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# 第一课 链表

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# 内容概述

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## 1.8道经典链表常考题目

例1-a:链表逆序(easy)

例1-b:链表逆序2(medium)

例2:链表求交点 (easy)

例3:链表求环(medium)

例4:链表划分(medium)

例5:复杂链表的复制(hard)

例6-a:2个排序链表归并(easy)

例6-b:K个排序链表归并(hard)

## 2.详细讲解题目多种解题方法、代码实现

## 3.一些学习与找工作的建议

# 预备知识:链表基础

```
#include <stdio.h>
```

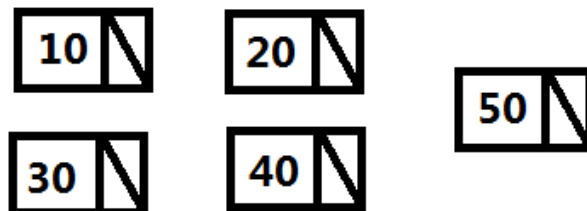
```
struct ListNode {  
    int val; //存储元素的数据域  
    ListNode *next;  
}; //存储下一个节点地址的指针域
```



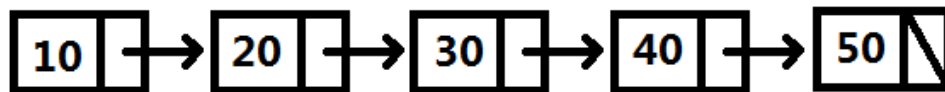
1分钟时间填写代码!

```
int main() {  
    ListNode a;  
    ListNode b;  
    ListNode c;  
    ListNode d;  
    ListNode e;  
    a.val = 10;  
    b.val = 20;  
    c.val = 30;  
    d.val = 40;  
    e.val = 50;  
    a.next = &b;  
  
    1  
    c.next = &d;  
    d.next = &e;  
  
    2  
    ListNode *head = &a;  
    while(head) {  
        printf("%d\n", head->val);  
        3  
    }  
    return 0;  
}
```

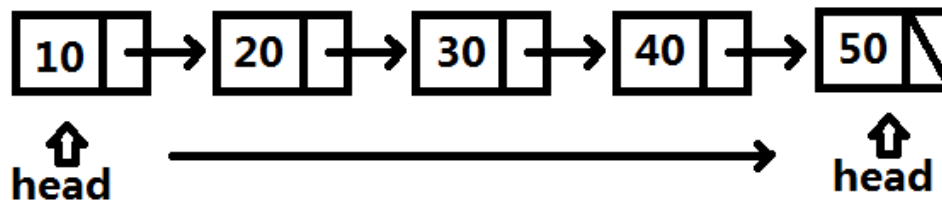
1.创建5个节点:



2.将它们连接在一起:



3.遍历它们,并打印节点的值:



# 预备知识:链表基础

```
#include <stdio.h>
```

```
struct ListNode {  
    int val; //存储元素的数据域  
    ListNode *next;  
}; //存储下一个节点地址的指针域
```



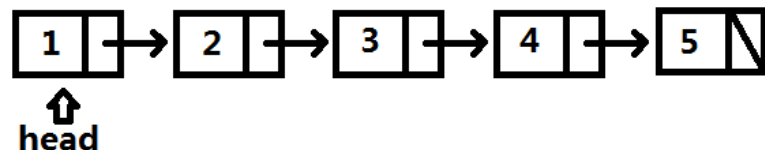
```
int main() {  
    ListNode a;  
    ListNode b;  
    ListNode c;  
    ListNode d;  
    ListNode e;  
    a.val = 10;  
    b.val = 20;  
    c.val = 30;  
    d.val = 40;  
    e.val = 50;  
    a.next = &b;  
    b.next = &c;  
    c.next = &d;  
    d.next = &e;  
    e.next = NULL;  
    ListNode *head = &a;  
    while(head) {  
        printf("%d\n", head->val);  
        head = head->next;  
    }  
    return 0;  
}
```

```
10  
20  
30  
40  
50  
请按任意键继续. . .
```

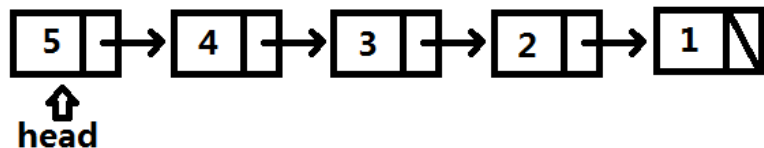
# 例1-a:链表逆序-a

已知链表**头节点**指针head, 将**链表**逆序。(不可申请**额外**空间)

逆序前:



逆序后:



```
struct ListNode {  
    int val; //数据域  
    ListNode *next; //指针域  
    ListNode(int x) : val(x), next(NULL) {}  
};  
//构造函数  
  
class Solution {  
public:  
    //链表头节点指针  
    ListNode* reverseList(ListNode* head) {  
    }  
    //返回链表逆序后的头节点指针  
};
```

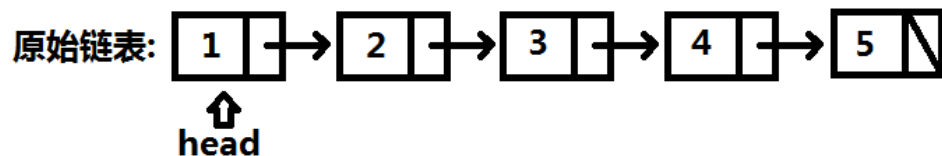
选自 **LeetCode 206. Reverse Linked List**

<https://leetcode.com/problems/reverse-linked-list/description/>

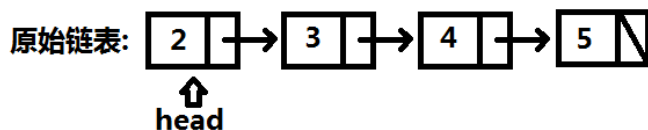
难度:**Easy**

# 例1-a:思路

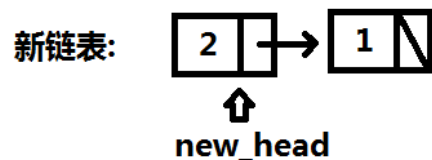
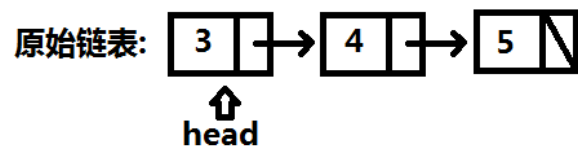
依次遍历链表节点，每遍历一个节点即逆置一个节点



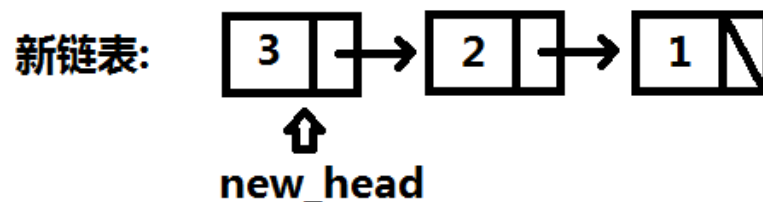
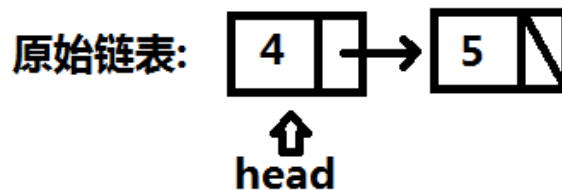
循环1次:



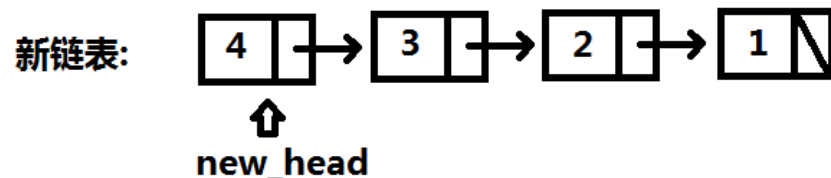
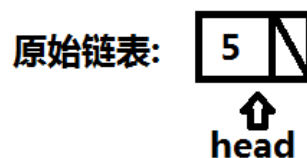
循环2次:



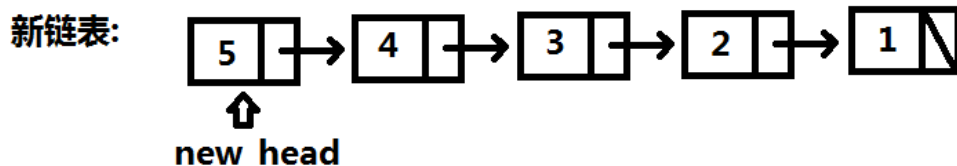
循环3次:



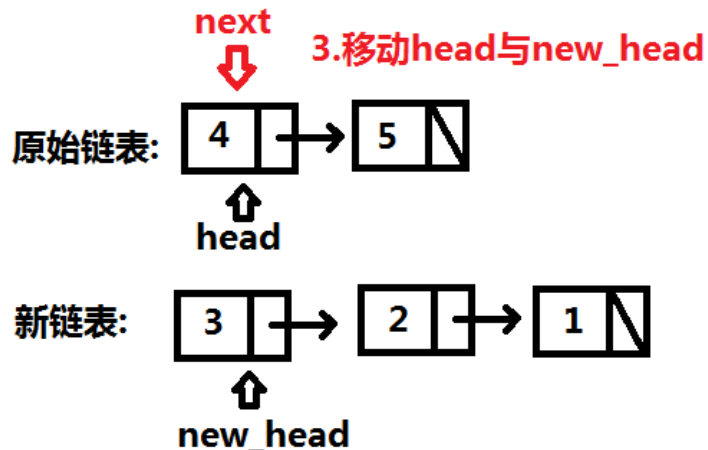
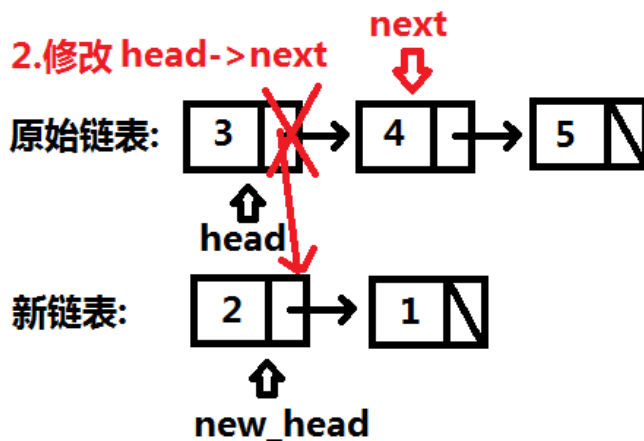
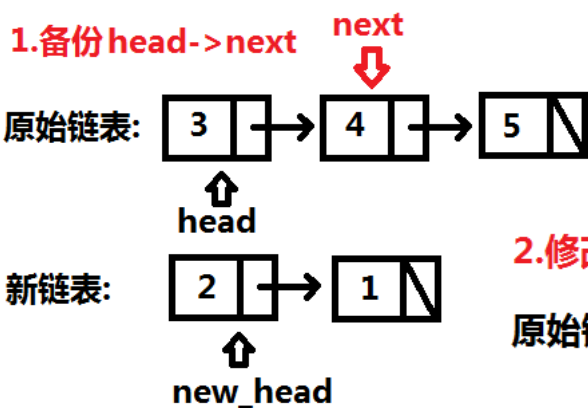
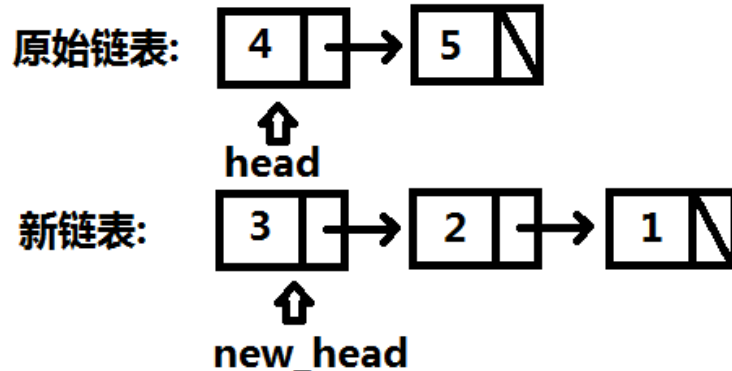
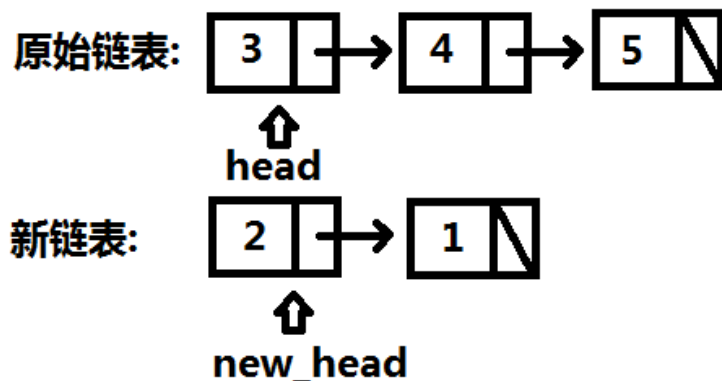
循环4次:



