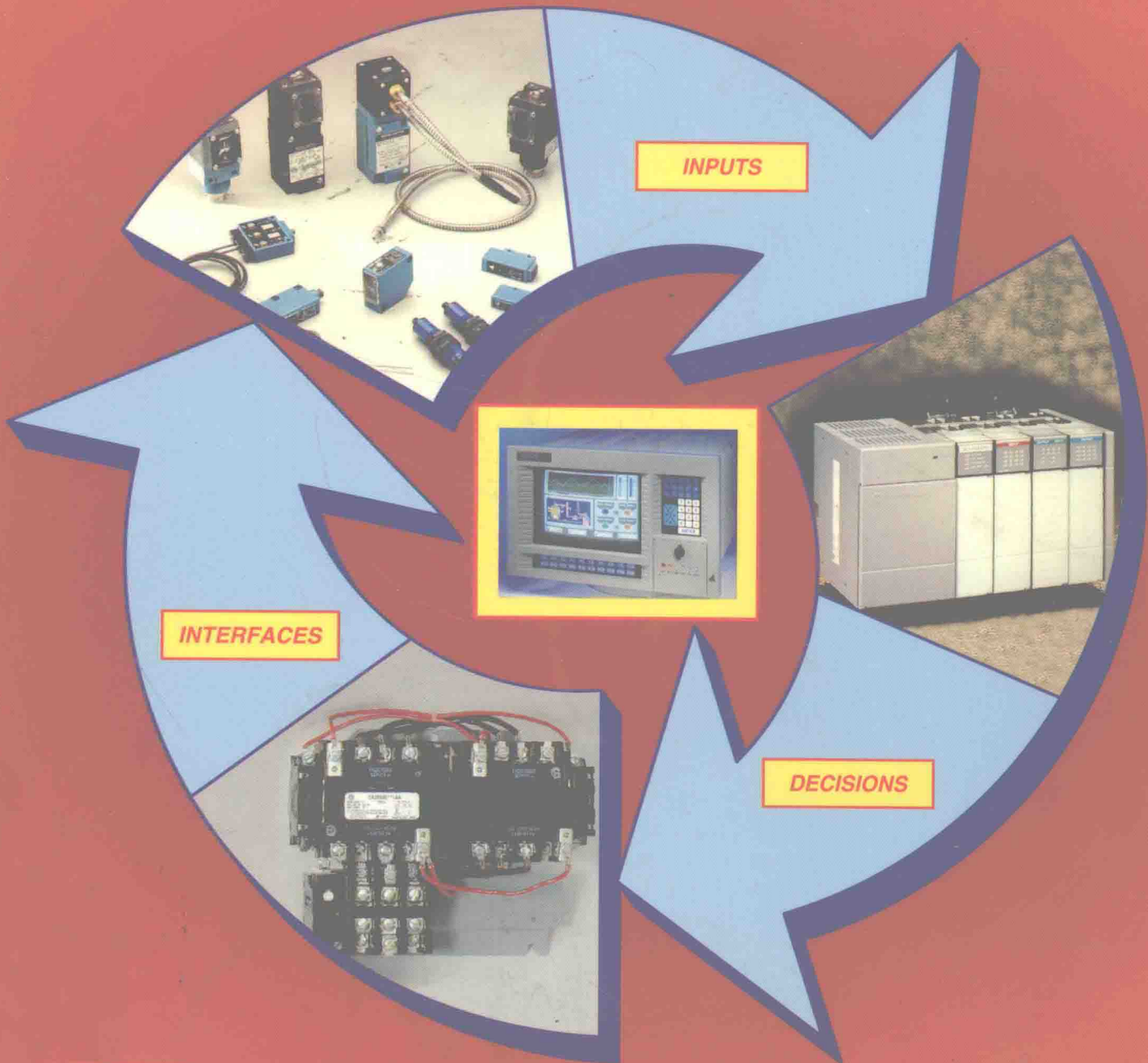


ELECTRICAL MOTOR CONTROLS

WORKBOOK



an

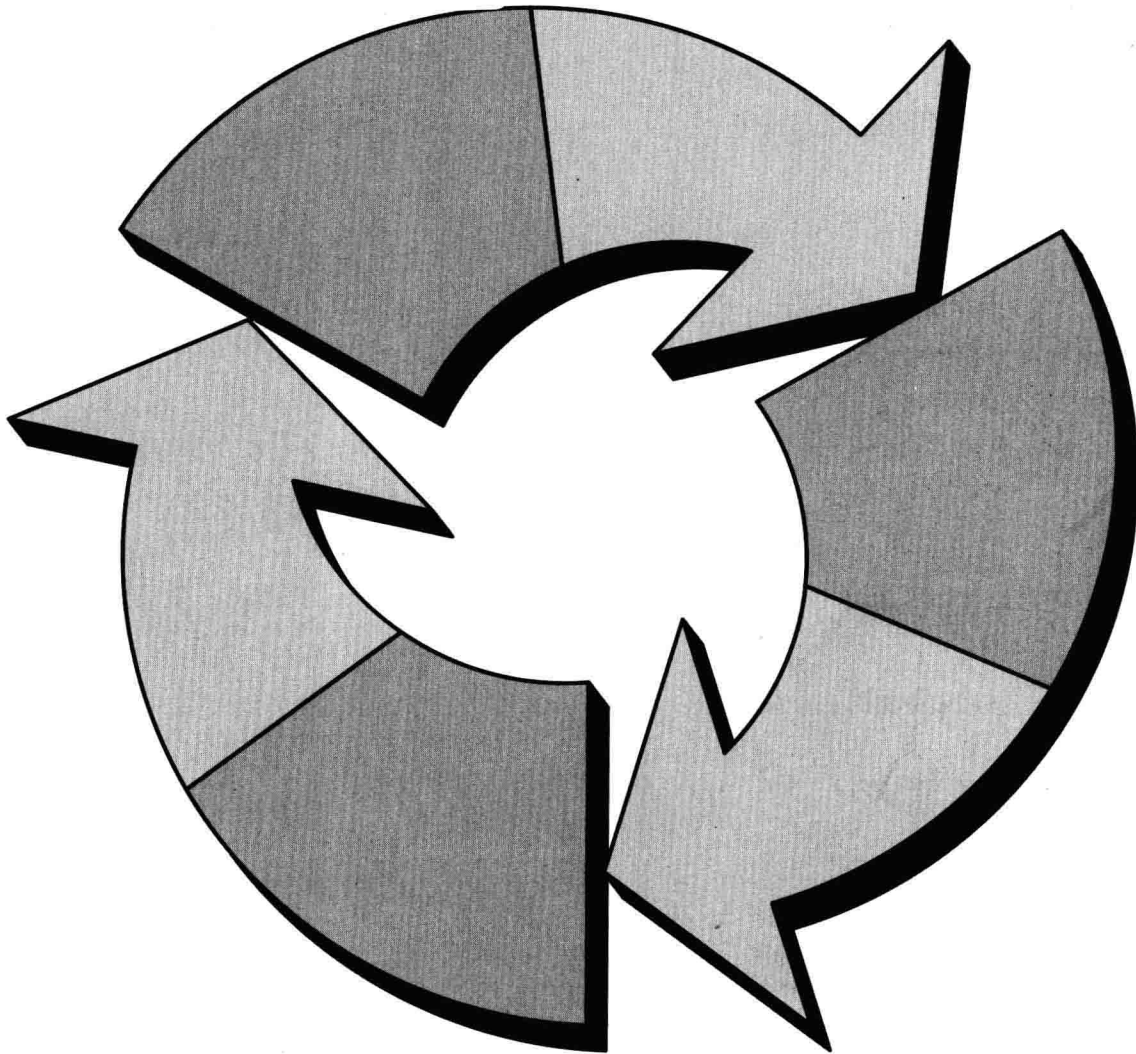


publication

Gary Rockis
Glen Mazur

ELECTRICAL MOTOR CONTROLS

WORKBOOK



AMERICAN TECHNICAL PUBLISHERS, INC.
HOMewood, ILLINOIS 60430

Gary Rockis
Glen A. Mazur

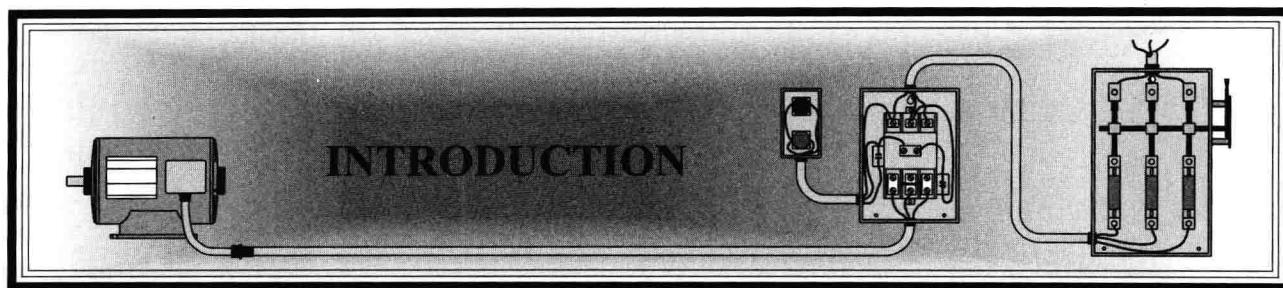
© 1997 by American Technical Publishers, Inc.
All rights reserved

1 2 3 4 5 6 7 8 9 - 97 - 9 8 7 6 5 4 3

Printed in the United States of America

ISBN 0-8269-1672-4





Electrical Motor Controls Workbook is designed to reinforce the concepts, provide hands-on applications, and test the material presented in *Electrical Motor Controls*. When studying the text, pay particular attention to italicized terms, illustrations, and examples. These key elements comprise a major portion of *Electrical Motor Controls Workbook*.

