HASHING

1) Open Hashing (closed addressing)

2) Closed Hashing (open addressing)

key = 6, 26 $\quad h(k_i) = k_i \% m$

$m = 10$

↳ $6 \% 10 = 6$

$26 \% 10 = 6$

→ Open Hashing - chaining method

→ Closed Hashing (open addressing)

- Linear Probing
- Quadratic Probing
- Double Hashing

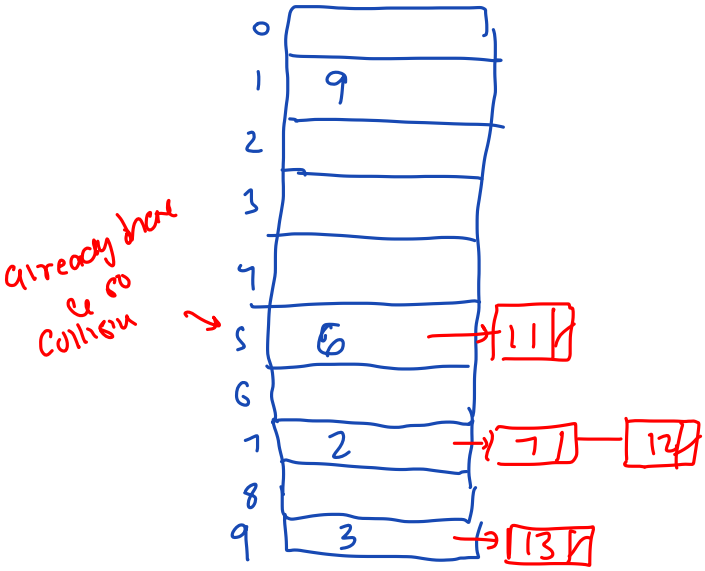
} to Resolve collision

① A = 3, 2, 9, 6, 11, 13, 7, 12] key value

$h(k) = 2k + 3$

$m = 10$ (size of hash table)

* use division method & closed addressing technique to store these values *



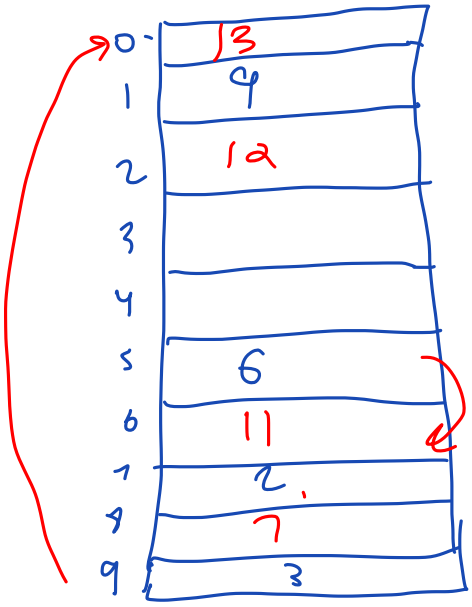
closed addressing / chaining

→ create linked list when collision occurs

$h(k) = k_i \% m$

key	location
3	$[2(3)+3] \% 10 = 9 \% 10 = 9$
2	$7 \% 10 = 7$
9	$21 \% 10 = 1$
6	$6(2)+3 = 15 \% 10 = 5$
11	$25 \% 10 = 5$
13	$29 \% 10 = 9$
7	$17 \% 10 = 7$
12	$27 \% 10 = 7$

→ Linear Probing Method / Open addressing



key	Location	Probes
3	9	1
2	7	1
9	1	1
6	5	1
11	5	2
13	9	2
7	7	2
12	7	6

Collision at 5th place so go to next place

Order of elements : 13, 9, 12, —, —, 6, 11, 2, 7, 3

→ Insert k_i at first free location from $(u + i) \% b\, m$ where $i = 0$ to $(m - 1)$

for 11 = $(\underbrace{u}_{loc} + i) \% b\, m$

$= (5 + 0) \% b\ 10 = 5 \% b\, 10 = 5$

so not free so $i = 1$

$(5 + i) \% b\, m = 6 \% b\, 10 = 6$ ✓ free

Double Hashing

A = 3, 2, 9, 6, 11, 13, 7, 12

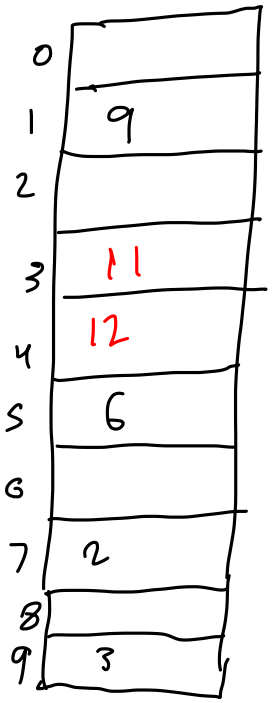
$h_1(k) = 2k + 3$ $\quad m = 10$

$h_2(k) = 3k + 1$

if collision,
insert K_i at first free place
from $(u + v * i) \% m$
$[i = 0 + (m-1)]$

