down the motor.

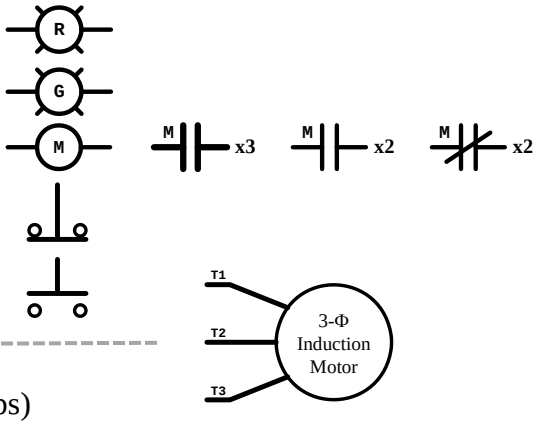
b) If a special (non-standard) Overload Relay is available that only contains a normally-open (NO) overload contact instead of the normally-closed (NC) overload contact (shown in the figure), **Re-draw** the control portion of the circuit with the NO overload contact properly wired-in such that overload protection would still be provided for the motor:

The NO OL contact can trigger a shutdown in the same manner as the NO Stop button if it is placed in parallel with Stop. When an OL occurs, the OL contact will energize CR coil, opening the CD NC contact, de-energizing M coil, in-turn shutting down the motor.



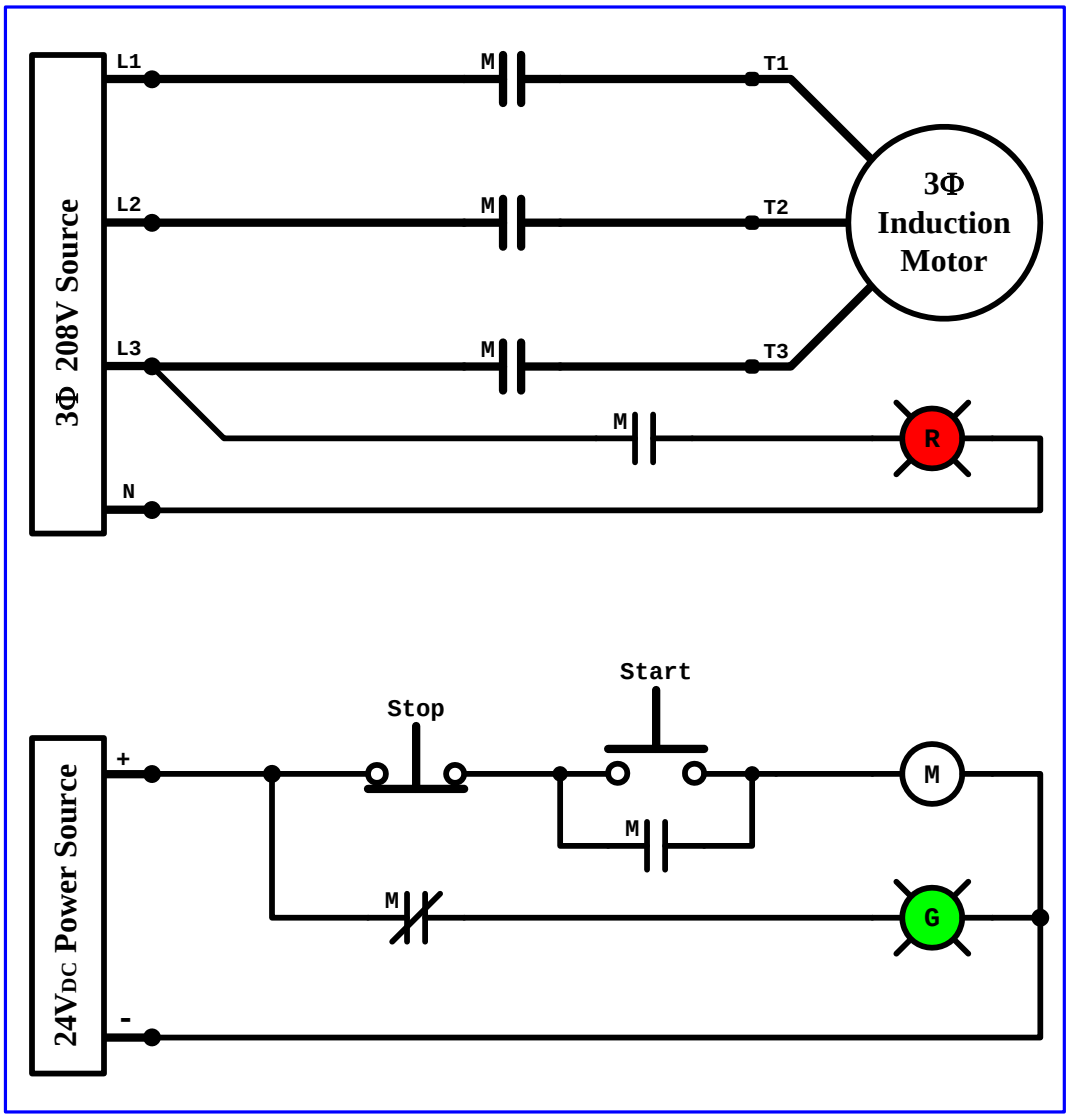
Problem #4) Given the following components:

- **Red Indicator Lamp** rated for **$120V_{AC}$**
- **Green Indicator Lamp** rated for **$24V_{DC}$**
- **Main Contactor** w/ **2-NO and 2-NC aux. contacts** (**field coil** rated for **$24V_{DC}$**)
- **Normally-Closed** (NC) Pushbutton (Stop)
- **Normally-Open** (NC) Pushbutton (Start)
- **$208V_{AC}$ 3Φ Induction Motor**
- **$208/120V_{AC}$ 3Φ Source** (for motor & indicator lamps)
- **$24V_{DC}$ Source** (for control circuit)



Neatly **draw** both the power and control circuits for a controller that will:

- **Energize** the **Motor**, turn **ON** the **Red** lamp, and turn **OFF** the **Green lamp** when "**Start**" is pressed,
- **De-energize** the **Motor**, turn **OFF** the **Red** lamp, and turn **ON** the **Green** lamp when "**Stop**" is pressed.



Part B - Notes for Problem #5:

CAREFULLY READ THESE IMPORTANT NOTES!

- The **pressing** and the **releasing** of a specific pushbutton is considered two independent steps.
- Whenever a pushbutton is either pressed or released, assume that enough time will pass for the circuit to reach **steady-state conditions** before the operator performs the next step.
- Assume that there is a small **delay** between the time that a specific relay's field-coil is energized and the time that the relay's armature actuates.
- Likewise, assume that there is a small **delay** between the time that a specific relay's field-coil is de-energized and the time that the relay's armature drops-out (returns back to normal position).
- Assume that all of the NO and NC contacts associated with a specific relay transition **simultaneously** (i.e. – from either OPENED→CLOSED or CLOSED→OPENED) when that relay's armature changes position.

Problem #5) Given the control system shown on the next page, determine the exact series of events that will occur within the control system if an operator performs the following set of ordered steps:

Step #1 – The "**Power Switch**" is **Closed** (**switched ON**)

Step #2 – Pushbutton #1 is **Pressed**

Step #3 – Pushbutton #1 is **Released**

Step #4 – Pushbutton #2 is **Pressed**

Step #5 – Pushbutton #2 is **Released**

Step #6 – Pushbutton #2 is **Pressed**

Step #7 – Pushbutton #2 is **Released**

Step #8 – Pushbutton #1 is **Pressed**

Step #9 – Pushbutton #1 is **Released**

As the operator performs **each step**, (in the spaces provided on the **last page** of this booklet) **specify**:

a) the **exact order** in which any of the various **field-coils** (**W**, **X**, **B**, **D**, **G**, **L**, and **R**) are either **energized** (**ON**) or **de-energized** (**OFF**) and state when **"steady-state" operation is reached** after each step is performed (note – **only show changes** in the operational states of any **field coil**), and

b) the **status** (**ON** or **OFF**) of all four **indicator lamps** (**White**, **Blue**, **Red**, and **Green**) when the **system reaches steady-state (SS) operation** after each step has been performed.

