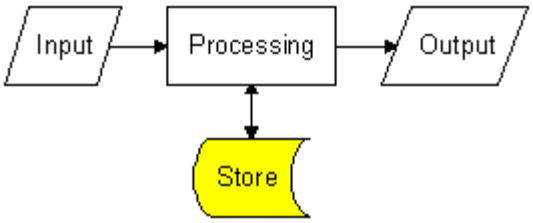
SECTION 3: STORAGE DEVICES AND MEDIA

STORAGE : Introduction

All information systems need to store data. This may be done temporarily whilst inputs are processed to produce outputs or for much longer periods of time.



For example :

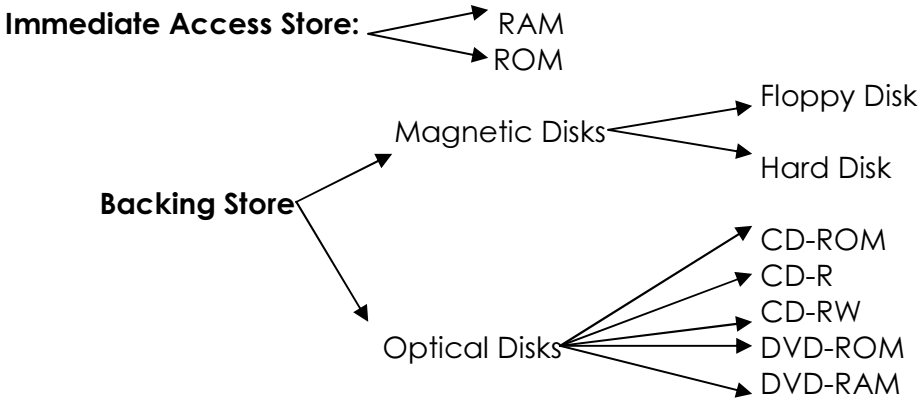
- A school uses a database package to keep a record of the achievements of its students. These records are kept for the seven year period that each student attends the school.
- A student is using a graphics package to draw a logo on the screen. The graphics package must store the colour of each pixel in the logo so that it can be printed.

A computerised information system must be able to store both programs (e.g. a word processing package) and data (e.g. a word processed letter).
A storage device stores programs and data either temporarily or permanently. All information systems contain two different types of storage :

→ Immediate Access Store (IAS) Immediate access store holds programs and data that the user is currently working with.
→ Backing Store Backing store keeps data and programs when the computer is turned off.

Immediate access store is also known as main store or primary store. Backing store is also known as secondary store.

The capacity (amount of data) that a storage device can hold varies significantly between different devices. Units such as bytes, kilobytes and megabytes are used to describe a storage device's capacity. Other factors such as speed of data access, cost and portability will also determine which storage device is the most appropriate one to use for a particular application.



If data needs to be kept whilst a computer is turned off then it must be stored on backing store. Any programs or data that are not currently being used by a computer will be kept on backing store. When programs or data are used they are copied (loaded) into immediate access store for faster access.
Information stored on backing store is placed on a storage medium. The most common media which are used for backing store are : **Magnetic Disks, Magnetic Tapes, Optical Disks** such as CD-ROMs**.**
The data is read from or written to the storage medium by a piece of hardware known as a drive or a **storage device**.

It takes much longer to access data which is on backing store than data which is in immediate access store, typically 100 to 1000 times as long. This is because most backing storage devices operate mechanically. Computers have much more backing store than immediate access store for two reasons :

- IAS **Immediate Access Store** only needs to store programs and data that are currently being used whereas the backing store needs to hold all of the programs and data that can be used on the computer.
- **Backing store** is much cheaper per Mb than IAS.

Programs and data can not be used directly from backing store. They must be copied (loaded) into immediate access store before they can be used. Any data which needs to be kept must be transferred back to the backing store from the immediate access store before the computer is switched off. This is called saving.
Sometimes data is compressed before it is stored. Compressing data reduces the storage space that a file uses without losing any of its contents.

