1. **What is the difference between a hard link and a symbolic link? Give an advantage of each one.**
   Hard link: 以相同的i-node指向相同的檔案，但只能用在同一個磁區，不能連結目錄，刪掉了其中一個，另一個仍然會可以讀取。
   Symbolic link: 以絕對路徑或相對路徑指向原始的檔案(類似windows里的捷徑)，可以簡化路徑。’

2. **A disk has 4000 cylinders, each with 8 tracks of 512 blocks. A seek takes 1 msec per cylinder moved. If no attempt is made to put the blocks of a file close to each other, two blocks that are logically consecutive will require an average seek, which takes 5 msec. If , however, the operating system makes an attempt to cluster related blocks, the mean interblock distance can be reduced to 2 cylinders and the seek time reduced to 100 micro sec. How long does it take to read a 100 block file in both cases, if the rotational latency is 10 msec and the transfer time is 20 microsec per block?**
   5 + (10+0.02) = 15.02msec
   15.02*100 = 1.502 sec
   0.1*2 + (1-+0.02) = 10.22msec
   10.22*100=1.022 sec

3. Consider the following page reference string:

1,2,3,4,2,1,5,6,2,1,2,3,7,6,3,2,1,2,3,6

How many page faults would occur for the following replacement algorithms, assuming one, two, three, four, five, six, or seven frames? Remember all frames are initially empty, so your first unique pages will all cost one fault each.

(a) LRU replacement:

One frames:

Frame 1	1	2	3	4	2	1	5	6	2	1	2	3	7	6	3	2	1	2	3	6
Page fault	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O

Page fault : 20

Two frames:

Frame 1	1	1	3	3	2	2	5	5	2	2	2	2	7	7	3	3	1	1	3	3
Frame 2		2	2	4	4	1	1	6	6	1	1	3	3	6	6	2	2	2	2	6
Page fault	O	O	O	O	O	O	O	O	O	O	X	O	O	O	O	O	O	X	O	O

Page fault : 18

Three frames:

Frame 1	1	1	1	4	4	4	5	5	5	1	1	1	7	7	7	2	2	2	2	2
Frame 2		2	2	2	2	2	2	6	6	6	6	3	3	3	3	3	3	3	3	3
Frame 3			3	3	3	1	1	1	2	2	2	2	2	6	6	6	1	1	1	6
Page fault	O	O	O	O	X	O	O	O	O	O	X	O	O	O	X	O	O	X	X	O

Page fault : 15

Four frames:

Frame 1	1	1	1	1	1	1	1	1	1	1	1	1	1	6	6	6	6	6	6	6
Frame 2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Frame 3			3	3	3	3	5	5	5	5	5	3	3	3	3	3	3	3	3	3
Frame 4				4	4	4	4	6	6	6	6	6	7	7	7	7	1	1	1	1
Page fault	O	O	O	O	X	X	O	O	X	X	X	O	O	O	X	X	O	X	X	X

Page fault : 10

Five frames:

Frame 1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Frame 2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Frame 3			3	3	3	3	3	6	6	6	6	6	6	6	6	6	6	6	6	6
Frame 4				4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3
Frame 5							5	5	5	5	5	5	7	7	7	7	7	7	7	7
Page fault	O	O	O	O	X	X	O	O	X	X	X	O	O	X	X	X	X	X	X	X

Page fault : 8

Six frames:

Frame 1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Frame 2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Frame 3			3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Frame 4				4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Frame 5							5	5	5	5	5	5	7	7	7	7	7	7	7	7
Frame 6								6	6	6	6	6	6	6	6	6	6	6	6	6
Page fault	O	O	O	O	X	X	O	O	X	X	X	X	O	X	X	X	X	X	X	X

Page fault : 7

Seven frames:

Frame 1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Frame 2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Frame 3			3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Frame 4				4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Frame 5							5	5	5	5	5	5	5	5	5	5	5	5	5	5
Frame 6								6	6	6	6	6	6	6	6	6	6	6	6	6
Frame 7													7	7	7	7	7	7	7	7
Page fault	O	O	O	O	X	X	O	O	X	X	X	X	O	X	X	X	X	X	X	X

Page fault : 7

(b) Optimal replacement

One frames:

Frame 1	1	2	3	4	2	1	5	6	2	1	2	3	7	6	3	2	1	2	3	6
Page fault	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O