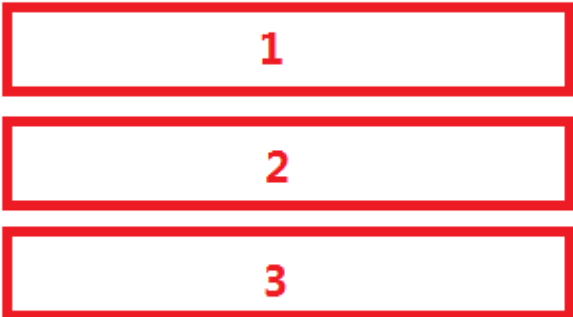
循环5次:



# 例1-a:思路



# 例1-a:课堂练习

```
class Solution {
public:
    ListNode* reverseList(ListNode* head) {
        ListNode *new_head = NULL; //指向新链表头节点的指针
        while(head) {
            
            head = next; //遍历链表
        }
        return new_head; //返回新链表头节点
    }
};
```

**3分钟**时间填写代码，有问题随时提出！



# 例1-a:实现

```
class Solution {
public:
    ListNode* reverseList(ListNode* head) {
        ListNode *new_head = NULL; //指向新链表头节点的指针
        while(head) {
            ListNode *next = head->next; //备份head->next
            head->next = new_head; //更新head->next
            new_head = head; //移动new_head
            head = next; //遍历链表
        }
        return new_head; //返回新链表头节点
    }
};
```

# 例1-a:测试与leetcode提交结果

```
int main() {
    ListNode a(1);
    ListNode b(2);
    ListNode c(3);
    ListNode d(4);
    ListNode e(5);
    a.next = &b;
    b.next = &c; //将节点简单的链接，进行测试
    c.next = &d; //无需构造复杂的链表操作(插入,删除)
    d.next = &e;
    Solution solve;
    ListNode *head = &a;
    printf("Before reverse:\n");
    while(head) {
        printf("%d\n", head->val);
        head = head->next;
    }
    head = solve.reverseList(&a);
    printf("After reverse:\n");
    while(head) {
        printf("%d\n", head->val);
        head = head->next;
    }
    return 0;
}
```

Before reverse:

1  
2  
3  
4  
5

After reverse:

5  
4  
3  
2  
1

请按任意键继续. . .

Reverse Linked List

Submission Details

27 / 27 test cases passed.

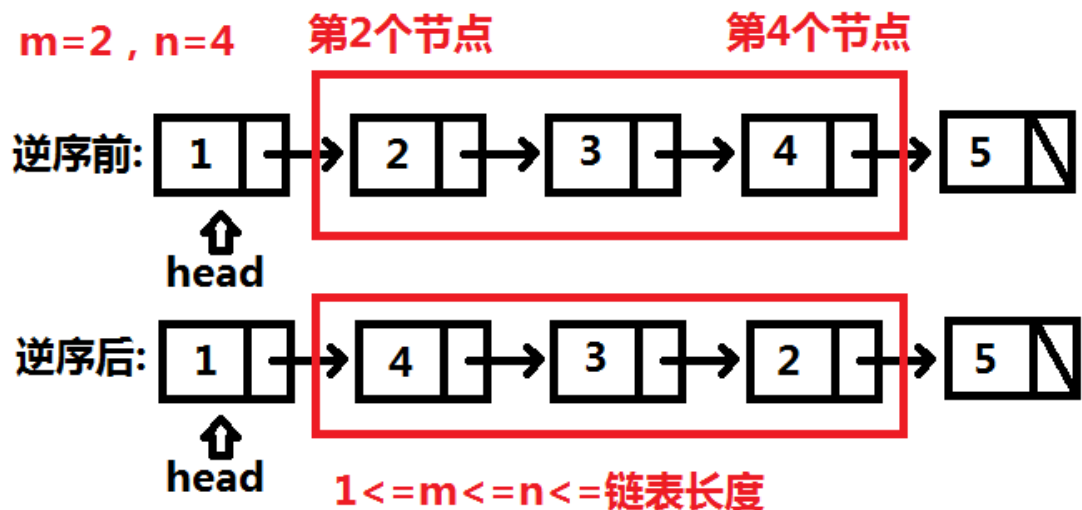
Status: **Accepted**

Runtime: 6 ms

Submitted: 0 minutes ago

# 例1-b:链表逆序-b

已知链表**头节点**指针head，将**链表**从位置m到n逆序。(不申请**额外**空间)



```
class Solution {  
public:  
    //链表头指针      //从m逆至到n  
    ListNode* reverseBetween(ListNode* head, int m, int n) {  
    }  
};
```

选自 **LeetCode 92. Reverse Linked List II**

<https://leetcode.com/problems/reverse-linked-list-ii/description/>

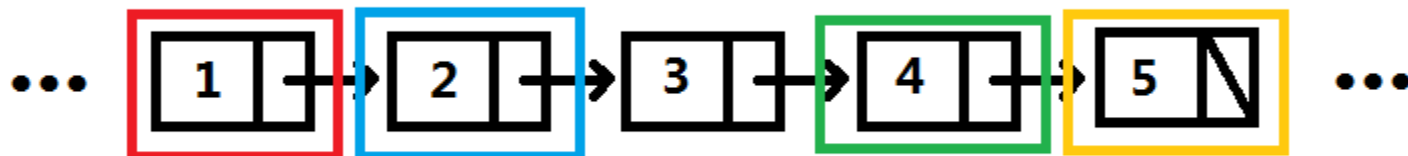
难度: **Medium**

# 例1-b:思路

寻找关键的节点:

逆置前头节点

逆置前尾节点, 逆置后头节点



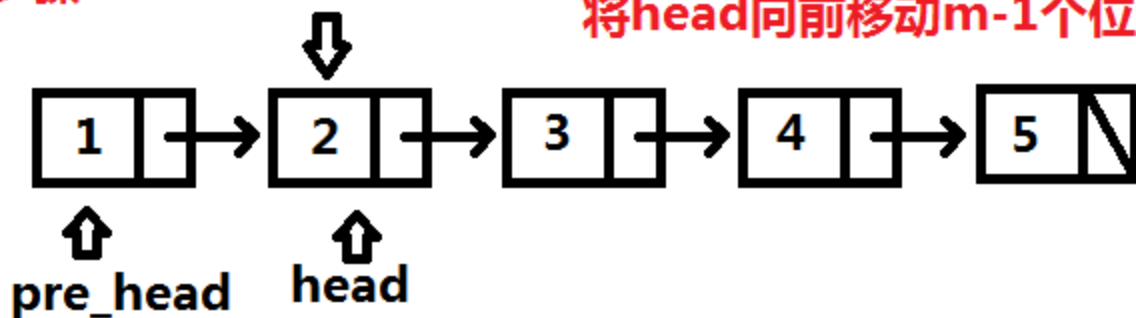
逆置段头节点的前驱

逆置后尾节点

逆置段尾节点的后继

步骤1: modify\_list\_tail

将head向前移动m-1个位置

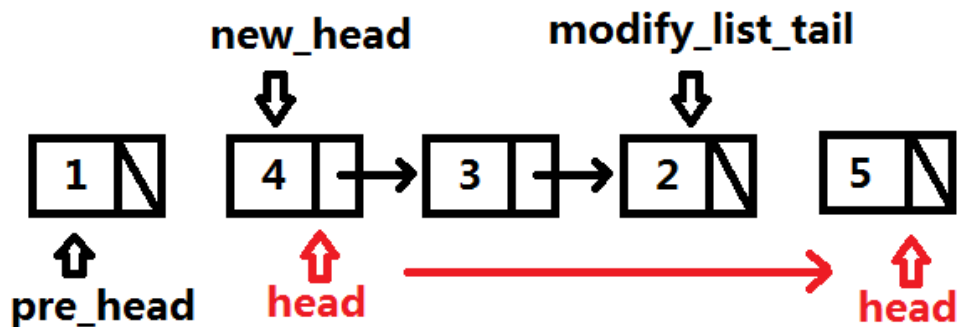


找到开始逆置的节点, 记录该节点前驱、该节点

# 例1-b:思路

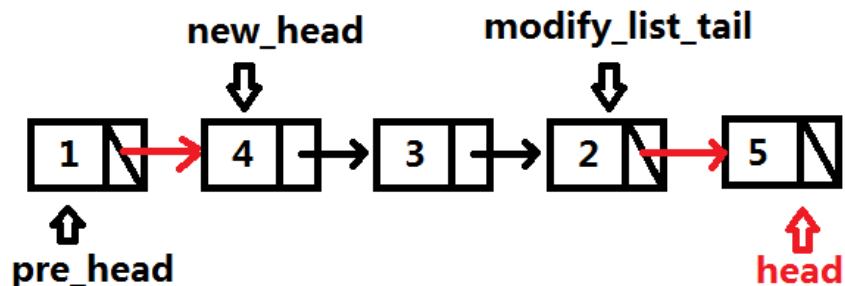
## 步骤2:

从head开始, 逆置change\_len =  $n-m+1$ 个节点



## 步骤3:

将pre\_head与new\_head连接, modify\_list\_tail与head连接



## 思考:

- 1.最终结果应该**返回**哪个节点?
- 2.如果 $m=1$ 时, 有什么**特殊**的?

```
class Solution {
```

```
public:
```

```
    ListNode* reverseBetween(ListNode* head, int m, int n) {
```

```
        int change_len = n - m + 1; //计算需要逆置的节点个数
```

```
        ListNode *pre_head = NULL; //初始化开始逆置的节点的前驱
```

```
        ListNode *result = head; //最终转换后的链表头节点，非特殊情况即为head
```

```
        while (head && --m) {
```

```
            //将head向前移动m-1个位置
```

1

```
            head = head->next;
```

```
        }
```

```
        //将modify_list_tail指向当前的head，即逆置后的链表尾
```

```
        ListNode *modify_list_tail = head;
```

```
        ListNode *new_head = NULL;
```

```
        while (head && change_len) { //逆置change_len个节点
```

```
            ListNode *next = head->next;
```

```
            head->next = new_head;
```

```
            new_head = head;
```

```
            head = next;
```

2

```
        }
```

3

```
        if (pre_head) {
```

```
            //如果pre_head不空，说明不是从第一
```

4

```
            个节点开始逆置的m>1
```

```
        }
```

```
        else {
```

5

```
        }
```

```
        return result;
```

```
    }
```

```
};
```

## 例1-b:课堂练习

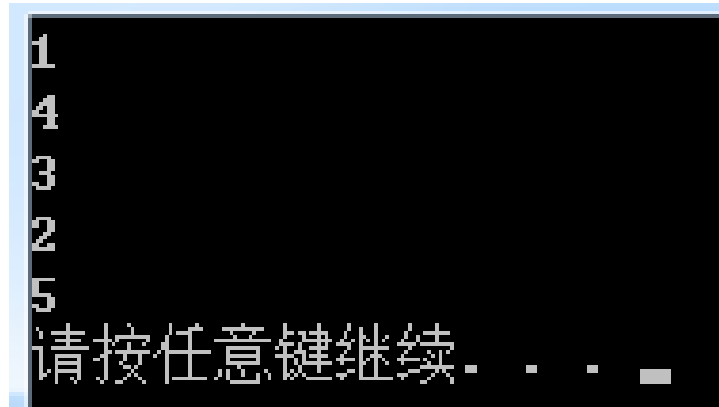
5分钟时间填写代码，  
有问题随时提出！

# 例1-b:实现

```
class Solution {
public:
    ListNode* reverseBetween(ListNode* head, int m, int n) {
        int change_len = n - m + 1; //计算需要逆置的节点个数
        ListNode *pre_head = NULL; //初始化开始逆置的节点的前驱
        ListNode *result = head; //最终转换后的链表头节点，非特殊情况即为head
        while (head && --m) {
            pre_head = head; //将head向前移动m-1个位置
            head = head->next; //记录head的前驱
        } //将modify_list_tail指向当前的head，即逆置后的链表尾
        ListNode *modify_list_tail = head;
        ListNode *new_head = NULL;
        while (head && change_len) { //逆置change_len个节点
            ListNode *next = head->next;
            head->next = new_head;
            new_head = head;
            head = next;
            change_len--; //每完成一个节点逆置，change_len--;
        }
        modify_list_tail->next = head; //连接逆置后的链表尾与逆置段的后一个节点
        if (pre_head) { //如果pre_head不空，说明不是从第一个节点开始逆置的m>1
            pre_head->next = new_head; //将逆置链表开始的节点前驱与逆置后的头节点链接
        } else {
            result = new_head; //如果pre_head为空，说明m==1从第一个节点开始逆置
        } //结果即为逆置后的头节点
        return result;
    }
};
```

# 例1-b:测试与leetcode提交结果

```
int main() {
    ListNode a(1);
    ListNode b(2);
    ListNode c(3);
    ListNode d(4);
    ListNode e(5);
    a.next = &b;
    b.next = &c;
    c.next = &d;
    d.next = &e;
    Solution solve;
    ListNode *head = solve.reverseBetween(&a, 2, 4);
    while(head) {
        printf("%d\n", head->val);
        head = head->next;
    }
    return 0;
}
```



```
1
4
3
2
5
请按任意键继续 . . .
```

Reverse Linked List II

Submission Details

44 / 44 test cases passed.