Tech-Cheks

Electrical Motor Controls Workbook contains 17 Tech-Cheks. Each Tech-Chek is a series of multiple choice, completion, and matching questions that are based on the text and art in the corresponding chapter of *Electrical Motor Controls*. Always study the assigned chapter of *Electrical Motor Controls* thoroughly before completing the Tech-Cheks.

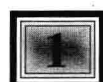
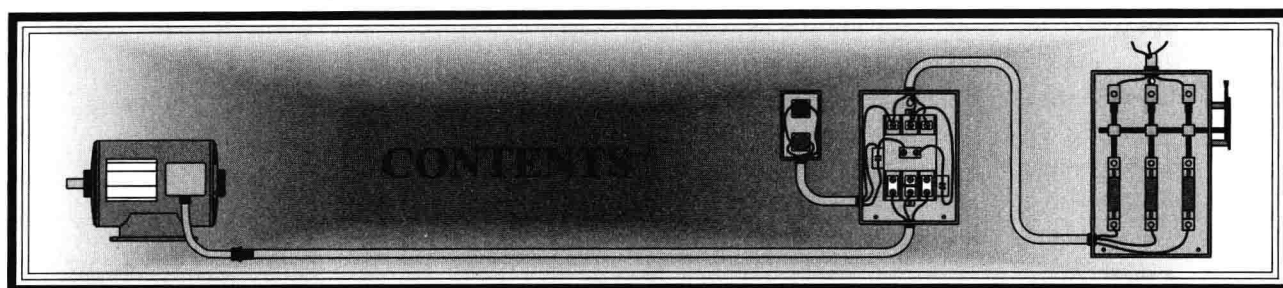
Worksheets

Electrical Motor Controls Workbook contains 111 Worksheets developed from the 17 chapters of *Electrical Motor Controls*. Worksheets provide opportunities to apply the concepts and theory in *Electrical Motor Controls* to practical problems. See Contents for a complete listing of Worksheets.

