Basics of Transformers and Ground Fault Monitors

Problem Booklet

Instructions

Read the information on this page and the next page. Then you will be asked 6 questions about this problem. Each question is on a separate page. Work through the exercise one page at a time. Don't jump ahead, but you may look back to earlier questions and your answers.

When you have finished reading the next page, read Question A on page 4. Think about the situation. Then select the correct answer for that question by circling its number on the answer sheet. When everyone in your group has marked their answer to Question A on their answer sheet, turn to page 5 in this problem booklet and look at the feedback page for Question A. Then talk about the answers.

Continue on and do the remaining questions in the same manner. Both Questions D and F have more than one right answer, so you will want to mark more than one answer on the answer sheet for each of these questions. Follow the directions for each question. When you finish you will learn how to score your performance.

Background Information

Mining equipment often makes use of AC circuits with transformers.

AC Circuits with transformers are the basis for ground fault monitoring systems that are used on shuttle cars and other equipment. These safety systems are designed to prevent electrical shocks to workers. If miners do not understand ground monitor systems, and if these systems are faulty or bypassed, serious injuries and fatalities can result.

This booklet contains a series of questions and diagrams about the primary and secondary sides in a simple transformer. Work through the questions one at a time. When you have finished the instructor will discuss the exercise and conduct a demonstration of the principles involved.

Problem

Transformers have primary and secondary sides. If miners and electricians are to work safely they must understand how transformers operate.

Assume the transformer in this exercise is nearly 100 percent efficient.

Turn the page and answer Question A. Then complete the remainder of the questions.

Question A

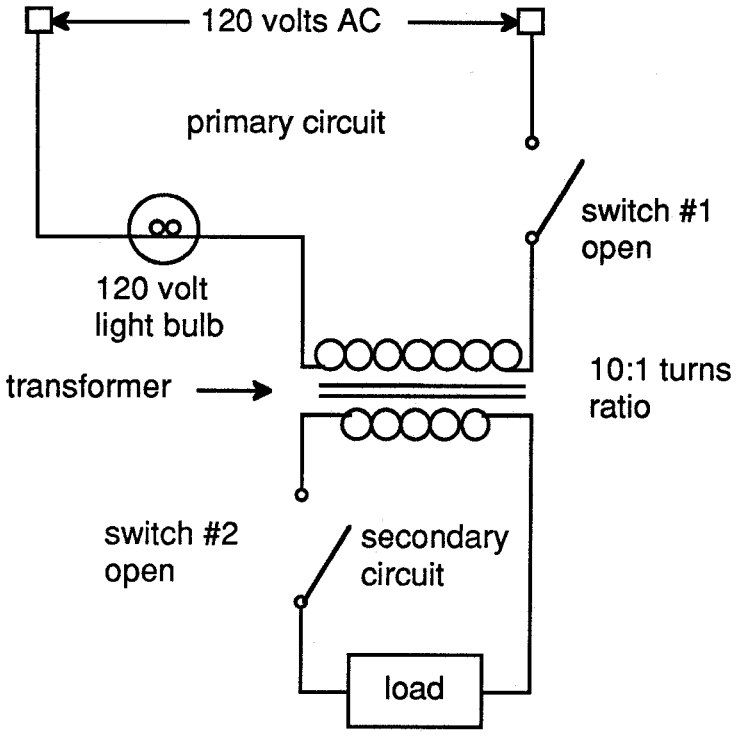
Look at Figure 1. It shows a transformer. The primary side of the circuit is plugged into a 120 volt AC outlet. The secondary side is hooked to a load (resistor). Will the light bulb on the primary side light up when the switches in the primary and secondary sides are arranged as shown in Figure 1? (Choose only ONE answer.)

1. Yes.

2. No.

When you have marked your answers on the answer sheet, turn the page and look at the Question A feedback.

Figure 1: Transformer with switches #1 and #2 open



Question A Feedback

1. Not possible!
2. Correct!

After you have thought about these answers, do question B.

Question B

Look at Figure 2. It is just like Figure 1 except that switch #1 on the primary side is closed. (Choose only ONE answer.)

