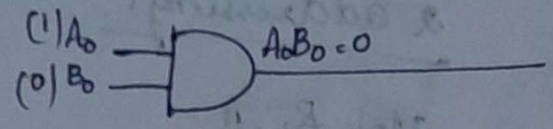
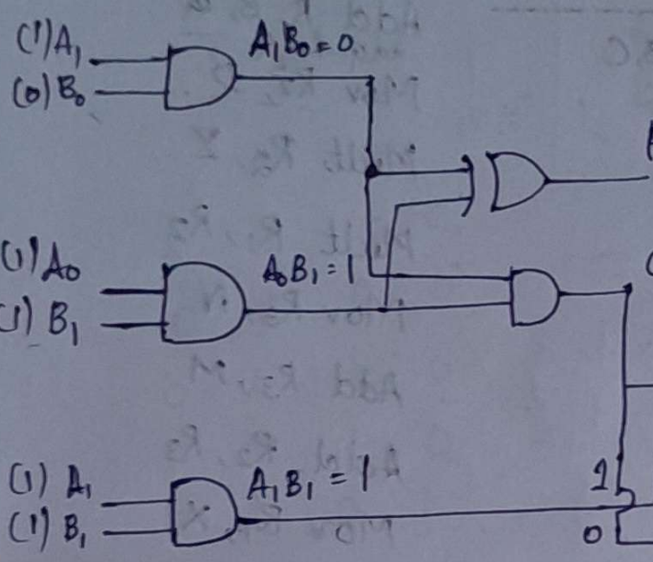
Binary multiplier:

A_1 A_0
A = 1 1 (3)
B_1 B_0
B = 1 0 (2)
×
0 0
1 1 ↓
1 1 0 (6)
P_2 P_1 P_0





0000 0101
1000 0010
1000 0111

12
11
12
12
132

Multiplier:

$12 \times 11 = 132$

$B_3B_2B_1B_0$
B → 12 → 1100
Q → 11 → 1011
$Q_3Q_2Q_1Q_0$

128
16
8

C A Q

0 → 0000 1011 } 1
0000 0101
1100
1100 0101 } 2
$Q_0 = 1$ → 1 1 1 0 → 0 0 1 0
$Q_0 = 0$ → 0111 0001
1100
$Q_0 = 1$ → 0011 1000
1 → 1001

Multiplier

① C A Q

$B_3\ B_2\ B_1\ B_0$

$B \rightarrow 12 \rightarrow 1100$

$Q \rightarrow 11 \rightarrow 1011$

$Q_3\ Q_2\ Q_1\ Q_0$

0 | 0000 | 1011

1100

$Q_0 = 1$ | 1100 | 1011 } cycle 1

A + B | 0 → 0 1 1 0 | 0 1 0 1

Shift

12
11
12
12
132

10110

1100

$Q_0 = 1$ ① ① 0 0 1 0 | 0 1 0 1 } Cycle 2

A + B → 1 0 0 1 | 0 0 1 0

Shift

$Q_0 = 0$ 0 → 0 1 0 0 | 1 0 0 1 } cycle 3.

