need both E and L at a cost of 8. For f, we can eliminate prime implicant C, since that row is dominated by row H and costs more. That requires us to choose H to cover m_{15}. Once H is chosen, all that remains to be covered are m_3 and m_{12}, which can be covered by A and B (respectively), each at a cost of 1. (J or G could have been used, but they would cost 3 each.) The final functions are

$$f = b'd' + ad + a'b'cd + abc'$$
$$g = abc' + bd + a'b'cd$$
$$h = b'd' + a'd' + cd' + a'b'cd$$

4.8 EXERCISES*

1. For each of the following functions, find all prime implicants using the Quine-McCluskey method.
   a. $f(a, b, c) = \Sigma m(1, 2, 3, 6, 7)$
   *b. $g(w, x, y) = \Sigma m(0, 1, 5, 6, 7)$
   c. $g(w, x, y, z) = \Sigma m(2, 3, 6, 7, 8, 10, 11, 12, 13, 15)$
   *d. $h(p, q, r, s) = \Sigma m(0, 2, 3, 4, 5, 8, 11, 12, 13, 14, 15)$
   e. $f(a, b, c, d) = \Sigma m(5, 7, 9, 11, 13, 14) + \Sigma d(2, 6, 10, 12, 15)$
   *f. $f(a, b, c, d) = \Sigma m(0, 2, 4, 5, 6, 7, 8, 9, 10, 14) + \Sigma d(3, 13)$
   g. $G(V, W, X, Y, Z) = \Sigma m(0, 1, 4, 5, 8, 9, 10, 15, 16, 18, 19, 20, 24, 26, 28, 31)$
   *h. $H(V, W, X, Y, Z) = \Sigma m(0, 1, 2, 3, 5, 7, 10, 11, 14, 15, 16, 18, 24, 25, 28, 29, 31)$
2. For the functions of Exercise 1, find all prime implicants using iterated consensus.
3. For the functions of Exercises 1 and 2, find all minimum sum of products expressions (b. 2 solutions, c. 2 solutions, d. 4 solutions, e. 4 solutions, f. 3 solutions, h. 2 solutions, all others, 1 solution).
4. For the following sets of functions, find all product terms that could be used in a minimum two-level AND/OR system using the Quine-McCluskey algorithm.
   a. $f(a, b, c, d) = \Sigma m(5, 8, 9, 12, 13, 14)$
      $g(a, b, c, d) = \Sigma m(1, 3, 5, 8, 9, 10)$
   *b. $F(W, X, Y, Z) = \Sigma m(1, 5, 7, 8, 10, 11, 12, 14, 15)$
      $G(W, X, Y, Z) = \Sigma m(0, 1, 4, 6, 7, 8, 12)$

*Each of the functions and sets of functions was included in the exercises of Chapter 3. Other exercises from that chapter could also be used here.

c. $f(a, b, c, d) = \Sigma m(1, 3, 5, 7, 8, 9, 10)$
$g(a, b, c, d) = \Sigma m(0, 2, 4, 5, 6, 8, 10, 11, 12)$
$h(a, b, c, d) = \Sigma m(1, 2, 3, 5, 7, 10, 12, 13, 14, 15)$

*d. $f(a, b, c, d) = \Sigma m(0, 3, 4, 5, 7, 8, 12, 13, 15)$
$g(a, b, c, d) = \Sigma m(1, 5, 7, 8, 9, 10, 11, 13, 14, 15)$
$h(a, b, c, d) = \Sigma m(1, 2, 4, 5, 7, 10, 13, 14, 15)$

5. For each of the sets of functions of Solved Problem 4, find all product terms that could be used in a minimum two-level AND/OR system using iterated consensus.

6. For each of the sets of functions of Solved Problems 4 and 5, find a set of minimum sum of products expressions, corresponding to a two-level AND/OR gate (or NAND gate) system.

a. 3 solutions, 8 gates, 25 inputs
b. 8 gates, 23 inputs
c. 2 solutions, 12 gates, 33 inputs
d. 2 solutions, 11 gates, 33 inputs

4.9 CHAPTER 4 TEST (50 MINUTES)*

1. For the following function, find all of the prime implicants using

a. the Quine-McCluskey method.
b. iterated consensus.

$$f(w, x, y, z) = \Sigma m(0, 2, 3, 6, 8, 12, 15) + \Sigma d(1, 5)$$

2. For the following function,

$$g(a, b, c, d) = \Sigma m(3, 4, 5, 6, 7, 8, 9, 12, 13, 14)$$

we have found the complete list of prime implicants

$a'cd$ bd'
$a'b$ ac'
bc'

Find both of the minimum sum of products solutions.

3. For the following set of functions, find all terms that can be used in a minimum two-level AND/OR system using

a. the Quine-McCluskey method.
b. iterated consensus.

$$f(w, x, y, z) = \Sigma m(1, 2, 5, 7, 10, 11, 13, 15)$$
$$g(w, x, y, z) = \Sigma m(0, 2, 3, 4, 5, 7, 8, 10, 11, 12)$$

*The timing assumes that the student will solve either 1a. or 1b. and either 3a. or 3b.