Status: **Accepted**

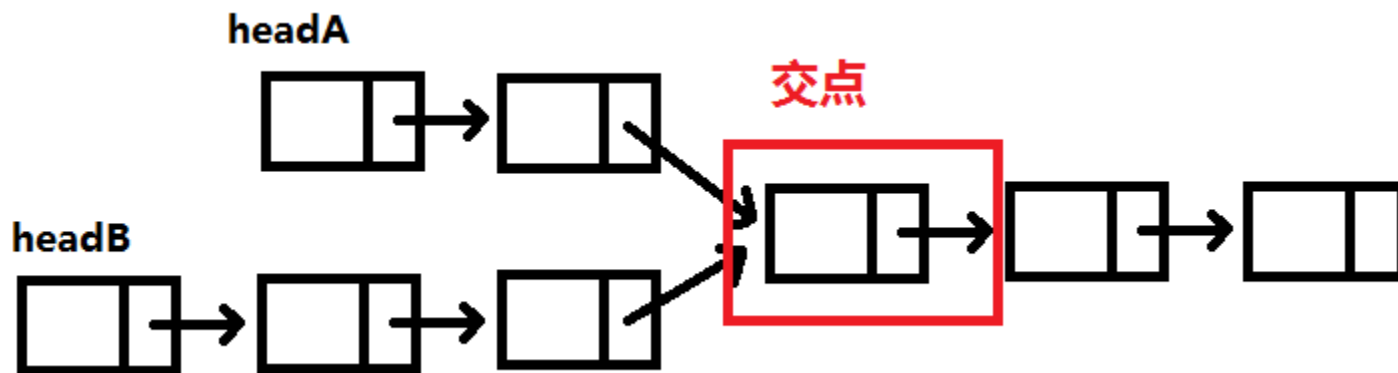
Runtime: 3 ms

Submitted: 0 minutes ago



# 例2:求两个链表的交点

已知链表A的**头节点**指针headA，链表B的**头节点**指针headB，两个链表**相交**，求两链表**交点**对应的节点



选自 **LeetCode 160. Intersection of Two Linked Lists**

<https://leetcode.com/problems/intersection-of-two-linked-lists/description/>

难度:**Easy**

# 例2:题目要求

```
struct ListNode {  
    int val; //数据域  
    ListNode *next; //指针域  
    ListNode(int x) : val(x), next(NULL) {  
        //构造函数  
    }  
};
```



```
class Solution {  
public:  
    //链表A头节点指针      链表B头节点指针  
    ListNode *getIntersectionNode(ListNode *headA, ListNode *headB) {  
        //求两个链表的交点  
    }  
};
```

- 1.如果两个链表**没有交点**，则**返回NULL**
- 2.在求交点的过程中，**不可以破坏**链表的**结构**或者**修改**链表的**数据域**
- 3.可以确保传入的链表A与链表B**没有任何环**
- 4\*.实现算法尽可能使**时间**复杂度 **$O(n)$** ，**空间**复杂度 **$O(1)$**

# 例2:方法1的必备知识(set的使用)

```
//STL set的使用
#include <set>
int main() { //O(nlogn)或O(n)的方法判断两数组是否有相同元素

    std::set<int> test_set; //STL set

    const int A_LEN = 7; //测试数组A与B的长度
    const int B_LEN = 8; //测试数组A与B, 其中有重复元素

    int a[A_LEN] = {5, 1, 4, 8, 10, 1, 3};
    int b[B_LEN] = {2, 7, 6, 3, 1, 6, 0, 1};

    for (int i = 0; i < A_LEN; i++) {
        test_set.insert(a[i]); //将数组a的元素插入set
    }

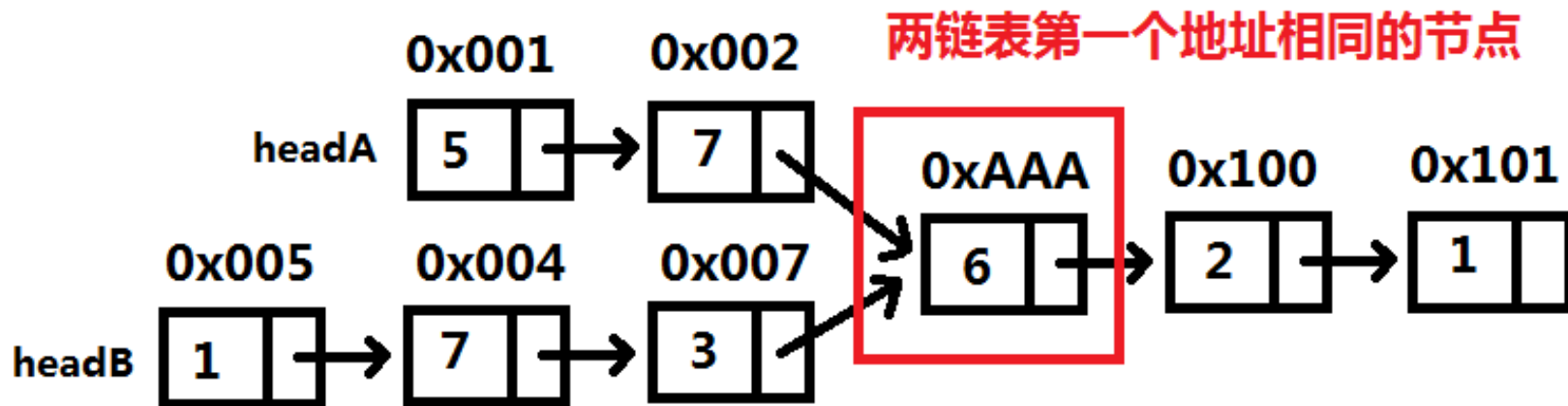
    for (int i = 0; i < B_LEN; i++) { //检查数组b中的元素是否在set中
        if (test_set.find(b[i]) != test_set.end()) {
            printf("b[%d] = %d in array A.\n", i, b[i]);
        }
    }

    return 0;
}
```

```
b[3] = 3 in array A.
b[4] = 1 in array A.
b[7] = 1 in array A.
请按任意键继续. . .
```

## 例2:思路1，使用set求交集

1. 遍历链表A，将**A中**节点对应的**指针(地址)**，插入set
2. 遍历链表B，将**B中**节点对应的**指针(地址)**，在set中**查找**，发现在set中的第一个节点地址，即是两个链表的**交点**。



# 例2:方法1， 课堂练习

```
class Solution {
public:
    ListNode *getIntersectionNode(ListNode *headA, ListNode *headB) {
        std::set<ListNode*> node_set; //设置查找集合node_set
        while(headA) {
            1
            headA = headA->next; //遍历链表A
        }
        while(headB) {
            if ( 2 ) {
                return headB; //当在headB中找到第一个出现在node_set中的节点时
            }
            3
        }
        return NULL;
    }
};
```

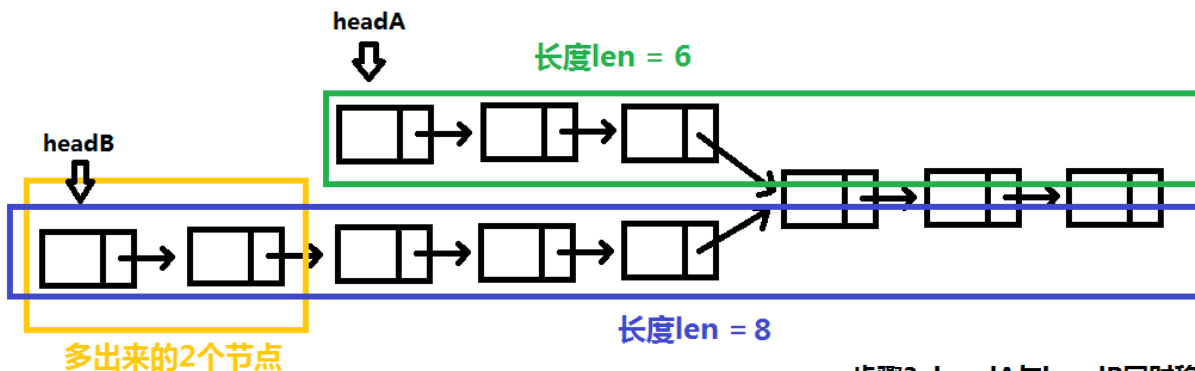
**3分钟**时间填写代码， **有问题随时提出！**

# 例2:方法1实现

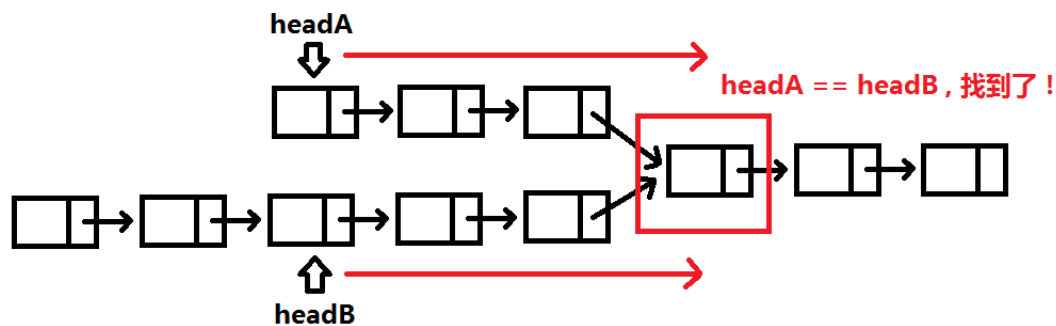
```
class Solution {
public:
    ListNode *getIntersectionNode(ListNode *headA, ListNode *headB) {
        std::set<ListNode*> node_set; //设置查找集合node_set
        while (headA) {
            node_set.insert(headA); //将链表A中的节点插入node_set
            headA = headA->next; //遍历链表A
        }
        while (headB) {
            if (node_set.find(headB) != node_set.end()) {
                return headB; //当在headB中找到第一个出现在node_set中的节点时
            }
            headB = headB->next; //遍历链表B
        }
        return NULL;
    }
};
```

# 例2:思路2, 空间复杂度 $O(1)$

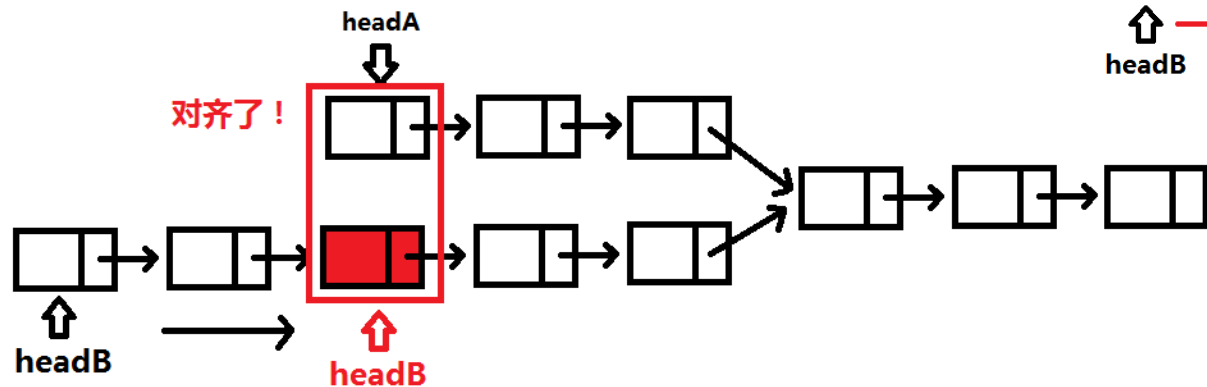
步骤1: 计算headA链表长度、计算headB链表长度, 较长的链表多出的长度



步骤3: headA与headB同时移动, 当两指针指向同一个节点时, 即找到了!



步骤2: 将较长链表的指针移动到和较短链表指针对齐的位置



## 例2:方法2, 课堂练习

```
int get_list_length(ListNode *head) {  
    int len = 0;  
    while(head) { //遍历链表, 计算链表长度  
        1  
        head = head->next;  
    }  
    return len;  
}  
  
ListNode *forward_long_list(int long_len,  
                             int short_len, ListNode *head) {  
    int delta = long_len - short_len;  
    while(head && delta) {  
        head = head->next;  
        2  
    }  
    return head;  
}  
  
class Solution {  
public:  
    ListNode *getIntersectionNode(ListNode *headA, ListNode *headB) {  
        int list_A_len = get_list_length(headA);  
        int list_B_len = get_list_length(headB); //求A、B两个链表长度  
        if (list_A_len > list_B_len) {  
            headA = forward_long_list(list_A_len, list_B_len, headA);  
            //如果链表A长, 移动headA到对应位置  
        }  
        else {  
            headB = forward_long_list(list_B_len, list_A_len, headB);  
        }  
        while(headA && headB) { //如果链表B长, 移动headB到对应位置  
            if ( 3 ) {  
                return headA;  
            }  
            headA = headA->next;  
            headB = headB->next;  
        }  
        return NULL;  
    }  
};
```

3分钟时间填写代码, 有问题  
随时提出!