Shift

10100

1100

$Q_0 = 1$ ① ① 0 0 0 0 | 1 0 0 1 } cycle 4

A + B → 1 0 0 0 | 0 1 0 0

Shift

128 64 32 16 | 8 4 2 1

128 + 4 = 132

② $2^{15} \rightarrow 1111 \rightarrow B$

$14 \rightarrow 1110 \rightarrow Q.$

160
15
210

C A Q

0 | 0000 | 1110 } 1

$Q_0 = 0$ → 0 000 | 0111

Shift

$Q_0 = 1$ 0 | 0000 | 0111 } 2

1111

A + B → 1111 | 1011

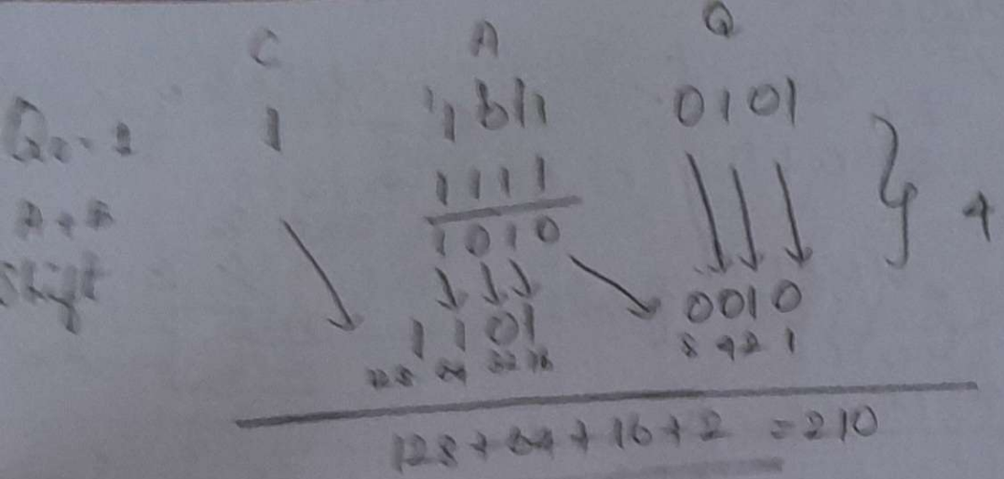
Shift → 0111

$Q_0 = 1$ 1 | 1011 | 1011 } 3

1110

A + B → 1101 | 1011

Shift → 1011



$$128+64+16+2 = 210$$

Signed numbers

M → Multiplicand
Q → Multiplier