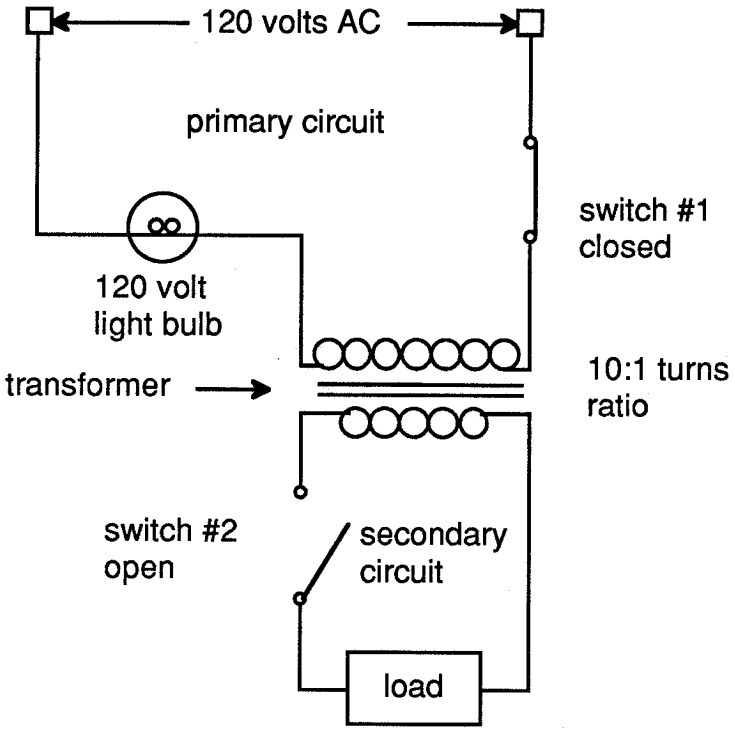
Now will the light bulb on the primary side light up?

3. Yes. The bulb will burn brightly.

4. No. The bulb will not light.

When you have marked your answers on the answer sheet, turn the page and look at the Question B feedback.

Figure 2: Transformer with switch #1 closed and switch #2 open



Question B Feedback

3. Even though switch #1 is closed, the bulb will not light.

4. Correct!

After you have thought about these answers, do question C.

Question C

Look at Figure 3. It's just like Figure 2 except switch #2 on the secondary side is now closed. (Choose only ONE answer.)

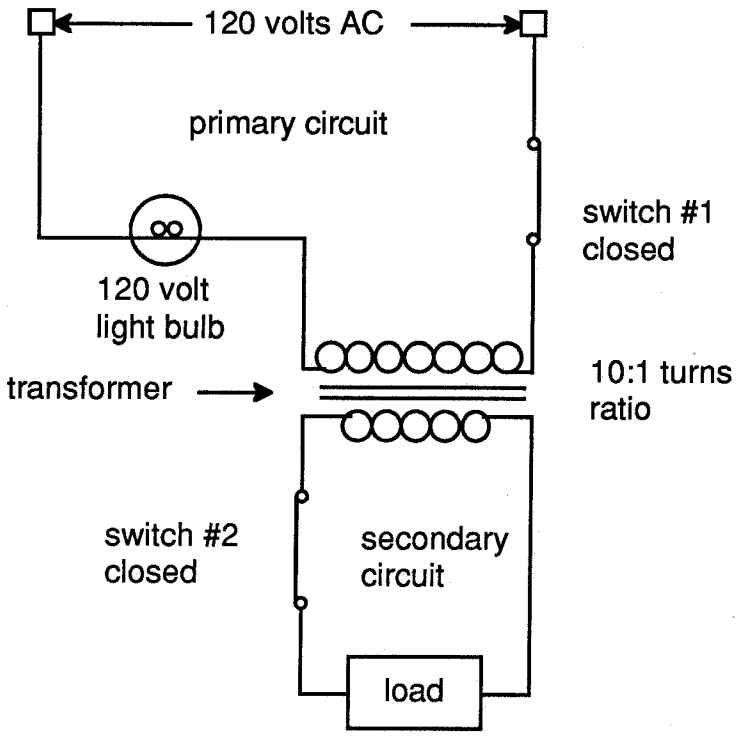
Now will the light bulb light up?

5. Yes, the bulb will burn brightly.

6. No, if it didn't light in Figure 2, it won't light now.

When you have marked your answers on the answer sheet, turn the page and look at the Question C feedback.

Figure 3: Transformer with switches #1 and #2 closed



Question C Feedback

5. Correct!

6. It will light now.

After you have thought about these answers, do question D.

Question D

Switches 1 and 2 in the primary and secondary circuits are closed, as shown in Figure 3. Why does the light bulb now burn brightly when it didn't before? (Select ALL the correct answers.)