The following box contains an EXAMPLE set of a fictional set of answers for a single press and release of PB#1:

Action **Field Coil Changes** "SS" denotes "Steady-State" (no further changes will occur)

Example

PB#1 Pressed: G ON → B ON → SS → ____ → ____

Indicator Lamp SS Status: Blue ON Green ON Red OFF White OFF

PB#1 Released: X ON → G OFF → W ON → SS → ____

Indicator Lamp SS Status: Blue ON Green OFF Red OFF White ON

Once "SS" operation is reached, leave the remaining (if any) spaces provided for that step blank

Only print and submit the LAST page of this exam booklet as your results for Part B of this exam.

Refer to the control system shown below that contains **seven** control **relays** (**W**, **X**, **B**, **D**, **G**, **L**, and **R**) and **four indicator lamps** (**White**, **Blue**, **Red**, and **Green**) for Problem #5 of Exam I (Part B).

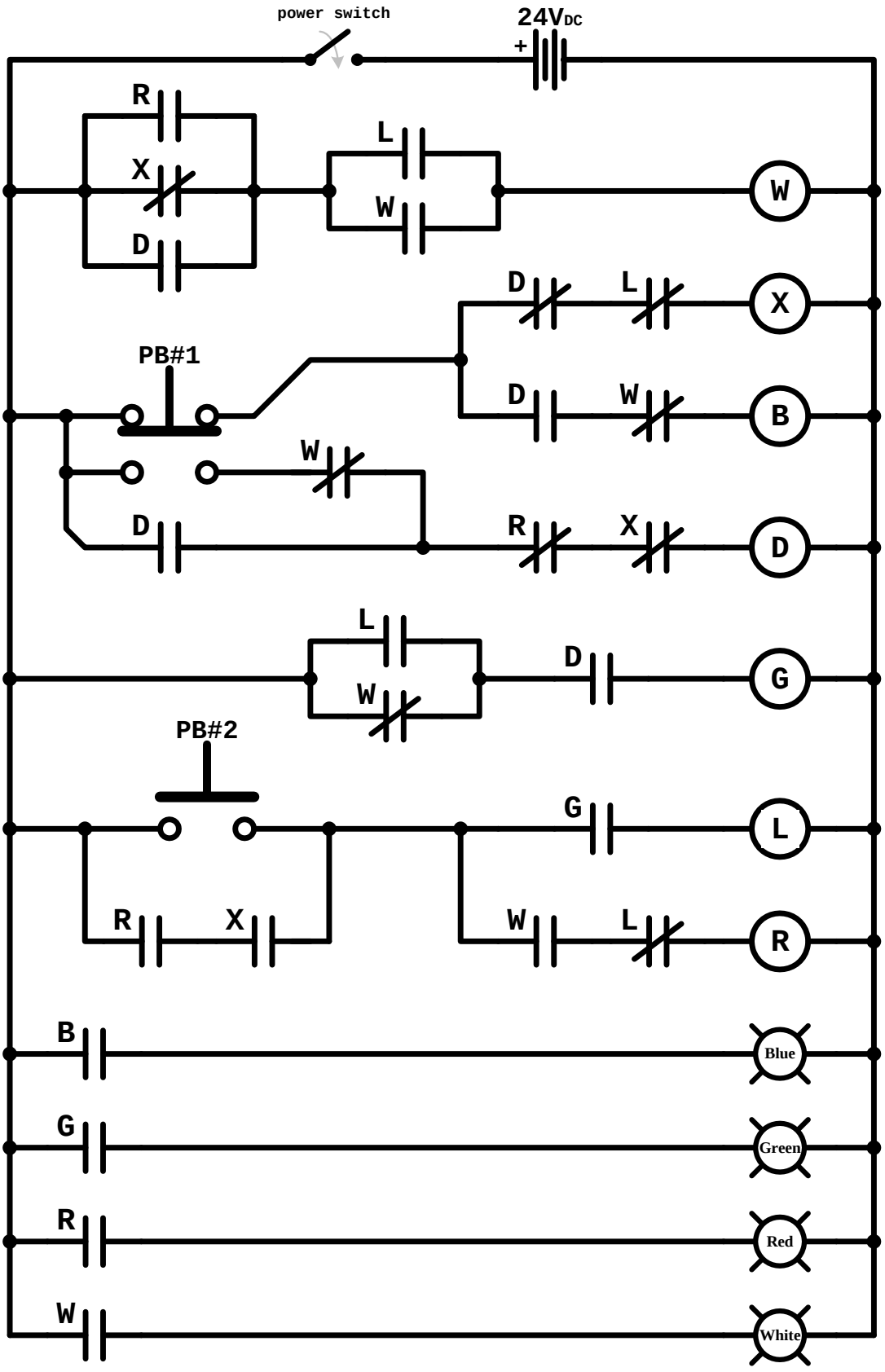


Figure for Part B (Problem #5)

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REMINDER – ONLY SHOW CHANGES IN THE STATUS OF ANY FIELD COIL WHEN A STEP IS PREFORMED
For example – if coil D is energized (D ON) during a step, then coil D should not appear again in the remaining lists of coil changes unless it becomes de-energized (D OFF)

Action **Field Coil Changes** (until steady-state operation is reached)

Step #1 **Switch Closed**: X ON → SS → _____ → _____ → _____

Indicator Lamp SS Status: Blue OFF Green OFF Red OFF White OFF

(Note that the answers for Step #1 have already been provided for you in the above spaces)