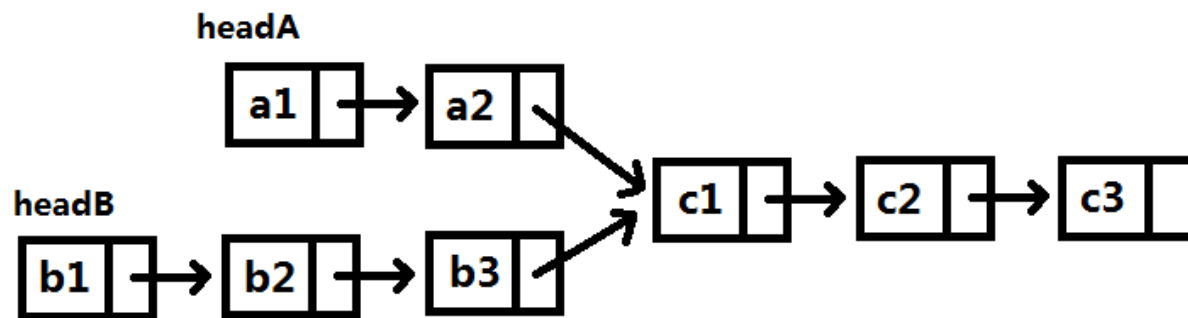


## 例2:方法2, 实现

```
int get_list_length(ListNode *head) {  
    int len = 0;  
    while (head) { //遍历链表, 计算链表长度  
        len++;  
        head = head->next;  
    }  
    return len;  
}  
  
ListNode *forward_long_list(int long_len,  
                             int short_len, ListNode *head) {  
    int delta = long_len - short_len;  
    while (head && delta) {  
        head = head->next; //将指针向前移动至多出  
                           //节点个数后面的位置  
        delta--;  
    }  
    return head;  
}  
  
class Solution {  
public:  
    ListNode *getIntersectionNode(ListNode *headA, ListNode *headB) {  
        int list_A_len = get_list_length(headA);  
        int list_B_len = get_list_length(headB); //求A、B两个链表长度  
        if (list_A_len > list_B_len) {  
            headA = forward_long_list(list_A_len, list_B_len, headA);  
        } //如果链表A长, 移动headA到对应位置  
        else {  
            headB = forward_long_list(list_B_len, list_A_len, headB);  
        } //如果链表B长, 移动headB到对应位置  
        while (headA && headB) {  
            if (headA == headB) {  
                return headA; //当两指针指向了同一个节点时, 说明找到了!  
            }  
            headA = headA->next;  
            headB = headB->next;  
        }  
        return NULL;  
    }  
};
```

# 例2:测试与leetcode提交结果

```
int main() {
    ListNode a1(1); //将节点简单的链接一下，即可进行测试
    ListNode a2(2); //无需构造链表插入、删除等复杂方法
    ListNode b1(3);
    ListNode b2(4);
    ListNode b3(5);
    ListNode c1(6);
    ListNode c2(7);
    ListNode c3(8);
    a1.next = &a2;
    a2.next = &c1;
    c1.next = &c2;
    c2.next = &c3;
    b1.next = &b2;
    b2.next = &b3;
    b3.next = &c1;
    Solution solve;
    ListNode *result = solve.getIntersectionNode(&a1, &b1);
    printf("%d\n", result->val);
    return 0;
}
```



Intersection of Two Linked Lists

Submission Details

42 / 42 test cases passed.

Status: **Accepted**

Runtime: 63 ms

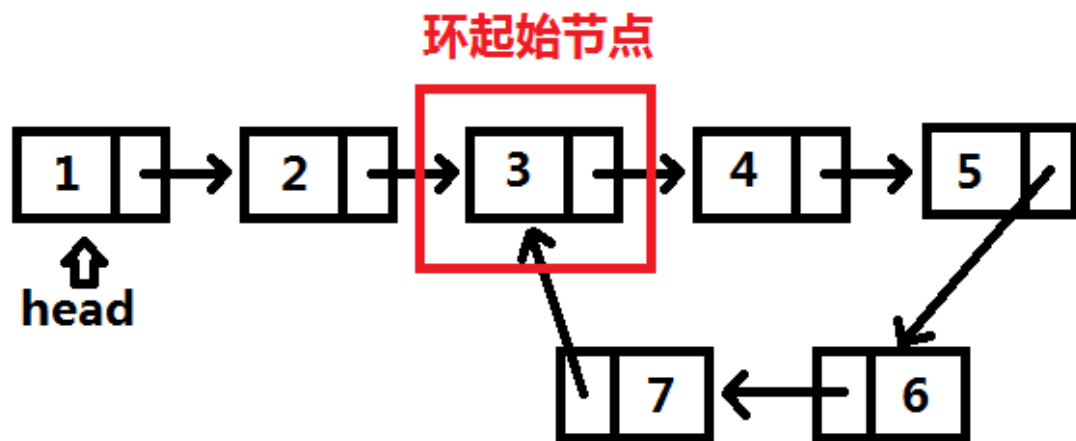
Submitted: 0 minutes ago

6

请按任意键继续 . . .

# 例3:链表求环

已知链表中**可能**存在**环**，若有环返回**环起始**节点，否则返回**NULL**。



```
class Solution {  
public:  
    ListNode *detectCycle(ListNode *head)  
    }  
};
```

选自 **LeetCode 141. Linked List Cycle** **142. Linked List Cycle II**

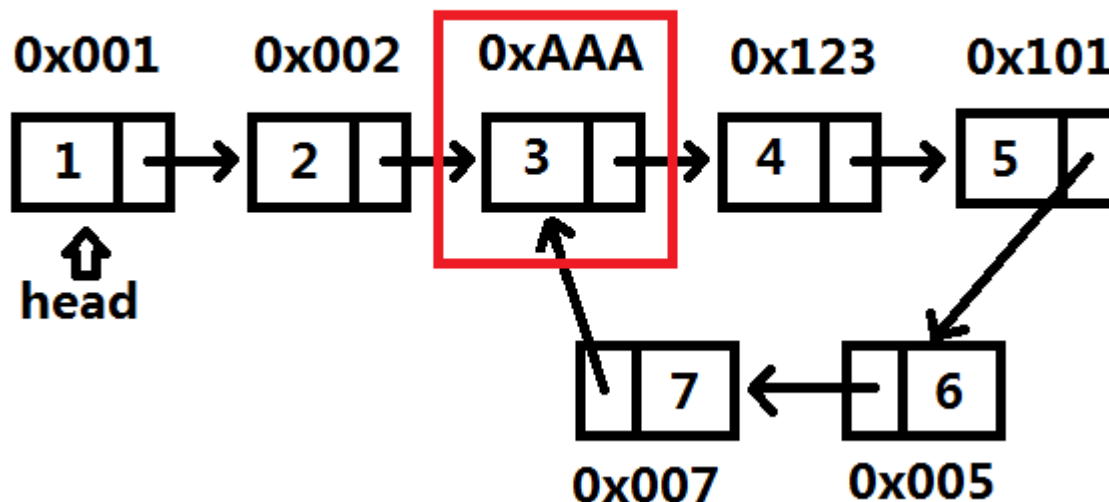
<https://leetcode.com/problems/linked-list-cycle-ii/description/>

难度:**Medium**

# 例3:思路1，使用set求环起始节点

- 1.遍历链表，将**链表中**节点对应的**指针(地址)**，**插入set**
- 2.在遍历时**插入节点前**，需要在set中**查找**，**第一个**在set中发现的节点地址，即是链表环的**起点**。

该节点是遍历时，第一个在set中已出现的节点，即环的开始



# 例3:方法1， 课堂练习

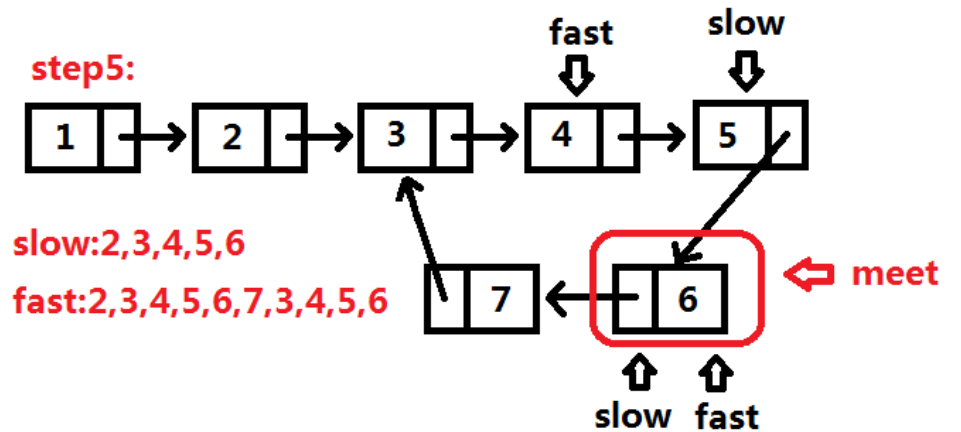
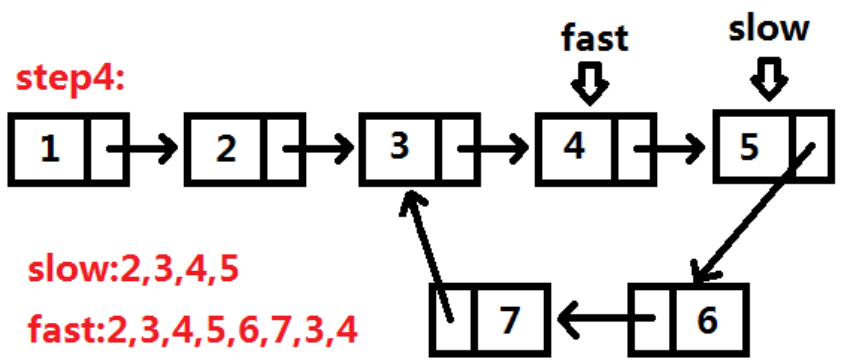
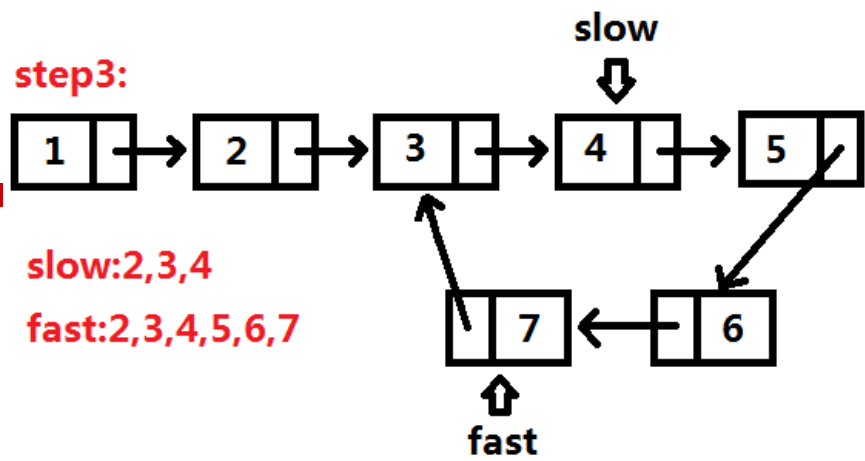
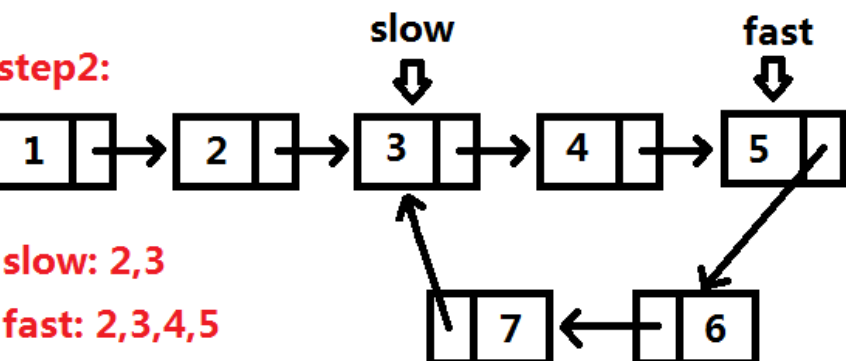
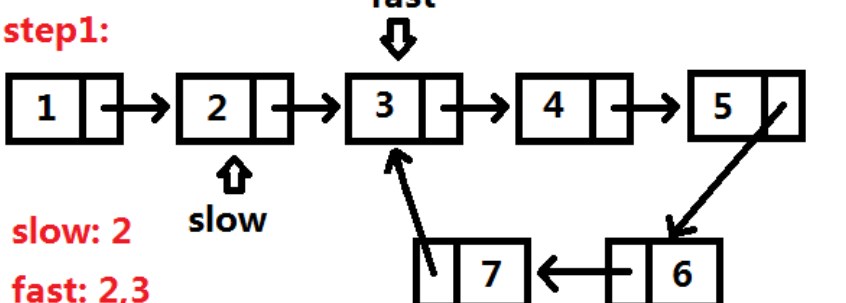
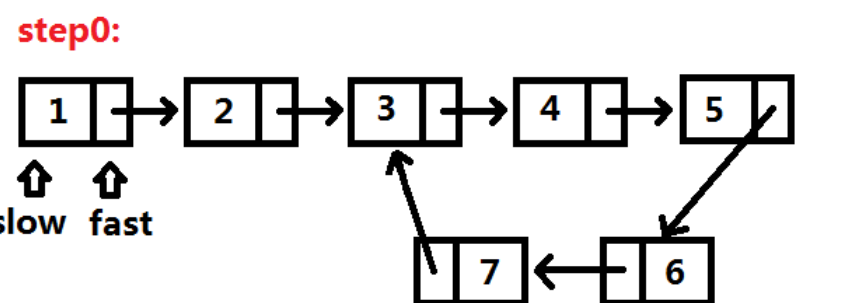
```
class Solution {  
public:  
    ListNode *detectCycle(ListNode *head) {  
        std::set<ListNode *> node_set; //设置node_set  
        while (head) { //遍历链表  
            if ( 1 ) {  
                return head; //返回环的第一个节点  
            }  
            2  
            head = head->next;  
        }  
        3  
    }  
};
```