Appendix

The Appendix contains Data Sheets, charts, and tables for use with the Worksheets. See page 169 for a complete listing of Data Sheets, charts, and tables in the Appendix.

The Authors and Publisher



Electrical Tools, Instruments, and Safety

Tech-Chek 1	Electrical Motor Controls	1
	Analog Displays	2
Worksheet 1-1	Tool Identification	3
Worksheet 1-2	Electrical Tool Identification	4
Worksheet 1-3	Informational Outputs	5
Worksheet 1-4	Multimeter Basic Measurements	6



Electrical Symbols and Line Diagrams

Tech-Chek 2	Electrical Motor Controls	7
	Device Identification	8
Worksheet 2-1	Electrical Symbols	9
Worksheet 2-2	Line Diagrams	11
Worksheet 2-3	Basic Circuit Design	13



Logic Applied to Line Diagrams

Tech-Chek 3	Electrical Motor Controls	15
	Logic Functions	16
	Reference Numbers	16
Worksheet 3-1	Motor Starting with Memory	17
Worksheet 3-2	Circuit Overload Protection	19
Worksheet 3-3	Multiple Conveyor Control	21
Worksheet 3-4	Selector Switch Control	22
Worksheet 3-5	OR Circuit Logic	24
Worksheet 3-6	AND/OR Combination Logic	26
Worksheet 3-7	Circuit Logic	28



AC Manual Contactors and Motor Starters

Tech-Chek 4	Electrical Motor Controls	29
Worksheet 4-1	NEMA Enclosures	31
Worksheet 4-2	Switching Arrangements	33



Magnetism and Magnetic Solenoids

Tech-Chek 5	Electrical Motor Controls	35
	Solenoid Identification	36
Worksheet 5-1	Pushbutton Circuit Control	37
Worksheet 5-2	Manual Control Circuit with Memory	38
Worksheet 5-3	Automatic Circuit Control	39
Worksheet 5-4	Manual Override Circuit Control	40
Worksheet 5-5	Selector Switch Circuit Control	41

6

AC/DC Magnetic Contactors and Motor Starters

Tech-Chek 6	Electrical Motor Controls	43
Worksheet 6-1	Wire Reference Numbers	45
Worksheet 6-2	Basic Motor Control	46
Worksheet 6-3	Motor Control with Pilot Light	47
Worksheet 6-4	Multiple Control Stations	48
Worksheet 6-5	Multiple Motor Control	49
Worksheet 6-6	Multiple Control of Multiple Motors	50
Worksheet 6-7	Circuit Wiring	51

7

Time Delay and Logic

Tech-Chek 7	Operational Diagrams	55
	Timers	55
	Timing Codes	56
	Timer Contact Symbols	56
Worksheet 7-1	Timer Settings	57
Worksheet 7-2	ON-Delay Motor Sequencing	58
Worksheet 7-3	OFF-Delay Motor Control	59
Worksheet 7-4	Timer Coding	60
Worksheet 7-5	Timer Motor Sequencing	61
Worksheet 7-6	Timer Safety Circuit	62
Worksheet 7-7	ON-Delay Timer Operational Diagrams	64

8

Control Devices

Tech-Chek 8	Electrical Motor Controls	65
	Truth Table	66
	Limit Switch Connections	66
Worksheet 8-1	Truth Tables	67
Worksheet 8-2	Heating Element Control	68
Worksheet 8-3	Vacuum Sensing	69
Worksheet 8-4	Pressure Control	70
Worksheet 8-5	Dual-Temperature Control	71
Worksheet 8-6	Fan/Heater Control	72
Worksheet 8-7	Level Control Relay	74

9

Reversing Motor Circuits

Tech-Chek 9	Electrical Motor Controls	75
	Motor Leads	76
	Motor Identification	76
Worksheet 9-1	Reversing 1 ϕ Motors	77
Worksheet 9-2	Reversing 3 ϕ Motors	78
Worksheet 9-3	Reversing Dual-Voltage, 1 ϕ Motors at Low Voltage	79
Worksheet 9-4	Reversing Dual-Voltage, 1 ϕ Motors at High Voltage	80
Worksheet 9-5	Reversing 1 ϕ Motors – All Wires Not Used	81
Worksheet 9-6	Interchanging Motor Leads	82
Worksheet 9-7	Reversing 2-Speed, 1 ϕ Motors at Low Speed	83
Worksheet 9-8	Reversing 2-Speed, 1 ϕ Motors at High Speed	84
Worksheet 9-9	Limit Switch Motor Stopping	85
Worksheet 9-10	Forward/Reverse Circuit with Indicator Lights	86
Worksheet 9-11	Selector Switch Motor Control	87
Worksheet 9-12	Selector Switch Jog/Run Control	88

10**Power Distribution Systems**

Tech-Chek 10	Electrical Motor Controls	89
	Transformers	90
Worksheet 10-1	Delta-to-Delta Connections	91
Worksheet 10-2	Wye-to-Wye Connections	92
Worksheet 10-3	Delta-to-Wye Connections	93
Worksheet 10-4	Wye-to-Delta Connections	94
Worksheet 10-5	Busway System Design	95
Worksheet 10-6	Busway System Calculation	96
Worksheet 10-7	Wiring Devices	97
Worksheet 10-8	Start/Stop Circuit Control	98
Worksheet 10-9	Jogging Circuit Control	99
Worksheet 10-10	Surge and Backspin Protection	100