$(u + i) \% m$
$(u + i^2) \% m$

Calculate v using 2nd hash function
$v = h_2(k) \% m$
↳ apply only during collision



key	location (u)	v	Probe
3	$(2(3)+3) \% 10 = 9$	—	1
2	7	—	1
9	1	—	1
6	5	—	1
11	5 (collision)	$v = 3(11)+1 = 34 \% 10 = 4$	3
13	9	$v = 3(13)+1 = 40 \% 10 = 0$	—
7	7	$v = 22 \% 10 = 2$	—
12	7	$v = 37 \% 10 = 7$	2 (i=0, i=1)

always get 9 so can't insert 13 into hash table

① $(9 + (0 * 0)) \% 10$
$9 \% 10 \rightarrow$ not

② $(9 + (0 *$ ↙ anything times 0 will be 0

$(u + v * i) \% m$
$(5 + (4 * 0)) \% m$
Probe ① $(5 + 0) \% m$
$5 \% 10 = 5 \rightarrow$ not free

probe ② $(5 + (4 * 1)) \% m$
$9 \% 10 = 9 \rightarrow$ not free

probe ③ $(5 + (4 * 2)) \% m$
$13 \% 10 = 3 \rightarrow$ FREE

① $(6 + (2 * 0)) \% m$
$7 \% 10 = 7 \rightarrow$ not free

② $(7 + (2 * 1)) \% 10$
$9 \% 10 \rightarrow$ not

③ $(7 + 4)$ clock$_2$
$11 \% 10 = 1 \rightarrow$ not

④ $(7 + 6) \% 10 = 3 \rightarrow$ not

⑤ $(7 + 8) \% 10 = 5 \rightarrow$ not

⑥ $(7 + 10) \% 10 = 7 \rightarrow$ not

⑦ $(7 + 2(6)) \% 10 = 19 \% 10 = 9$

⑧ $(7 + 2(7)) \% 10 = 21 \% 10 = 1$

⑨ $(7 + 2(8)) \% 10 = 23 \% 10 = 3$

⑩ $(7 + 2(9)) \% 10 = 25 \% 10 = 5 \rightarrow$ not free ← also calculate using formula

* Order of elements:

—, 9, —, 1, 12, 6, —, 2, —, 3

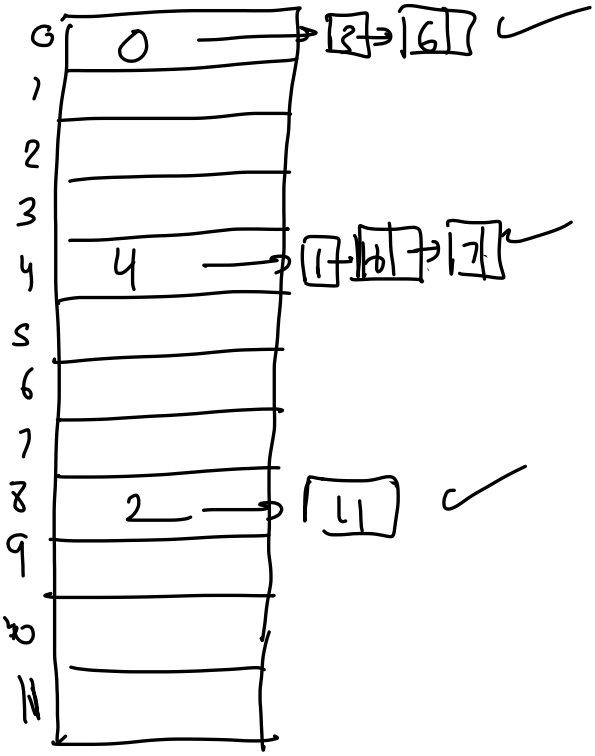
Hashing Practice Problems

0, 4, 7, 1, 2, 3, 6, 11, 16

$m = 12$

$h(k) = 4x$

CHAINING



Key	Location
0	$4(0) \% 12 = 0$
4	$16 \% 12 = 4$
7	$28 \% 12 = 4$
1	$4 \% 12 = 4$
2	$8 \% 12 = 8$
3	$12 \% 12 = 0$
6	$24 \% 12 = 0$
11	$44 \% 12 = 8$
16	$64 \% 12 = 4$

$12 \overline{)28}\ 2,\ 24,\ 4$

$12 \overline{)28}\ 2,\ 24,\ 8$

$G(4) = 24$

$24 \% 12$

$12 \overline{)24}$

LINEAR PROBING

2, 4, 6, 7, 15, 13, 19

$m = 13$

$h(k) = 3k$

Key	hash	Rdl
2	$3(2) \% 13 = 6$	6
4	12	12
6	18	5
7	21	8
15	45	6
13	39	0
19	57	5

0	13
1	/
2	/
3	/
4	/
5	6
6	2
7	15
8	7
9	19
10	/
11	/
12	4

$12 \overline{)58}\ 3,\ 36,\ 22$

$= 9$

Double Hashing

$m = 11$

keys to insert : 20, 34,