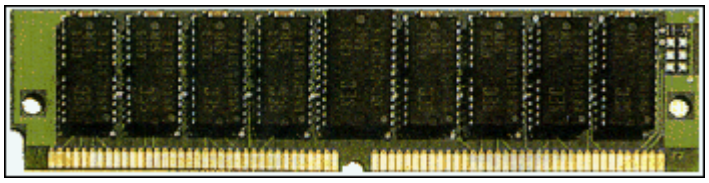
IMMEDIATE ACCESS STORE (**IAS**) OR MAIN INTERNAL MEMORY

Immediate Access Store (IAS) holds programs and data that the user is currently working with. For example :

- A word processed document that is being edited will be loaded into IAS.
- An email program that is currently transmitting a message will be loaded into IAS.

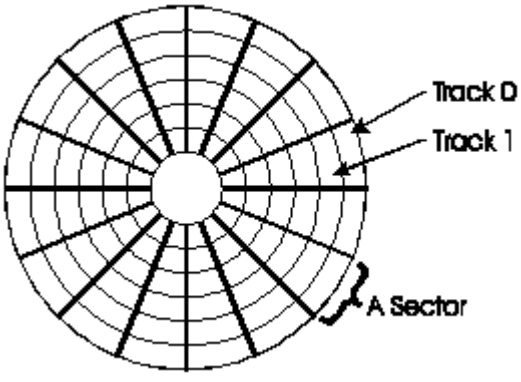
There are two different types of IAS :

- Read Only Memory (ROM) : The contents of ROM is permanent. It can not be altered by the user. The content is written onto the ROM when it is first made. ROM keeps its contents even when the computer is turned off and so is known as non-volatile memory. On some computers a special piece of software called the operating system is stored in ROM. ROM is also often used in embedded systems where a small built-in computer is used to control a device such as a washing machine. The program that controls the machine is stored on ROM.
- Random Access Memory (RAM) : RAM is used to store programs and data that are being used by the computer. When the computer is turned on the RAM is empty. Data and programs can be put into RAM from either an input device or backing store. The data in RAM is lost when the computer is turned off so it is known as volatile memory. To keep data the user must save it to backing store before the computer is turned off.



The process of transfering data/programs from backing store into RAM so they can be used is known as loading.
The process of transfering data/programs from RAM to backing store so that they will be retained when a computer is turned off is known as saving.
It is easy to add extra RAM to a microcomputer by inserting extra RAM cards called SIMM cards :

IAS is located inside the computer. Data can be written to and read from IAS electronically at very high speeds, much faster that it can be written to or from backing store. IAS is much more expensive to buy per Mb than backing store is.



SECONDARY BACKING STORAGE

MAGNETIC DISKS: *HARD DISK AND FLOPPY DISK*

Magnetic disks are the most common backing storage device. Data is stored using magnetised spots called domains

on the disk. Each domain can store one bit of data (a 0 or a 1).

- → 1.44Mb floppy disk used on a PC contains 16,777,216 such spots.
- → 6Gb hard disk drive contains over six billion spots!

Data stored on disks is arranged along a series of concentric rings called tracks. Each track is divided up into a number of sectors. Data is read to and written from a disk one sector at a time. A sector usually contains 512 or 1024 bytes of data.

The process of dividing a disk up into tracks and sectors so it can be used on a computer is known as formatting. You must format a new disk before you can use it.

Data is read from the disk using a disk head which moves mechanically about the disk (rather like a record player tone arm). The disk head can move directly to any sector on the disk. Because of this a computer system can load a file or a record from a file very quickly. The system can move directly to the location of the record/file and read it without having to read any other data from the disk. This is known as direct access. For most applications using a direct access medium is much faster than using a serial access medium.

The two main types of magnetic disks are floppy disks and hard disks.

HARD DISKS

Hard disks are magnetic disks. They have much larger storage capacities than floppy disks. Data can be transferred to and from a hard disk much more quickly than from a floppy disk. Hard disks are usually fixed inside a computer and can not be moved between different machines. Some expensive hard disks can be moved between computers. These are called *exchangeable hard drives*.