11**Solid-State Electronic Control Devices**

Tech-Chek 11	Electrical Motor Controls	101
	Solid-State Component Identification	104
Worksheet 11-1	PC Boards	105
	Solid-State Components	105
Worksheet 11-2	Diode Operation	106
	Zener Diode Operation	106
Worksheet 11-3	SCR Operation	107
	Amplifiers	107
Worksheet 11-4	Solid-State Devices	108
Worksheet 11-5	Solid-State Symbol Identification	109
	Light-Activated Devices	109
	Integrated Circuits	110
	Logic Gates	110
	Transistors	110

12**Electromechanical and Solid-State Relays**

Tech-Chek 12	Electrical Motor Controls	111
	Reed Relay Actuation	112
	EMR and SSR Comparison	112
Worksheet 12-1	Electromechanical Relay Contact Addition	113
Worksheet 12-2	Pole/Throw/Break Identification	115
Worksheet 12-3	Control Circuit Solid-State Relay Use	116
Worksheet 12-4	Forward and Reversing Solid-State Relay Use	118

13**Photoelectric and Proximity Controls**

Tech-Chek 13	Electrical Motor Controls	119
	Scanning Methods	120
	Switching Methods	120
Worksheet 13-1	Level Control	121
Worksheet 13-2	Part Checking	122
Worksheet 13-3	Carton Filling	123
Worksheet 13-4	Carton Gluing	124
Worksheet 13-5	Conveyor Jam Control	125
Worksheet 13-6	Paper Roll Monitoring	126
Worksheet 13-7	Steel Cutting Operation	127
Worksheet 13-8	Bottle Cap Control	128

Worksheet 13-9	Piston Control	129
Worksheet 13-10	Proximity Switch Piston Control	130



Programmable Controllers

Tech-Chek 14	Electrical Motor Controls	131
	PLC Logic Functions	132
	PLC Programming Diagrams	132
Worksheet 14-1	Line Diagram to PLC Diagram Conversion	133
Worksheet 14-2	Selector Switch Line Diagram to PLC Diagram Conversion	134
Worksheet 14-3	Two-Speed Line Diagram to PLC Diagram Conversion	135
Worksheet 14-4	Forward and Reversing Line Diagram to PLC Diagram Conversion	136
Worksheet 14-5	Forward and Reversing PLC Diagram to Line Diagram Conversion	137
Worksheet 14-6	Two-Speed PLC Diagram to Line Diagram Conversion	138



Reduced-Voltage Starting

Tech-Chek 15	Electrical Motor Controls	139
Worksheet 15-1	Primary Resistor Starting	141
Worksheet 15-2	Part-Winding Starting	142
Worksheet 15-3	Wye/Delta Connections	144
Worksheet 15-4	Autotransformer Starting	145
Worksheet 15-5	Motor Load Monitoring	146



Accelerating and Decelerating Methods

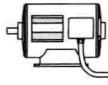
Tech-Chek 16	Electrical Motor Controls	147
Worksheet 16-1	Motor Plugging	149
Worksheet 16-2	Two-Speed Starting	150
Worksheet 16-3	Multispeed Starting	151
Worksheet 16-4	Selective Multispeed Starting	152
Worksheet 16-5	Unrestrictive Multispeed Starting	153
Worksheet 16-6	Compelling Circuit Logic	154
Worksheet 16-7	Dynamic Braking	155
Worksheet 16-8	Motor Temperature Control	156



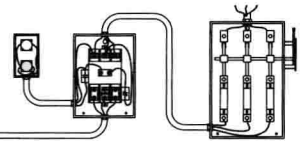
Preventive Maintenance and Troubleshooting

Tech-Chek 17	Electrical Motor Controls	157
	Voltage Identification	158
	Motor Insulation Tests	158
Worksheet 17-1	Motor Protection	159
Worksheet 17-2	Phase Loss Protection	160
Worksheet 17-3	Overload Protection	161
Worksheet 17-4	Manual/Automatic Circuit Troubleshooting	163
Worksheet 17-5	Carton Fill Circuit Troubleshooting	164
Worksheet 17-6	Multiple Starter Circuit Troubleshooting	165
Worksheet 17-7	Primary Resistor Starting Circuit Troubleshooting	166
Worksheet 17-8	Motor Braking Circuit Troubleshooting	167
Worksheet 17-9	Selector Switch Circuit Troubleshooting	168