**3分钟**时间填写代码，**有问题**  
**随时提出！**

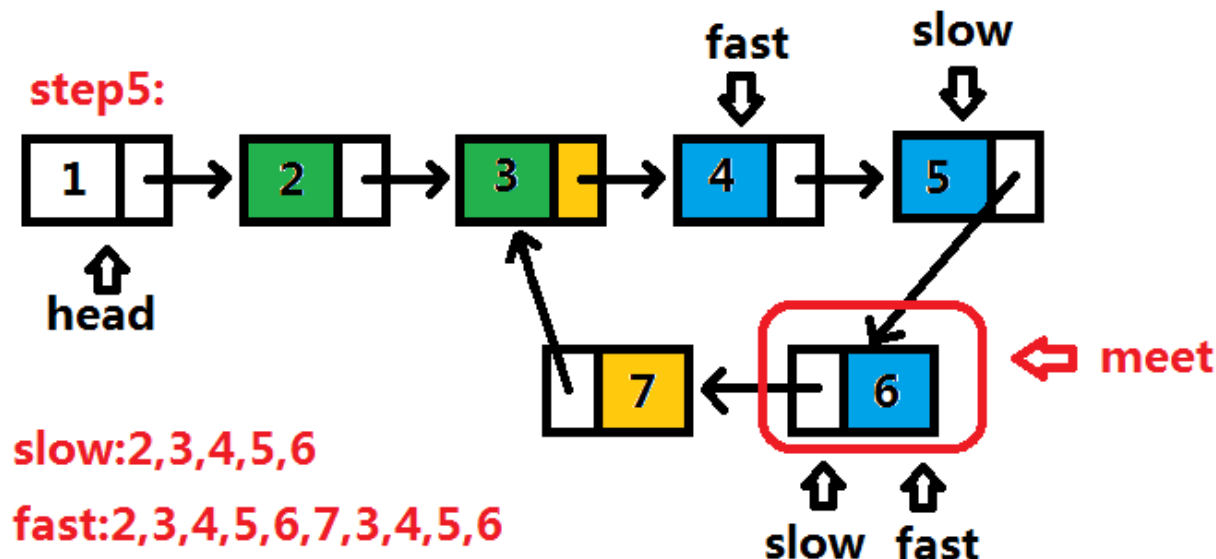
# 例3:方法1实现

```
class Solution {
public:
    ListNode *detectCycle(ListNode *head) {
        std::set<ListNode *> node_set; //设置node_set
        while (head) { //遍历链表 //如果在node_set已经出现了
            if (node_set.find(head) != node_set.end()) {
                return head; //返回环的第一个节点
            }
            node_set.insert(head); //将节点插入node_set
            head = head->next;
        }
        return NULL; //没有遇到环，则返回NULL
    }
};
```

# 例3:思路2， 快慢指针赛跑



# 例3:思路2, 快慢指针



设:

- 1) 绿色 2, 3 段为 a
- 2) 蓝色 4, 5, 6 段为 b
- 3) 橙色 7, 3 段为 c

$$\text{slow} = a + b$$

$$\text{fast} = a + b + c + b$$

由于 fast 走的路程 是slow的两倍  
故:

$$2 * (a + b) = a + b + c + b$$

$$a = c$$

结论: 从head 与 meet 出发, 两指针速度一样, 相遇时即为环的起点



# 例3:方法2, 课堂练习

```
class Solution {
public:
    ListNode *detectCycle(ListNode *head) {
        ListNode *fast = head; //快慢指针
        ListNode *slow = head;
        ListNode *meet = NULL; //相遇的节点
        while(fast) {
            slow = slow->next;
            fast = fast->next; //slow与fast先各走一步
            if (!fast) {
                1
            }
            2
            if (fast == slow) {
                3
                break;
            }
        }
        if (meet == NULL) {
            4
        }
        while(head && meet) {
            if ( 5 ) {
                return head;
            }
            head = head->next; //head与meet每次走1步
            meet = meet->next;
        }
        return NULL;
    }
};
```

5分钟时间填写代码, 有问题  
随时提出!

# 例3:方法2, 实现

```
class Solution {
public:
    ListNode *detectCycle(ListNode *head) {
        ListNode *fast = head; //快慢指针
        ListNode *slow = head;
        ListNode *meet = NULL; //相遇的节点
        while (fast) {
            slow = slow->next; //slow与fast先各走一步
            fast = fast->next;
            if (!fast) {
                return NULL; //如果fast遇到链表尾, 则返回NULL
            }
            fast = fast->next; //fast再走1步
            if (fast == slow) {
                meet = fast; //fast与slow相遇, 记录相遇位置
                break;
            }
        }
        if (meet == NULL) {
            return NULL; //如果没有相遇, 则证明无环
        }
        while (head && meet) {
            if (head == meet) { //当head与meet相遇, 说明遇到环的起始位置
                return head;
            }
            head = head->next; //head与meet每次走1步
            meet = meet->next;
        }
        return NULL;
    }
};
```

# 例3:测试与leetcode提交结果

```
int main() {
    ListNode a(1);
    ListNode b(2);
    ListNode c(3);
    ListNode d(4);
    ListNode e(5);
    ListNode f(6);
    ListNode g(7);
    a.next = &b;
    b.next = &c;
    c.next = &d;
    d.next = &e;
    e.next = &f;
    f.next = &g;
    g.next = &c;
    Solution solve;
    ListNode *node = solve.detectCycle(&a);
    if (node) {
        printf("%d\n", node->val);
    }
    else {
        printf("NULL\n");
    }
    return 0;
}
```

## Linked List Cycle II

### Submission Details

16 / 16 test cases passed.

Status: **Accepted**

Runtime: 9 ms

Submitted: 0 minutes ago

3

请按任意键继续 . . .

# 课间休息10分钟

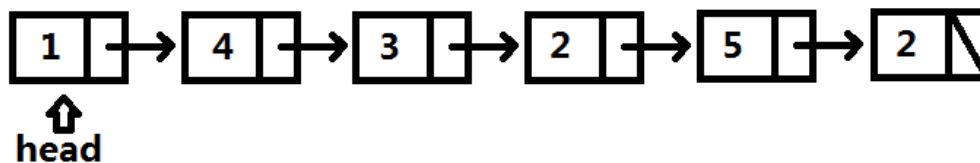
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## 课前小问题解答

# 例4:链表划分

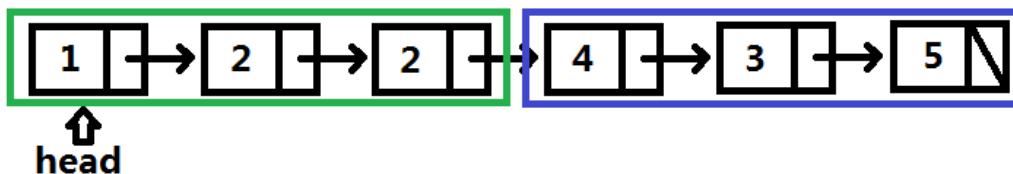
已知链表头指针head与数值x，将所有小于x的节点放在大于或等于x的节点前，且保持这些节点的原来的相对位置。

划分前:  $x=3$



划分后:  $<x(3)$

$\geq x(3)$



```
class Solution {
public:
    ListNode* partition(ListNode* head, int x) {
    }
};
```

选自 **LeetCode 86. Partition List**

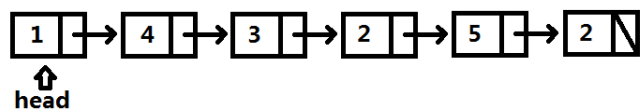
<https://leetcode.com/problems/partition-list/description/>

难度: **Medium**

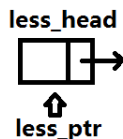
# 例4:思路，巧用临时头节点

划分前:

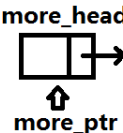
$x=3$



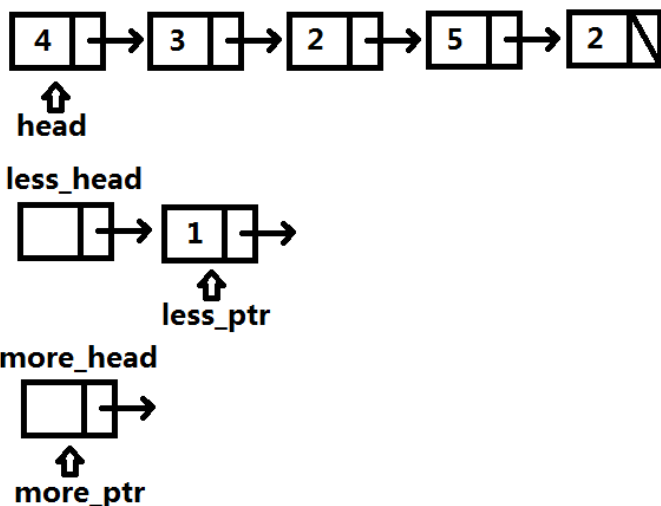
$< x(3)$ 的节点向该节点后插入



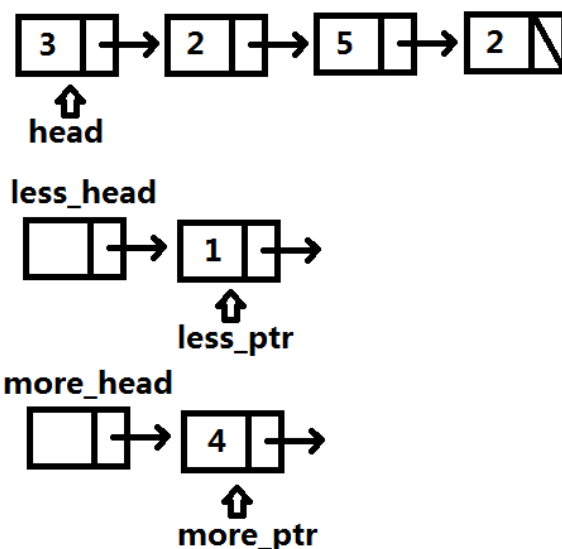
$\geq x(3)$ 的节点向该节点后插入



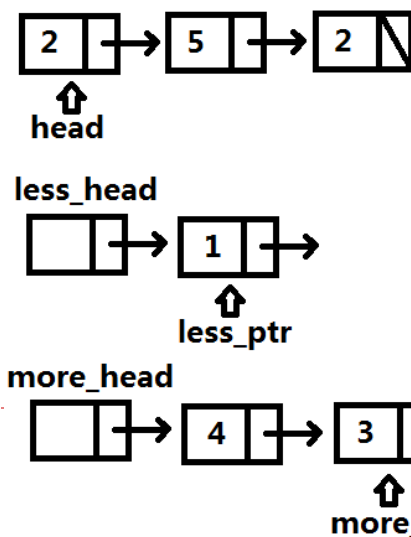
循环1次



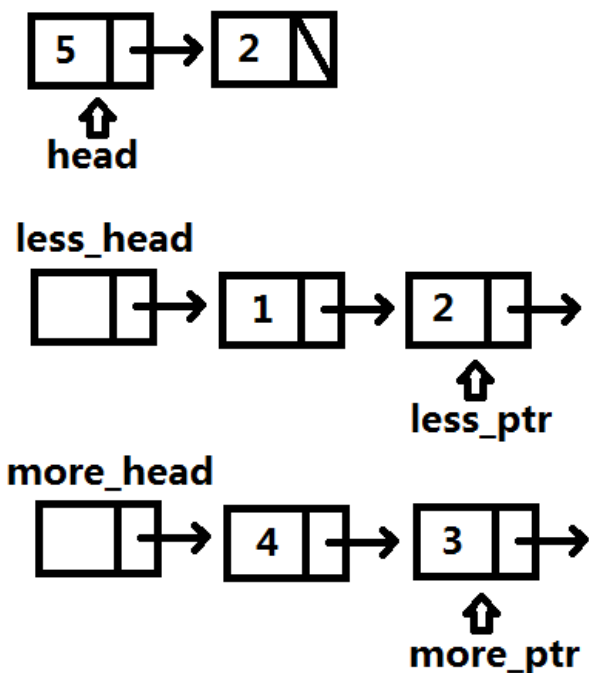
循环2次



循环3次

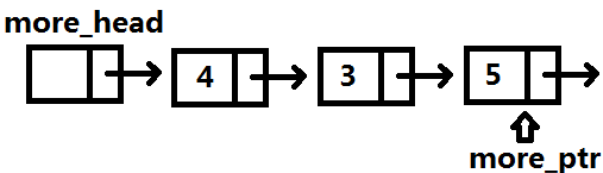
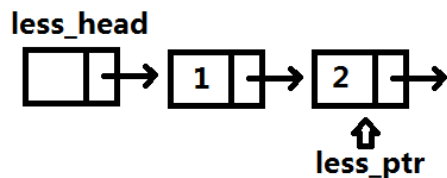
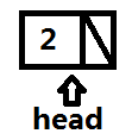