A hard disk is made of a rigid disk which is coated with a magnetisable material. The magnetic material used is of a much higher quality than that found on floppy disks. Hard disks spin much more quickly (typically 60 to 120 revolutions per second) than floppy disks and the disk head is positioned very close to the disk (thousandths of a millimetre away). Because the disk head is positioned so close to the disk hard drives can easily be damaged by dust or vibration. Therefore the disk, the drive head and all the electronics needed to operate the drive are built together into a sealed unit. This picture shows a hard disk drive with the case removed.

Usually (as in the picture above) several physical disks are contained in one hard disk unit. Each disk is known as a platter. Typical hard disk capacities for a home PC now start at 40Gb and units storing up to 80Gb are available. If larger storage capacities are required then multiple hard drives can be combined. Using appropriate hardware or software many hard disks can be made to look like one very large hard disc to the user.

The hard disk is usually the usual main backing storage media for a typical computer or server. The operating system (e.g. Microsoft® Windows), applications software (e.g. word-processor, database, spreadsheet, etc.), and any program data would all be stored on a hard disk.

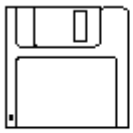
<u>Advantages:</u>

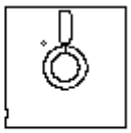
Very fast access to data.

Data can be read directly from any part of the hard disk (random access).

The access speed is about 1000 KB per second.

FLOPPY DISKS





3.5" Floppy 5.25" Floppy

Floppy disks are magnetic disks. They are portable (can be moved between computers) but have a small storage capacity. Reading and writing data from a floppy disk is very slow. The most common type of floppy disk is the 3.5" disk that can store 1.44Mb of data when it is used on a PC (enough to store about 350 pages of A4 text). Older disks were 5.25" or 8" in size but could store much less data.

A floppy disk is manufactured from a flexible plastic disk. This disk is coated with a magnetisable material. For protection the disk is encased in a plastic shell. All sizes of floppy disk

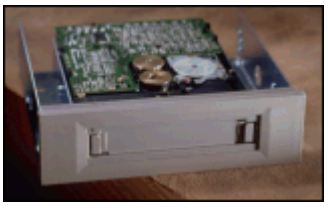
have a write protect tab built into the shell. If this tab is set then data can be read from the disk but not written to it. The write protect tab can be used as a security measure to prevent important data being deleted or changed accidentally.
Most disks are now sold already formatted for PC's.
Floppy disks are useful for transferring data between computers and for keeping a back-up of small files.
Advantages/disadvantages:
They are easily physically damaged if unprotected and magnetic fields can damage the data.
They are relatively slow to access because floppy disks rotate far more slowly than hard disks, at only six revolutions per second, and only start spinning when requested. The access speed is about 36 KB per second.
Floppy disks are used for three main purposes :

- Transferring Information Files can be transferred from one computer to another using a floppy disk. This is possible because floppy disks are portable. Unfortunately the small storage capacity of a floppy disk means that large files can not easily be transferred this way.
- Backups Floppy disks can be used to make extra copies (backups) of files that are stored on a computer's hard disk. If the copy of a file on the hard disk is lost or corrupted than the backup copy can be used instead so the file is not lost. Increasingly other media such as magnetic tapes or optical disks are being used instead of floppy disks to store backup files. This is because they are faster at reading and writing data and have much greater storage capacities.
- Distributing Software Software is often distributed (sold) on floppy disks. A package may be supplied on up to thirty floppy disks. CD-ROMs are now a more common medium for distributing software because an entire package can be stored on one CD-ROM and a CD-ROM is less vulnerable to physical damage.

Some hardware companies now produce storage devices which are very similar to floppy disks but can store 100Mb or even 2 Gb of data. These devices are also much faster than standard floppy disk drives. **ZIP AND JAZ** drives are similar to floppy drives because the individual disks are removable and portable but they hold much larger amounts of data (typically between 100 MB and 2 GB).

MAGNETIC TAPES

Magnetic tape comes in two different forms :
Reels Large reels of tape (1/2 inch wide and 2400 feet long) which must be loaded into a reel-to-reel tape drive. This type of tape is usually used by mainframe computers.