Page fault : 20

Two frames:

Frame 1	1	1	3	4	4	1	5	6	6	1	1	3	3	3	3	3	1	1	1	6
Frame 2		2	2	2	2	2	2	2	2	2	2	2	7	6	6	2	2	2	3	3
Page fault	O	O	O	O	X	O	O	O	X	O	X	O	O	O	X	O	O	X	O	O

Page fault : 15

Three frames:

Frame 1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3	6
Frame 2		2	2	2	2	2	2	2	2	2	2	2	7	7	7	2	2	2	2	2
Frame 3			3	4	4	4	5	6	6	6	6	6	6	6	6	6	1	1	1	1
Page fault	O	O	O	O	X	X	O	O	X	X	X	O	O	X	X	O	O	X	X	O

Page fault : 11

Four frames:

Frame 1	1	1	1	1	1	1	1	1	1	1	1	1	7	7	7	7	1	1	1	1
Frame 2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Frame 3			3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Frame 4				4	4	4	5	6	6	6	6	6	6	6	6	6	6	6	6	6
Page fault	O	O	O	O	X	X	O	O	X	X	X	X	O	X	X	X	O	X	X	X

Page fault : 8

Five frames:

Frame 1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Frame 2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Frame 3			3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Frame 4				4	4	4	4	6	6	6	6	6	6	6	6	6	6	6	6	6
Frame 5							5	5	5	5	5	5	7	7	7	7	7	7	7	7
Page fault	O	O	O	O	X	X	O	O	X	X	X	X	O	X	X	X	X	X	X	X

Page fault : 7

Six frames:

Frame 1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Frame 2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Frame 3			3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Frame 4				4	4	4	4	4	4	4	4	4	7	7	7	7	7	7	7	7
Frame 5							5	5	5	5	5	5	5	5	5	5	5	5	5	5
Frame 6								6	6	6	6	6	6	6	6	6	6	6	6	6
Page fault	O	O	O	O	X	X	O	O	X	X	X	X	O	X	X	X	X	X	X	X

Page fault : 7

Seven frames:

Frame 1	1	2	3	4	2	1	5	6	2	1	2	3	7	6	3	2	1	2	3	6
Frame 1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Frame 2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Frame 3			3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Frame 4				4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Frame 5							5	5	5	5	5	5	5	5	5	5	5	5	5	5
Frame 6								6	6	6	6	6	6	6	6	6	6	6	6	6
Frame 7													7	7	7	7	7	7	7	7
Page fault	O	O	O	O	X	X	O	O	X	X	X	X	O	X	X	X	X	X	X	X

Page fault : 7

4. Consider a file currently consisting of 100 blocks. Assume that the file control block and the index block, in the case of indexed allocation is already in memory. Calculate how many disk I/O operators are required for contiguous, linked, and indexed allocation strategies, if, for one block, the following conditions hold. In the contiguous allocation case, assume that there is no room to grow in the beginning, but there is room to grow in the end. Assume that the block information to be added is stored in memory.

(a) The block is added in the beginning.

Contiguous: 100+100+1= 201

Linked: 1

Indexed: 1

(b) The block is added in the middle.

Contiguous : 50+50+1= 101

Linked : 50+1+1= 52

Indexed: 1

(c) The block is added in the end.

Contiguous : 1

Linked : 2+2= 3

Indexed: 1

(d) The block is removed from the beginning.

Contiguous : 99+99 = 198

Linked : 1

Indexed: 0

(e) The block is removed from the middle.

Contiguous : 49+49= 98

Linked : 50+1+1= 52

Indexed: 0

5. A certain computer provides its users with a virtual-memory space of 2^32 bytes, The computer has 2^18 bytes of physical memory, The virtual memory is implemented by paging, and the page size is 4096 bytes. A user process generates the virtual address 0x11123456. Explain how the system establishes the corresponding physical location. Distinguish between software and hardware operations.

0001 0001 0001 0010 0011 0100 0101 0110

Page size : 2^12 , table size 2^32/2^12=2^20

So 12bit (0100 0101 0110) will be page displacement

the remaining 20 bits 0001 0001 0001 0010 0011 are used as the displacement in the page table. The offset bits are then concatenated to the resulting physical page number (from the page table),to form the final address.