循环4次

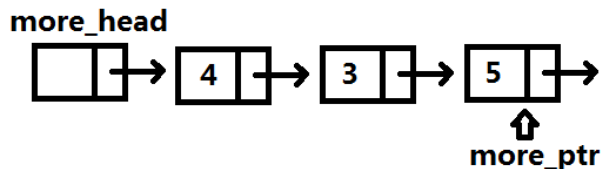
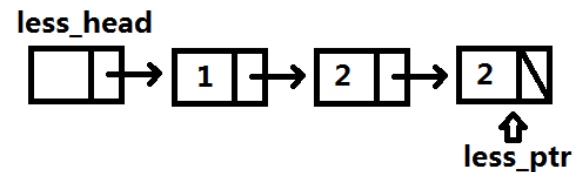
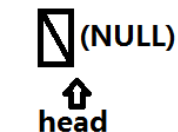


# 例4:思路, 巧用临时头节点

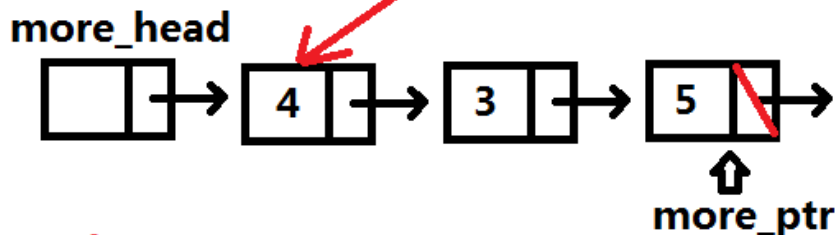
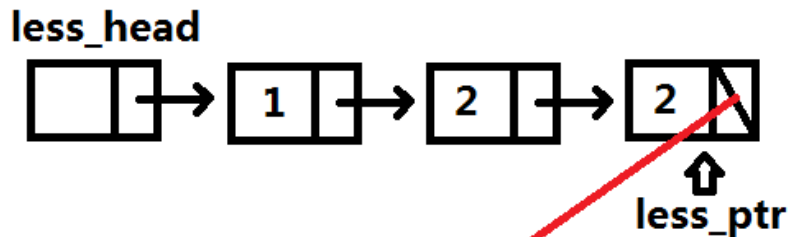
循环5次:



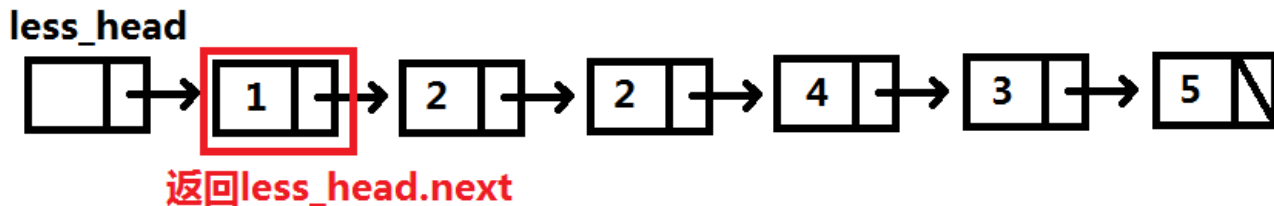
循环6次:



连接less\_ptr->next 与 more\_head.next



置空more\_ptr->next



# 例4:课堂练习

```
class Solution {
public:
    ListNode* partition(ListNode* head, int x) {
        ListNode less_head(0); //设置两个临时的头节点
        ListNode more_head(0); //对应指针指向这两个头节点
        ListNode *less_ptr = &less_head;
        ListNode *more_ptr = &more_head;
        while(head) {
            if (head->val < x) { //如果节点值小于x，则将该节点插入less_ptr后
                less_ptr->next = head;
                1
            }
            else { //否则将该节点插入more_ptr后
                2
                more_ptr = head;
            }
            head = head->next; //遍历链表
        }
        3
        more_ptr->next = NULL; //将more_ptr即链表尾节点next置空
        return less_head.next;
    }
}; //less_head的next节点即为新链表头节点，返回
```

3分钟时间填写代码，有问题随时提出！



# 例4:实现

```
class Solution {
public:
    ListNode* partition(ListNode* head, int x) {
        ListNode less_head(0); //设置两个临时的头节点
        ListNode more_head(0);
        ListNode *less_ptr = &less_head;
        ListNode *more_ptr = &more_head; //对应指针指向这两个头节点
        while(head) {
            if (head->val < x) { //如果节点值小于x，则将该节点插入less_ptr后
                less_ptr->next = head;
                less_ptr = head; //链接完成后，less_ptr向后移动，指向head
            }
            else { //否则将该节点插入more_ptr后
                more_ptr->next = head;
                more_ptr = head;
            }
            head = head->next; //遍历链表
        }
        less_ptr->next = more_head.next; //将less链表尾，与more链表头相连
        more_ptr->next = NULL; //将more_ptr即链表尾节点next置空
        return less_head.next;
    };
    //less_head的next节点即为新链表头节点，返回
};
```

# 例4:测试与leetcode提交结果

```
int main() {
    ListNode a(1);
    ListNode b(4);
    ListNode c(3);
    ListNode d(2);
    ListNode e(5);
    ListNode f(2);
    a.next = &b;
    b.next = &c;
    c.next = &d;
    d.next = &e;
    e.next = &f;
    Solution solve;
    ListNode *head = solve.partition(&a, 3);
    while(head) {
        printf("%d\n", head->val);
        head = head->next;
    }
    return 0;
}
```

Partition List

Submission Details

166 / 166 test cases passed.

Status: **Accepted**

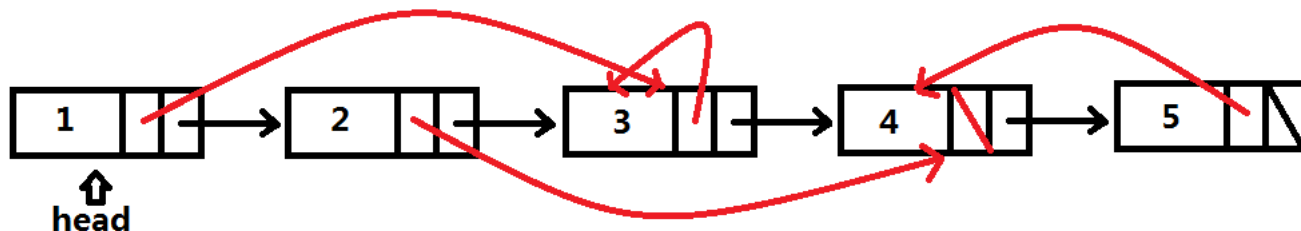
Runtime: 6 ms

Submitted: 1 hour, 9 minutes ago

```
1
2
2
4
3
5
请按任意键继续. . .
```

# 例5:复杂的链表的深度拷贝

已知一个**复杂**的链表，节点中有一个指向本链表**任意某个**节点的**随机**指针(也可以为空)，求这个链表的**深度拷贝**。



```
struct RandomListNode {
    int label;           //带有随机指针的链表节点
    RandomListNode *next, *random;
    RandomListNode(int x) : label(x), next(NULL), random(NULL) {}
};

class Solution {
public:
    RandomListNode *copyRandomList(RandomListNode *head) {
        //返回是深度拷贝后的链表
        //深度拷贝:构造生成一个完全新的链表,即使将原链表毁坏,新链表可独立使用
    }
};
```

**1分钟**理解  
题目，**有问  
题随时提  
出！**

选自 **LeetCode 138. Copy List with Random Pointer**

<https://leetcode.com/problems/copy-list-with-random-pointer/description/>

难度:**Hard**

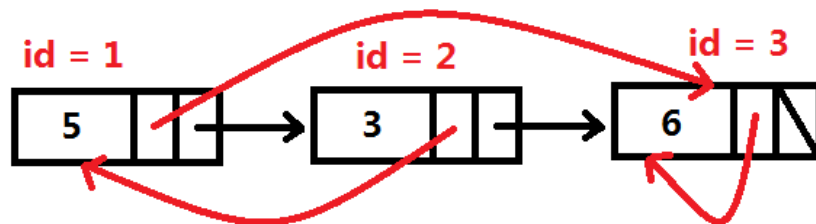
# 例5:必备知识(STL Map的使用)

```
#include <stdio.h>
#include <map> //STL map头文件
```

```
struct RandomListNode {
    int label;
    RandomListNode *next, *random;
    RandomListNode(int x) : label(x), next(NULL), random(NULL) {}
};
```

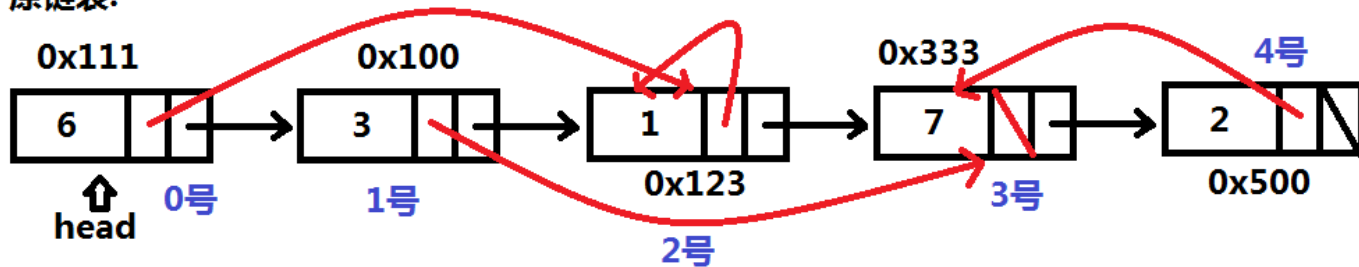
```
int main() {
    std::map<RandomListNode *, int> node_map;
    RandomListNode a(5);
    RandomListNode b(3); //设置一个节点map, key为节点地址, value为整型
    RandomListNode c(6);
    a.next = &b;
    b.next = &c;
    a.random = &c;
    b.random = &a;
    c.random = &c;
    node_map[&a] = 1;
    node_map[&b] = 2;
    node_map[&c] = 3;
    printf("a.random id = %d\n", node_map[a.random]);
    printf("b.random id = %d\n", node_map[b.random]);
    printf("c.random id = %d\n", node_map[c.random]);
    return 0;
}
```

```
a.random id = 3
b.random id = 1
c.random id = 3
请按任意键继续. . .
```

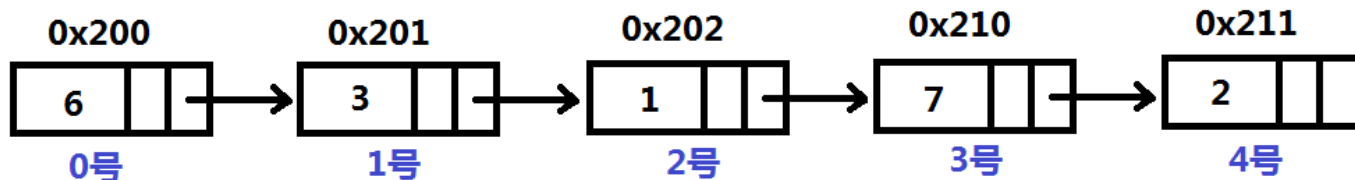


# 例5:思路:节点地址与节点序号对应

原链表:



新链表:



Map1 :

原链表节点地址 -> 节点位置(第几个节点)

0x111 -> 0 random 0x123指向 2号节点  
0x100 -> 1 random 0x333指向 3号节点  
0x123 -> 2 random 0x123指向 2号节点  
0x333 -> 3 random NULL 指向 NULL  
0x500 -> 4 random 0x333指向 3号节点

Map2 :

节点位置(第几个节点) -> 新链表节点地址

0 -> 0x200 random = 2号节点地址(0x202)  
1 -> 0x201 random = 3号节点地址(0x210)  
2 -> 0x202 random = 2号节点地址(0x202)  
3 -> 0x210 random = NULL  
4 -> 0x211 random = 3号节点地址(0x210)