Appendix	169
---------------------------	------------



Electrical Tools, Instruments, and Safety



Name _____ Date _____

TECH-CHEK 1

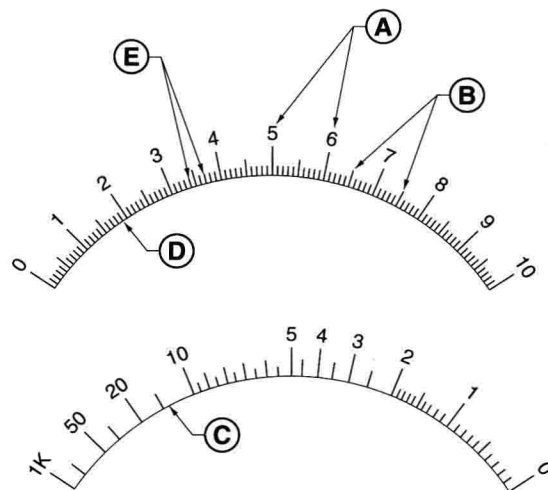
Electrical Motor Controls

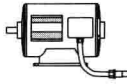
- _____ 1. Electrical tools may be organized using a(n) _____.
 A. pegboard
 B. electrician's pouch
 C. portable tool box
☒ D. A, B, and C
- _____ 2. All power tools should be properly secured before being used.
- _____ 3. Ensure the switch is in the OFF position before connecting a tool to a power source.
- _____ 4. Always remove the Hot side of a fuse when removing fuses from circuits.
- _____ 5. Ensure the source of electricity is open and locked out before performing any repair on a piece of electrical equipment.
- _____ 6. Class A fires consist of burning wood, clothing, or paper.
- _____ 7. Class C fires consist of burning electrical equipment.
- _____ 8. Class B fires consist of flammable liquids, such as gasoline and oil.
- _____ 9. Class D fires consist of burning combustible metals such as magnesium.
- _____ 10. A(n) voltmeter is used when checking voltage in a circuit.
- _____ 11. A(n) ammeter is used when checking the current level in a circuit.
- _____ 12. A(n) ohmmeter is used when checking the resistance in a component or device.
- _____ 13. Never assume the power is OFF when working on an electrical circuit.
- _____ 14. A(n) _____ is the best system for organizing tools to be used on the job or at a test bench.
 A. pegboard
☒ B. electrician's pouch
 C. portable tool box
 D. neither A, B, nor C
- _____ 15. Cutting tools should be _____.
 A. stainless steel
 B. new
☒ C. sharp and clean
 D. well used
- _____ 16. All power tools should be grounded unless _____.
 A. the area has low humidity
 B. the area is dry
☒ C. they are double-insulated
 D. permission has been granted to use them without grounding

- _____ 17. A change in sound during tool operation normally indicates _____.
 A. normal operation C. the tool is in reverse
B. trouble of some type D. overheating
- _____ 18. Install a fuse _____ when replacing fuses.
 A. line side first C. load and line side simultaneously
B. load side first D. with a screwdriver
- _____ 19. Rags containing oil, gasoline, alcohol, shellac, paints, varnish, or lacquer must be _____.
A. kept in a covered metal container C. stored in a cool, dry place
 B. stored in a wastebasket D. left out to dry
- _____ 20. All unfamiliar wires should be treated as if they are _____.
 A. dead C. harmless
B. alive D. A, B, and C
- _____ 21. Acid on hands and face should be immediately washed away with plenty of _____.
A. water C. vaseline
 B. glycerine D. gasoline
- _____ 22. A(n) meter is any output device that displays data about the circuit or operation.
- _____ 23. Lockout is the process of _____.
 A. putting a danger tag on an electrical source C. putting a lockout tag on an electrical source
B. padlocking the electrical source D. neither A, B, nor C
- _____ 24. A(n) wrap around analog is a bar graph that displays a fraction of the full range on the graph.
- _____ 25. A(n) _____ is an electromechanical device that indicates readings on a meter by the mechanical motion of a pointer.

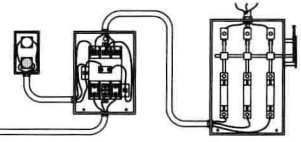
Analog Displays

- C 1. Nonlinear scale
- B 2. Secondary divisions
- E 3. Subdivisions
- D 4. Linear scale
- A 5. Primary divisions





Electrical Tools, Instruments, and Safety



Name _____ Date _____

WORKSHEET 1-1

Tool Identification

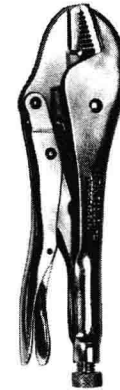
- | | |
|----------|---------------------------------|
| <u>F</u> | 1. Ball peen hammer |
| <u>H</u> | 2. Chain wrench |
| <u>D</u> | 3. Slip-joint pliers |
| <u>B</u> | 4. Adjustable wrench |
| <u>J</u> | 5. Phillips screwdriver |
| <u>A</u> | 6. Flathead screwdriver |
| <u>C</u> | 7. Locking pliers |
| <u>G</u> | 8. Hex key wrench |
| <u>E</u> | 9. Folding rule |
| <u>I</u> | 10. Phillips offset screwdriver |



(A)



(B)



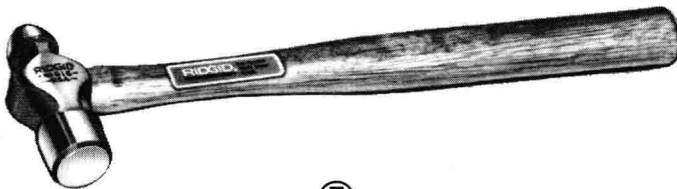
(C)



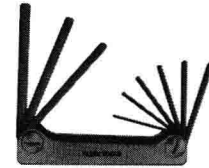
(D)



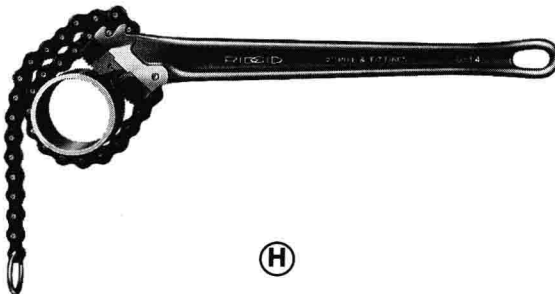
(E)



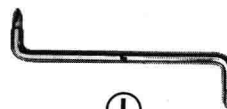
(F)



(G)



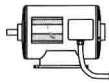
(H)



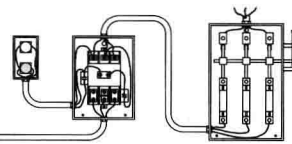
(I)



(J)