Cartridges The tape is supplied in a small cartridge rather like a music tape. The tape is typically 1/4 inch wide and 300 feet long. This type of tape is used on PCs (microcomputers) and the device used to read/write the tapes is called a tape streamer. The picture below is of a tape streamer for a PC. Capacities of cartridges vary from 10Gb to 200Gb.
The storage capacities of tape cartridges are now so great that reels of tape are not used in new computer systems.
A computer tape is divided up into many blocks. A block on a tape is like a sector on a disk. To read data from a particular block on the tape all of the blocks that come before it must be read first. This means that finding a particular file/record on a tape can take much longer than finding a particular file/record on a disk. However once the file or record has been located it can be read more quickly from a tape than in could be from a hard disk. Having to read through all of the files/records that are stored before the file/record you want to access is known as serial access.
Often files or records are stored on a tape in a particular order (e.g. sorted alphabetically by a key field). If this is the case then the tape is described as having sequential access. Because locating data on a tape takes a long time, magnetic tapes are not used as general purpose storage devices. They are only useful for a few applications. The two main applications tape is used for are :

- Backup Often a tape streamer is used to make copies of data stored on a hard disk in case the data becomes corrupted. If this happens then the correct data can be restored from the tape. A backup copy of the contents of the hard disk could be made once every week. Tapes are more suitable for making backups than floppy disks or CD-ROMs. This is because the entire contents of a hard disk can be written onto one tape, producing the backup will be much quicker and tapes are cheaper to buy. It does not matter that tapes are serial access because when a backup is made or restored every file on the tape has to be accessed.
- Batch Processing In a batch processing system when processing occurs the whole master file and the whole transaction file are read to produce a new master file. Because the master file and transaction file are both sorted into the same order the data can be read sequentially from each file. A batch processing system does not have to move backwards and forwards through a tape looking for records. The system is designed so that the next record to be read is stored immediately after the current record on the tape. Therefore using a serial access medium instead of a direct access medium will not slow down processing. Tapes are preferred to disks in batch processing systems due to their relative low costs and fast read/write speeds.

Uses:
Magnetic tape can be used for permanent storage. Tapes are often used to make a copy of hard disks for back-up (security) reasons. This is automatically done overnight on the KLB network and the tapes are kept in a safe place away from the computer.
Advantages/disadvantages:
Accessing data is very slow and you cannot go directly to an item of data on the tape as you can with a disk. It is necessary to start at the beginning of the tape and search for the data as the tape goes past the heads (serial access).
Magnetic tape is relatively cheap and tape cassettes can store very large quantities of data (typically 26 GB).
Extra information:
Just like the tape in a tape-recorder, the data is written to or read from the tape as it passes the magnetic heads.

OPTICAL DISKS

Optical disks store data by changing the reflective properties of a plastic disk. Binary computer data (0s and 1s) are represented by the way the disk reflects light when a low power laser is shone at it. A 0 stored on a disk reflects light differently to a 1 stored on a disk.
Like floppy disks, optical disks can be moved from one computer to another. They have much larger storage capacities than floppy disks but can not store as much data as a hard disk. Data can be read from an optical disk more quickly than from a floppy disk but hard disks are much quicker. As with a hard disk the drive head in an optical drive can move directly to any file on the disk so optical disks are direct access.
There are five types of optical disks that are currently in use. They are :
CD-ROM(Compact Disk - Read Only Memory)
This is by far the most widely used type of optical disk. A CD-ROM disk can store up to 650/700Mb of data. The data is written onto the CD-ROM disk before it is sold and can not be changed by the user. Because of this CD-ROMs are often described as Write Once Read Many times (WORM) disks. CD-ROMs are used for applications such as distributing software, digital videos or multimedia products. They are also known as optical disks because the data is read by a laser beam reflecting or not reflecting from the disk surface. Like a floppy disk, a CD-ROM only starts spinning when requested and it has to spin up to the correct speed each time it is accessed. It is much faster to access than a floppy but it is currently slower than a hard disk (a modern 50x speed CD-ROM drive is 50 times faster than the 15 KB per second of the original single-speed CD-ROM's).
CD's are available in 3 formats:

CD-ROM's - ROM means Read Only Memory and this means you can only read from the disc, not write or store data onto it. This is the most common sort of CD available and is the way most software programs are now sold.
CD-R (Compact Disc - Recordable): A CD-R disk can store up to 650Mb of data. A CD-R disk is blank when it is supplied. The user can write data to it just once. After data has been written to the disk it can not be changed. A special CD-R drive which contains a higher powered laser than a CD-ROM drive is required to write to the disk. CD-Rs are often used for making permanent backups of data and distributing software when only a small number of copies are required.
these CDs are initially blank but you can use a special read/write CD drive unit to store programs and data onto the disc but they can only be written to once.
CD-RW (Compact Disc - Rewriteable): A CD-RW disk can store up to 650/700Mb of data. CD-RW disks can be read from and written to just like a hard disk. CD-RWs can be used for any application that a hard disk can be used for but the time taken to access data is much longer than that for a hard disk. CD-RW - these are similar to the 'R' type above but you can read, write and delete files from the disc many times, just like a hard disk.
Both CD-ROMs and CD-Rs can be referred to as WORM devices. This stands for Write Once Read Many times.
DVD-ROM (Digital Versatile Disk - Read Only Memory): DVD is the new standard for optical disks. By using a shorter wavelength laser, storing data on both sides of the disk and having more than one layer of data on each side of a disk. DVD disks are able to store much more data than CD disks. The DVD standard includes disk capacities up to 18Gb. Current DVD disks store far less than this. DVD-ROM disks can be read from but can not be written to. Because of their high capacity, DVD-ROM disks are used to store high quality video such as complete movies. Often extra data such as information about the making of the film or the actors and actresses who star in it are also stored on the disk. Unlike movies recorded on video tape, DVD-ROM movies can be interactive. The user can make selections on the screen and change what they see.
DVD drives are now replacing CD drives in computers due to the huge memory capacity of the disk and the high quality of stored images. A DVD single sided, single layer DVD can store up to 4.7 GB of data, the equivalent of 26 CD-ROMS. This means full-motion films with sound tracks and subtitles in multiple languages can easily be stored on one DVD disk.
A film stored on a DVD has significant advantages over magnetic VHS video tape because the digital images and sound tracks are of a higher quality and do not deteriorate with constant use. The user can also move to any part of the film immediately (random access).
Multi-layer and double sided DVD's can hold up to 17GB of of data.
DVD-RW drives (writable drives) are still quite expensive but may eventually replace home CD systems and VHS tapes as a way of recording films and music.
DVD-RAM (Digital Versatile Disk - Random Access Memory): DVD-RAM disks have all of the benefits of DVD-ROM disks and can be written to as well. These very high capacity disks are ideal for producing backups. In the next five years they may replace video tapes for recording television programmes.

BACKUPS : INTRODUCTION

No-one likes losing data that they have entered into a computer. Lost data represents a waste of time and effort. For companies the loss of data can be especially serious. Many companies store essential information such as customer accounts or stock databases on computer. Loss or corruption of this information could cost a company a lot of money.
If data is very important then appropriate security measures should be put in place to try and avoid any data loss or corruption. However problems can still occur :

- An employee could accidentally delete a file or a storage device could fail resulting in data being completely lost.
- Data could be changed accidentally. For example an employee may incorrectly update a set of records in a database. A virus could deliberately change the contents of a file.

Therefore extra copies of important data should be made on a regular basis. These copies are known as backups. If the original files become corrupt then the data can be restored from a backup copy. A company should have a backup strategy which sets out how backups will be made.

BACKUP STRATEGIES

A backup strategy is a plan which details how backups will be made and how data will be restored in the event of a system failure. There are many important factors that should be considered in a backup strategy. These include :

1. How often should data be backup up ?
2. When should data be backed up ?
3. What storage medium should the backups be stored on ?
4. Where should backups be stored ?
5. Who will carry out the backup procedure ?
6. What will happen if data is lost ?
7. How many copies to keep ?
8. How often should data be backup up ?

1. How often should data be backup up ?

If a file is corrupted and you restore the file from a backup copy then some data may still be lost. This is the data that was added to the file since the backup was made. If backups are made once a week then a whole week's work could be lost. On the other hand if backups are made once a day then only a day's work would be lost. Backups should therefore be made as regularly as possible.

Unfortunately backups cost money to produce. Storage media must be purchased and staff time is taken up. Therefore a balance has to be struck between making backups very frequently and keeping backup costs down.