# 例5:课堂练习

```
class Solution {
public:
    RandomListNode *copyRandomList(RandomListNode *head) {
        std::map<RandomListNode *, int> node_map; //地址到节点位置的map
        std::vector<RandomListNode *> node_vec;
        RandomListNode *ptr = head; //使用vector根据存储节点位置访问地址
        int i = 0;
        while (ptr) { //将新链表节点push入node_vec,生成了新链表节点位置到地址的map
            node_vec.push_back(new RandomListNode(ptr->label));
            1
            ptr = ptr->next; //遍历原始列表
            i++; //i记录节点位置
        }
        node_vec.push_back(0);
        ptr = head;
        i = 0; //再次遍历原始列表 连接新链表的next指针、random指针
        while (ptr) {
            2
            if (ptr->random) { //当random指针不空时
                int id = node_map[ptr->random]; //根据node_map确认
                3
            }
            ptr = ptr->next;
            i++;
        }
        return node_vec[0];
    }
};
```

3分钟时间填写代码，有问题随时提出！

原链表random指针指向的位置即id

# 例5:实现

```
class Solution {
public:
    RandomListNode *copyRandomList(RandomListNode *head) {
        std::map<RandomListNode *, int> node_map; //地址到节点位置的map
        std::vector<RandomListNode *> node_vec;
        RandomListNode *ptr = head; //使用vector根据存储节点位置访问地址
        int i = 0;
        while (ptr) { //将新链表节点push入node_vec,生成了新链表节点位置到地址的map
            node_vec.push_back(new RandomListNode(ptr->label));
            node_map[ptr] = i; //记录原始链表地址至节点位置的node_map
            ptr = ptr->next; //遍历原始列表
            i++; //i记录节点位置
        }
        node_vec.push_back(0);
        ptr = head;
        i = 0; //再次遍历原始列表 连接新链表的next指针、random指针
        while (ptr) {
            node_vec[i]->next = node_vec[i+1]; //连接新链表next指针
            if (ptr->random) { //当random指针不空时
                int id = node_map[ptr->random]; //根据node_map确认
                node_vec[i]->random = node_vec[id]; //原链表random指针指向的位置即id
            }
            ptr = ptr->next; //连接新链表random指针
            i++;
        }
        return node_vec[0];
    }
};
```

# 例5:测试与leetcode提交结果

```
int main() {
    RandomListNode a(1);
    RandomListNode b(2);
    RandomListNode c(3);
    RandomListNode d(4);
    RandomListNode e(5);
    a.next = &b;
    b.next = &c;
    c.next = &d;
    d.next = &e;
    a.random = &c;
    b.random = &d;
    c.random = &c;
    e.random = &d;
    Solution solve;
    RandomListNode *head = solve.copyRandomList(&a);
    while(head) {
        printf("label = %d ", head->label);
        if (head->random) {
            printf("rand = %d\n", head->random->label);
        }
        else{
            printf("rand = NULL\n");
        }
        head = head->next;
    }
    return 0;
}
```

Copy List with Random Pointer

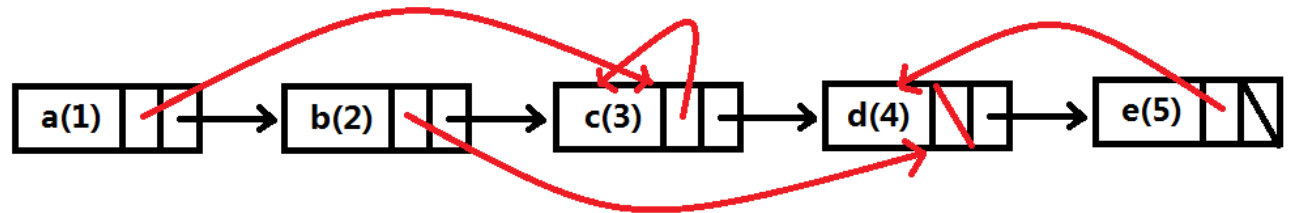
Submission Details

12 / 12 test cases passed.

Status: **Accepted**

Runtime: 66 ms

Submitted: 0 minutes ago

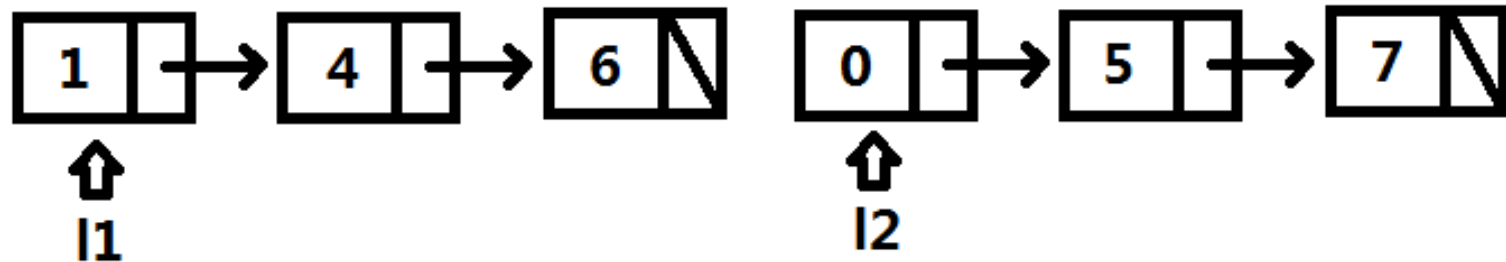


```
label = 1 rand = 3
label = 2 rand = 4
label = 3 rand = 3
label = 4 rand = NULL
label = 5 rand = 4
请按任意键继续. . .
```

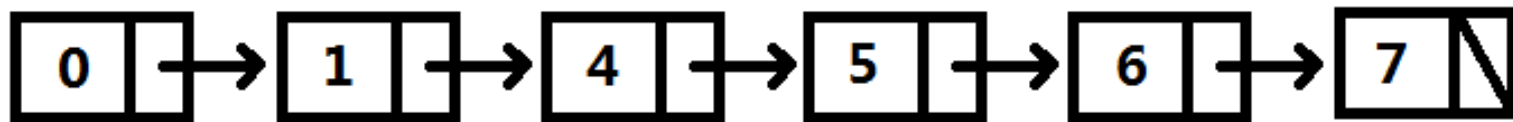


# 例6-a:排序链表的合并(2个)

已知两个**已排序**链表头节点指针l1与l2，将这两个链表**合并**，合并后仍为**有序**的，返回合并后的**头节点**。



合并后链表:



选自 **LeetCode 21. Merge Two Sorted Lists**

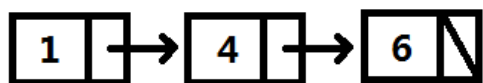
<https://leetcode.com/problems/merge-two-sorted-lists/description/>

难度:**Easy**

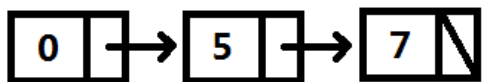
# 例6-a:思路

**比较** l1和l2指向的节点，将**较小的**节点插入到**pre指针**后，并**向前移动**较小节点对应的指针。

初始:



↑  
l1



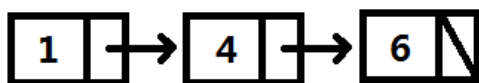
↑  
l2

temp\_head (临时头节点)



↑  
pre

循环1次:

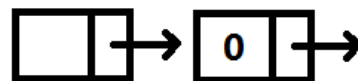


↑  
l1



↑  
l2

temp\_head (临时头节点)

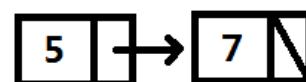


↑  
pre

循环2次:

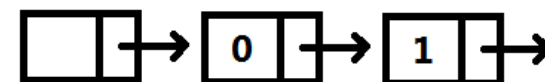


↑  
l1



↑  
l2

temp\_head (临时头节点)

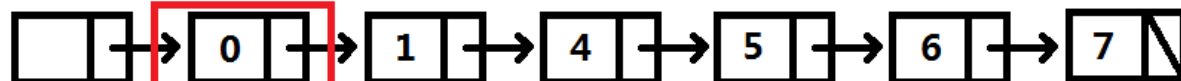


↑  
pre

...

最终结果:

temp\_head (临时头节点)



返回temp\_head.next

↑  
pre

# 例6-a:课堂练习

```
class Solution {
public:
    ListNode* mergeTwoLists(ListNode* l1, ListNode* l2) {
        ListNode temp_head(0); //设置临时头节点temp_head
        ListNode *pre = &temp_head; //使用pre指针指向temp_head
        while (l1 && l2) {
            if (l1->val < l2->val) { //l1与l2同时不空时，对它们进行比较
                1
                l1 = l1->next; //如果l1对应的节点小于l2对应的节点
            }
            else {
                2
                l2 = l2->next;
            }
            3
        }
        if (l1) { //如果l1有剩余
            4
        }
        if (l2) { //如果l2有剩余
            5
        }
        return temp_head.next;
    }
};
```

5分钟时间填写代码，有问题随时提出！

# 例6-a:实现

```
class Solution {
public:
    ListNode* mergeTwoLists(ListNode* l1, ListNode* l2) {
        ListNode temp_head(0); //设置临时头节点temp_head
        ListNode *pre = &temp_head; //使用pre指针指向temp_head
        while (l1 && l2) {
            if (l1->val < l2->val) { //l1与l2同时不空时，对它们进行比较
                pre->next = l1; //如果l1对应的节点小于l2对应的节点
                l1 = l1->next;
            } //将pre与较小的节点进行连接
            else {
                pre->next = l2;
                l2 = l2->next;
            }
            pre = pre->next; //pre指向新连接的节点
        }
        if (l1) { //如果l1有剩余
            pre->next = l1; //将l1接到pre后
        }
        if (l2) { //如果l2有剩余
            pre->next = l2; //将l2接到pre后
        }
        return temp_head.next;
    }
};
```

# 例6-a:测试与leetcode提交结果

```
int main() {
    ListNode a(1);
    ListNode b(4);
    ListNode c(6);
    ListNode d(0);
    ListNode e(5);
    ListNode f(7);
    a.next = &b;
    b.next = &c;
    d.next = &e;
    e.next = &f;
    Solution solve;
    ListNode *head = solve.mergeTwoLists(&a, &d);
    while(head) {
        printf("%d\n", head->val);
        head = head->next;
    }
    return 0;
}
```

Merge Two Sorted Lists

## Submission Details

208 / 208 test cases passed.

Status: **Accepted**

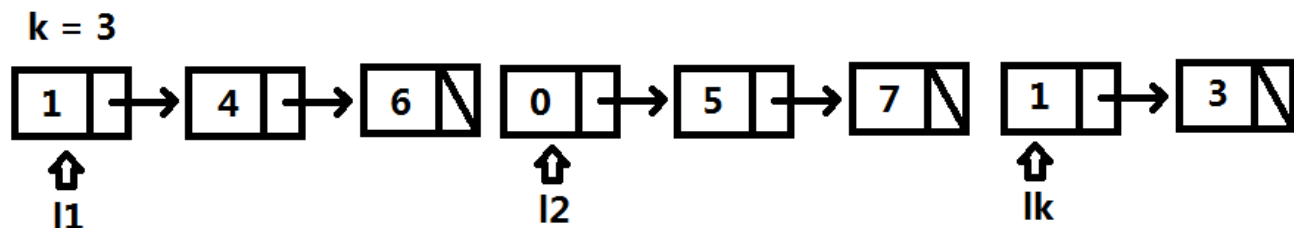
Runtime: 9 ms

Submitted: 0 minutes ago

```
0
1
4
5
6
7
请按任意键继续. . .
```

# 例6-b:排序链表的合并(多个)

已知k个**已排序**链表头节点指针，将这k个链表**合并**，合并后仍为**有序**的，返回合并后的**头节点**。



合并后链表:



```
class Solution {  
    public:                                //链表头节点使用vector  
        ListNode* mergeKLists(std::vector<ListNode*>& lists) {  
        }                                  //最终返回merge后的有序的链表头  
};
```