Electrical Tools, Instruments, and Safety



Name _____ Date _____

WORKSHEET 1-2

Electrical Tool Identification

D

1. Cable cutter

G

2. Fuse puller

E

3. Rigid conduit hickey

H

4. Long-nose pliers

J

5. Side-cutting pliers

A

6. End-cutting pliers

I

7. Skinning knife

C

8. Reaming tool

B

9. Diagonal-cutting pliers

F

10. Wire stripper



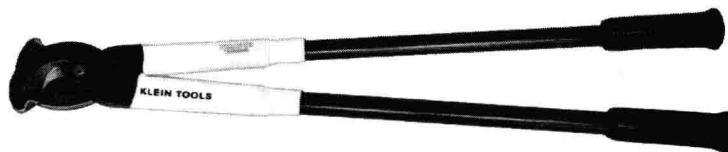
(A)



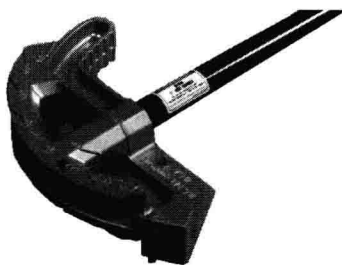
(B)



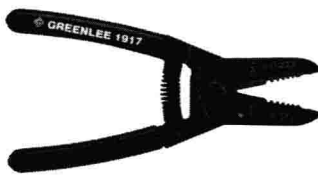
(C)



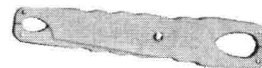
(D)



(E)



(F)



(G)



(H)



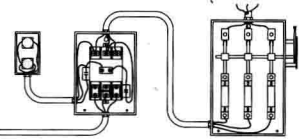
(I)



(J)



Electrical Tools, Instruments, and Safety

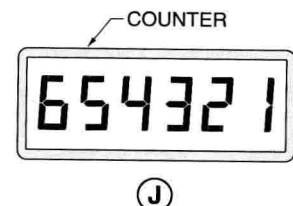
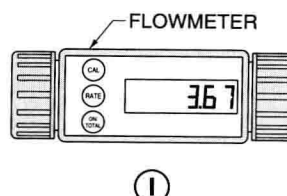
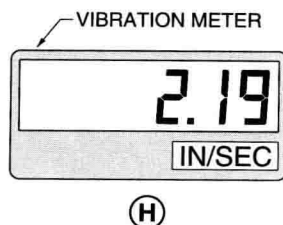
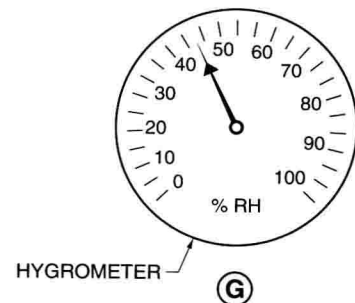
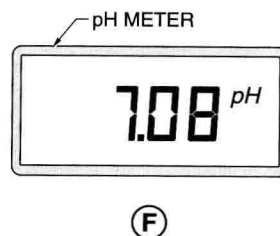
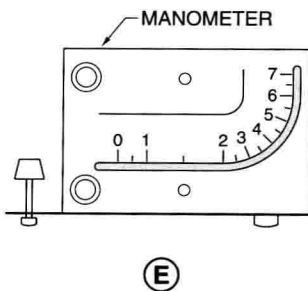
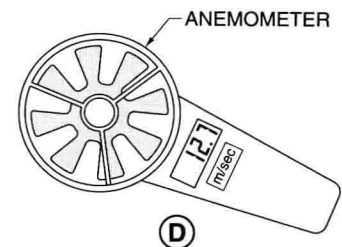
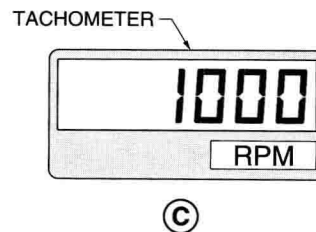
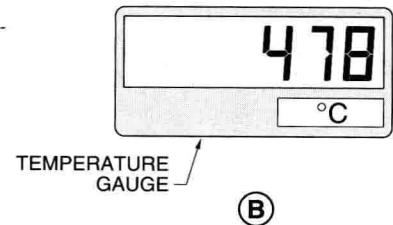
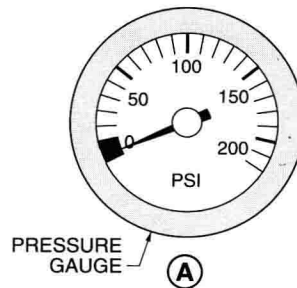


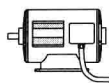
Name _____ Date _____

WORKSHEET 1-3

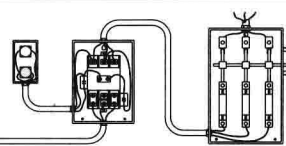
Informational Outputs

- | | |
|----------|-----------------------------|
| <u>D</u> | 1. Air velocity or force |
| <u>G</u> | 2. Relative humidity |
| <u>H</u> | 3. Imbalance |
| <u>I</u> | 4. Fluid flow |
| <u>C</u> | 5. Speed of rotating object |
| <u>J</u> | 6. Number of devices |
| <u>A</u> | 7. Fluid pressure |
| <u>B</u> | 8. Heat |
| <u>F</u> | 9. Acidity or alkalinity |
| <u>E</u> | 10. Pressure differential |