As a general rule files which change frequently should be backed up often whereas files which do not change very much can be backed up less frequently.

2. When should data be backed up ?

Backing up data can tie up a computer so that it can not be used whilst the backup is in progress. Therefore backups are usually made overnight or at weekends when a computer system is less likely to be in use.

3. What storage medium should the backups be stored on ?

There are a variety of different storage media that backups can be stored on. These include magnetic and optical disks and magnetic tapes. The best medium to use in a particular situation will probably depend upon the volume of data to be backed up and the speed at which the backup must be performed.

- Floppy Disks : Only suitable for backing up small amounts of data (1.44Mb) and very slow. Some high capacity floppy disks which can stored up to 120Mb are know available. These can store more data but are still relatively slow.
- Optical Disks : Optical disks such as CD-RWs can back up much more data than floppy disks but not as much data as a tape. Typical capacities are around 650Mb. They are much faster than floppy disks but not as fast as magnetic tapes in most circumstances.
- Magnetic Tapes : These are suitable for backing up large volumes of data (tens of gigabytes). The backups can be performed very quickly. Tapes are very cheap to buy but the initial cost of the hardware required can be high.

4. **Where should backups be stored ?**

There is no point in making a backup copy if the backup may be damaged. These guidelines should be followed to ensure that backups are stored safely :

Store at least one backup at a site away from the main computer system. If the main system is damaged by a natural disaster such as a fire then the off site backup will be safe. Any backups kept on site may be destroyed.
Control access to backups so that unauthorised personnel can not remove them or steal data from them.
Keep backups in a clean, dust-free environment so that the medium that the backups are stored on will not be damaged.

5. **Who will carry out the backup procedure ?**

In a small company each employee may make his or her own backups. In a larger organisation however the task of producing backups will usually be performed by one selected individual. This individual can be properly trained in using the backup procedure and can keep accurate records of the backups that have been made.

6. **What will happen if data is lost ?**

If data is lost then it will have to be restored from the backup. A disaster recovery plan should be in place which describes how the data will be restored.

7. **How many copies to keep ?**

It is a good idea to make more than one backup copy. This gives you the extra assurance that if a file is corrupt and the backup is also corrupt then you have another backup which may still be operational.

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BACKUPS BY TYPE OF PROCESSING

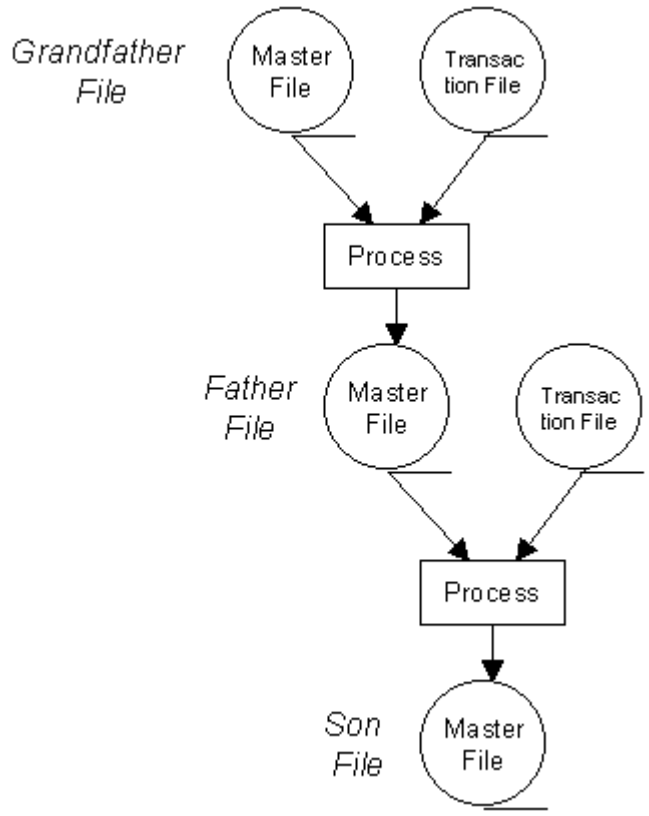
Often the method used to make backups will depend upon the type of processing that is being carried out :

Backups by Type of Processing	
Batch Processing	Backups are kept using the Ancestral or Grandfather-Father-Son system.
Transaction Processing	Periodically a copy of the master file called a file dump is made. Recent transactions are stored in a transaction log file.
Real-time Processing	A lot of backup hardware is employed to reduce the risk of failure.