7. The resistance in the secondary circuit is lower with switch #2 closed than with it open.

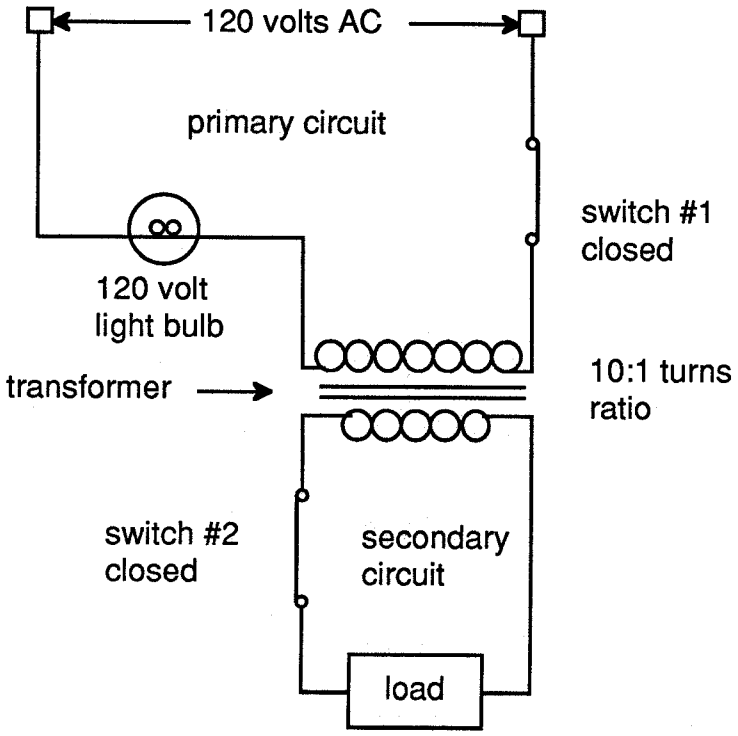
8. The circuit on the primary side is complete when switch #1 is closed.

9. When a transformer is nearly 100% efficient, power into the primary circuit must be approximately equal to the power out of the secondary circuit.

10. With both switches #1 and #2 closed both the primary and secondary circuits have equal impedance.

When you have marked your answers on the answer sheet, turn the page and look at the Question D feedback.

Figure 3: Transformer with switches #1 and #2 closed



Question D Feedback

7. Correct!

8. The primary circuit was complete in Figure 2, but the bulb didn't light.

9. Correct! Since P = I x E, then primary I x E = secondary I x E.

10. The resistance in the primary circuit is much larger than the resistance in the secondary circuit.

After you have thought about these answers, do question E.

Question E

Look at Figure 3. If the resistance in the secondary circuit increases by 1 ohm, what will happen to the resistance in the primary circuit? (Choose only ONE answer.)

11. It will not change.

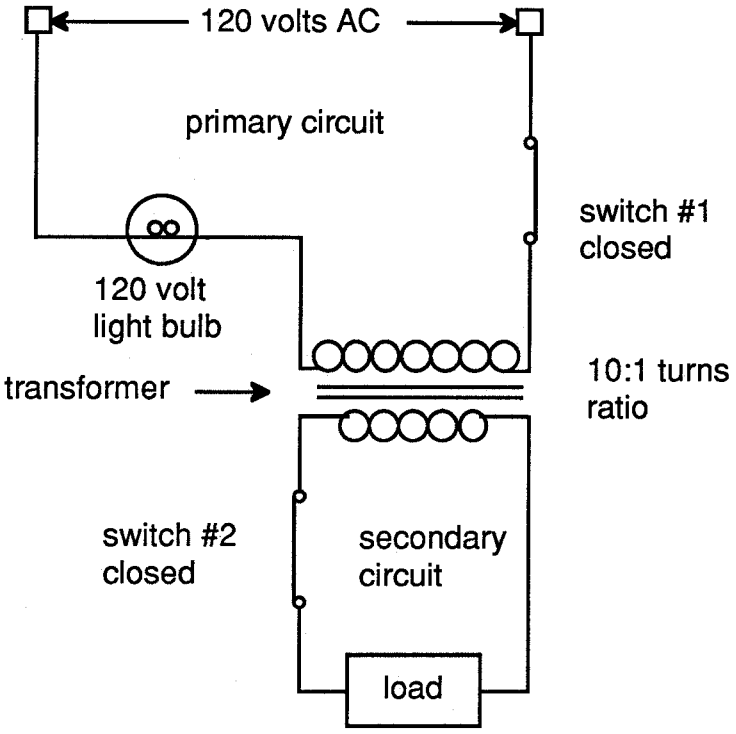
12. It will increase by 1 ohm.