Electrical Tools, Instruments, and Safety



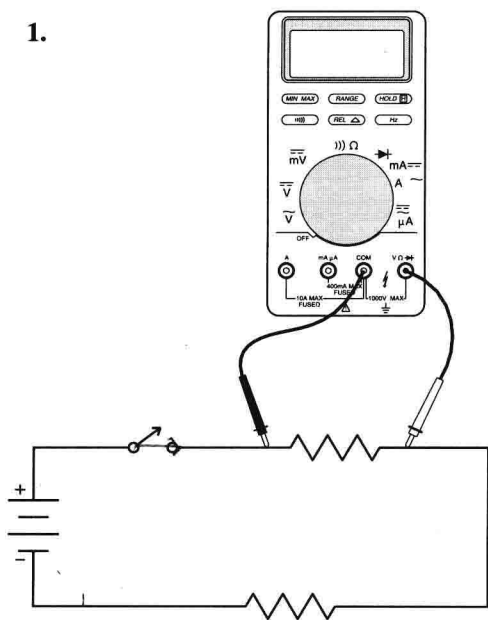
Name _____ Date _____

WORKSHEET 1-4

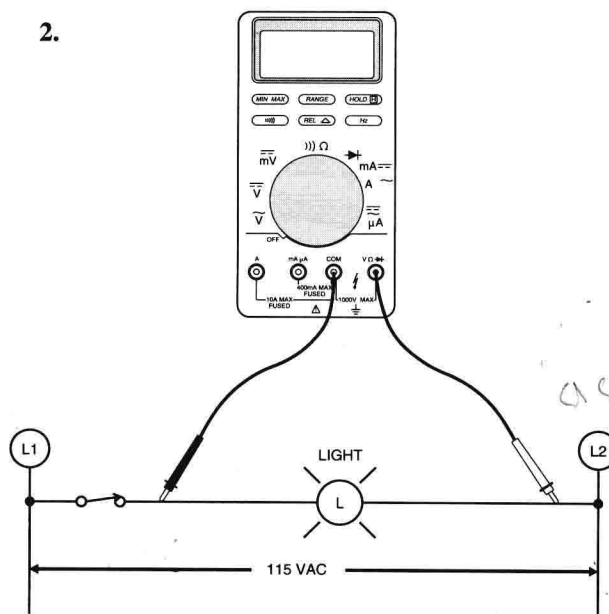
Multimeter Basic Measurements

Draw the correct position of the function switches to measure the electrical quantity based on the meter connections and circuit.

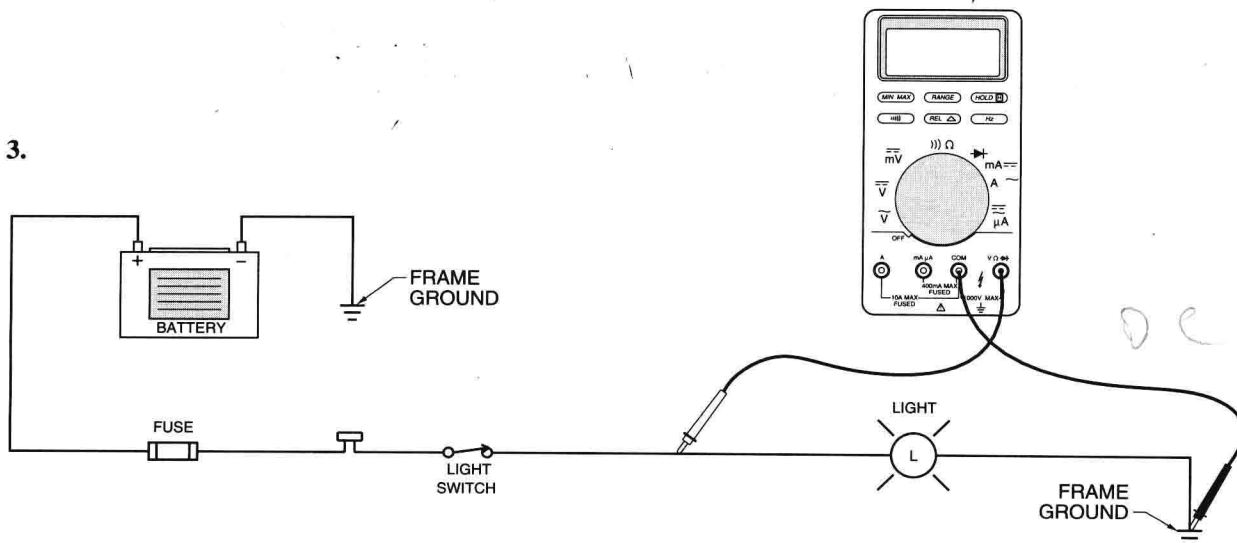
1.

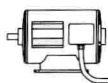


2.

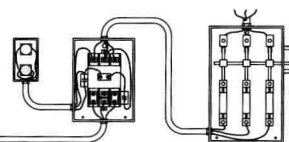


3.





Electrical Symbols and Line Diagrams



Name _____ Date _____

TECH-CHEK 2

Electrical Motor Controls

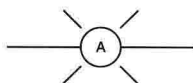
- _____ 1. In electrical circuits, the basic means of communicating the language of control is through a _____ diagram.
 A. pictorial ☒ C. line
 B. schematic D. wiring
- _____ 2. In a line diagram, the power source is shown in _____ lines than the rest of the diagram.
☒ A. heavier C. straighter
 B. thinner D. neither A, B, nor C
- _____ 3. In a line diagram, the path of current flow through the various parts of the control circuit, such as the pushbuttons, etc., is shown in _____ lines than the rest of the diagram.
 A. heavier C. straighter
☒ B. thinner D. neither A, B, nor C
- _____ 4. A pushbutton is an example of a(n) _____ control switch.
☒ A. manual C. mechanical
 B. automatic D. neither A, B, nor C
- _____ 5. A liquid level switch is an example of a(n) _____ control switch.
 A. manual ☒ C. mechanical
 B. automatic D. neither A, B, nor C
- _____ 6. A line diagram is always read from line 1 to line 2.
- _____ 7. In a line diagram, one side of the overload contacts are connected to line 1.
- _____ 8. The _____ contacts are always used when using a float switch to maintain a pre-determined level.
 A. NO C. auxiliary
☒ B. NC D. neither A, B, nor C
- _____ 9. The _____ contacts are always used when using a float switch to control a sump pump.
☒ A. NO C. auxiliary
 B. NC D. neither A, B, nor C
- _____ 10. A(n) ACC is an electrical device which consists of a frame, plunger, and coil and is used to create a push or pull action.
- _____ 11. A(n) Soleno is an electrical device which consists of a frame, plunger, and coil and is used to open and close a set of contacts.