-6×7

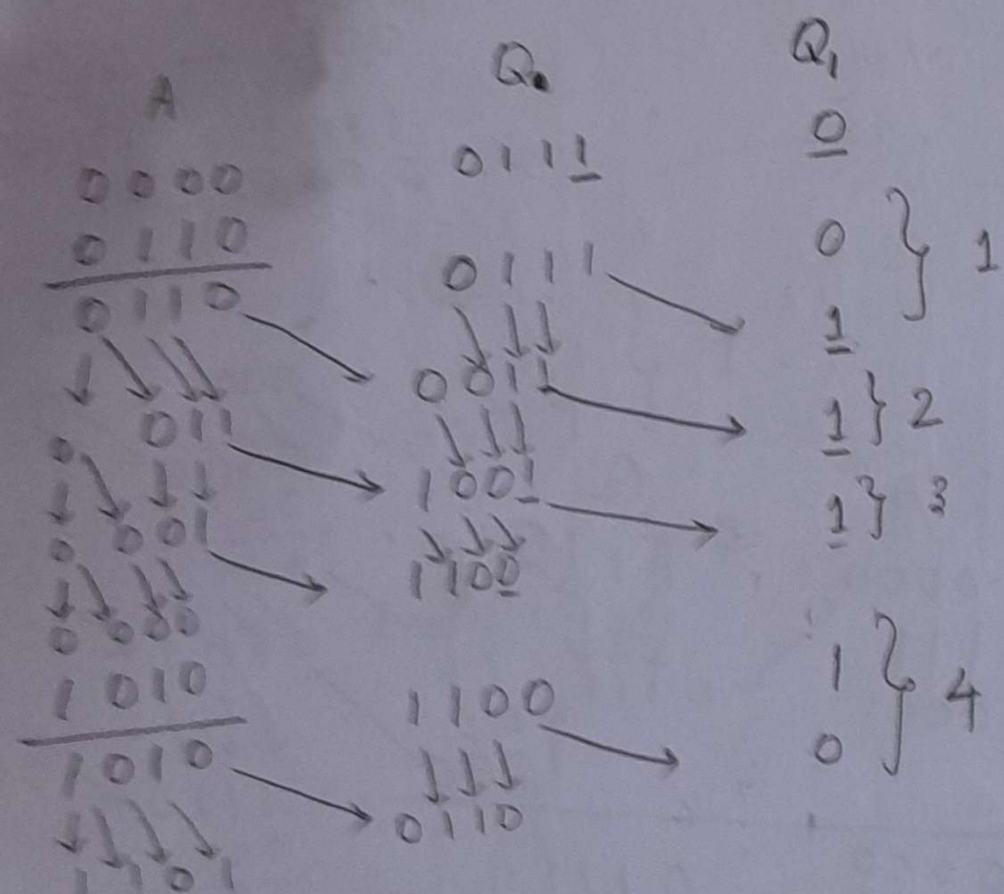
M = -6
Q = 7

→ M = 1010
-M = 0110
Q = 0111

Q_0	Q_1	
0	0	Shift
1	1	Shift
1	0	→ A − M, Shift
0	1	→ A + M, Shift

$$\begin{array}{r} 0110 \\ \times\ 1001 \\ \hline 1010 \end{array}$$

$$\begin{array}{r} 1010 \\ 0101 \\ \hline 0110 \end{array}$$



7 x -6

M → 7

Q → -6 ⇒ 0110

1001

1

1010

+M = 0111

-M = 1001

+Q = 1010

-Q = 0110

+M = 0111

1000

1001

0101

1

0110

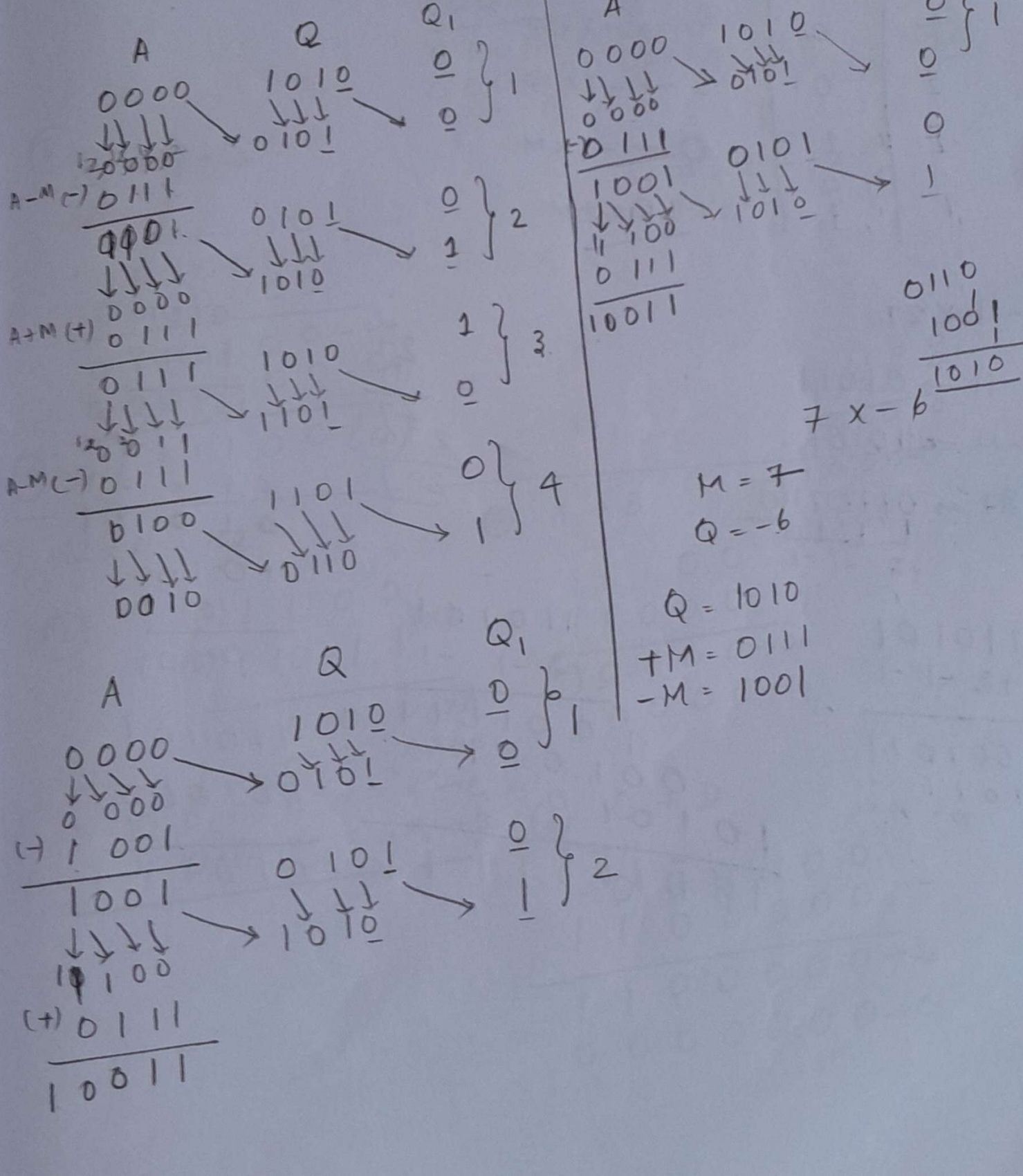
1/2 0 0 0 0

0 1 1 1

1001

1000

1001



Bit Pair recoding of Multiplier

Multiplier:

+ → 0
− → 1

i+1	i	i-1
0	0	0 → 0×M
0	0	1 → +1×M
0	1	0 → +1×M
0	1	1 → +2×M
1	0	0 → −2×M
1	0	1 → −1×M
1	1	0 → −1×M
1	1	1 → 0×M

−11 × 27

11 → 01011

−11 → 110101

27 → 011011 0

+2 −1 −1

```
  110101
  +2 -1 -1
  --------
  001011
0010 11 xx
```

```
  27
  11
  --
  27
 27
 ---
 297
```

```
 01011
 10100
     1
 -----
 10101
```

```
16 8 4 2 1
 0 1 0 1 1
 1 0 1 0 0
         1
 ---------
 1 0 1 0 1
```

```
      110101
      +2 -1 -1
      --------
      001011
    1 01011 xx
  001010 xx
1010 10
-------------
101110 0 1 1 1 1
```

```
 110101
 001010
      1
 ------
 001011
```

16/10/2023
Monday

Carry Save addition

①

① (x) 1010 (10) } = 60
0110 (6) }

```
    0000  → A
   1010x  → B
  1010xx  → C
00 00xxx  → D
```

② A + B

```
  0 0 0 0
  1 0 1 0 0
-----------
1 0 1 0 0 → S1
0 0 0 0 0 → C1
```

③ C + D

```
  1 0 1 0 0 0
  0 0 0 0 0 0 0
---------------
0 1 0 1 0 0 0 → S2
0 0 0 0 0 0 0 → C2
```

④ $S_1 + C_1 + S_2$

```
  10100
  00000
 0101000
---------
0111100 → S3
0000000 → C3
```

2
32
16
8
4

60

⑤ $S_3 + C_3 + C_2$

```
  0111100
  0000000
  0000000
---------
0111100 - S4
0000000 - C4
-----------
0111100 (60)
```

⑥

64 32 16 8 4 2 1
0 1 1 1 1 0 0

```
   1100
   1100
---------
  10100
 10000
```

---

② 12 × 11 = 132

① (12) 1100
(11) 1011 (x)

```
    1100 → A
   1100x → B
  0000xx → C
1100xxx → D
```

② A + B

```
  1100
 11000
-------
10100 → S1
10000 → C1
```

③ C + D

```
  0000000
 1100000
---------
1100000 → S2
0000000 → C2
```

④ $S_1 + C_1 + S_2$

```
  1 0 1 0 0
  1 0 0 0 0
1 1 0 0 0 0 0
-------------
1 1 0 0 1 0 0 → S3
0 1 0 0 0 0 0 → C3
```

⑤ $S_3 + C_3 + C_2$

```
  1 1 0 0 1 0 0
  0 1 0 0 0 0 0
  0 0 0 0 0 0 0
---------------
  1 0 0 0 1 0 0 → S4
  1 0 0 0 0 0 0 → C4
---------------
1 0 0 0 0 1 0 0 (132)
128 64 32 16 8 4 2 1
```

2 | 66 | 33 | 16 | 8 | 4 | 2 | 1 | 0
1 | 33 | 16 | 8 | 4 | 2 | 1 | 0 | 0
1 | 16 | 8 | 4 | 2 | 1 | 0 | 0 | 0
1 | 8 | 4 | 2 | 1 | 0 | 0 | 0 | 0
1 | 4 | 2 | 1 | 0 | 0 | 0 | 0 | 0
1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0
1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0
0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0

1 1 1 1 0 0

1 0 0 0 0 1 0 0

Division (Restoring)

① Left Shift
② A = A − M
③ Bit = 0 ⇒ Q[0] → 1
④ Bit = 1 → Q[0] = 0 (Restore A)

① 10 ÷ 3

Q → 10 → 1010 (doesn't change)
M → 3 → 00011 (add one bit)(0)

−M = 11101

A = 00000

2's complement of M

```
00011
11100
-----
11101
```

```
  3
2 | 10
  -9
  --
   1
```

```
  5
2 | 11
  -10
  ---
   1
```

Q

A

1 0 1 0 → Initial Stage

```
00000
00010
11101
-----
11111
00001
00010
11101
-----
11110
00101
00010
11101
-----
11111
00010
```

```
1 0 1 0
0 1 0 □
1 0 1 0 Q
1 0 0 □
1 0 0 □
1 0 0 0
```

① $10 \div 3$

3 (Q)

$3 \overline{)10}$

-9

1 (R)