13. It will increase by 10 ohms.

14. It will increase by 100 ohms.

When you have marked your answers on the answer sheet, turn the page and look at the Question E feedback.

Figure 3: Transformer with switches #1 and #2 closed



Question E Feedback

11. It must increase.

12. It must increase much more.

13. The turns ratio is 10:1, but the resistance ratio will be much greater.

14. Correct! The 10:1 turns ratio will produce a $(10:1)^2$ resistance ratio. Since $10^2 = 100$ and $1^2 = 1$, $(10:1)^2 = (100: 1)$

After you have thought about these answers, do question F.

Question F

Now let's think about how these transformer principles apply to ground fault monitor systems on mining equipment. Study Figure 4 on the next page. Then read the following information.

The pilot wire runs from the secondary side of the power center ground monitor transformer to the frame of the shuttle car. The ground wire runs from the shuttle car back to the ground monitor in the power center to complete the secondary circuit. Both conductors run through the trailing cable. The pilot wire is much smaller than any other wire in the cable. Therefore, it can be damaged more easily than the other wires in the cable. Damage may result from running over the cable or too much tension at the anchor point or take up reel.

Suppose the pilot wire in a shuttle car cable is broken. Which of the following statements are correct? (Select ALL the correct answers.)

15. The shuttle car will be de-energized immediately.

16. The current flow in the secondary side of the ground monitor transformer will cease.

17. The current flow in the primary side of the ground monitor transformer will drop to nearly zero.

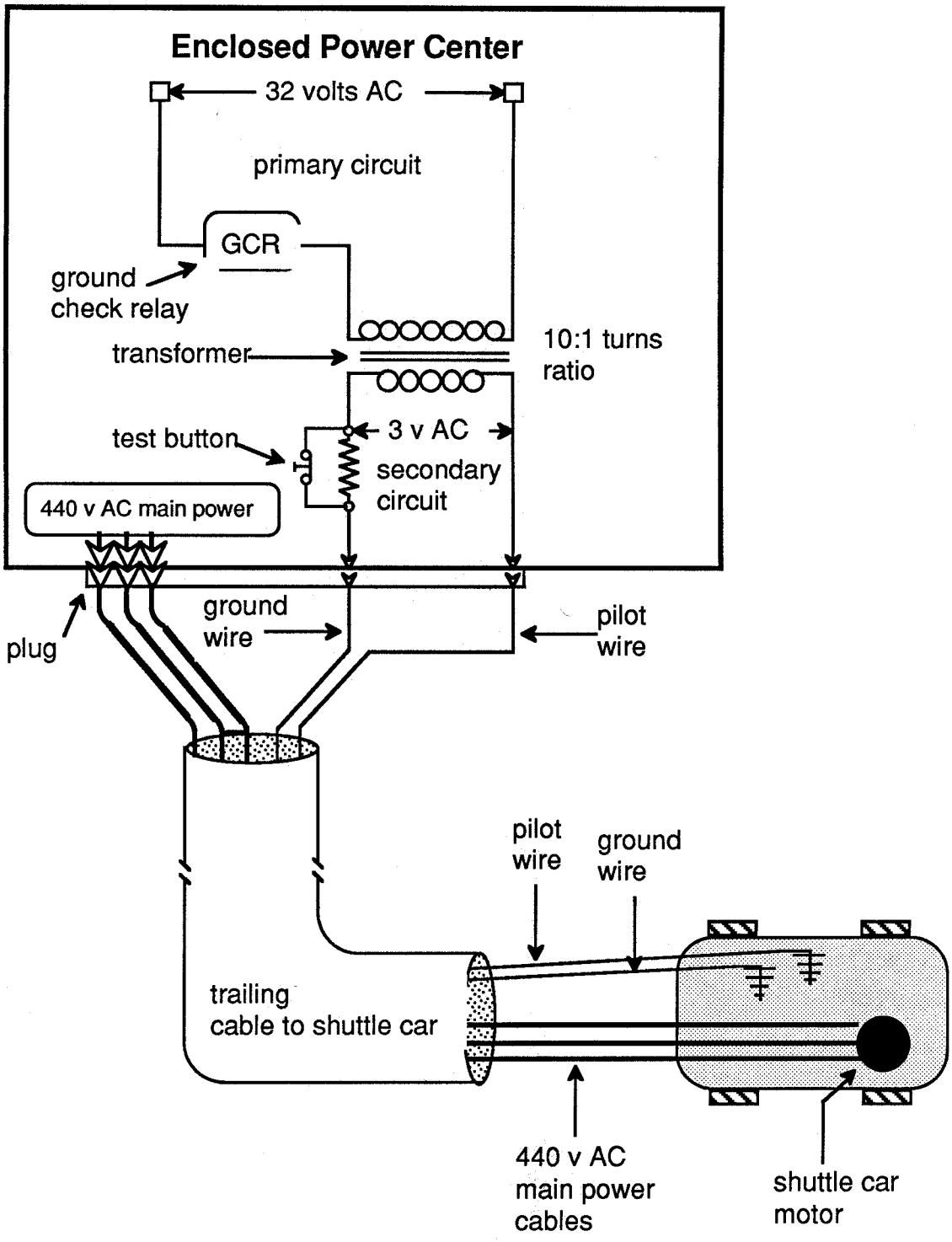
18. The ground check relay in the primary circuit of the ground monitor system will drop out.