12. A(n) mag not starter is an electrical device which consists of a frame, plunger, and coil and is used to open and close a set of contacts in addition to providing overload protection.
13. The locking contacts are used in the control circuit to maintain an electrical holding circuit.
14. DC control voltage may be marked with a positive or NIS sign.
15. For consistency, the locking symbol is always drawn in a line diagram after the motor.
16. mag contacts are attached to the side of a contactor and are opened or closed with the power contacts.
17. Overloads have contacts which sense excessive current flow to the motor.
18. control language is communicated using line diagrams.
19. Solenoids, contactor, and magnetic motor starters are used for remote control of devices.
20. A(n) manual control circuit is a circuit that requires a person to initiate an action for the circuit to operate.

Device Identification

H

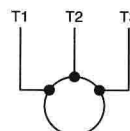
1. Foot switch



(A)



(B)



(C)

D

2. Silicon-controlled rectifier

F

3. NC limit switch

A

4. Pilot light

m

5. Solenoid

L

6. Liquid level switch

I

7. 1 ϕ motor

C

8. 3 ϕ motor

J

9. Temperature switch

K

10. Pressure or vacuum switch

B

11. Flow switch

E

12. Control transformer

P

13. Motor starter

m

14. Overload contacts

N

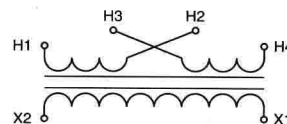
15. Electrical junction

A

16. NO pushbutton



(D)



(E)



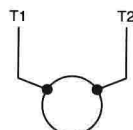
(F)



(G)



(H)



(I)



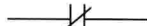
(J)



(K)



(L)



(M)



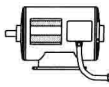
(N)



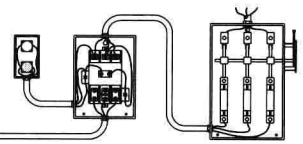
(O)



(P)



Electrical Symbols and Line Diagrams



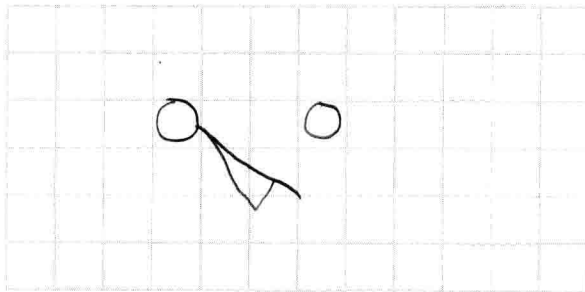
Name _____ Date _____

WORKSHEET 2-1

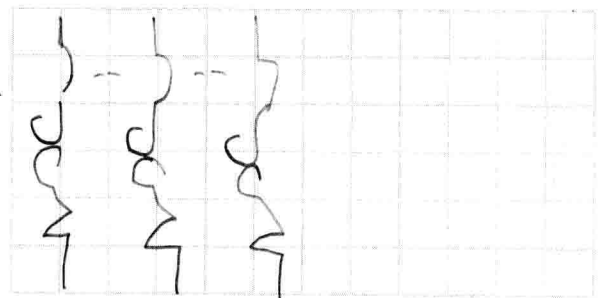
Electrical Symbols

Draw the appropriate symbol.

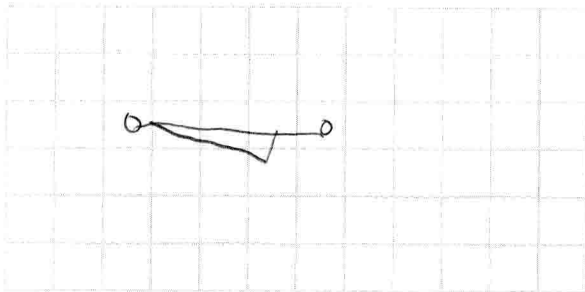
1. NO limit switch



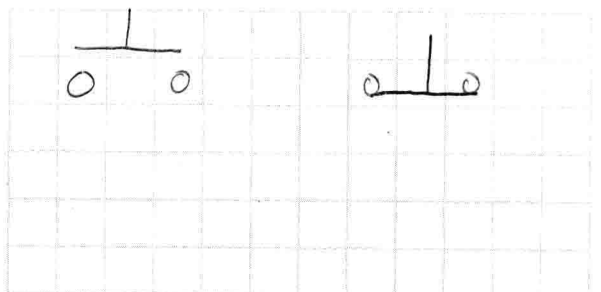
2. Circuit breaker with thermal and magnetic overload



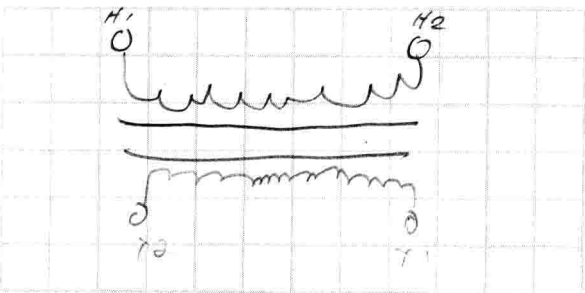
3. NO held-closed limit switch



4. NO and NC pushbutton



5. Single-voltage transformer



6. Dual-voltage transformer