$Q \rightarrow 10 \rightarrow 1010$

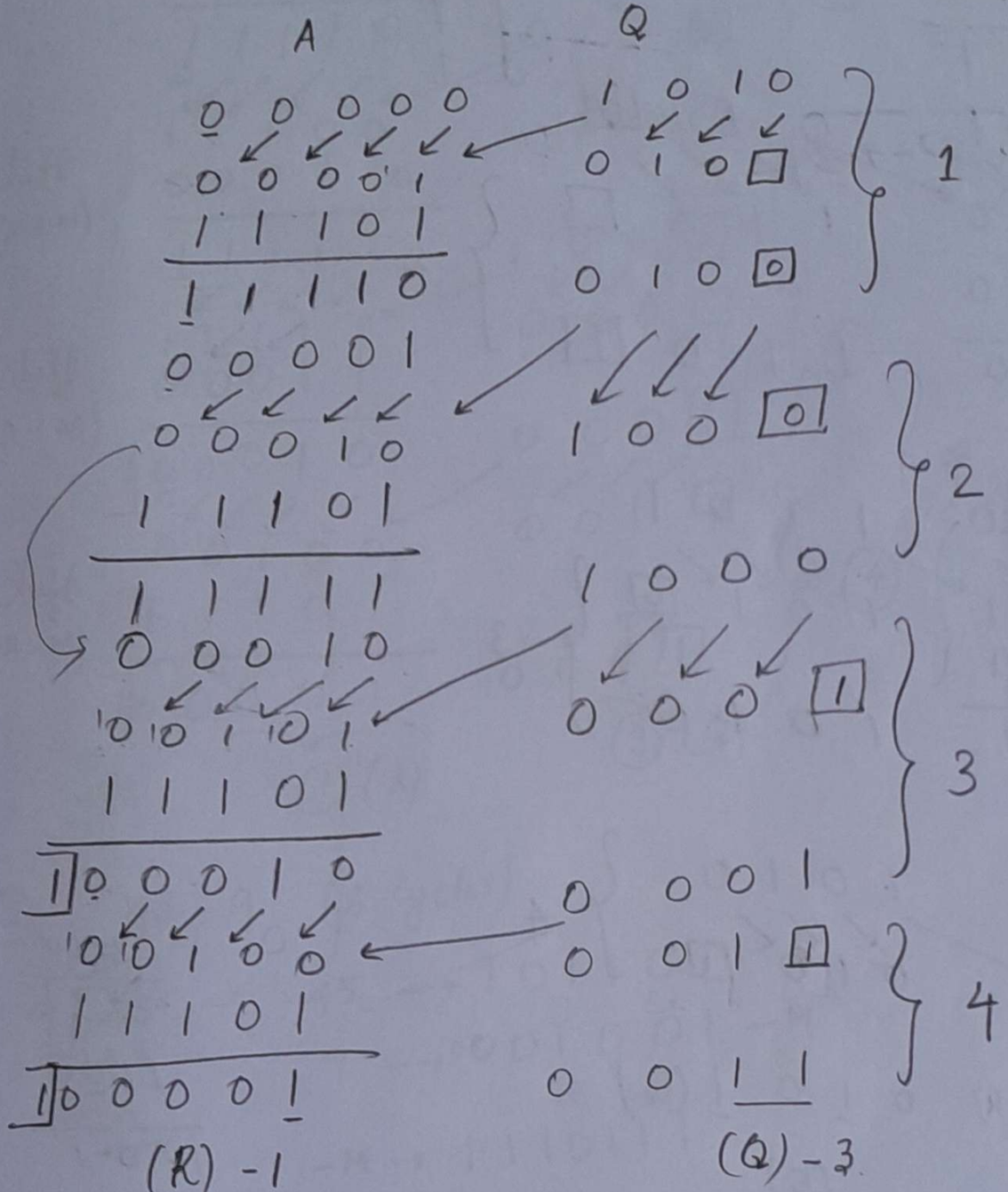
$M \rightarrow 3 \rightarrow 00011$

$\boxed{-M = 11101}$

00011

11109 } 2's complement

11101



② $11 \div 2$

5 (Q)

$2 \overline{)11}$

-10

1 (R)