19. If someone had bridged out the pilot and ground wire at the plug at the power center, the ground check relay would not drop out.

20. The shuttle car will continue to operate as long as at least either the pilot wire or the ground wire in the trailing cable is not damaged.

When you have marked your answers on the answer sheet, turn the page and look at the Question F feedback.

Figure 4: Schematic diagram showing the primary and secondary circuits of a transformer that serves as a ground monitor for a shuttle car.



Question F Feedback

15. Correct! This safety feature protects miners from electrocution in case of a ground fault on the shuttle car.

16. Correct! Because of the broken pilot wire, the resistance becomes very high and the current flow stops.

17. Correct! The turns ratio of 10:1 in the ground monitor transformer will produce 100 times greater impedance (AC resistance) in the primary circuit than in the secondary.

18. Correct! When this relay drops out, it trips the circuit breaker for the shuttle car trailing cable. This cuts the power to the machine.

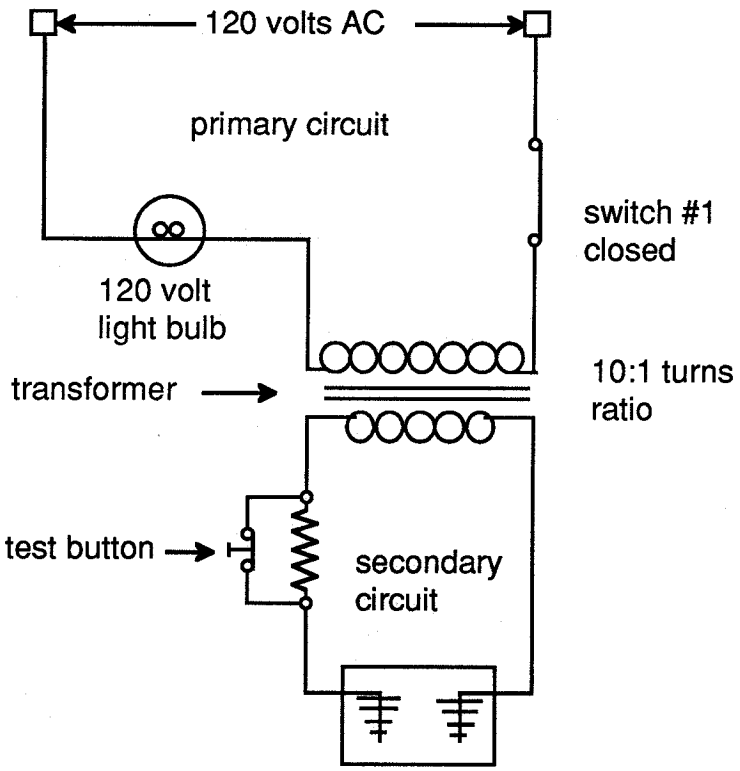
19. Correct! This is dangerous and illegal. This bridge prevents the ground monitor system from "knowing" what is happening to either the pilot wire or the trailing cable. If there is a ground fault on the shuttle car the frame will be energized and deadly.

20. Both wires must be intact if the secondary side of the ground monitor transformer is to remain a complete circuit. Otherwise the ground check relay will trip the circuit breaker and cut the power.

The transformer shown in Figures 1 through 3 operates the same way as the transformer in the power center that comprises the ground monitor for the shuttle car cable. Look at Figure 5 on the next page. Match the components in Figure 5 to the components in the ground monitor system in Figure 4.

Question F Feedback (continued)

Figure 5: Schematic of the transformer, pilot, and ground wire portions of a transformer like the one in the power center ground monitoring system for the shuttle car



End of Problem

Now use the feedback pages to score your answer sheet. Then discuss the exercise with your instructor.