选自 **LeetCode 23. Merge k Sorted Lists**

<https://leetcode.com/problems/merge-k-sorted-lists/description/>

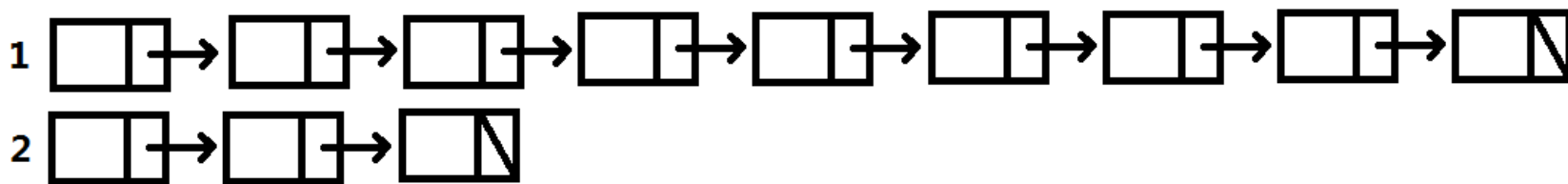
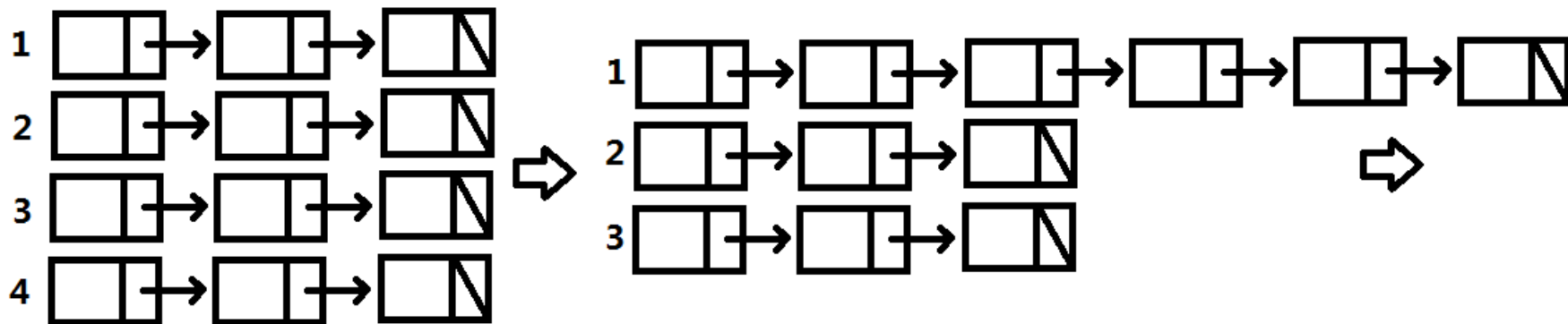
难度:**Hard**

# 例6-b:方法1思考，暴力合并

**方案1**:最**普通**的方法，k个链表**按顺序合并**k-1次。

设有**k个链表**，平均每个链表有**n个节点**，时间复杂度:

$$(n+n)+(2n+n)+((k-1)n+n) = (1+2+\dots+k-1)n + (k-1)n = (1+2+\dots+k)n - n = (k^2+k-1)/2 * n = O(k^2 * n)$$



● ● ●

$$(3+3) + (6+3) + (9+3) = 27 \text{ 次比较}$$

# 例6-b:方法2思考，排序后相连

**方案2:**将 $k*n$ 个节点放到vector中，再将vector**排序**，再将节点**顺序相连**。

设有 **$k$ 个链表**，平均每个链表有 **$n$ 个节点**，时间复杂度:

$kN*\log kN + kN = O(kN*\log kN)$  (比如 $k=100, n = 10000$ )  $\log kN = 20, k = 100$

```
#include <vector>
#include <algorithm> //STL 排序算法 std::sort
bool cmp(const ListNode *a, const ListNode *b) {
    return a->val < b->val;
}
//比较函数，对节点进行从小到大的排序
int main() {
    ListNode a(3);
    ListNode b(2);
    ListNode c(5);
    ListNode d(0);
    std::vector<ListNode *> node_vec;
    node_vec.push_back(&a);
    node_vec.push_back(&b);
    node_vec.push_back(&c);
    node_vec.push_back(&d); //调用排序函数
    std::sort(node_vec.begin(), node_vec.end(), cmp);
    for (int i = 0; i < node_vec.size(); i++) {
        printf("%d\n", node_vec[i]->val);
    }
    return 0;
}
```

```
0
2
3
5
请按任意键继续. . .
```



# 例6-b:方法3思考，分制后相连

**方案3:**对k个链表进行**分制**，**两两进行合并**。

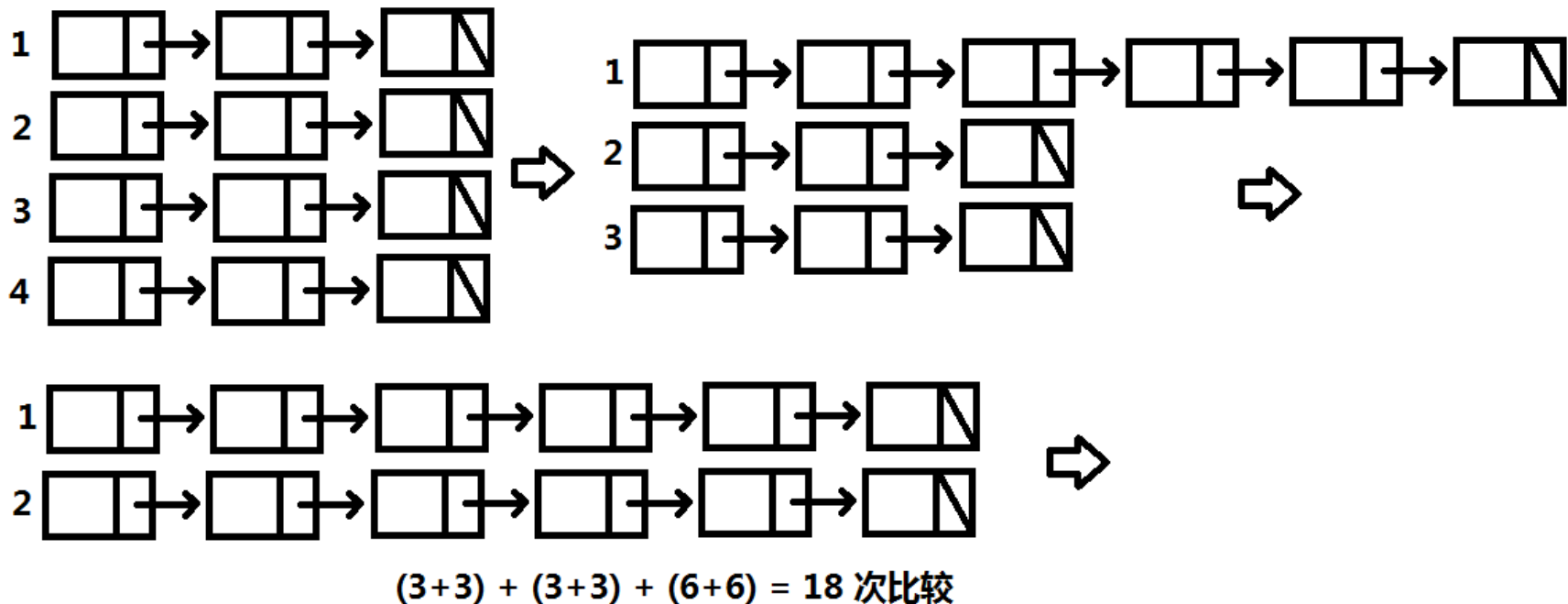
设有**k个链表**，平均每个链表有**n个节点**，时间复杂度：

**第1轮**，进行k/2次，每次处理2n个数字；**第2轮**，进行k/4次，每次处理4n个数字； ...；

**最后一次**，进行k/(2<sup>logk</sup>)次，每次处理2<sup>logk</sup>\*N个值。

$$2N * k/2 + 4N * k/4 + 8N * k/8 + \dots + 2^{\log k} * N * k/(2^{\log k})$$

$$= Nk + Nk + \dots + Nk = O(kN \log k)$$



# 例6-b:课堂练习(排序)

```
#include <vector>
#include <algorithm>
```

```
bool cmp(const ListNode *a, const ListNode *b) {
    return a->val < b->val;
}
```

```
class Solution {
public:
```

```
    ListNode* mergeKLists(std::vector<ListNode*>& lists) {
```

```
        std::vector<ListNode *> node_vec;
```

```
        for (int i = 0; i < lists.size(); i++) {
```

1

//遍历k个链表，将节点全部添加至

```
        while(head) {
```

node\_vec

2

```
            head = head->next;
```

```
        }
```

```
    }
```

```
    if (node_vec.size() == 0) {
```

```
        return NULL;
```

//根据节点数值进行排序

```
    }
```

```
    std::sort(node_vec.begin(), node_vec.end(), cmp);
```

```
    for (int i = 1; i < node_vec.size(); i++) {
```

3

```
    }
```

```
    node_vec[node_vec.size()-1]->next = NULL;
```

```
    return node_vec[0];
```

```
}
```

```
};
```

3分钟时间填写代码，有问题随时提出！

# 例6-b:实现(排序)

```
#include <vector>
#include <algorithm>

bool cmp(const ListNode *a, const ListNode *b) {
    return a->val < b->val;
}

class Solution {
public:
    ListNode* mergeKLists(std::vector<ListNode*> & lists) {
        std::vector<ListNode*> node_vec;
        for (int i = 0; i < lists.size(); i++) {
            ListNode *head = lists[i]; //遍历k个链表，将节点全部添加至
            while (head) { //node_vec
                node_vec.push_back(head);
                head = head->next;
            }
        }
        if (node_vec.size() == 0) {
            return NULL;
        }
        //根据节点数值进行排序
        std::sort(node_vec.begin(), node_vec.end(), cmp);
        for (int i = 1; i < node_vec.size(); i++) {
            //连接新的链表
            node_vec[i-1]->next = node_vec[i];
        }
        node_vec[node_vec.size()-1]->next = NULL;
        return node_vec[0];
    }
};
```

# 例6-b:课堂练习(分制)

```
ListNode* mergeKLists(std::vector<ListNode*>& lists) {  
    if (lists.size() == 0) { //如果lists为空, 返回NULL  
        return NULL;  
    }  
    if (lists.size() == 1) {  
        1  
    }  
    if (lists.size() == 2) { //如果只有两个list, 调用两个list merge函数  
        return mergeTwoLists(lists[0], lists[1]);  
    }  
    int mid = 2  
    std::vector<ListNode*> sub1_lists;  
    std::vector<ListNode*> sub2_lists; //拆分lists为两个子lists  
    for (int i = 0; i < mid; i++) {  
        sub1_lists.push_back(lists[i]);  
    }  
    for (int i = mid; i < lists.size(); i++) {  
        sub2_lists.push_back(lists[i]);  
    }  
    ListNode *l1 = 3  
    ListNode *l2 = 4  
    5  
}
```

3分钟时间填写代码, 有问题随时提出!

# 例6-b:实现(分制)

```
ListNode* mergeKLists(std::vector<ListNode*>& lists) {  
    if (lists.size() == 0) { //如果lists为空, 返回NULL  
        return NULL;  
    }  
    if (lists.size() == 1) {  
        return lists[0]; //如果只有一个lists, 直接返回头指针  
    }  
    if (lists.size() == 2) { //如果只有两个list, 调用两个list merge函数  
        return mergeTwoLists(lists[0], lists[1]);  
    }  
    int mid = lists.size() / 2;  
    std::vector<ListNode*> sub1_lists;  
    std::vector<ListNode*> sub2_lists; //拆分lists为两个子lists  
    for (int i = 0; i < mid; i++) {  
        sub1_lists.push_back(lists[i]);  
    }  
    for (int i = mid; i < lists.size(); i++) {  
        sub2_lists.push_back(lists[i]);  
    }  
    ListNode *l1 = mergeKLists(sub1_lists);  
    ListNode *l2 = mergeKLists(sub2_lists);  
    return mergeTwoLists(l1, l2); //分制处理  
}
```



# 例6-b:测试与leetcode提交结果

```
int main() {
    ListNode a(1);
    ListNode b(4);
    ListNode c(6);
    ListNode d(0);
    ListNode e(5);
    ListNode f(7);
    ListNode g(2);
    ListNode h(3);
    a.next = &b;
    b.next = &c;
    d.next = &e;
    e.next = &f;
    g.next = &h;
    Solution solve;
    std::vector<ListNode *> lists;
    lists.push_back(&a);
    lists.push_back(&d);
    lists.push_back(&g);
    ListNode *head = solve.mergeKLists(lists);
    while(head) {
        printf("%d\n", head->val);
        head = head->next;
    }
    return 0;
}
```

Merge k Sorted Lists

排序算法时间

Submission Details

130 / 130 test cases passed.

Status: Accepted

Runtime: 42 ms

Submitted: 0 minutes ago

Merge k Sorted Lists

分制算法时间

Submission Details

130 / 130 test cases passed.

Status: Accepted

Runtime: 32 ms

Submitted: 0 minutes ago

```
0
1
2
3
4
5
6
7
请按任意键继续. . .
```

# 一些建议:关于课程复习与面试准备

---

1. 在不看回放与复习的前提下, **重新编写**这8道题目进行提交测试。
2. 尽量多的**通过**这些题目。
3. 再看一轮回放, **再编写**一遍题目并提交通过。
4. 纸上写代码, **反复练习**。
5. 将leetcode其他链表相关题目**完成**。

## 一些建议:关于学习，如何成为一名优秀的研发工程师

---

1. 掌握一门**编译语言**
2. 掌握**算法与数据结构**
3. 掌握一门**脚本语言**
4. 掌握**开发环境**
5. 丰富其他**前沿知识**



# 一些建议:关于面试

---

1. 听清并**搞懂**问题

2. **冷静思考**

3. 努力解决，**不**轻易**放弃**

4. 自信并**谦虚**

# 一些建议:关于实习

---

1. 实习是拿到BAT offer的捷径
2. 实习的岗位有许多:RD、QA、FE、OP、PM等
3. 尽量在一个实习岗位坚持半年
4. 实习还有不菲的薪水喔~
5. 关于学校课堂与上课, 自己把握

# 结束

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非常感谢大家！

林沐