Step #2 **PB#1 Pressed**: X OFF → D ON → G ON → SS → _____

Indicator Lamp SS Status: Blue OFF **Green ON** Red OFF White OFF

Step #3 **PB#1 Released**: B ON → SS → _____ → _____ → _____

Indicator Lamp SS Status: **Blue ON** **Green ON** Red OFF White OFF

Step #4 **PB#2 Pressed**: L ON → W ON → B OFF → SS → _____

Indicator Lamp SS Status: Blue OFF **Green ON** Red OFF **White ON**

Step #5 **PB#2 Released**: L OFF → G OFF → SS → _____ → _____

Indicator Lamp SS Status: Blue OFF Green OFF Red OFF **White ON**

Step #6 **PB#2 Pressed**: R ON → D OFF → X ON → SS → _____

Indicator Lamp SS Status: Blue OFF Green OFF **Red ON** **White ON**

Step #7 **PB#2 Released**: SS → _____ → _____ → _____ → _____

Indicator Lamp SS Status: Blue OFF Green OFF **Red ON** **White ON**

Step #8 **PB#1 Pressed**: X OFF → R OFF → SS → _____ → _____

Indicator Lamp SS Status: Blue OFF Green OFF Red OFF **White ON**

Step #9 **PB#1 Released**: X ON → W OFF → SS → _____ → _____

Indicator Lamp SS Status: Blue OFF Green OFF Red OFF White OFF

You must sign the following affirmation before submitting your completed exam:

"I do affirm that all of the work (answers) shown for Part B of this exam is my own, that no assistance was provided to me by any other person while completing Part B, that I have not viewed the work for Part B by any other person, and that I have not allowed any other person to view or obtain knowledge relating to my Part B work."

Sign Name: _____

#5) _____ /30