$Q \rightarrow 11 \rightarrow 1011$

$M \rightarrow 2 \rightarrow 00010$

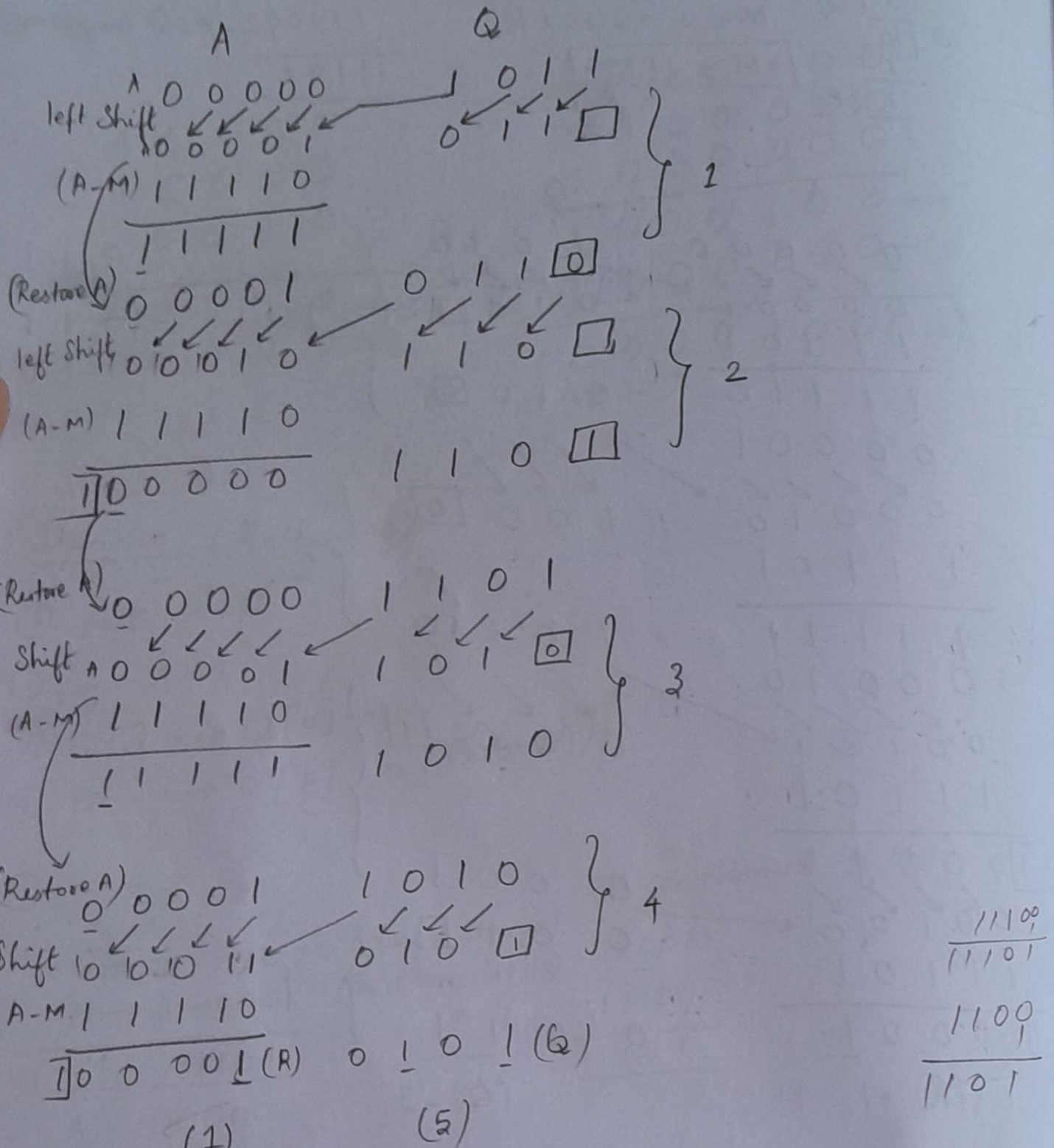
$\boxed{-M = 11110}$

$A = 00000$

00010

11101

11110



(1) (5)

19/10/2023
Thursday

Non-Restoring

$10 \div 3$

Steps:

1) 0 → L.S, A = A − M
2) 1 → L.S, A = A + M
3) 0 → Q[0] = 1
4) 1 → Q[0] = 0

$Q = 10 \Rightarrow 1010$

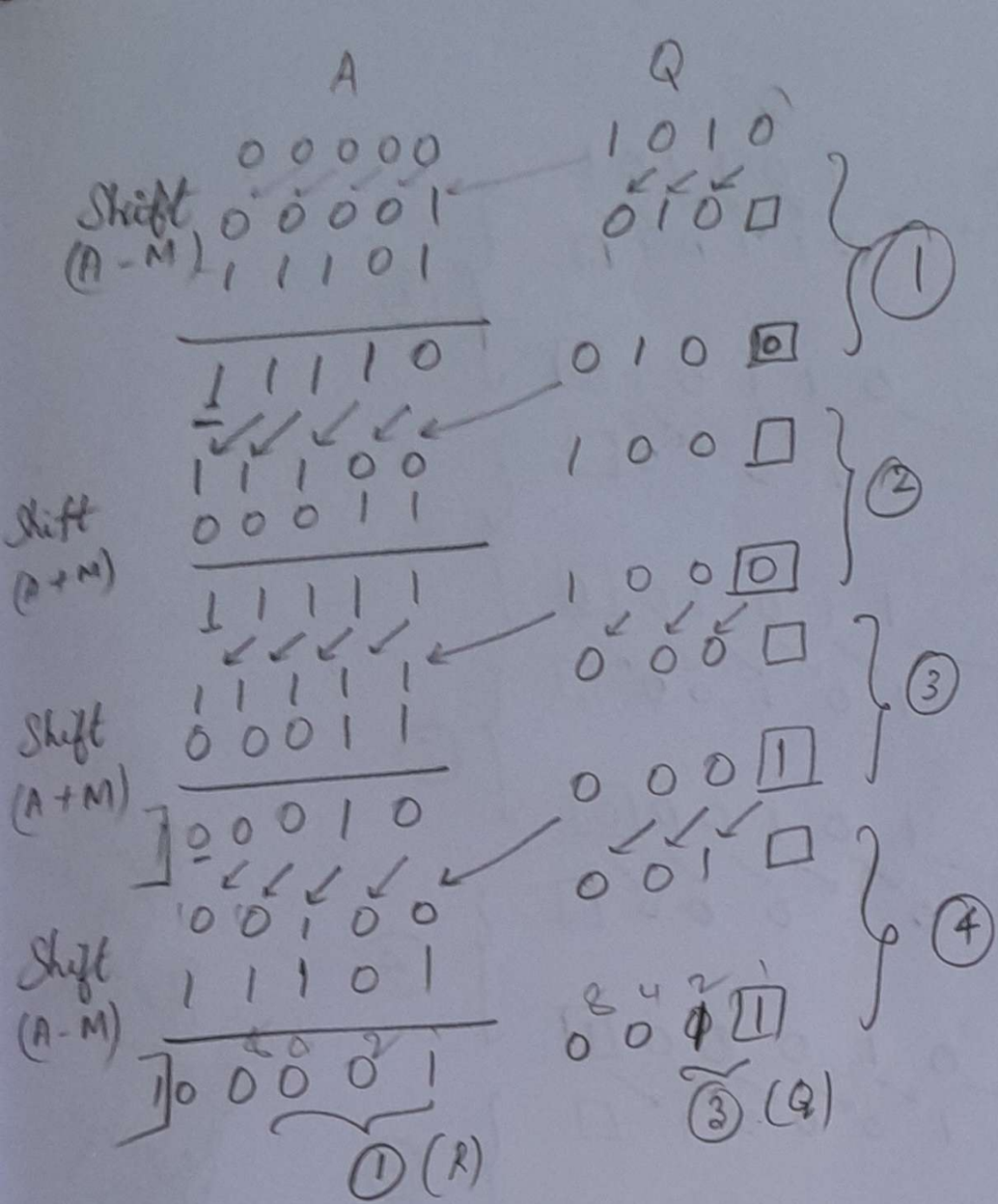
$M = 3 \Rightarrow 00011$

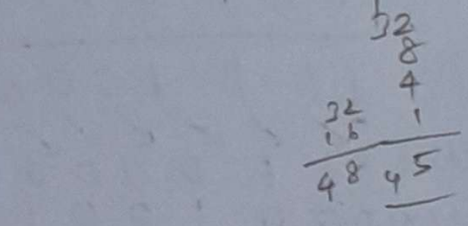
$\boxed{-M = 11101}$

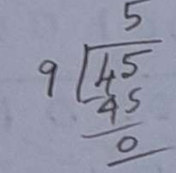
11100
11101

1100
1101

$3 - (Q)$
$3 \overline{)10}$
-9
$1 - (R)$







② $45 \div 9$ (6 cycles)