A backup is not the same thing as an archive. An archive is a file containing old data which is no longer used but which must be kept. Archive files are often kept under the same conditions as backups.

The method used to backup data is often determined by the type of processing that a computer system is carrying out. Different backup strategies are appropriate for batch, transaction and real-time systems.

BACKUPS IN BATCH PROCESSING SYSTEMS



In a batch processing system the File Generation or Grandfather-Father-Son backup method is used. Remember that in a batch processing system all transactions are entered into a transaction file. This file is then used to update the current master file to produce a new updated master file.
When processing takes place the master file is known as the father file. Processing the father file with the transaction file produces the new master file which is known as the son file.
The father file and transaction file are stored securely. If the son file becomes corrupt the father file can be processed with the transaction file again to reproduce the son file. In this way the father file and its associated transaction file act as a backup of the son file.
An older copy of the master file called the grandfather file is also kept. If the son file and the father file are both corrupted then :

The grandfather file and its associated transaction file can be processed to recreate the father file.
The recreated father file and its transaction file can then be used to recreate the son file.
Every time processing occurs the tapes are moved back one generation. So the father file becomes the grandfather file and the son file becomes the father file. The old grandfather file is erased to be reused.

BACKUPS IN TRANSACTION PROCESSING SYSTEMS

Backups for a transaction processing system are produced in a different way to those for a batch processing system. At the end of each time period a backup copy of the master file is made. The time period between each backup could be a day or a week. Making a complete copy of the master file like this is known as file dumping. The copy of the master file is known as a file dump. Every time an alteration is made to the master file, since the last backup was made, details of the alteration are stored in a transaction log file. If the system breaks down then two things happen :
The most recent file dump of the master file is restored to replace the corrupt current master file. This contains all of the lost data except any new transactions made since the backup.
The transaction log file is used to update the restored master file so that any transactions made since the file dump was produced are restored.
By following this process no data should be lost. If there was no transaction log file then all of the transactions since the last file dump would be lost.

BACKUPS IN REAL-TIME PROCESSING SYSTEMS

The consequences of failure in many real-time systems (e.g. flying a missile/passenger plane, running a nuclear power station) are immense. There is not a lot of point in keeping backup copies of data in a real-time system as there is unlikely to be time to restore backups if anything goes wrong. When a real-time system is developed the emphasis is placed on ensuring that the system will not go wrong rather than on designing a backup method to restore the system if it does go wrong.

Therefore most real-time systems incorporate a lot of spare hardware. Having much more hardware than you need to do a job means that if some hardware fails you can carry on doing the job. For example three identical computers may be used to decide which direction a missile should fly in. The computers

each have a "vote" on which direction the missile should fly in. Because the computers are identical all three will normally agree on which direction to take. If one computer goes wrong then it will be outvoted by the two working computers so the missile will still function properly despite the failure. If two computers go wrong you are in trouble.

Sometimes backing up data to disk can be useful in real-time systems. Although this data could not be used to put the system back into its proper state, it could be used later to analyse why a systen failed. The "black box" that records flight data in an aircraft is an example of this type of system.

Questions
(1) What is a backup ?
(2) Why should backups be kept ?
(3) What is a backup strategy ?
(4) Identify five factors that should be dealt with in a backup plan.
(5) Which storage medium would be most suitable for backing up data in the following situations :
a) A network file server which stores 25Gb of data for 100 users.
b) A small home computer which is mainly used for word processing documents.

(6) In a large company backups could be made in one of two ways :
a) Each employee could backup his own work.
b) A specific employee could be nominated to backup everyones work.

Give one advantage of each possible method of backup.

(7) Explain how backups are usually made in batch processing systems.
(8) Explain how backups are usually made in transaction processing systems.
(9) What is the importance of the transaction log file when backing up a transaction processing system ?