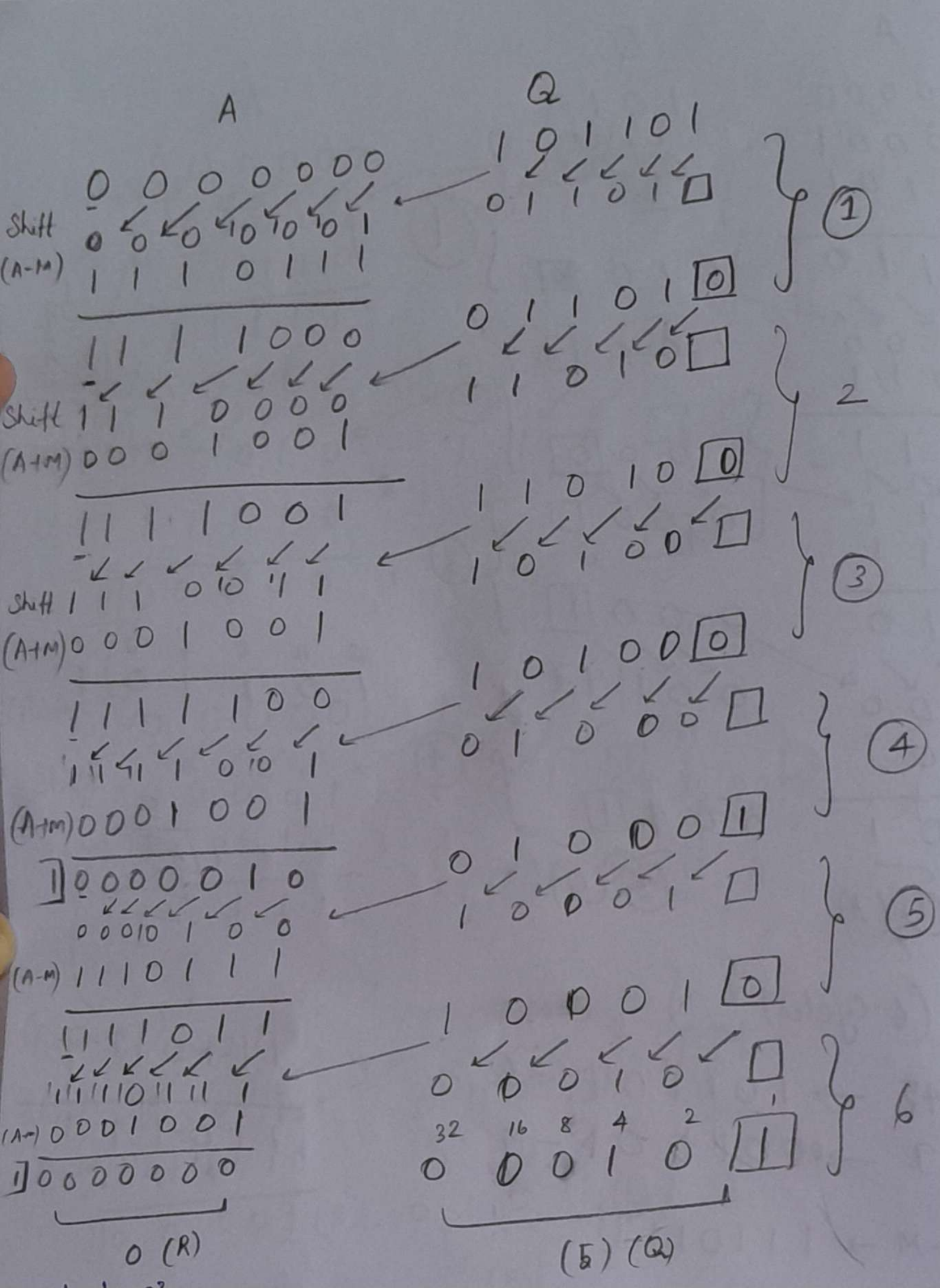
$$\begin{array}{r} 5 \\ 9\overline{)45} \\ -45 \\ \hline 0 \end{array}$$

$45 \rightarrow 101101$ - Q

$9 \rightarrow 0001001$ - M

$-M \rightarrow 1110111$

$$\begin{array}{r} 1110110 \\ \quad\quad\quad\quad 1 \\ \hline 1110111 \end{array}$$


A
Q
Shift
(A-M)
(A+M)
(R)
(Q)
1
2
3
4
5
6